The Multiple Benefits of Ozone in Municipal Wastewater Treatment and Recycling

James R. Jackson

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Abstract

Global climate change has created regional drought conditions, making water scarcity a grim reality that threatens the economic vitality of both local and regional communities. California's $ 45 billion agricultural sector, for example, may leave over a half-million acres fallow this year due to severe cuts in the water supply. This has caused high unemployment in the California farm communities and potentially higher produce prices at supermarkets across North America.

A growing number of utilities located in drought regions have installed advanced treatment processes at their wastewater treatment facilities for indirect reuse as an alternate water source for agricultural and domestic use or for seawater intrusion protection of ground water.

This presentation reviews three case histories where ozone is used in conjunction with other treatment processes to bring wastewater effluent into compliance with water quality standards for agricultural application or the replenishment of a regional drinking water source. Description of the advance treatment processes featuring ozone application method by high efficiency side stream venturi injection (SVI) and pipeline flash reactor (PFR) bulk flow mixing and lesson's learned when utilizing ozone on secondary wastewater will be review.

Proceedings of the Pan American Group Regional Conference, August 24-27, 2014, Montreal, Canada

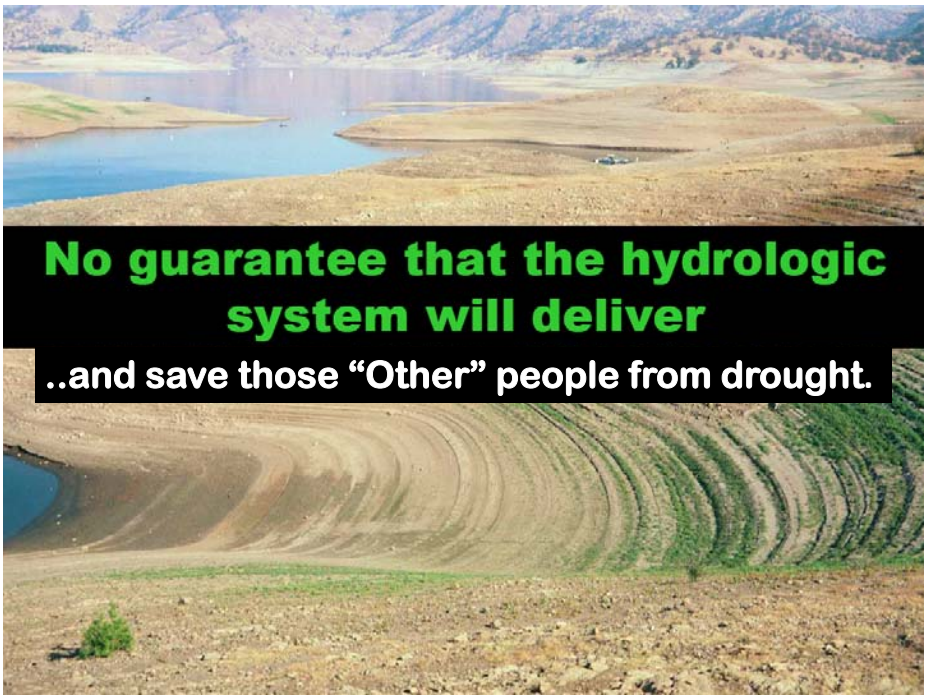
THE MULTIPLE BENEFITS OF OZONE

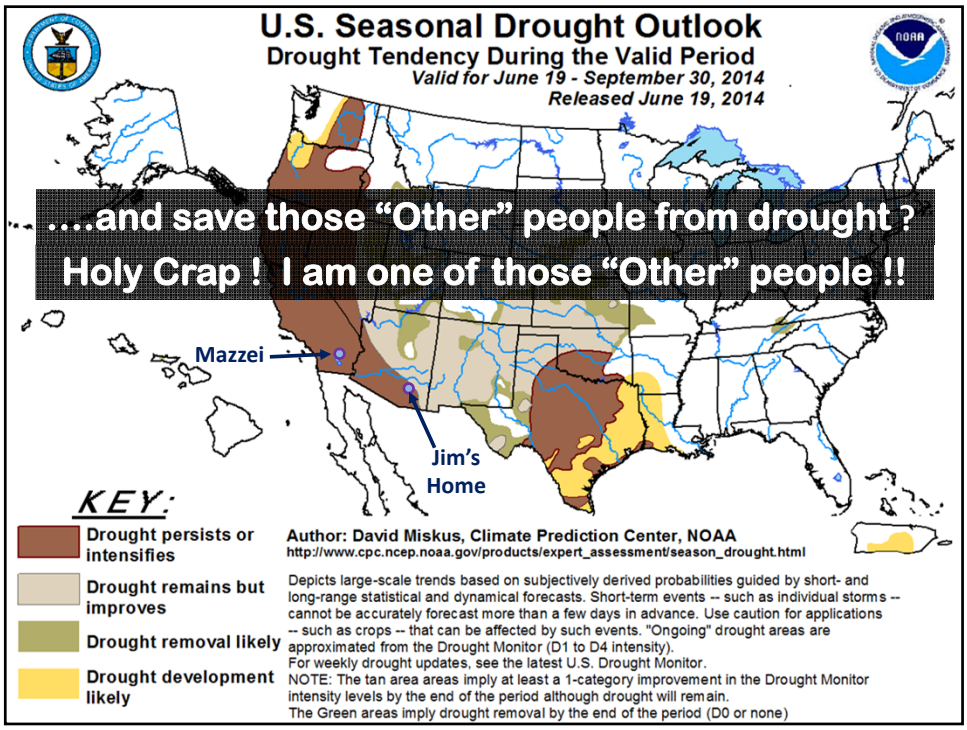
IN MUNICIPAL WASTEWATER REUSE PROJECTS

JJACKSON@MAZZEI.NET

DEMOGRAPHIC PRESSURES
On World Water Supply

- **0001 AD World Population 3% Of Now**
- **1900 World Population 1 Billion**
- **2000World Population 6 Billion**
- **Population Increasing By 150 People Per Minute**
- **2025 Water Scarcity For 3.3 Billion**

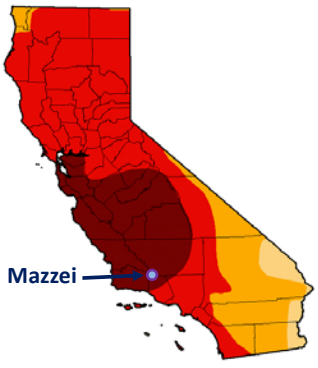

No guarantee that the hydrologic system will deliver
..and save those "Other" people from drought.


U.S. Seasonal Drought Outlook
Drought Tendency During the Valid Period
Valid for June 19 - September 30, 2014
Released June 19, 2014
....and save those "Other" people from drought ?
Holy Crap ! I am one of those "Other" people !!
Mazzei
Jim's Home
KEY:
Drought persists or intensifies
Drought remains but improves
Drought removal likely
Drought development likely
Author: David Miskus, Climate Prediction Center, NOAA
http://www.cpc.ncep.noaa.gov/products/expert_assessment/season_drought.html
Depicts large-scale trends based on subjectively derived probabilities guided by short- and long-range statistical and dynamical forecasts. Short-term events -- such as individual storms -- cannot be accurately forecast more than a few days in advance. Use caution for applications -- such as crops -- that can be affected by such events. "Ongoing" drought areas are approximated from the Drought Monitor (D1 to D4 intensity).
For weekly drought updates, see the latest U.S. Drought Monitor.
NOTE: The tan area areas imply at least a 1-category improvement in the Drought Monitor intensity levels by the end of the period although drought will remain.
The Green areas imply drought removal by the end of the period (D0 or none)

Jim's Backyard !

A haboob looms over Phoenix, as seen from the National Weather Service office on July 5, 2011 (NOAA)

Drought Milestone: 100 Percent of California Now in Drought



A Fourth Drought Year For California; What Are the Odds ?

Low water levels at San Luis Reservoir in February, 2014 (Josh Cassidy/KQED)

Courtesy KQED Science

Some Profit From California Drought

Fights break out over controversial water sales. Some farmers say they need the water to keep trees alive..

Courtesy KQED Science

…And Some Do Not

An almond tree that has been uprooted due to drought near Los Banos, California (Lindsey Horshaw/KQED)

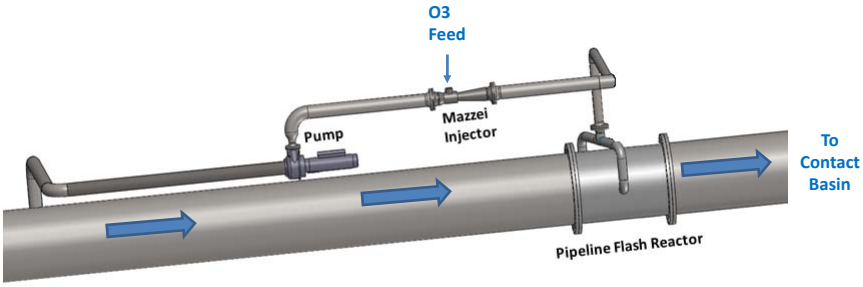
Courtesy KQED Science

WATER REUSE PROJECTS

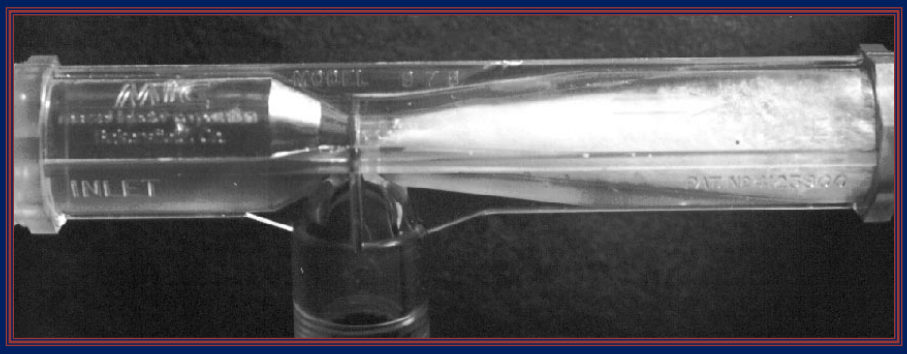
Wastewater Aeration Method

Waste Water Effluent Aeration
Hancock County, MS, USA

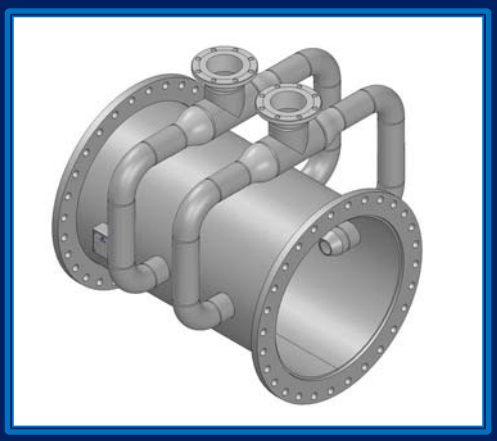
Selected Ozone Contacting Method



Primary Gas Mixing
Side Stream Venturi Injection



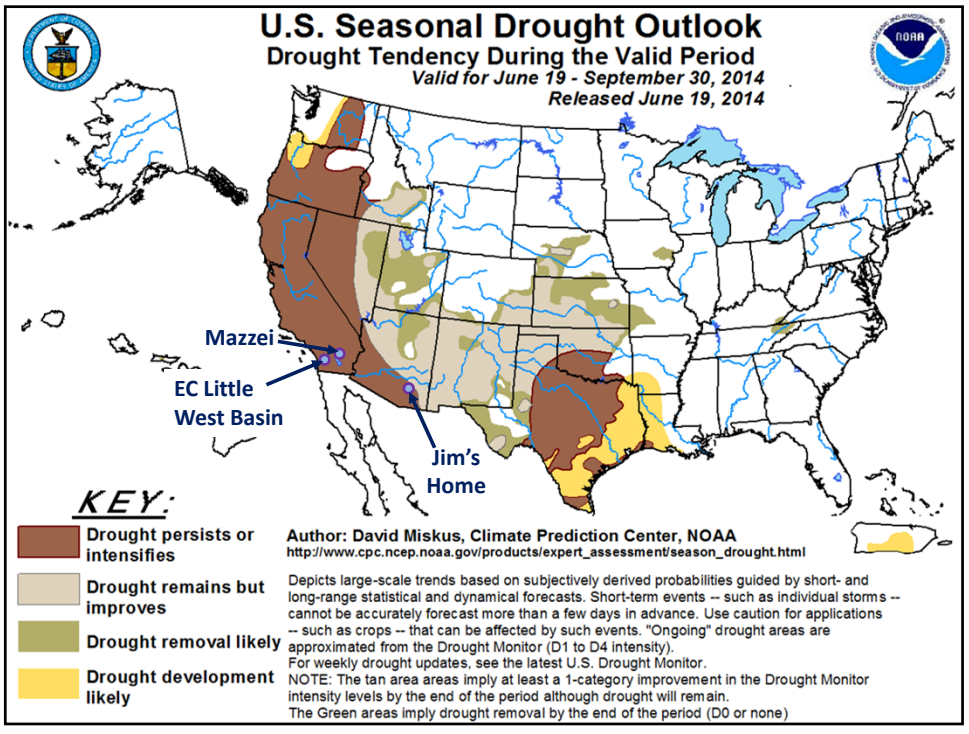
Secondary Gas Mixing
Pipeline Flash Reactor



Secondary Gas Mixing
Pipeline Flash Reactor

WEST BASIN MUNICIPAL WATER DISTRICT

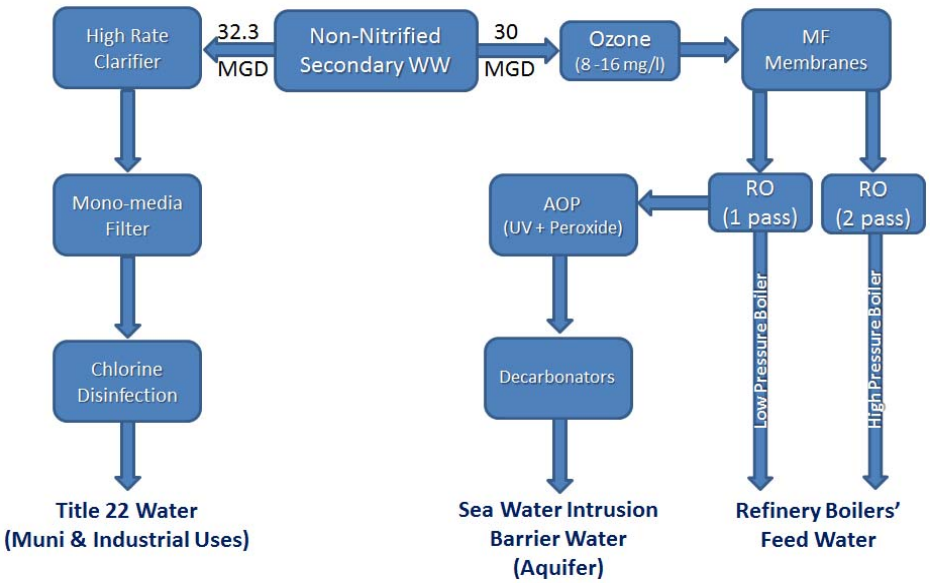
EDWARD C. LITTLE WATER RECYCLING FACILITY



EDWARD C. LITTLE WATER RECYCLING FACILITY

- Largest recycling facility of its kind in the US.
- Produces multiple grades of recycled water for municipal, commercial and industrial users.

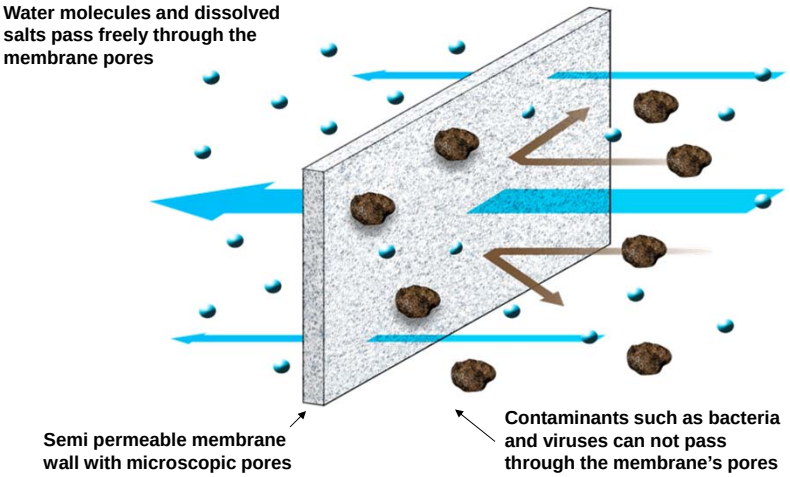
E.C. Little Water Recycling Treatment Processes



Ozone Treatment Objectives

1. Reduce MF membrane fouling from natural organic matter (NOM) and effluent organic matter (EfoM) to extend membrane service life.
2. Reduce pump energy costs by improving membrane flux.

How do Membranes Work?



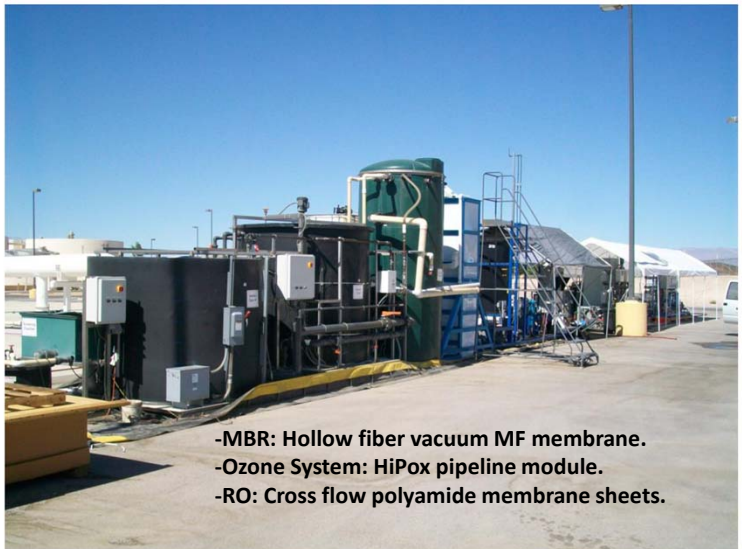
Barriers to Water Reuse and Utilization of RO Membranes

- (Public Perception)
- Cost
  - Energy, materials, construction
- Fouling
  - Colloidal
  - Inorganic
  - Biological
  - Organic

1. **Natural Organic Matter (NOM)**
2. **Effluent Organic Matter (EfOM)**

From, "Pre-ozonation Effects on the Reduction of Reverse Osmosis Membrane Fouling"
Clean Water Coalition, Benjamin D. Stanford, Aleks Pisarenko, and Shane Snyder

City of Las Vegas Water Pollution Control Facility Pilot-Scale Water Reuse Treatment Pilot



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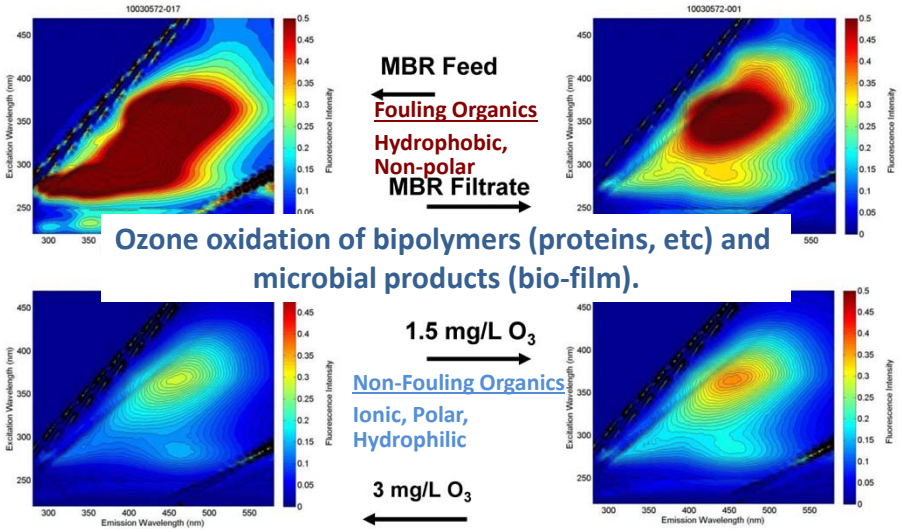
NOM/EfROM Changes Through Pilot

(Fluorescence Excitation – Emission Matrix Spectroscopy: EEM)



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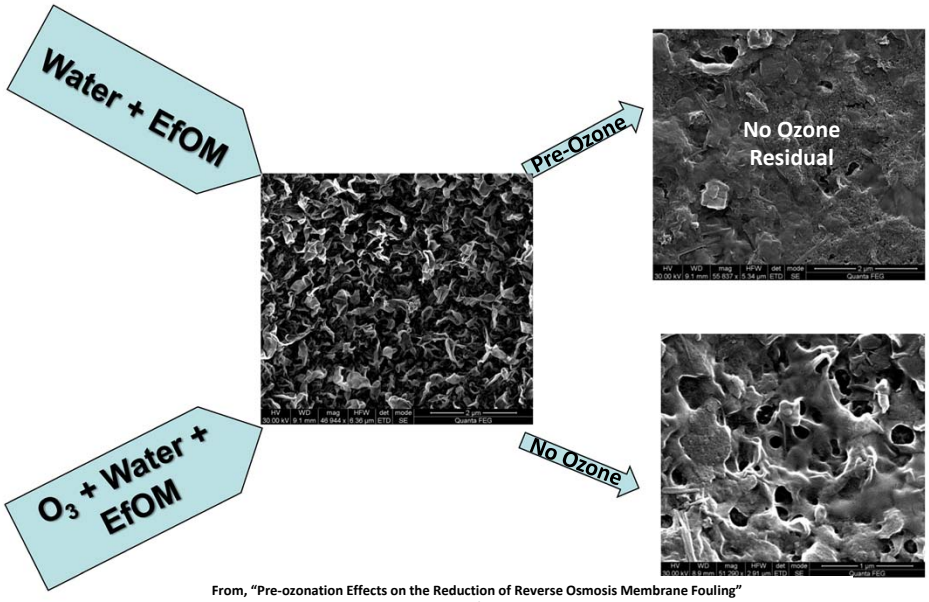
Effectiveness of Pre-Ozone Oxidation



From, "Pre-ozonation Effects on the Reduction of Reverse Osmosis Membrane Fouling"
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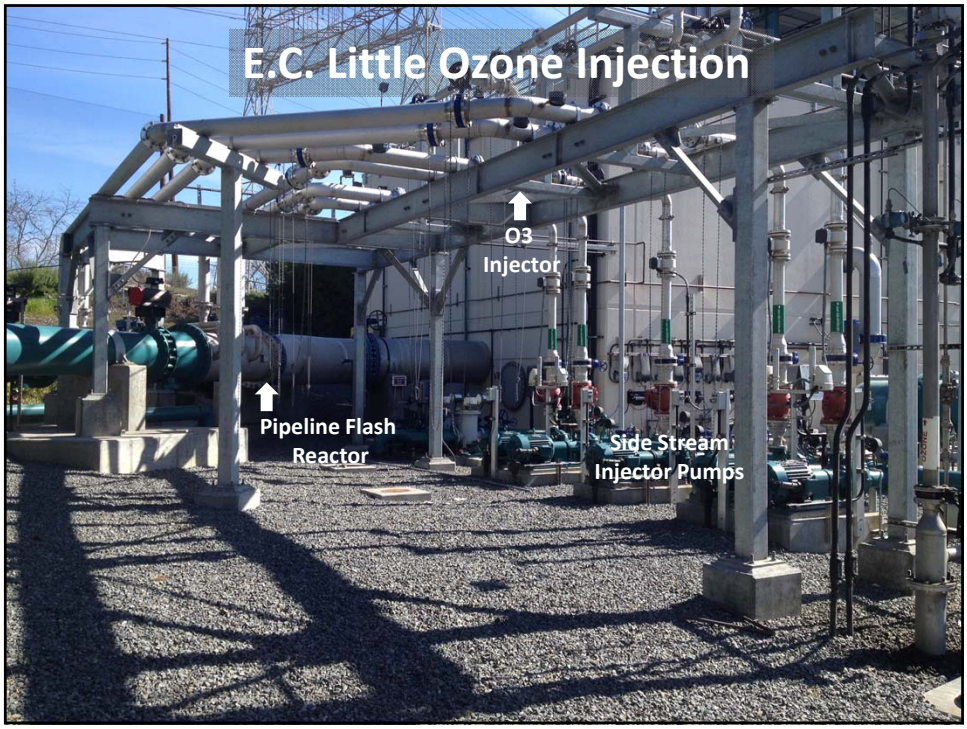
Pilot Operation Data: Specific Flux

Temperature Corrected Specific Flux (gfd/psi)

Edward C. Little Water Recycling Facility

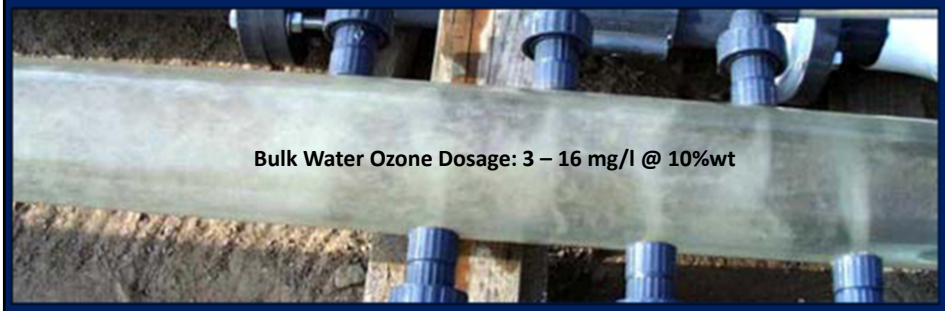
Will Pre-Ozone Increase MF Flux and Extend Service Runs ?

From, "Pre-ozonation Effects on the Reduction of Reverse Osmosis Membrane Fouling"
Clean Water Coalition, Benjamin D. Stanford, Aleks Pisarenko, and Shane Snyder


E.C. Little Ozone Injection
O3
Injector
Pipeline Flash
Reactor
Side Stream
Injector Pumps


Pipeline Flash Reactor

Secondary Gas Mixing
Pipeline Flash Reactor

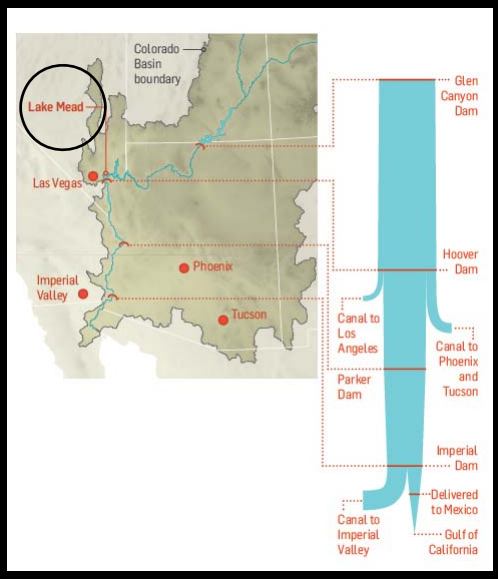


EDWARD C. LITTLE WATER RECYCLING FACILITY

- Commissioned February 2013
- Decreased MF Cleaning:
  - ✓ From 1 – 2 days now every 21 days

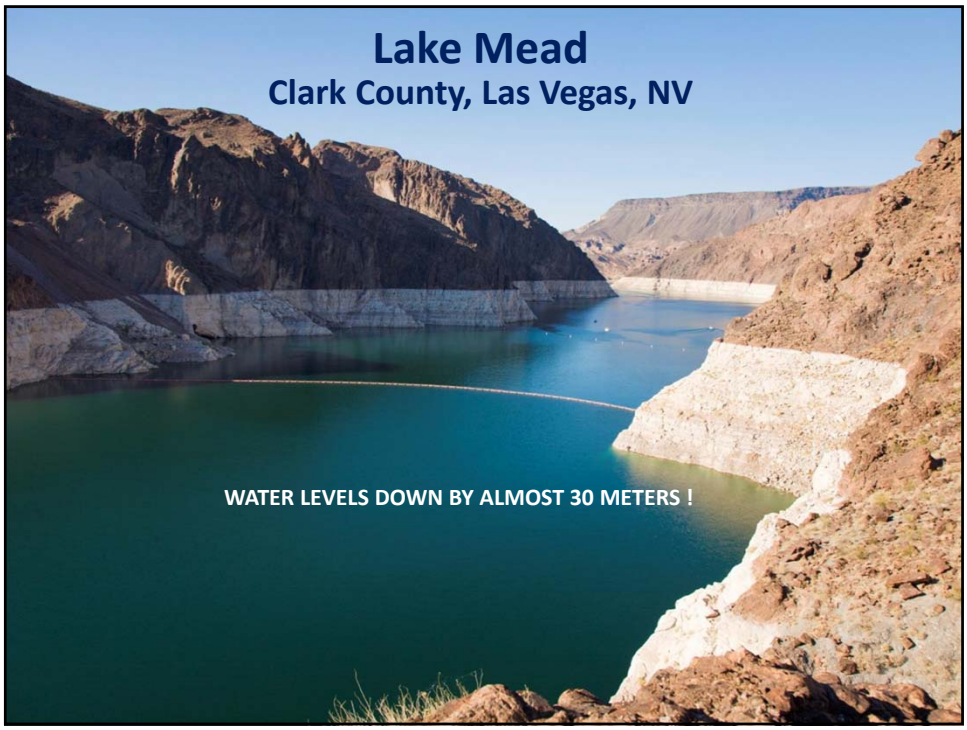
Colorado River Basin Drought

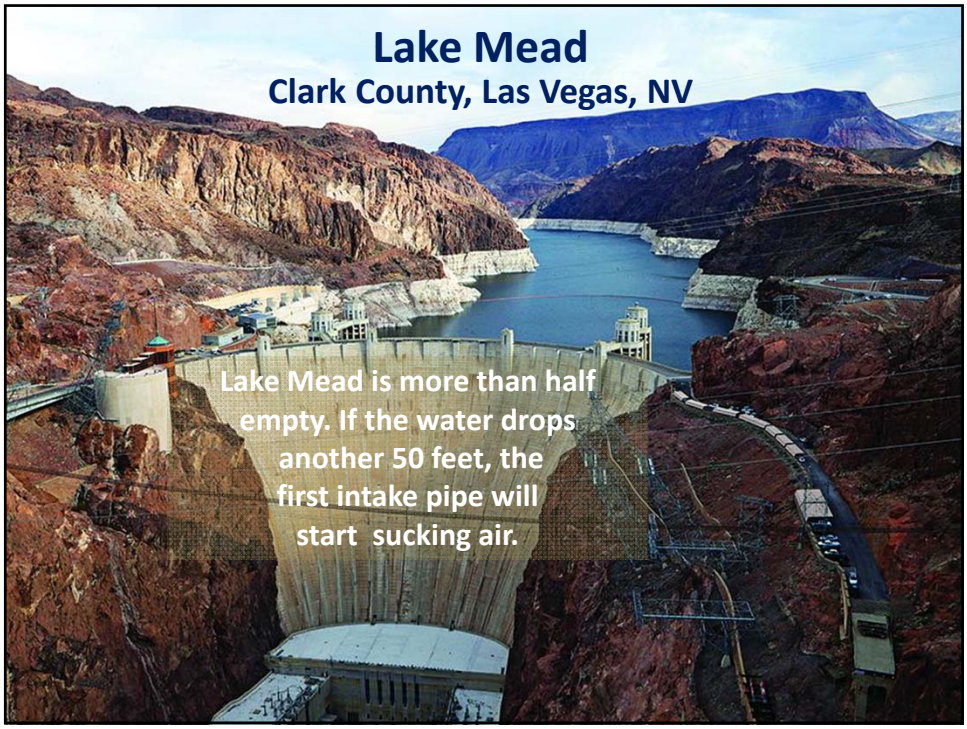
14 Years and No Relief in Sight



Lake Mead

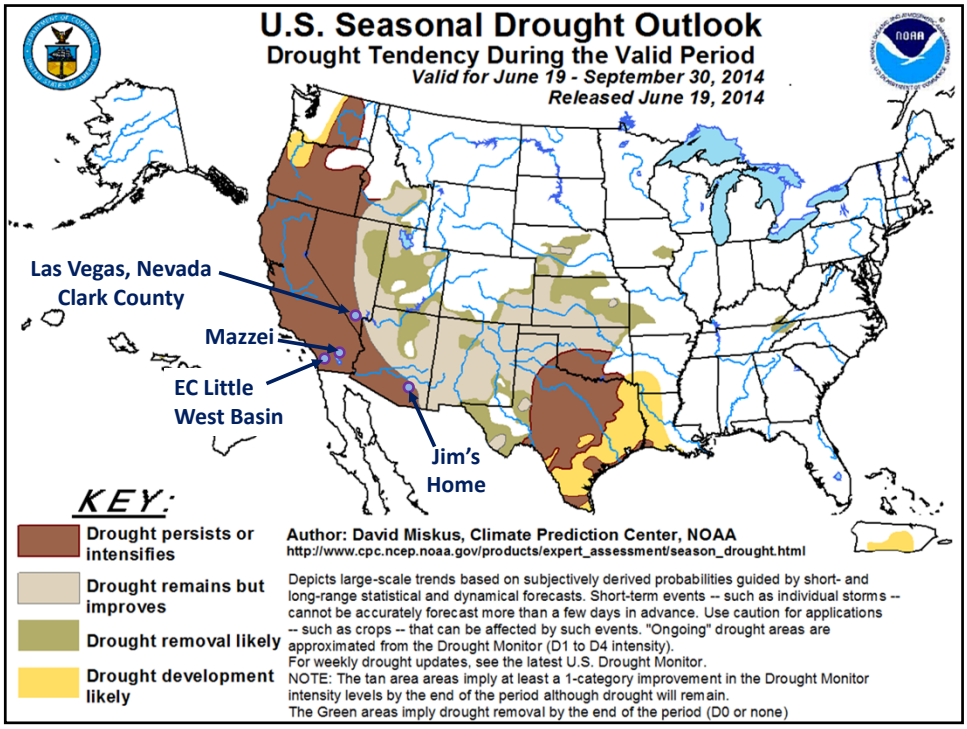
Clark County, Las Vegas, NV





CLARK COUNTY
WATER RECLAMATION DISTRICT

AWT PHASE I
MEMBRANE AND OZONE FACILITY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http://www.cpc.ncep.noaa.gov/products/expert_assessment/season_drought.html
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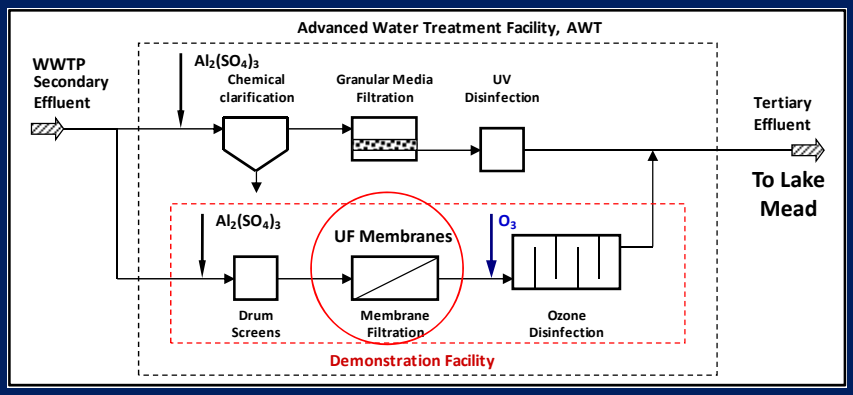
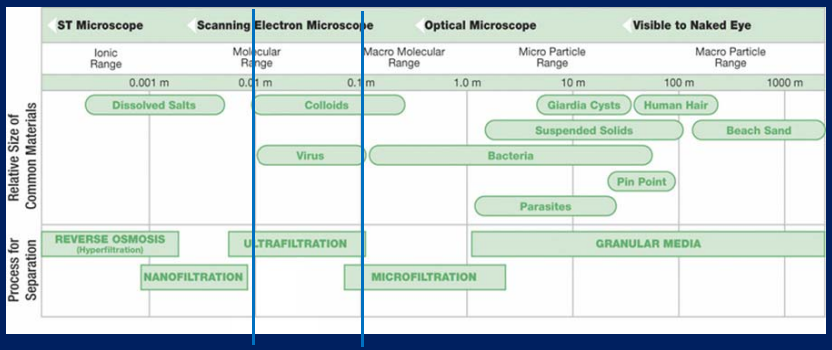
CLARK COUNTY
WATER RECLAMATION DISTRICT
AWT PHASE I
MEMBRANE AND OZONE FACILITY

AWT 113 MLD Demonstration Facility
Simplified Process Flow Diagram



AWT 113 MLD Demonstration Facility
Ulltrafiltration



What's left for ozone ?

O3 EFFECTIVE STAND ALONE TREATMENT

<30% Removal	30% to 70% Removal	>70% Removal
Musk Ketone	Meprobamate	Testosterone
TCEP	Atrazine	Progesterone
	Iopromide	Androstenedione
		Estriol
		Ethynylestradiol
		Estrone
		Estradiol
		Erythromycin-H2O
		Sulfamethoxazole
		Triclosan
		Trimethoprim
		Naproxen
		Diclofenac
		Ibuprofen
		Hydrocodone
		Acetaminophen
		Carbamazepine
		Dilantin
		Diazepam
		Caffeine

SOUTHERN NEVADA WATER AUTHORITY
Las Vegas

* From Dr. Shane Snyder, Principal Investigator concerning AwwaRF Project #2758

Ozone System Design Parameters

Parameter	*Value*
Design applied ozone dose	8 mg/L **(Virus + CEC Reduction)**
Design ozone concentration	10%
Design ozone production	38 kg/h (2,000 lb/d)
Total ozone production capacity	114 kg/h (6,000 lb/d)
Design cooling water temperature	30°C (86°F)

AWT 113 MLD Demonstration Facility
Ozone Contactor

No. Basins: 2

Fine Bubble Diffusion (FBD) Basins Designed For a 10 Minute HRT (t_{10} / t = 0.6)

Total Basin Volume: 3,000 m3 (both)

Basin Footprint: 753.6 m2

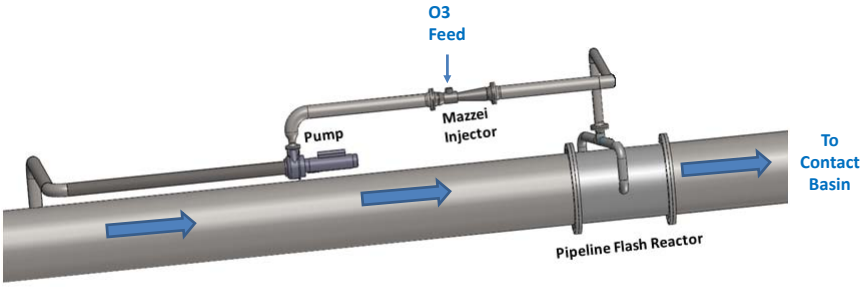
Side Water Depth: 6.7 m

Diffusers: 240 per contactor accounting for 40% of the basin floor area

Soil Conditions Impact Basin Design

- ✓ Foundation cracking in existing structures from differential setting.
- ✓ Soil borings identified soil as “critically expansive and highly compressible”.
- ✓ FBD basins size and weight required extensive & costly subsurface concrete piers.

Selected Ozone Contacting Method



Basin Design Modification

Reduced 10 minute HRT to 4 minute HRT.

ORIGINAL DESIGN: FBD

- 2- Basins
- Total No. Diffusers: 480
- Diffuser Footprint: 107.6 m3
- Total Footprint: 753.6 m2
- Side Water Depth: 6.7 m
- Total Volume: 3,000 m3

REVISED : Pipeline Flash Reactor

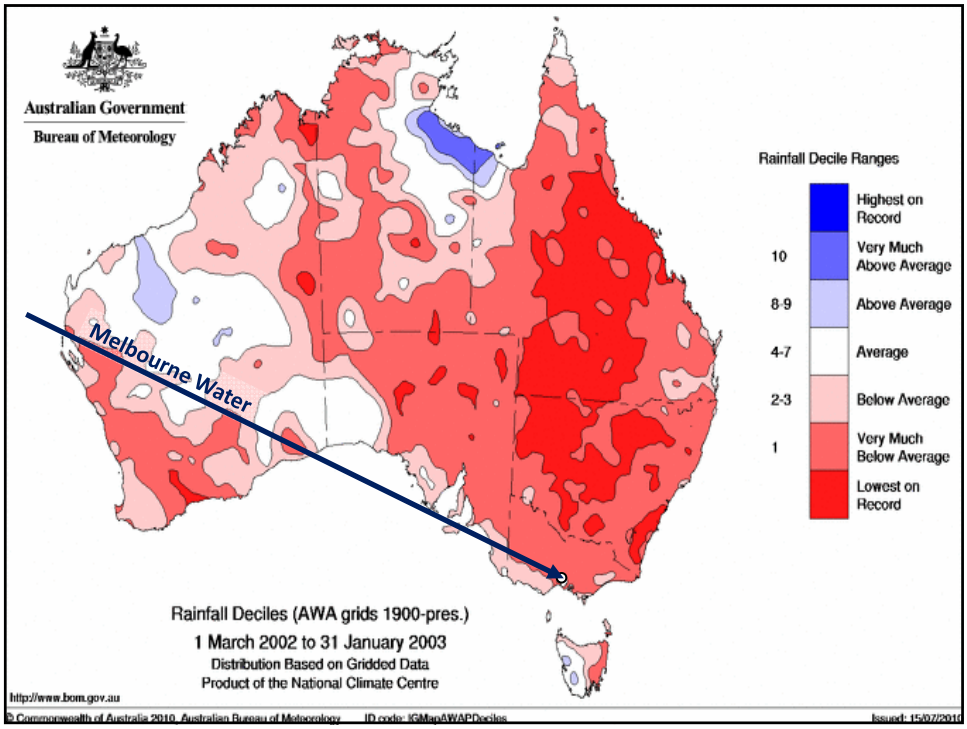
- 1- Low Profile Serpentine Basin
- No. Diffusers: 0
- Diffuser Footprint: 0 m3
- Footprint: 156.4 m2
- Side Water Depth: 3.7 m
- Total Volume: 610 m3


COMMISSIONING
Summer 2014
CLARK COUNTY
WATER RECLAMATION DISTRICT
AWT PHASE I
MEMBRANE AND OZONE FACILITY

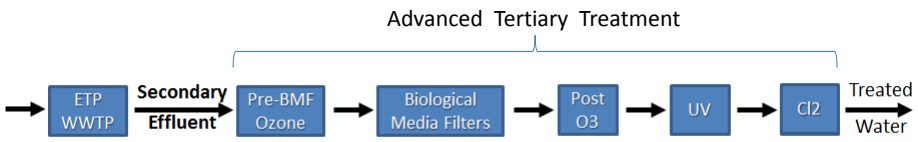

ARCTIC OCEAN
Greenland
Svalbard (Nor.)
Russia
Iceland
Norway
Sweden
Finland
Canada
United Kingdom
Ireland
Denmark
Neth.
Ger.
Pol.
Estonia
Latvia
Belarus
Ukraine
Kazakhstan
Mongolia
United States of America
ATLANTIC OCEAN
Portugal
Spain
France
Italy
Rom.
Bulgaria
Georgia
Azer.
Turkey
Greece
Uzb.
Turkm.
Kyrgyzstan
Tajikistan
China
N. Korea
S. Korea
Japan
Morocco
Tunisia
Lebanon
Syria
Iraq
Iran
Afg.
Pakistan
Nepal
Bhutan
Algeria
Libya
Israel
Jordan
Kuwait
U.A.E.
Saudi Arabia
Oman
India
Laos
Taiwan
Western Sahara
Egypt
Mauritania
Mali
Niger
Chad
Eritrea
Yemen
Djibouti
Sudan
Bangl.
Burma
Thailand
Vietnam
Philippines
Mexico
Honduras
Guatemala
Nicaragua
Costa Rica
Panama
Colombia
Ecuador
Ven.
Guyana
Suriname
French Guiana
Senegal
Guinea-Bissau
Sierra Leone
Liberia
Cote d' Ivoire
Ghana
Nigeria
Cam.
C.A.R.
Ethiopia
Somalia
Uganda
Kenya
Tanzania
Rwanda
Burundi
Rep. of the Congo
Gabon
Sri Lanka
Cambodia
Malaysia
Indonesia
Papua New Guinea
INDIAN OCEAN
Peru
Brazil
Bolivia
Paraguay
Chile
Argentina
Uruguay
Angola
Zambia
Malawi
Namibia
Zimbabwe
Botswana
Mozambique
Madagascar
Swaziland
Lesotho
South Africa
Australia

MELBOURNE WATER

ADVANCED TERTIARY TREATMENT PLANT



ADVANCED TREATMENT PROCESSES



Design of Oxygen and Ozone Systems for a Large Scale Advanced Tertiary Treatment Plant
John Mieog et.al., IOA IUVA World Congress, & Exhibition, Paris , France – May 23 – 27, 2011

Plant Treatment Objectives

1. Compliance with requirements for discharge to the marine environment for 100% of the time.
2. Compliance with requirements for Class A recycled water production for at least 98% of the time.
   a) Requires a 4.5 – 5.5 log removal of virus, bacteria and protozoa.
   b) Can be used on crops.

Design of Oxygen and Ozone Systems for a Large Scale Advanced Tertiary Treatment Plant
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Ozone Dosage & Transfer

PRE-BMF OZONE

- Ozone dosage: 8.3 – 10 mg/l
- Transfer: Sidestream gas injection with pipeline gas contactor.

POST BMF OZONE

- Ozone dosage: 2.5 – 5.2 mg/l
- Transfer: Sidestream gas injection with basin nozzle manifold.

Design of Oxygen and Ozone Systems for a Large Scale Advanced Tertiary Treatment Plant
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Ozone Treatment Objectives

PRE-BMF OZONE

- Color reduction from 90 – 15 PtCo (median performance)
- UV transmittance improvement from 40 – 60 %
- Foam reduction (in conjunction with BMF)
- Oxygenation to support ammonia reduction by BMF treatment

POST BMF OZONE

- Significant disinfection (Crypto, Virus, Bacteria)
- Further residual color reduction
- UV transmittance improvement from 60 – 75 %
- Re-oxygenation following BMF treatment

Design of Oxygen and Ozone Systems for a Large Scale Advanced Tertiary Treatment Plant
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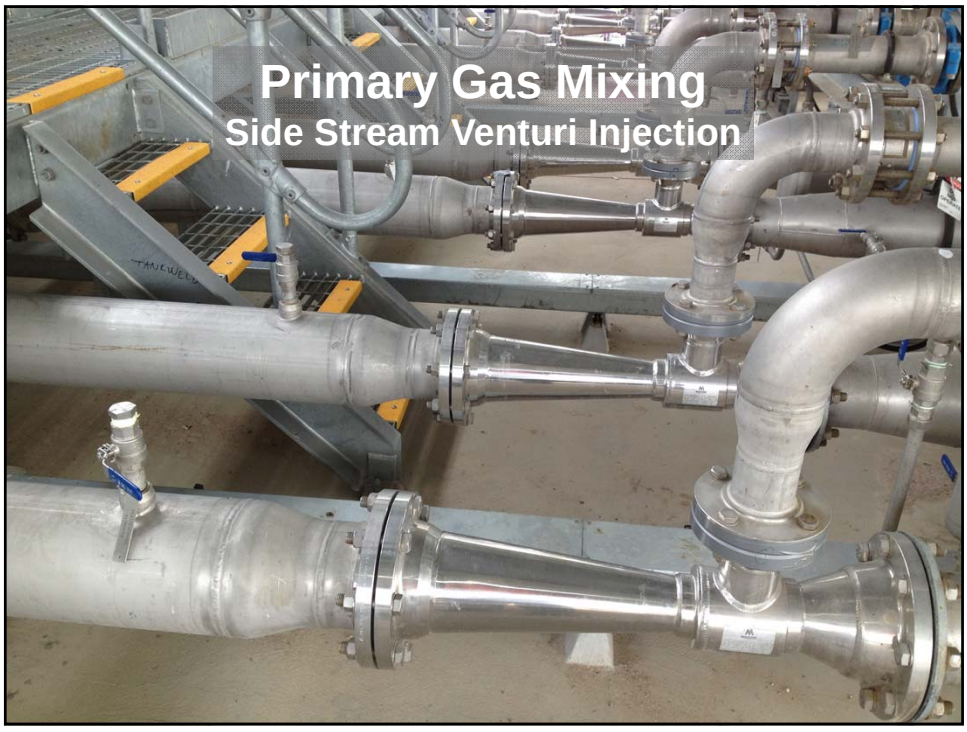
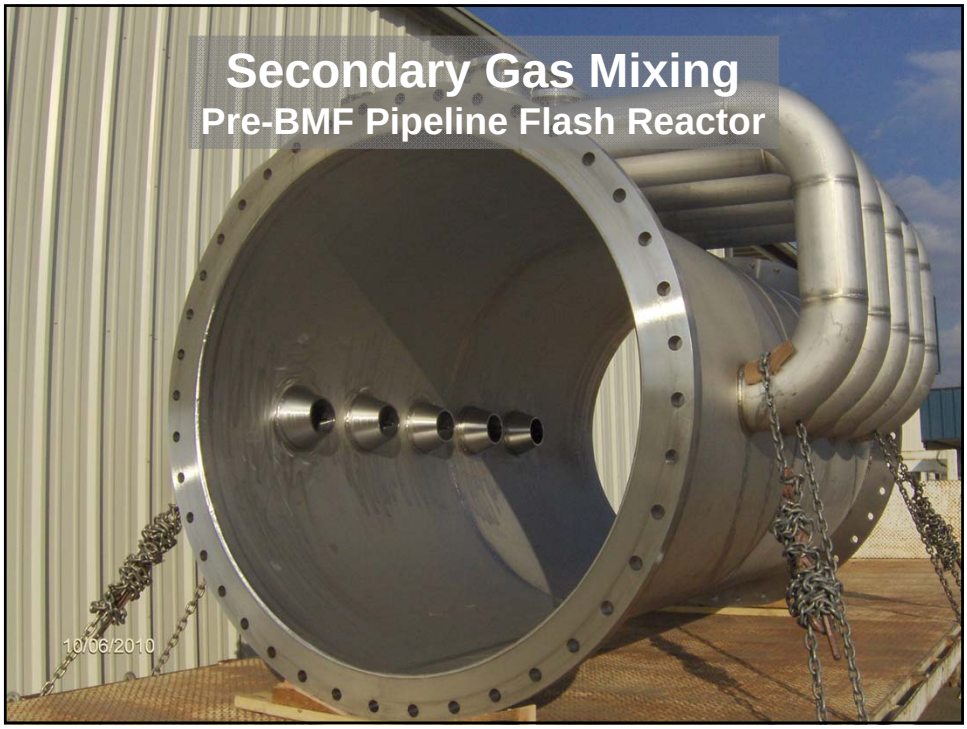
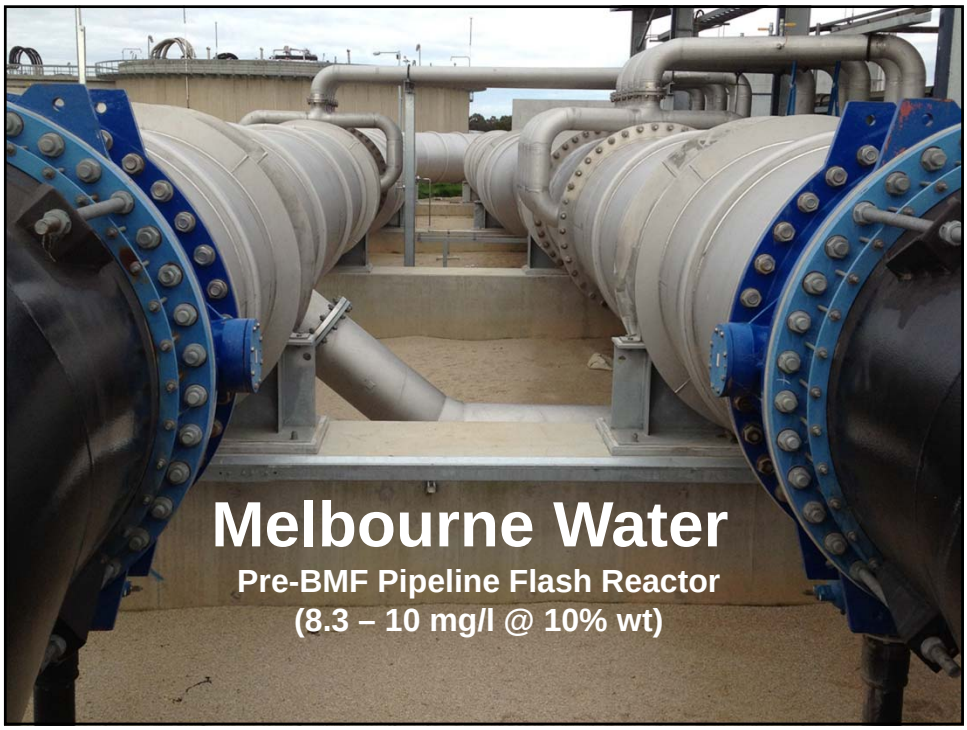
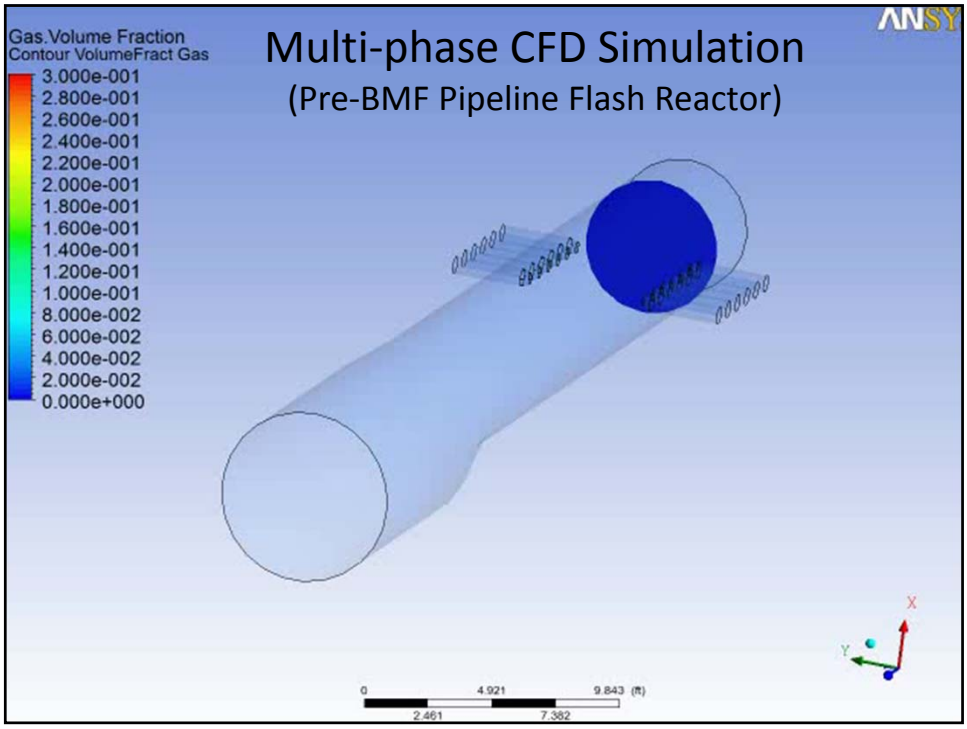



Secondary Gas Mixing
Pre-BMF Pipeline Flash Reactor
10/06/2010


Melbourne Water
Pre-BMF Pipeline Flash Reactor
(8.3 – 10 mg/l @ 10% wt)


Gas.Volume Fraction
Contour VolumeFract Gas
3.000e-001
2.800e-001
2.600e-001
2.400e-001
2.200e-001
2.000e-001
1.800e-001
1.600e-001
1.400e-001
1.200e-001
1.000e-001
8.000e-002
6.000e-002
4.000e-002
2.000e-002
0.000e+000
Multi-phase CFD Simulation
(Pre-BMF Pipeline Flash Reactor)
ANSYS
X
Y
0
4.921
9.843 (ft)
2.461
7.382


Melbourne Water
Pre-BMF Pipeline Flash Reactor
40 m to O3 PFR
Off Gas
Basin

POST BMF

SECONDARY GAS MIXING

Ozone Treatment Objectives

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POST BMF OZONE

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MELBOURNE WATER

ADVANCED TERTIARY TREATMENT PLANT

IS IN OPERATION AND MEETING ALL

TREATMENT OBJECTIVES

WATER REUSE PROJECTS

Pre-filter Ozone To Increase
MF Flux and Service Runs

Post Filter Ozone Disinfection
And CEC Reduction

Clark County
Water Reclamation District

Melbourne Water
Eastern Treatment Plant
Pre & Post Filter O3 Oxidation &
Disinfection

Retrofit of O3 Contact Basins With SVI and Basin Nozzle Manifolds