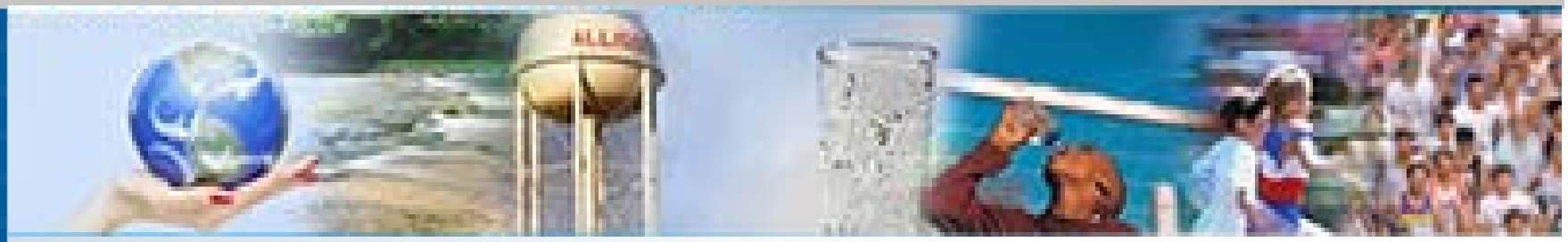
USEPA Webinar Series

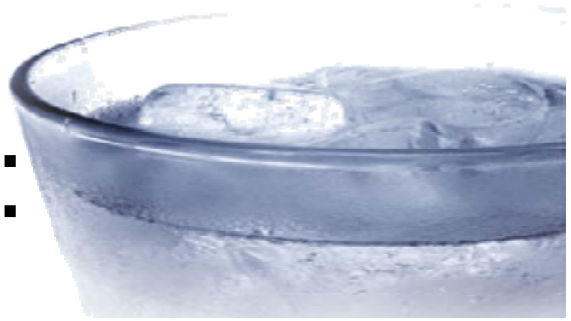
Best Practices for Simultaneous Compliance

Office of Ground Water and Drinking Water



Simultaneous Compliance Planning Issues for Ground Water Systems

OGWDW Contract No. EP-CI-08-018
Work Assignment 0-06



2009 Webinar Series:

- Source/Treatment Changes
  - What Primacy Agencies Should Consider
- **Simultaneous Compliance Planning Issues for Ground Water Systems**
- Simultaneous Compliance Planning Issues for Surface Water Systems
- Water Quality Management in Distribution Systems - Simultaneous Compliance and Unintended Consequences

Outline of Today's Discussion

1. Frame compliance issues unique to GW systems
2. SDWA-driven regulations that most frequently impact GW systems
   - *How impacted?*
   - *Utility compliance actions driven by these rules*
3. Specific utility actions and related simultaneous compliance issues
   - *What to watch for..*
   - *How to overcome challenges*
4. Wrap-Up

Key Acronyms

GW - ground water
VOC - volatile organic chemical
SOC – synthetic organic chemical
IOC – inorganic chemical
DBP – disinfection by-product
LCR – Lead & Copper Rule
GWR – Groundwater Rule
TCR – Total Coliform Rule
CCT – corrosion control treatment
GAC – granular activated carbon
IX – ion exchange
RO – reverse osmosis
NF – nanofiltration (loose RO)

Key Acronyms

TOC - total organic carbon
AOC - biologically-assimilatible organic carbon
NOM – naturally-occurring organic material
ORP – oxidation reduction potential
NO3 – nitrate
PO4 – phosphate
SO4 – sulfate
Fe/Mn – iron/manganese
As+3 – arsenite
As+5 - arsenate
GWUI – groundwater under direct influence of surface water
MMM – multimedia mitigation
WWTP – wastewater treatment plant

Framing Compliance Issues Unique to Ground water Systems

Ground Water Systems Represent a Massive Compliance Challenge

Type of Water System	Ground Water	Surface Water
Community Water Systems	40,315	12,024
Non-Transient Non-Community Water Systems	18,429	616
Transient Non-Community Water Systems	83,356	1904
Total	142,100	14,544

- USEPA CWSS, 2006

Ground Water Systems Represent a Massive Compliance Challenge

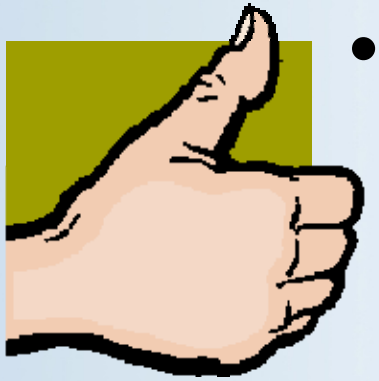
Type of Water System	Ground Water	Surface Water
Water Systems	18,429	610
Total	142,100	14,544

Over 75% of groundwater systems serve less than 3300 people, and over one-half serve less than 500 people.

Small systems often have limited financial and technical Resources devoted to regulatory compliance.

- USEPA CWSS, 2006

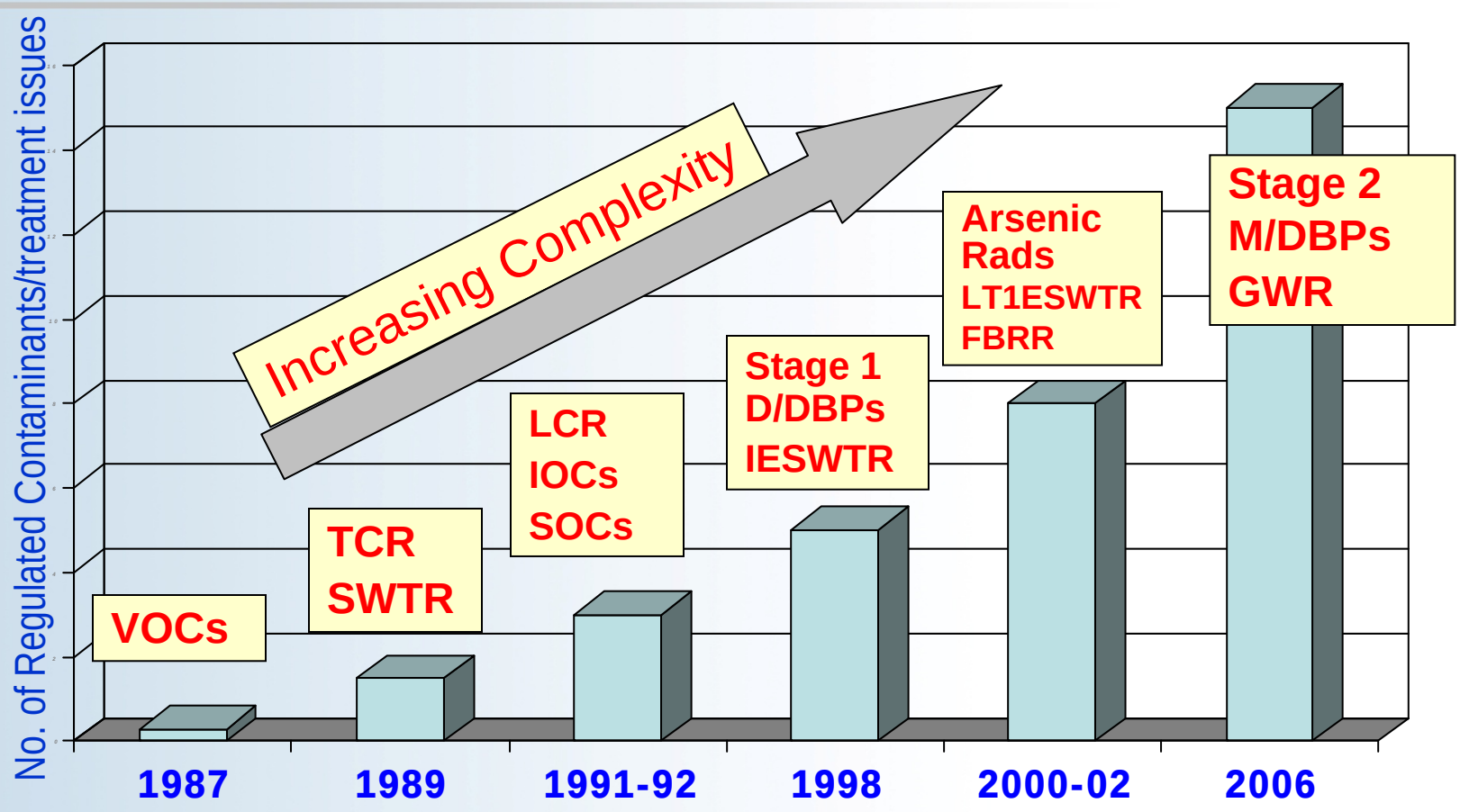
Inherent Dichotomy of Groundwater



- Reliable and stable source of water often requiring minimal treatment
  - Consistent WQ and Temp
  - Low NOM and turbidity

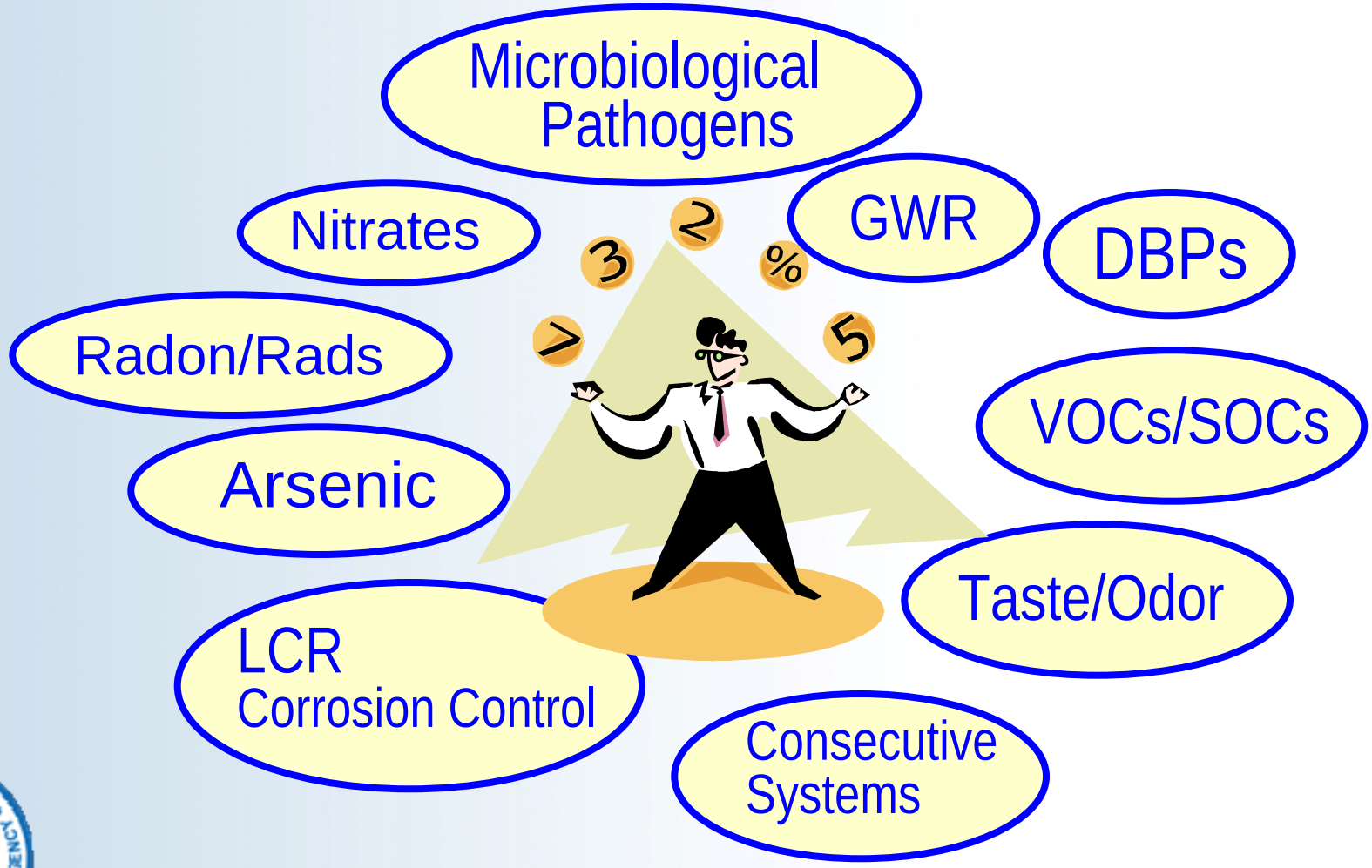
- Limited yields; sudden/subtle contamination potential; and multiple well issues
  - Localized, limited capacity
  - Susceptibility to contamination
  - Multiple wells – WQ variations

Simultaneous Compliance Complexity has Increased Significantly in 20 Years

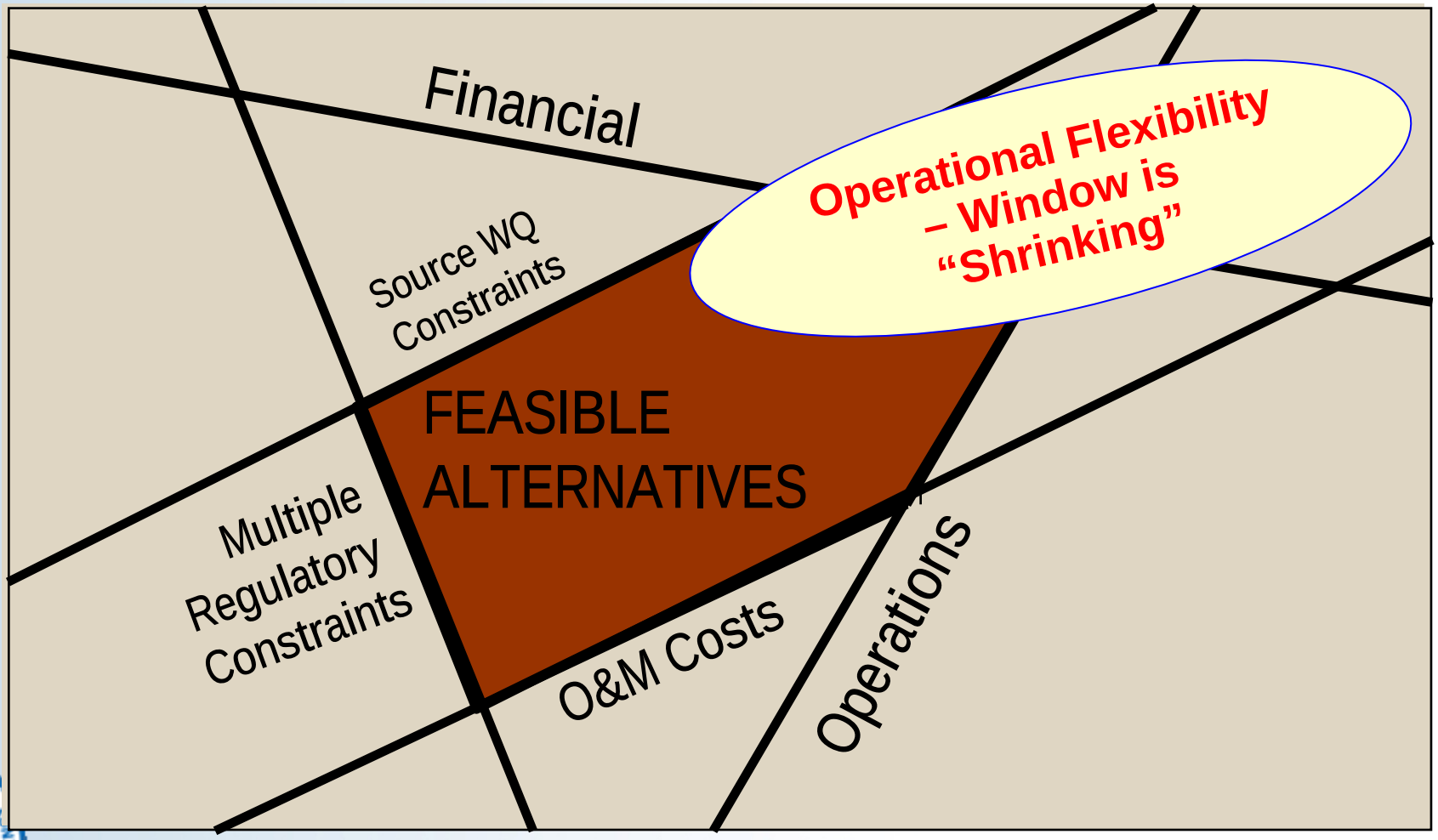


Many "secondary water quality impacts" are also related to SDWA regulatory compliance

Ground Water Systems Increasingly Required to Juggle Competing Regulatory Requirements



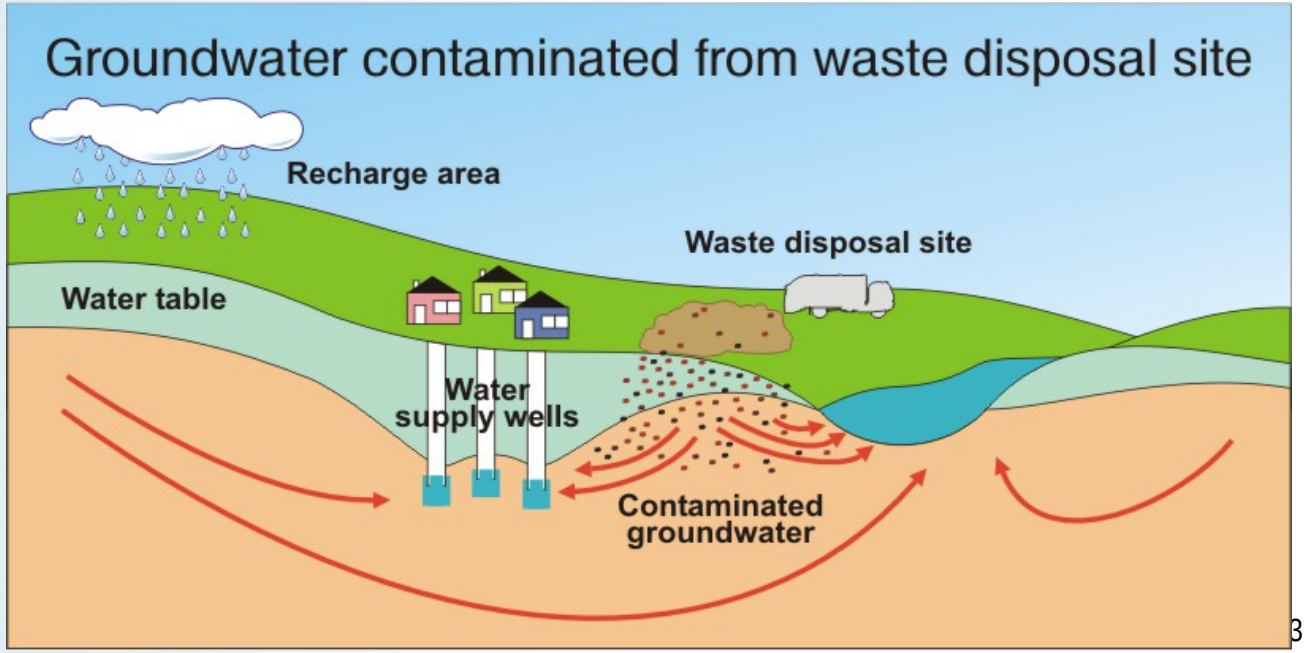
PWS Operations are Increasingly Complex and Flexibility is Shrinking



Source: Balancing Multiple Water Quality Objectives, AWWARF, 1998

Typical Origins of Ground Water Simultaneous Compliance Actions

- Source changes – long-term shifts in raw WQ
- MCL violations (TCR/IOCs/NO_3/VOCs/SOCs)
- Treatment requirements (LCR, GWR, GWUI)
- Ground water contamination event



MCL & Treatment Technique Violations

System Size	TCR	LCR	NO_3	Rads	VOCs/ SOCs	As
Very Small <500	7,527	1211	997	714	72	1554
Small 501-3300	989	259	147	337	9	412
Medium 3301-10,000	272	55	9	80	4	166

- EPA Factoids, 2008
EPA 816-K-08-004

SDWA-driven Regulations that Most Frequently Impact GW Systems

SDWA-Driven Regulations Impacting Ground Water Systems

Frequently Impact GW Systems

Volatile Organics (VOCs)
Synthetic Organic Chemicals (SOCs)
Ground Water Rule (GWR)
Lead and Copper Rule (LCR)
Arsenic Rule • Nitrates
Radionuclides Rule
Wellhead/Well Field Protection

Rules Drive Compliance Actions

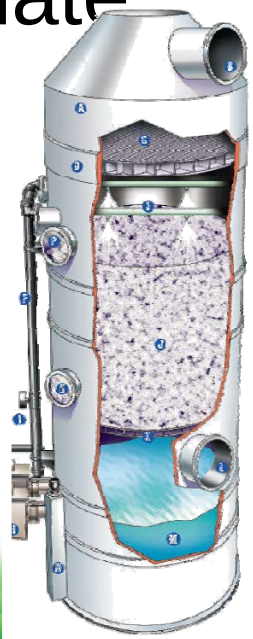
Compliance Actions Create Conflicts & Challenges

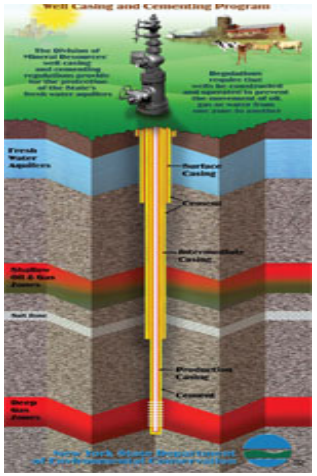
***Somewhat* Less Frequent GW Impact:**

Stage 1 and 2 D/DBP Rules
Total Coliform Rule (TCR)
Inorganic Chemicals (except As & NO_3)

Wide Array of Possible Actions Driven by Regulatory Requirements

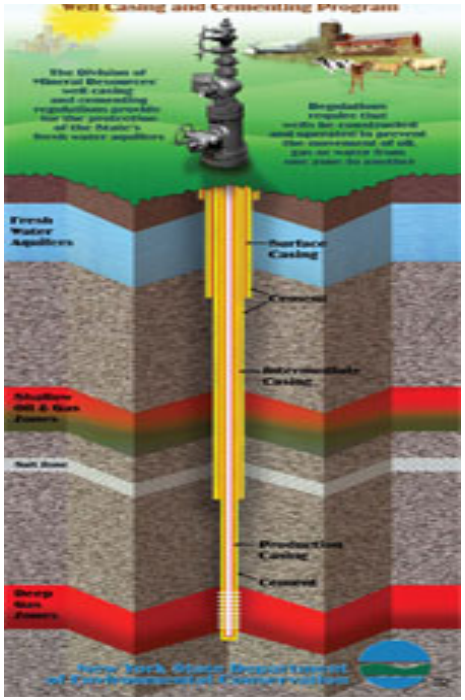
- Modify **source utilization** to eliminate source of contamination
- Provide **new treatment** to remove contaminants:
  - VOCs/SOCs
  - Arsenic (As), nitrate (NO_3)
  - Rads (radium, uranium)





Wide Array of Possible Actions (cont)

- Provide 4-log treatment for viruses
  - Add new technology
  - Change existing technology
- Modify existing treatment
- Hardness/Fe/Mn

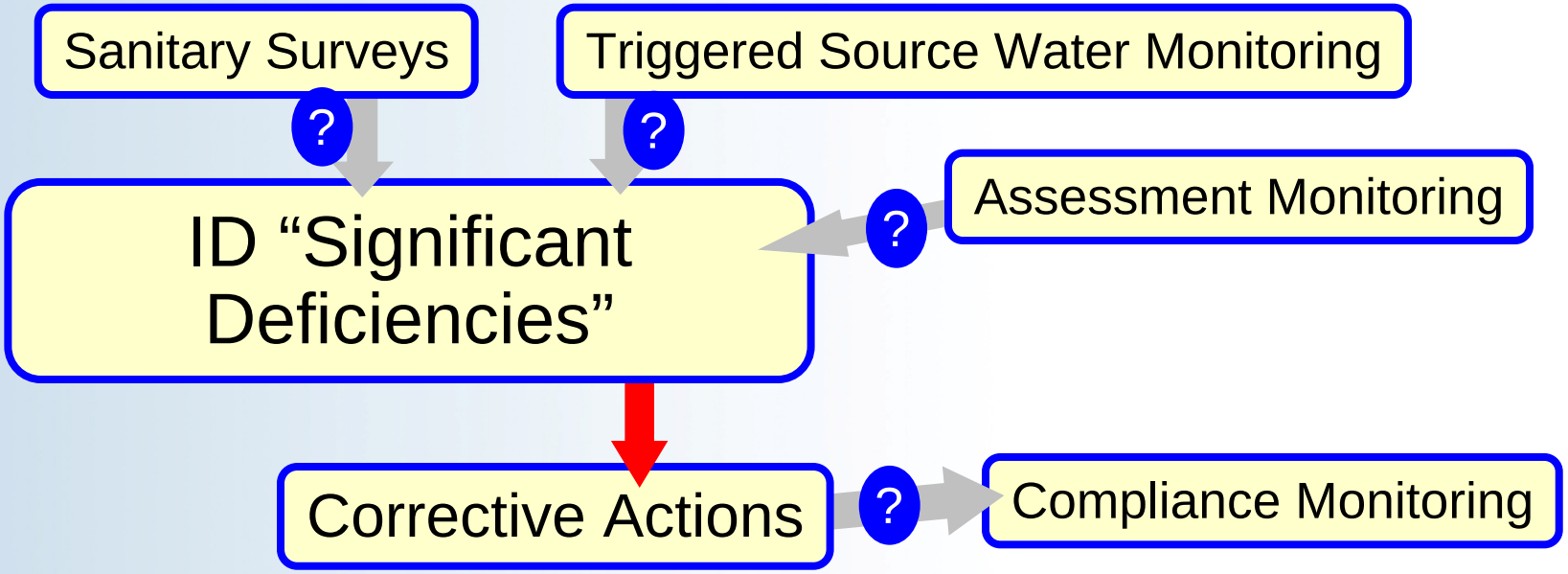


How Rules May Impact GW Systems - VOCs/SOCs

- Source of Supply Changes
  - shift well production (shutdown)
  - new wells
  - new blending scenarios
- Treatment Processes - VOCs
  - aeration, GAC adsorption, ion exchange, NF/RO
- Treatment Processes – SOCs
  - GAC adsorption, ion exchange, NF/RO
- Modify Existing Processes
  - coagulation, softening, disinfection

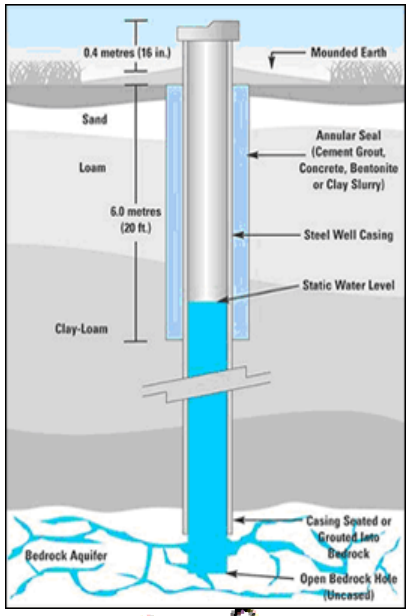
How Rules May Impact GW Systems - Groundwater Rule (GWR)

"... *to provide for increased protection against microbial pathogens in public water systems that use ground water sources*."



How Rules May Impact GW Systems - GWR "Significant Deficiencies"

- Source of Supply
  - Well design/location/protection
  - Subject to flooding
- Treatment
  - Inadequate disinfection practices
  - Chemical treatment reliability
  - Failure to meet other requirements
- Distribution System Practices
  - Storage subject to contamination
  - Unprotected cross-connections
  - Corrosion control



How Rules May Impact GW Systems - Groundwater Rule (GWR)

- Source of Supply Changes
  - New sources / shutdown existing well(s)
  - Wellhead protection/well design
  - New blending scenarios
- Disinfection Process
  - Introduction of disinfectant for first time
  - Improve existing disinfection practices
- Addition/Modification of treatment processes impacting distribution system chemistry (pH, ORP, alkalinity, PO4)

How Rules May Impact GW Systems - Lead & Copper Rule (LCR)

- Action level exceedance for Pb or Cu leads to re-optimization of corrosion control treatment (CCT)
- New or modified treatment process impacts CCT chemistry (pH, alkalinity, ORP, SO_4, PO_4)
  - Oxidation/disinfection
  - Coagulation/softening
  - Ion exchange/NF/RO
- Desktop, bench or pilot-scale CCT studies may be necessary (these take time!)

How Rules May Impact GW Systems - Arsenic/Nitrates/Radionuclides

- Source of Supply Changes
  - shift well production (shutdown)
  - new wells / new blending scenarios
- New Treatment Processes
  - ion exchange (As^{+5}; NO_3, uranium)
  - adsorptive medias (greensand, iron-based media)
  - NF/RO (almost everything)
  - activated alumina (As^{+5}, uranium)
- Modify Existing Processes
  - Pre-oxidation/disinfection
  - coagulation/filtration
  - precipitative softening (As^{+5}, radium, uranium)

GW Systems Also Under Pressure to Meet Secondary Water Quality Goals

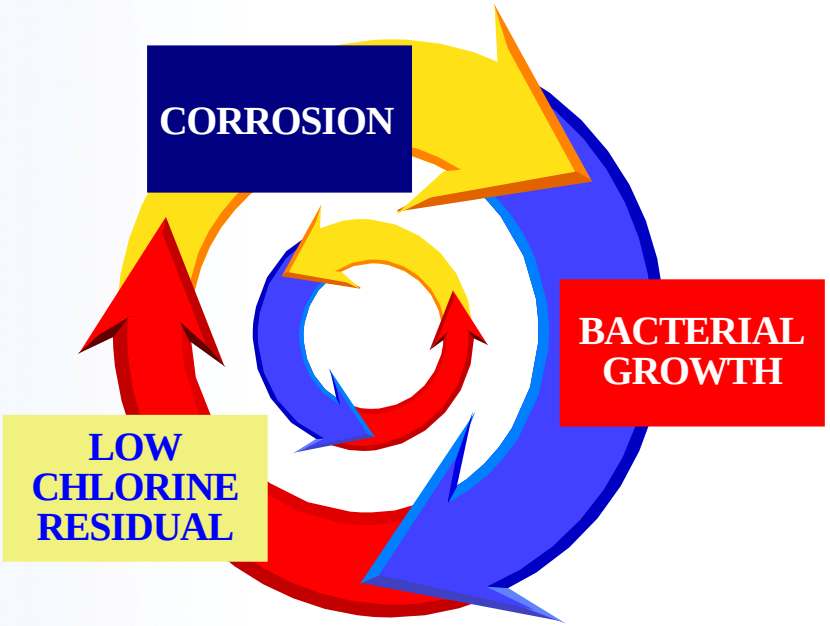
- Hardness
- Dirty water
- Taste & odor
- Scale stability
- Fe/Mn
- Other Secondary MCLs

Specific Ground Water Utility Actions and Related Simultaneous Compliance Issues

- *What to watch for..*
- *How to overcome challenges*

Negative Water Quality Impacts Can Result from a Diverse Array of Changes

- Source Water
  - New Source
  - Blending of sources
- Treatment
  - Major unit process modifications/additions
  - Oxidants/disinfectants
  - O_3, chlorine dioxide, or UV
  - Long-term shifts in ORP, dose
  - Enhanced/modified Softening
  - Modified CCT
- Distribution System
  - Conversion to chloramines
  - Switch from Cl_2 gas to NaOCl
  - Nitrification
  - Nitrification control



Required LCR Notification
40 CFR 141.90 (a) (3)

*"… as early as possible prior to the **addition of a new source or any long-term change** in water treatment, a water system deemed to have optimized corrosion control… shall **submit written documentation** to the State describing the change or addition.*

*The State must **review and approve** the addition of a new source or long-term change in treatment **before it is implemented**…*

Examples of long-term treatment changes include the addition of a new treatment process or modification of an existing treatment process. ."

LCR Notification
Long-Term v. Short-Term Changes

Long-Term Changes

- New treatment process
- Modification of existing treatment process
- Switching secondary disinfectants
- Switching coagulants
- Switching corrosion inhibitors

Short-Term Changes (notification not required)

- Adjust chemical feed rates to match variations in source water quality
- Distribution system BMPs (nitrification control, flushing, etc.)
- Other “optimization” efforts

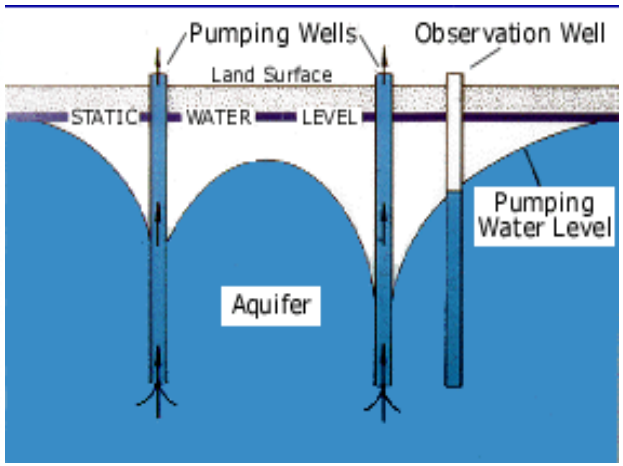
Outline of Specific Utility Actions We'll Cover Today:

- Source of Supply Changes
- Disinfection Practices
- VOC/SOC Removal
- Arsenic Removal
- Softening
- Corrosion Control Treatment (CCT)
- Distribution System Operations

Some Specific Changes

Source of Supply Changes

- Adding new source(s)
- Blending multiple sources
- Modifications to existing sources of supply to reduce O&M costs



Most source changes will impact treatment requirements and/or distribution system chemistry.

Some Specific Changes

Why Change Source Water?

To Add Capacity!!

To Improve Quality/Consistency:

- Avoid VOC/SOC Contaminants
- Avoid IOCs/Arsenic/nitrates/Rads
- Improve microbial quality (GWR)
- Decrease NOM/DBP precursors
- Lower disinfectant demand
- Residuals production

… to increase production, avoid contamination or minimize treatment requirements

Some Specific Changes

Source Water Changes

- New source of supply
- New blending scenarios
- New treatment requirements
- New system "entry points"

- Assessment monitoring
- New contaminants
- New treatment processes/ interactions
- Shifts in CCT chemistry (pH, ORP, alkalinity, PO4)

Source Water Change
Other Possible Conflicts/Challenges

- Temperature shifts from SW/GW blending may help/hurt treatment
- Raw water quality shifts require adjustments of coagulation/softening
- Alternating between sources requires careful control of CCT chemistry
- Source changes can negatively affect aesthetics; regrowth potential, scale stability, Fe/Mn/Sulfides

Source Water Change
Overcoming Conflicts/Challenges

- Identify/evaluate potential conflicts/interactions
- Recognize the potential for source changes to impact existing treatment and distribution system chemistry
  - Exercise positive control over coagulation and softening chemical treatment/dosages
  - Maintain pH and alkalinity targets in both plant and distribution system
  - Monitor TOC and shifts in disinfectant demand

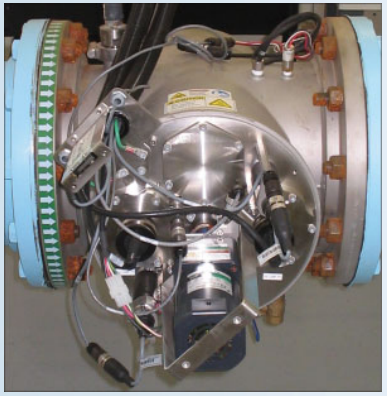
Source Water Change
Overcoming Conflicts/Challenges

- Collect data! Evaluate!
- Re-optimize CCT as needed, and ensure CCT is effective over the full range of raw water quality conditions
- Keep distribution system chemistry as consistent as possible to promote scale stability and mitigate dirty water episodes

Some Specific Changes

Disinfection Changes

- Dosage changes
- Relocating disinfectant application point
- Switching to a new disinfectant
- Applying multiple disinfectants



Some Specific Changes

Why Change Disinfection Practices?

- DBP control
- Meet GWR disinfection criteria under changing source water conditions
- Improve “secondary” disinfectant residual in distribution system
- Reduce disinfectant consumption
- Oxidation of iron and manganese
- Control microbial regrowth
- Aesthetics (taste & odor)

GWR-specific Corrective Actions for Improving Disinfection

Application of **multiple barrier treatment** using combinations of:

- New disinfection chemicals or increased dosages (chlorine, chlorine dioxide, ozone)
- UV disinfection[§]
- High-pressure membrane technologies (reverse osmosis or nanofiltration) [§]

[§] May not achieve 4-log virus removal/inactivation unless used in combination with chemical disinfectants

Disinfection Changes
Possible Conflicts/Challenges

- Conversion to chloramines may cause seasonal nitrification in distribution system
- Chlorine dioxide may form chlorides and chlorates under some conditions
- Oxidation of TOC, NOM may cause shifts in DBP formation/speciation
- Shifts in pH, alkalinity, ORP and NOM may require re-optimization of CCT
- Softening chemistry may limit disinfection alternatives upstream of granular media filtration
- Ozone impacts on downstream treatment processes (e.g., bio-regrowth; fouling of membranes)

Disinfection Changes Overcoming Conflicts/Challenges

- Identify/evaluate potential conflicts/interactions
- Control chlorine/ammonia ratio, water age and other factors to avoid nitrification
- Recognize potential for ozone impacts on downstream treatment processes
  - AOC & bio-regrowth potential
  - Biological filtration may be needed
  - Membrane fouling potential

Disinfection Changes Overcoming Conflicts/Challenges

- Conduct treatability testing to establish how new oxidation conditions impact DBP speciation, Pb/Cu, chlorides/chlorates, etc.
- Site-specific demonstrations of pre-filtration CT in softening reactors may be necessary
- Re-optimize CCT as needed, and ensure CCT is effective over the full range of raw water quality conditions
- Keep distribution system chemistry as consistent as possible to promote scale stability and avoid AL exceedences or aesthetics problems

Some Specific Changes

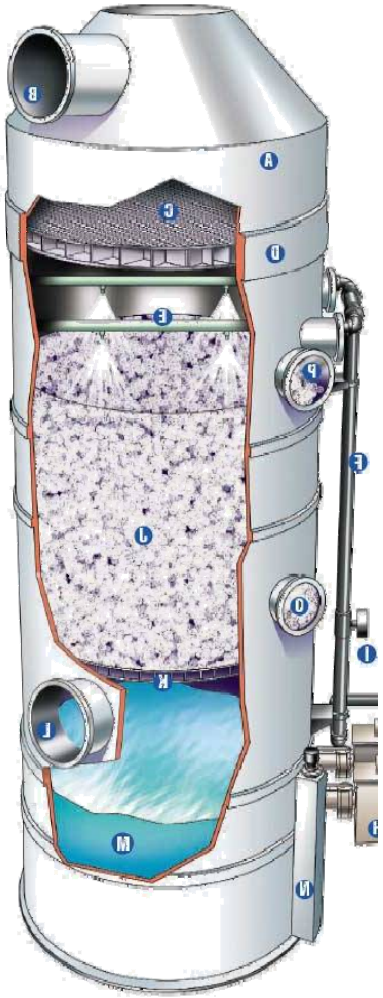
VOC/SOC Removal Processes

- Aeration for VOC removal
- GAC Adsorption
- Nanofiltration/Reverse Osmosis
- Precipitate softening (SOCs)
- Ozone and Ozone-related AOPs

VOC/SOC Removal Processes
Simultaneous Compliance Challenges

Aeration for VOC Removal

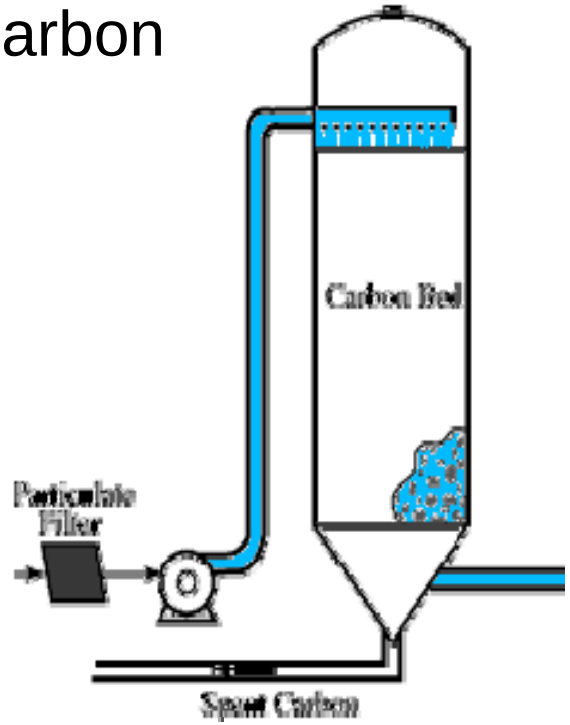
- Very effective for “volatile” compounds
- Diffused bubble, packed tower & tray configurations
- Increased scaling potential – water may need to be stabilized
- Clean Air Act issues



VOC/SOC Removal Processes
Simultaneous Compliance Challenges

Granular Activated Carbon Adsorption

- Good DBP precursor removal
- Enhanced T&O Removal
- Removes assimilatible organic carbon (AOC) after ozone
- Limits ability to pre-chlorinate
- Unintended reduction in disinfectant residual
- Bacteria release from biologically-active GAC
- Residuals - spent GAC disposal



Atrazine & TOC Removal using GAC Filter-Adsorbers in Higginsville Missouri

- 2 MGD facility / 12-hr/day operation
- Converted dual-media filters to GAC filter-adsorbers (7.5 min EBCT)
- Trade-off between removal of Atrazine and DBP precursors (pH effects)
  - 50% Atrazine removal
  - 25% TOC removal
- Good particulate removal
- Bench-scale testing needed before implementation

VOC/SOC Removal Processes
Simultaneous Compliance Challenges

- Nanofiltration/Reverse Osmosis
  - Rejects bacteria, viruses, protozoa
  - Removes DBP precursors
  - Removes As^{+3} and As^{+5}
  - NF/RO membranes easily fouled by organics/precipitated minerals
  - Demineralization increases corrosivity
  - Residuals – disposal of high TDS reject stream

VOC/SOC Removal Processes
Simultaneous Compliance Challenges

Ozone / Ozone-related AOPs

- Good broad-spectrum oxidant for Fe/Mn, T&O, natural organics.
- O3 + bromide = Bromates
- AOC biologically assimilatible organic carbon (food for bugs in distribution system)
- Can form unregulated DBPs (Aldehydes, ketones, bromimated organics)
- Potential Coagulation/filtration benefits

Ozone for Primary Disinfection and Taste & Odor Control at Ann Arbor MI

- 50 MGD two-stage softening plant
- Blended SW/GW
- Switched from pre-chlorination and pre-chloramination to Pre-ozonation followed by biological filtration
- Ozone added following recarbonation
- NaOH and phosphate inhibitor for CCT
- Enhanced filtered water chloramination to protect against biosolids shedding
- Post-chloramination

Ozone for Primary Disinfection and Taste & Odor Control at Ann Arbor MI

- Lessons Learned
  - THM/HAA formation reduced
  - 45-55% TOC removal
  - Enhanced *Giardia* and virus inactivation
  - Ozone induced AOC must be controlled by biological filtration
  - Ozone forms bromate when bromides present in source
  - High degree of operator attention required

VOC/SOC Removal Processes
Overcoming Compliance Challenges

- Recognize potential for VOC/SOC removal processes to impact existing treatment and distribution system chemistry
  - Anti-scaling chemicals for aeration, NF/RO
  - GAC impacts on disinfectant residual
  - Control release of bio-mass from GAC
  - NF/RO membrane fouling potential
  - Clean air act permit requirements?

VOC/SOC Removal Processes
Overcoming Compliance Challenges

- Recognize potential for ozone impacts on downstream treatment processes (e.g., bio-regrowth; fouling of membranes)
- Re-optimize CCT as needed, and ensure CCT is effective over the full range of treated water quality conditions
- Keep distribution system chemistry as consistent as possible
- Evaluate impact of GAC and membrane processes on residuals quantity, character and disposal options

Some Specific Changes

Arsenic Removal

- Adsorptive Media Processes
  - Silicon-based diatomaceous earth
  - Iron oxides
  - Activated alumina (Al_2O_3)
- Coagulation/Filtration
- Ion Exchange (anionic)
- Lime Softening
- High pressure membranes (NF/RO)

Some Specific Changes

Arsenic Removal

- Pre-oxidation is often required to achieve target As removal using adsorptive media, IX or coag/filt.
- Coagulation/Filtration
  - Less effective at pH >8
  - Fe salt coagulants seem to work best
- Ion Exchange
  - Sulfates, nitrates, other cations will compete for adsorptive sites >>> adds to cost!
- High pressure membranes (NF/RO)
  - 20-40% of water lost to reject stream
  - Extensive pretreatment & post treatment needed

Arsenic Removal by Lime Softening

As Solids in Residuals Stream!!

Species	pH < 10	pH >10.5
Arsenite (+3) Groundwater	0 – 10%	Up to 75%
Arsenate (+5) Surface Water Groundwater	0 – 10%	60 – 95%

Reference: *Arsenic Removal from Drinking Water by Coagulation/Filtration and Lime Softening Plants*. Fields, et al. USEPA, June 2000.

Some Specific Changes

Softening Practices

- Precipitative Softening
  - Straight Lime
  - Lime-soda Softening
  - Excess Lime Softening
- Membrane Softening (nanofiltration)
  - Removes all particulates
  - Inorganic and larger dissolved organic compounds
- Ion Exchange
  - Exchanges Ca & Mg for Na
  - Effective for As, NO_3, rads, perchlorate

Some Specific Changes
Softening Practices

All softened waters not equal!

- Lime or Membrane Softening
  - Removes/lowers alkalinity
  - Removes/lowers dissolved solids
- Ion Exchange Softening
  - Exchanges Na^{+} for Ca^{++} and Mg^{++}
  - Does not remove/lower alkalinity
    - High alkalinity may promote Cu problem
  - Does not remove/lower dissolved solids

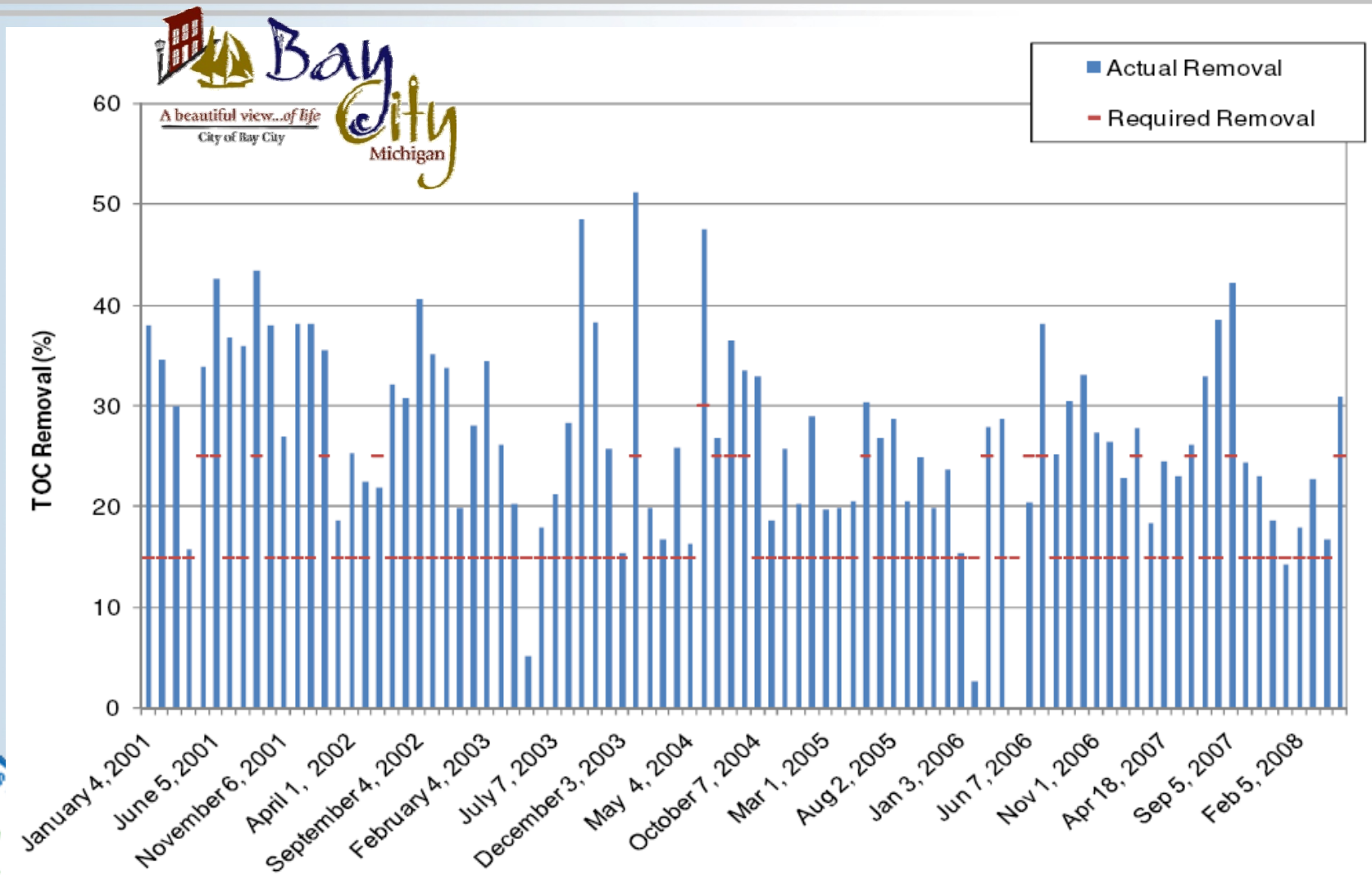
Simultaneous Compliance Challenges and Treatment Process Interactions are Likewise Unequal

Softening
Simultaneous Compliance Challenges

Precipitative Softening

- Removes TOC/DBP precursors (with coagulant)
- Stabile WQ if enough alkalinity
- Required stabilization
  - recarbonation
  - Bypass/blending
  - sequestering agent
- Limits disinfection alternatives
- Increases scaling potential
- High residuals production

Bay City, Michigan
TOC Removal by Straight Lime Softening



Softening
Simultaneous Compliance Issues

Nanofiltration/Reverse Osmosis

- Rejects bacteria, viruses, protozoa
- Removes DBP precursors, As
- NF/RO membranes fouled by organics/minerals
- Increases corrosivity
- High TDS residuals stream

NF Membrane Softening for TOC Removal at West Palm Beach, FL

- 13.5 MGD lime softening plant converted to membrane softening
  - High DBPs / High TOC GW
  - Achieved softening, 90% TOC removal, other organics
- Significant pre-treatment and post treatment
  - Degasification air stripping
  - Raw water blending for carbonate stability and CCT
  - Chloramination

Softening
Simultaneous Compliance Issues

Softening practices have significant simultaneous compliance interactions

- May constrain primary disinfection options
  - Chlorine CT not well-defined above pH 9
  - ClO2 plus recarbonation >> Chlorates
  - High pH with ozone may form more bromate
- CCT Impacts
  - pH/Alkalinity/DIC shifts
  - Cl/SO4 ratio shifts

Softening
Simultaneous Compliance Issues

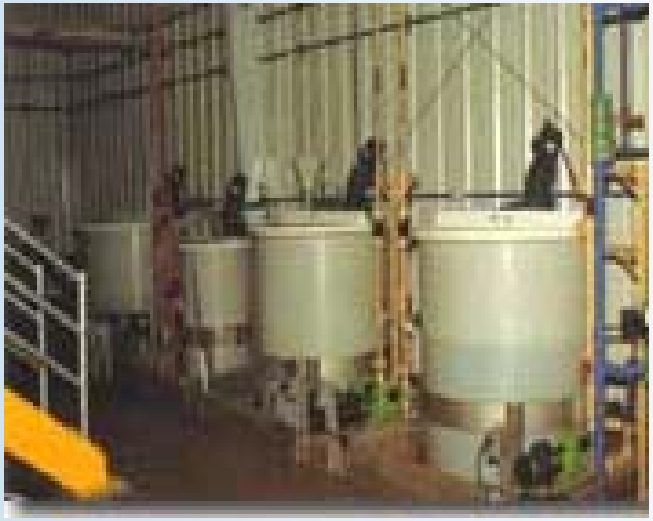
Softening practices have significant simultaneous compliance interactions

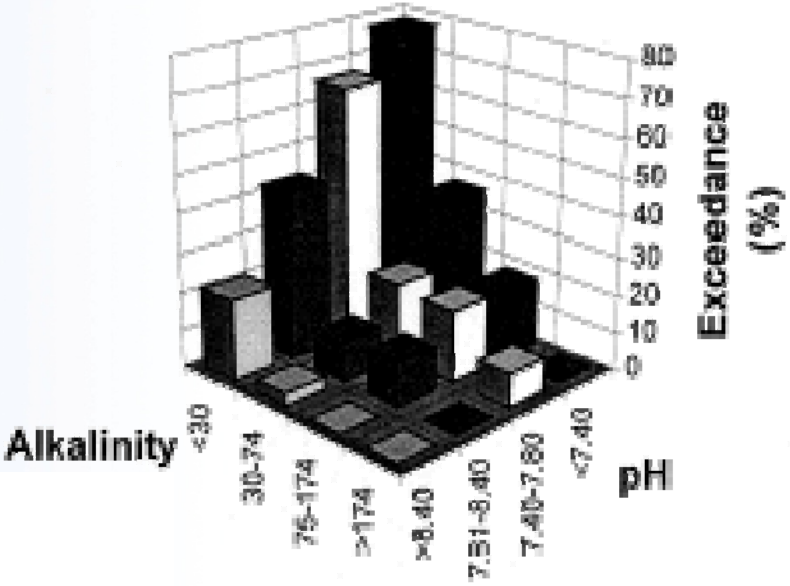
- Recarbonation or sequestering agent for stabilization
  - Stabile water if pH/alkalinity right
  - If not, may increase scaling potential
  - Excessive use of sequestering agents may destabilize scale in distribution system
- NF/RO membranes easily fouled by organics/minerals
- NF/RO will increases corrosivity
- High residuals production
- High TDS residuals stream

Some Specific Changes

LCR Corrosion Control Treatment

- Carbonate Passivation (adjust pH, alk)
- Carbonate Precipitation (adjust pH, Ca)
- Passivation using corrosion inhibitor chemical (PO_4)





Why Optimize/Re-Optimize CCT?

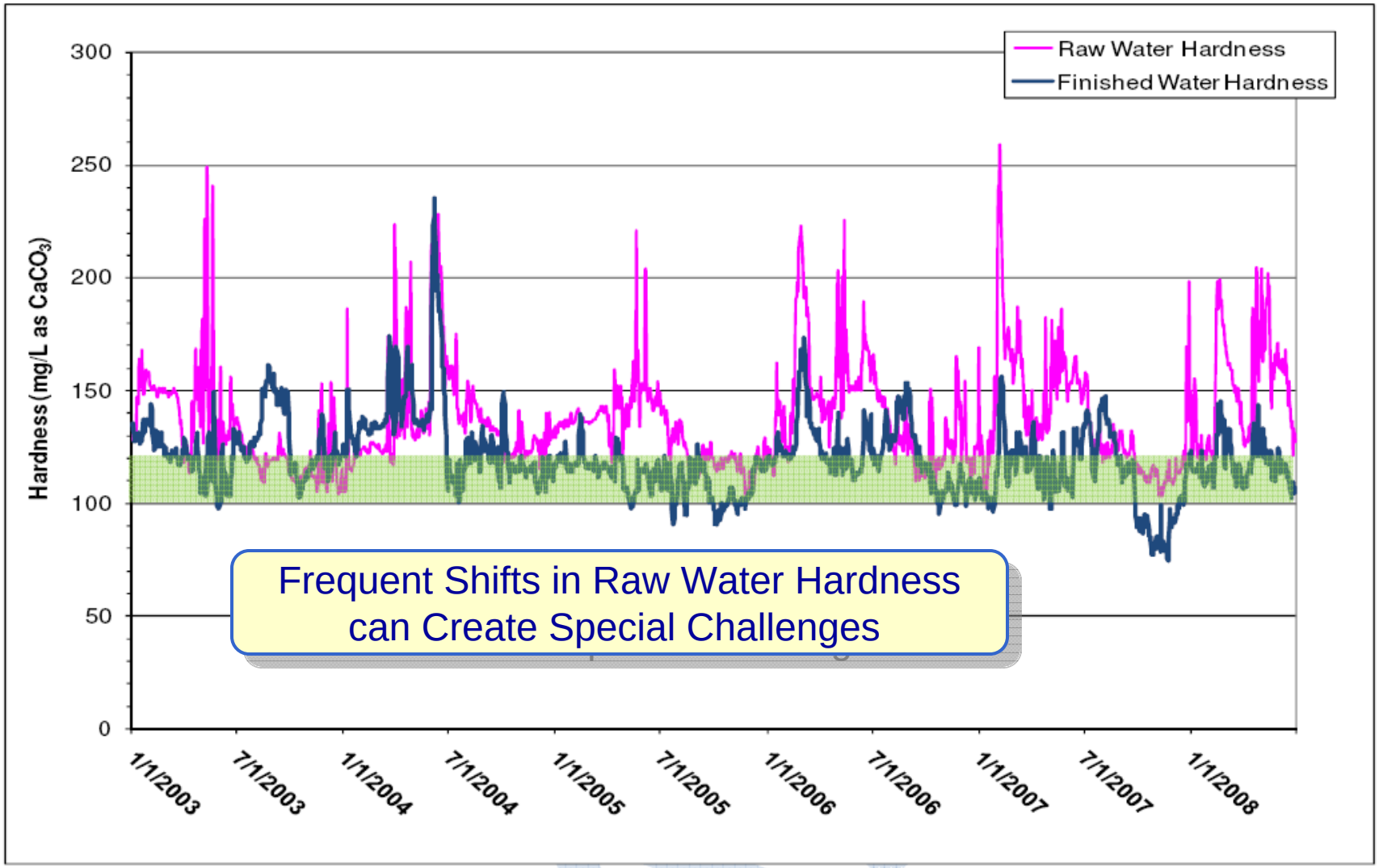
- CCT required by LCR, and to avoid:
  - AL exceedance/Public Education
  - LSL Replacement
- Maintain CCT effectiveness in conjunction with process modifications
- Address Fe/Mn/dirty water/aesthetics
- Mitigate/manage POTW Issues
  - Zinc
  - Phosphorus

Managing CCT is Frequently about Consistency

- pH, alkalinity, orthophosphate, ORP, NOM, TDS, nitrifying bacteria, etc. etc.
- Solubility (Pb, Cu, Ca, Cd, ?)
- Scale "Stability"
  - Deposition, permeability and scale hardness

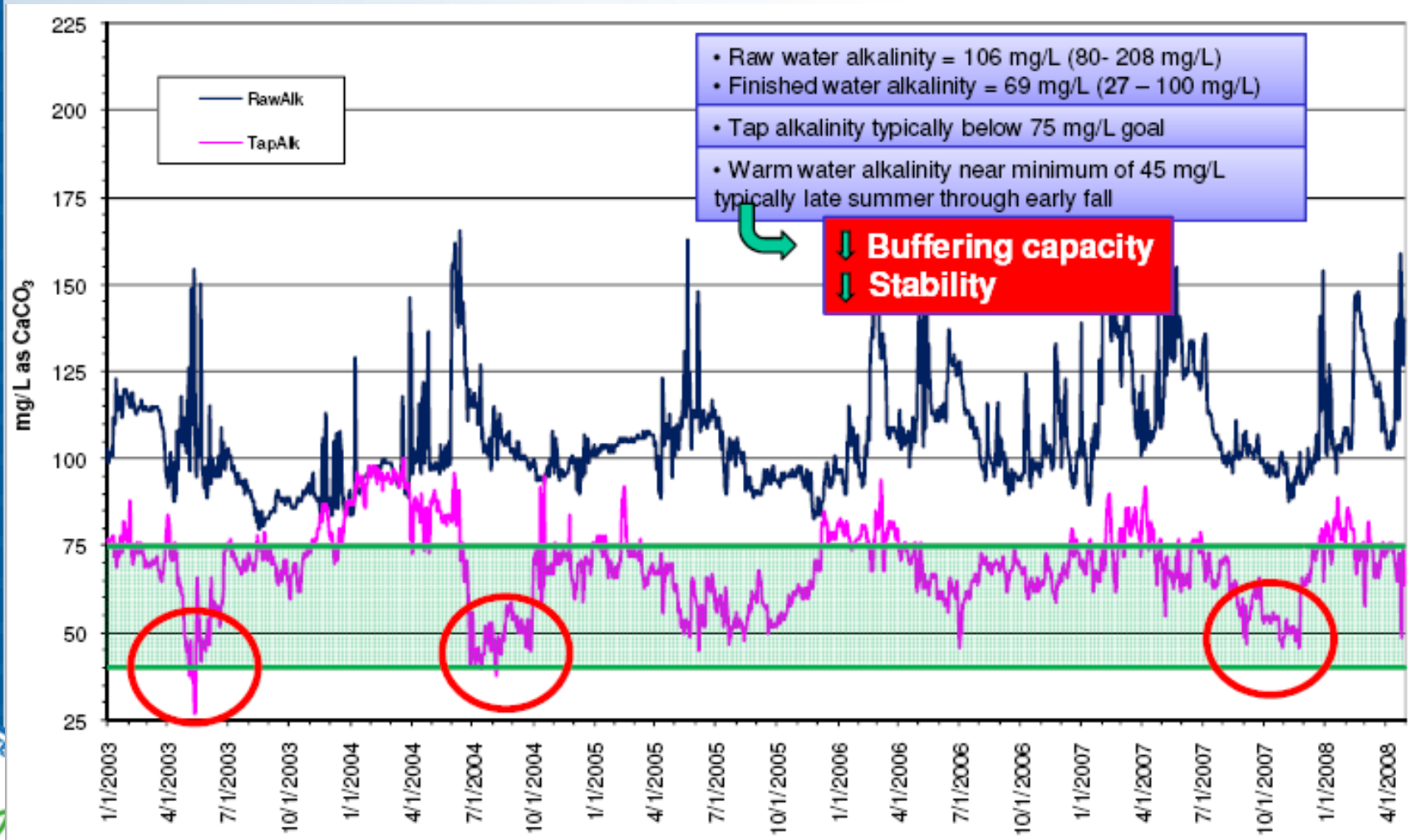
Poor Scale Stability → Particulates → Higher Tap Lead Levels

Bay City, MI



Frequent Shifts in Raw Water Hardness can Create Special Challenges

Bay City Carbonate Stability

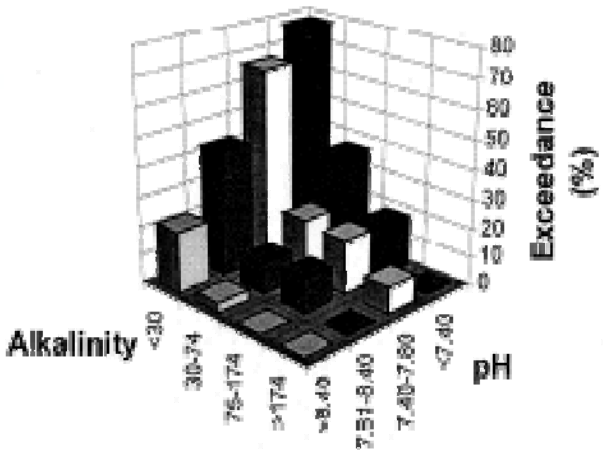


LCR CCT Re-Optimization
Overcoming Compliance Challenges

- Maintaining consistent target pH/alkalinity to minimize Pb/Cu and promote scale stability
- Optimum CCT pH may not be optimum for secondary disinfection
- ORP shifts related to disinfectant chemical changes may impact lead solids in home plumbing

LCR CCT Re-Optimization
Overcoming Compliance Challenges

- Update CCT studies
  - Desktop
  - Bench scale CCT study
  - Pilot scale CCT study (1-2 years)



- Maintain Cl:SO4 ratio <0.6
- Consider secondary constraints:
  - red water / “dirty water” / aesthetics
- Recognize WWTP impacts (P, Zn)

Some Specific Changes

Distribution System O&M Practices

Distribution system operational changes also have the potential to impact compliance

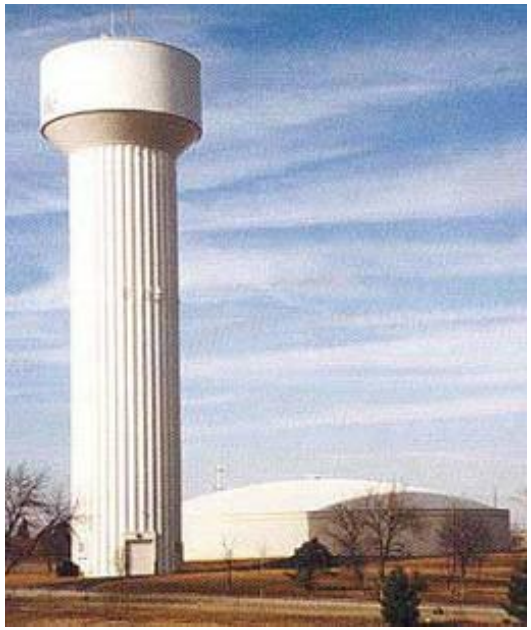
- Cross connection control programs are mandatory in most states
- Operational practices can increase/decrease water age, which impacts:
  - Secondary disinfectant residual
  - DBP formation
- Storage tank O&M can influence microbiology and water age
- Flushing programs can improve disinfection and aesthetics
- Meter change-out programs and LSL Replacement under LCR can introduce particulates into service lines

Why might GW Utilities Implement Distribution System Changes?

- Improve primary disinfection
- Increase disinfectant residual in periphery of system
- Reduce water age to lower DBP formation
- Help maintain stable water quality
- GWR other significant deficiencies Reduce nitrification / regrowth

Distribution System O&M Changes Possible Conflicts/Challenges

- Negative impact on CCT effectiveness
- Nitrification/regrowth spikes
- Release/re-suspension of sediments
- Dirty water complaints
- Reduced storage for emergencies (e.g., fire protection)



Wrap-Up

SDWA Primacy Agencies Need to Anticipate Interactions/Conflicts/Challenges

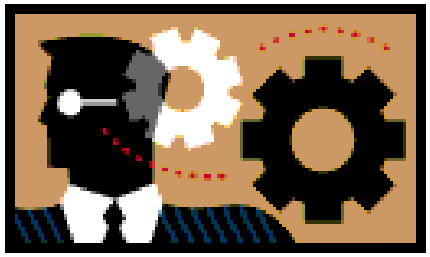
- Direct SDWA-driven Rule conflicts
- Treatment process interactions/impacts
  - Disinfection
  - Oxidation/aeration
  - Softening
  - GAC Adsorption
  - Residuals production
- Distribution system impacts
  - Microbial/regrowth
  - Chemistry/Corrosion/Pipe-scale
  - Secondary/Aesthetics/O&M practices

ID possible solutions

Recognize Potential Issues

Screen Alternatives

Collect Site-specific Data



PWS Will Look to Primacy Agencies for Advice about "Change Impacts" on:

- Primary and secondary WQ goals
- Compatibility/interactions with existing unit process operations
- Compatibility with distribution system operations
- CCT Impacts
- Overall facility capacity
  - Design standards; redundancy, reliability
- Consecutive system requirements

Numerous and Subtle *Secondary Impacts* Increasingly Constrain Water System Operations

Hardness
Taste & Odor
Iron/manganese
"Dirty Water"
Degradation of Filter Performance

Scale Stability & Metals Release
Nutrients and Regrowth Problems
Residuals Issues (As, Rads)
WWTP conflicts

Blending of source/finished waters
Changes in flow, direction and pressure
Cross connection control
Flushing and other maintenance activities

Take Away

- GWR > More sanitary surveys for all GW systems
- Numerous GW systems without resources to assess simultaneous compliance issues
- GW systems need help to recognize and assess <u>changes</u> which impact:
  - *source of supply*
  - *water quality performance*
  - *treatment process effectiveness*
  - *distribution system pH, disinfectant concentrations*
  - *corrosion control treatment*
- Utility compliance responses are sometimes constrained by “aesthetics/secondary” issues
- Many technical resources are available

Resources

- USEPA. November 2008. Ground Water Rule Corrective Actions Guidance Manual. EPA 815-R-08-011
- USEPA. October 2008. Sanitary Survey Guidance Manual for Ground Water Systems
- USEPA. January 2009. Ground Water Rule (GWR) Implementation Guidance
- USEPA. March 2007. Simultaneous Compliance Guide for the Long Term 2 and Stage 2 DBP Rules. EPA 815-R-07-017
- 1999. Microbial and Disinfection Byproduct Rules Simultaneous Compliance Manual. EPA 815-R-99-015
- WRF "Balancing Multiple Water Quality Objectives," 1998.
- WRF 3115 "Simultaneous Compliance Tool" 2009
- AWWA "*Managing Lead and Copper Rule Corrosion Control Practices to Avoid Unintended Consequences*"

Discussion

Q&A