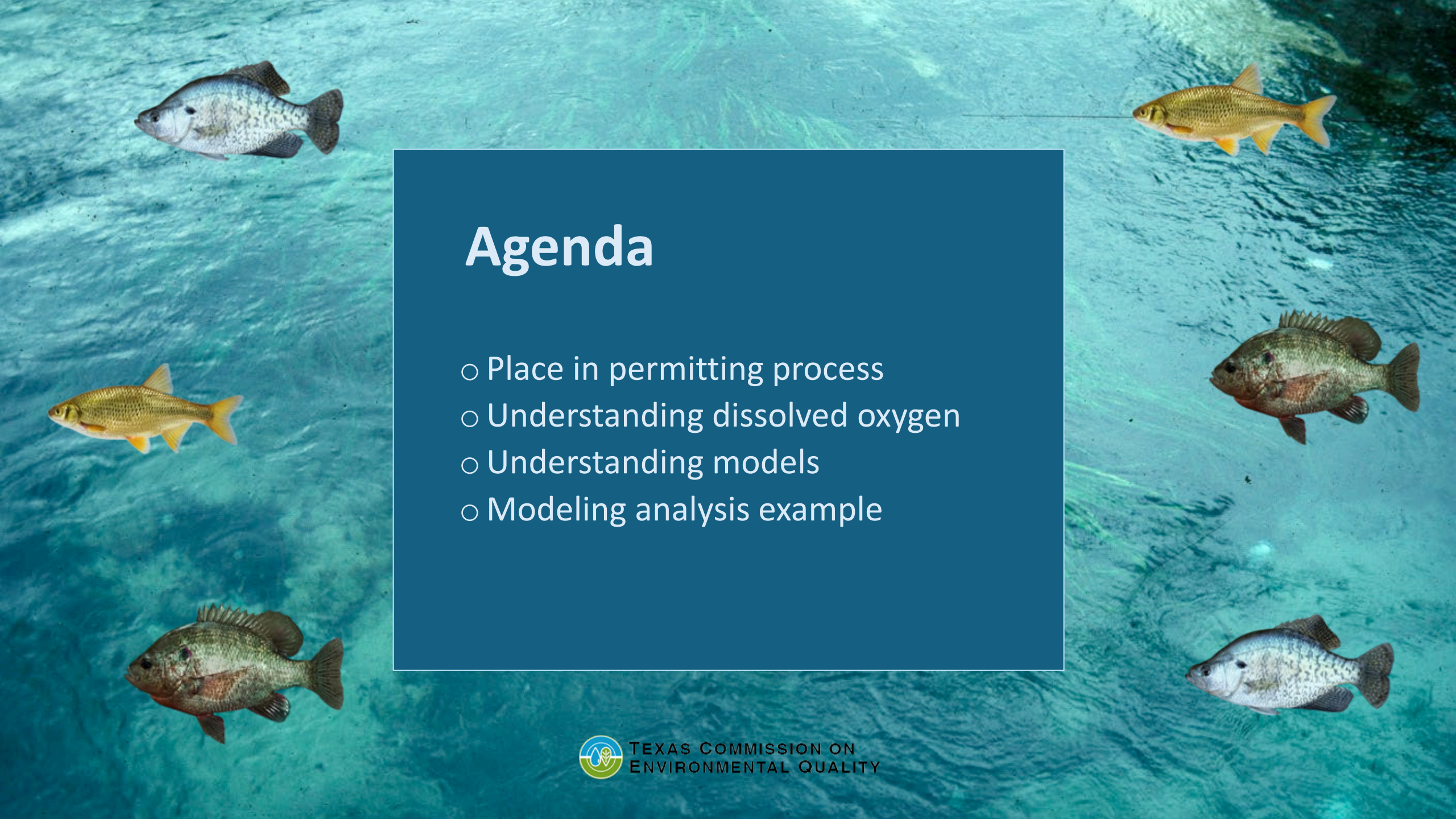


Dissolved Oxygen Modeling of Surface Waters for TPDES Permits

Claire Dittelmier
TCEQ Water Quality Division



TEXAS COMMISSION ON
ENVIRONMENTAL QUALITY

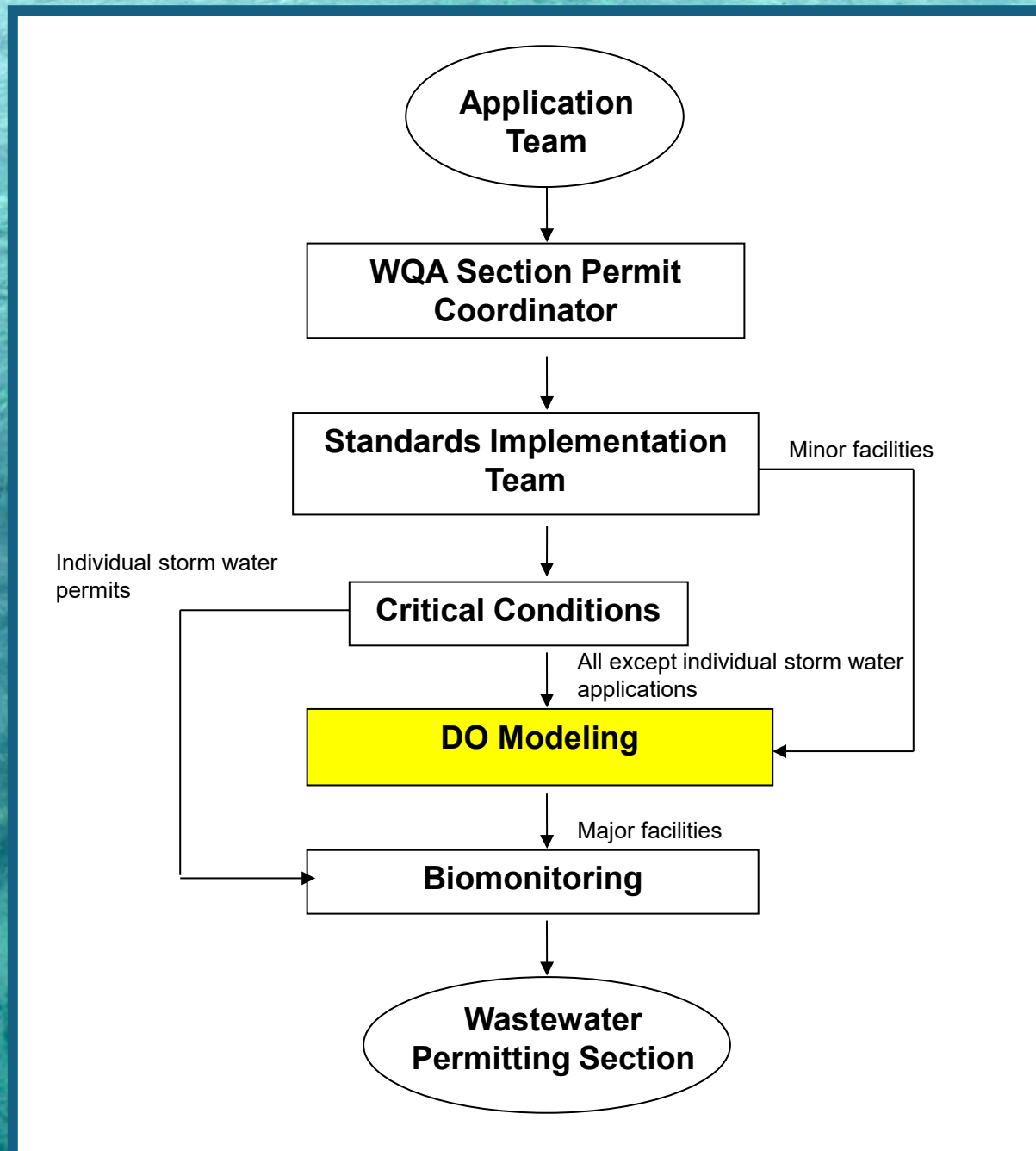
The background of the slide is a photograph of several fish swimming in clear, blue water. The fish are of various species, including what appear to be bluegills and golden shiners, scattered across the frame. A dark blue rectangular box is centered on the slide, containing the title and agenda items.

Agenda

- Place in permitting process
- Understanding dissolved oxygen
- Understanding models
- Modeling analysis example



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EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

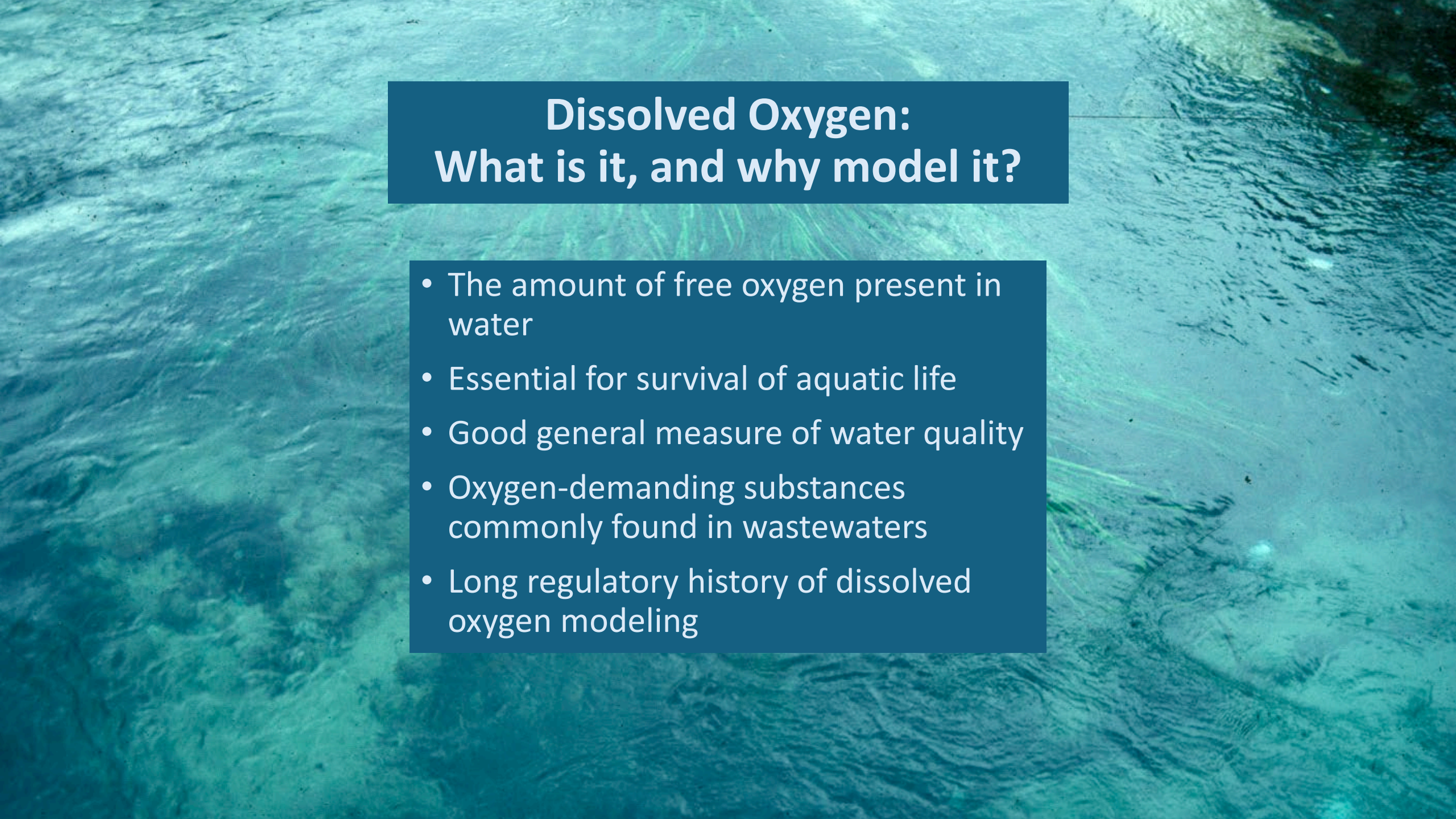
Outfall Number 001

During the period beginning upon the date of issuance and lasting through the date of expiration, the permittee is authorized to discharge subject to the following effluent limitations:

The annual average flow of effluent shall not exceed 2.5 million gallons per day (MGD); nor shall the average discharge during any two-hour period (2-hour peak) exceed 4,403 gallons per minute (gpm).

<u>Effluent Characteristic</u>	<u>Discharge Limitations</u>				<u>Min. Self-Monitoring Requirements</u>	
	Daily Avg. mg/l (lbs/day)	7-day Avg. mg/l	Daily Max. mg/l	Single Grab mg/l	Report Daily Avg. & Daily Max. Measurement Frequency	Sample Type
Flow, MGD	Report	N/A	Report	N/A	Continuous	Totalizing Meter
Carbonaceous Biochemical Oxygen Demand (5-day)	10 (208)	15	25	35	Two/week	Composite
Total Suspended Solids	15 (313)	25	40	60	Two/week	Composite
Ammonia Nitrogen	3 (63)	6	10	15	Two/week	Composite
Total Nitrogen	Report (Report)	N/A	Report	N/A	One/month	Composite
Total Phosphorus	Report (Report)	N/A	Report	N/A	One/month	Composite
<i>E. coli</i> , CFU or MPN/100 ml	126	N/A	399	N/A	One/week	Grab

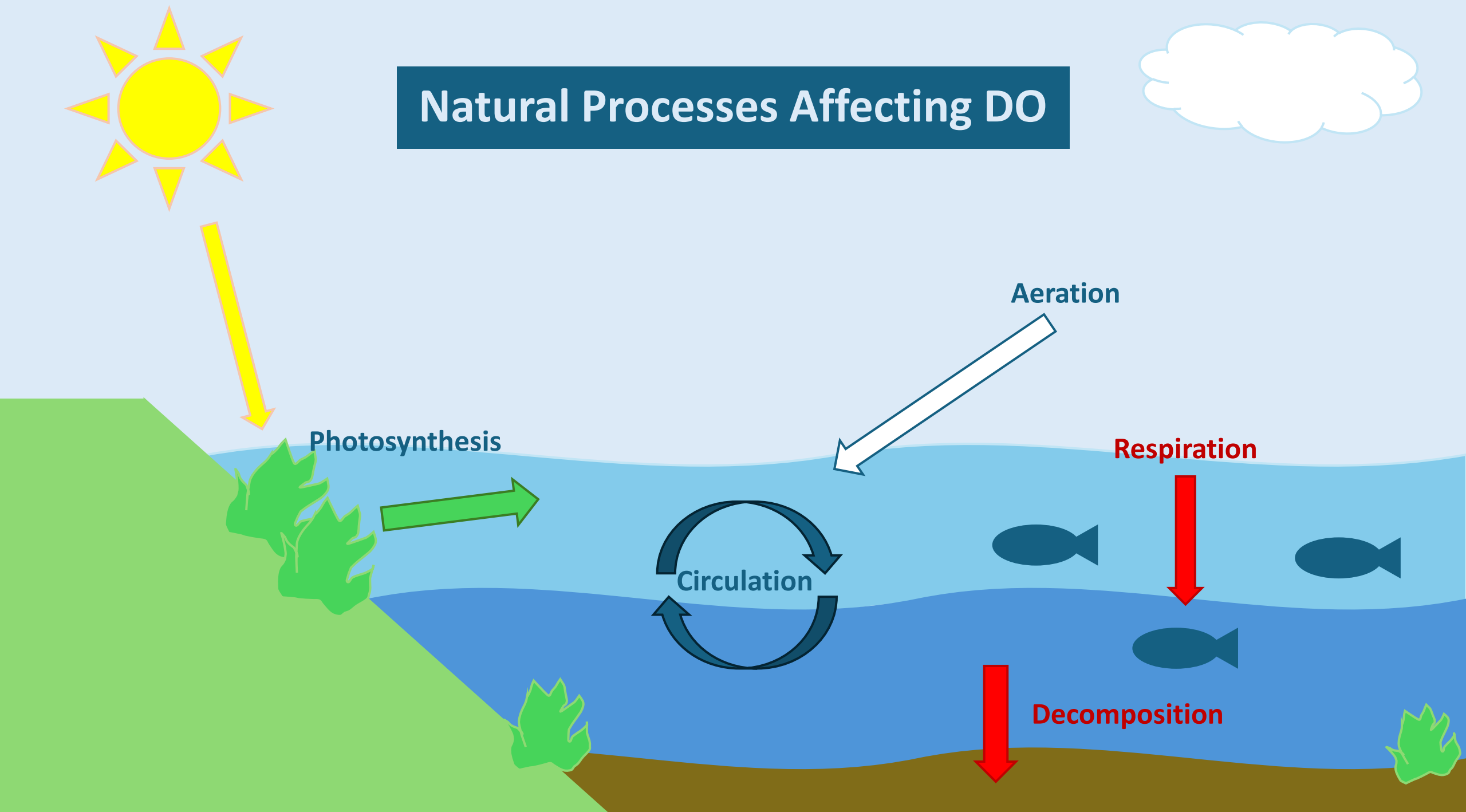
- . The effluent shall contain a chlorine residual of at least 1.0 mg/l after a detention time of at least 20 minutes (based on peak flow) and shall be monitored daily by grab sample. The permittee shall dechlorinate the chlorinated effluent to less than 0.1 mg/l chlorine residual and shall monitor chlorine residual daily by grab sample after the dechlorination process. An equivalent method of disinfection may be substituted only with prior approval of the Executive Director.
- . The pH shall not be less than 6.0 standard units nor greater than 9.0 standard units and shall be monitored once per week by grab sample.
- . There shall be no discharge of floating solids or visible foam in other than trace amounts and no discharge of visible oil.
- . Effluent monitoring samples shall be taken at the following location(s): Following the final treatment unit.
- . The effluent shall contain a minimum dissolved oxygen of 5.0 mg/l and shall be monitored twice per week by grab sample.
- . The annual average flow and maximum 2-hour peak flow shall be reported monthly.



Dissolved Oxygen: What is it, and why model it?

- The amount of free oxygen present in water
- Essential for survival of aquatic life
- Good general measure of water quality
- Oxygen-demanding substances commonly found in wastewaters
- Long regulatory history of dissolved oxygen modeling

Natural Processes Affecting DO



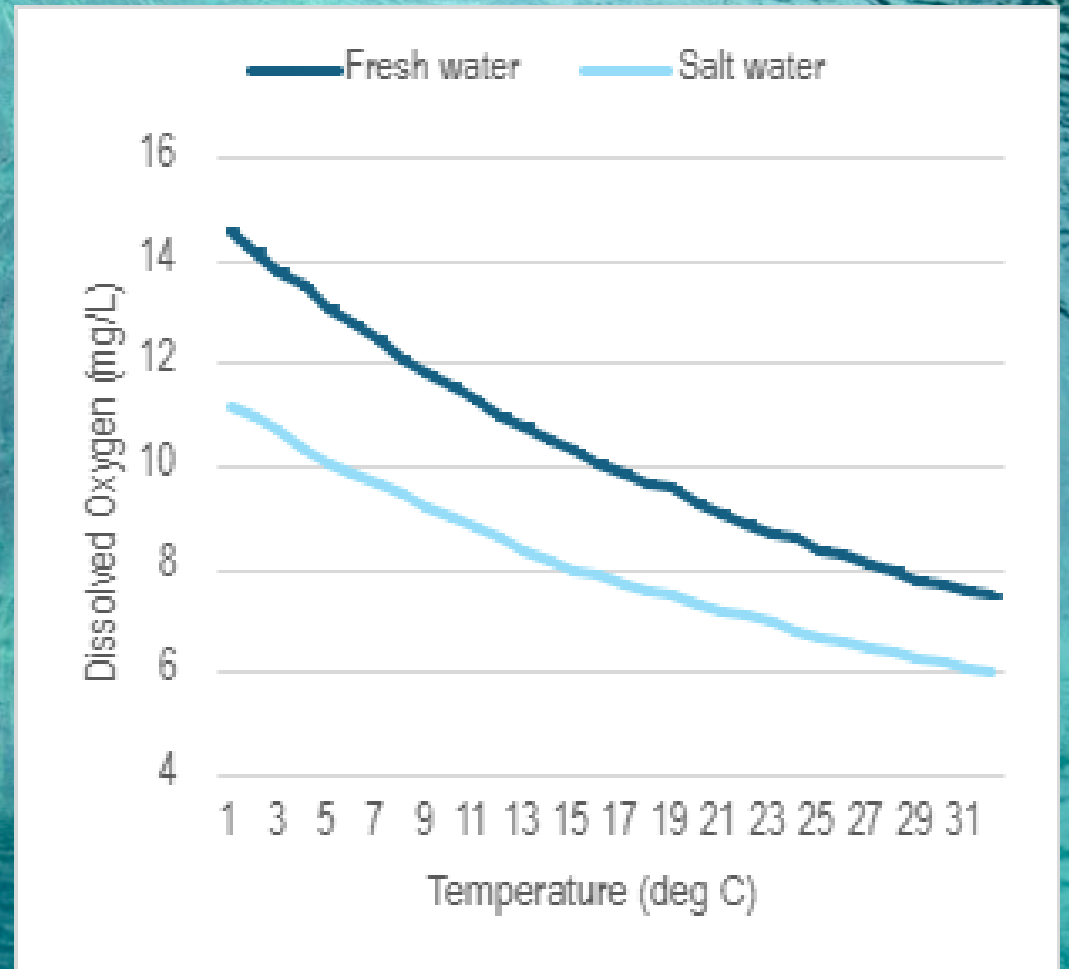
Natural Processes Affecting DO

Temperature

Increase in temperature = less DO

Salinity

Increase in salinity = less DO

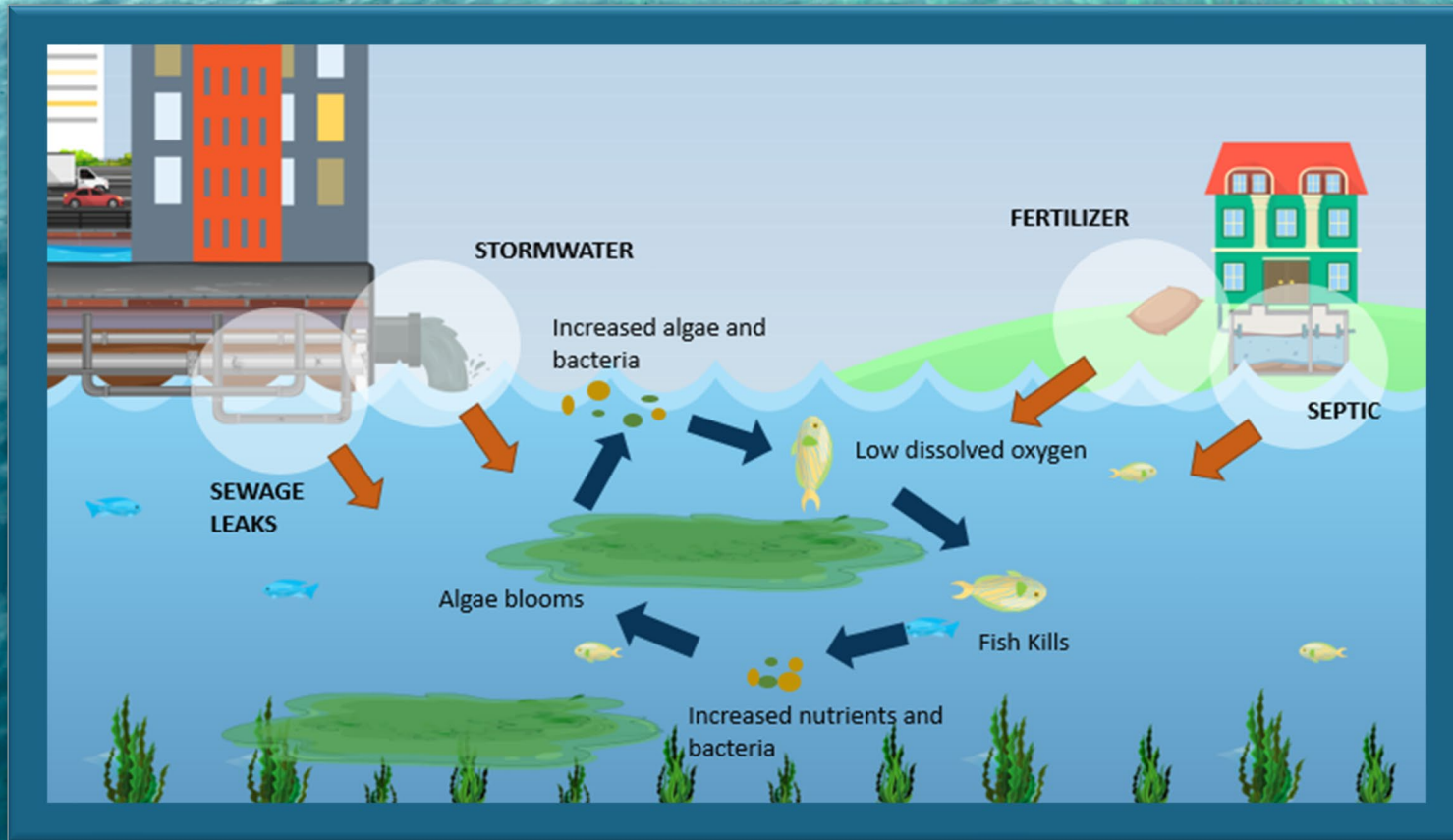


DO Criteria

TABLE 3
Aquatic Life Use Subcategories

Aquatic Life Use Subcategory	Dissolved Oxygen	Dissolved Oxygen	Dissolved Oxygen	Aquatic Life Attributes	Aquatic Life Attributes	Aquatic Life Attributes	Aquatic Life Attributes	Aquatic Life Attributes	Aquatic Life Attributes
	Freshwater mean/minimum	Freshwater in Spring mean/minimum	Saltwater mean/minimum	Habitat Characteristics	Species Assemblage	Sensitive species	Diversity	Species Richness	Trophic Structure
Exceptional	6.0/4.0	6.0/5.0	5.0/4.0	Outstanding natural variability	Exceptional or unusual	Abundant	Exceptionally high	Exceptionally high	Balanced
High	5.0/3.0	5.5/4.5	4.0/3.0	Highly diverse	Usual association of regionally expected species	Present	High	High	Balanced to slightly imbalanced
Intermediate	4.0/3.0	5.0/4.0	3.0/2.0	Moderately diverse	Some expected species	Very low in abundance	Moderate	Moderate	Moderately imbalanced
Limited	3.0/2.0	4.0/3.0		Uniform	Most regionally expected species absent	Absent	Low	Low	Severely imbalanced
Minimal	2.0/1.5								

Wastewater Impacts on DO



Oxygen-demanding constituents

- $BOD_5/CBOD_5$
- Ammonia Nitrogen

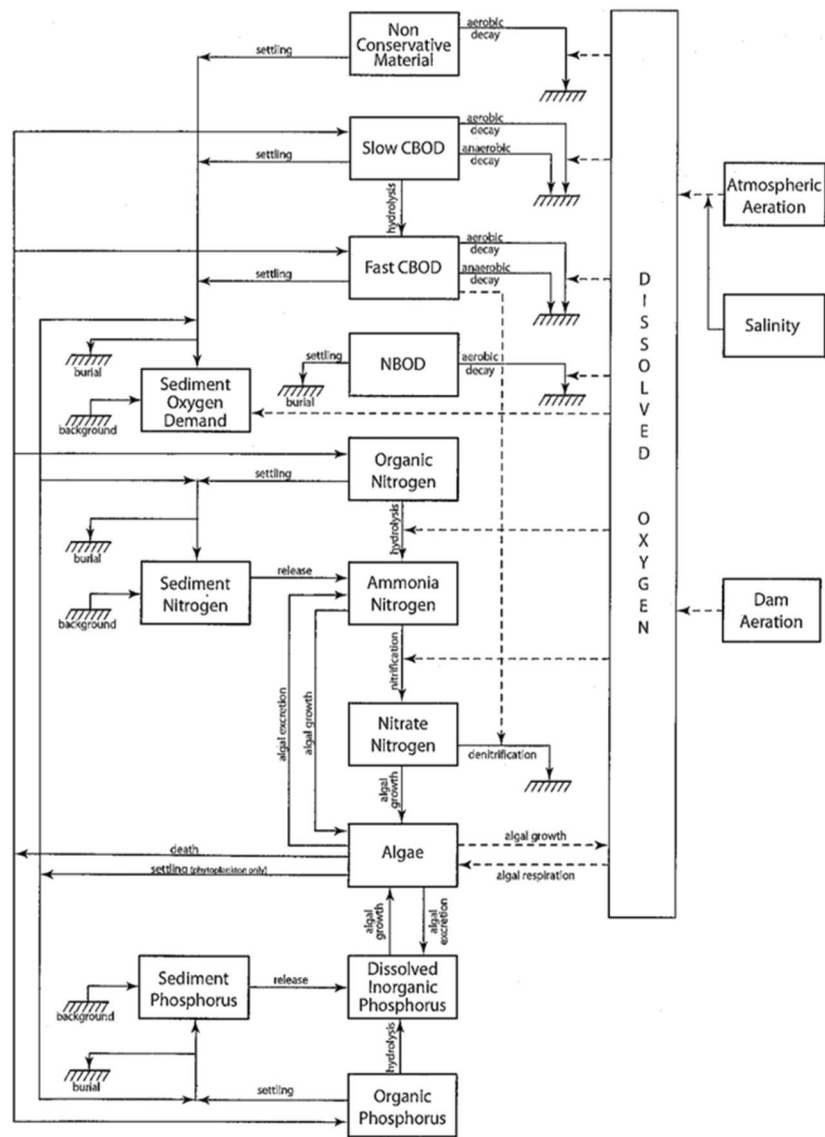
Dissolved Oxygen Models: What are they really?

A collection of mathematical equations meant to describe interrelated chemical and physical processes contributing to DO in natural waters.

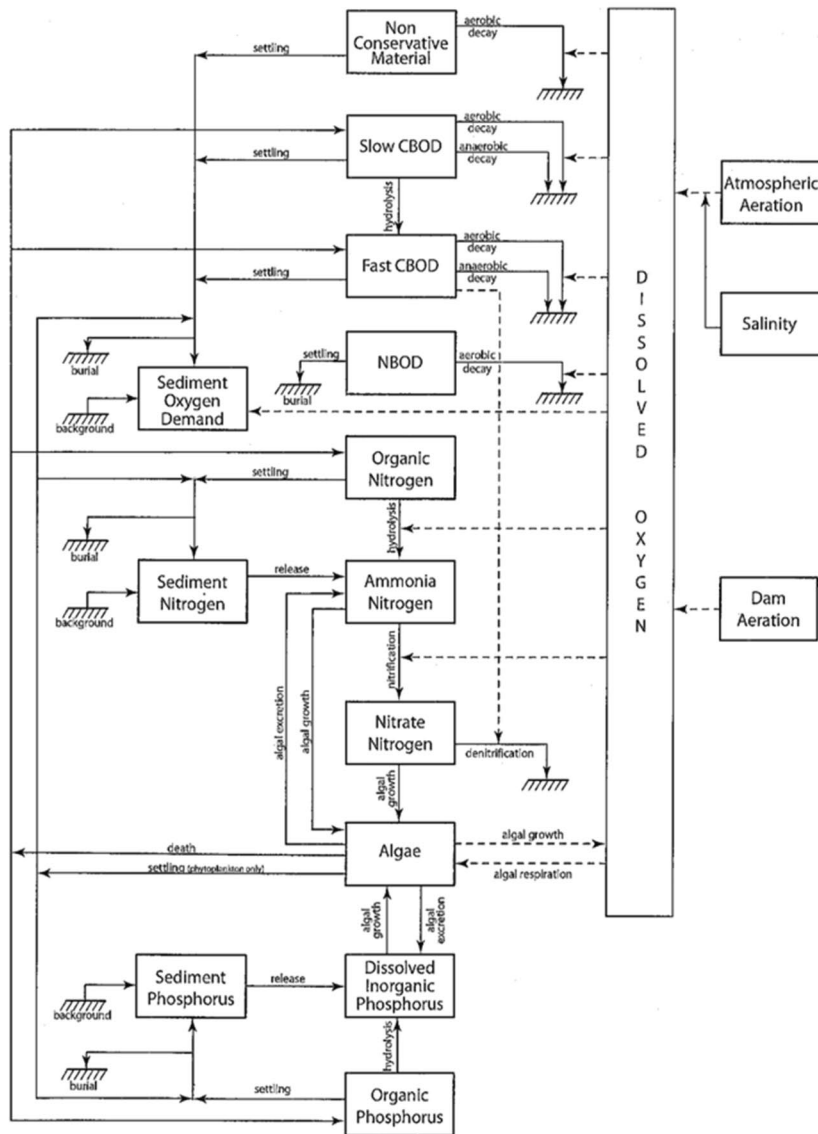
Or, more simply

A dissolved oxygen accounting program that considers major “deposits” and “withdrawals” of DO

APPENDIX A - CONSTITUENT INTERACTIONS



APPENDIX A – CONSTITUENT INTERACTIONS



'Simple' Model Equation (Streeter-Phelps)

$$D = \frac{k_1 L_a}{k_2 - k_1} (e^{-k_1 t} - e^{-k_2 t}) + D_a e^{-k_2 t}$$

D is the saturation deficit, ($D = DO_{sat} - DO$)

k_1 is the deoxygenation rate

k_2 is the reaeration rate

L_a is the initial oxygen demand of organic matter in the water, also called the ultimate BOD (BOD at time $t = \infty$).

D_a is the initial oxygen

t is the elapsed time

Common Models

Creeks and rivers

- QUAL-TX
- QUAL2K

Ponds and Lakes

- CSTR
- WASP

Diffusers

- CORMIX

Limitations

VS

Strengths

- Nature is complex.
- Results sensitive to assumptions
- No one model is appropriate for all situations.
- Requires special training to maintain consistency

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VS

Strengths

- Nature is complex.
- Results sensitive to assumptions
- No one model is appropriate for all situations.
- Requires special training to maintain consistency

- Results are repeatable and consistent with scientific principles.
- Can evaluate environmental conditions quickly
- Can run protective scenarios without collecting large amounts of site-specific data

Example DO Modeling Analysis

Information from the applicant

Flow in MGD:

1.0 MGD domestic discharge for City of Friendly, TX

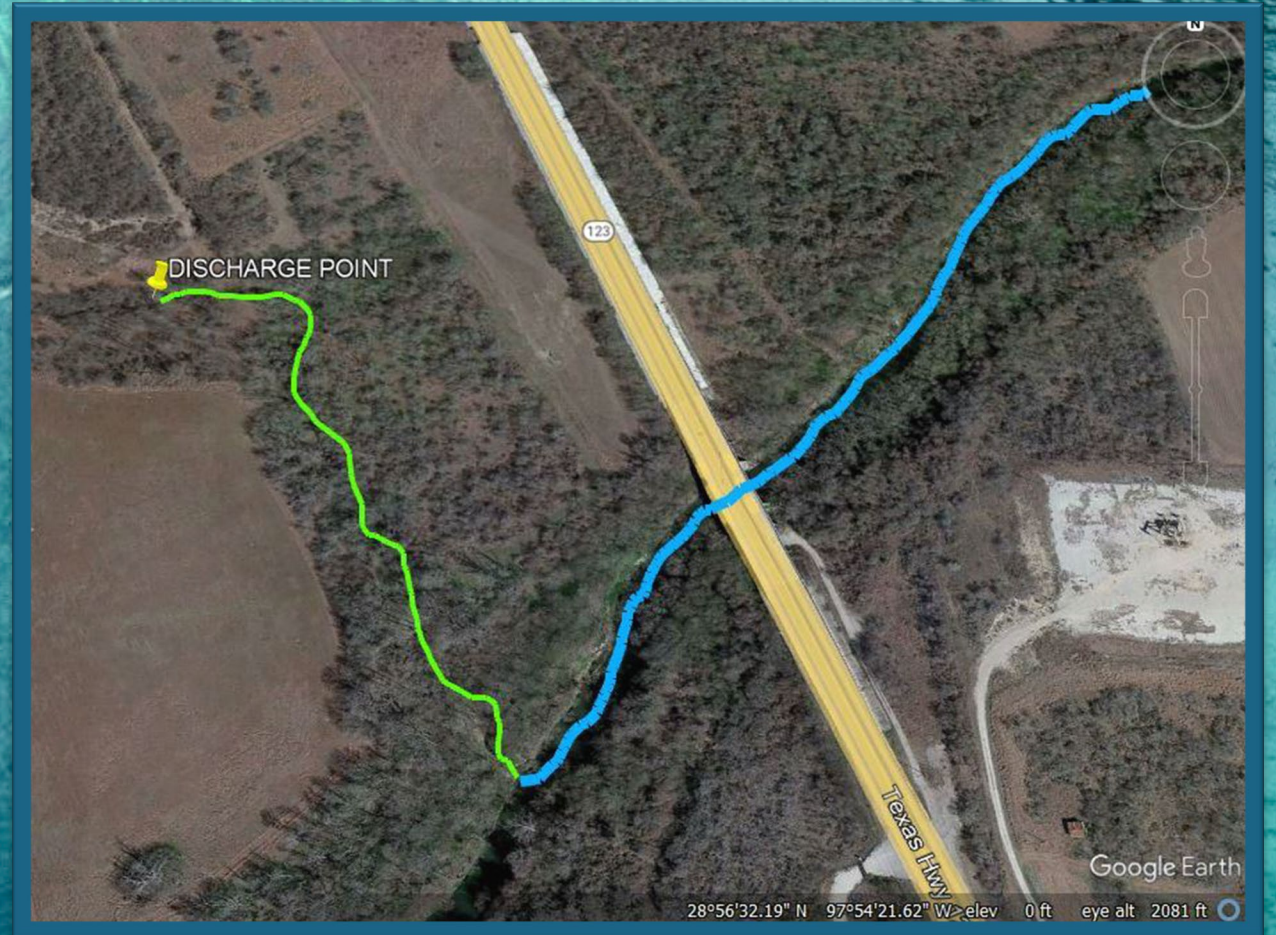
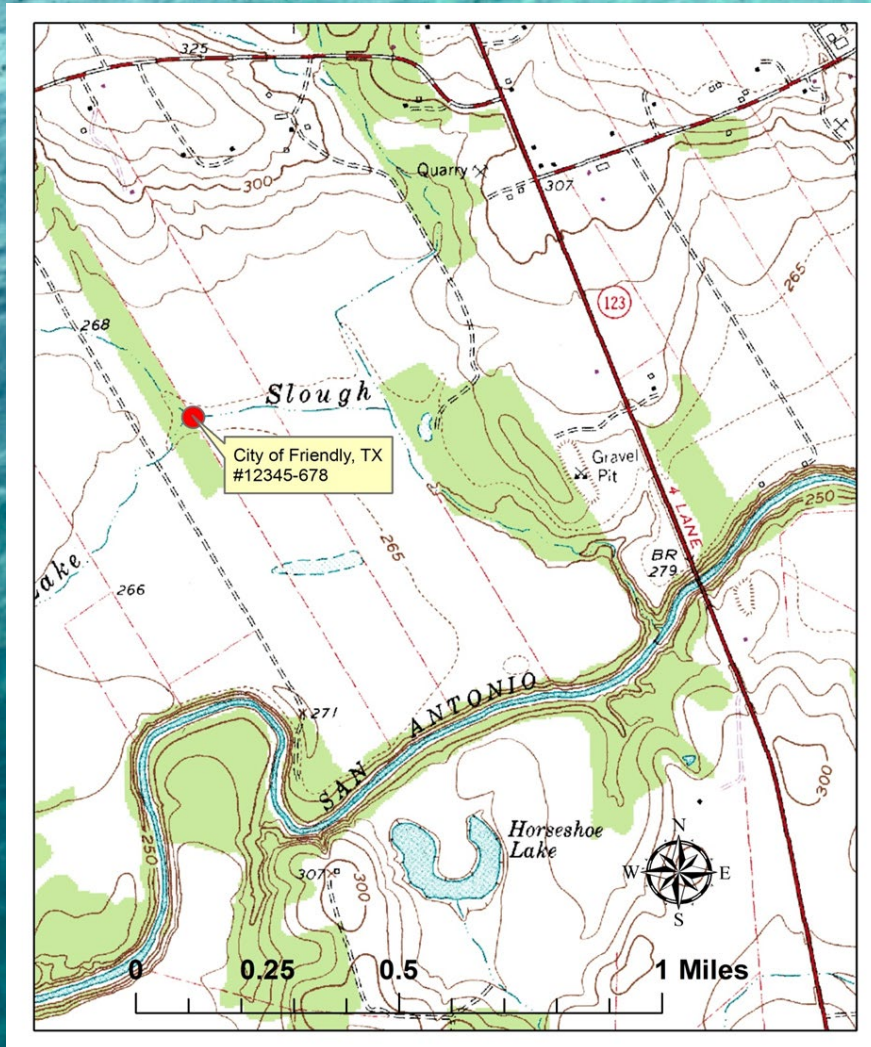
Discharge Route:

Discharge proposed into an unnamed tributary thence into the San Antonio River

Proposed Limits:

20 mg/L BOD₅, __ mg/L NH₃, 2.0 mg/L DO

Example DO Modeling Analysis



Key information

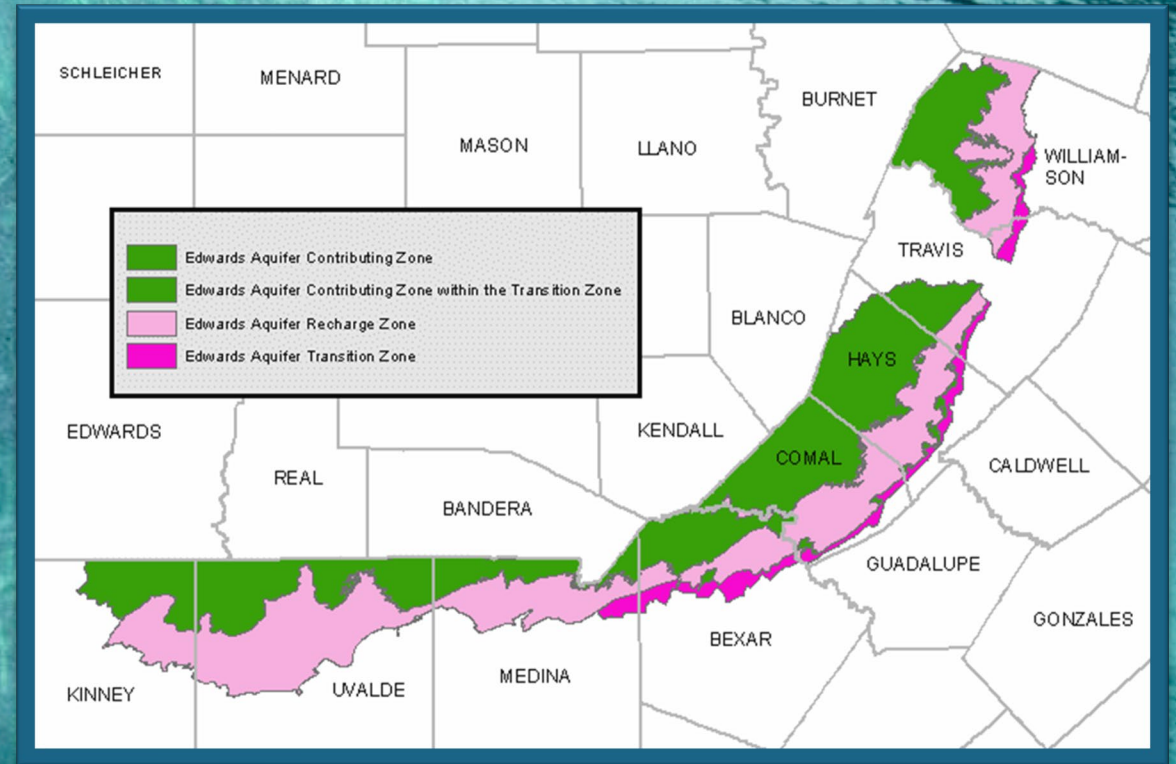
- Receiving water DO criteria
 - Unnamed tributary: Limited ALU, 3 mg/L
 - San Antonio River: High ALU, 5 mg/L
- Base flow
 - 0.0 cubic feet per second (cfs) for unnamed tributary
 - 1.2 cfs for San Antonio River
- Other dischargers to consider
 - None
- Site-specific values
 - None provided by applicant; use default hydraulics

Model Results

Treatment Level (mg/L) (BOD ₅ /Ammonia-N/DO)	DO Criteria (mg/L) (Unnamed tributary/San Antonio River)	Minimum Predicted DO (mg/L) (Unnamed tributary/San Antonio River)
20/12/2	3 / 5	1.67 / 5.95
20/12/6	3 / 5	1.70 / 5.95
10/12/6	3 / 5	1.80 / 5.95
10/3/4	3 / 5	3.03 / 5.98

Prohibited Discharges

- 303(d)-listed segment for depressed dissolved oxygen
- Discharge into the Edwards Aquifer Recharge Zone (30 TAC 213)
- No effluent limits satisfy the model at the proposed flow volume and/or location



Conclusions

- Dissolved oxygen is a good general indicator of water quality.
- Oxygen-demanding constituents are commonly found in wastewaters.
- Wastewaters can negatively impact aquatic life.
- DO modeling determines what permit effluent limits are required to meet the DO criteria of a waterbody.

Modeling Staff

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Questions?

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