CITY OF WADSWORTH
SINCE 1814
WATER & WASTE WATER DISTRIBUTION

OPTIMIZATION OF LIME –SOFTENING PROCESS AT WADSWORTH WTP

OPERATOR TRAINING COMMITTEE OF OHIO, INC.

PROCRASTINATORS WORKSHOP

December 11, 2014

OTCO 1964 50 Years 2014

BURGESS & NIPLE

CELEBRATING 100 YEARS 1912 ~ 2012

Agenda

CITY OF WADSWORTH
SINCE 1814
WATER & WASTE WATER DISTRIBUTION

- Plant Overview
- Plant Process Description
- Water Quality Data
- Hardness Removal Chemistry
- Recarbonation Systems
- Chemical Optimization Study
- Recommended Improvement Plan
- Alternatives
- Lessons Learned
- Questions

Wadsworth Water Quality Data 2013

CITY OF WADSWORTH SINCE 1814
WATER & WASTE WATER DISTRIBUTION

	Plant Tap										Distribution System		
	pH	P Alk	Tot Alk	Total Hardness	Ca	Mg	$CaCO_3$ Stability	Free Cl_2	Total CL_2	Fl	Free Cl	Tot Cl	Fl
Max.	8.1	0	88	223	127	96	0	1.2	1.4	1.03	0.9	1.1	1.00
Min.	7.9	0	69	186	117	91	0	1.0	1.1	0.91	0.7	0.8	0.90
AVG.	8.1	0	81	208	122	94	0	1.1	1.2	0.96	0.8	0.9	0.95

Purpose of the Study to Optimize Hardness Removal

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Water Well Information

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WATER & WASTE WATER DISTRIBUTION

Well #	2	3	4	7A	9	10A	11	12	13	14	15	19
Depth, Feet	275	275	275	275	275	275	275	275	275	275	275	275
Capacity, GPM	300	250	360	195	390	245	335	250	300	240	300	700

Notes:

1. #16 used as monitoring well.
2. Wells #7A & #9 cannot run at the same time.
3. Wells #11 & #12 cannot run at the same time unless it is an emergency.

Average Annual Daily Flow Rates

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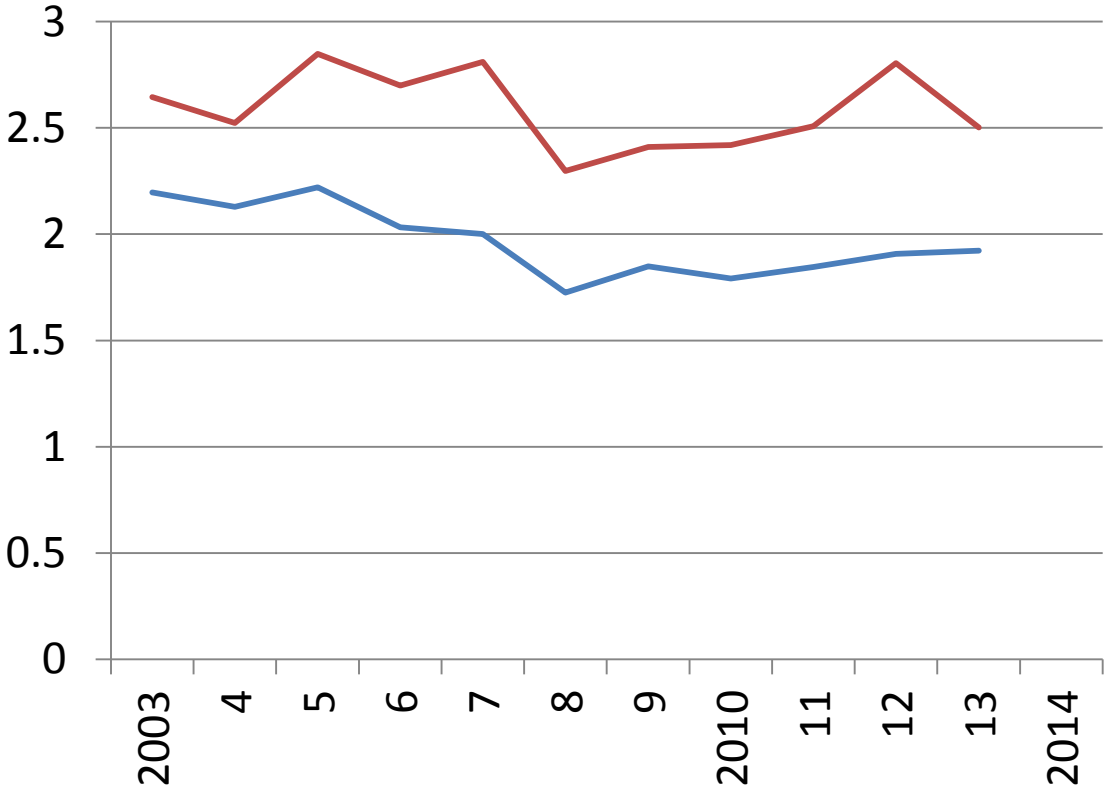
WATER & WASTE WATER DISTRIBUTION



Peak Day Factor
Max Flow: Avg. Flow = 1.3

Annual Average Daily Flow, MGD

Annual Max Daily Flow, MGD

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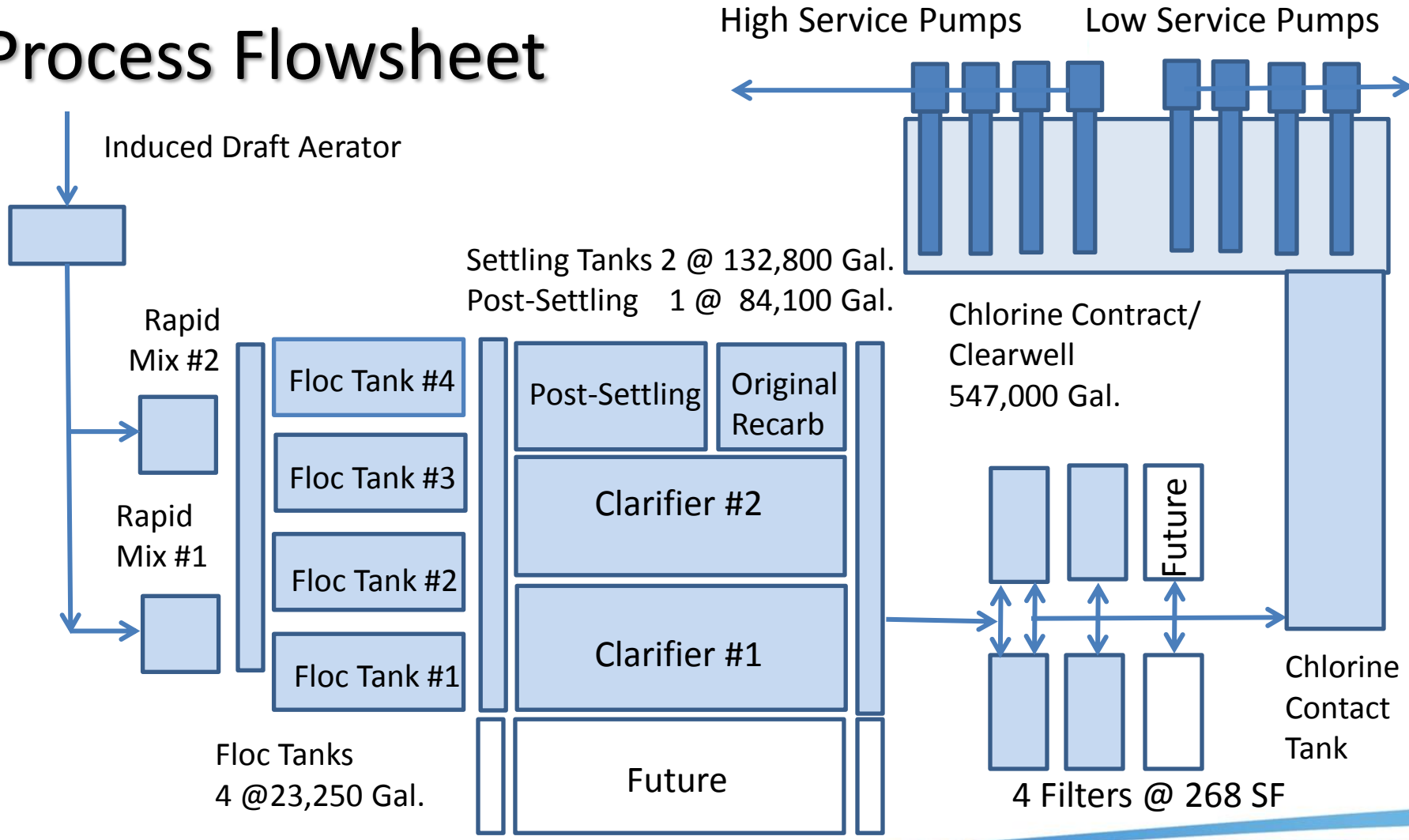
Process Flowsheet



INDUCED DRAFT AERATOR

CITY OF WADSWORTH SINCE 1814
WATER & WASTE WATER DISTRIBUTION

- Oxidation of Iron and Manganese
- Reaction Basin: 64,000 gallons
- Detention Time: 20 Min. @4.6 MGD
- Plant Design Capacity; 3 MGD
- Peak Hourly Flow 3.3 MGD
- Peak Day Capacity 4.5 MGD
- Treatment to Reduce Hardness
  - Lime Feed to Precipitate Ca++ and Mn++ at pH 8.9
  - No pH Re-adjustment
  - Chlorination
  - Flouridation

Flash Mix

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WATER & WASTE WATER DISTRIBUTION

- Two (2) units each:
  - 2 HP Mixer
  - 5.5’ x5.5’ x 5.5’ SWD
  - 166.4 CF 1,244 Gallons
  - Detention Time:
    - 60 sec Min Required
    - 72 sec @ 3.0 MGD

FLoculation

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WATER & WASTE WATER DISTRIBUTION

- Four (4) tanks each:
  - 2 HP Mixer
  - 33.0’ x 9.42’ x 12’ SWD
  - 3730.3 CF
  - 27,903 Gallons Each
  - 111,611 Gallons Total
  - Detention Time:
    - 53.6 Minutes (4 in service)

Settling Basins

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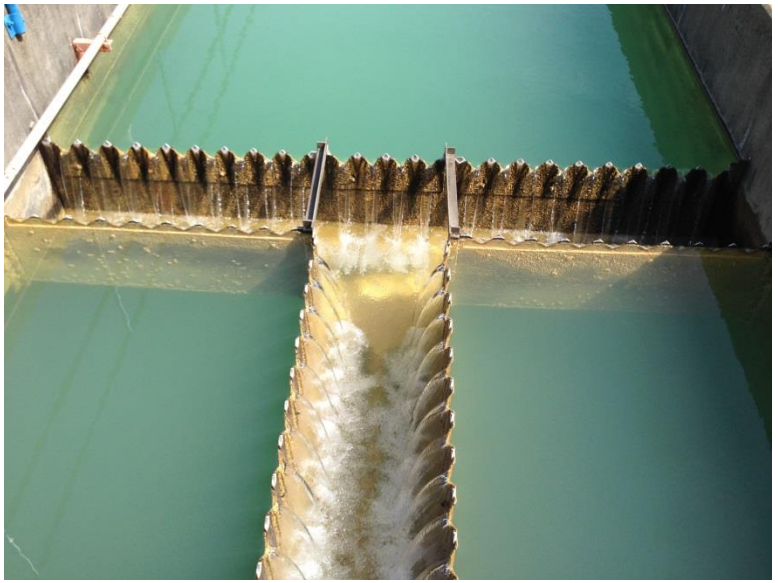
SINCE 1814
WATER & WASTE WATER DISTRIBUTION

- Two (2) tanks each:
  - 88.5’ x 20.0’ x 12’ SWD
  - 21,240 CF
  - 158,875 Gallons Each
  - 317,750 Gallons Total
  - Detention Time:
    - 2.54 Hours (2 @ 3 MGD)

Existing Recarb & Post Settling Basin

- Post Settling Basin (1 Each):
  - 76.0’ x 14.83’ x 12’ SWD
  - 13,525 CF
  - 101,167 Gallons Each
  - 418,917 Gallons Total
  - Detention Time:
    - 0.81 Hours (Post Settling Tank only)
    - 3.35 Hours (2 Settling & 1 Post Settling Tanks in Service)



Chemical Feed:

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WATER & WASTE WATER DISTRIBUTION

- Zinc Orthophosphate

- Chlorine Feed

Sand Filters

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WATER & WASTE WATER DISTRIBUTION

- 4 Filters each:
  - 16.5’ x 16’
  - Dual Media
  - 268 SF Each (Typical 4)
- Loadings w/1 Filter Out of Service
  - 804 SF
  - 3.48 MGD @ 3 gpm/sf
  - 4.63 MGD @ 4 gpm/sf
- Filters Rebuilt in 2013-14

High Service Pump Station

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- **High Service Pumps:**
  - 3 @ 1,400 gpm
  - 1 @ 2,000 gpm
  - Max. Hydraulic Pumping Rate:
    - 2,800 GPM
    - 4.00 MGD
- **Low Service Pumps:**
  - 3 @ 1,500 gpm
  - 1 @ 2,000 gpm
  - Max. Hydraulic Pumping Rate :
    - 1,800 GPM
    - 1.87 MGD

CLEARWELL CAPACITY = 0.547 MG

Hardness Classification

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WATER & WASTE WATER DISTRIBUTION

- Hardness Classification Scale:
  - 0 – 75 mg/L as $CaCO_3$: Soft
  - 75 – 150 mg/L as $CaCO_3$: Moderately Hard ***Goal***
  - 150 – 300 mg/L as $CaCO_3$: Hard ***Current Condition***
  - > 300 mg/L as $CaCO_3$: Very Hard

Wadsworth Water Quality Data 2013

CITY OF WADSWORTH SINCE 1814
WATER & WASTE WATER DISTRIBUTION

	Plant Tap										Distribution System		
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AVG.	8.0	0	79	216	122	94	0	1.1	1.2	0.97	0.8	0.9	0.95

Purpose of the Study to Optimize Hardness Removal

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Hardness of Tap Water

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WATER & WASTE WATER DISTRIBUTION

- Total Hardness:
  - Calcium + Magnesium

    = 122 mg/l + 94 mg/l = 216 mg/l
- Carbonate Hardness:
  - Alkalinity

    = 79 mg/l
- Non-Carbonate Hardness:
  - Total Hardness – Carbonate Hardness

    = 216 mg/l - 79 mg/l = 137 mg/l

Goals:

Calcium	*80 mg/l*
Magnesium	*40 mg/l*
Total Hardness	*150 mg/l*

Non-Carbonate Hardness can only be removed: by lime & soda ash

- Calcium Sulfate: $CaSO_4$
- Calcium Chloride: $CaCl_2$
- Magnesium Sulfate: $MgSO_4$
- Magnesium Chloride: $MgCl_2$

Influent Water Quality

Composite Wells Raw and Post-Aerator

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WATER & WASTE WATER DISTRIBUTION

	Wells #	Total Alk	Total Hard-ness	Non-Carb Hardness	Calcium Hard-ness	Mag Hard-ness	Iron	Mn	TDS	pH	CO2
Raw 10/1/14	15-19	196	336	140	230	106	7.76	0.56	430	7.2	28.62
Aerator 10/1/14	15-19	176	338	162	230	108	5.70	0.56	430	7.3	25.7
Raw 10/2/14	3-10-12-14-19	209	310	101	204	106	4.20	0.34	340	7.3	30.51
Aerator 10/2/14	3-10-12-14-19	194	330	136	208	122	3.30	0.33	500	7.6	11.25
Raw 10/9/14	4-11-13-15	192	302	110	200	102	8.30	0.67	440	7.2	28.02
Aerator 10/9/14	4-11-13-15	170	318	148	224	94	6.70	0.63	430	6.9	39.44

Secondary Limits:

- **Iron = 0.30 mg/l (99.65% Removal)**
- **Manganese = 0.05 mg/l (99.25% Removal)**

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Secondary OEPA Standards

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WATER & WASTE WATER DISTRIBUTION

- Aesthetic
  - Standards related to color:
    - Aluminum, Color, Copper, Foaming Agents, Iron, Manganese, Total Dissolved Solids
  - Standards related to odor and taste:
    - Chloride, Copper, Foaming Agents, Iron, Manganese pH, Sulfate, Threshold Odor Number (TON), Total Dissolved Solids, Zinc
- Cosmetic
  - Silver and Fluoride
- Technical
  - Standards related to corrosion and staining:
    - Chloride, Copper, Corrosivity, Iron, Manganese, pH, Total Dissolved Solids, Zinc
  - Standards related to scale and sediments:
    - Iron, pH, Total Dissolved Solids, Aluminum.

Secondary Drinking Water Regulations:

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WATER & WASTE WATER DISTRIBUTION

Contaminant	Secondary MCL	Noticeable Effects above the Secondary MCL
Aluminum	0.05 - 0.2 mg/L*	colored water
Chloride	250 mg/L	salty taste
Corrosivity	Non-corrosive	metallic taste; corroded pipes/ fixtures staining
Fluoride	2.0 mg/L	tooth discoloration
Iron	0.3 mg/L	rusty color; sediment; metallic taste; reddish or orange staining
Manganese	0.05 mg/L	black to brown color; black staining; bitter metallic taste
pH	6.5 - 8.5	low pH: bitter metallic taste; corrosion high pH: slippery feel; deposits
Sulfate	250 mg/L	salty taste
Total Dissolved Solids (TDS)	500 mg/L	hardness; deposits; colored water; staining; salty taste
Zinc	5 mg/L	metallic taste
*mg/L is milligrams of substance per liter of water.		

Hardness Removal

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- Most chemical forms of hardness are water soluble, except:
- Exceptions: Calcium Carbonate & Magnesium Hydroxide removed by precipitation
- Lime softening removes only carbonate hardness
  - Calcium Carbonates [$CaCO_{3]}$ & Calcium Bicarbonates [$Ca(HCO_3)_{2]}$
  - Magnesium Carbonates [$CaCO_{3}$}and Mg Bicarbonates $Mg(HCO_3)_2$
- ***Lime & Soda Ash softening required to remove non-carbonate hardness***

Hardness due to Anions:

- **Bicarbonate (HCO_3^-)**
- **Carbonate (CO_3^{2-})**
- **Sulfate (SO_4^{2-})**
- **Chloride (Cl^-)**
- **Nitrate (NO_3^-)**
- **Silica (SiO_3^{2-})**

- Chloride: $MgCl_2$
- Calcium Sulfate: $CaSO_4$
- Calcium Chloride: $CaCl_2$
- Magnesium Sulfate: $MgSO_4$
- Magnesium Chloride: $MgCl_2$

Alkalinity and pH

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WATER & WASTE WATER DISTRIBUTION

- **Alkalinity = Measure of the acid neutralizing capacity of water**

- **Forms:**
  - Bicarbonate
  - Carbonate
  - Hydroxide

- **Total Alkalinity = [Bicarbonate] + [Carbonate] + [Hydroxide]** expressed in mg/L as calcium carbonate

Lime Required for Removal of Carbonate Hardness and Magnesium

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- CaO (lb/mil gal) =
  = 10.6 lbs./MG x CO_2 (mg/L as CO_2)
  + 4.7 [Alkalinity (mg/L as $CaCO_3$)
  + Mg hardness (mg/L as $CaCO_3$)
  + required excess hydroxide alkalinity as $CaCO_3$ (typically 30 -70 mg/l)]
- CaO x MGD = CaO/divided by 0.88 to 0.95 (actual chemical purity of CaO)
- $CaO_{Total/MGD}$ Required x 3 MGD) =
- $CaO_{Total/MGD}$ x 3 MGD /.90 purity = Required Daily Usage

Acid Feed for Neutralization

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- CO2 offers safer and more robust system over acids as shown in Table 1:
- Final pH should be selected by looking at scaling indices:
  - Langlier index
  - CCPP (Calcium Carbonate Precipitation Potential)
  - Ryznar index
  - Lead solubility

Table 1: Comparison of chemicals for pH control at water treatment plant

	CO_2	H_2SO_4	HCl
Safety	●	◔	◔
Permit for use	●	◑	◑
Availability	◕	●	●
Price Variability	●	◑	◑
Ease of Storage	●	◔	◔
System Maintenance	●	◔	◔
Environment-friendliness	●	◔	◔
Process Control	●	●	●
Effect of Overdosing	●	◔	◔
Cost of Implementation	◕	●	●
Limitations for Use	◑	◕	◕

Recarbonation Chemistry

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WATER & WASTE WATER DISTRIBUTION

- The effluent from lime softening process is supersaturated with carbonates at high pHs (10 or greater) and it is necessary to stabilize the water to prevent deposition of a hard carbonate scale on the piping and filters.
- Lime Softening

  $Ca(HCO_3)_2 + Ca(OH)_2 \rightarrow 2CaCO_3 + 2H_2O$

  $Mg(HCO_3)_2 + 2Ca(OH)_2 \rightarrow Mg(OH)_2 + CaCO_3 + 2H_2O$
- Recarbonation

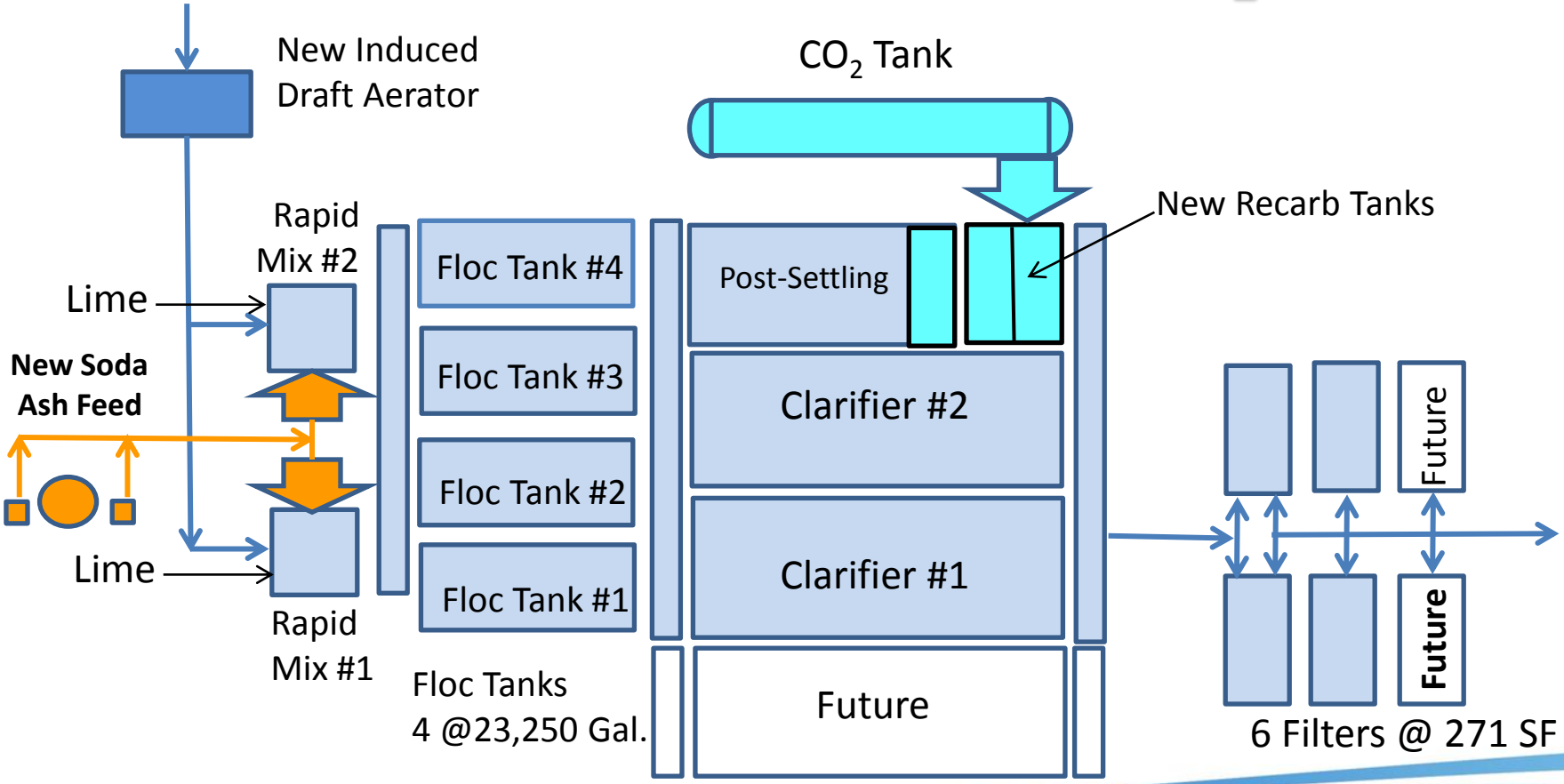
  $CaCO_3 + CO_2 + H_2O \rightarrow Ca(HCO_3)_2$

  $Mg(OH)_2 + CO_2 \rightarrow MgCO_3 + H_2O$

Process Flowsheet
Soda Ash & Recarbonation with CO_2

High Service Pumps Low Service Pumps

WADSWORTH SINCE 1914
WATER & WASTE WATER DISTRIBUTION



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Carbonate Forms vs. pH

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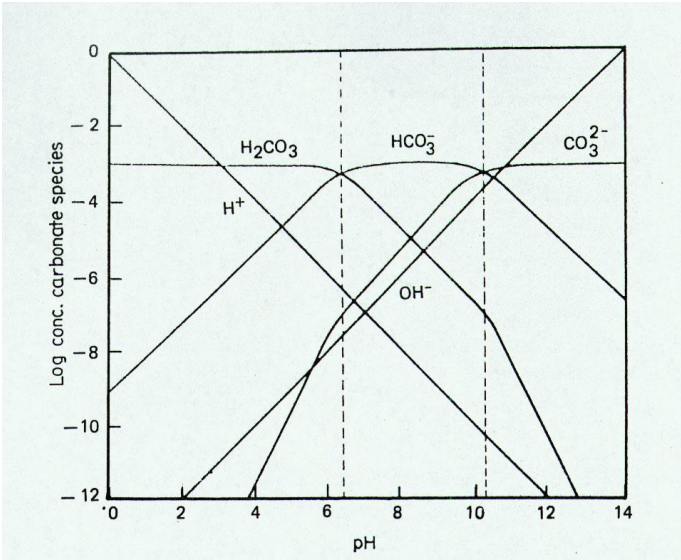
WATER & WASTE WATER DISTRIBUTION

- The effluent from lime softening process is supersaturated with carbonates at high pHs (10 or greater) and it is necessary to stabilize the water to prevent deposition of a hard carbonate scale on the piping and filters.
- pH lowered to below pH of 9.5 and dissolve the CaCO3 into bicarbonate form.
- CO2 Usage
  - Theoretical 330 lbs /MG
- Finished Water pH = 8.8 - 9.2 (Adjustable)



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CO2 Recarbonation Schematic

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WATER & WASTE WATER DISTRIBUTION

Gas Feed Systems Recommended Design Parameters

- Contact basins shall provide a minimum detention time 30 minutes, and
- Tank water depths greater than 15 feet to achieve 60 – 85% transfer efficiency.

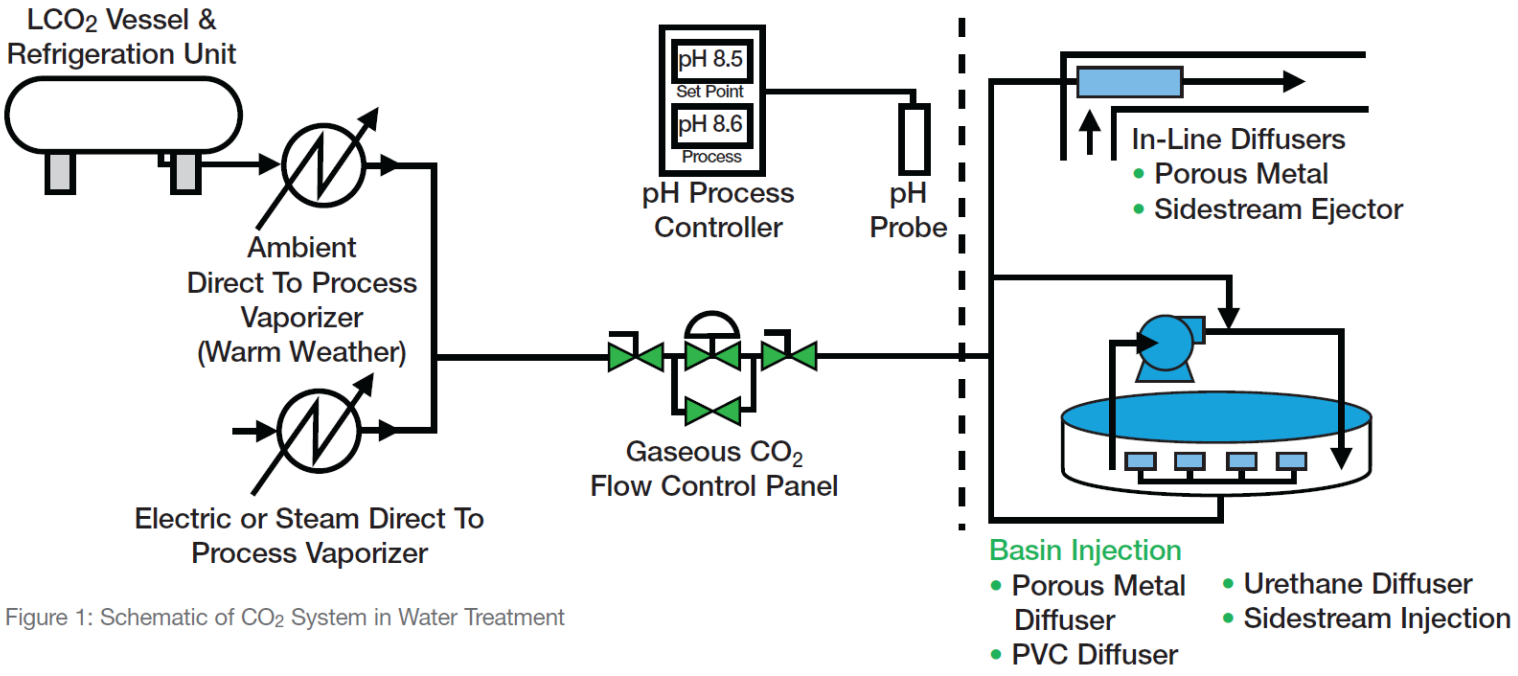

Figure 1: Schematic of CO_2 System in Water Treatment

Pressurized CO2 Feed System

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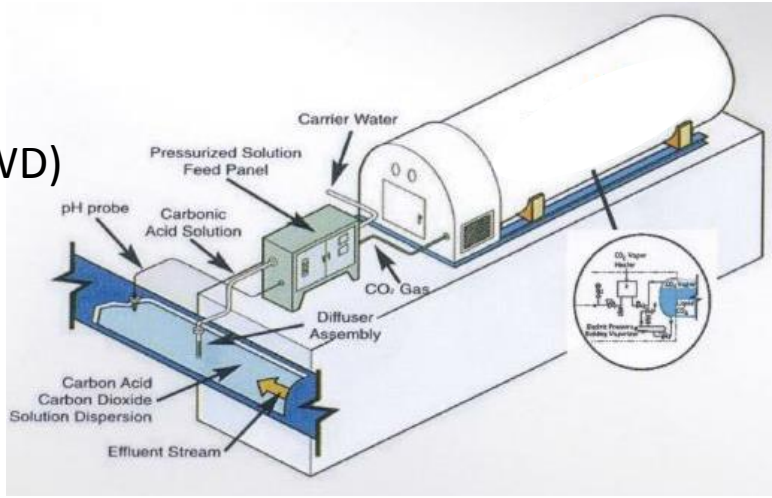
WATER & WASTE WATER DISTRIBUTION

- 99.9% of the chemical reaction has taken place within 3 minutes of the carbonic acid injection.
- **pH is controlled and the water is stabilized within this 3 minute period.**
- **Recarb Basin Basis of Design = 4.5 MGD x 1.33**
  - Flow = 6 MGD
  - Detention Time = 5 minutes (min.)
- **Existing Recarb Basin** (11.5’ x 14.83’ x 12’ SWD)
  - Capacity = 15,300 gallons
  - Detention Time (Ex. Recarb Tank) = 3.67 min.
- **Add Mix Chamber in Influent Channel**
  - 14.83’ x 5’ x 12’ SWD = 890 CF
  - Capacity = 6,655 gallon
  - Detention Time = @ 1.6 minutes



CO2 Storage Tank & Feed System

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Process Flowsheet
Soda Ash & Recarbonation with CO_2

High Service Pumps Low Service Pumps

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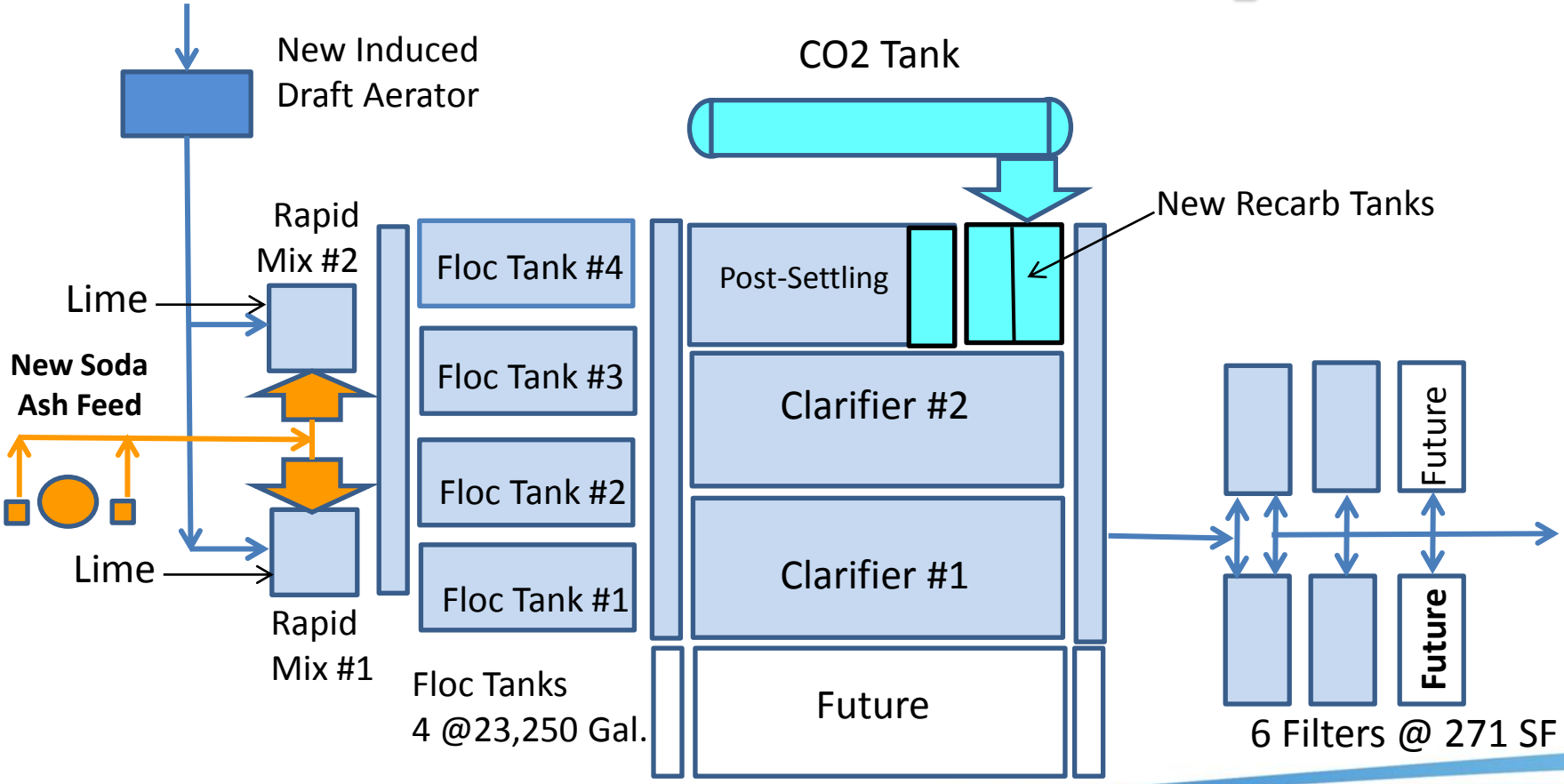
WATER & WASTE WATER DISTRIBUTION



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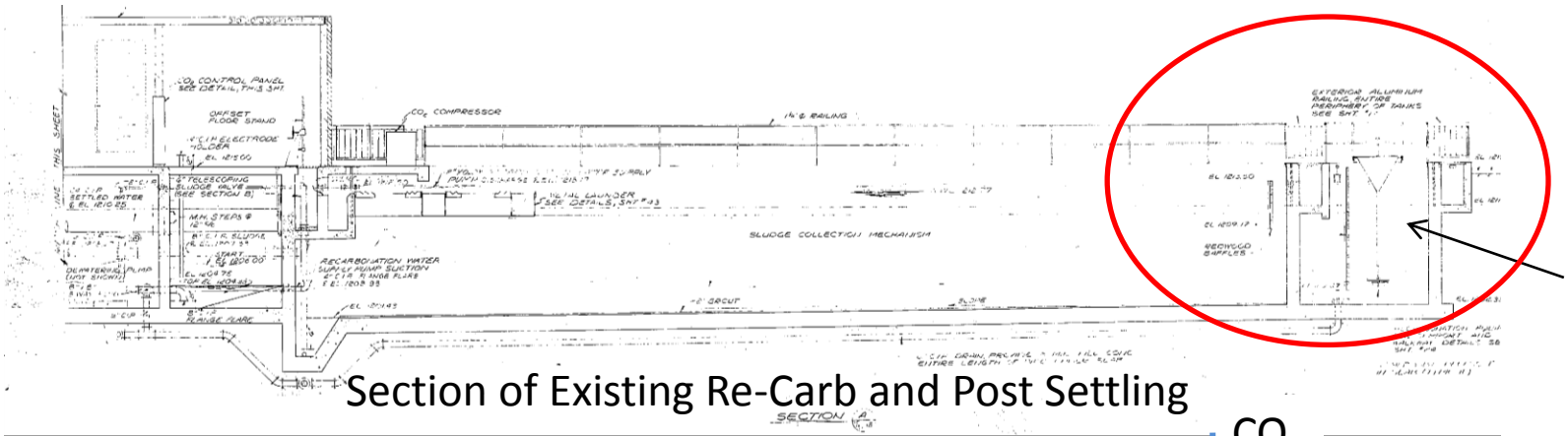
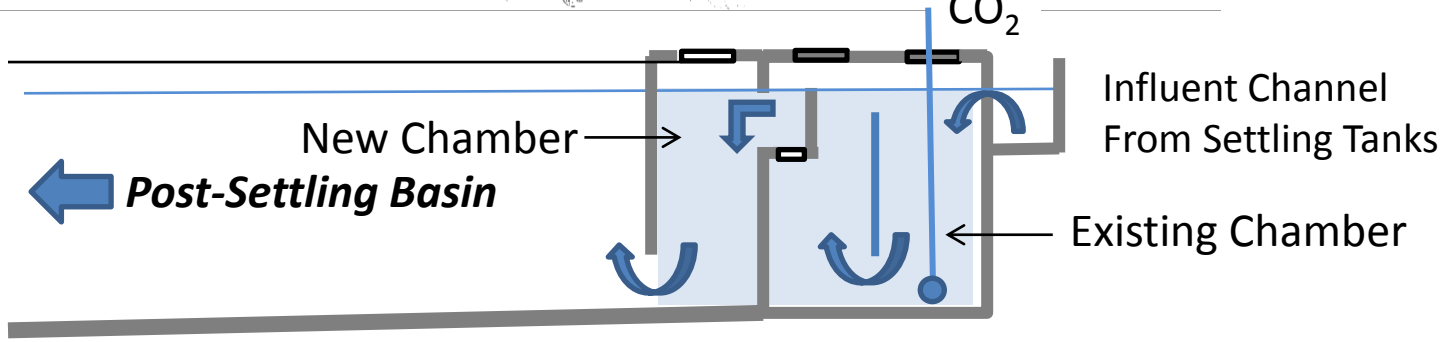


Section of Existing Re-Carb and Post Settling



New Pressurized Recarb Basin

Optimization for Hardness Removal

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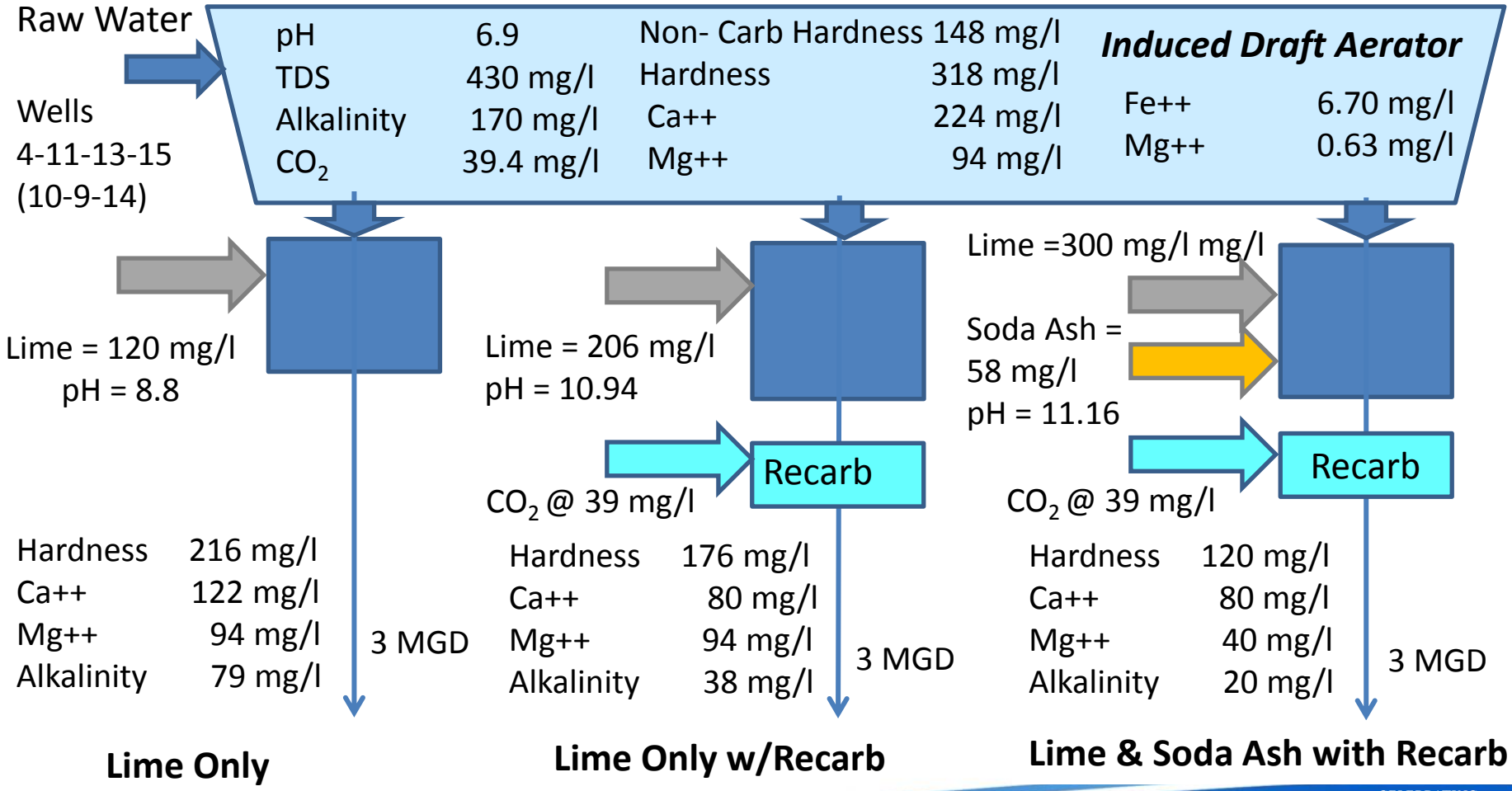

Sludge Production for Alternates

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Parameter		Lime w/o Recarb	Lime w/ Recarb	Lime & Soda Ash /w Recarb
pH		8.8	10.97	11.16
Magnesium Hydroxide	mg/l	0	0	38
	Lbs./MG	0	0	321
Calcium Carbonate	mg/l	284	338	442
	lbs./MG	2,380	2,831	3,685

Blending or Split Treatment W/O Soda Ash

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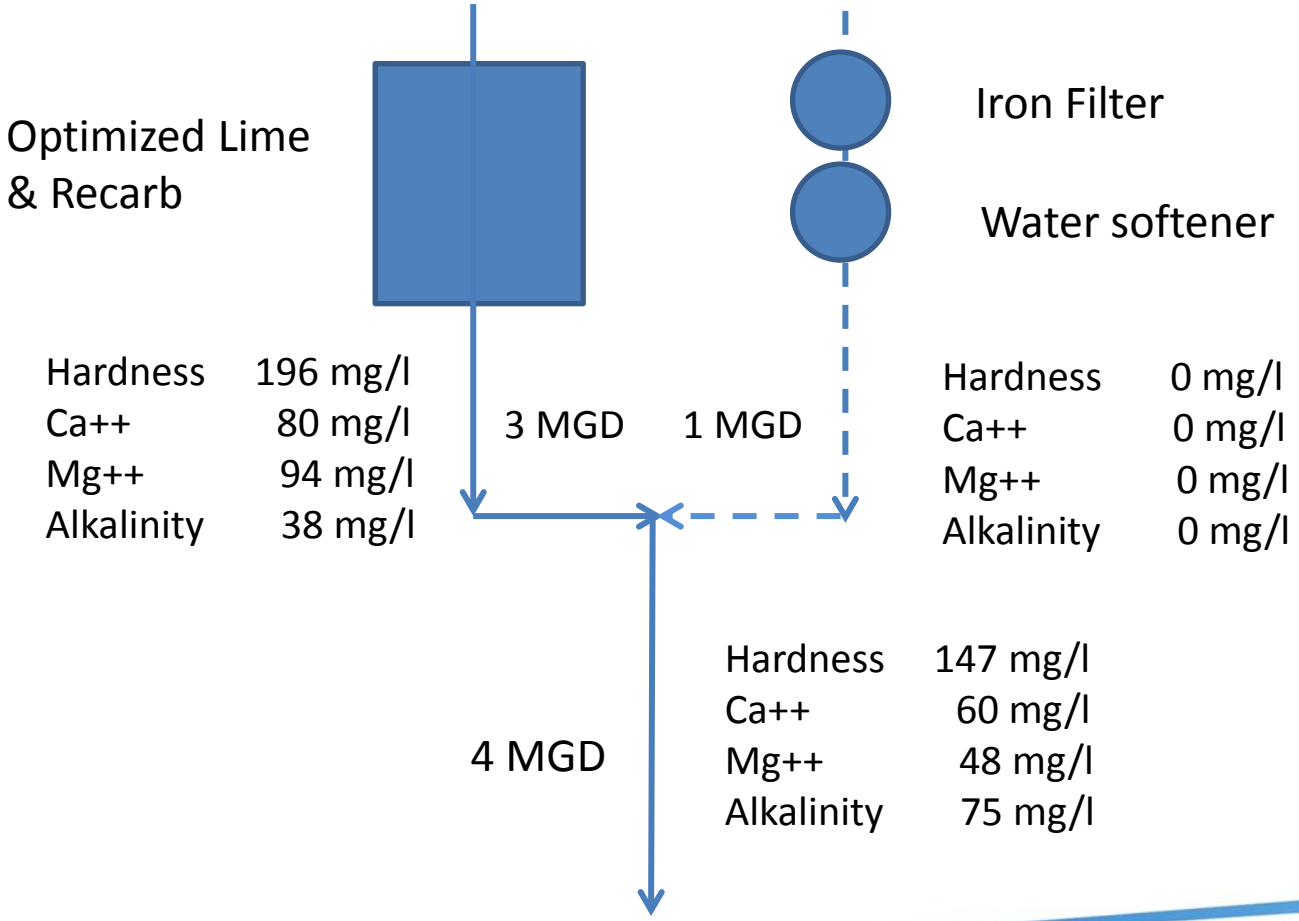

Pressure Filters and Softeners

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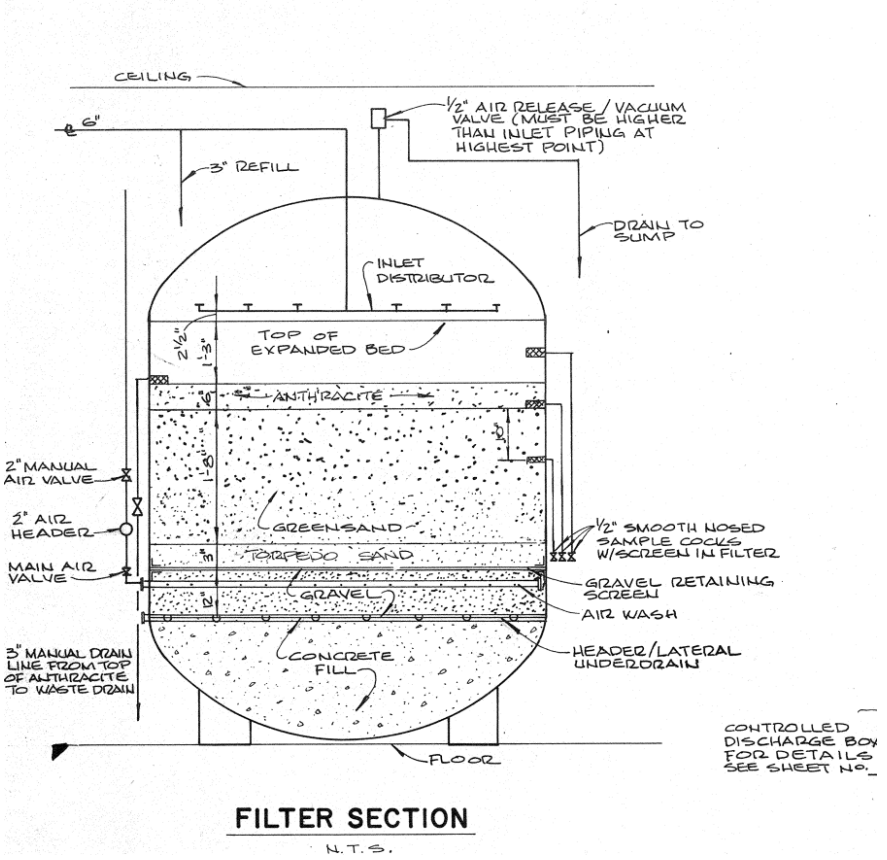

FILTER SECTION
N.T.S.

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Water Softeners

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Res-Kem GENERAL WATER

FEATURES AND SPECIFICATIONS

Model Prefix	Vessel Diameter inches	Flow Rate Range gpm	Resin Quantity cubic feet	Capacity Range grains		Inlet/Outlet Pipe Size Range inches	Brine Tank Diameter x Height inches	Approximate Dimensions L x D x H inches
ZSO-20	20	26-54	5-7	150,000	210,000	1 to 1 ½	24x54	56x32x94
ZSO-24	24	37-75	7-10	210,000	300,000	1 ½ to 2	24x54	60x36x94
ZSO-30	30	59-118	11-16	330,000	480,000	2 to 2 ½	30x60	72x42x98
ZSO-36	36	85-170	16-24	480,000	720,000	2 to 3	39x48	87x48x98
ZSO-42	42	115-230	21-32	630,000	960,000	2 ½ to 3	50x60	104x54x101
ZSO-48	48	150-225	28-42	840,000	1,260,000	2 ½ to 4	50x60	110x60x101
ZSO-54	54	190-380	36-53	1,080,000	1,590,000	3 to 4	60x46	126x66x110
ZSO-60	60	235-470	44-65	1,320,000	1,950,000	3 to 4	72x46	144x72x110
ZSO-66	66	285-570	53-79	1,590,000	2,370,000	3 to 4	72x46	150x78x110
ZSO-72	72	340-680	64-94	1,920,000	2,820,000	4 to 6	84x46	168x84x110
ZSO-78	78	400-795	75-111	2,250,000	3,330,000	4 to 6	Not Included	174x90x110
ZSO-84	84	460-925	87-128	2,610,000	3,840,000	4 to 6	Not Included	180x96x110

Specification Bases: (For your specific water source, contact Res-Kem for estimates)

Flow Rate Range: Minimum Flow 12 gpm/ft2 to Maximum Flow 24 gpm/ft2
Resin Quantity: Bed Depth 27 – 40 inches
Capacity Range: Regeneration Level is 15lbs NaCl /ft3

Area = 700 GPM/2 units
= 350 gpm/12 gpm/sf = 29.2 sf
Provide 3 - 72” Dia. (1 standby)

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Water Softener Regeneration

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Regeneration = 84” Dia. Bed Capacity/ Loading

$$= \frac{\text{2,400,000 Grains Hardness}}{\text{360 mg/l / 17.1 mg/l / grain}}$$

$$= \frac{\text{2,400,000 gr x 3 beds}}{\text{700 gpm x 21.05 gr/gallon}}$$

= 8.4 hours / bed @ 1 MGD flow

Stabilization for Corrosion Control

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WATER & WASTE WATER DISTRIBUTION

STABILIZATION
Process of making water less corrosive and less depositing

- Increasing Ca hardness, alkalinity or pH:
  - Increase scaling and decrease corrosive tendency
- Increasing temperature:
  - Increase scaling and corrosive tendency
- TDS can affect scaling and corrosivity
- Caustic soda is commonly used as an acidity buffer
- Unstable water: red water, lead and copper corrosion problems
- Orthophosphates, silicates used to prevent lead & copper corrosion, sequester Ca & carbonate
- CCPP: Calcium Carbonate Precipitation Potential

Conclusions

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- Assess variability in raw water quality analysis and water demand.
- Assess impact of process improvements for aeration, mixing, settling, recarb, filters, chemical feed, and solids handling.
- Establish effluent water quality goals.
- Establish EPA rules and water quality standards.
- Evaluate options and improvements needed to meet goals.
- Estimate any additional O&M costs or savings.
- Prepare Capital Improvement Plan with prioritized improvement plan, budgetary costs, impact on rates, and funding sources.

Thank You!

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Any Questions?

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