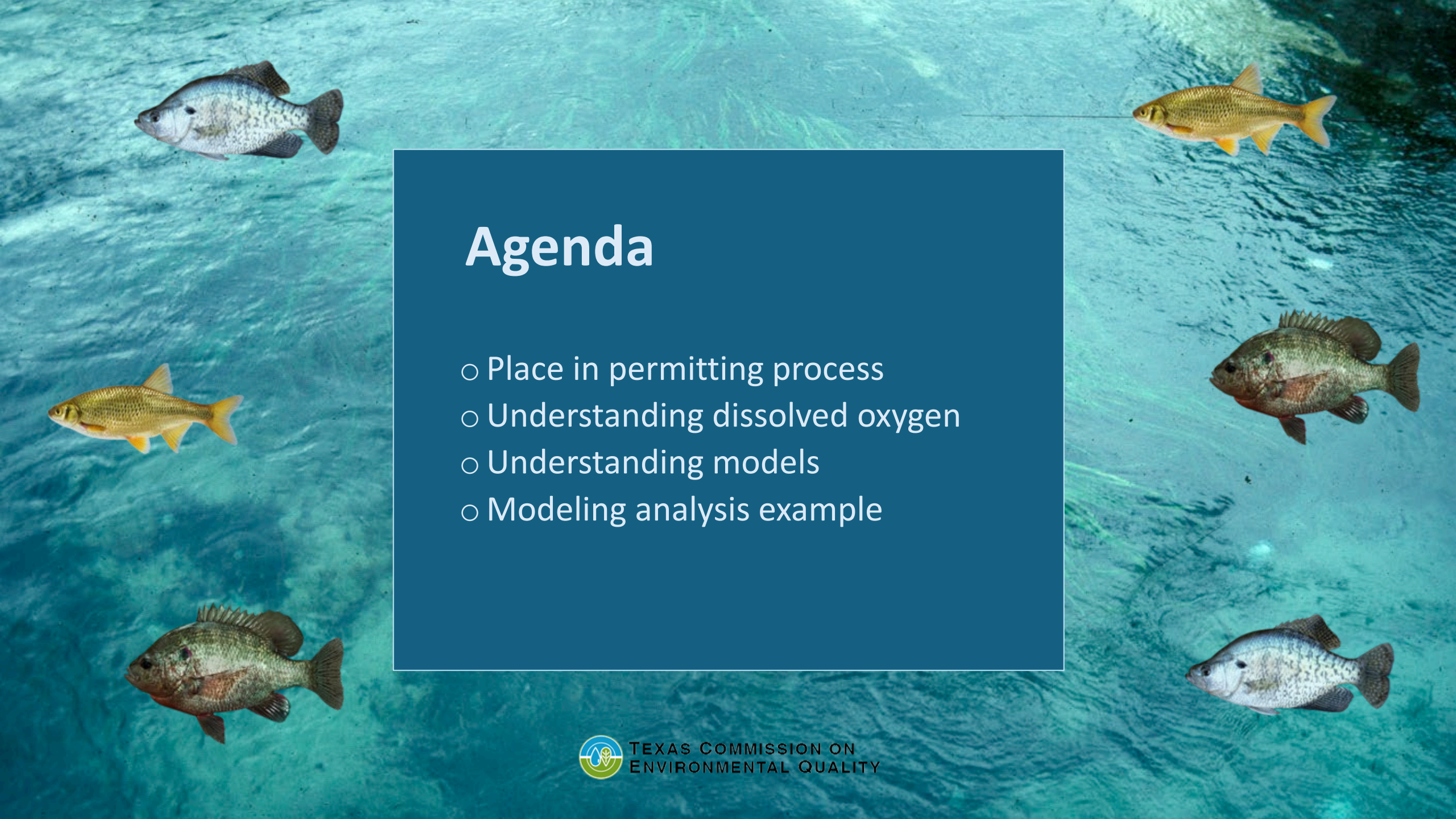
Dissolved Oxygen Modeling of Surface Waters for TPDES Permits

Claire Dittelmier

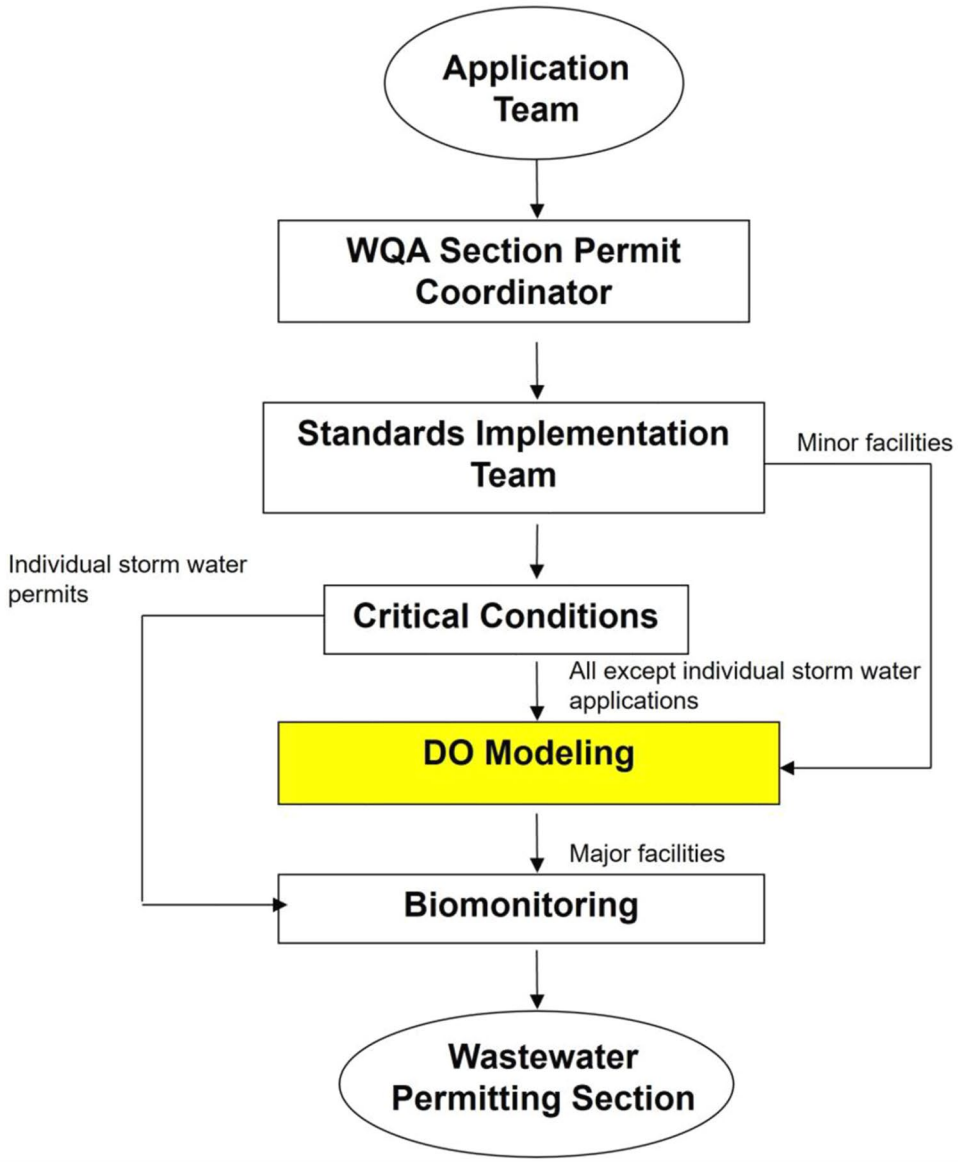
TCEQ Water Quality Division

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY



Agenda

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


Application Team
WQA Section Permit Coordinator
Standards Implementation Team
Minor facilities
Individual storm water permits
Critical Conditions
All except individual storm water applications
DO Modeling
Major facilities
Biomonitoring
Wastewater Permitting Section

FFLUENT 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).

Effluent Characteristic	Discharge Limitations				Min. Self-Monitoring Requirements	
	Daily Avg.	7-day Avg.	Daily Max.	Single Grab	Report Daily Avg. & Daily Max.	
	mg/l (lbs/day)	mg/l	mg/l	mg/l	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
E. coli, 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?

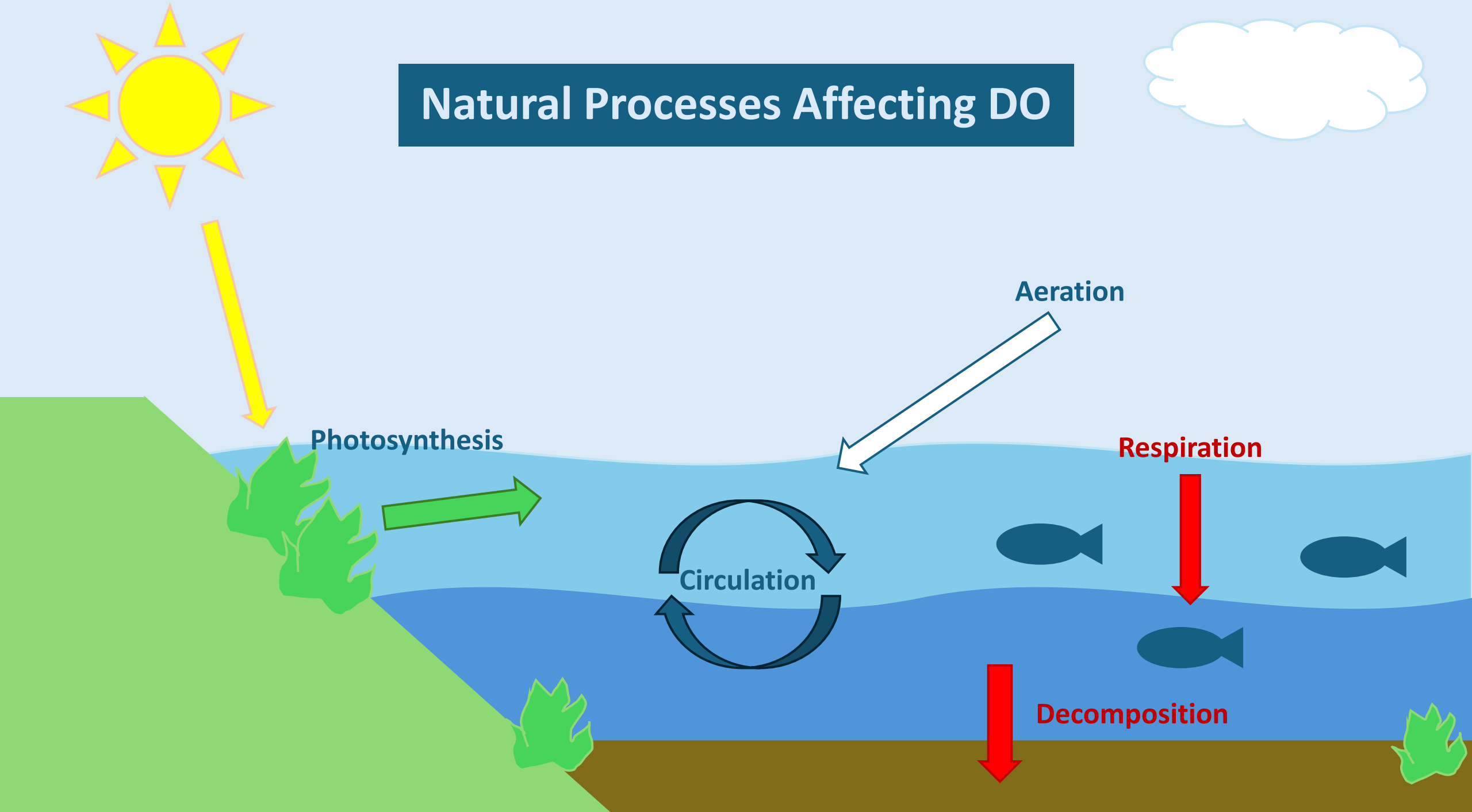
- The amount of free oxygen present in water
- Good general measure of water quality
- Essential for survival of aquatic life
- Oxygen-demanding substances commonly found in wastewaters
- Long regulatory history of dissolved oxygen modeling

DO Criteria

TABLE 3
Aquatic Life Use Subcategories

Aquatic Life Use Subcategory	Dissolved Oxygen Freshwater mean/ minimum	Dissolved Oxygen Freshwater in Spring mean/ minimum	Dissolved Oxygen Saltwater mean/ minimum	Aquatic Life Attributes Habitat Characteristics	Aquatic Life Attributes Species Assemblage	Aquatic Life Attributes Sensitive species	Aquatic Life Attributes Diversity	Aquatic Life Attributes Species Richness	Aquatic Life Attributes 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								

Natural Processes Affecting DO



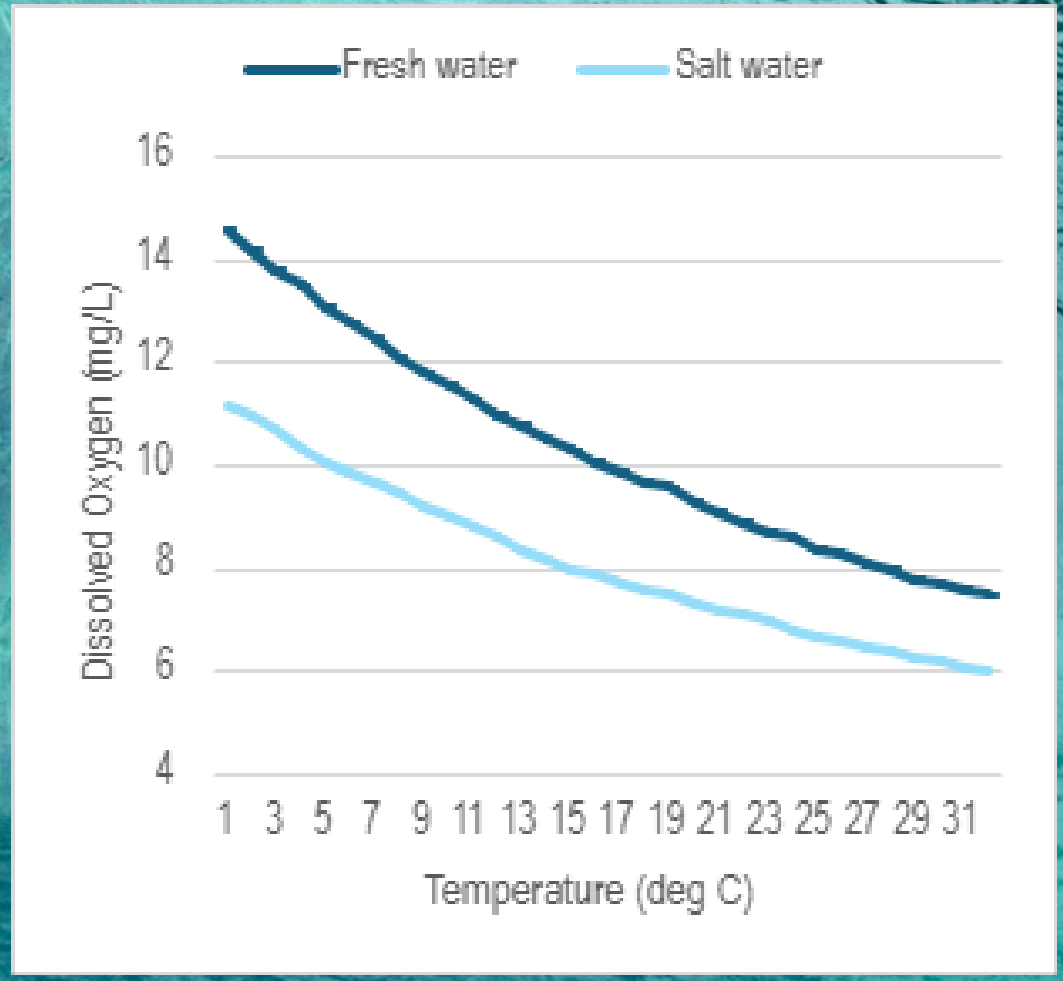
Natural Processes Affecting DO

Temperature

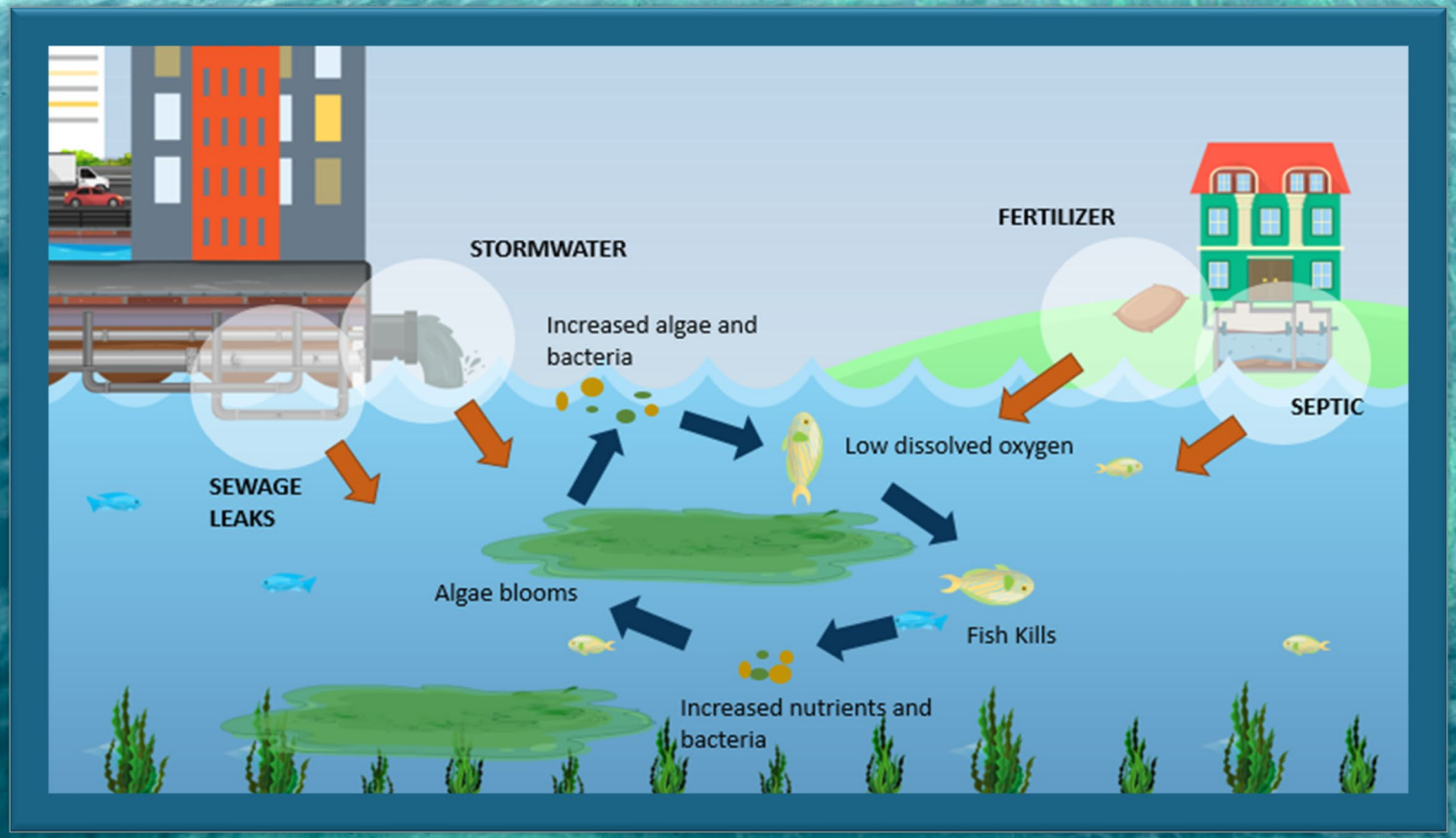
Increase in temperature = less DO

Salinity

Increase in salinity = less DO



Wastewater Impacts on DO



Oxygen-demanding constituents

- BOD_5/$CBOD_5$
- Ammonia Nitrogen

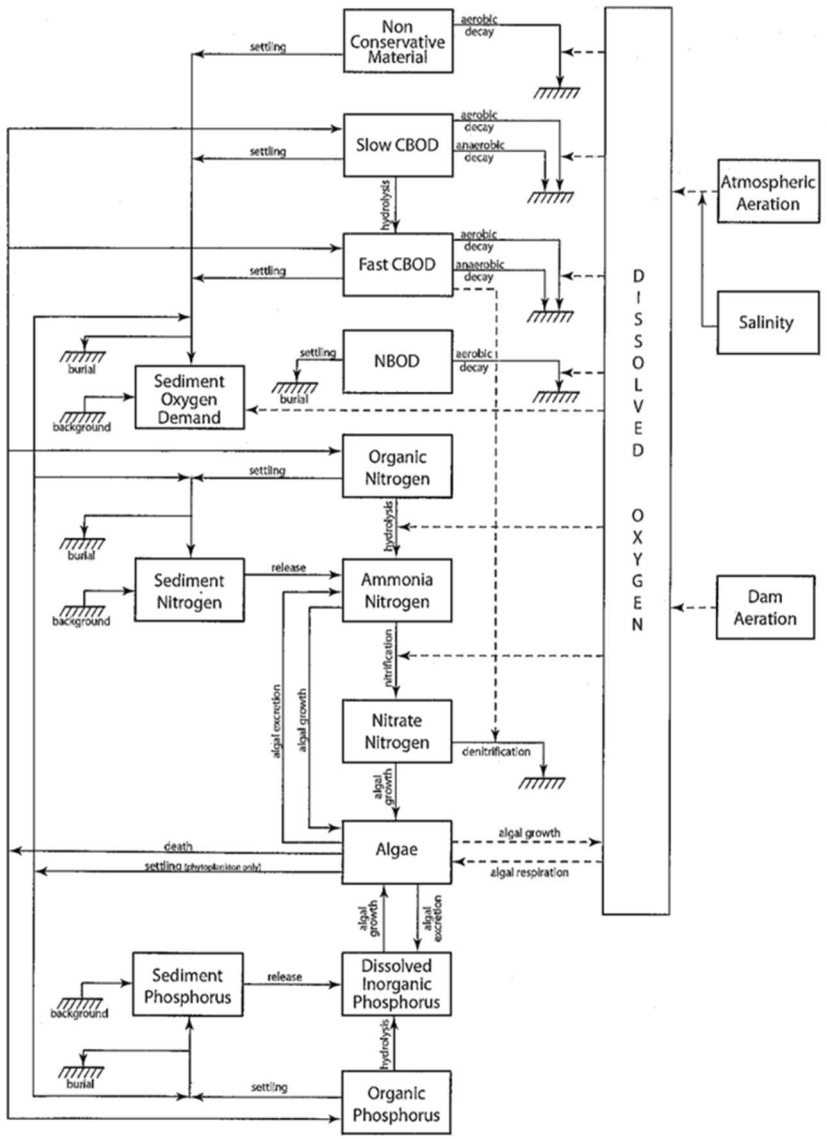
Dissolved Oxygen Models: What are they really?

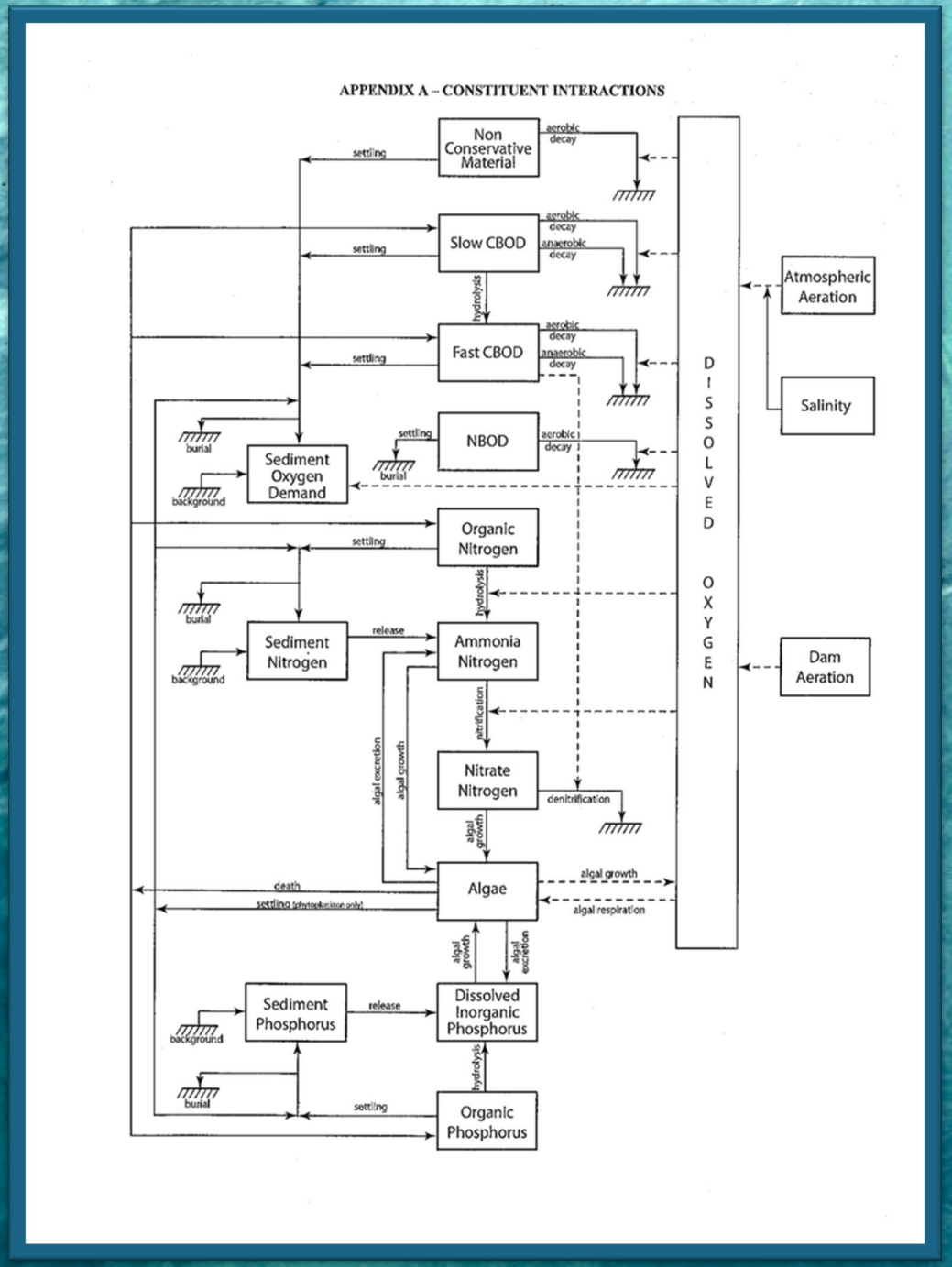
A collection of mathematical equations meant to describe interrelated chemical and physical processes contributing to DO in natural waters.

Or, more simply

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

APPENDIX A – CONSTITUENT INTERACTIONS





‘Simple’ Model Equation (Streeter-Phelps)

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

D is the saturation deficit, (D = DOsat - DO)
$\mathbf{k_1}$ is the deoxygenation rate
$\mathbf{k_2}$ is the reaeration rate
$\mathbf{L_a}$ is the initial oxygen demand of organic matter in the water, also called the ultimate BOD (BOD at time t=infinity).
$\mathbf{D_a}$ 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

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

VS

Strengths

- 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

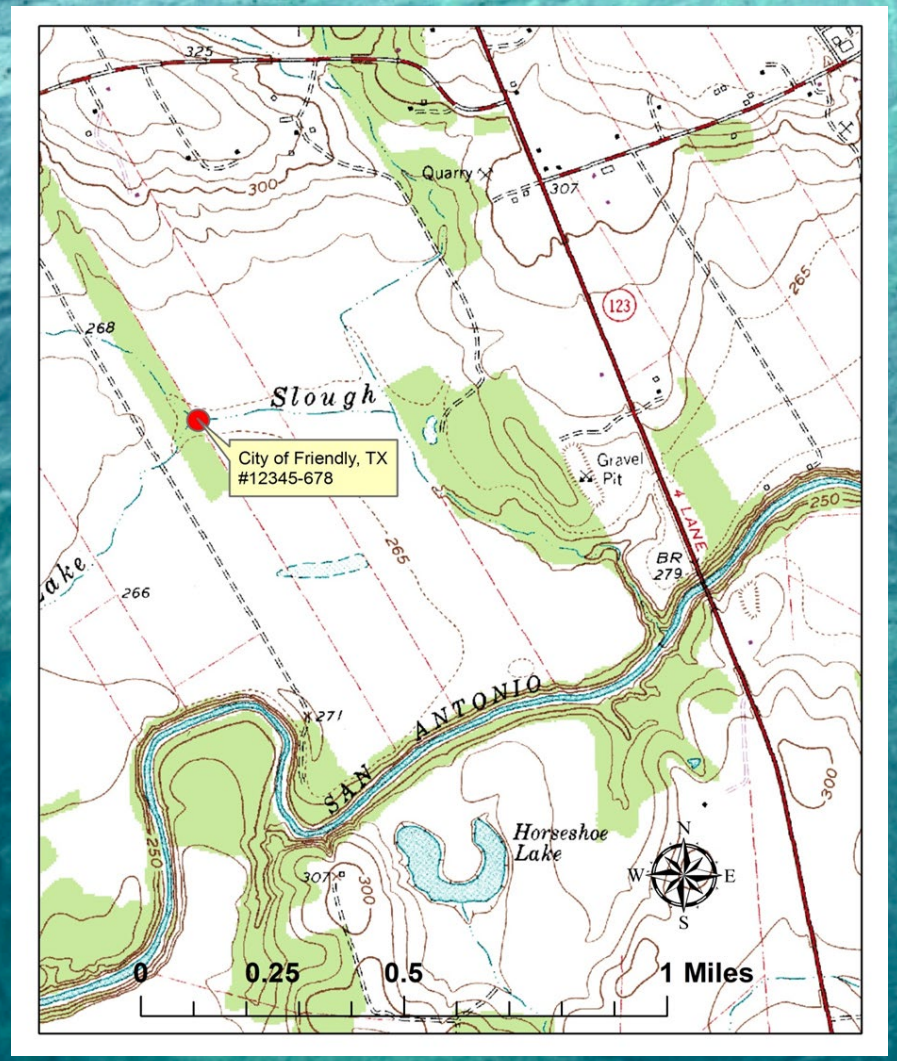
Discharge Route:

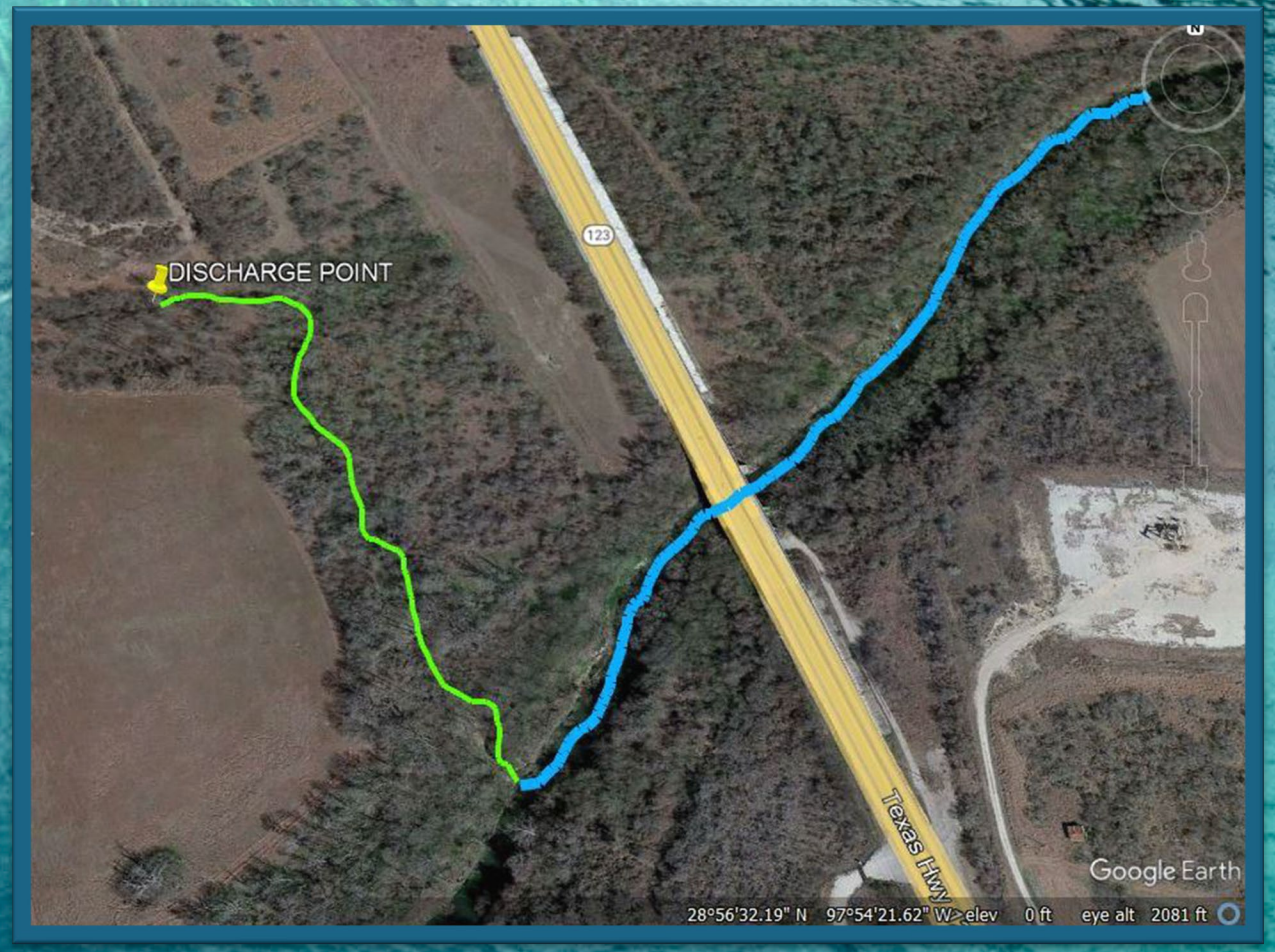
Discharge proposed into an unnamed tributary thence into the San Antonio River

Proposed Limits:

20 mg/L BOD_5, __ mg/L NH_3, 2.0 mg/L DO

Example DO Modeling Analysis





Key information

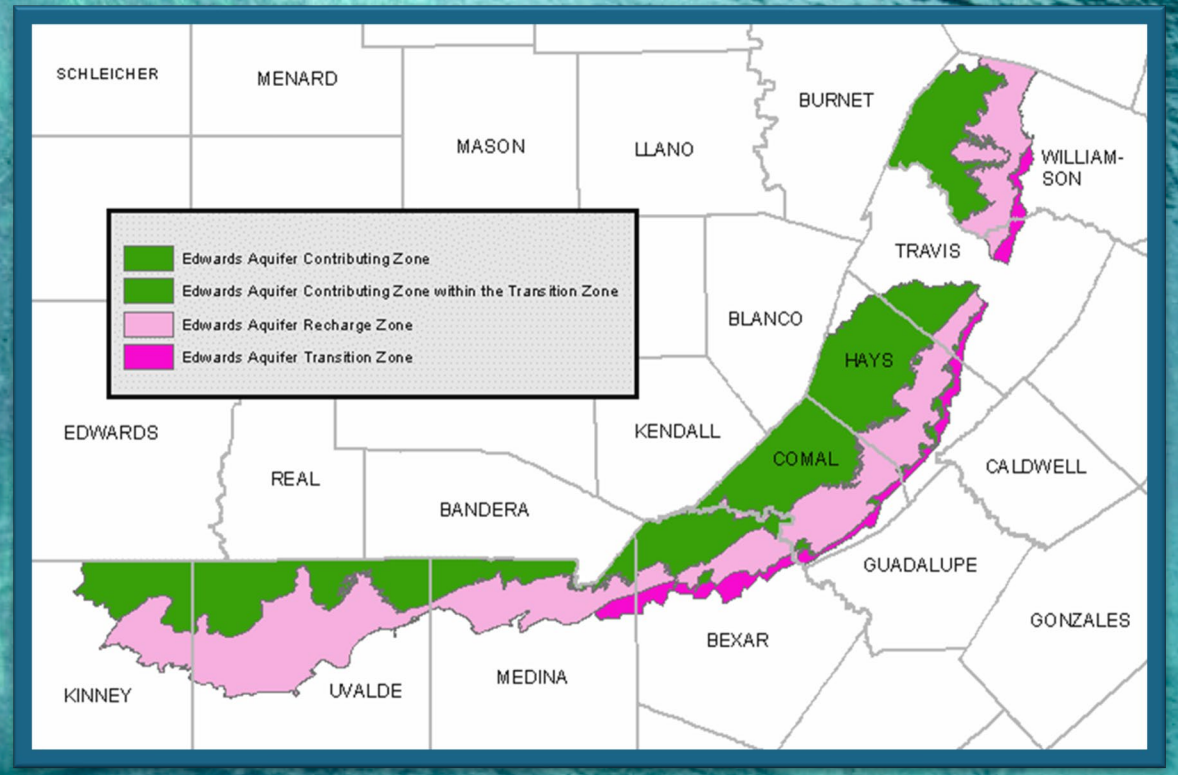
- Receiving water DO criteria
  - Unnamed tributary: 3 mg/L
  - San Antonio River: 5 mg/L
- Base flow
  - 0.0 cfs for unnamed tributary
  - 1.2 cfs for San Antonio River
- Other dischargers to consider
  - None
- Site-specific values
  - None provided by applicant; use default hydraulics

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	3.73 / 5.98

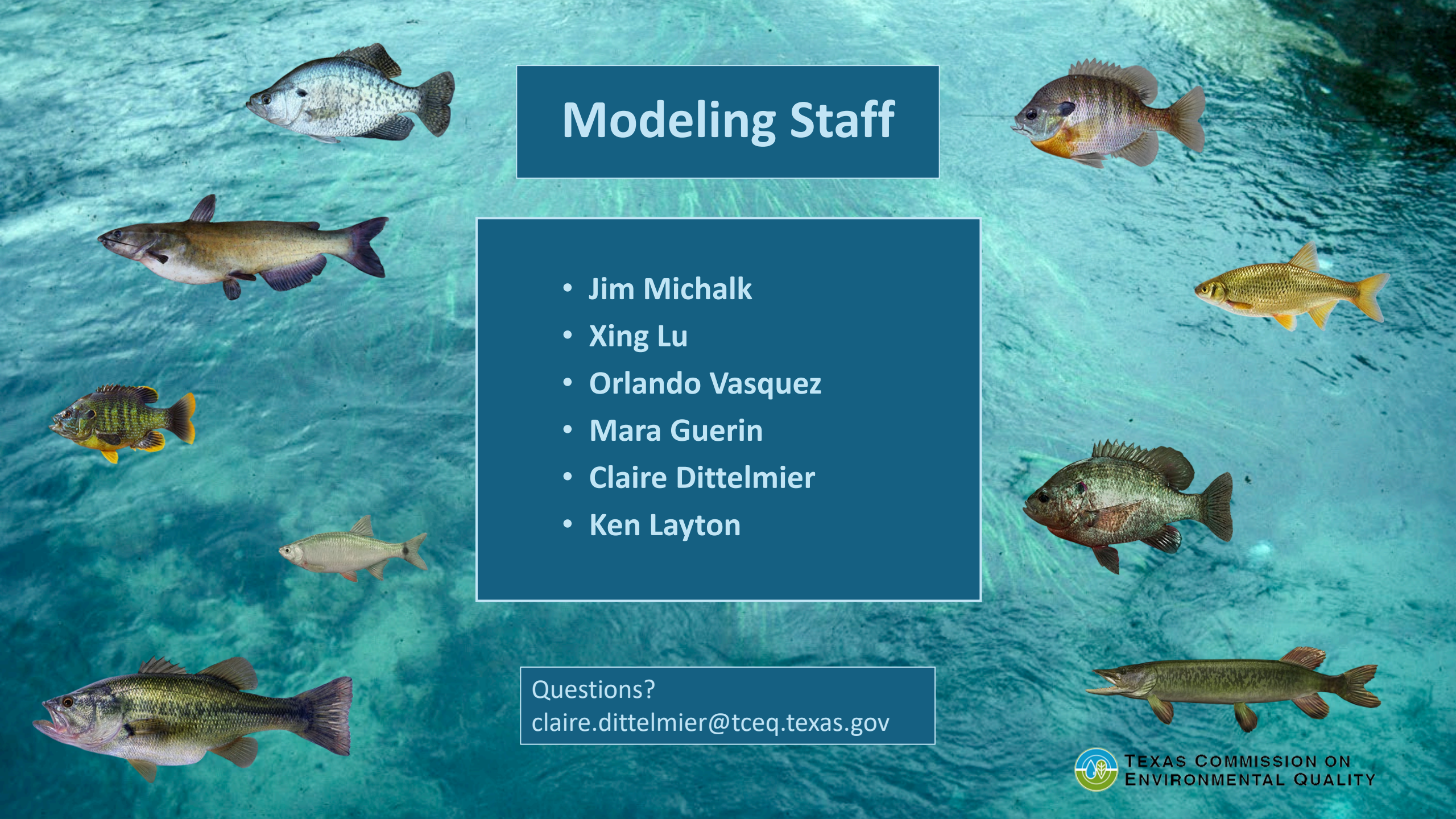
Prohibited Discharges

- 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

- Jim Michalk
- Xing Lu
- Orlando Vasquez
- Mara Guerin
- Claire Dittelmier
- Ken Layton

Questions?
claire.dittelmier@tceq.texas.gov

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY