Potable Reuse for Inland Applications: Pilot Testing Results Tucson, AZ

Water Resource Research Center - Brownbag
October 26, 2016

Presenters: Jeff Biggs, Tucson Water
Michael Hwang, CH2M

Agenda

- Background
- New Potable Reuse Treatment Scheme
- Pilot Site Selection and Design
- Water Quality Results
- Conclusions

BACKGROUND

Residuals Management Can be a Major Challenge for Inland Reuse Programs

Major coastal programs have the benefit of an ocean outfall

Orange County Water District's
Groundwater Replenishment System

Residuals management costs for inland facilities can *<u>equal or exceed</u> main treatment facility costs*

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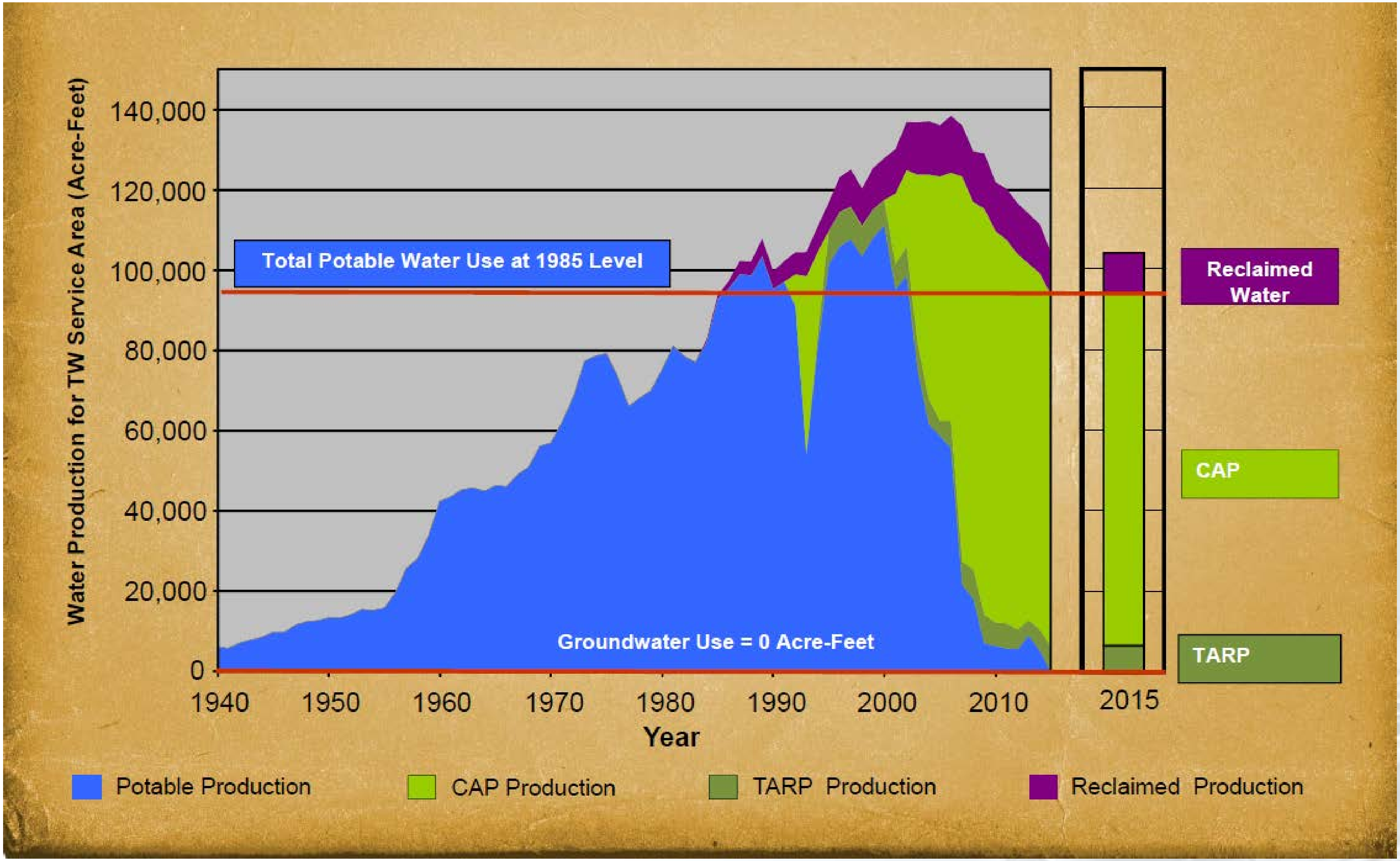
Transition to Renewable Water Supplies



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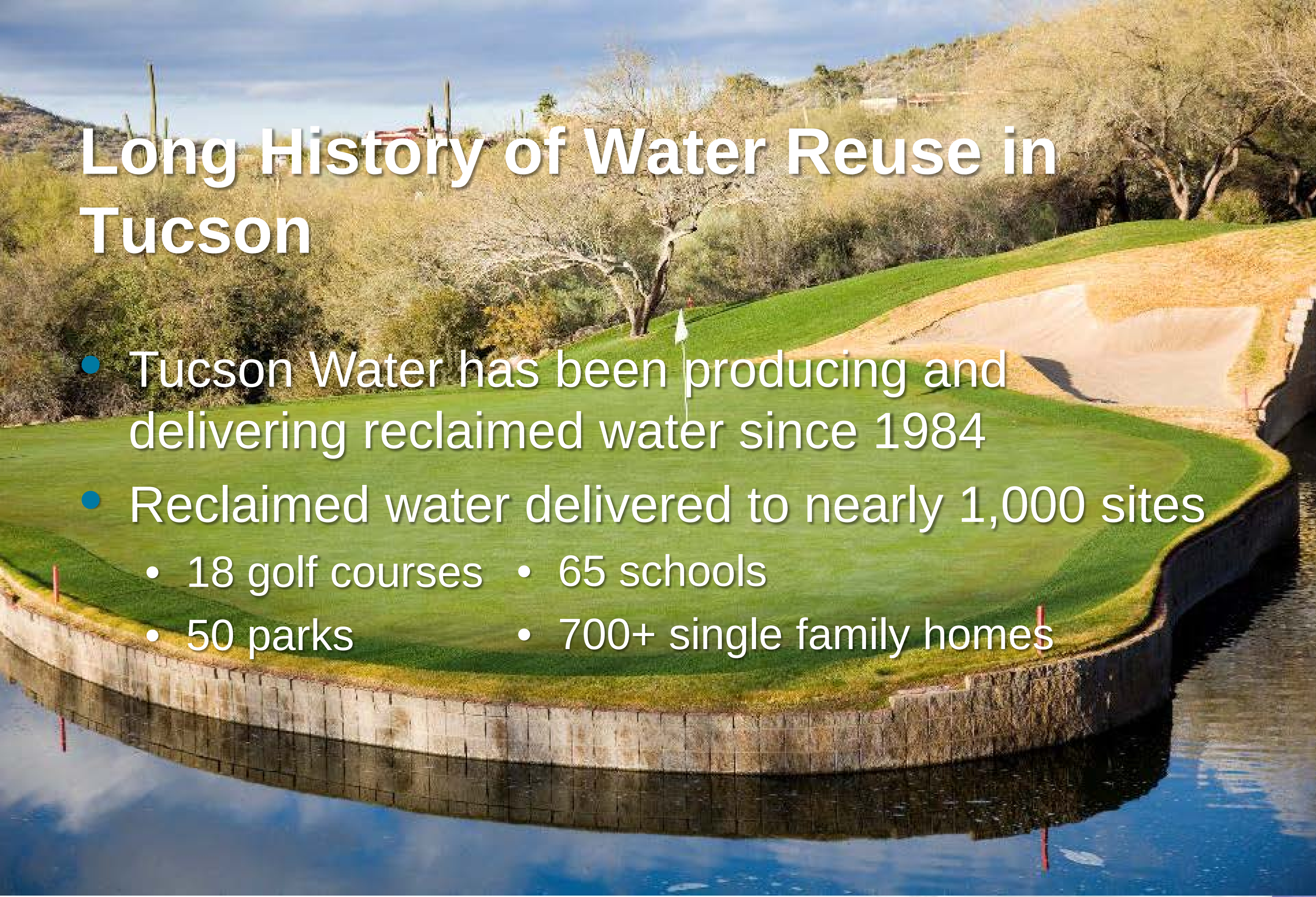
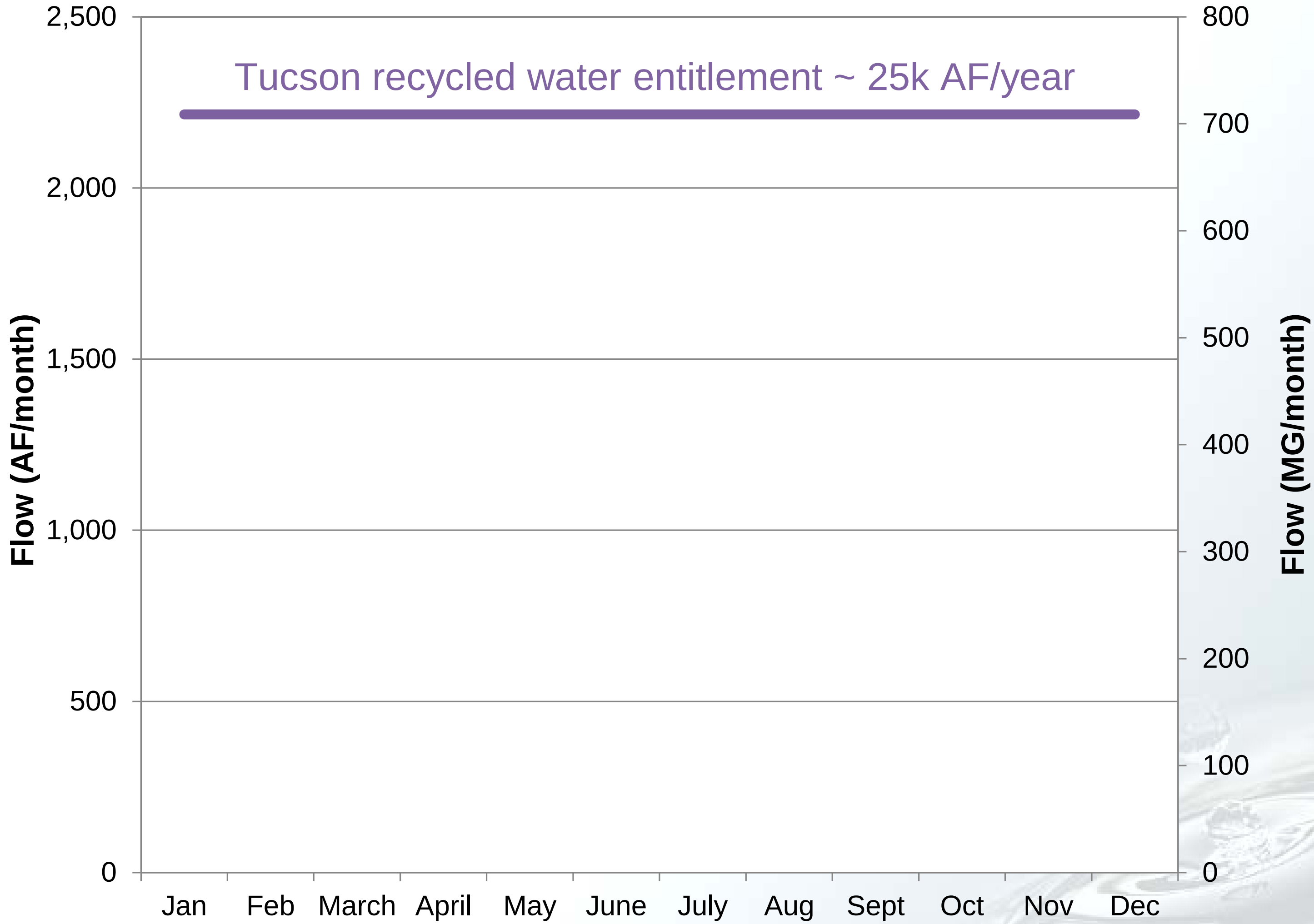


Long History of Water Reuse in Tucson

- Tucson Water has been producing and delivering reclaimed water since 1984
- Reclaimed water delivered to nearly 1,000 sites
  - 18 golf courses
  - 65 schools
  - 50 parks
  - 700+ single family homes

Seasonal variation in available recycled water impacts potable reuse concept



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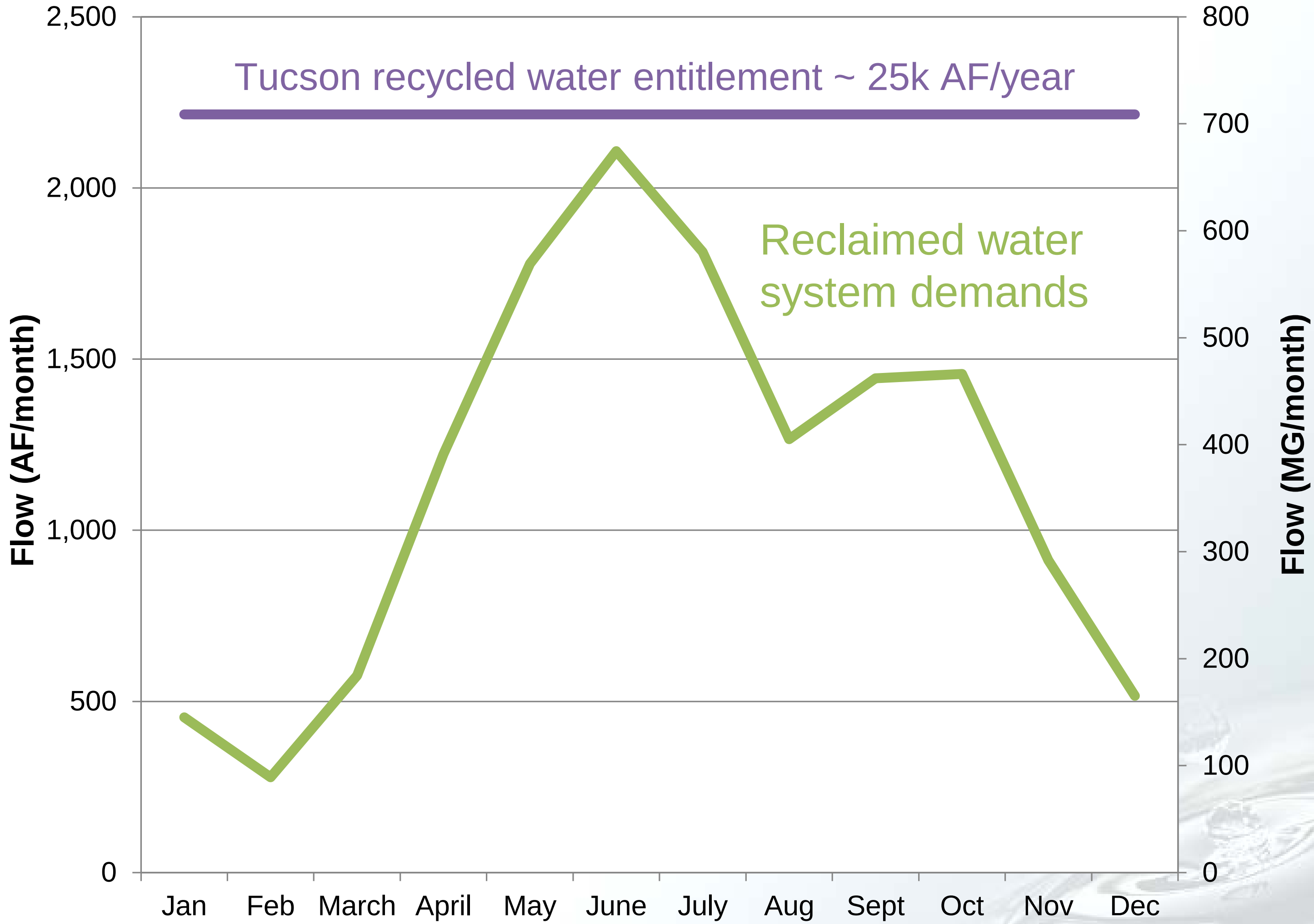

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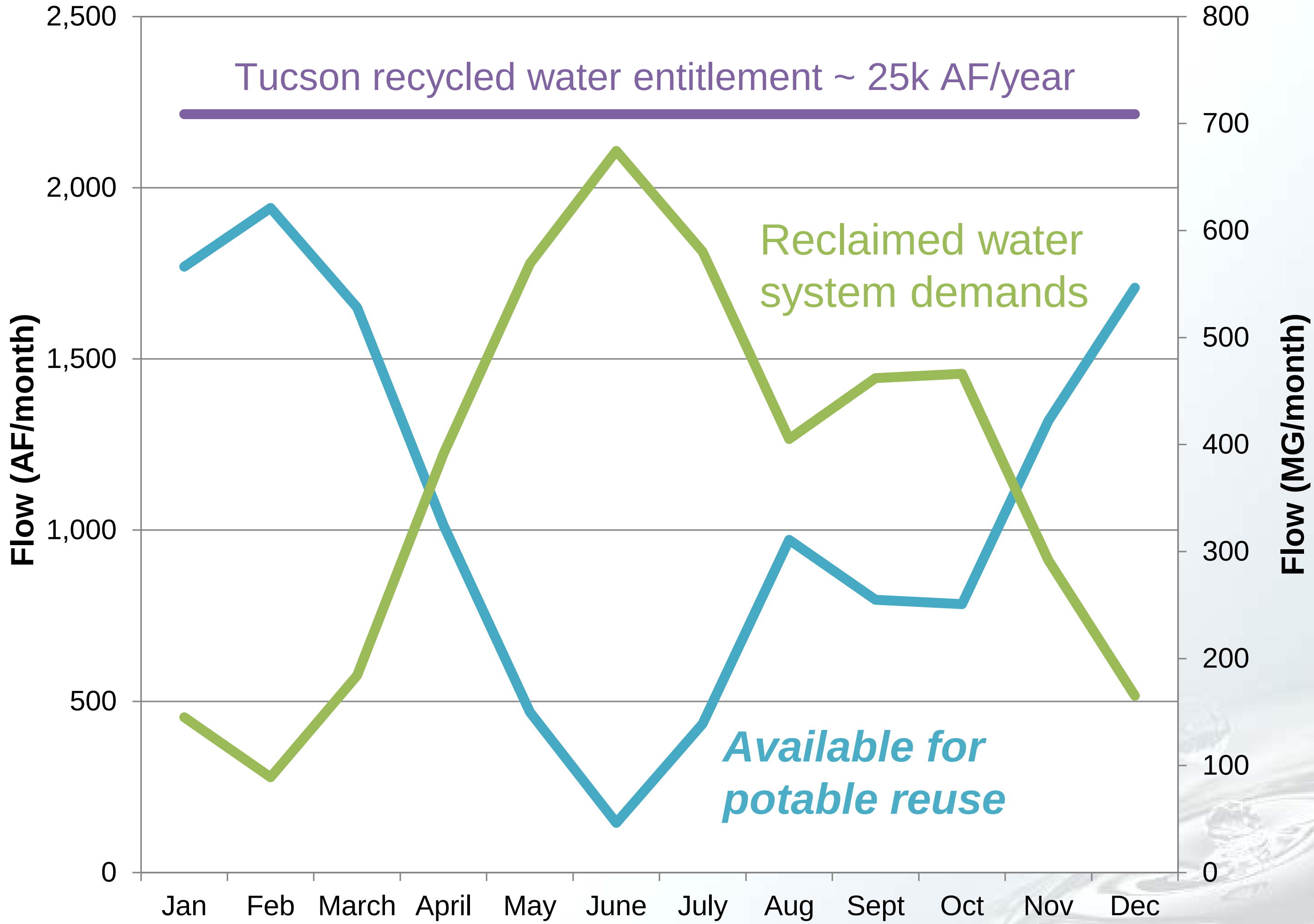

Recycled Water Master Plan Recommendations

RECYCLED WATER MASTER PLAN

Continue to invest in the Reclaimed Water System to maintain efficient service to existing and potential future customers

Pursue full utilization of the City's recycled water entitlement through potable reuse to diversify renewable supplies

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Phased Implementation Steps for a Potable Reuse Program

Feasibility Study → Planning → Pilot Testing → Demonstration Facility → Design → Construction

- Regulatory Coordination
- Public Outreach & Communication
- Independent Advisory Committee Review
- Financial Planning

WRRF 13-09 supplements early implementation efforts for Tucson's Recycled Water Program

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Considering Alternatives to "Full Advanced Treatment"

What treatment is needed?

- MF-RO-UVAOP has been shown to be effective
- Treatment alternatives could increase the feasibility of potable reuse at inland locations while providing:
  - Multiple barriers for organics and pathogens
  - Reduction of salt concentrations
  - Reduced energy consumption
  - Mitigated concentrate disposal

Technical, financial, and public outreach factors will determine treatment process decisions

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NEW POTABLE REUSE TREATMENT SCHEME

Operational Potable Reuse Plants

Project	Location	Type of Potable Reuse	Year in Operation	Capacity (MGD)	Current Advanced Treatment Process
Montebello Forebay, CA	Coastal	GW recharge via spreading basins	1962	44	GMF + Cl_2 + SAT (spreading basins)
Windhoek, Namibia	Inland	Direct potable reuse	1968	5.5	O_3 + Coag + DAF + GMF + O_3/H_2O_2 + BAC + GAC + UF + Cl_2
UOSA	Inland	Surface water augmentation	1978	54	Lime + GMF + GAC + Cl_2
Hueco Bolson, El Paso, TX	Inland	GW recharge via direct injection and spreading basins	1985	10	Lime + GMF + Ozone + GAC + Cl_2
Clayton County, GA	Inland	Surface water augmentation	1985	18	Cl_2 + UV disinfection + SAT (wetlands)
West Basin, El Segundo, CA	Coastal	GW recharge via direct injection	1993	12.5	MF + RO + UVAOP
Scottsdale, AZ	Inland	GW recharge via direct injection	1999	20	MF + RO + Cl2
Gwinnett County, GA	Inland	Surface water augmentation	2000	60	Coag/Floc/Sed + UF + Ozone + GAC + Ozone
NEWater, Singapore	Coastal	Surface water augmentation	2000	146 (5 plants)	MF + RO + UV disinfection
Los Alamitos, CA	Coastal	GW recharge via direct injection	2006	3.0	MF + RO + UV disinfection
Chino GW Recharge, CA	Inland	GW recharge via spreading basins	2007	18	GMF + Cl_2 + SAT (spreading basins)
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Queensland, Australia	Coastal	Surface water augmentation	2009	66 (3 plants)	MF + RO + UVAOP
Arapahoe County, CO	Inland	GW recharge via spreading	2009	9	SAT (via RBF) + RO + UVAOP
Loudoun County, VA	Inland	Surface water augmentation	2009	11	MBR + GAC + UV
Big Spring ,TX	Inland	Direct potable	2013	1.8	MF + RO + UVAOP

Source: Adapted from Schimmoller et al. (2014), Drewes and Kahn (2010); Asano et al. (2007)

Notes: ARR = Aquifer Recharge and Recovery; BAC = Biological Activated Carbon filtration; Cl_2 = Chlorine Disinfection; Coag = Coagulation; DAF = Dissolved Air Flotation; GAC = Granular Activated Carbon; GMF = granular media filtration; GW = groundwater; H_2O_2 = Hydrogen Peroxide; MF = Microfiltration; O_3 = Ozone; RBF = riverbank filtration; RO = Reverse Osmosis; SAT = Soil Aquifer Treatment; UF = Ultrafiltration; UV = Ultraviolet; UVAOP = UV Advanced Oxidation

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- Soil Aquifer Treatment (SAT) successfully implemented for potable reuse
- Advanced treatment not always required due to good removal of organics and pathogens

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- GAC-based treatment also very successful
- Provided good adsorption of organics and often sustained removal through biological filtration

Source: Adapted from Schimmoller et al. (2014), Drewes and Kahn (2010); Asano et al. (2007)

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- Reverse Osmosis (RO) is a common treatment approach for potable reuse
- Concentrate disposal more easily achieved at coastal locations

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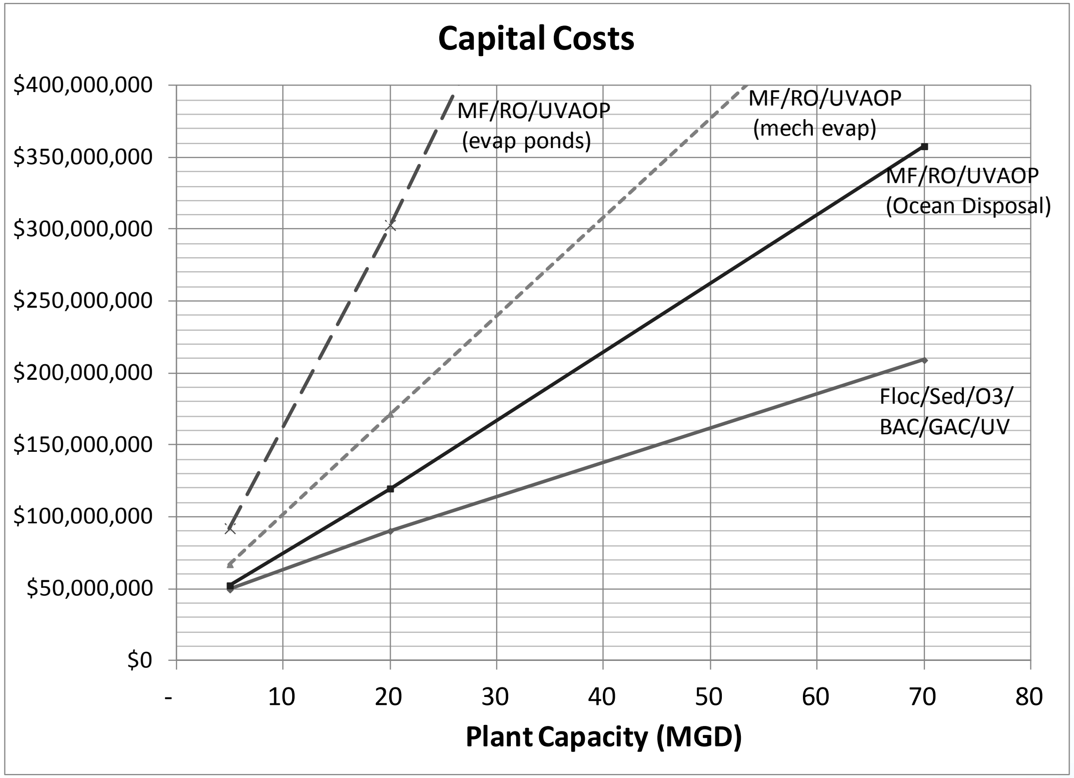
Potable Reuse Costs: RO-based vs. GAC-based



Source: Figure taken from WRRF 10-01. Figures are WateReuse Research Foundation's Intellectual Property

- GAC-based treatment less expensive
- High treatment cost for RO-based treatment due to costs for concentrate disposal, especially at inland locations
- Pretreatment to RO typically MF and also expensive
- SAT costs (not shown), are site specific but assumed to be reasonable with right geologic conditions

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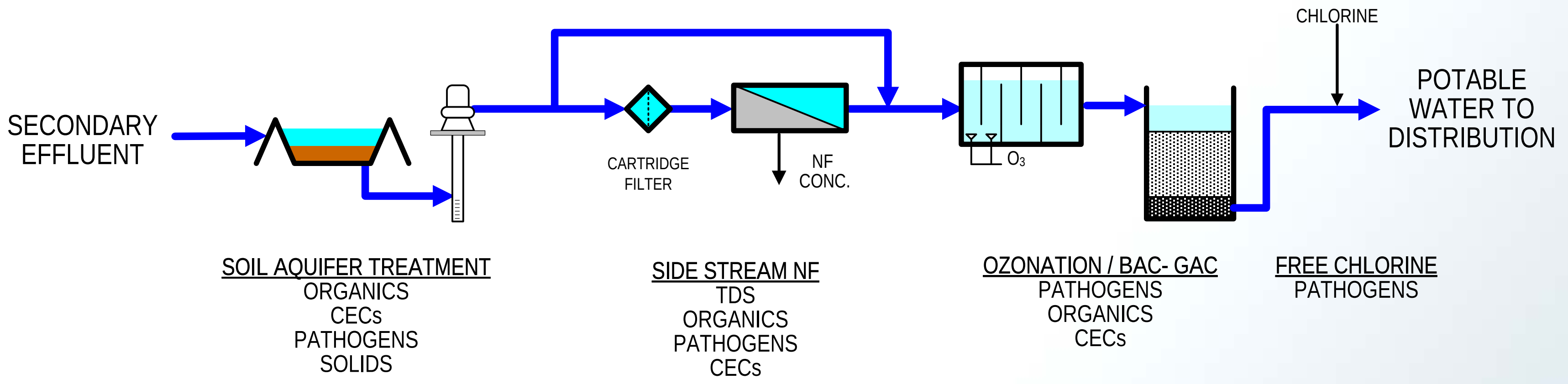
New Treatment Approach for Potable Reuse

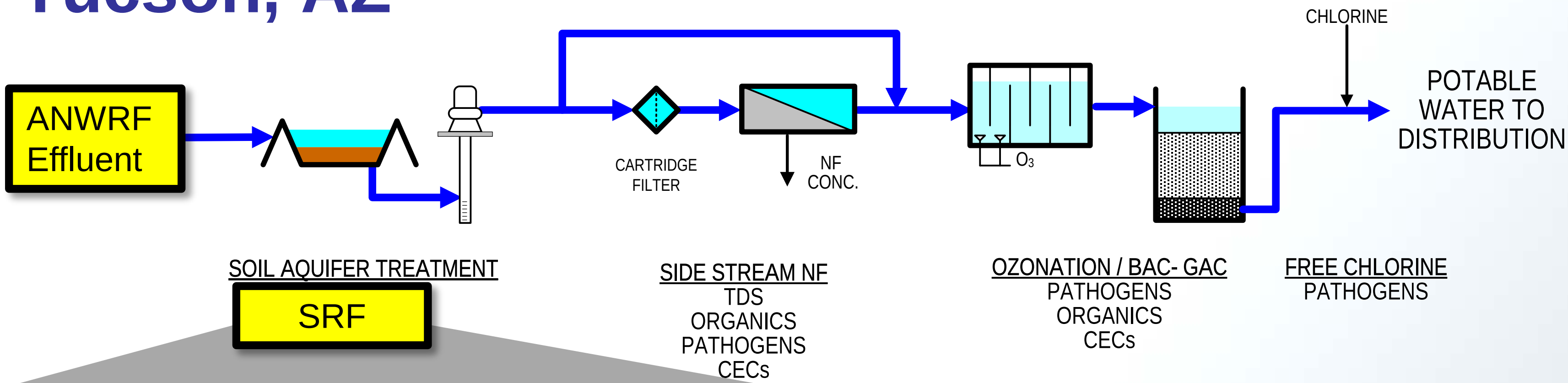
- SAT, GAC and RO-based treatment all successful around to world for potable reuse
- RO-based treatment or blending typically implemented when TDS reduction is *also* required
- Cost control of RO-based treatment achievable through:
  - Alternative pretreatment to MF
  - Blending, slip-stream RO, or use of nanofiltration (NF)
- Hybrid treatment approach combining SAT, NF and GAC was identified and tested as part of WRRF 13-09

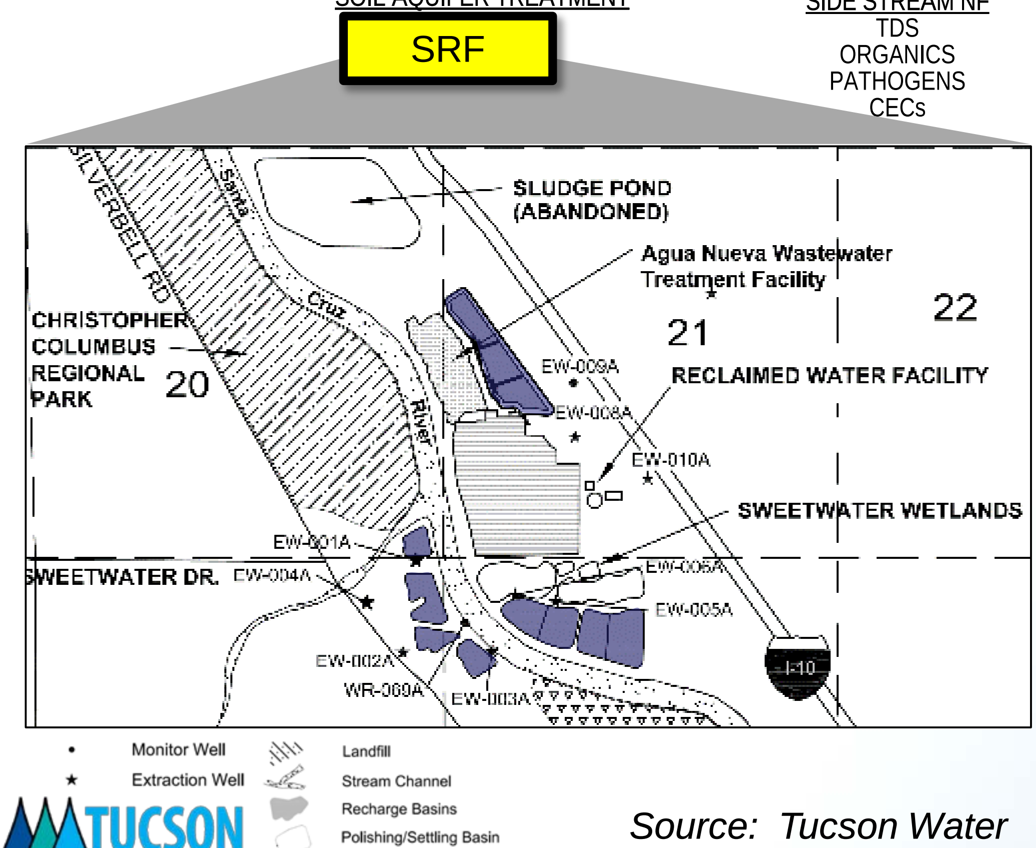
New Treatment Approach for Potable Reuse



- ✓ Provides multiple barriers for organics and pathogens
- ✓ Reduces salt concentrations
- ✓ Reduces energy consumption
- ✓ Mitigates concentrate disposal

Applying Proposed Treatment Approach in Tucson, AZ





Source: Tucson Water

- Tucson Water has long history of reclaiming Pima County wastewater effluent dating back to 1980s
- Includes Sweetwater Recharge Facilities (SRF) which currently recharge Agua Nueva WRF Effluent

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Tucson Water Sweetwater Recharge Facilities

- SRF permitted to recharge and recover 13,000 ac-ft of reclaimed water to meet non-potable demands
- 11 recharge basins (38 acres)
- 8 south basins installed first and well documented:
  - Percolation provides effective filtration and pathogen removal (SAT)
  - Alternating wet & dry cycles at SRF facilitate aerobic & anaerobic SAT (Fox, et al., 2001)

Pilot Location Selection

- Monitoring Well WR-069B selected to be used to supply pilot
  - Close proximity to recharge basins
  - 14-day travel time (Fox, et al., 2001)
- Well Design
  - Constructed in 1991
  - Casing extends 200 feet below land surface
  - 1.5 ft/day average infiltration at adjacent recharge basins

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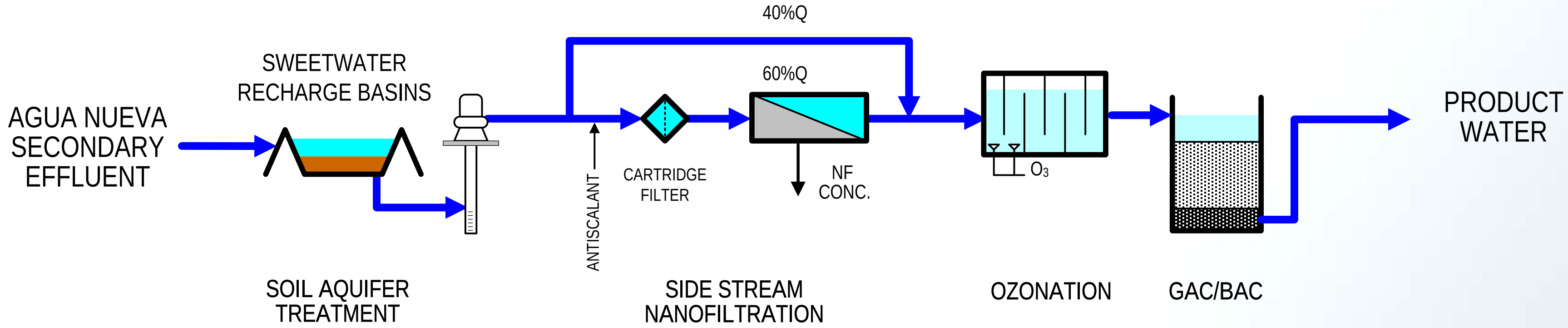
PILOT GOALS & FACILITIES

Pilot Testing Goals



- **Primary Goal:**
  Test the viability of the proposed treatment scheme for Tucson Water's future Potable Reuse Project through water quality testing and treatment process performance monitoring
- **Secondary Goals:**
  1. Test the viability of short-term SAT as a pretreatment approach to NF
  2. Test ozone for oxidation of CECs
  3. Determine GAC regeneration requirements

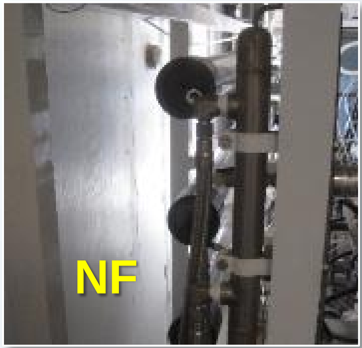
Pilot Facilities – Overview

Equipment

- 3 equipment skids provided by UA for NF, Ozone and GAC

Operations

- Period: Oct 2014 – April 2015
- SAT/NF operating conditions kept same during entire pilot
- Ozone/GAC operations modified after 3 months
- **Phase 1** (3 months):
  - Allow GAC to become BAC
- **Phase 2** (3 months):
  - Adjust Ozone dose as needed
  - Compare virgin GAC performance to BAC established during Phase 1



Pilot Facilities – NF Hybrid Design

Parameter	Unit	Value
Number of Stages	#	2
Pressure Vessel Array		2:1
Number of Pressure Vessels	#	6
Elements per Vessel	#	3
Total Elements	#	18
Stage 1 Element		Dow NF 270-2540
Stage 2 Element		Dow NF 90-2540
Design Recovery	%	82.4%
Average Design Flux	gfd	13.4
Bypass Flow Percentage	%	40%
Total Feed Flow	gpm	8.8
Bypass Flow	gpm	3.1
NF Feed Flow	gpm	5.7
NF Permeate Flow	gpm	4.7
NF Concentrate Flow	gpm	1.0
Feed TDS	mg/L	750
Permeate TDS	mg/L	312
Combined Product TDS	mg/L	487
Antiscalant Product		Avista Vitec 4000
Antiscalant Dose	mg/L	2 – 5

2-Stage Hybrid NF System

82.5% Recovery @ 13.4 gfd

40% Feed Bypass

Product Water to meet
500 mg/L TDS
(Secondary MCL)

Pilot Facilities – Ozone & GAC

- **Ozone**
  - Containerized Xylem (Wedeco) UV / AOP trailer provided by University of Arizona
  - UV and Peroxide components were not used
  - Skid includes onsite O_3 generator
  - Target O_3 Dose = 0.5 – 1.0 mg/L
  - Key to balance oxidation of CECs while mitigating bromate formation
- **GAC Skid**
  - 4 x 4-inch column GAC pilot skid provided by U of A
  - Calgon F400M and Norit GAC 400 used
  - Both GACs tested in Phase 1 (2 columns total)
  - 2 additional columns loaded with virgin GAC in Phase 2
  - Design loading rate = 3 gpm / ft^2 (~10 min EBCT)

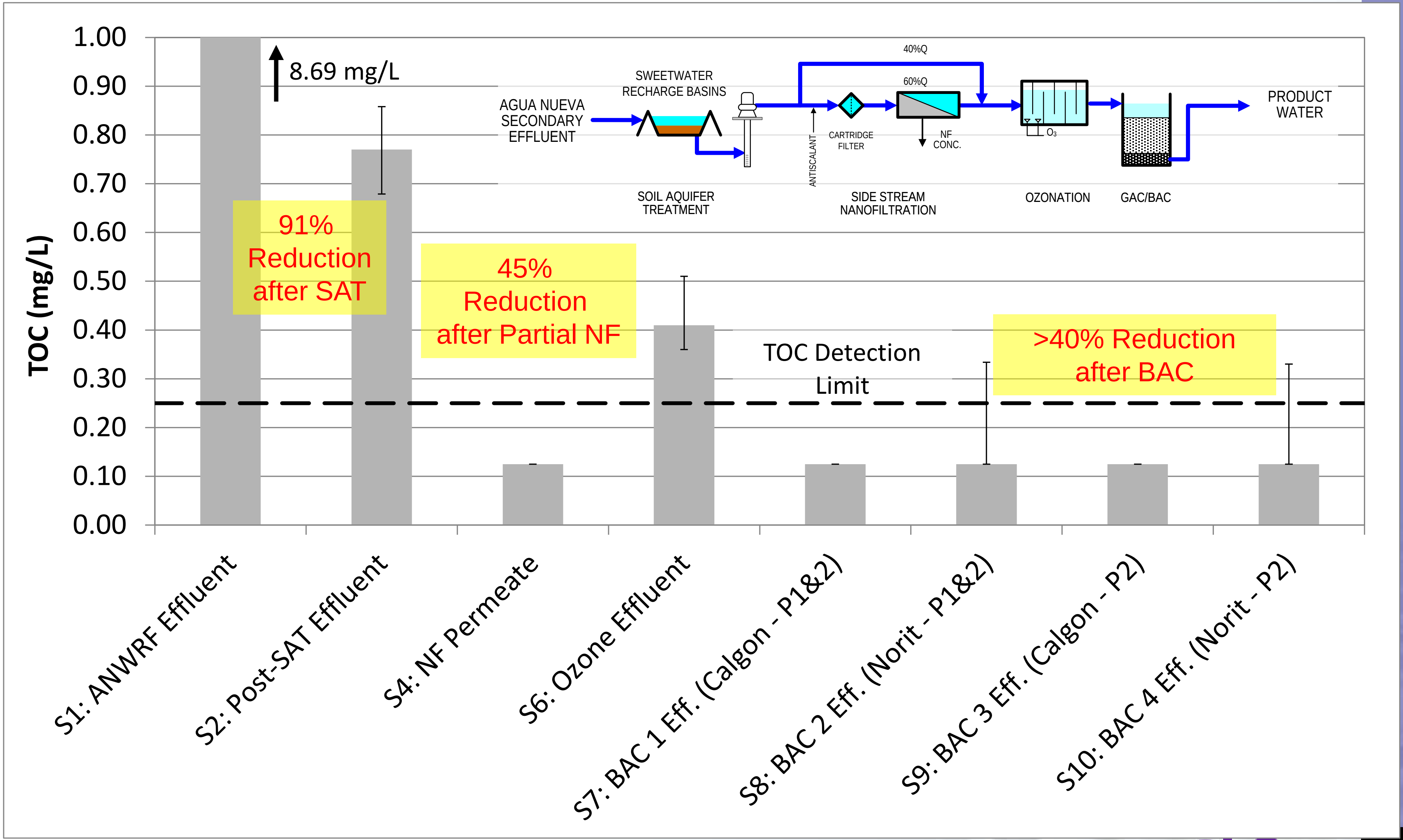
WATER QUALITY RESULTS

Water Quality Testing

Parameter	Lab	Sample Location and Frequency									
		Agua Nueva Effluent (Sweetwater Recharge Basin Feed)	Post-SAT Effluent (Shallow Monitoring Well)	NF Feed (after Cartridge Filtration)	NF Permeate	NF Concentrate	Ozone Effluent	BAC1 Calgon Effluent (Phase I and II)	BAC2 Norit Effluent (Phase I and II)	BAC3 Calgon Effluent (Phase II only)	BAC4 Norit Effluent (Phase II only)
Sample Designation		**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**	**S10**
Tucson Water Designation		**510**	**Well WR-069B**	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
pH	Field			Daily		Daily					
Temperature	Field			Daily							
Conductivity	Field			Daily	Daily	Daily					
SDI	Field		3x/week	3x/week							
Ozone Residual	Field						Weekly				
Turbidity	Field		Weekly								
TSS	TW		Weekly			Biweekly					
Alkalinity	TW	Monthly**	Weekly		Weekly	Biweekly					
TDS	TW	Monthly**	Weekly		Weekly	Biweekly					
TOC	TW	Biweekly**	Weekly		Weekly		Weekly	Weekly	Weekly	Weekly	Weekly
Total Nitrogen	TW	Monthly**	Biweekly		Biweekly	Biweekly					
Total Phosphorus	TW	Monthly**	Biweekly		Biweekly	Biweekly					
Bromide	TW		Biweekly		Biweekly	Biweekly					
Calcium	TW		Biweekly		Biweekly	Biweekly					
Magnesium	TW		Biweekly		Biweekly	Biweekly					
Sodium	TW		Biweekly		Biweekly	Biweekly					
Sulfate	TW		Biweekly		Biweekly	Biweekly					
Chloride	TW		Biweekly		Biweekly	Biweekly					
Boron	TW		Biweekly		Biweekly	Biweekly					
Silica	TW		Biweekly		Biweekly	Biweekly					
Barium	TW		Biweekly								
Strontium	TW		Biweekly								
UVT-254	UA		Weekly		Weekly		Weekly	Weekly	Weekly	Weekly	Weekly
Bromate	UA		Monthly		Monthly		Biweekly	Biweekly	Biweekly	Biweekly	Biweekly
CECs	UA	Monthly	Biweekly		Biweekly		Biweekly	Biweekly	Biweekly	Biweekly	Biweekly
EEM	UA	Monthly	Biweekly		Biweekly		Biweekly	Biweekly	Biweekly	Biweekly	Biweekly
NDMA	UA	Monthly	Biweekly					Biweekly	Biweekly	Biweekly	Biweekly
Heterotrophic Plate Counts (5-day)	TW		Biweekly			Biweekly		Biweekly	Biweekly	Biweekly	Biweekly
Total Coliform	TW		Monthly		Monthly			Monthly	Monthly		
E. Coli	TW		Monthly		Monthly			Monthly	Monthly		
Enteric Virus	UA	Monthly***	Monthly***				Monthly***				
Crypto / Giardia	UA	Monthly***	Monthly***				Monthly***				

- Field Parameters
- Metals, Salts, Nutrients
- Trace Organics (CECs)
- Nitrosamines & Bromate
- Pathogens/Microorganisms

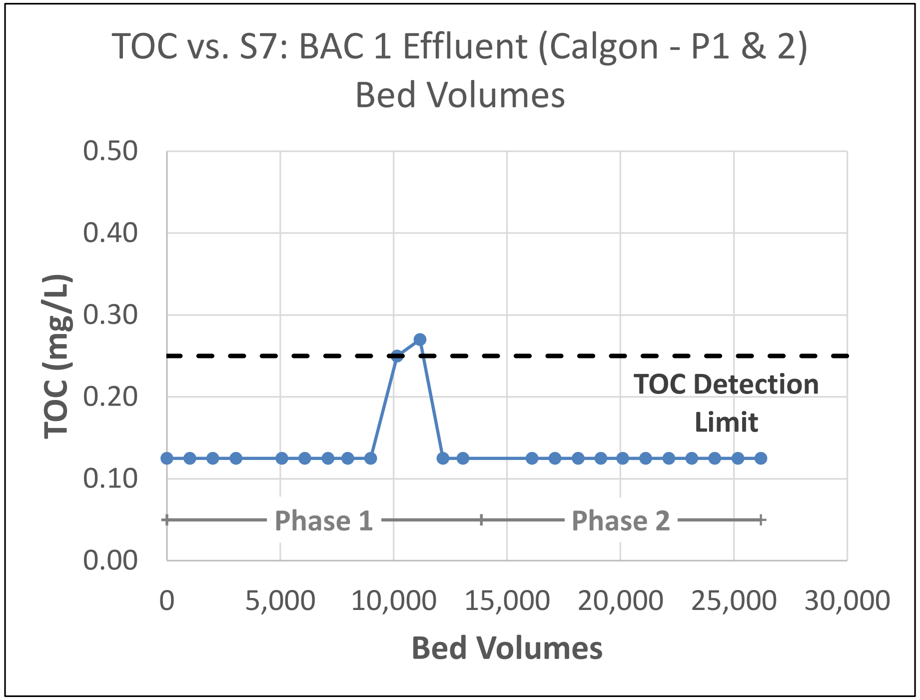
Total Organic Carbon (50th percentile)

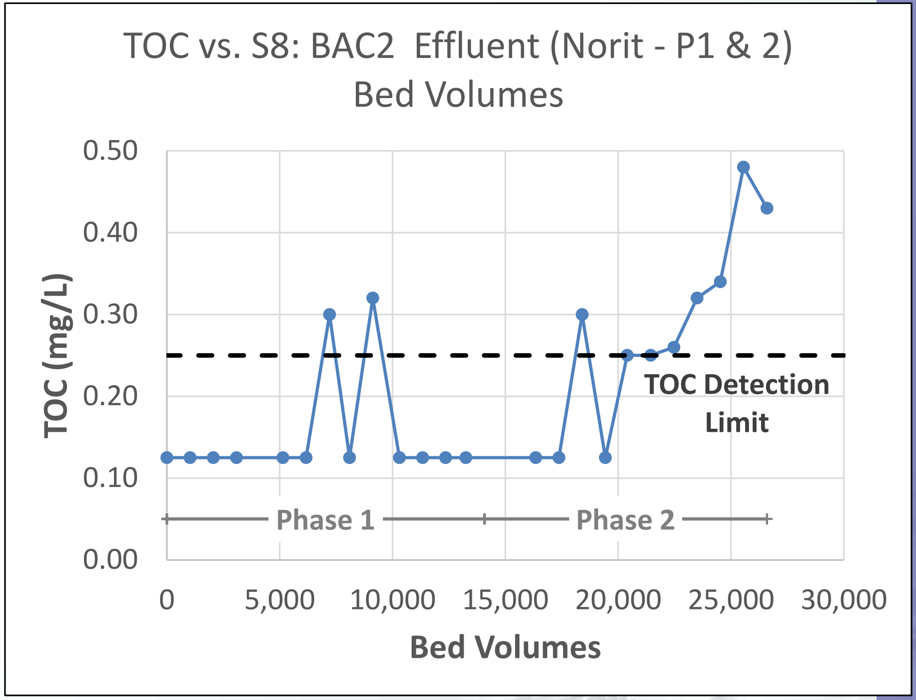


Total Organic Carbon versus Filtration Bed Volumes

No breakthrough for Calgon BAC after 6 months

Breakthrough observed for Norit BAC





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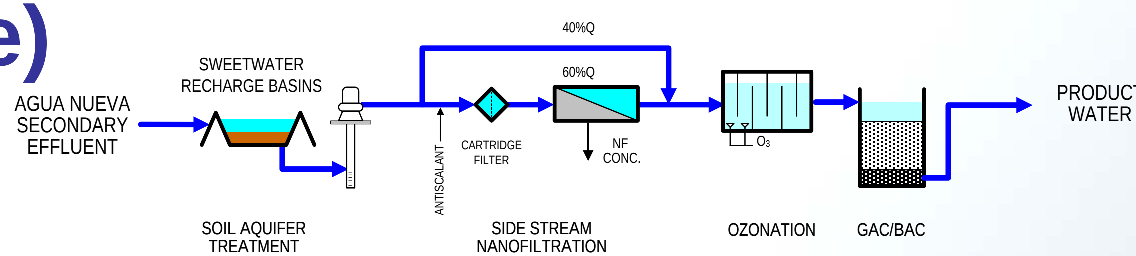
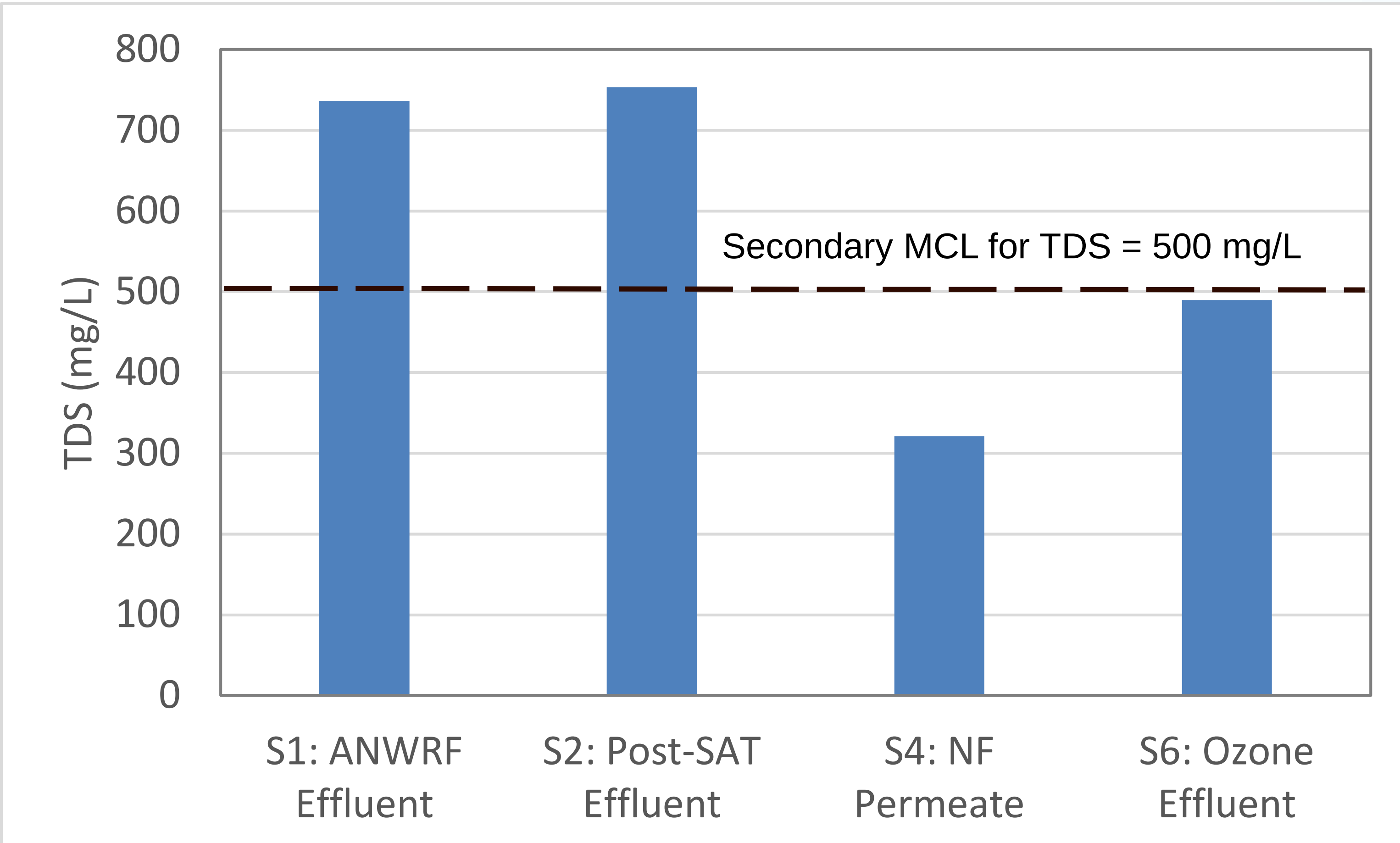
Total Dissolved Solids (50th percentile)



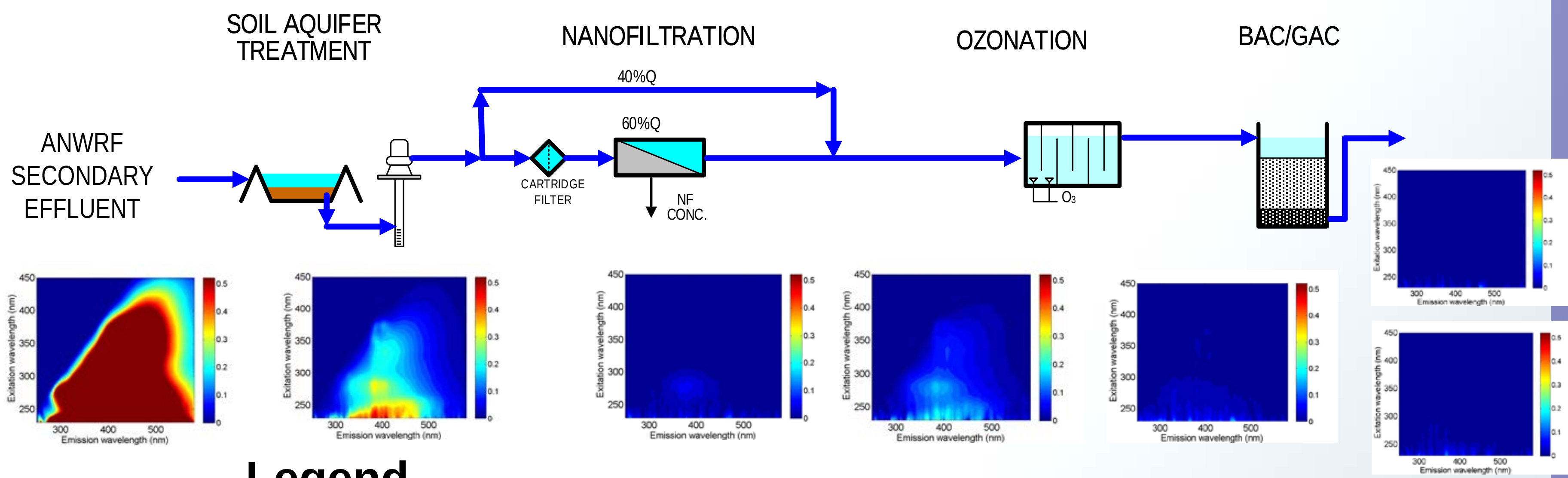


Chemicals of Emerging Concern

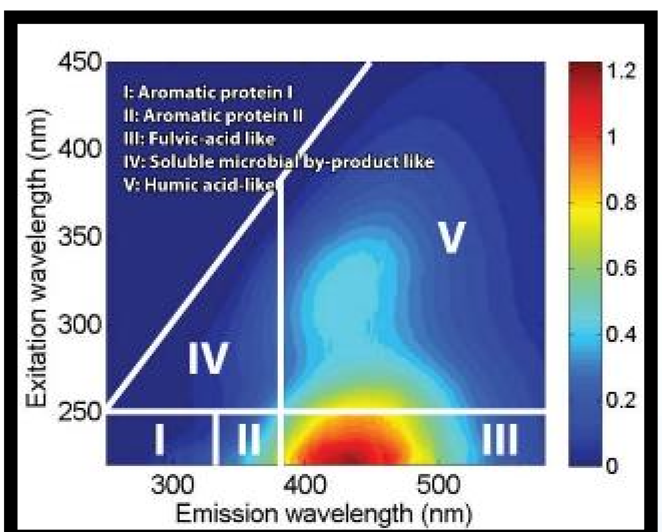
- 44 CECs monitored – **All below the detection limit in finished water**
- Some CECs are recalcitrant to certain treatment, so multiple barriers is important

2015/04/30	Concentration of Trace Organics in ng/L								
Compounds	**Category**	**Agua Nueva Effluent**	**Well 69B**	**Ozone Influent**	**Ozone Effluent**	**BAC C1 (Calgon) Effluent**	**BAC C2 (Calgon) Effluent**	**BAC C3 (Norit) Effluent**	**BAC C4 (Norit) Effluent**
Benzophenone	Industry (paint,	129	< 30	< 16	< 30	< 28	< 29	< 30	< 29
Benzotriazole	De-icing, inhibitor,	4236	4755	4051	2416	< 480	< 480	< 470	< 500
Caffeine	stimulant	< 4.0	< 5.2	< 4.4	< 5.6	< 3.9	< 4.1	< 3.7	< 3.8
Carbamezapine	Anit-epileptic	363	487	126	< 1.6	< 1.6	< 1.5	< 1.5	< 1.5
DEET	Insect repellant	172	7.0	14	< 6.0	< 4.1	< 4.0	< 3.8	< 3.6
Gemfibrozil	cholesterol drug	5.4	< 1.0	< 1.0	< 1.1	< 0.9	< 0.9	< 0.9	< 0.9
Ibuprofen	anti-inflamatory,	< 2.8	< 3.7	< 3.5	< 4.9	< 3.6	< 3.5	< 3.0	< 3.5
Iopamidol	Angiography	29677	3188	913	1395	< 27	< 28	< 26	< 31
Iopromide	x-ray contrast	5465	< 24	< 34	< 24	< 27	< 28	< 26	< 31
Meprobamate	tranquilizer	455	58	28	29	< 10	< 10	< 10	< 10
PFOA	cookware, textiles, clothing,	2.2	32.3	16.3	15.8	< 0.8	< 0.8	< 0.7	< 0.7
PFOS	Stain repellant	< 6.3	256	124	123	< 3.5	< 3.5	< 3.8	< 3.9
Primidone	Anit-epileptic	14	165	90	87	< 4.3	< 5.7	< 4.8	< 4.8
Sucralose	Artifical sweetner	51567	26702	7595	13459	< 220	< 240	< 240	< 250
Sulfamethoxazole	antibiotic	1903	36	15	< 8.0	< 5.0	< 4.9	< 4.5	< 4.9
TCEP	Flame retardant	128	181	31	125	< 22	< 22	< 23	< 23
TCPP	Flame retardant	715	< 24	129	83	< 22	< 22	< 23	< 23
Triclosan	soap	44	< 12	< 9	< 13	< 13	< 14	< 13	< 14

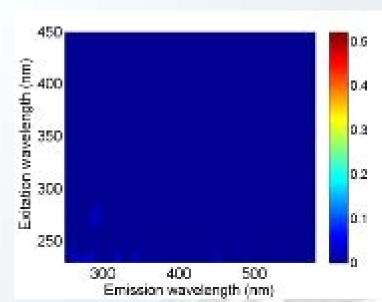
Trace Organics Removal
Excitation Emission Matrix Results



Legend

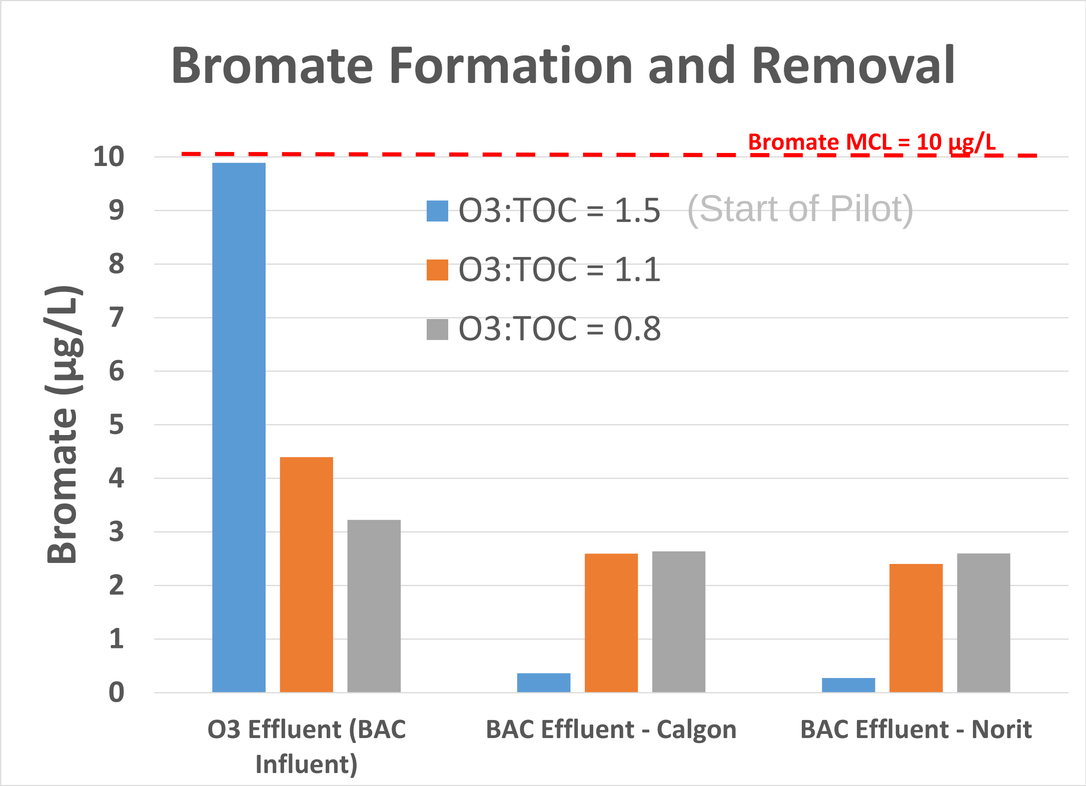


Blank: Milli-Q Water



Bromate

- Bromate is a disinfection byproduct from ozone addition
- Bromide concentration in secondary effluent was relatively high (~0.3 mg/L)
- Bromate formation:
  – Significant at O3 doses > 0.5 mg/L (O3:TOC ratio > 1.0)
  – Low at O3 doses < 0.5 mg/L (O3:TOC <1.0)
- Bromate removal by BAC/GAC was significant



TUCSON WATER

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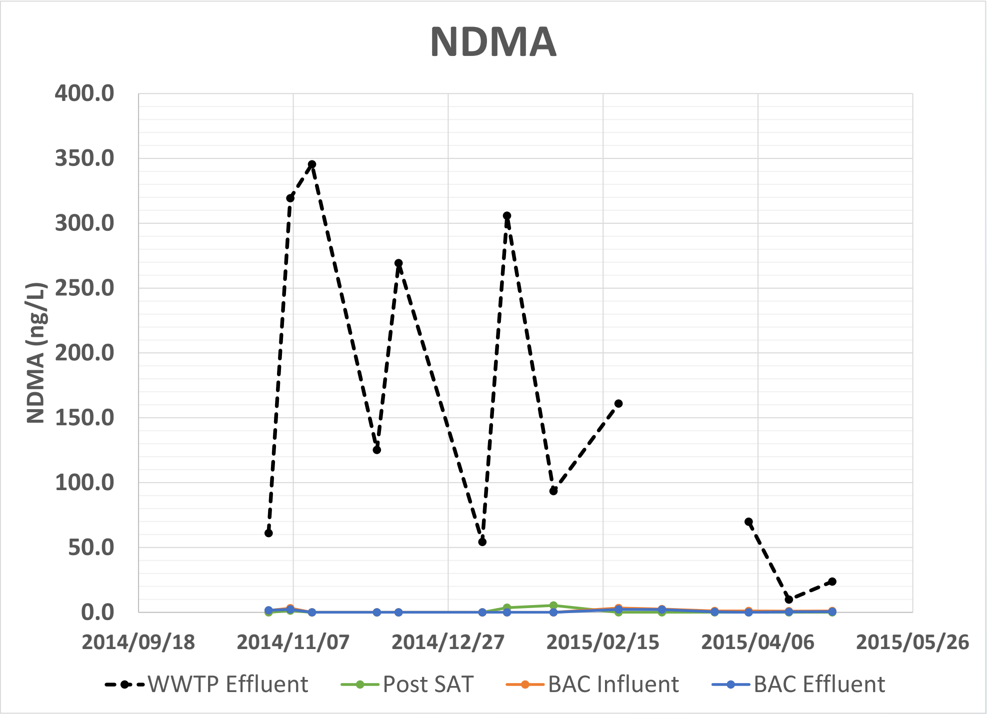
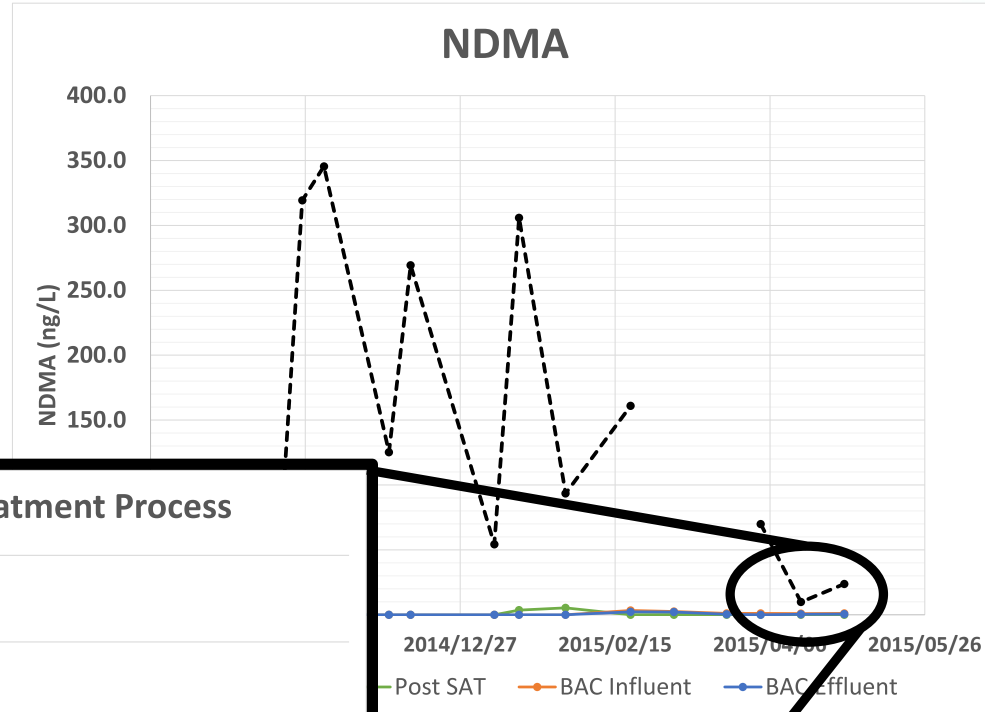
NDMA

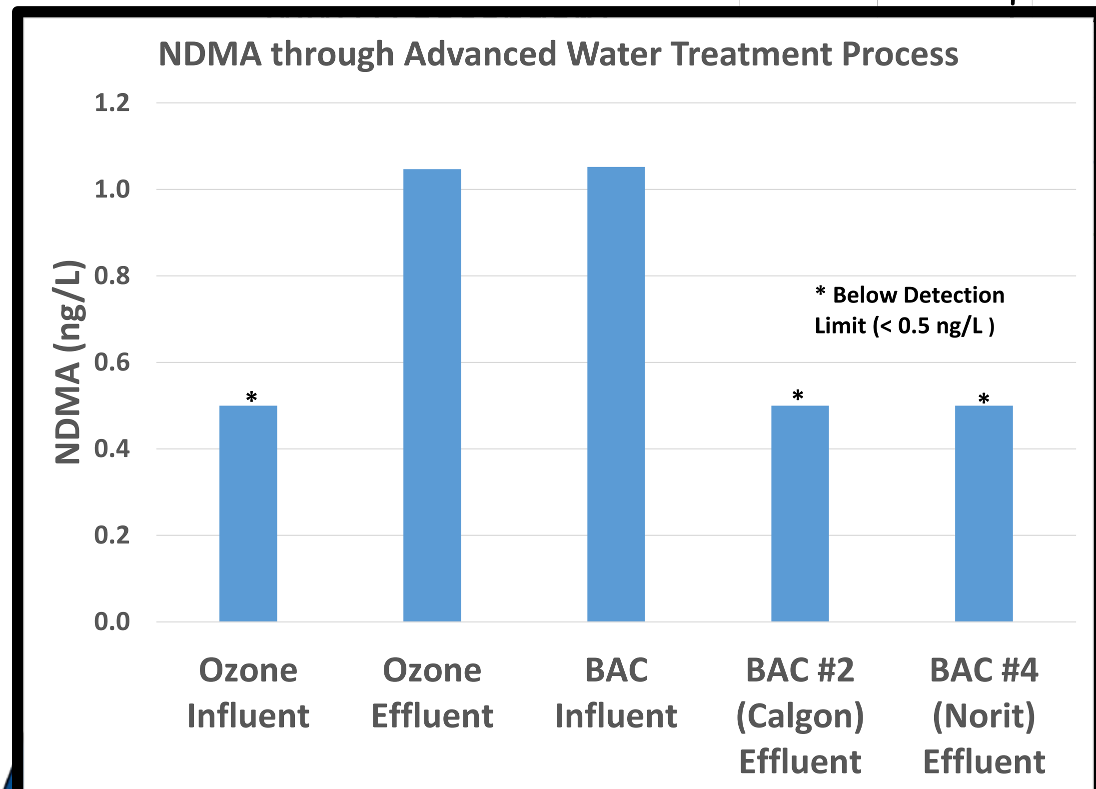
- NDMA is disinfection byproducts from ozone addition
- NDMA Formation:
  - Very high in the WWTP secondary effluent
  - Excellent removal by SAT (< 10 ng/L)



NDMA

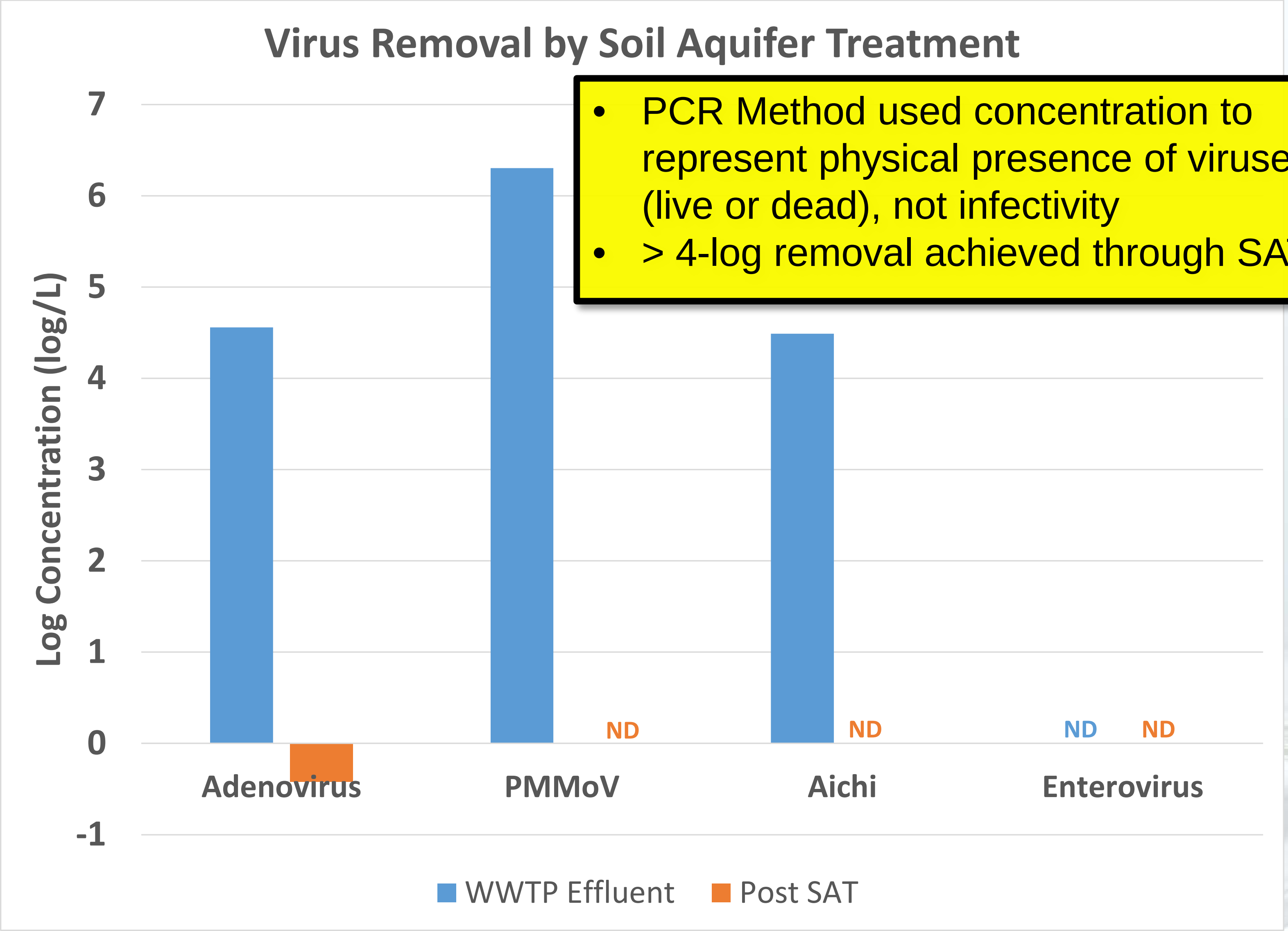
- NDMA is disinfection byproducts from ozone addition
- NDMA Formation:
  - Very high in the





Small production by ozone, but subsequent removal by BAC

Pathogen Removal By SAT



- PCR Method used concentration to represent physical presence of viruses (live or dead), not infectivity
- > 4-log removal achieved through SAT

Conclusions

Issue	Answer
Do multiple organics barriers provide suitable water quality?	Yes; finished water quality: 1) TOC< 0.25 mg/L 2) All 44 CECs non-detect
Can TDS goal be met with sidestream NF treatment?	Yes, TDS < 500 mg/L consistently met
Can bromate and NMDA formation be controlled?	Yes, both were well below regulated limits: Bromate < 3 µg/L (MCL = 10 µg/L) NDMA < 0.5 ng/L (CA limit 10 ng/L)
Are pathogens adequately removed?	Yes, post-SAT water was non-detect for viruses and protozoa; >4-log removal of viruses by just SAT
Is GAC-based train suitable for potable reuse at Tucson?	Yes and costs are much lower than RO-based train

The Final Report for WRRF 13-09 is currently under review and will be published in 2016

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Acknowledgements

Team Member	Role
Justin Mattingly, WRRF	WRRF Project Manager
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Terry Miley, TW	Hydrogeologist
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Ryan Rhoades, Hazen & Sawyer (formerly CH2M)	Project Delivery
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Dr. Ian Pepper, UA	Pathogen and ATP Testing
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Josh Campbell, UA	NF Pilot Operations
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Minkyu Park, UA	Ozone and BAC/GAC operations; Water Quality Analysis

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Questions?

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