Immersed Membrane Bioreactors For Water Reuse: Summary of 5 Years Experience

Presented

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ZENON

Water for the World

ZeeWeed! Everywhere!

The Problem

- In Arid Regions, such as the Gulf countries, fresh water severely limited
- Sea Water Desalination is an expensive alternative
- Wastewater generation rates, and characteristics exceed the attenuation capacity of the environment

- Reusing this sewage as a water source for high level reuse would allow:
  - Reduced water costs
  - Growth in water short areas

The Solution

- Recycle Wastewater for:
  - Irrigation of crops, parks, gardens
  - Industrial - cooling waters
    - wash water
    - process water
  - Indirect potable water when injected in the aquifer

However

Treated sewage is not just treated sewage…

As population density increases, and

New parasites develop…

The reuse of treated sewage can become a huge liability if not implemented properly:

- parasites in the treated water → diseases
- contamination of aquifers → pollution
- dirty cooling towers, etc…

Alternatives

1) Activated Sludge + Clarifiers + Sand Filter
2) Activated Sludge + Clarifiers + Membranes (Advanced Tertiary Treatment)
3) Membrane Bioreactor

The Best Solution

Membrane Bioreactors …

- Better effluent quality:
  - No parasites – barrier technology
  - Lower contaminants levels – aquifers protected
  - No suspended solids
    - Better cooling water
    - Better RO feed-water
    - Better irrigation for golf courses

- Less Process Equipment:
  - Easier to operate
  - Smaller footprint

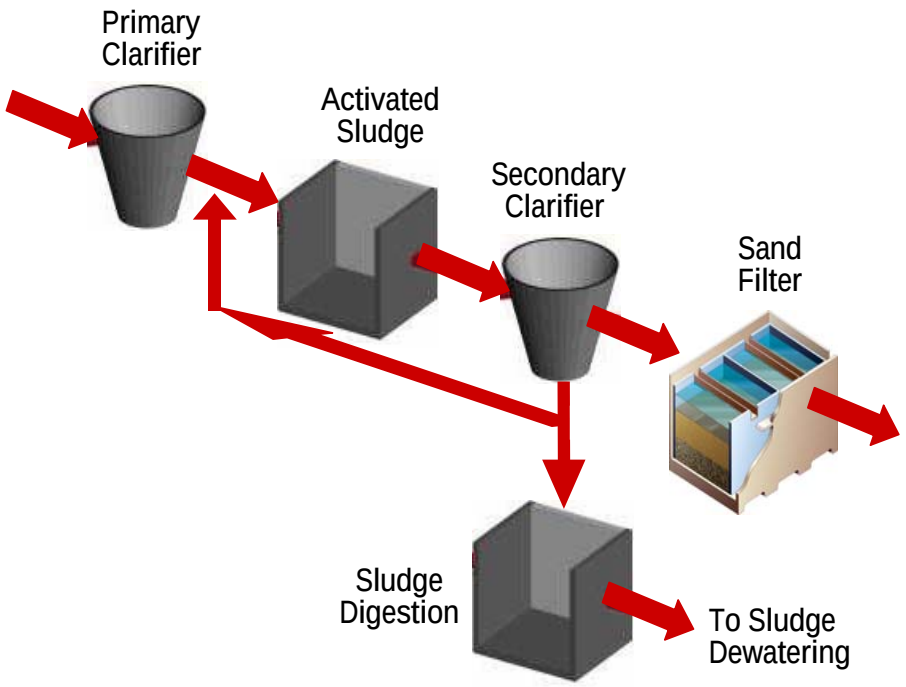
ZeeWeed MBR Technology

Membrane Bioreactor (MBR)

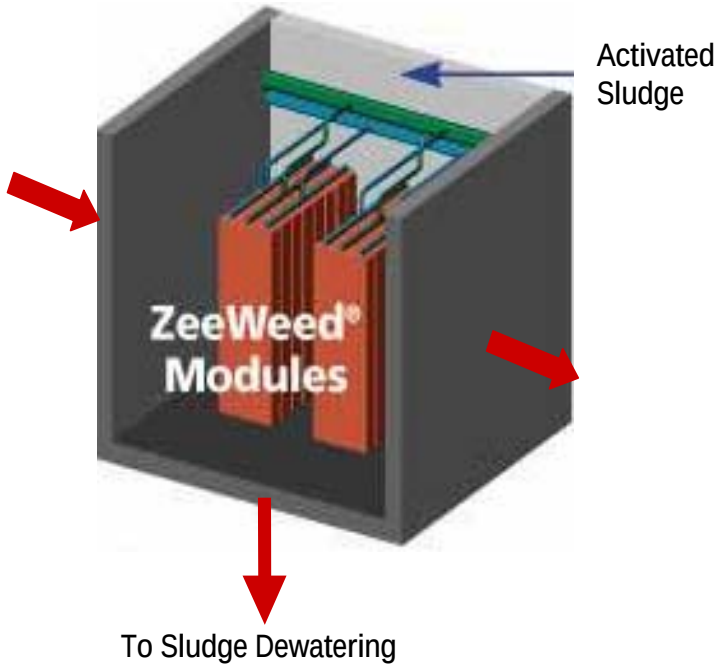
Membrane Filtration used in place of Secondary Clarifiers and Tertiary Filters in an Activated Sludge Process

Conventional ASP vs. Submerged MBR

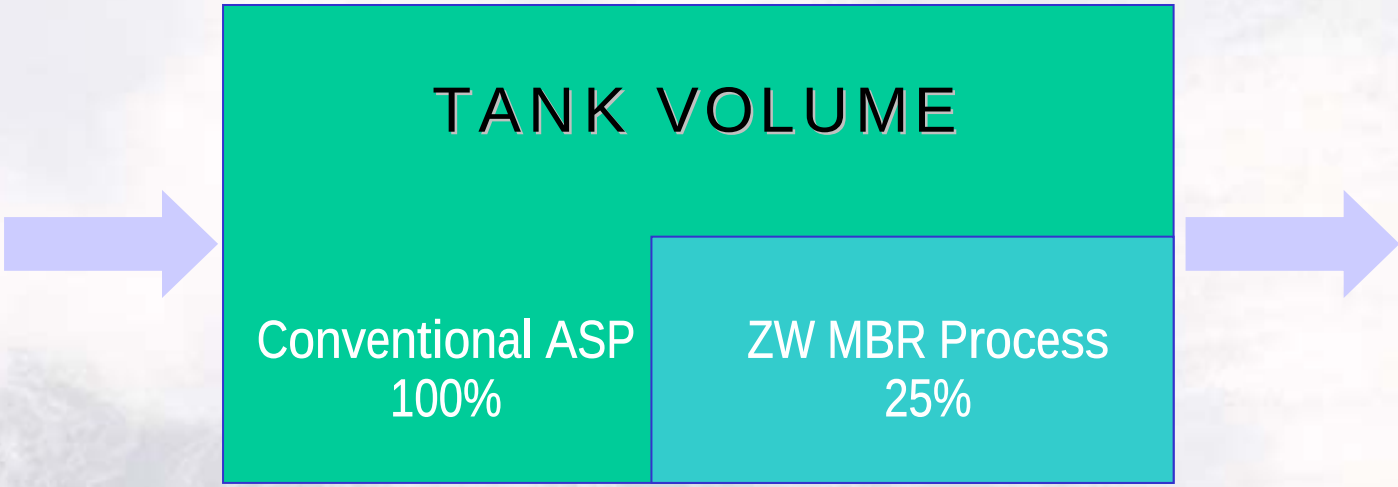
Conventional WAS Process



ZeeWeed® MBR Process



Conventional ASP vs. Submerged MBR



HIGH-RATE BIOREACTOR

- Large throughput
- Extra-compact footprint
- Low sludge production

ZeeWeed® MBR Effluent Quality

- BOD < 5 mg/L (typically non-detectable)
- TSS < 5 mg/L (typically non-detectable)
- NH3-N < 1 mg/L (typically <0.5 mg/L)
- TN < 10 mg/L (<3 mg/L achievable in warm climate)
- TP < 0.2 mg/L (<0.05 mg/L achievable)
- Turbidity < 1 NTU (<0.2 NTU 95% of the time achievable)

Best approach to meet future effluent quality requirements

ZeeWeed® MBR Advantages

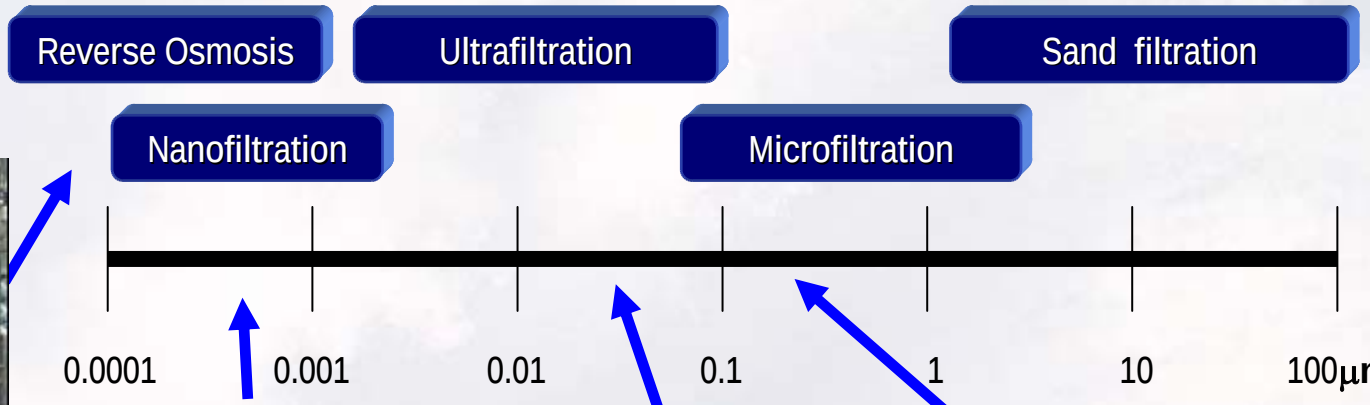
- Compact: Smaller bioreactor, no clarifier, no sand filters
- High MLSS: Membranes operate at 8,000 to 15,000 mg/L
- Reliable: Performance independent of sludge settling characteristics
- Entirely aerobic; no offensive odors
- Ideal for water reuse
- Year round nitrification ensured
- Readily adapted for N removal
- Low effluent TP with coagulant addition
- Readily adapted for Bio-P removal
- Adaptable to existing tanks (minimize civil works) ideal for retrofitting and upgarding
- Ideal for staged expansion

ZeeWeed® MBR Operation

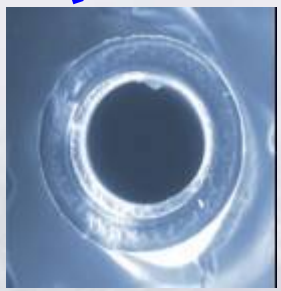
- Pretreatment
  - Fine screening (2-3 mm)
- Membrane Cleaning
  - Membrane scour by cyclic aeration
  - Automated backpulse/relax
  - Automated maintenance cleans
  - In-tank or Dip tank recovery cleans
- Membrane Integrity and Repair
  - Online monitoring of effluent turbidity
  - Broken fibers can be repaired on site

Membrane Configurations

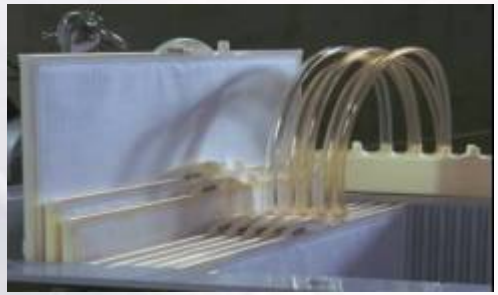
Reverse Osmosis



Spiral wound/tubular: best suited to NF/RO



Hollow fiber: best suited for MF/UF



Flat plate

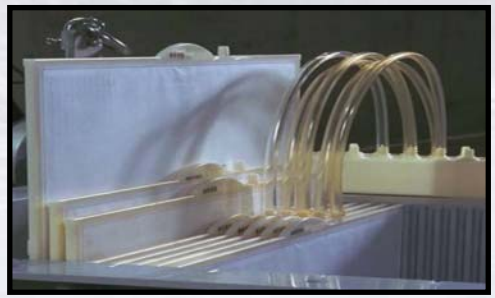
Separation of ions requires greater pressure than separation of particles

Immersed Membrane Configurations for Membrane Bioreactors

Reinforced Hollow Fiber

Non-Reinforced Hollow Fiber

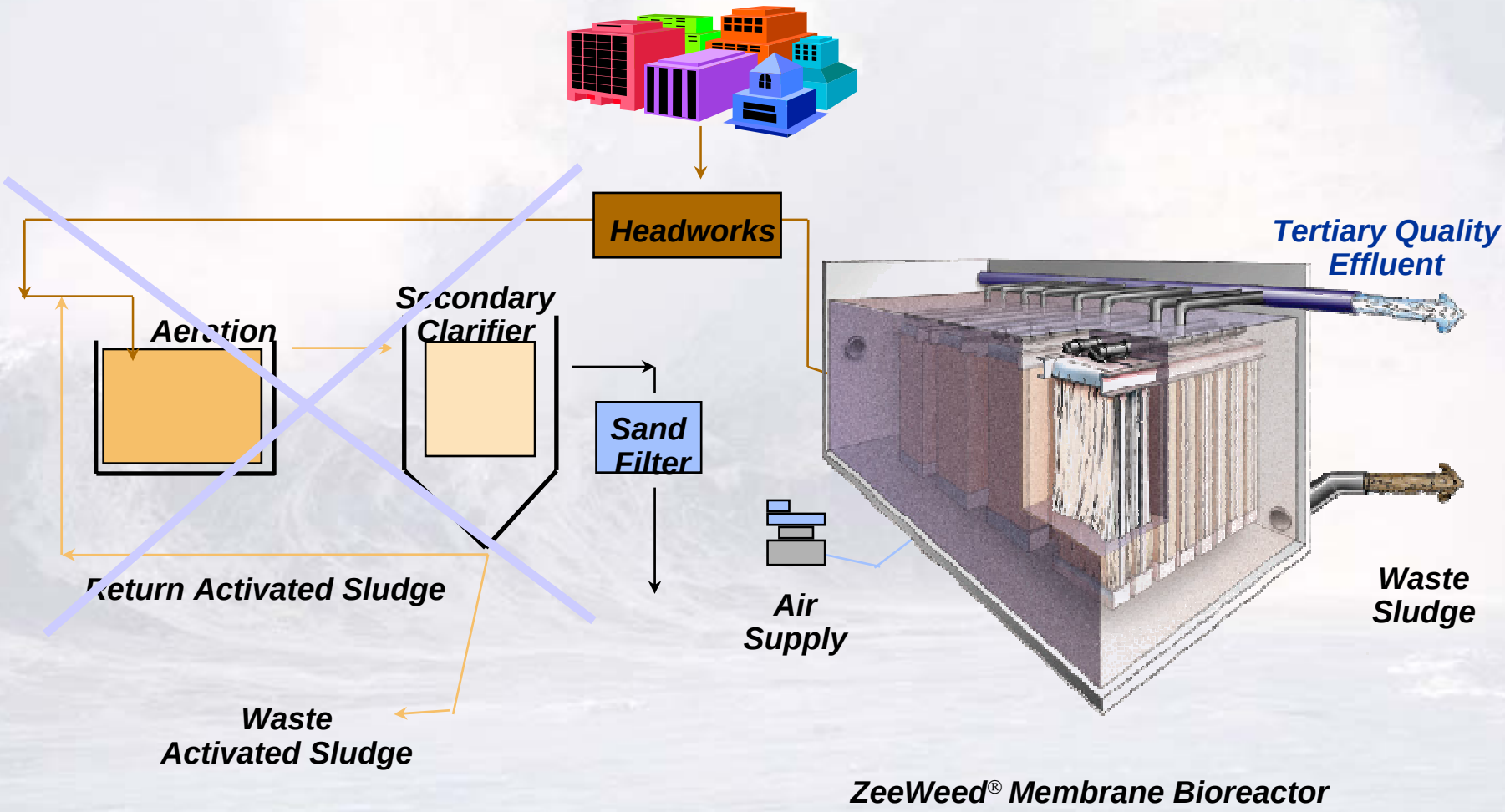
Flat Plates



Conventional ASP vs. Submerged MBR

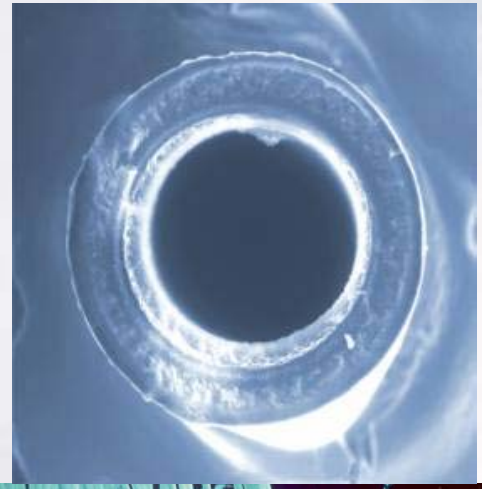
	Conventional Activated Sludge	ZeeWeed® MBR Process
Final Clarifier	Yes	No
Tertiary Filter	Yes	No
MLSS (mg/L)	< 3,000	>10,000
Sludge Age (day)	< 10	>10
Footprint	Large	3 – 5 times smaller
Process Stability	Sensitive to sludge bulking	Not sensitive to upsets

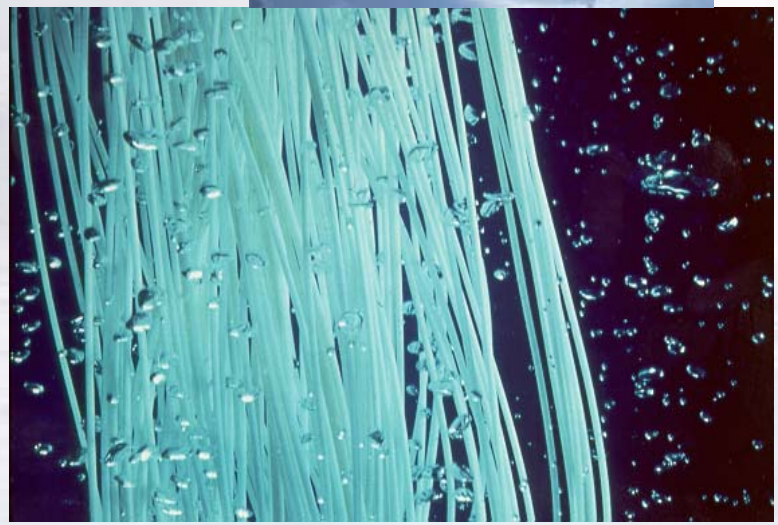
Membrane Bioreactor (MBR)



ZeeWeed® Immersed Hollow Fiber UF

- **Outside-In Supported Hollow Fiber (i.e membrane cast on outside of fiber)**
- **0.035 µm nominal pore size (0.1 µm absolute)**
- **1.9 mm Fiber OD**
- **Chlorine tolerant**
  - **> 1,000,000 ppm-hrs**
  - **2,000 mg/L**
- **5 – 9.5 operating pH range**
- **2 – 11 cleaning pH range**
- **PVDF Chemistry**

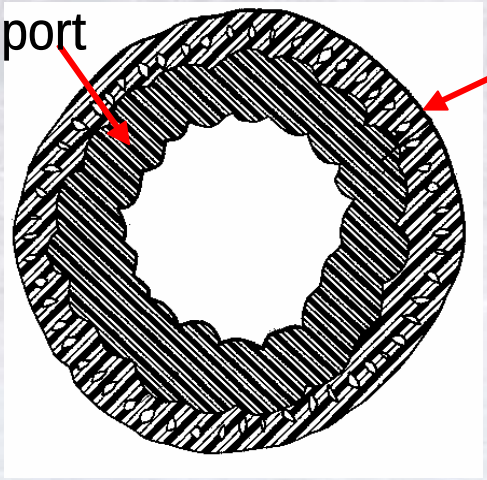




ZeeWeed® 500 Membrane

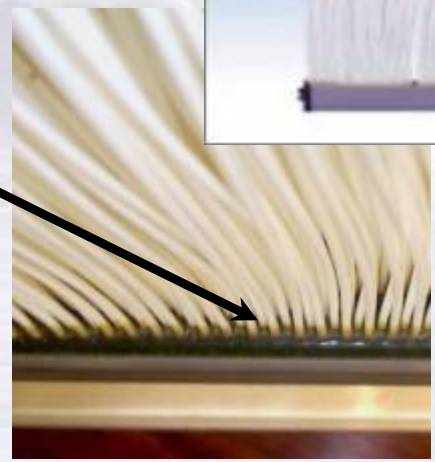
Benefits:

- World's strongest hollow fiber membrane
- Reinforced for maximum strength
- Maximum membrane life



ZeeWeed® 500 – Modules

- Optimum spacing between fibers
- Fiber slack prevents solids buildup
- Defined spatial distribution of fibers for higher solids tolerance

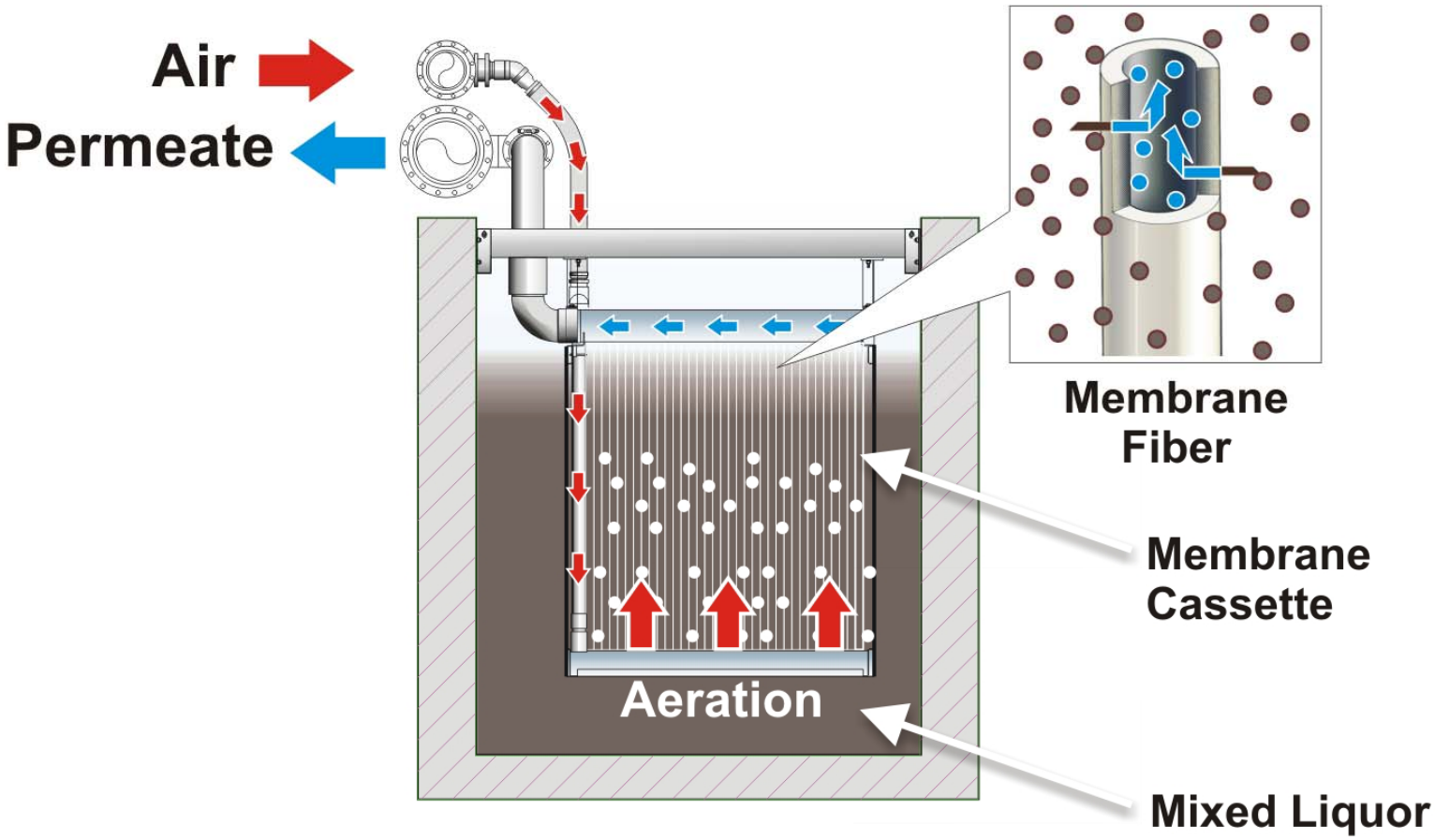


ZeeWeed® Membrane Modules

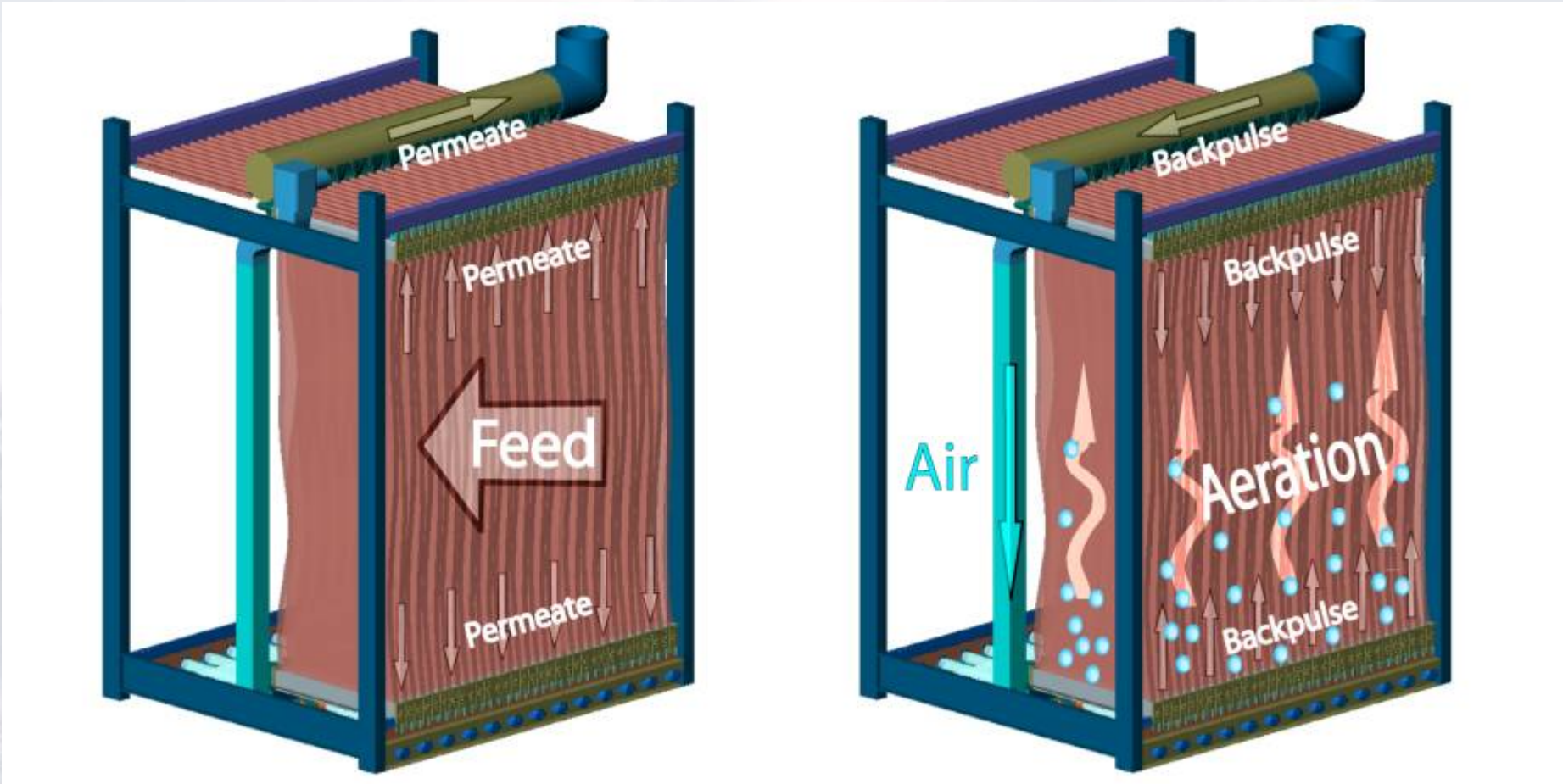
ZeeWeed® Membrane Module

ZeeWeed® Membrane Cassettes

ZeeWeed® 500d Flow Diagram



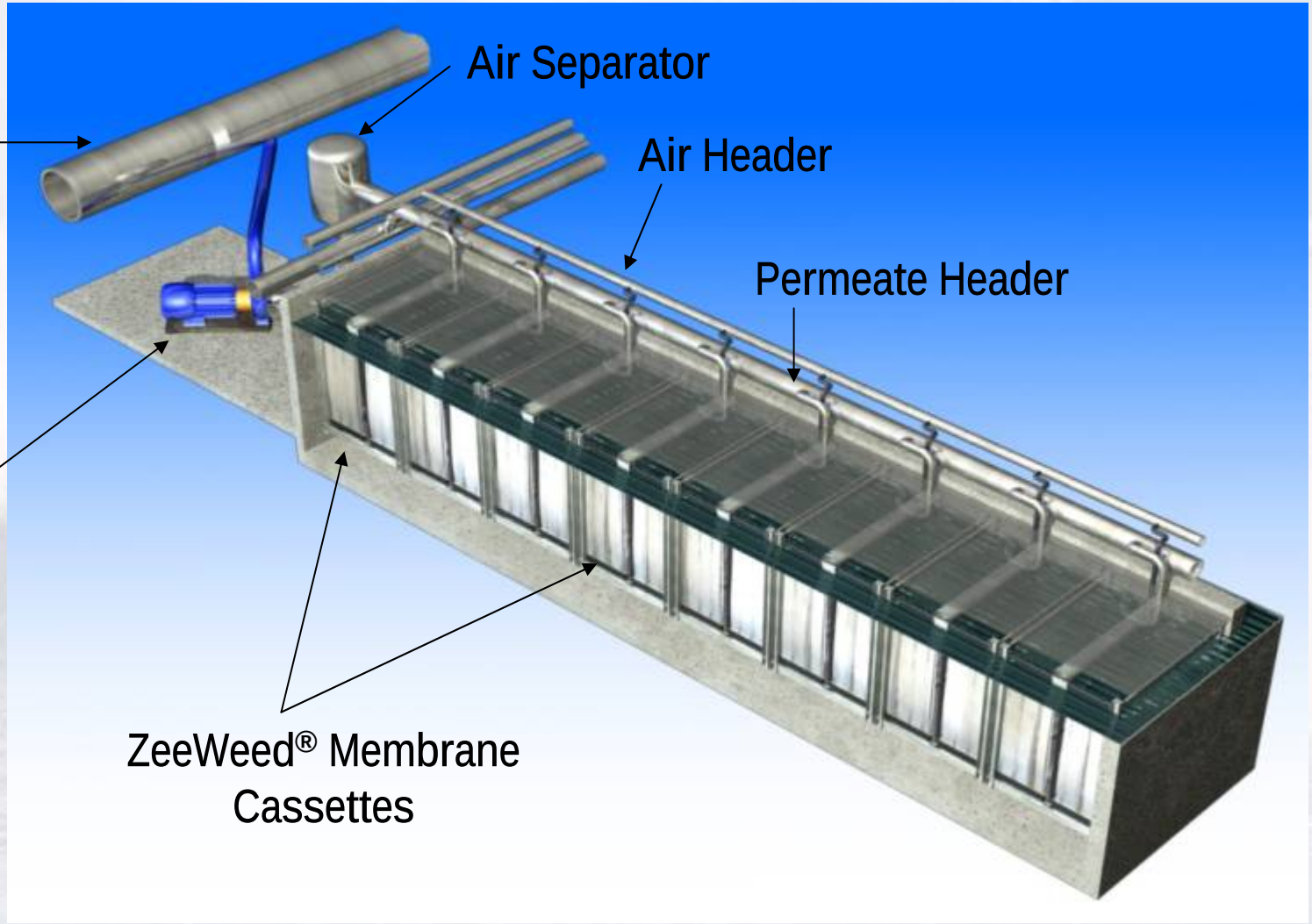
ZeeWeed® 500 – Cassettes



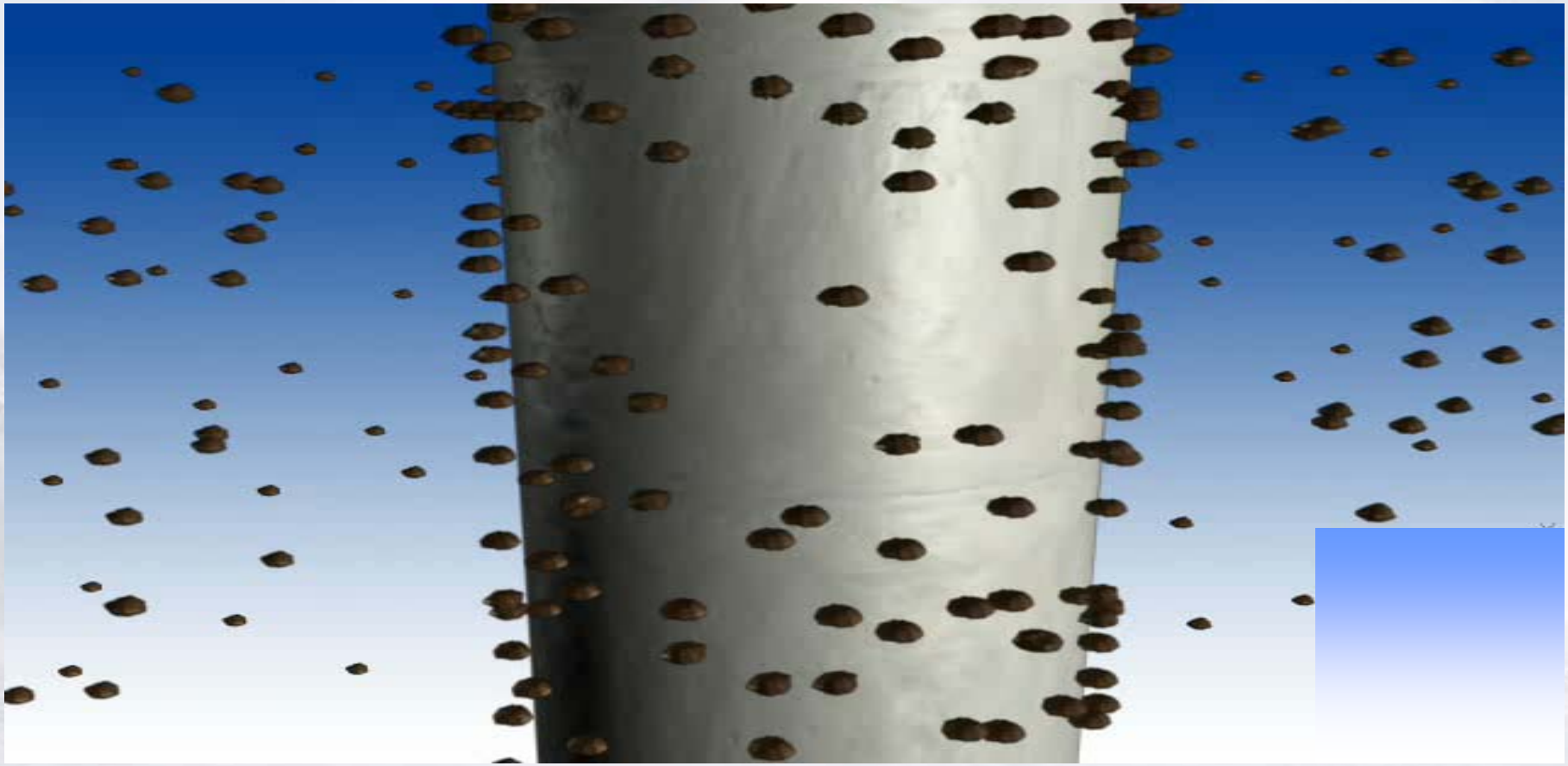
Production Flow

Back pulse Flow

ZeeWeed® 500 System



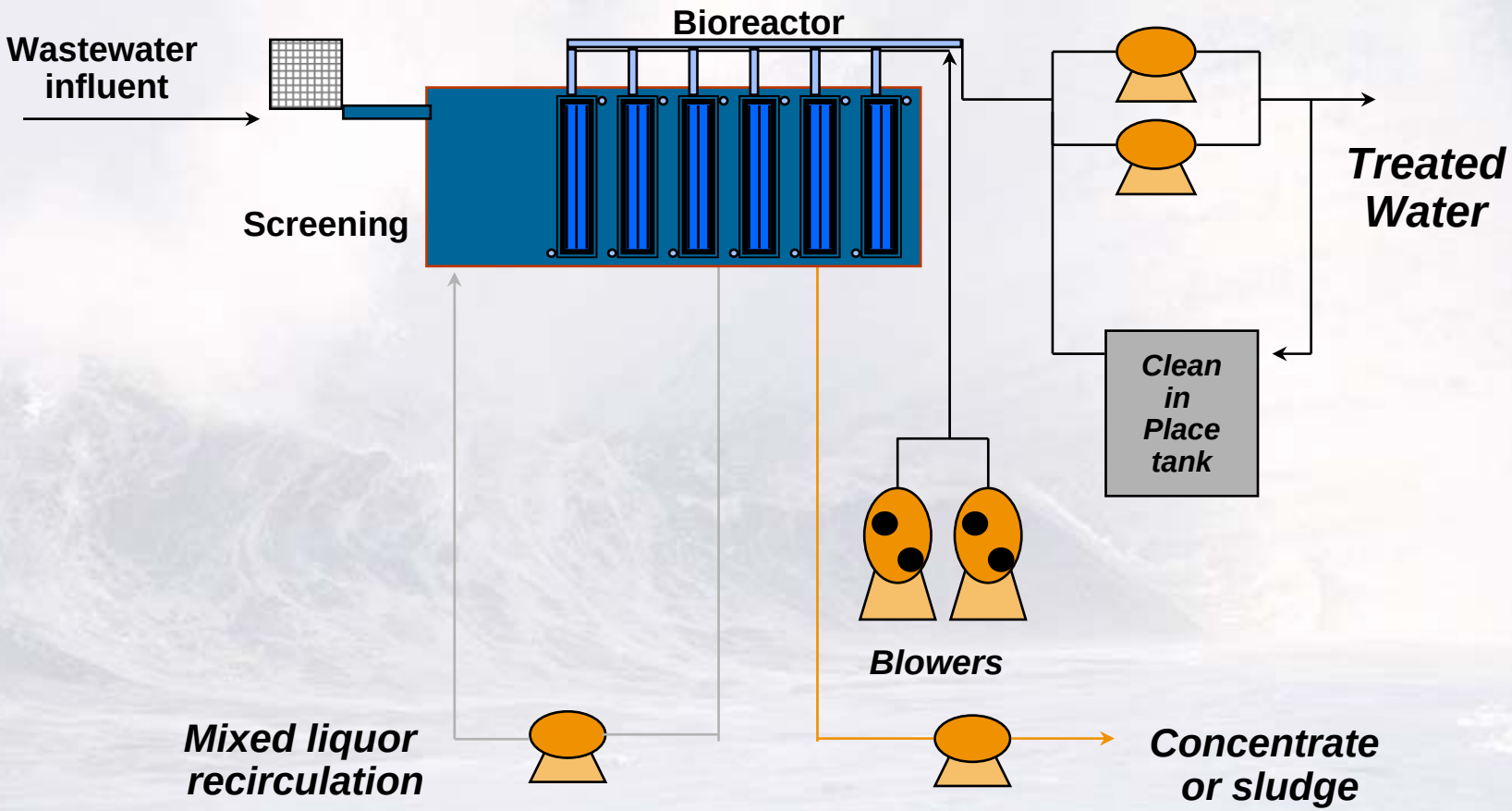
Fiber Clip



500D Clip

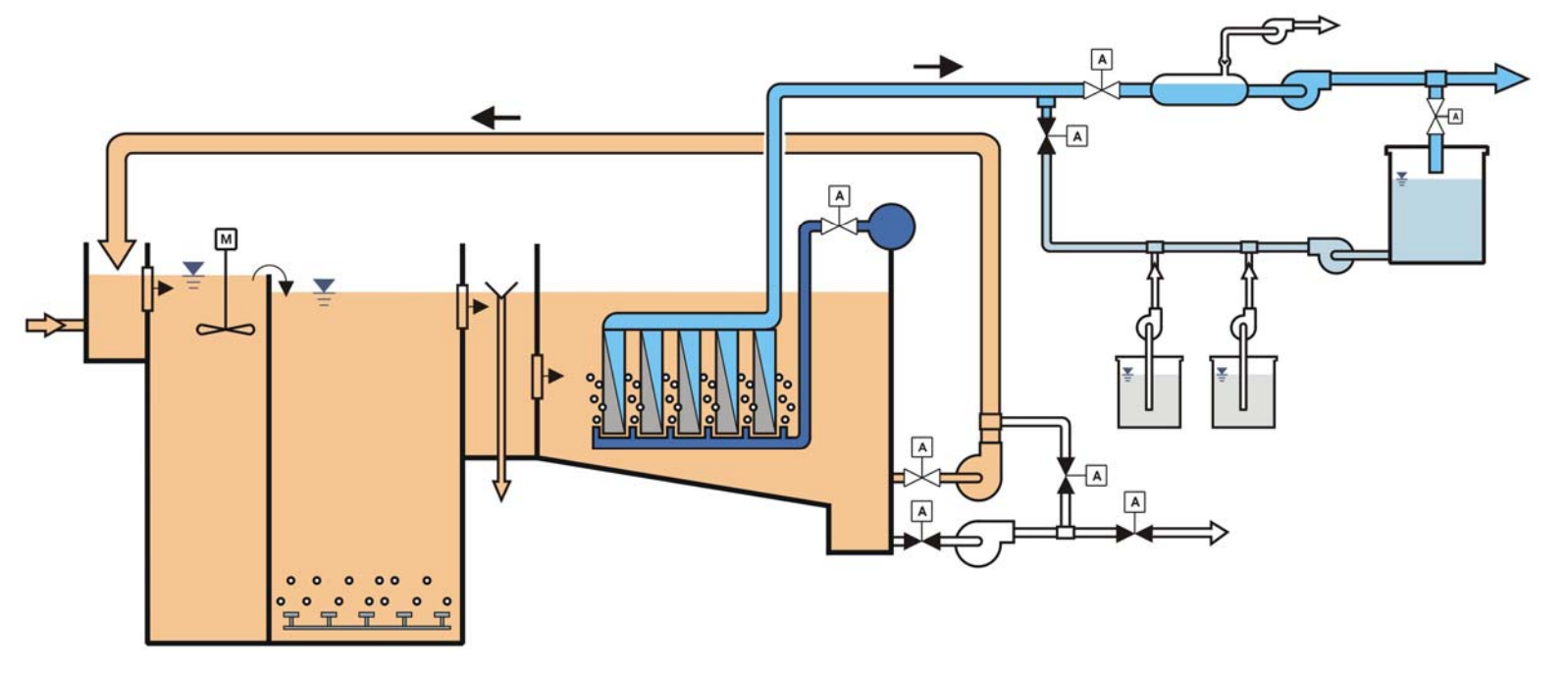
Cassette Clip

ZeeWeed® MBR Schematic



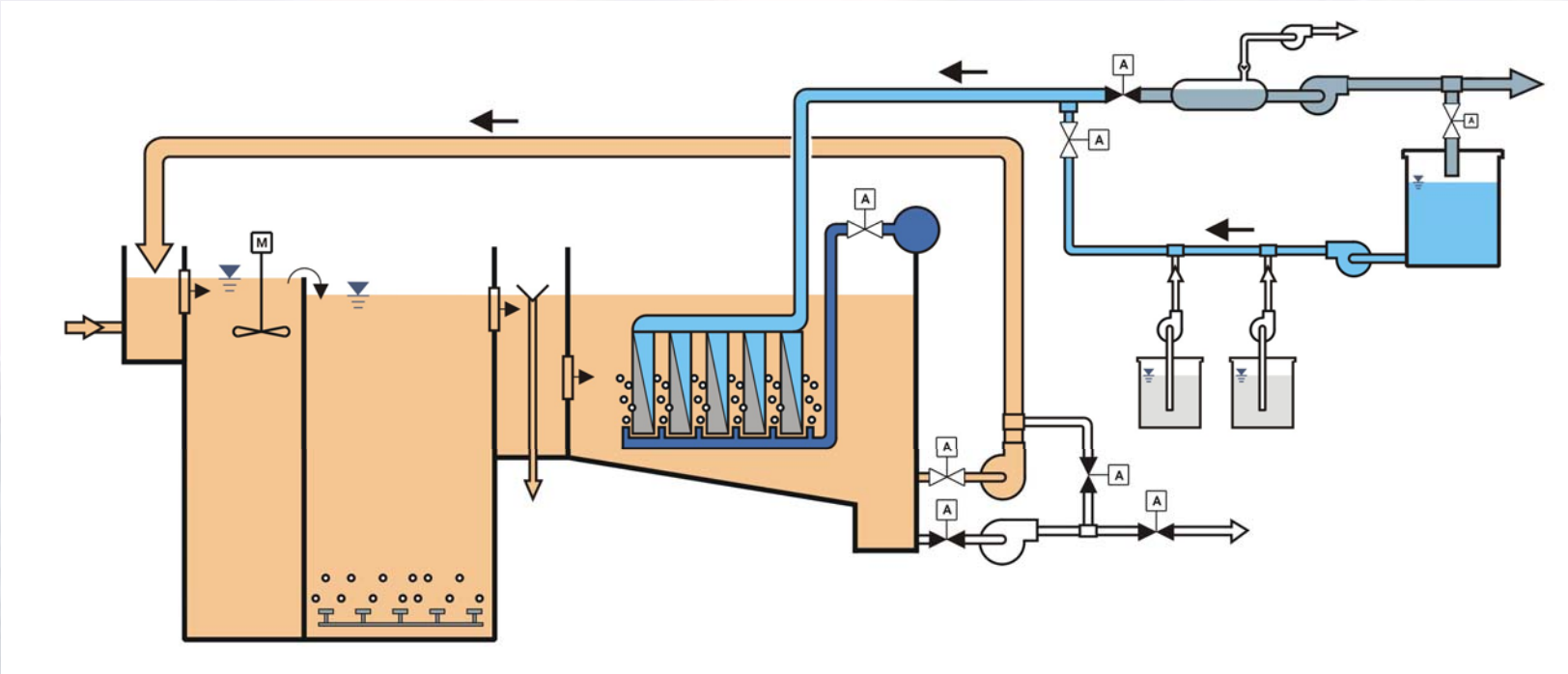
ZeeWeed® MBR Process

Production



ZeeWeed® MBR Process

Backpulse



ZeeWeed® MBR Operation

- Pretreatment: 2 –3 mm screen operating
- Membranes contained in frames within aeration tanks (clean in place or dip clean option)
- Pumping rate controlled by VFD based on aeration tank level (ability to design with peak flows with ZW design)
- Membrane scouring provided by airflow (82.5 ACFM / ZW-500c cassette, 4 psi at base of cassette)
- Membrane air typically provides ~50% of biological requirements
- Fine bubble aeration supplements membrane aeration
- Fully automated backpulse/relax (30 seconds every 15 – 30 minutes)

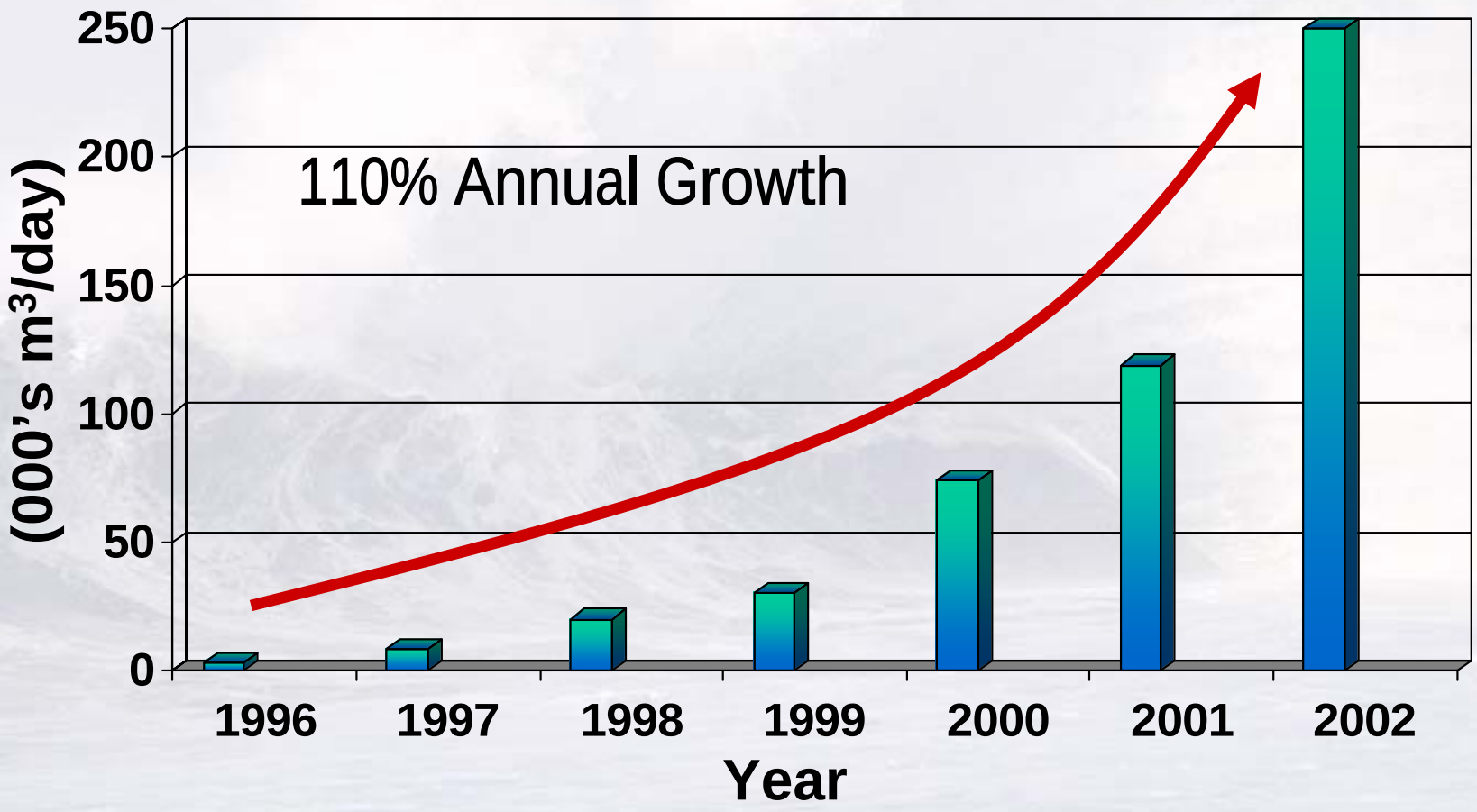
ZeeWeed® MBR Advantages

- Compact footprint : Membranes immersed within bioreactor (no clarifiers no sand filters)
- Membranes allow higher MLSS operation (8,000 - 15,000 mg/L)
- Reliable: Performance independent of sludge settling characteristics
- Minimal effluent TP with coagulant addition (TP < 0.1 mg/L)
- Year-round nitrification ensured (Ammonia < 1 mg/L)
- Readily adaptable for N removal (TN < 3 mg/L)
- Entirely aerobic; no odors
- Absolute barrier to particulate discharge, excellent for water re-use
- Adaptable to existing tanks (minimize civil works)
- Ideal For Staged Expansion

ZeeWeed® MBR Effluent Quality

- BOD5 < 5 mg/L
- Ammonia-Nitrogen < 1 mg/L
- Total Nitrogen < 10 mg/L (moderate climate)
- Total Nitrogen < 3 mg/L (hot climate)
- Turbidity < 0.5 NTU
- Total Suspended Solids < 5 mg/L
- Total Phosphorus < 0.1 mg/L
  * With chemical addition
- Fecal Coliform < 10 CFU/100 mL
  * before downstream disinfections
- SDI < 3

ZeeWeed® ZenoGem® Wastewater Capacity



MBR Development Pre-1990

- Started in the early 1970s
- Residential/office complexes, shopping centers, hotels, schools, resorts where sewage collection is not available
- More than 100 plants in sizes ranging from 10-200 m^3/d.
- Bioreactor with long HRT (up to 24h) and SRT (up to one year)
- Initially equipped with tubular modules; all new plants since 1994 equipped with immersed membranes

ZeeWeed® MBR Development 1990 - 1995

- Package systems (< 200 gpm)
- Minimal pre-treatment
- Long HRT (> 12 hours)
- Long SRT (> 50 days)
- Elevated MLSS concentration (15 – 25 g/L)
- Low flux (< 10 gfd)
- External recovery cleaning (soak tank)

ZeeWeed® MBR Development 1995 - 2000

- Small Municipal plants (< 2 MGD)
- Greater attention to pre-treatment (fine screening)
- Typically no EQ
- Reduced HRT (6 hours typical)
- Reduced SRT (15 - 25 days)
- Reduced MLSS concentration (10 - 15 g/L)
- Moderate flux (15 - 25 gfd)
- In-situ maintenance cleaning
- External recovery cleaning (soak tank)

ZeeWeed® MBR Development 2000 +

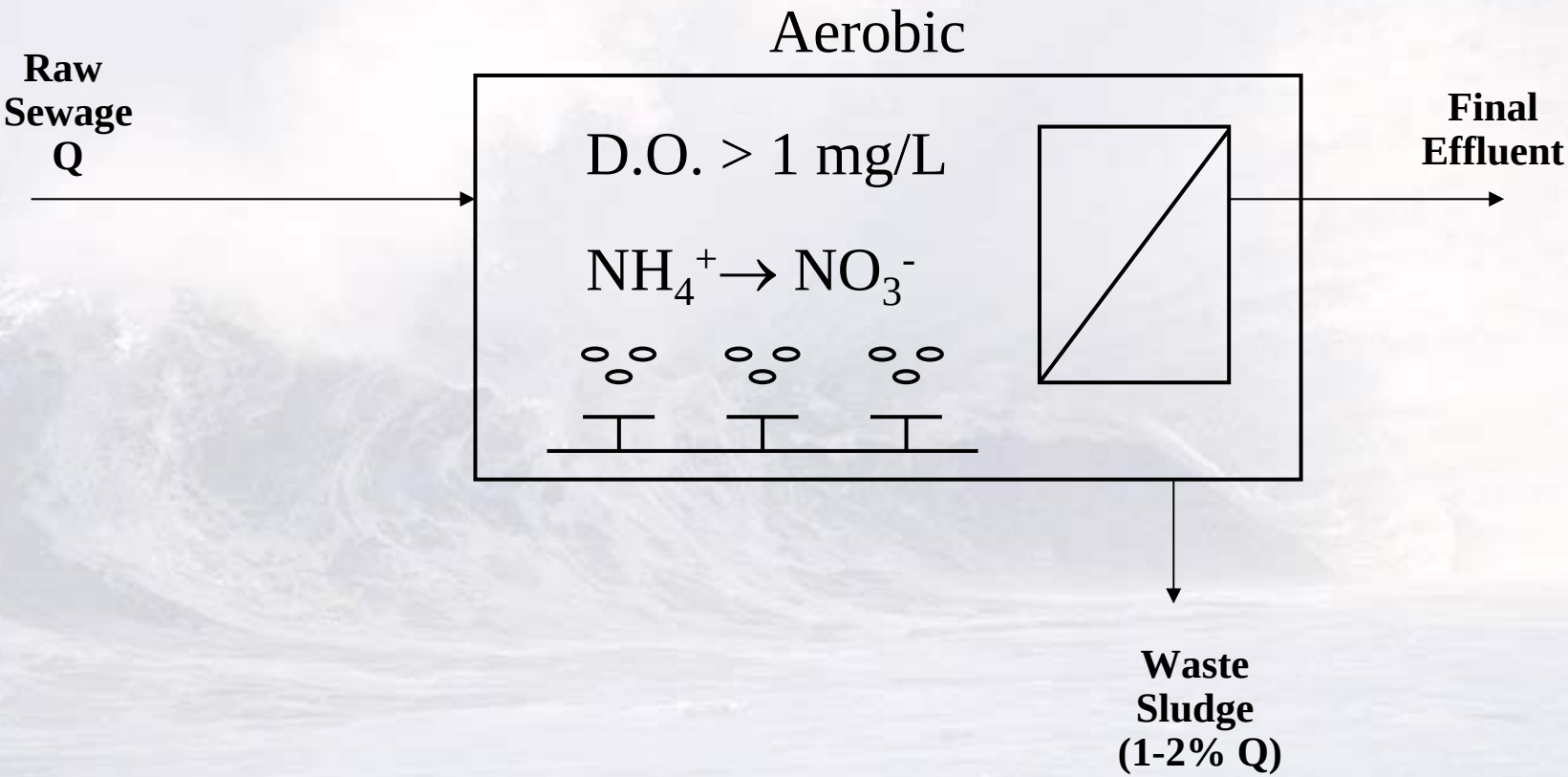
- Medium to large Municipal plants (> 10 MGD)
- Reduced MLSS concentration (10 g/L)
- Reduced flux rates (10-20 gfd)
- Improved module design (ZW-500c / ZW-500d)
- Cyclic membrane aeration (energy reduction)
- In-situ recovery cleaning

Bioreactor Configuration

Aerobic Only	▪ No TN removal required ▪ Sufficient alkalinity in feed for nitrification
Anoxic – Aerobic	▪ Most Typical Design ▪ Up to 80% TN removal ▪ Recover aeration energy and alkalinity
Pre-Anoxic + Swing Zones	▪ For TN removal > 80% and <90%
Pre & Post Anoxic	▪ For TN removal > 90% ▪ External carbon addition may be required (always for TN < 3 mg/L)
Bio-P Designs	▪ Project Specific

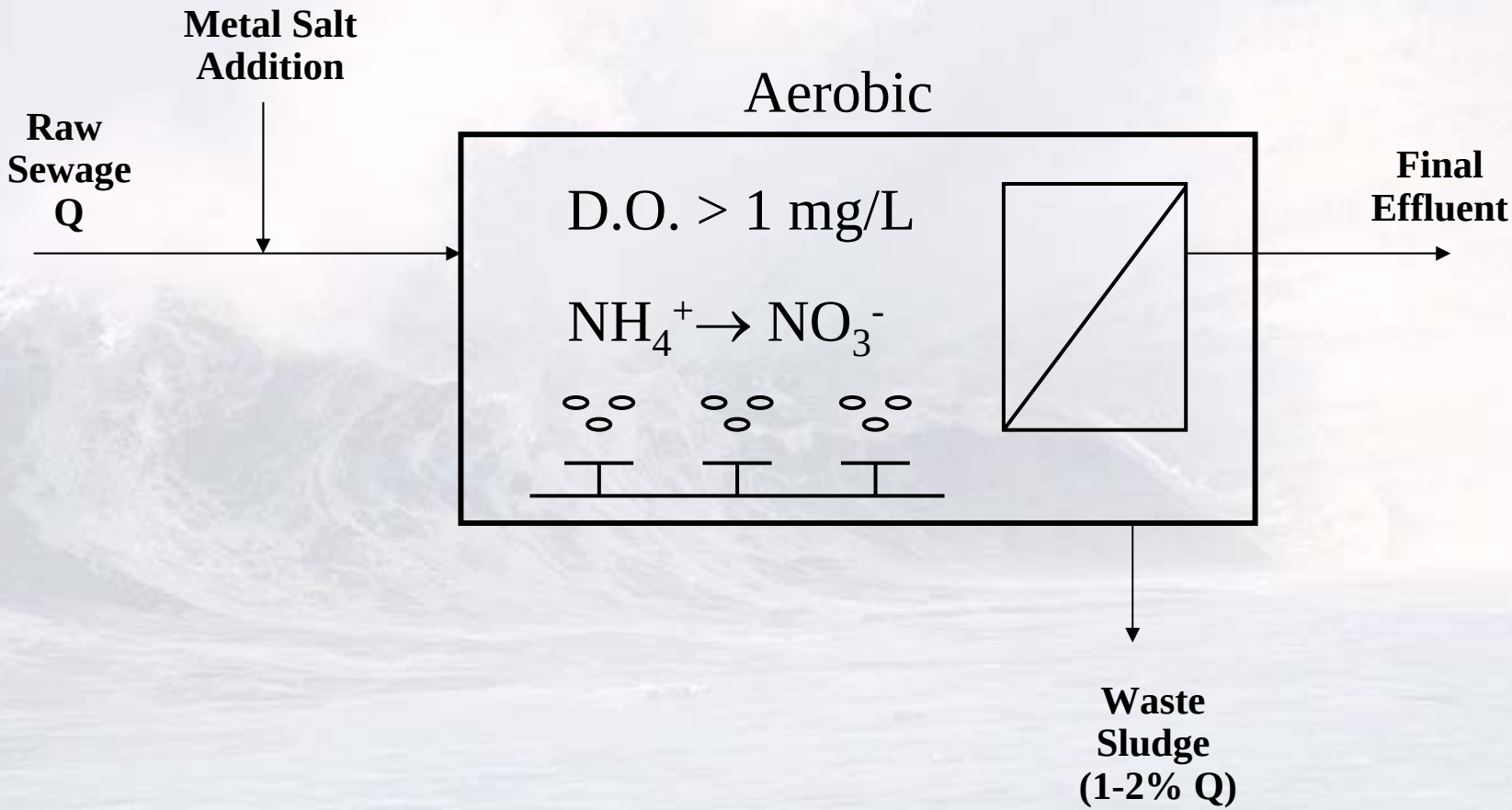
ZenoGem® Process Configurations

Nitrification and BOD & TSS Removal



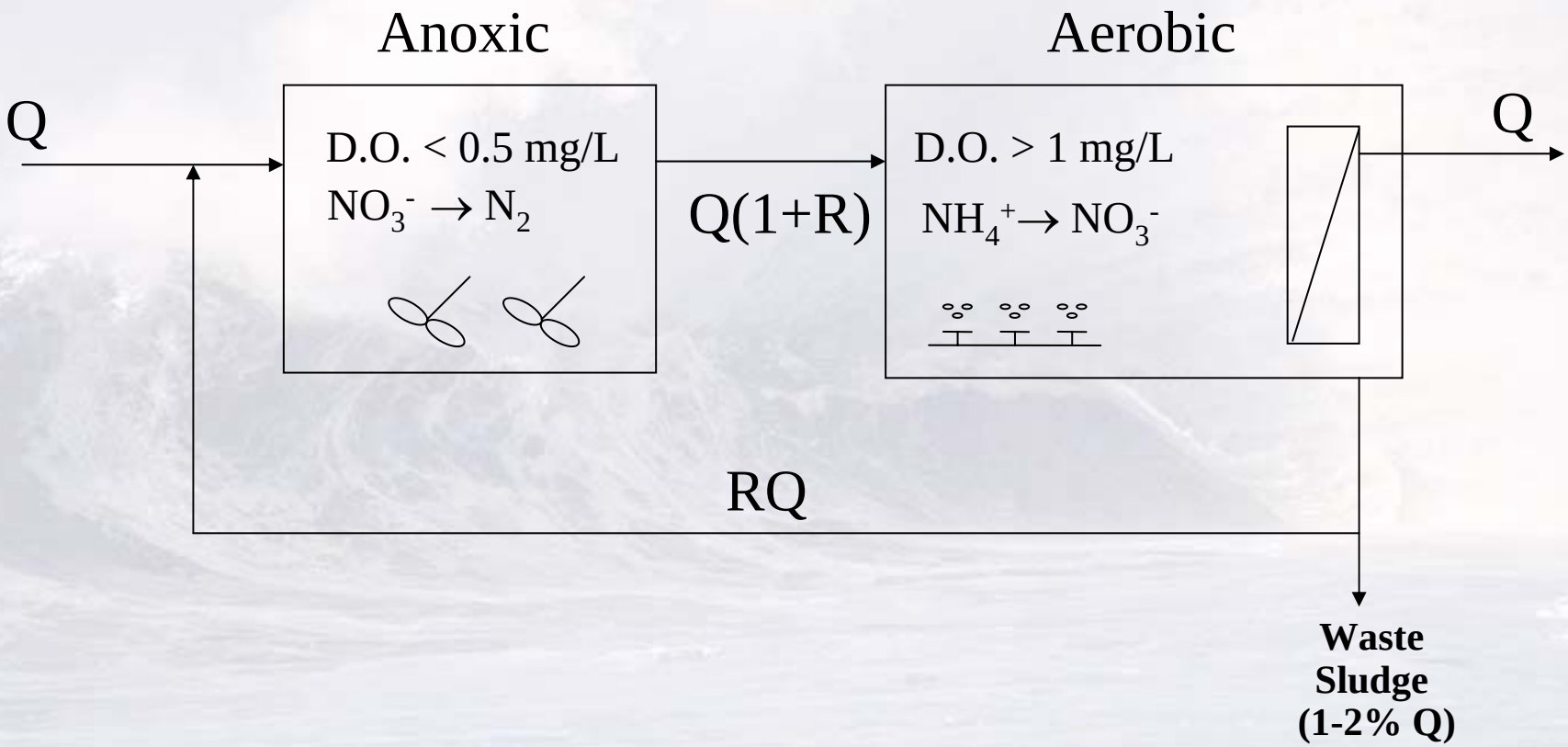
ZeeWeed® MBR Process Configurations

Nitrification and BOD Removal
Chemical TP Removal



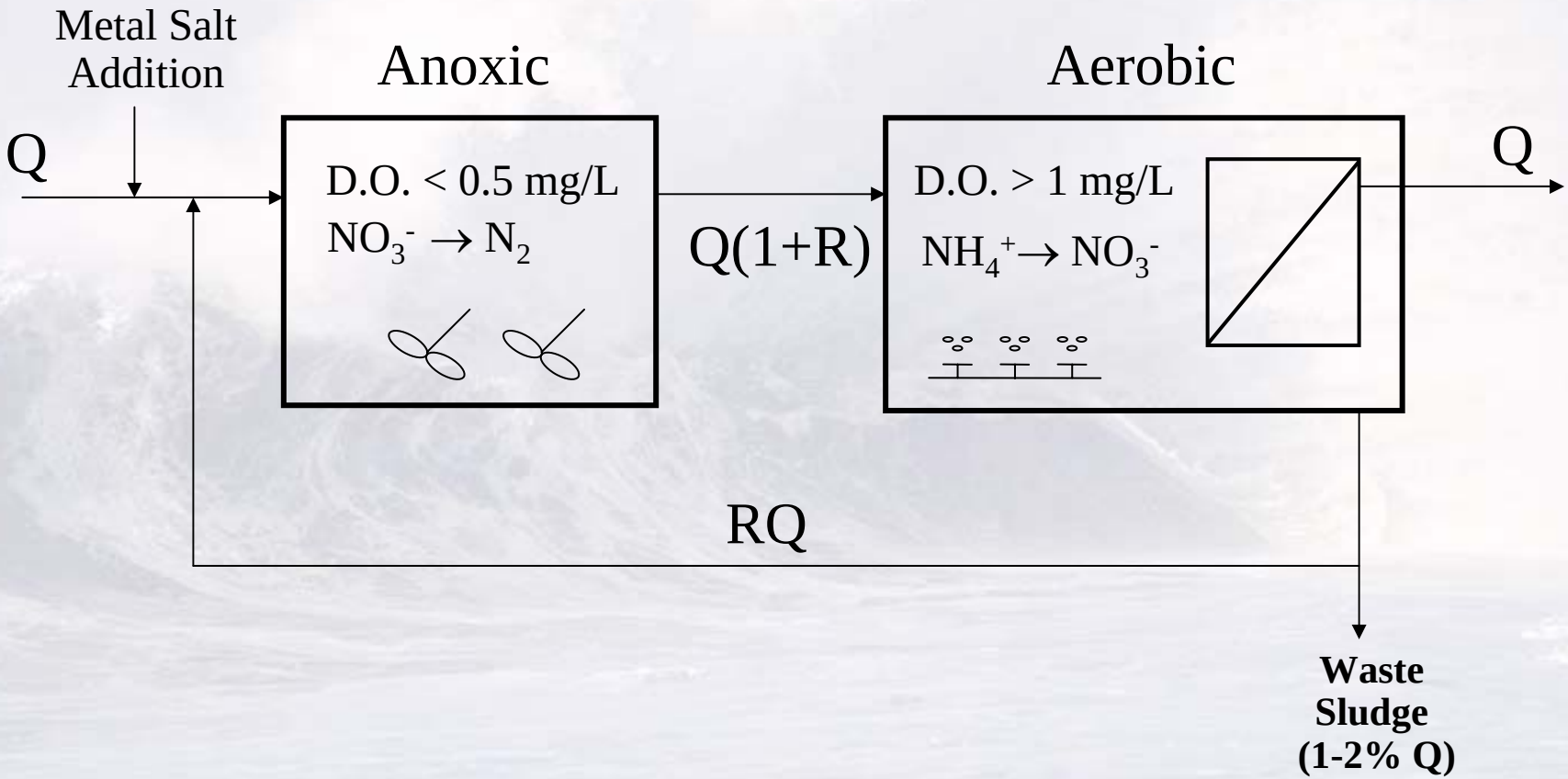
ZenoGem® Process Configuration

BOD, TSS and Total-N Removal



ZeeWeed® MBR Process Configurations

BOD and Total-N Removal
Chemical TP Removal



Biological Design Parameters

Parameters	Units	Design Range	Typical Design[3]
COD Loading Rate[1]	kgCOD/m^3/d	1 - 4	2
F/M Ratio	kgCOD/kgVSS/d	0.15 – 0.5	0.3
SRT	day	8 – 30	15
MLSS	g/L	8 – 12	8
Sludge Recycle Rate	Q	4 – 8Q	4Q
Oxygen Utilization Rate	mgO_2/L/h	<100	75
Biological Sludge Yield[2]	kgVSS/kgBOD	0.4 – 0.6	0.5
% Anoxic Volume	%	15 – 40%	25%

[1] COD loading rate = F/M ratio x MLVSS concentration

[2] Yield is a function of SRT and bioreactor temperature

[3] Typical design values for municipal sewage at minimum temperature of 15 ^oC and effluent TN < 10 g/L

Case Studies

Viejas Casino, California

Viejas Casino, California
0.2 MGD

Key Features

Retrofit of Extended Aeration Plant

- Online: July 2000
- Benefits of MBR:
  - Variable flows and loadings from casino and commercial mall
  - Reuse of tanks
  - Speed of implementation
  - Consistent effluent quality (below Title 22 objectives) with variable feed quality (BOD peaks)

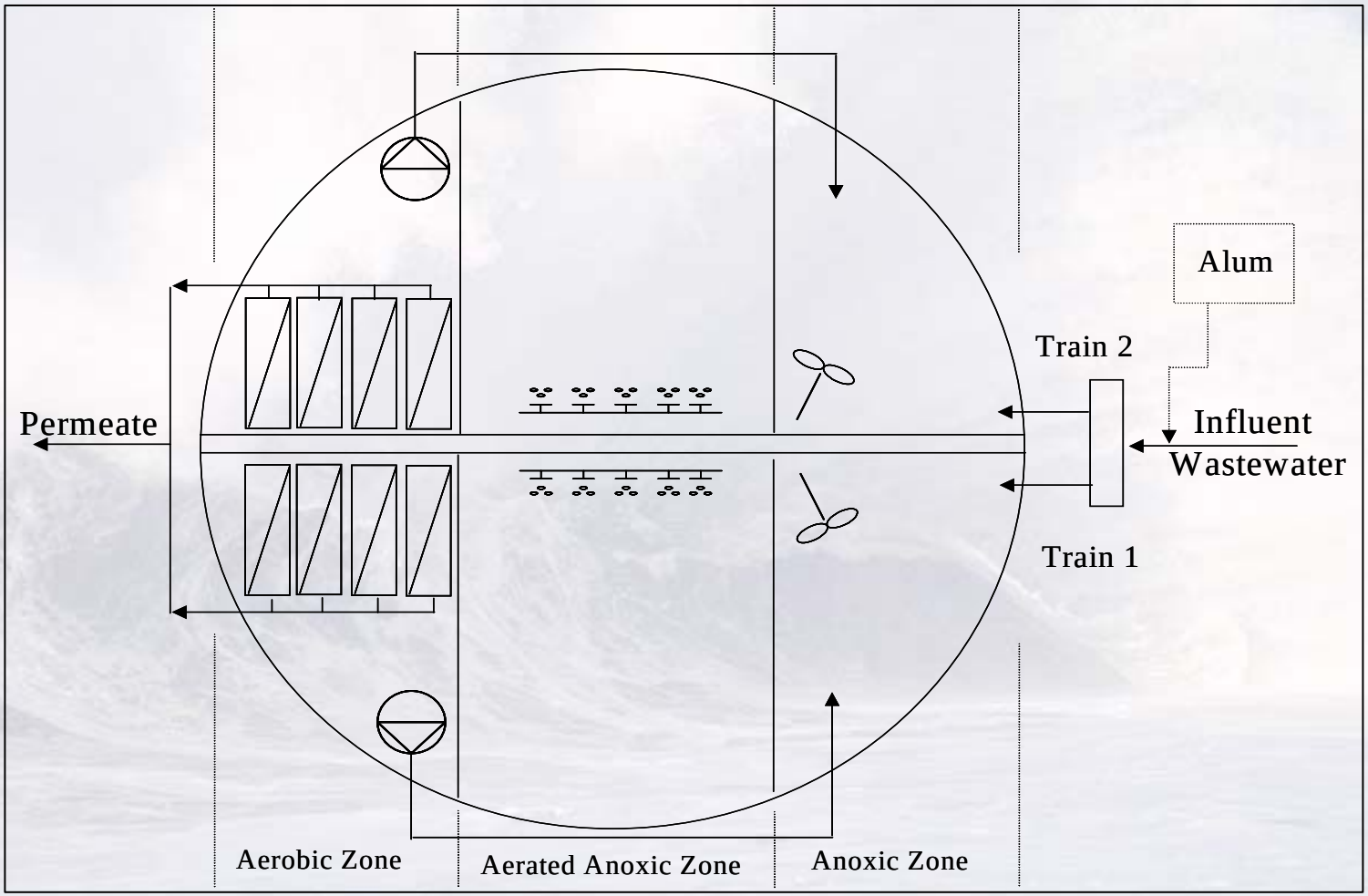
Viejas Casino, California
0.2 MGD

Typical Effluent Quality

BOD < 2 mg/L
TSS < 2 mg/L
Ammonia-N < 0.2 mg/L
Nitrate-N < 10 mg/L
Turbidity < 0.1 NTU

Key Colony, Florida

Key Colony, Florida



Key Colony, Florida
0.25 MGD

Key Features

- Online: July 1999
- Effluent Design Requirements

BOD < 5
TSS < 5
TN < 3
TP < 1

Cauley Creek

Cauley Creek, Georgia

Cauley Creek, Georgia
2.5 MGD

Key Features

- 2 trains with 4 membrane tanks, CIP, new construction
- Online: May 2002
- Other technologies considered: SBR
- Benefits of MBR: Innovative Technology, Design Build

Cauley Creek, Georgia, USA
Driver: Water Reuse

Existing Plant

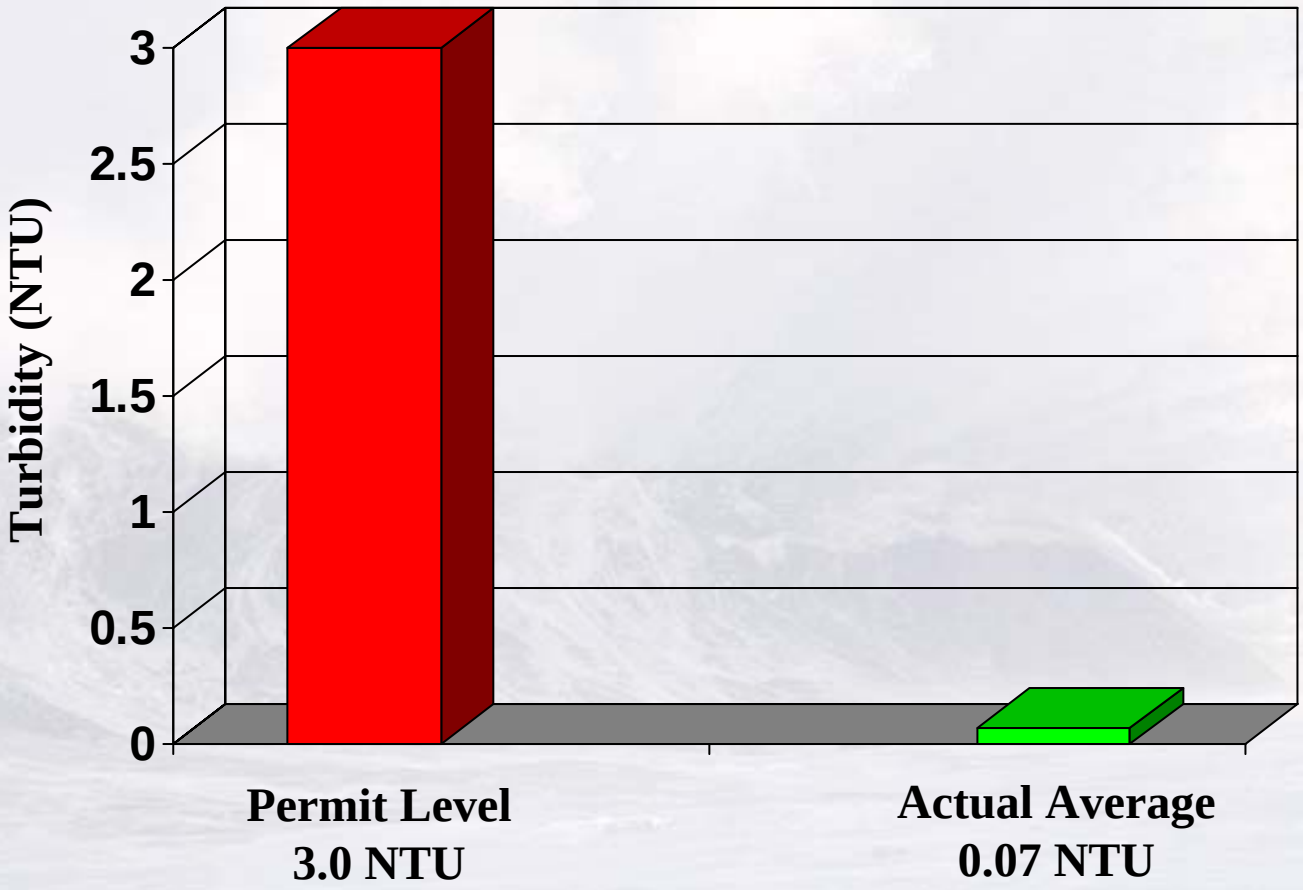
- 2.5 MGD capacity
- Commissioned May 2002
- Features:
  - 2 biotrains + 4 ZW tanks
  - In-situ recovery cleaning
  - Cyclic aeration
  - Ferric Chloride addition
- Design performance:
  - Turbidity < 0.5 NTU
  - TN < 5 mg/L
  - TP < 0.13 mg/L

Phase II Expansion

- 5.0 MGD capacity
- Expected Start-up May 2004
- Features:
  - 4 biotrains + 8 ZW tanks
  - ZW Sludge Thickener
  - Surface wasting
  - Combined Bio-P and Ferric
- Design performance:
  - Turbidity <0.5 NTU
  - NH3-N <0.5 mg/L
  - TN <10 mg/L
  - TP < 0.13 mg/L

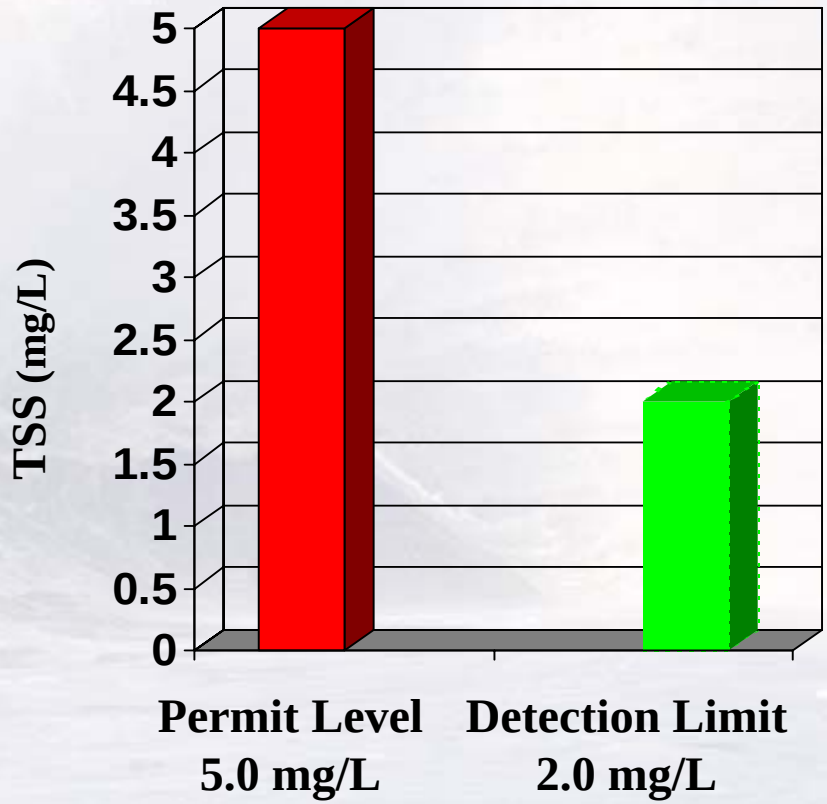
Membrane Trains

Turbidity


Turbidity (NTU)
3
2.5
2
1.5
1
0.5
0
Permit Level
3.0 NTU
Actual Average
0.07 NTU

Total Suspended Solids

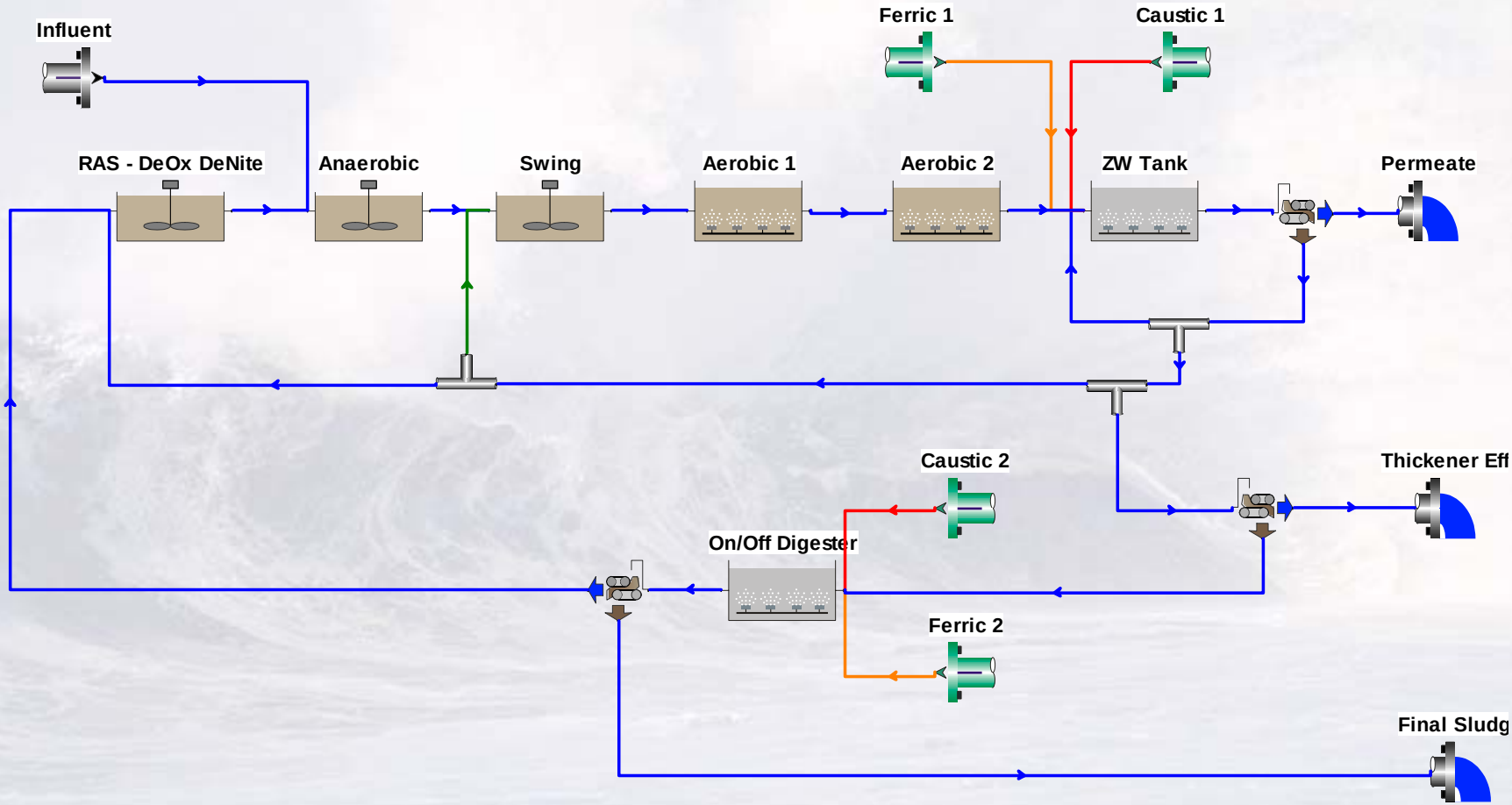
- Permit limit is 5 mg/L
- Average TSS is below detection limit



Biochemical Oxygen Demand

- BOD requirements
  - Permit = 5 mg/L
  - Average BOD is below detection limit
- COD requirements
  - Monitoring only, no permit requirement
  - Average COD is 11 mg/L

Biological Phosphorus Removal
Cauley Creek Approach



Expansion Plans

Existing Plant

- 2.5 MGD capacity
- Commissioned May 2002
- Features:
  - 2 trains with 4 membrane tanks
  - In-situ recovery cleaning
  - Ferric Chloride addition
- Design performance:
  - Turbidity < 0.07 NTU
  - TN < 5 mg/L
  - TP < 0.13 mg/L

Proposed Expansion

- 5.0 MGD capacity
- Early 2004
- Features:
  - 4 trains with 8 membrane tanks
  - ZW-Thickener
  - Surface wasting
  - Combined Bio-P and Ferric
- Design performance:
  - TN <10 mg/L
  - TP < 0.13 mg/L

Keys to Success

- Successfully designed to blend into surrounding community (housing in area - $350 to $900K)
- County listened and responded to neighborhood concerns (very high community interest)
- Re-use system offers inexpensive irrigation water to surrounding area (drought-proof)
- Asset to neighborhood
- Low impact use of land cause minimum impact to neighborhood infrastructure
- Provides green space
- High quality reuse water

Conclusions

- Effluent Quality from MBR is as good as UF used as a tertiary treatment
- MBRs are smallest footprint water reuse technology
- MBRs are most cost-effective means of reusing wastewater in a safe way
- Any existing tank can be converted into an MBR and into a water recycling facility
- Membrane Bioreactors are no longer a new technology.

THANK YOU

ZENON
Water for the World

ZeeWeed! Everywhere!