Water Treatment Technology Overview

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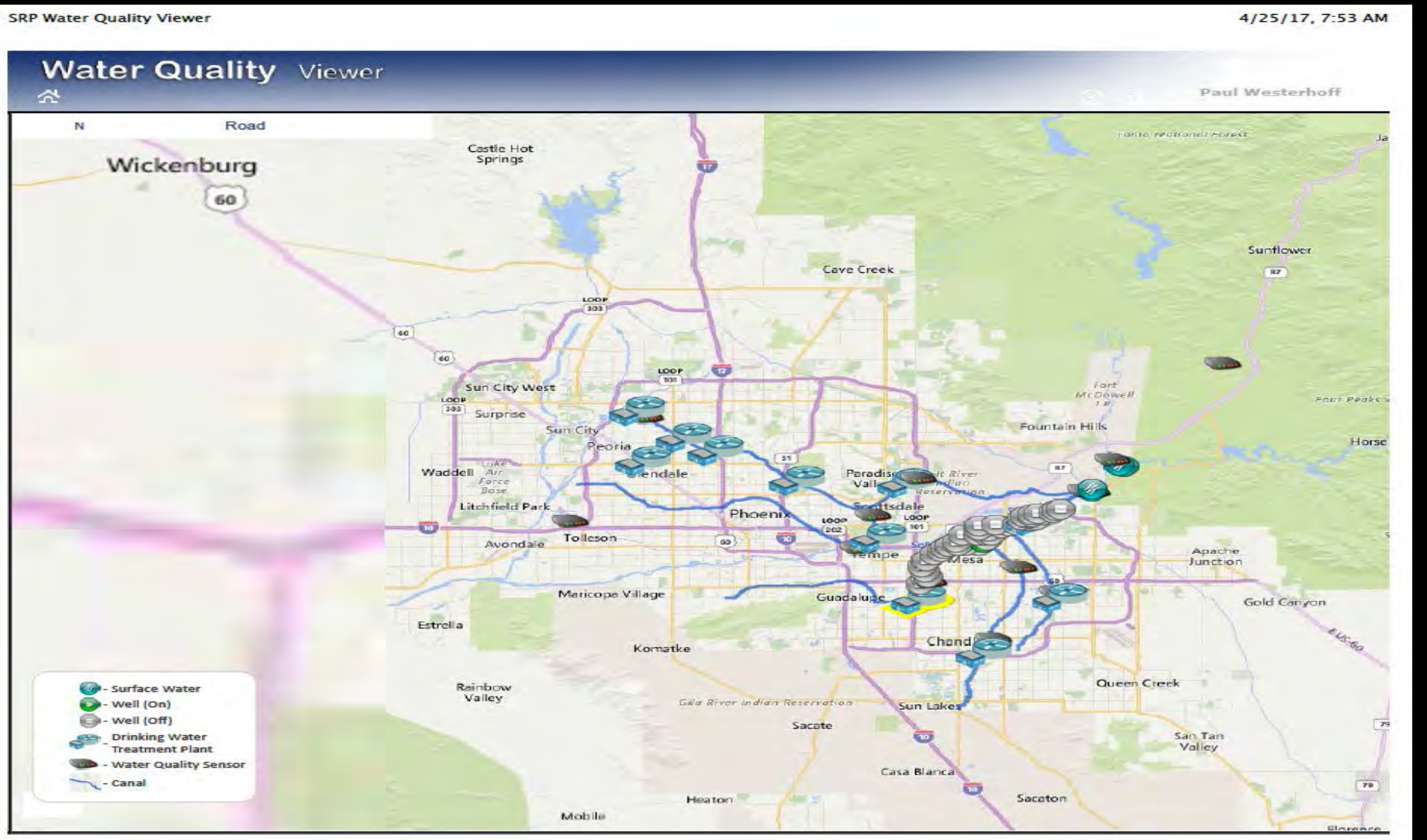
Potential Water Quality Parameters that could influence CAP Canal

- General water quality
  - Salinity
  - Consider also: pH, temperature, turbidity, hardness, total organic carbon (TOC), color
- Regulated drinking water metals
  - Arsenic (almost always occrurs as As(V) rather than As(III) in Arizona)
  - Mercury
  - Chromium (Cr(VI) vs Cr(III); regulation is total)
- Regulated inorganic anions in drinking water
  - Nitrate (but also consider nitrite, ammonia, organic nitrogen)
  - Fluoride
- Volatile Organics
  - Long regulated list
  - Disinfection by-products (THM, HAA, NDMA)
- Boron impacts agriculture but not human health
- Emerging Contaminants (endocrine disrupters etc.)
- Other relevant chemicals
  - Bromide ion, iodide ion
  - Ammonia
  - CCL3 or UCMR4 lists –(e.g., PFCs)
  - Pathogens (virus, Cryptosporidium, Giargia)

Water Quality Parameter	Coag-Floc-Sed-Filt (Conv WTP)	Activated Carbon	Biological treatment	Other Sorbent media	Ion Exchange	UF/MF	RO/NF
Bulk organics (TOC)	✓✓	✓✓✓	✓	✗	✗	✗	✓✓✓
Trace organics	✗	✓✓✓	✓✓	✗	✗ (except PFC)	✗	NF: ✓✓ RO: ✓✓✓
Tastes & odors	✗	✓✓✓	✗	✗	✗	✗	NF: ✗ RO: ✓✓
Turbidity & pathogens	✓✓✓	✗	✓✓	✗	✗	✓✓✓	✗
Salinity / TDS	✗	✗	✗	✗	✗	✗	NF: ✓✓ RO: ✓✓✓
Arsenic	✓✓✓	✗	✗	✓✓✓ (E33)	✓✓✓	✗	✓✓✓
Cr(VI)	✓✓	✗	✓✓	✗	✓✓✓	✗	✓✓✓
Nitrate	✗	✗	✓✓✓	✗	✓✓✓	✗	NF: ✓✓ RO: ✓✓✓
Fluoride	✗	✗	✗	✓✓ (AA)	✗	✗	NF: ✓ RO: ✓✓✓
Hardness (Ca/Mg)	✗ (Softening ✓)	✗	✗	✗	✓✓	✗	✓✓✓
Boron	✗	?	✗	✓	✓✓	✗	Low unless increase pH

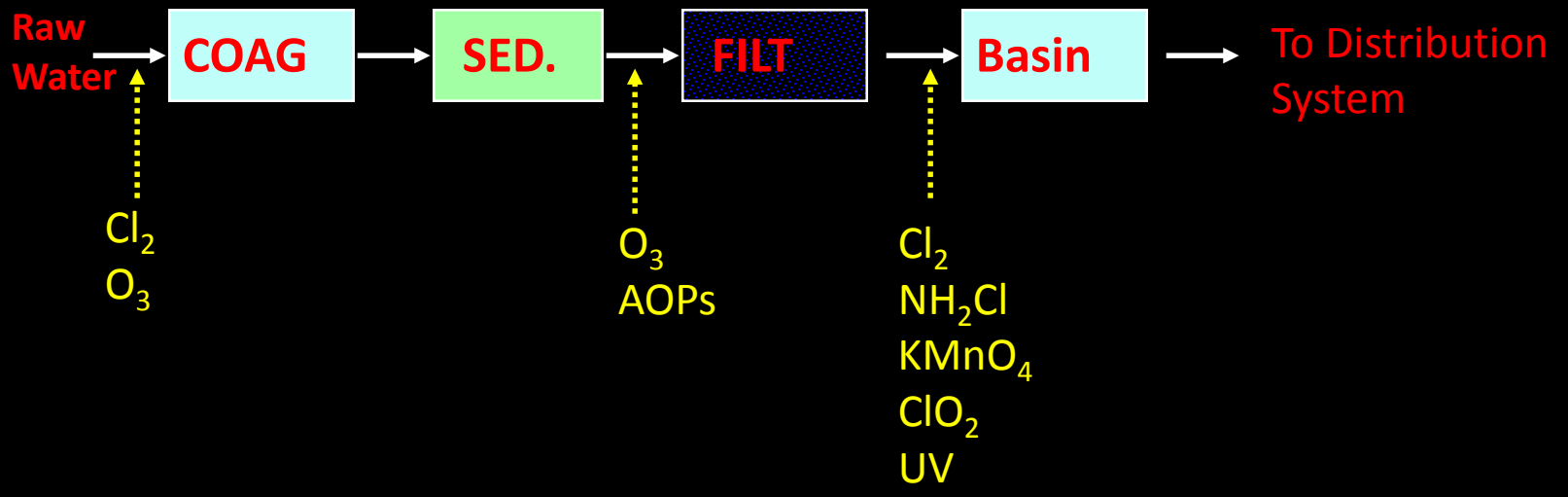
SRP Water Quality Stations (Turbidity spikes & Nitrate)



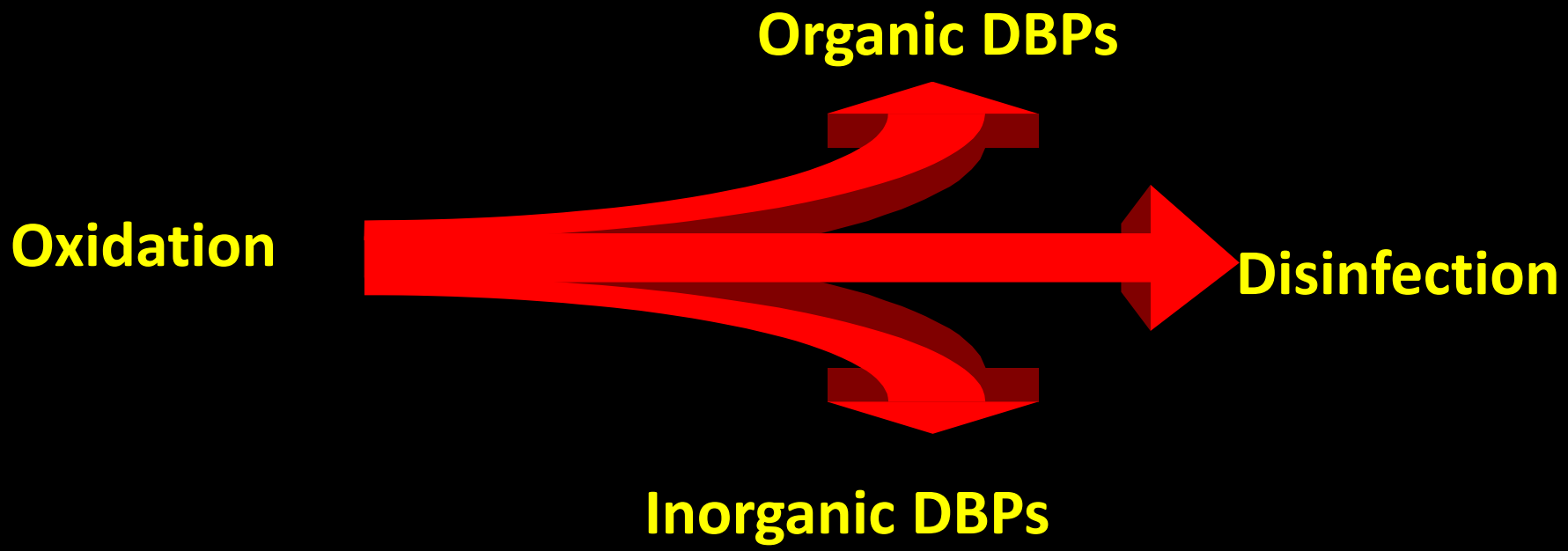
Overview of Water Treatment Plant Unit Processes Operating in metro-Phoenix

- **Rarely are any 2 treatment plants the same**
- Conventional treatment (dominant)
  - Alum or ferric chloride coagulants
- Direct filtration (2) – no sedimentation
- Ozone (3-4) – limited by BrO_3^- DBP formation
- Powder activated carbon (possible at most)
- Granular activated carbon (~50%)
- Membranes (2-3)
- All use free chlorine as a residual disinfectant
- Most struggle with compliance due to NOM, high turbidity, and THMs (some for nitrate)
- All have TDS above SMCL of 500 mg/L & all have “very hard” water (leads to many POU systems)

Conventional Water Treatment Plant



Disinfection / Oxidation Leads to Disinfection By-Product Formation



DBPs Formation

Formation of Mixed Halogen Specie:

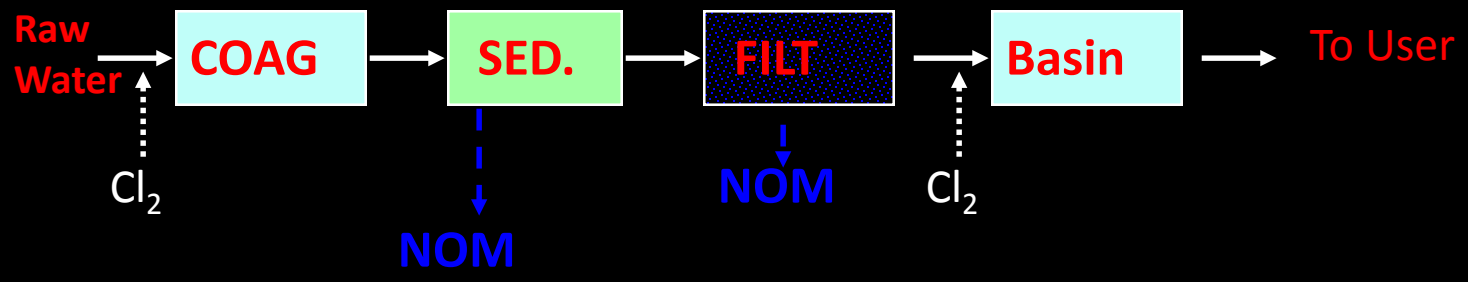
NOM + $HOCl/OCl^-$ => Chlorinated DBPs
Br^- + $HOCl/OCl^-$ => $HOBr/OBr^-$
NOM + $HOBr/OBr^-$ => Brominated DBPs

Important DBP Precursors: NOM & Br^-

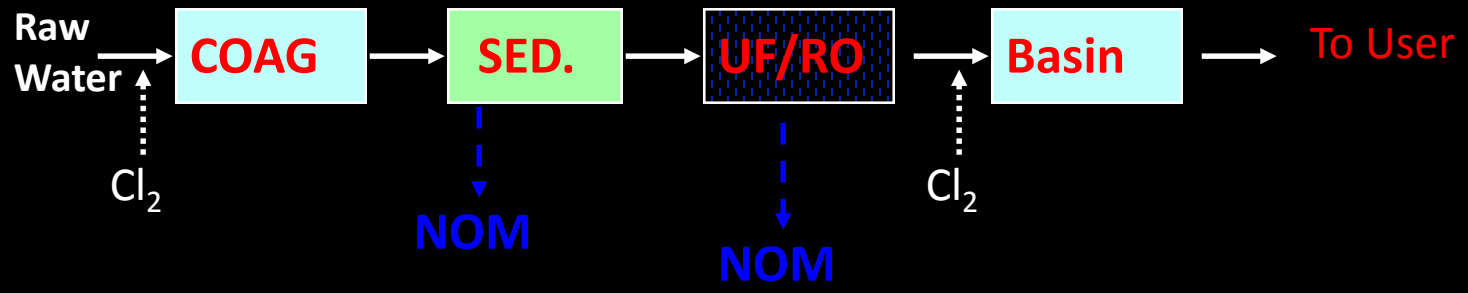
NOM Measured as DOC: 1-10 mg/L
Bromide (1/300th chloride): 10-2,000 ug/L
Br/DOC ratio is important for DBP formation

Methods to Lower NOM Concentrations

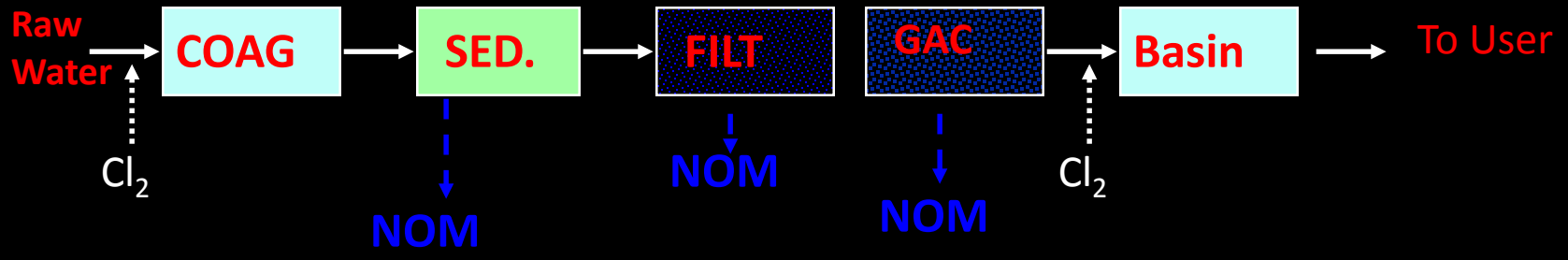
1. Conventional Treatment



2. Membrane Filtration

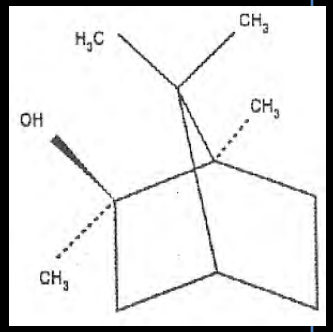
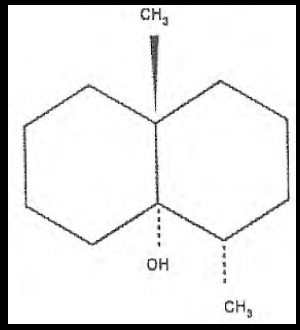


3. Activated Carbon Adsorption



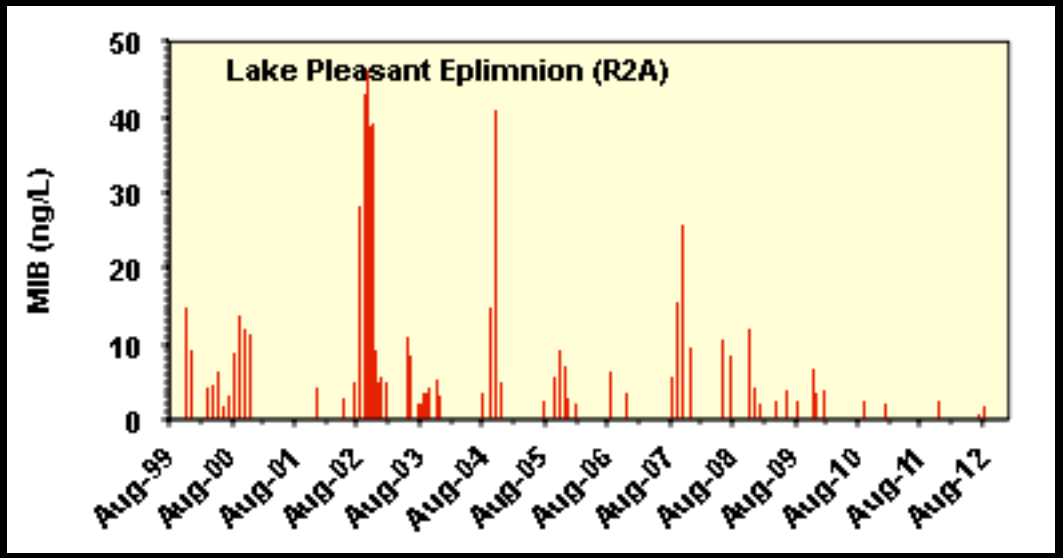
Common Algal T&O Compounds

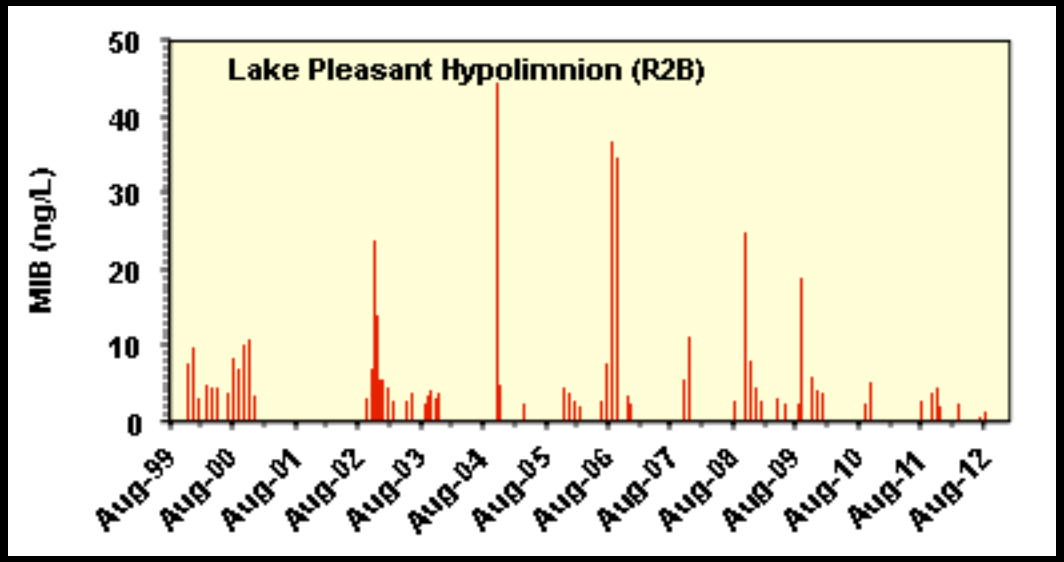
- Taste threshold ~ 10 ng/L
- Chlorine residual can "mask" odors
- T&O is a worldwide issue affecting the publics "confidence" in drinking waters, but is not regulated

Parameter	MIB (2-methyisoborneol)	Geosmin
Full Name	(1-R-exo)-1,2,7,7-tetramethyl bucyclo-[2,2,1]-heptan-2-o1	tran-1, 10-dimethyl-trans-9-decalol
Molecular Formula	$C_{11}H_{20}O$	$C_{12}H_{22}O$
Molecular Weight	168 g-mole^{-1}	182 g-mole^{-1}
Boiling Point	197 ^{o}C	165 ^{o}C
Aqueous Solubility	195 mg/L	150 mg/L
K_{ow}	3.13	3.7
Henry's Law Constant	5.76×10^{-5} atm m^3-mole^{-1}	6.66×10^{-5} atm m^3-mole^{-1}
Structure		

Source: (Pirbazari et al. 1992)

MIB Data – Lake Pleasant





WTPs with Activated Carbon

- GAC removes
  - EDC, PPCPs, PFCs, T&O and other trace organics
  - NOM that forms DBPs (TOC goal ~ 1 mg/L)
  - Requires regeneration ~ every 6 months
- PAC
  - Removes same trace organics
  - Does not remove NOM well
  - Typical dosages are 10-25 mg/L
  - Requires sedimentation / filtration & sludge processing
  - Usually applied seasonally

Ozone or UV/H2O2

- Disinfection
  - Ozone or UV light
  - ClO2 also used as an alternative disinfectant
  - Free chlorine is used after water treatment
- Oxidation of trace organics
  - Powerful oxidants that can generate HO radicals

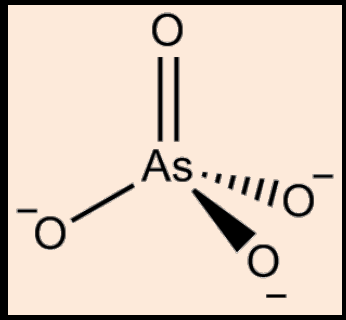
Membranes

- Micro/ultrafiltration
  - used at a few plants instead of coagulation-floc-settling – sand filters
  - Removes particulates (Turbidity, Giardia, Crypto, Bacteria, Some virus)
  - Does not remove trace organics or salts
  - Can remove arsenic and other pollutants if iron salts are added (> 1 MGD)
  - Achieves ~98% water recovery
- Nanofiltration
  - Not used in Valley currently
  - Removes divalent ions ($Ca/Mg/SO_4^{2-}$)
  - Newer NF membranes remove trace organics
  - Operates at lower pressure and higher water recovery than RO
- Reverse osmosis membranes
  - Used for wastewater reuse at some locations
  - Requires pretreatment to prevent fouling
  - Typically achieves 85% recovery (15% is concentrated brine)
  - Adoption of *energy recovery* devices significantly lowered operating costs
  - Membranes replaced ~ every 5 years
  - Removes almost everything

Nitrate (NO_3^-)

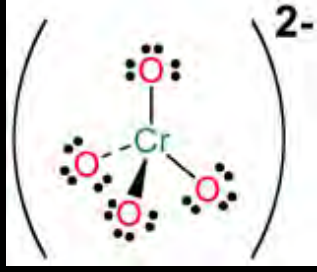
- Drinking water
  - Ion exchange is the typical removal mechanism
    - Requires 5-20% NaCl brine to clean resin frequently
    - Advances in chemical or biological brine regeneration are on the horizon
  - Blending is commonly used to manage NO_3^- in SRP canal and wells entering distribution systems
  - Nitrite is a concern
  - Ammonia is concern for water utilities
- Wastewater
  - Has high levels of ammonia, nitrate and/or nitrite
  - Requires biological denitrification

Arsenate ($H_2AsO_4^-$)

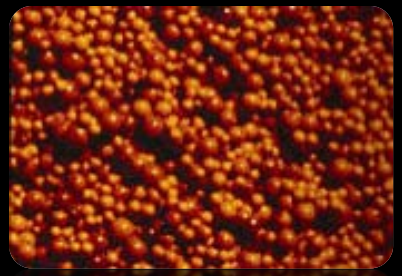


- Naturally occurring in Arizona
  - Groundwaters
  - Verde River water
- Groundwater wellhead treatment options
  - Ion exchange
  - Iron oxide packed bed media (E33, GFH, etc)
  - Ferric chloride + MF or filtration
- Surface water
  - Alum/Ferric at conventional WTPs

Hexavalent Chromium vs Cr(III)



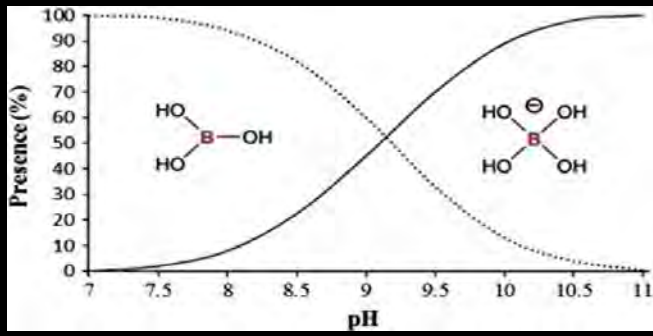
- Cr(VI) regulation pending (CA is 10 ppb) vs EPA MCL for chromium of 100 ppb
- Metal (Hydr)Oxide Based Resins
  - Bayoxide E33
  - Granular Ferric Hydroxide
  - Adsorbsia GTO
- Weak Base Anion Exchange Resins
  - ResinTech SIR700 – 2.7 eq/L
  - Purolite S106 – 2.0 eq/L
- Hybrid Media
  - Layne RT – nanoscale iron hydroxide impregnated anion excnange
- Cr(VI) removal processes
  - Selective ion exchange
  - Ferrous reduction, coagulation, filtration
- Reverse osmosis
- Reductive coagulation/separation (Fe^{2+}, Sn^{2+})



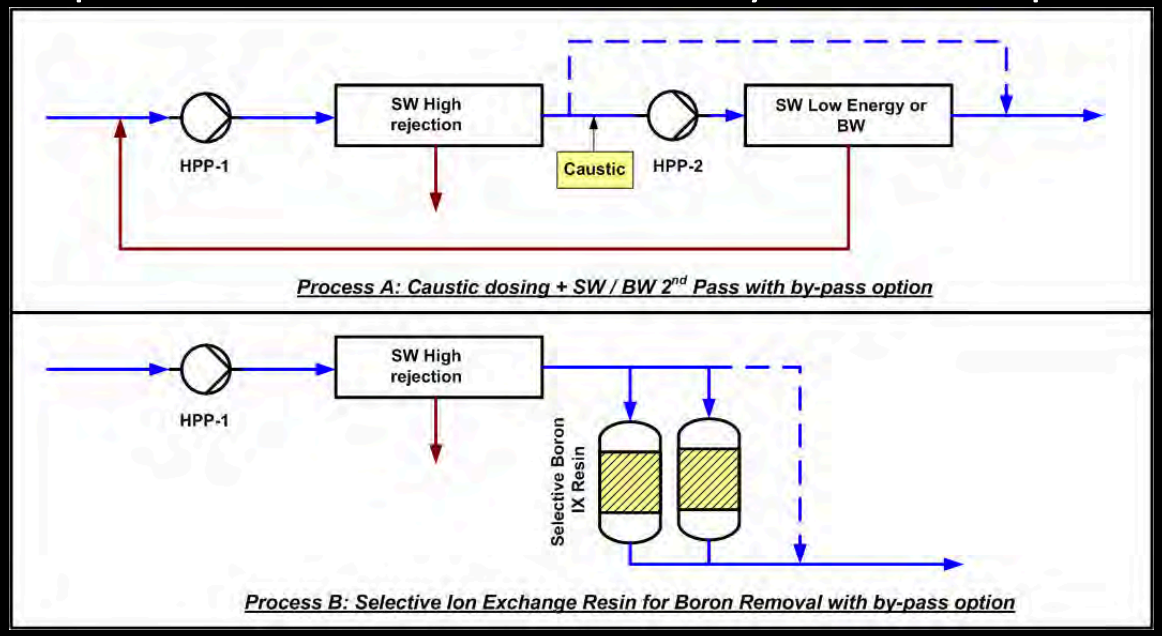
Flouride (F^-) & other halides

- Complicated regulation
  - Regulation has a low & high end concentration range (0.5-1.5 mg/L)
  - Most water utilities add fluoride to water
- Fluoride removal
  - Sorption onto activated alumina (used by some GW facilities in AZ) in packed bed designs with frequent acid regeneration
- Bromide and iodide are difficult to treat
- RO remove Cl^-, I^-, Br^-, F^-

Boron removal



- Boron regulation for plants is more strictive than for human health
- Generally < 1 mg/L target (CA ~ 0.5 mg/L for citrus in some areas)
- Ion Exchange
  - Some boron-selective ion-exchange resin does not require pH adjustment
  - Most of commercial resins are modified by N-methyl-D-glucamine (NMDG) functional group such as Diaion WA30, Diaion CRB 02, Purolite S108, Dowex2x8, Dowex XUS 43594.00, Amberlite IRA 743, XSC-700
- RO/NF processes can remove boron if you increase pH



Seawater (SW) systems to remove boron to < 1 ppm (Lenntech)

Table 2. Summary of PPCP/EDC levels in different waters

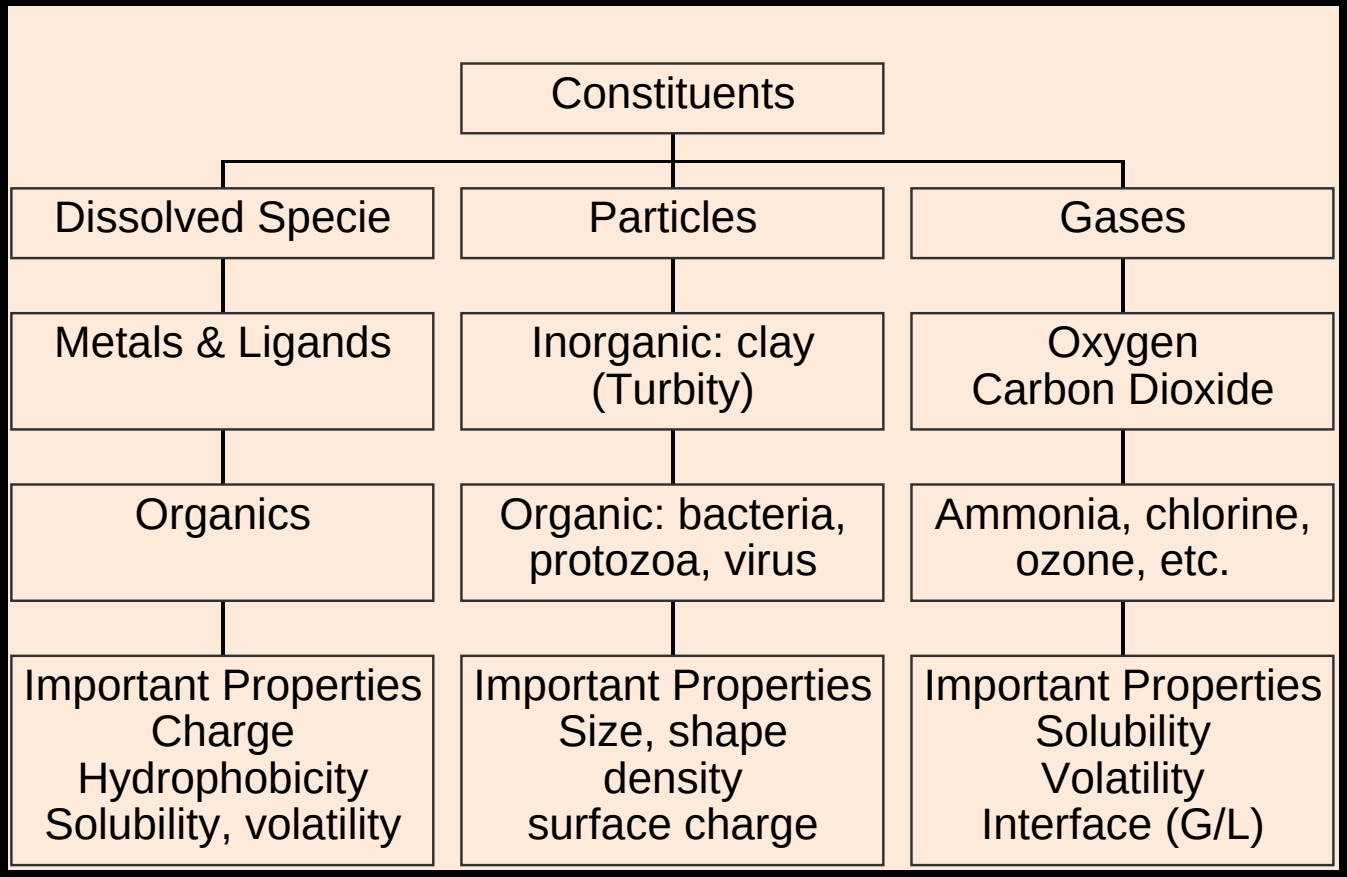
Source	< 2 ng/L & ≤ Blank	2 to 10 ng/L	10 to 20 ng/L	20 ng/L to 1 ug/L	> 1 ug/L
Ground water at recharge site	Steroids and others	Acetaminophen, caffeine, DEET, erythromycin, meprobamate, oxybenzone, pentoxifylline	None	Sulfamethoxazole, sucralose (from one site)	None
SRP waters (Verde River & Salt River)	Steroids and others	Sucralose, sulfamethoxazole, acetaminophen, cotinine, dilantin,	Caffeine, DEET	Oxybenzone	None
CAP Canal from Colorado River	Steroids and others	Sulfamethoxazole, oxybenzone, meprobamate, DEET, cotinine, dilantin, carbamazepine, acetaminophen, primidone, estradiol	Caffeine, triclosan	Sucralose	None
Activated sludge WWTP with nitrification	Steroids	Acetaminophen, ibuprofen, diazepam, pentoxifylline	Cotinine	Caffeine, naproxen, oxybenzone, TBBA, carbamazepine, hydrocodone, meprobamate, sulfamethoxazole, DEET, erythromycin, trimethoprim, primidone, dilantin, triclosan, diclofenac, sucralose, fluoxetine	None
Raw wastewater	None	None	Diazepam, ethinyl estradiol, progesterone	Testosterone, hydrocodone, pentoxifylline, erythromycin, trimethoprim, primidone, fluoxetine carbamazepine, dilantin, diclofenac	Ibuprofen, naproxen, triclosan, sucralose, acetaminophen, caffeine, cotinine, oxybenzone, DEET, meprobamate, TBBA, sulfamethoxazole

Recharge / Soil Aquifer Treatment

- Organics Removal
  - Reduces NOM / TOC
  - Taste and odor removed
  - Many trace organics (but not all)
- No removal of salts
- Can mobilize local pollutants
- Denitrified wastewater recharged or RO treated is common in Arizona

Backup slides

Example Constituents



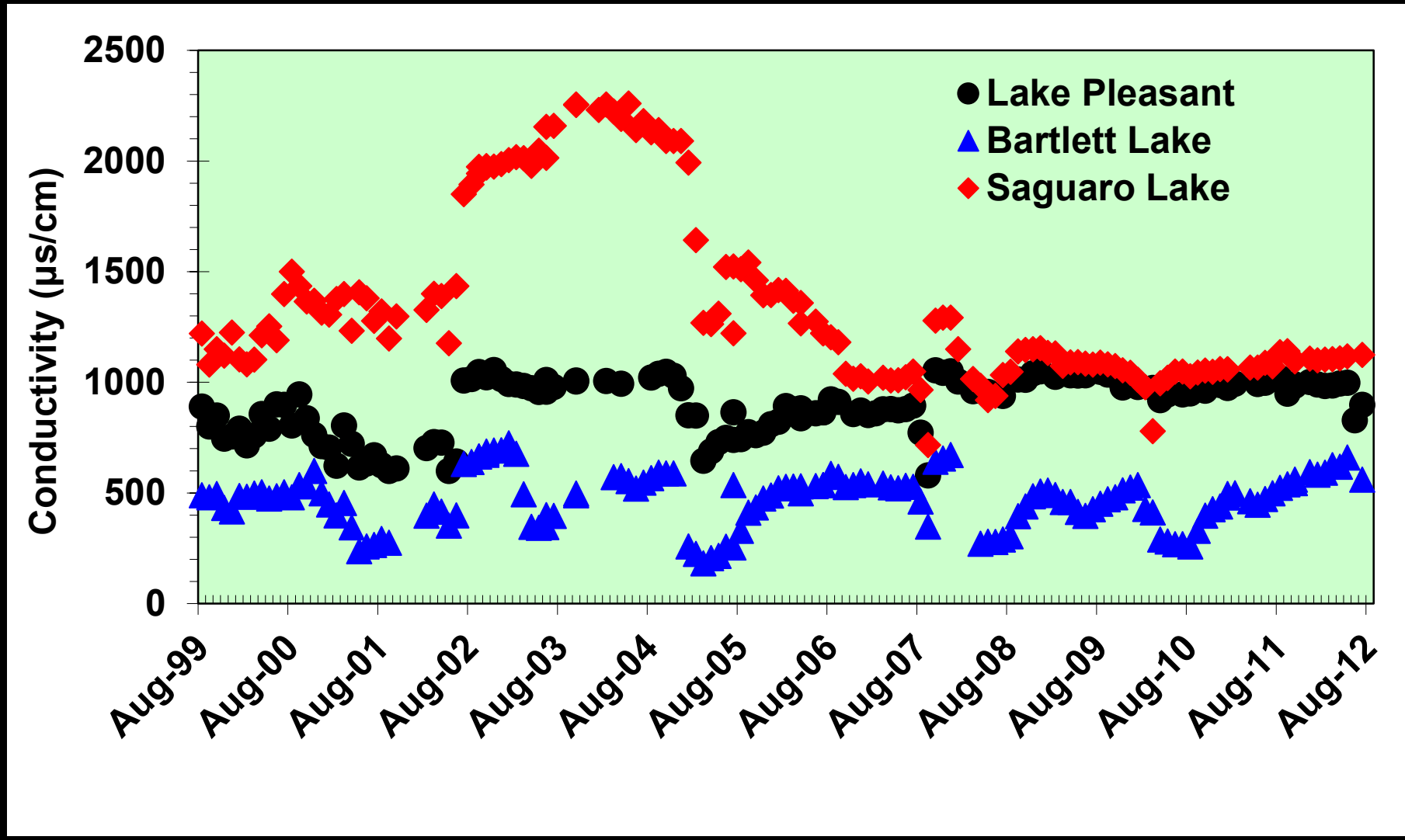
Treatment of these systems is largely governed by regulatory mandates for human and ecological health. Processes include:

- Coag/floc (P)
- Sedimentation
- Filtration
- Flotation
- Membranes

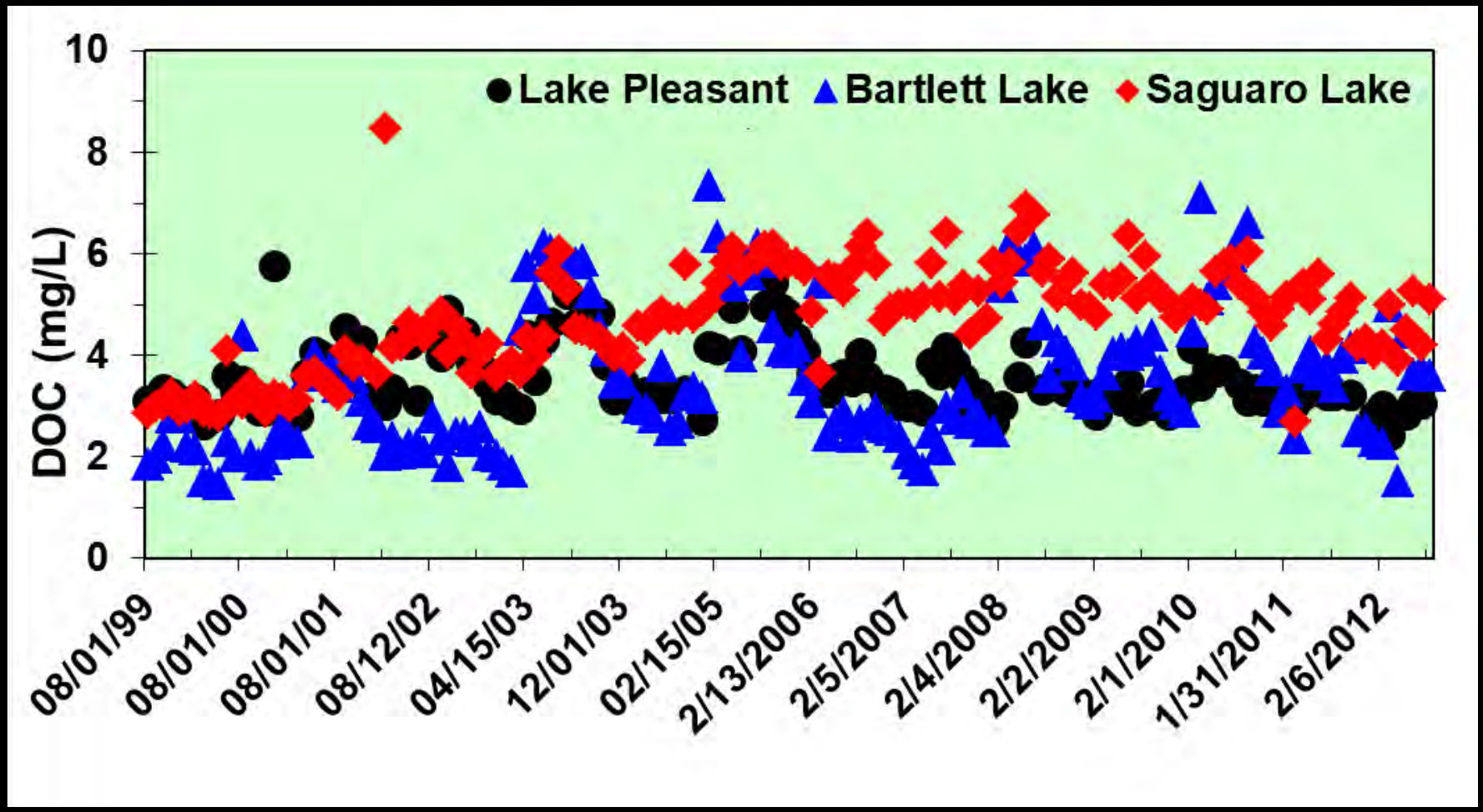
- Aeration (G)
- Stripping

- Oxidation/reduction (D)
- Precipitation
- Ion Exchange
- RO membranes
- Biological Treatment
- Softening
- Adsorption

Hydrology Affects Water Quality
(conductance can affect algal dominance)



Up-stream reservoirs attenuate DOC



Current Levels