Performance of a subsurface flow pilot wetland for treating high concentrations of nitrogen, phosphorus and carbon

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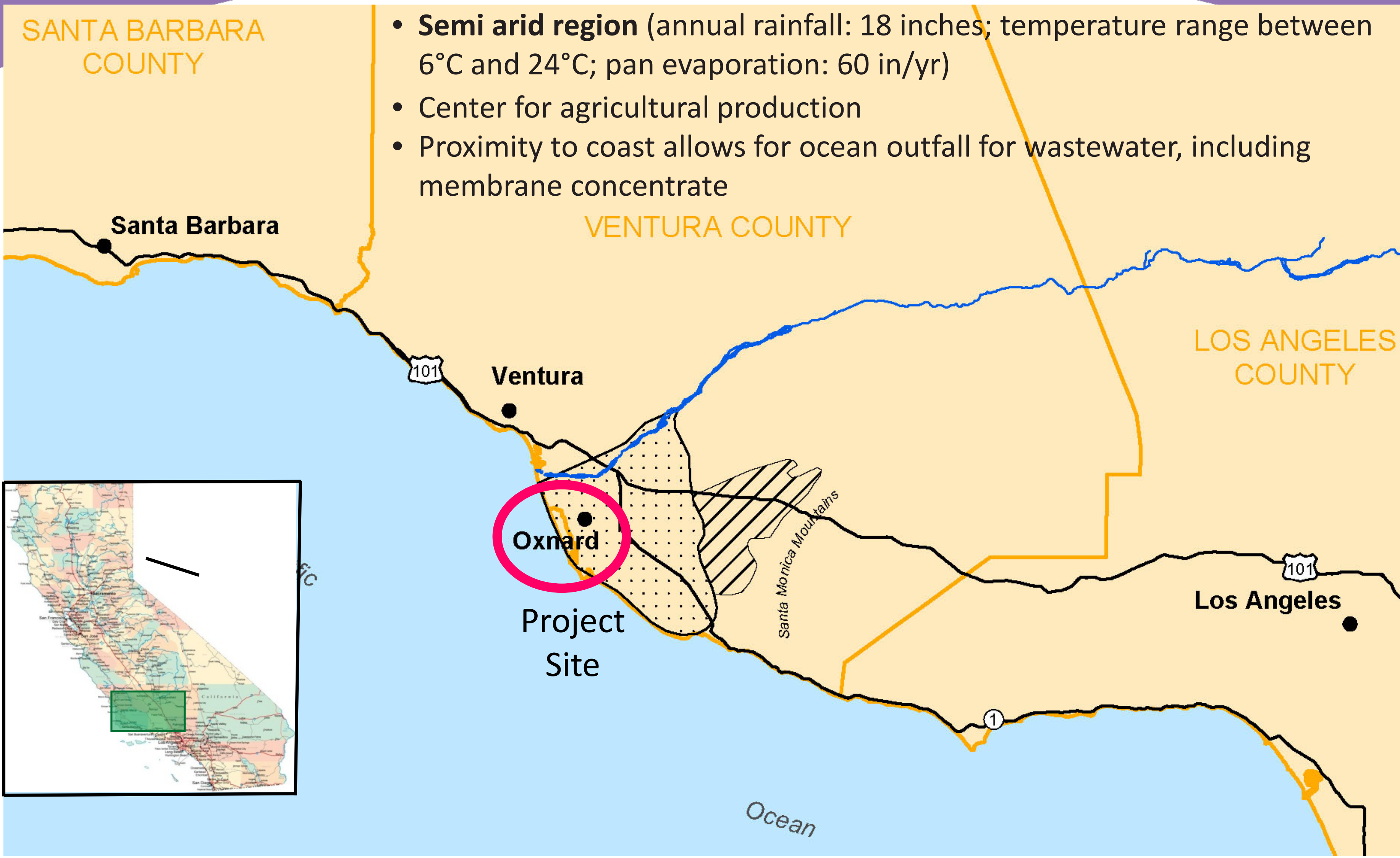
Outline

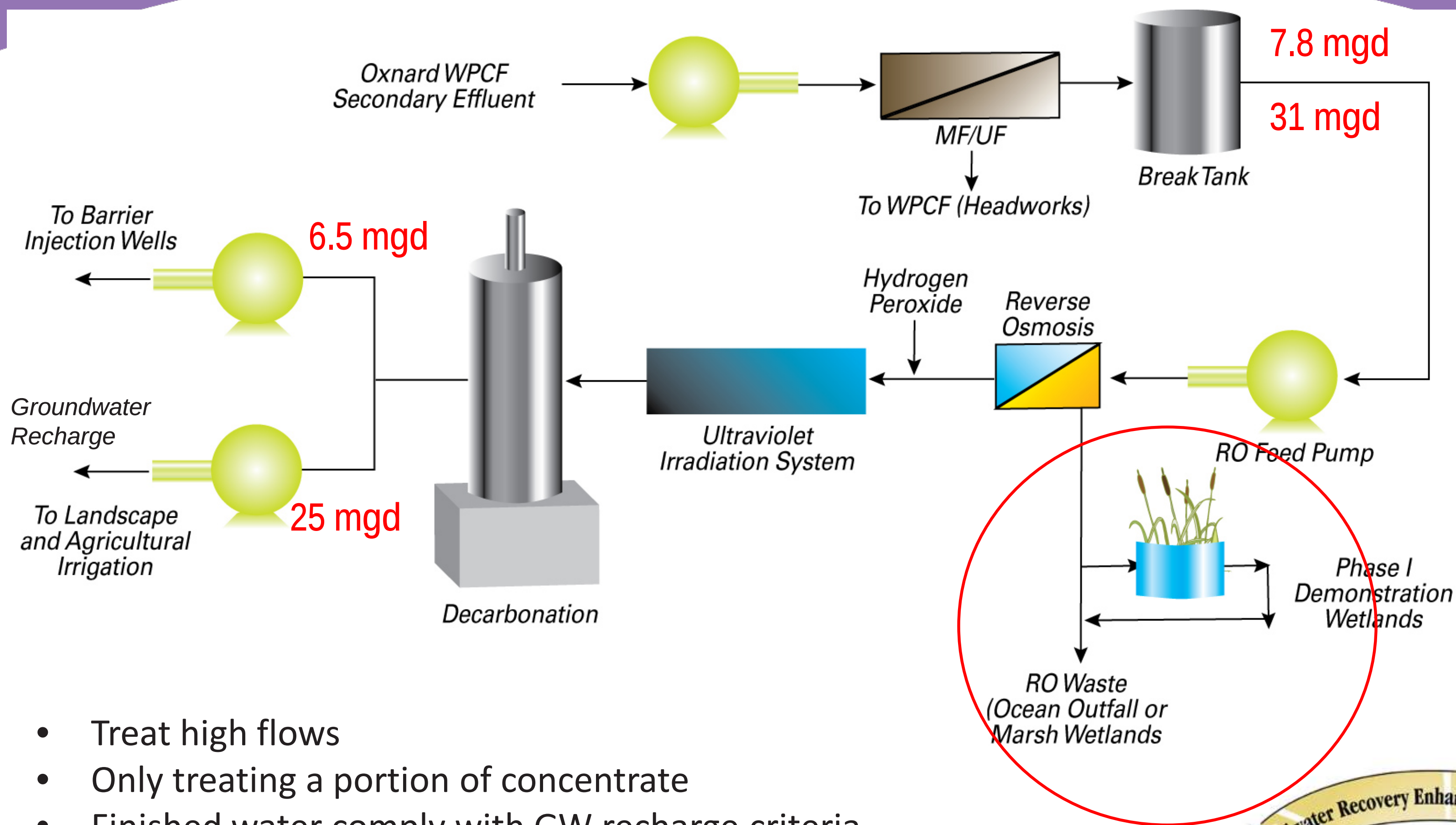
- Background
- Wetlands for concentrate management
- Pilot study description
- Results
  - Removal efficiency of nutrients
  - Mass balance of Nitrogen
- Conclusions

Oxnard: A Coastal Community in Southern California is Building Needed Future Water Supply Capacity

- **Semi arid region** (annual rainfall: 18 inches; temperature range between 6°C and 24°C; pan evaporation: 60 in/yr)
- Center for agricultural production
- Proximity to coast allows for ocean outfall for wastewater, including membrane concentrate



Oxnard AWPF Process Includes Wetlands Treatment of Concentrate Sidestream



- Treat high flows
- Only treating a portion of concentrate
- Finished water comply with GW recharge criteria

- Question: Can the concentrate be a reusable resource?

Oxnard Previously Established Feasibility of Treating Groundwater Concentrate Using Wetlands

- Surface flow high marsh (SFHM),
- Surface flow low marsh (SFLM),
- Horizontal subsurface flow (SSF),
- Peat-based vertical upflow (VF),
- Submerged aquatic vegetation (SAV), and
- Saltgrass evaporation bed (SE).

✓6 types

✓3 years

✓ Metals, nutrients

✓ Toxicity reduction

✓ Volume reduction

This study	GREAT program
Brackish Water	RO Concentrate
TDS: 2 - 5 g/L	TDS: 12-15 g/L
NH_3-N: 0.1 – 0.5 mg/L	NH_3-N: 100 – 150 mg/L
NO_3-N: 30-50 mg/L	NO_3-N: 20 - 40 mg/L
Se: 20 – 30 µg/L	Se: 30 – 60 µg/L

Parameter	Secondary Effluent (mg/L)	RO Concentrate (mg/L)
TDS	1,750	11,833
NO_3-N	1.2	14
TN	25.9	170
NH_3-N	22.2	121.7
TOC	16.6	72.3

To gain confidence in the performance of wetlands, ***another pilot study*** was needed before design of the full scale plant.

The AWPF Will Treat Higher Strength Concentrate: A Bridging Study Was Needed to Confirm Results

AWPF Layout

Three Types of Treatment Wetlands (1.2 Acre):

- ***Subsurface horizontal flow*** for ***ammonia*** removal (aeration, recirculation, nitrification of NH4)
- ***Anaerobic subsurface upflow*** reactors for ***metals*** reduction (bacterial reduction for NO3, Se)
- ***Free water surface*** wetlands for ***habitat*** and ***nutrient*** removal (denitrification, contaminant polishing)

- Demonstration wetlands adjacent to the visitor center; water needs to "good neighbor"

A Pilot Study was Needed to Bridge the Gap between Concentrate Strengths

Objectives

1. Confirm the survival and growth of brackish marsh plants receiving the RO concentrate
2. Confirm that the aesthetics of the treatment wetland would be acceptable (i.e., no offensive odors or colors would be generated)
3. Assess the pollutant removal performance of wetlands treating the RO concentrate

Trailer- Mounted Pilot Wetland Co-Located with RO Pilot System at WWTP

Bulrush (*Schoenoplectus californicus*)

L = 3.7 m

W = 2.4 m

D = 1.3 m

A = 8.9 m^2

V = 11.9 m^3

Portable Subsurface Flow Constructed Wetland

Mobile Environmental Solutions (MES), Tustin, CA

- The wetland was well vegetated, with some open water; Unique setup
- Flow rate adjustable

Hydraulic Data Summary

Dates	Sampling duration (day)	Flows (L/min)	HRT (day)	HLR (cm/day)	Comments
9/1/2008 - 9/24/2008	23	1.9	1.3	24.5	Initial Acclimation Period; no sampling
10/1/2008 - 1/19/2009	110	1	2.5	12.9	Sampling period 1
1/20/2009 - 3/5/2009	40	0.5	5	6.5	Sampling period 2

HLR = Hydraulic Loading Rate
HRT = Hydraulic Residence Time

- These are relatively higher HLRs and shorter HRTs than most wetlands

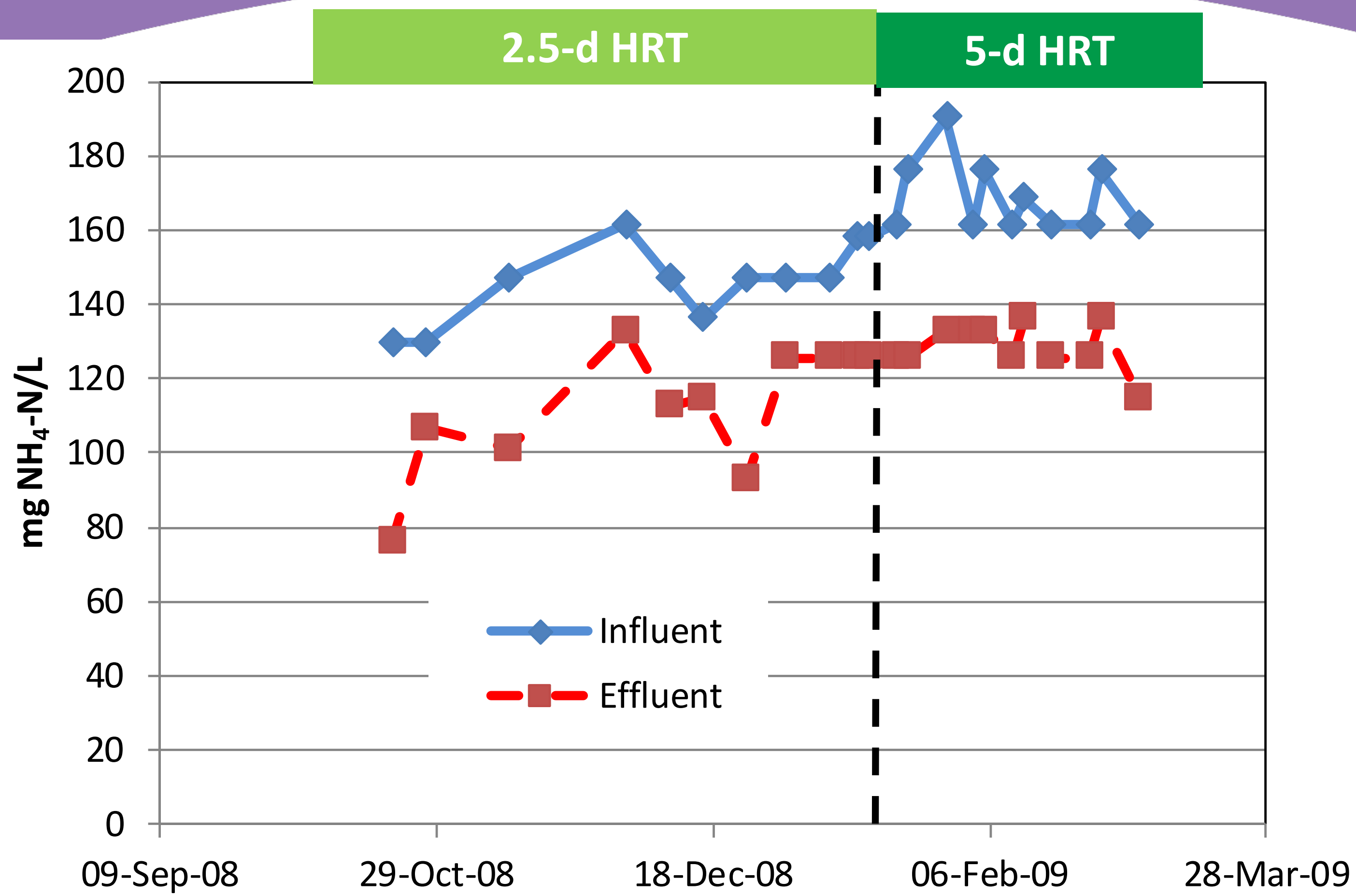
Normal, Vigorous Plant Growth and Survival

Before (T = 0, August 2008)

After (T = 7 Months, March 2009)

- Plant response shows no adverse effects due to high salt content

Ammonium Mass Reduction: 42%

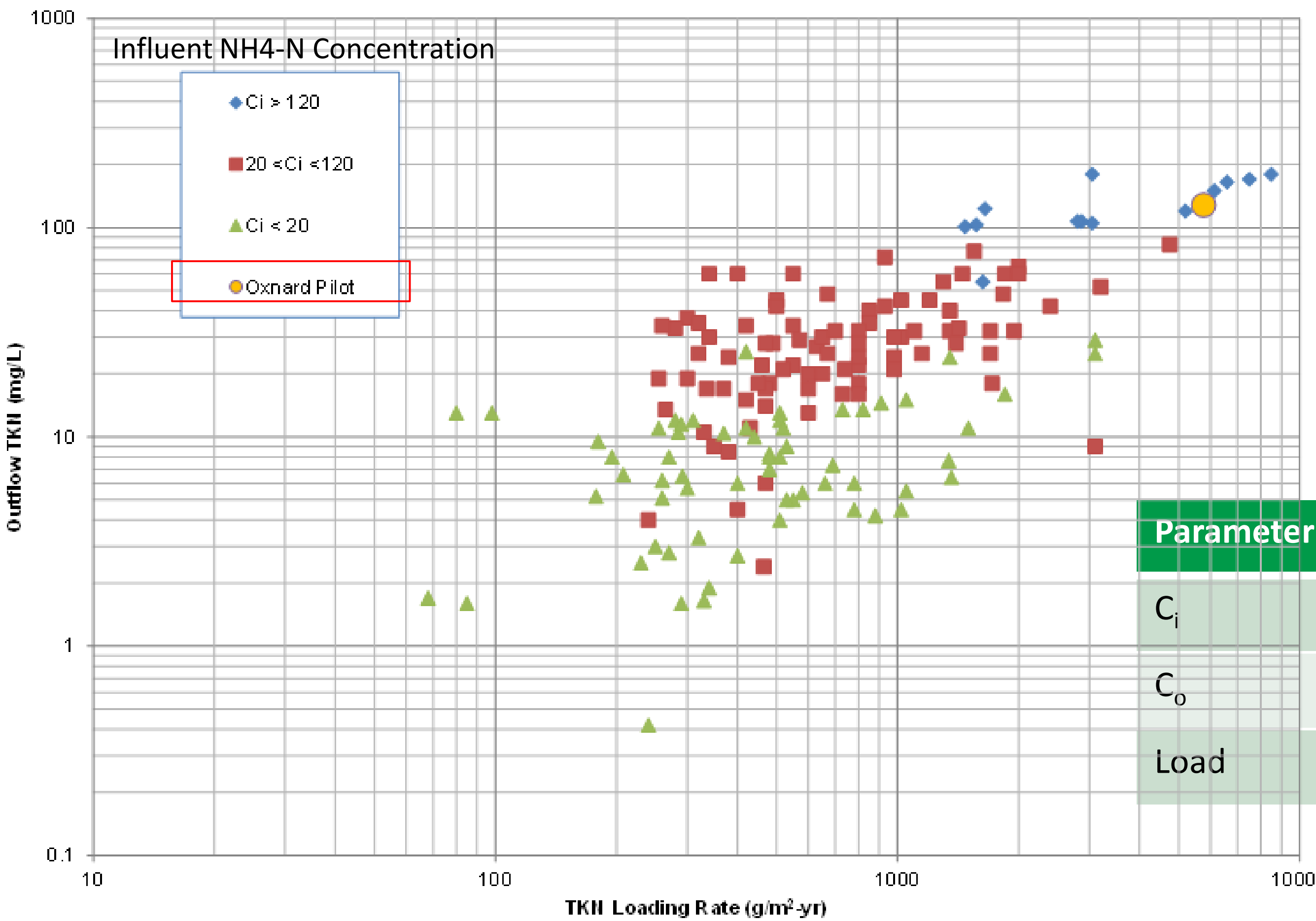


42%

43%

- Consistent reduction – impact of HRT is negligible
- High strength loading from reclaimed water is unusual for wetlands
- Uptake and nitrification in soil root zone

Consistent Loading Response Position of the Oxnard AWPF Pilot Indicates Similarity to Global Data Set: Ammonia-N

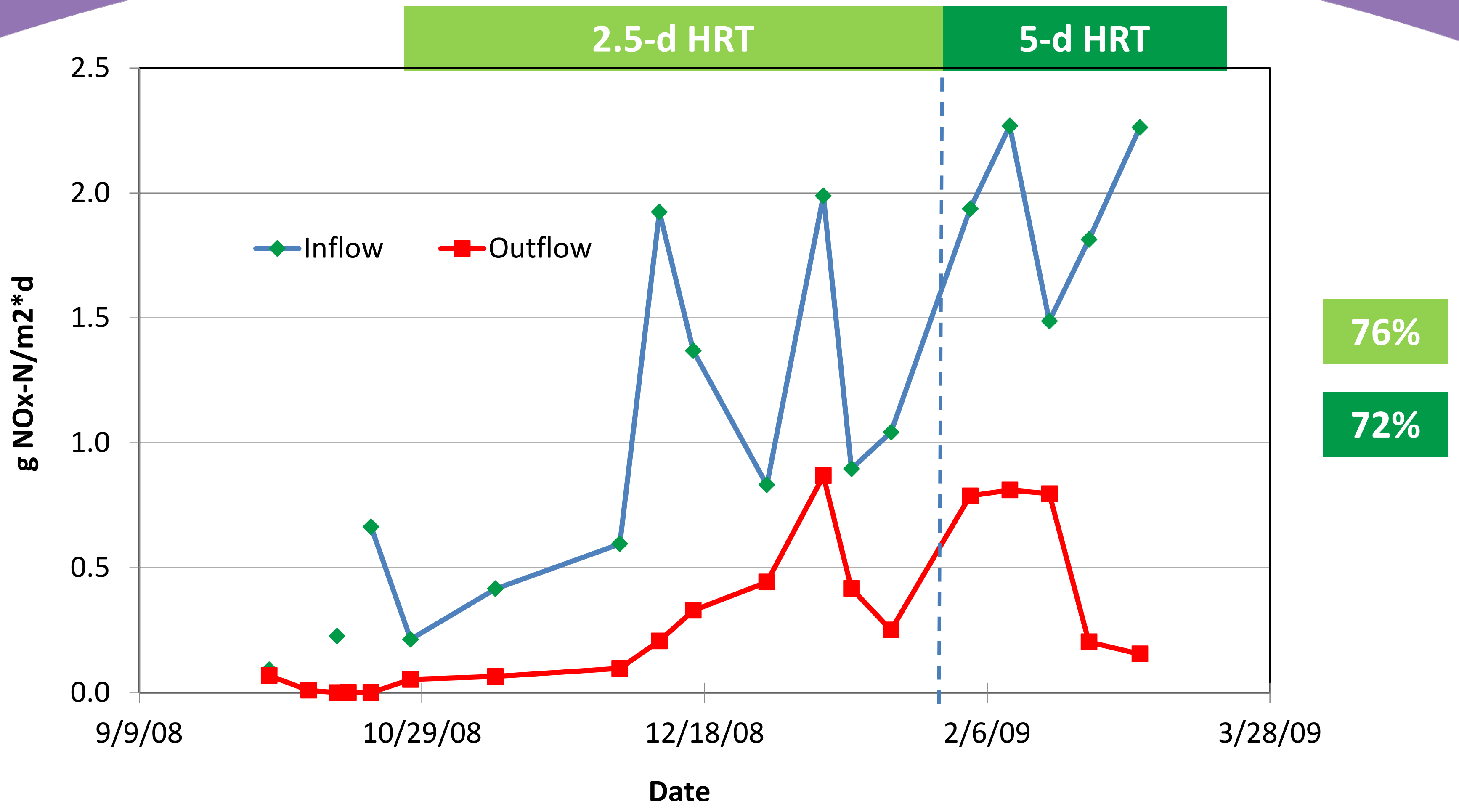


Parameter	Units	Mean
C_i	mg/L	157
C_o	mg/L	120
Load	g/m^2*yr	5,441

Source: Kadlec & Wallace 2009

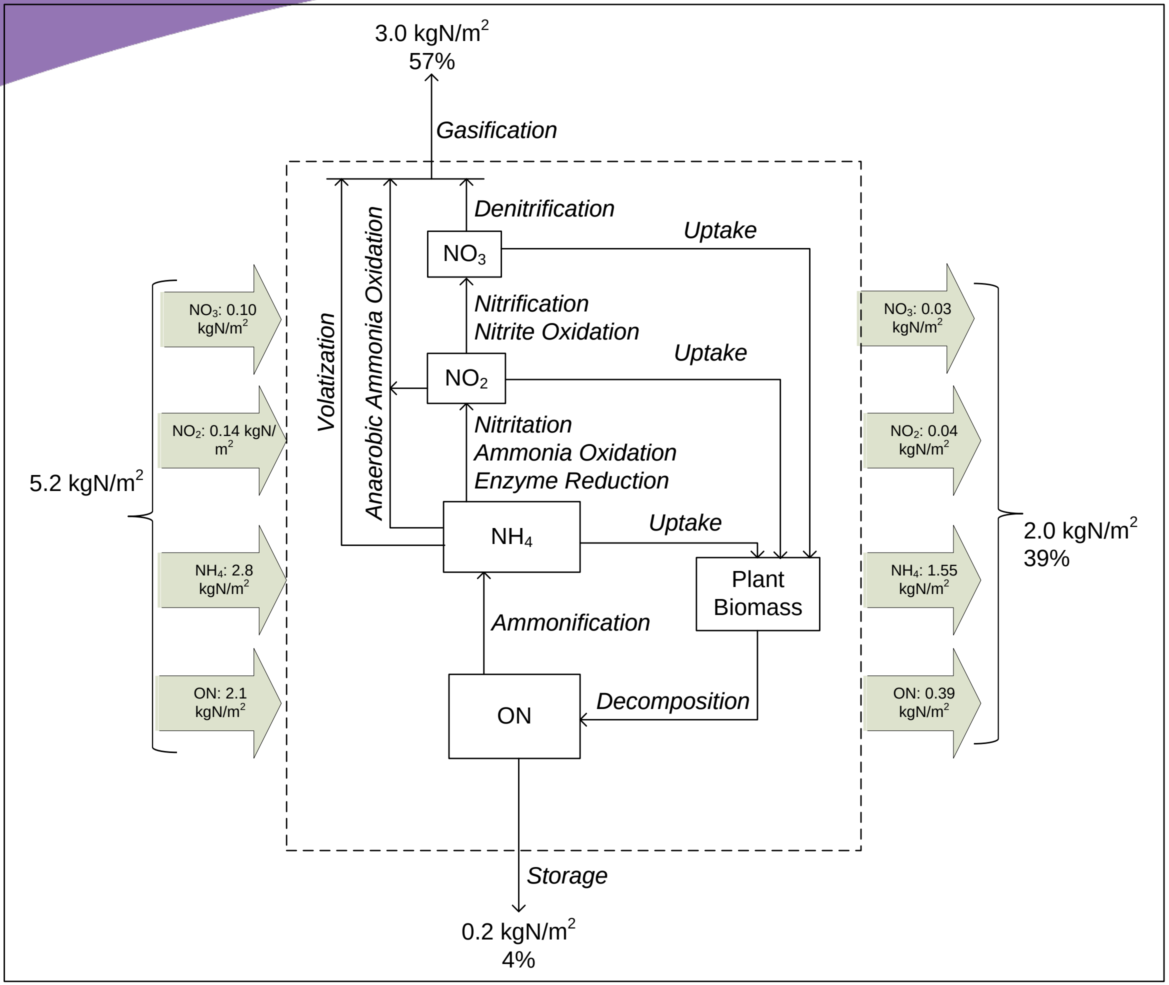
- The dominant removal processes are microbial, not plants
- Sufficient oxygen is required to achieve full nitrification

Oxidized Nitrogen (NOx-N) Mass Reduction: 75% (Nitrite-N + Nitrate-N)



- Not enough oxygen to complete transformation of nitrite to nitrate

Nitrogen Mass Balance Analysis (6 months)



Processes:

- Particulate **settling** and resuspension
- **Diffusion** of dissolved forms
- Plant **translocation,**
- **Litterfall**
- Ammonia (un-ionized) **volatilization** (gasification)
- Anaerobic ammonia oxidation (**Anamox**)
- **Sorption** of soluble nitrogen on substrates (detritus and sediment)

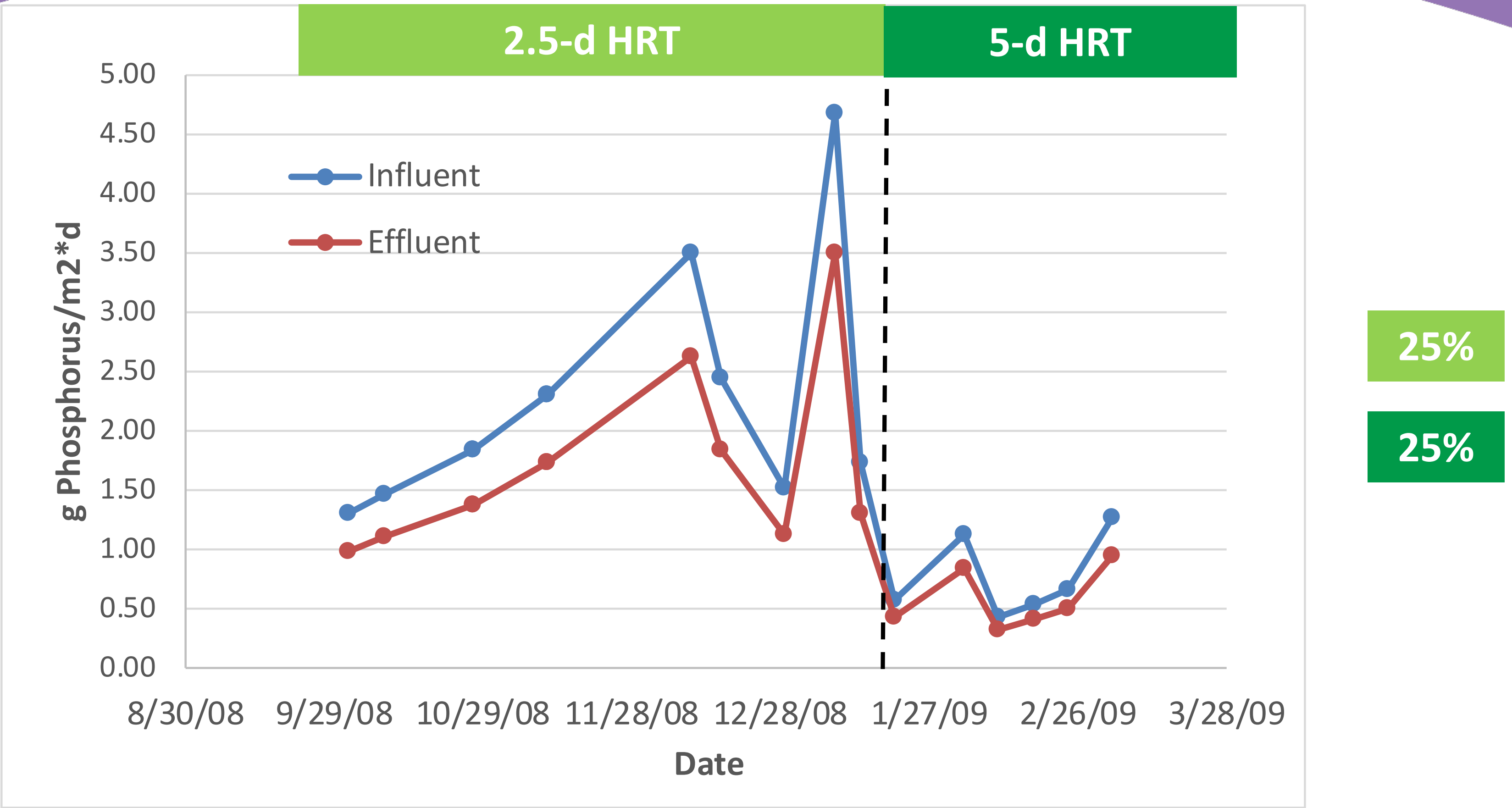
Major Transformation Processes:

- Ammonification (mineralization)
- Nitrification
- Denitrification (carbon dependent)
- Assimilation
- Decomposition

Inflow: NH_4: 54% of load; ON: 41% of load
Outflow: NH_4: 77% of load; ON: 20% of load

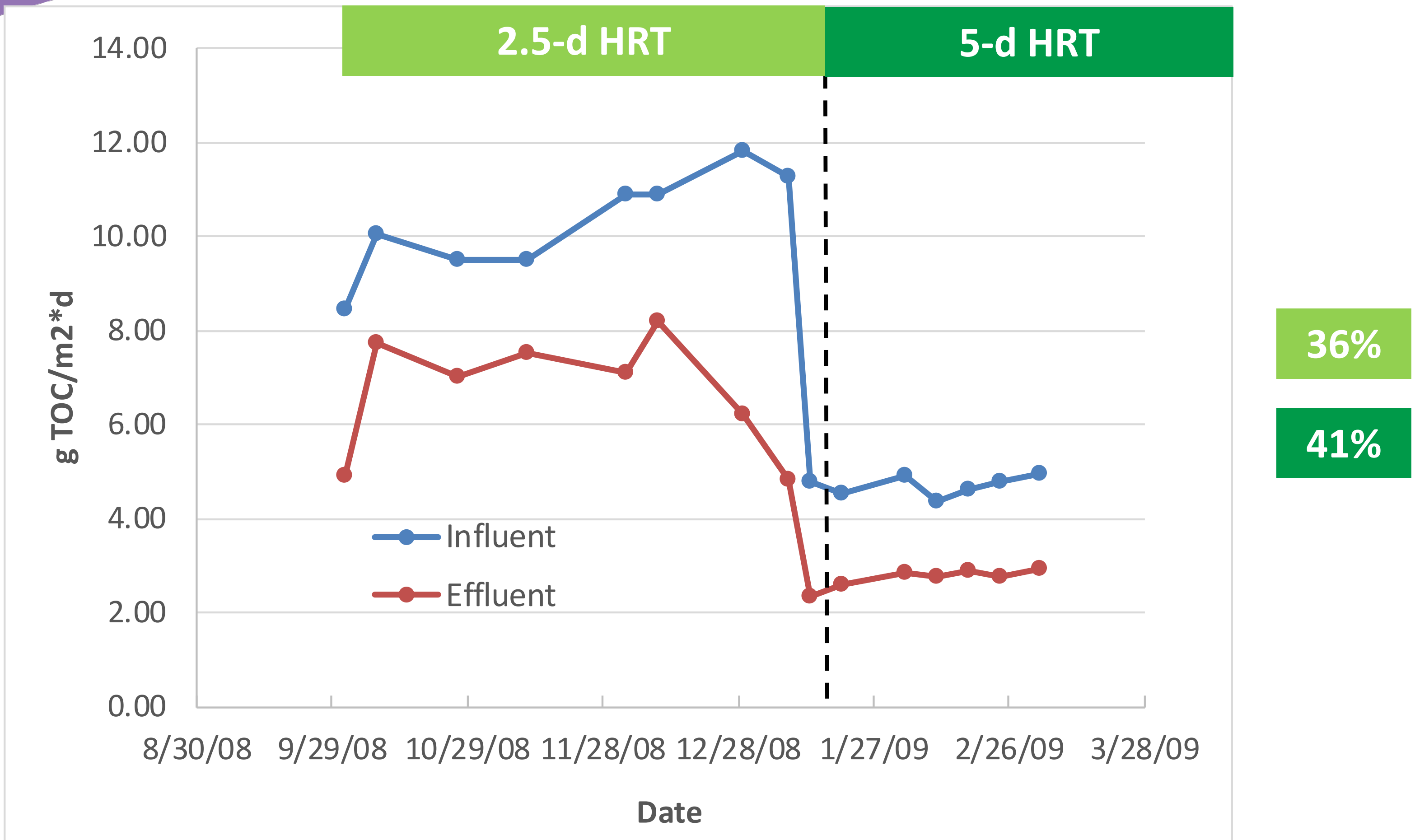
Removed TN: 61% of load
Microbial metabolism dominates transformation

Total Phosphorus Mass Reduction: 25%



- Mass reduction is consistent – impact of HRT is negligible

TOC Mass Reduction: 37%



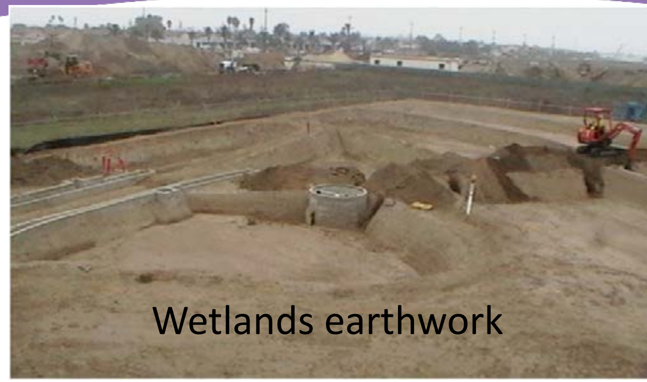
- Slight reduction due to metabolism of labile carbon but leaving residual carbon
- Reduction is consistent with denitrification

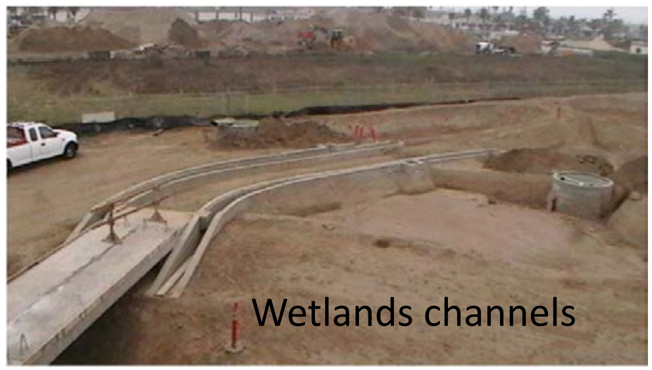
Conclusions

- Plants tolerated the high levels of salts and nutrients
  - TDS ranged between 15-25 g/L
- No odor detectable from the RO concentrate influent
- Mass balance of nutrients shows distribution of mass in soil, water, air and outflow
- Reduction in nitrogen concentration and mass
- Treatment performance consistent with wetland database
- Doubled residence time did not produce significantly better performance
- Wetlands technology can support healthy ecosystems, recreation, reduce concentrate volume, and polish effluent and reduce concentration of pollutants

AWPF Demonstration Wetland Unit Process Construction


Visitor center and wetlands


Wetlands earthwork


Wetlands channels


Horizontal flow cells


Surface flow cells


Wetlands after planting

- No concentrate available
- Currently, monitored by Bureau of Reclamation

Acknowledgements

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