

Nutrient Management: Innovative Technologies & Watershed Approaches

Mike Falk, PhD, PE

Mike.Falk@hdrinc.com

September 16, 2026



Acknowledgements



SOUTHERN CALIFORNIA
COASTAL WATER
RESEARCH PROJECT



Applying next-generation science to aquatic ecosystems management
A PUBLIC AGENCY



- 01 **Perspective**
- 02 **Current Themes**
- 03 **Treatment Performance**
- 04 **Watershed-based Approach**





Harmful Algal Blooms

Human wastewater
is feeding harmful
algae blooms off of
Southern
California's coast
UCL-led study explains how much
damage is caused by treated sewage

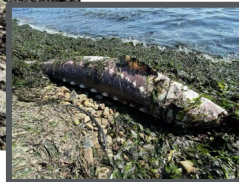
- IMPAIRMENT OF AESTHETICS, RECREATION, AQUATIC LIFE, AND WATER SUPPLY
- STRATEGIC TO “SQUEEZE THE PIPES” MORE EFFECTIVELY

California Coastal Perspective

- Bay Area (>\$10B; Harmful Algal Blooms (HABs); DO Suppression; Fish Mortality)
- Southern California Coast (>\$20B; HABs; Mammalian Deaths)
- What about Inland Dischargers?

San Francisco Chronicle

Poop and pee cause algae blooms in S.F. Bay. Water agencies will spend \$11 billion to fix the problem



Voices

Sean Bothwell

California's ocean is breaking heat records — but we can control it

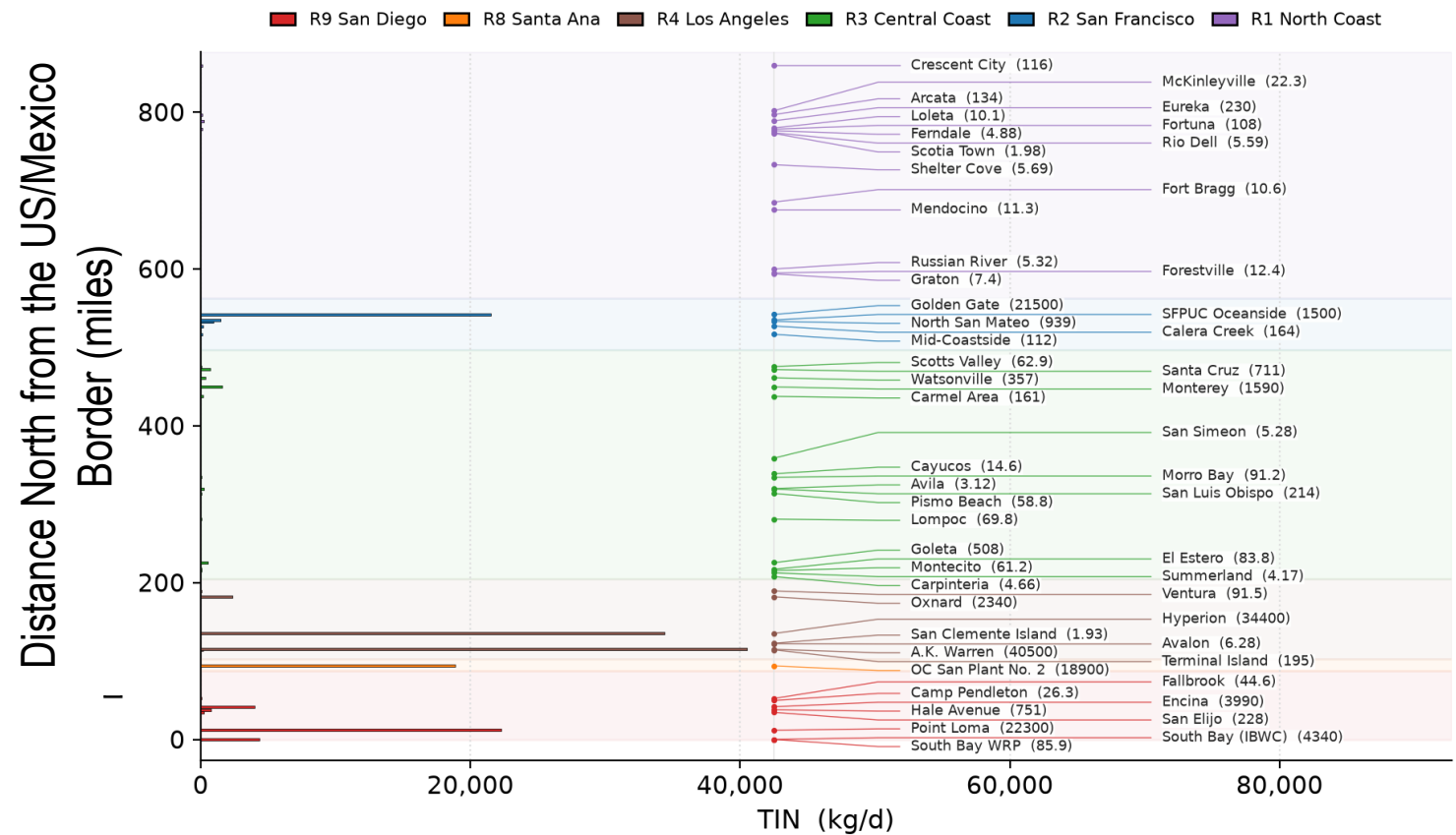


California's coastal economy generates \$44 billion annually and sustains thousands of jobs in fishing, tourism and recreation. (Jacqueline Pinedo / Los Angeles Times)

By Sean Bothwell
Guest contributor

April 30, 2026 3 AM PT

Perspective: Nutrient Discharged to the Pacific (~160,000 kg N/d)

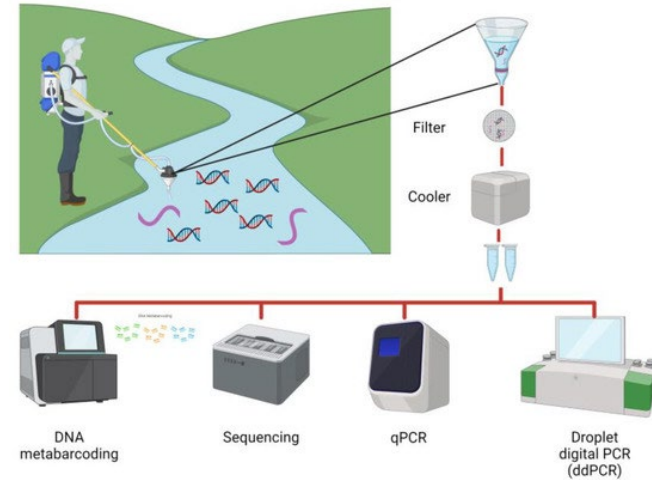


California Inland Dischargers

- Give Yourself a Pat on the Back



- Issue:
 - Toxicity (key issue for inland dischargers)
 - Potential Low Limits: Freshwater Mussels Example
 - Nutrients of Interest: Ammonia, Phosphorus, Nitrate, Total N



Why are there so Many Nutrients of Interest for Inland Dischargers versus Coastal?

Current Themes

On-Going and Future Treatment Themes

- Treatment and Process

- (How to “Squeeze” More Out of the Pipes):

- Optimization
 - Sidestream Treatment
 - Upgrades
 - Process Intensification
 - Resource Recovery



- Supply/Reuse: Non-Potable and Potable Reuse
- By Other Means: Reuse, Nature-based Solutions, etc.
- Non-Point Source Loads: Agriculture, Stormwater, etc.



Intensification: What is it and What are the Technologies?

- **Intensification**: fancy term for increasing treatment capacity within existing tankage
- **Example Intensification Technologies**:
 - Aerobic Granular Sludge (AGS)
 - Membrane Aerated Biofilm Reactor (MABR)
 - Mobile Organic Biofilm (MOB)
 - Densified Activated Sludge (DAS)
 - Others

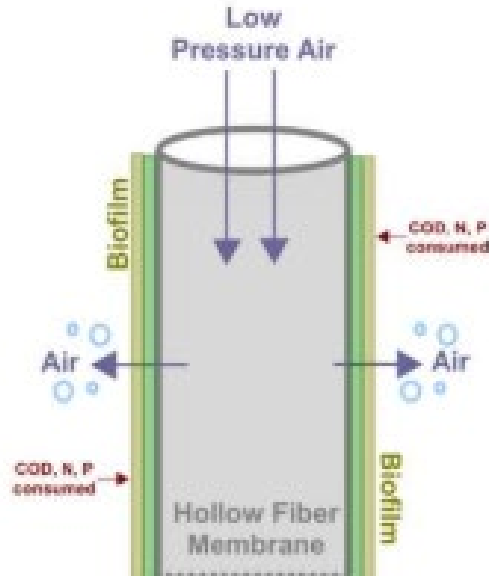


Conventional Biol. Nitrogen Removal (2X Footprint of MABR in this Example)



MABR & Process Intensification Goal

Intensification Example: Membrane Aerated Biofilm Reactor (MABR)



Reliable Recycled Water for Regional Sustainability

Harvest Water, California's largest agricultural water recycling project, will provide reliable, high-quality recycled water to agricultural lands and existing habitats in southern Sacramento County. When complete, Harvest Water will supply billions of gallons of drought-resistant recycled water each year—equivalent to more than 24,000 Olympic-sized swimming pools—and bring other lasting environmental benefits to the region.



How Partnerships Power Sacramento
waterloop



THE
PARTNERSHIPS

0:00 / 0:32

Harvest Water Epitomizes a Regional Multi-Benefit Project (what about Nutrients though?)

Treatment Performance: What is Possible?

The Colorado Story

- **Regulation 85 standards:**
 - 15 mg/L TIN annual median / 20 mg/L TIN annual 95th percentile
 - 1.0 mg/L TP annual median / 2.5 mg/L TP annual 95th percentile
- **Regulation 31 standards:**
 - 0.38 to 2.01 mg/L TN
 - 0.021 to 0.17 mg/L TP



Scientific, Technical, and Policy Recommendations for Nutrient Discharge Limits

Consensus Findings
and Recommendations by the
NWRI Expert Panel on Colorado Nutrient Limits

Prepared for
Colorado Department of Health and Environment (CDPHE)
Colorado Wastewater Utility Council (CWWUC)
(PO, FEGA, 202500005159)

Prepared by
National Water Research Institute
18700 Ward St.
Fountain Valley, CA 92708

August 4, 2026

Disclaimer

This report was prepared by an Independent Peer Review Panel, which was administered by the National Water Research Institute. Any opinions, findings, conclusions, or recommendations

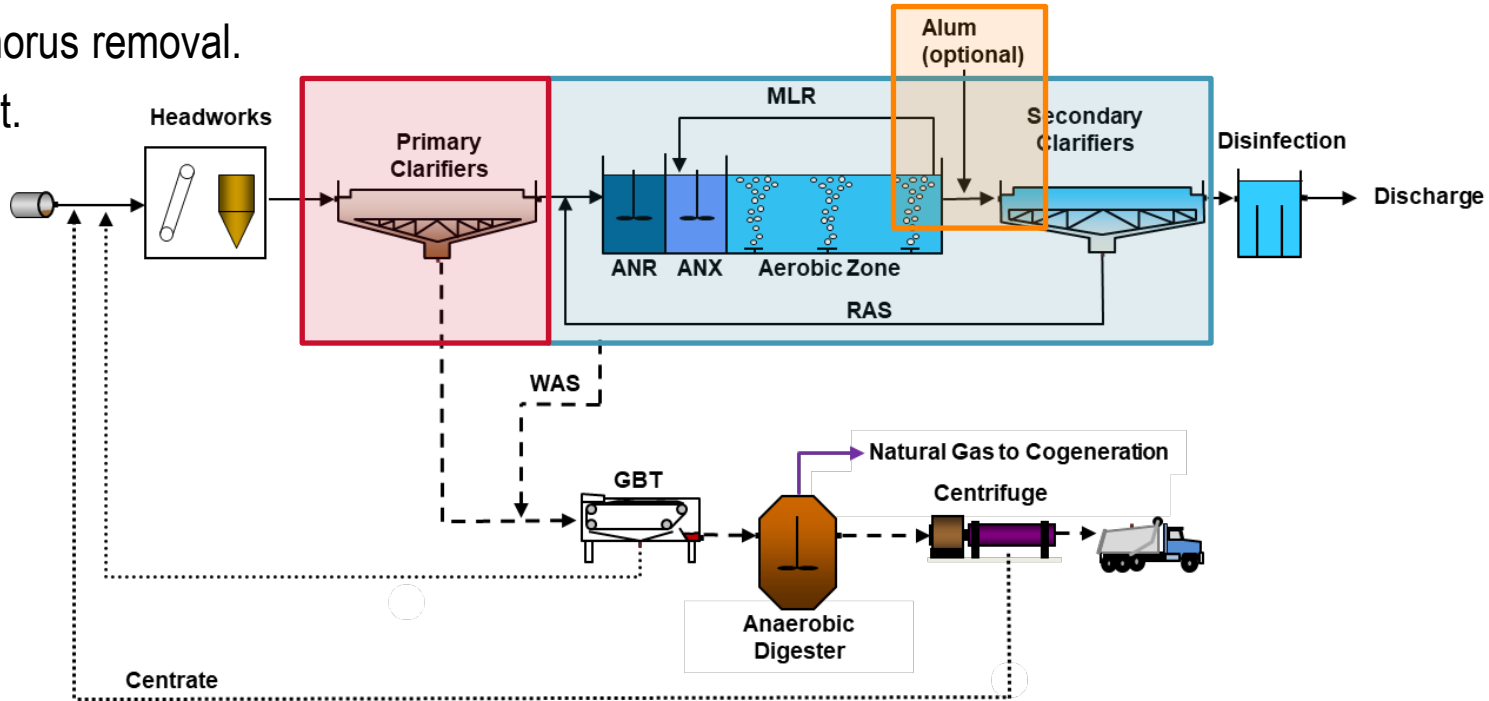
Can Treatment Plants Meet Regulation 31 Standards?

Methods: 3 Variables that Distinguish Facilities

1. Secondary process configuration.
2. Chemical phosphorus removal.
3. Primary treatment.

Excluded Variables:

- Digestion.
- Digestion type.
- Recycle flows.



Summary of NWRI Findings for Colorado

Total Inorganic Nitrogen (TIN = Ammonia + Nitrite + Nitrate) Findings

Treatment Process	Without Primary Treatment Average Annual [Maximum Month] (mg/L)	With Primary Treatment Average Annual [Maximum Month] (mg/L)
N/DN	4.9 [8.5]	10.0 [17]
BNR	3.8 [8.9]	9.5 [13]
Advanced BNR	1.4 [2.5]	5.7 [9.6]
ENR	3.2 [7.1]	8.7 [10]

N/DN = Nitrification/Denitrification; BNR = Biological Nutrient Removal; ENR = Enhanced Nutrient Removal

Whether you have Primaries has a Profound Impact on Nitrogen Removal Performance!

Why does Primary Treatment Impacts Nutrient Removal?

- Affects carbon balance, which affects ability to denitrify.
 - No primaries = more carbon for denitrification = can go lower.
-
- Tradeoffs
 - Larger aeration basins
 - More aeration demand
 - Less potential to recover energy



Watershed-based Approaches

Where has this been Done?

- Bay Area
- Southern California Coast
- Puget Sound
- Delaware River
- Montana
- Delaware River
- Montana
- Colorado
- Long Island Sound
- Chesapeake Bay
- Gulf of Mexico/America
- Others



BACWA
(wastewater utilities)



The approach in the Bay Area for managing nutrients has received national attention and lauded for its collaboration, as evidenced by receipt of a National Environmental Achievement Award in 2019 from the National Association of Clean Water Agencies (NACWA). NACWA is the nationally recognized leader in legislative, regulatory, and legal clean water advocacy.





Watershed-based Approaches (Lessons Learned)

01

**Holistic Approach to Improve
Nutrient Management (WRF4974)**

02

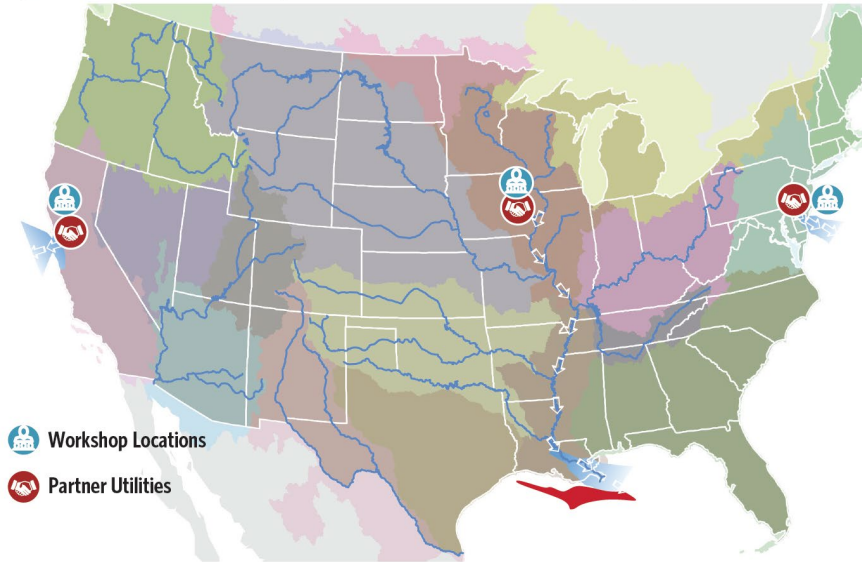
**3P's Framework: Practices, Policies,
Partnerships**

03

**3 P's Assessment of 2 Sample
Watersheds**

Holistic Approach to Improved Nutrient Management: Phase 1 WRF #4974

Figure 1. US Watersheds and Strategic Locations of Partner Utilities and Workshop Locations



THE
Water
Research
FOUNDATION



PHILADELPHIA
WATER
— DEPARTMENT —



BACWA
BAY AREA
CLEAN WATER
AGENCIES



LimnoTech



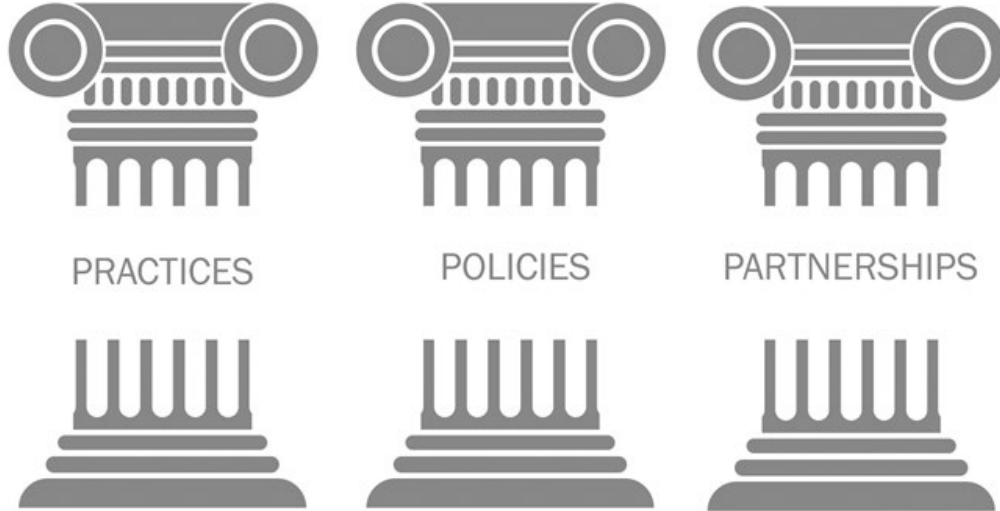
UNIVERSITÉ
LAVAL

Holistic Nutrient Management: Practices, Policies, and Partnerships (WRF4974)



THE
**Water
Research**
FOUNDATION

Key Factors Influencing Holistic Nutrient Management



- Practices
 - Nutrient Removal Treatment
 - Best Management Practices
- Policies
 - Regulatory Frameworks
 - Watershed Governance
- Partnerships
 - Collaboration
 - Leadership

7M+

SERVICE
POPULATION



37

WASTEWATER
TREATMENT PLANTS



~450

MILLION GALLONS PER DAY
TREATED
EFFLUENT



2/3's

OF NUTRIENT
LOADS TO THE BAY



B A C W A
B A Y A R E A
C L E A N W A T E R
A G E N C I E S



San Francisco Bay Nutrient Watershed Permit: Working Together for Practical Regulation



BACWA
(wastewater utilities)



Regional Water Board
(regulatory)



San Francisco Estuarine Institute
(science)



Non-Govt Organizations
(NGOs)

The approach in the Bay Area for managing nutrients has received national attention and lauded for its collaboration, as evidenced by receipt of a National Environmental Achievement Award in 2019 from the National Association of Clean Water Agencies (NACWA). NACWA is the nationally recognized leader in legislative, regulatory, and legal clean water advocacy.



Sa
Pe
Re



Bay Area Nutrient Management Assessment

Practices

- + Nutrient loads: prior to this effort, there was minimal knowledge on the nutrient contributors to the Bay. The Group Annual Report (2015-present) summarizes trends and it has informed who the largest contributors are.
- + Progress...but there is more to do for additional nitrogen load reductions
- +/- Baywide WQ model needs to be enhanced to address nutrient management questions to inform long-term nutrient management regulations (algal productivity and toxicity)

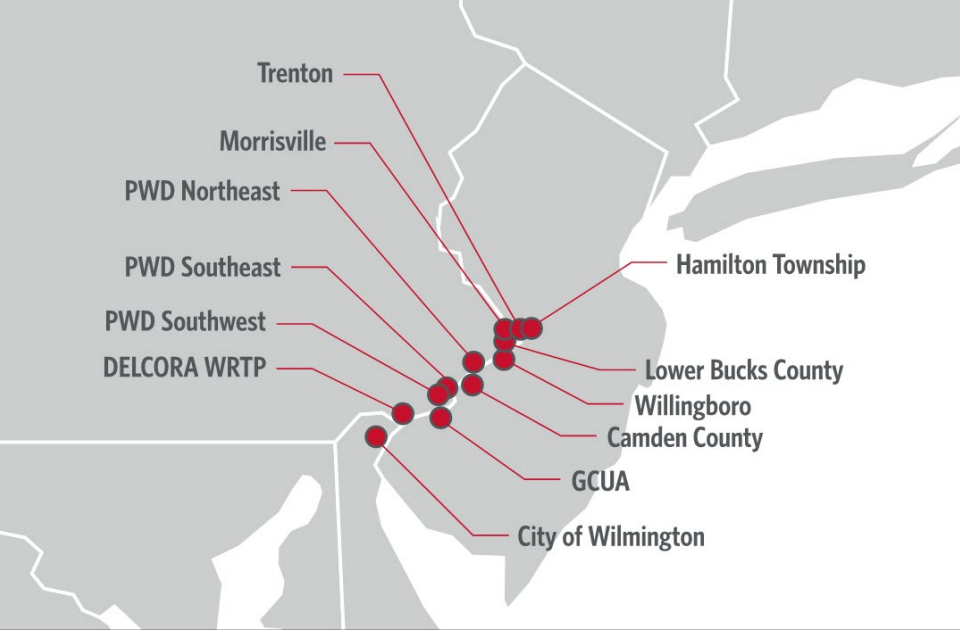
Policies

- +/- Initial 2 Watershed Permits (2014 and 2019) were the first of their kind. Resulted in a menu of options to inform nutrient management projects
- +/- 3rd Watershed Permit (2024) is challenging!
- 10 year Compliance Schedule inadequate
- Funding challenges

Partnerships

- + Successful collaboration has been a cornerstone strength

Bay Area Clean Water Agencies (BACWA), Regional Water Board (RWB), San Francisco Estuary Institute (SFEI), and Bay Keeper



Delaware River and Estuary

12 Wastewater Utilities

- Ammonia
- Nutrients
- Wet Weather Compliance
- Toxics

- Low Dissolved Oxygen
- Endangered Species (ESA)
- Litigation

Delaware Estuary Nutrient Management Assessment

Practices

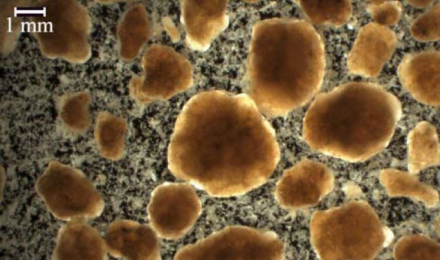
- +/- Ammonia load reduction in design at some utilities with cost being a major challenge
 - Sidestream ammonia removal in design at least two facilities
 - Disagreement from utilities and regulators on actual cost to remove ammonia
- +/- Coupled Hydrodynamic/Eutrophication Model (EFDC-WASP)
 - DRBC developed water quality model but not evaluating dynamic discharge flows and loads

Policies

- + History of improved DO in the Delaware Estuary
 - Improvements from 1967 onward have allowed for the observed reproduction and propagation of various fish species including Atlantic sturgeon
- EPA stepped in to speed up DO criteria development
 - Interrupted DRBC's process of incorporating stakeholder comments and based DO criteria on reports that were never finalized.

Partnerships

- +/- Partnership with 9 active utilities formed to share information and resources
- + DRBC's Water Quality Advisory Committee meetings includes multiple stakeholders including utilities
- Strained relationships between wastewater utilities, NGOs, and EPA
- EPA/River Keeper proposed consent decree



Nutrient Management: Innovative Technologies & Watershed Approaches

Mike Falk, PhD, PE
Mike.Falk@hdrinc.com

September 16, 2026



Hip Pocket

Puget Sound Nutrient Management Assessment

Practices

- + Detailed Water Quality Modeling (Salish Sea Model)
- +/- Limited Number of Nutrient Removal Facilities
- Secondary Treatment Facilities with Peak Wet Weather Flow Challenges
- Lack of Nonpoint Source Controls

Policies

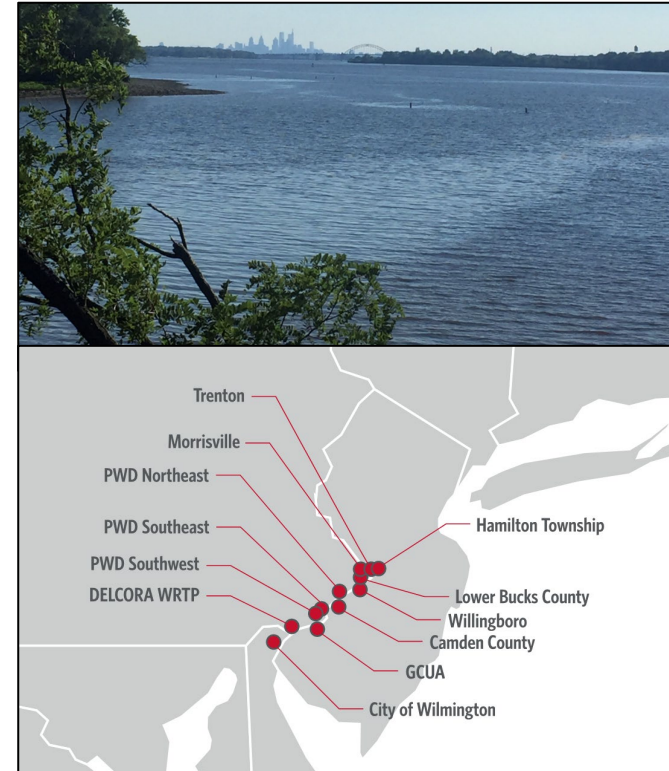
- Puget Sound Nutrient General Permit (PSNGP)
 - Narrative Effluent Limits, Optimization, Nutrient Reduction Evaluation
 - PCHB Invalidates PSNGP
- Washington Dissolved Oxygen (DO) Standard
 - Restrictive Ecology Interpretation of Natural Conditions D.O. Standard
 - EPA Disapproval of Washington D.O. Standard
- Funding?

Partnerships

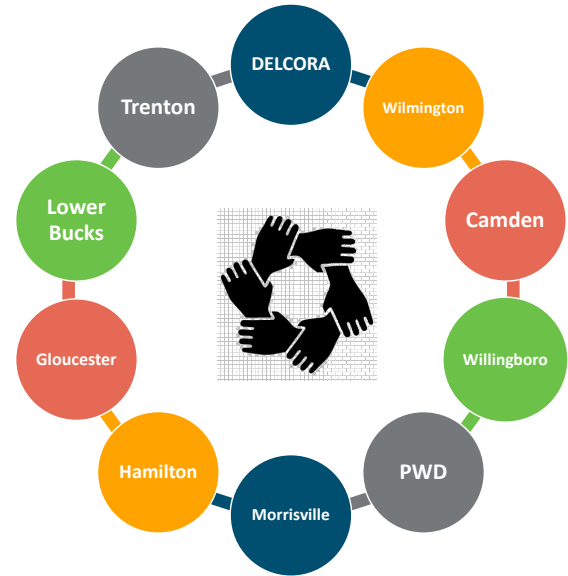
- +/- Formation of “Puget Sound Clean Water Alliance”
- + University of Washington/Puget Sound Institute
- Ecology Led Nutrient Workgroup and Advisory Committee
 - Ineffective Facilitation, Lack of Mission Consensus
- Conflict
 - Litigation Challenge to Basis for Impairment and Need for PSNGP
 - Administrative Appeal of PSNGP
- +/- 2025 Draft Nutrient Reduction Plan (Advance Restoration Plan)
 - Feasibility of Nonpoint Source Reductions?
 - 25 Year Compliance by 2050

Delaware Estuary

- **Dissolved Oxygen**
 - **Aquatic Life Designated Use (ALU)** change proposed from fish maintenance to fish propagation in the urbanized reach of the Delaware River.
 - EPA proposed water quality criteria and comment period has closed.
- **Recreational Use Designation**
 - Potential to change the recreational use designation from secondary to primary contact activities in the urbanized reach of the Delaware River.
 - Focus on reducing CSO bacteria contributions to the river.
- **PFAS**
 - Provisions for PFAS biosolids limits if EPA designates PFAS as hazardous under CERCLA
 - Lawsuits filed against 3M
 - DuPont, Chemours, and Corteva settle with the state of Delaware in July 2021
- **Total Dissolved Solids**
- **PCBs**
- **Other Emerging Contaminants (1,4-Dioxane, Microplastics)**



Delaware Estuary Water Quality Improvement Partnership (DEWQIP)



Delaware Estuary Water Quality Improvement Partnership (DEWQIP), One Year In

First year focused on the proposed ALU and the corresponding DO criteria.

Fostered communication and alignment regarding this proposed rule.



Going forward: learning from ALU experience to tackle the next issue(s).

How Partnerships Impact Policy

WRF 4974: Holistic Approach to Improved Nutrient Management



DEWQIP Workshop 1

41

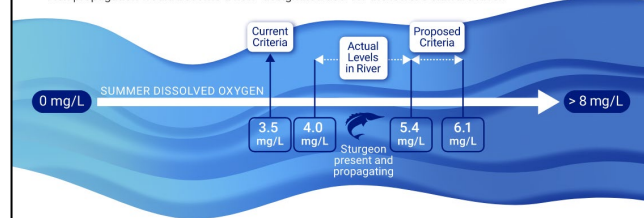
Laying the groundwork for how partnerships can impact policy.

Shared resources between members and developed communication tools in response to the proposed DO criteria.

EPA Water Quality Proposal for the Delaware River Estuary

The Proposal

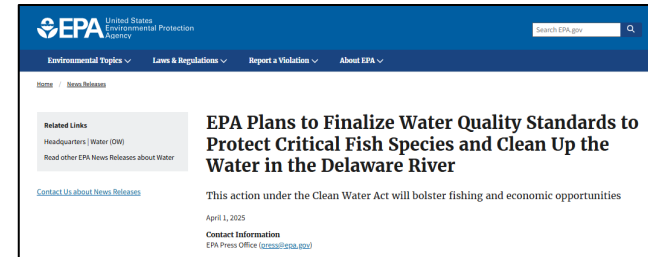
This proposed rulemaking would require the Delaware River Estuary's water to meet **higher dissolved oxygen (DO) criteria** to create better conditions for fish reproduction and survival, including for sturgeon. Fish propagation would become a new "designated use" for the lower Delaware River.



One-page data sheet developed by DEWQIP

Delaware River Dissolved Oxygen Standards Rulemaking

- 2023 EPA Proposes Water Quality Standards to Protect Aquatic Life
 - Would Require Effluent Ammonia Limits
 - Delaware Riverkeeper Lawsuit
- EPA/River Keeper Proposed Consent Decree Requiring EPA Finalize DO Std by June 30, 2025
 - Consent Decree Not Finalized
- • April 1, 2025 EPA Announces Plan to Finalize DO Std
- July 14, 2025 EPA Delivers Final Rule Package to Office of Management and Budget
- July 21, 2025 Court Issued Stipulated Order Requiring EPA Finalize Rule by Sept 22, 2025
- Compliance Cost Estimates Differences
 - Wastewater Utilities v. DRBC



[Water Quality Standards: Delaware River | US EPA](#)

[EPA Proposes Water Quality Standards to Protect Aquatic Life in Certain Sections of the Delaware River | US EPA](#)



San Francisco Bay Nutrient Management

- Bay Area Clean Water Agencies (BACWA)
- Regional Water Board (RWB)
- San Francisco Estuary Institute (SFEI)
- Wastewater Nutrient Removal
 - Optimization & Intensification
 - New Technologies
- Reuse
 - Nutrient Diversion & Water Supply
- Nature Based Solutions (NbS)
 - Horizontal Levees
 - Resiliency, Shoreline Restoration, Habitat

Leadership and Collaboration

San Francisco Bay Watershed Nutrient General Permit

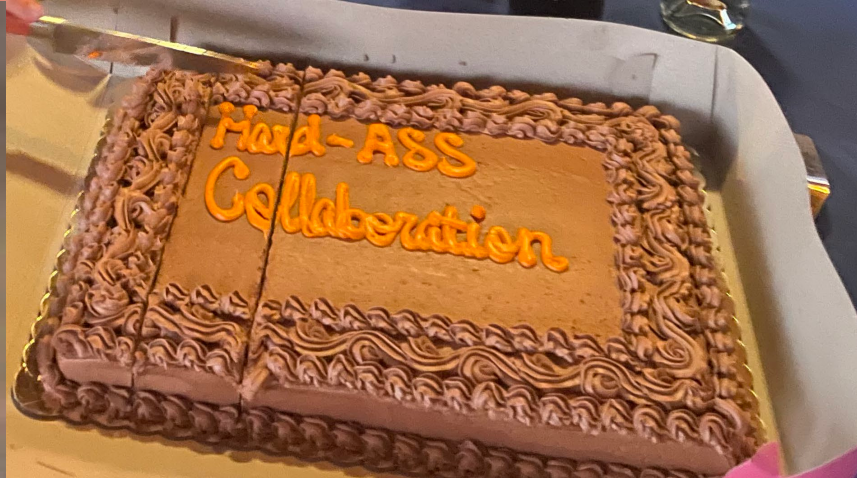
- Unique Collaboration of 37 WRRFs, Regulators, Scientists
- Innovative and Cooperatively Developed
- Targets
- Incentives
- David R. Williams, Former Executive Director, Bay Area Clean Water Agencies (BACWA)
- Tom Mumley, Assistant Executive Office, San Francisco Bay Regional Water Quality Control Board



Leadership and Collaboration

San Francisco Bay Watershed Nutrient General Permit

- David R. Williams, Former Executive Director, Bay Area Clean Water Agencies (BACWA)
 - *Shuttle Diplomacy*
- Tom Mumley, Assistant Executive Officer at San Francisco Bay Regional Water Quality Control Board
 - *Hard-Ass Collaboration*



Multiple Benefit Investments

- San Francisco Bay Watershed Nutrient Permit
 - Incentives for Early Actions
 - Nutrient Reduction by Other Means
 - Reuse
 - Nature Based Solutions
 - » Oro Loma Sanitary District
 - » Horizontal Levee
 - » <https://youtu.be/OHt7qtl1kso>
- Multiple Benefits
 - Nutrient Reduction
 - Water Supply Resiliency
 - Sea Level Rise Mitigation
 - Habitat Restoration



Oro Loma Sanitary District

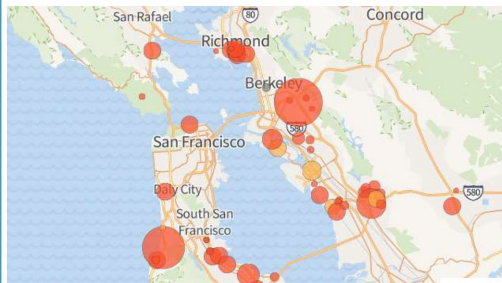
Poop and pee fueled the huge algae bloom in San Francisco Bay. Fixing the problem could cost \$14 billion



Storms in the Bay Area have unleashed millions of gallons of untreated sewage

Bay Area sewage spills during recent storms

Affects waterway Does not affect waterway Unknown / no data



Storms send sewage pouring into streets, creeks, San Francisco Bay and Pacific Ocean

LISA M. KRUGER Bay Area News Group Jan 10, 2023 Updated 11:45 am



San Francisco Bay Climate Impacts

- Summer 2022 Harmful Algae Bloom
 - Fish Kill
- Nutrients + Water Clarity + Hot Weather + Limited Mixing
 - “unprecedented red tide leading to massive fish kills during a heat wave”
- Winter 2023 Atmospheric River
 - Flooding
 - NPR Weekend Edition: *“Most susceptible in low income communities of color”*
 - “wastewater treatment plants need to be overhauled”
 - “utilities must prepare for ongoing climate whiplash”



BACWA Update: 2024 Permit Renewal

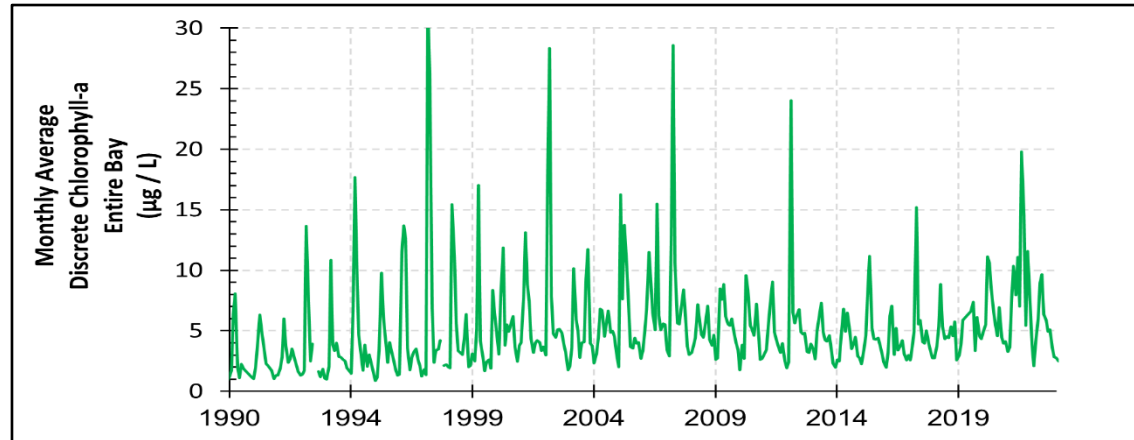
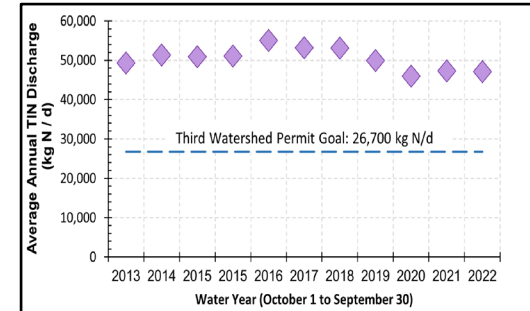
- Limits will be Implemented
 - August 2022 and 2023 algal blooms
 - Acute toxicity
 - Baywide limits by year 2035 (40% reduction of total inorganic nitrogen (TIN):
 - 26,700 kg N/d during the dry season (May 1 to Sept 30)
 - On-going construction projects which should reduce the loads to $<40,000$ kg N/d
 - Additional upgrades needed to achieve 26,700 kg N/d.
- Challenges still remain:
 - Compliance timeline is tight
 - Nutrient management balance with other competing multi-benefit projects
 - Funding limitations
 - Upgrades $> \$10B$
 - Baywide WQ model needs to be further enhanced
- Next generation nitrogen reduction efforts:
 - Nutrient trading program?

San Francisco Bay Wastewater Nitrogen Loadings v. Chlorophyll-a

- Bay Area Clean Water Agencies



USGS Chlorophyll-a Data Averaged Across All Stations and All Recorded Depths



Need to Address Algal Productivity Chl-a and Harmful Algal Bloom (HAB) Aquatic Toxicity

Bay Area Nutrient Management Assessment

Practices

- + Nutrient loads: prior to this effort, there was minimal knowledge on the nutrient contributors to the Bay. The Group Annual Report (2015-present) summarizes trends and it has informed who the largest contributors are.
- + Progress...but there is more to do for additional nitrogen load reductions
- +/- Baywide WQ model needs to be enhanced to address nutrient management questions to inform long-term nutrient management regulations (algal productivity and toxicity)

Policies

- +/- Initial 2 Watershed Permits (2014 and 2019) were the first of their kind. Resulted in a menu of options to inform nutrient management projects
- +/- 3rd Watershed Permit (2024) is challenging!
- 10 year Compliance Schedule inadequate
- Funding challenges

Partnerships

- + Successful collaboration has been a cornerstone strength

Bay Area Clean Water Agencies (BACWA), Regional Water Board (RWB), San Francisco Estuary Institute (SFEI), and Bay Keeper

NWRI Findings for Colorado (NO Quiz on this Plot!)

