GA Summit

Technologies For Industrial Water Reuse

Presented by

GE
Water & Process Technologies

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Agenda: Track A
Technologies for Industrial Water Reuse

- Overview - Reduce/Reuse/Recycle — Bob Hultz
- Water savings strategies — Rick Krichten, Paul DiFranco, Ed Greenwood
- Case Study - Michelin Cooling Water — George Harrison
- Q & A – Panel Discussion

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Experts Panel
Technologies for Industrial Water Reuse

- **Bob Hultz – GEWPT General Manager Southern Region – Panel Moderator**

- **Rick Krichten – GEWPT Utilities Project Manager**

His areas of specialization include statistical analysis, 6-Sigma trained; heat and material balances; water systems design and troubleshooting (boiler, cooling, influent, wastewater); heat transfer efficiency; cold lime softening; project financial analysis, NPV; water reuse, recycle, and Zero-Liquid Discharge (ZLD). BS ChemEng, MBA

- **Ed Greenwood – GEWPT Regional Sales Manager, GEZenon Membrane Solutions**

Has direct process application and design experience with multiple water and wastewater treatment processes. His extensive background includes work experience in multiple industries including power generation; petrochemical; pharmaceutical; semiconductor; pulp and paper; food processing; oil and gas production; oil refining and municipal water treatment. He holds a Bachelor's degree in Chemical Engineering.

Experts Panel
Technologies for Industrial Water Reuse

- **Paul DiFranco – GEWPT Senior Cooling Technical Advisor**

Held various positions within the Technical R&D, Marketing/ Technical Support functions including Engineering Manager for HPI & CPI water treatment chemicals and Regional Cooling Marketing Manager for South America, based out of Cotia, Brazil.

- **Gary Brown – GEWPT Sales Manager – Southern Region Capital Equip.**

Plant Manager of multiple chemical manufacturing facilities, Global quality and manufacturing experience, RSE or account manager, experience working with chemical, power, steel, water processing equipment which includes multi media filtration, softeners, reverse osmosis, EDI, ion exchange and experience in ultrafiltration.

Experience utilizing mobile filtration, ion exchange and reverse osmosis for various industries.

Experience in the facilitation of outsourcing water treatment systems for various industries.

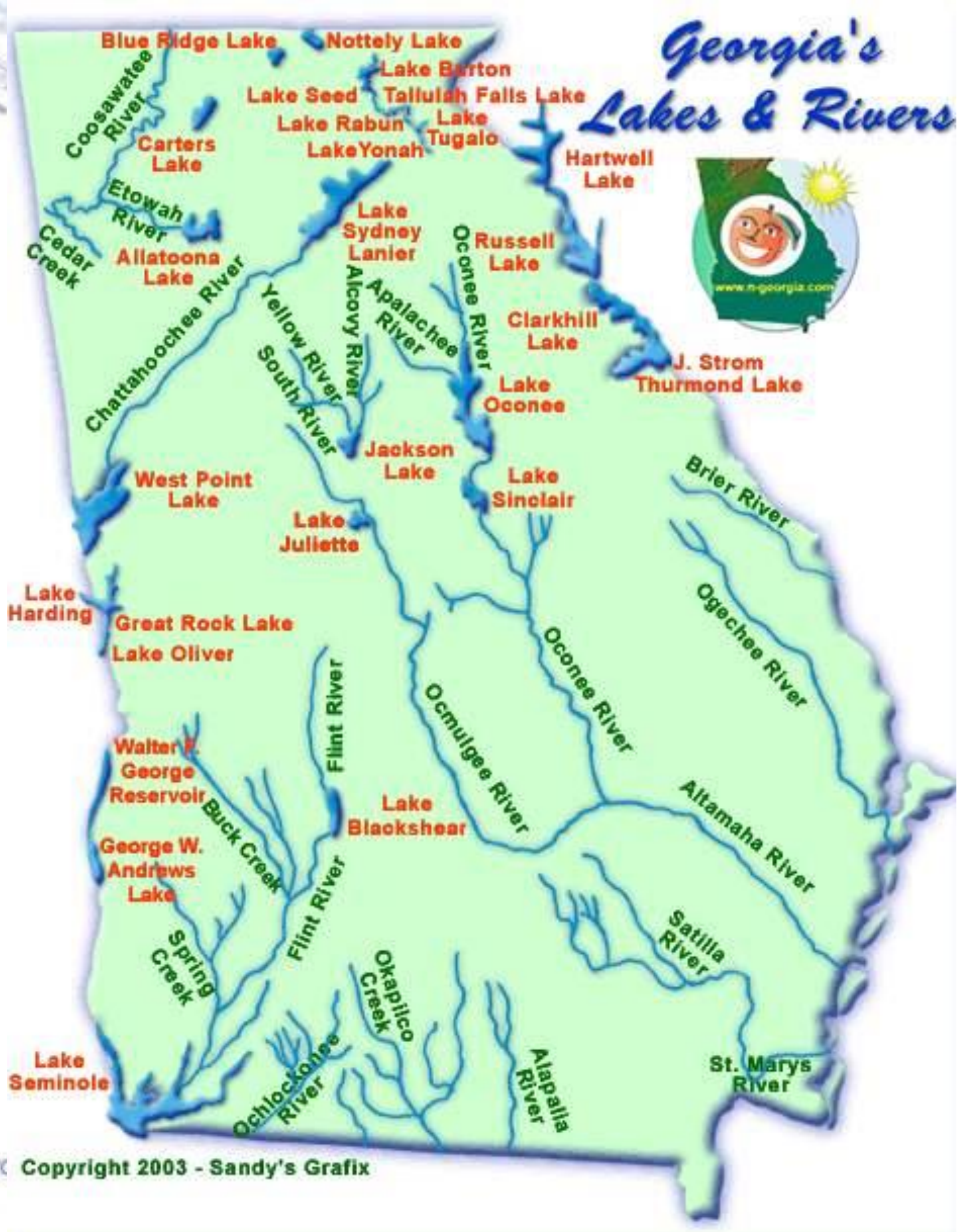
Session Objective

To provide practical ideas utilizing process equipment & treatment chemistries to take back to your industrial plants/companies to help reduce water consumption and create new sustainable sources of water through reduce/recover/recycle

Tuesday, October 23, 2007…….

Governor Perdue Orders Utilities, Permit Holders to Reduce Water Use by 10 Percent

Effects 61 Northern Counties



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Paradigm Shift

Yesterday

- Water Economics > Water Conservation

Today

- Water Conservation > Water Economics

Definition: Sustainability

" Meeting the needs of the present without compromising the ability of future generations to meet their own needs"

Hanover Principles –Expo 2000
World Commission on Environment

Total Site Water Management

- Optimization
- Internal Reuse
- Alternative Water Sources
- Site WW Reuse

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A Question of Balance

Hydraulic

Suspended Solids

Ionic Load

Organic Load

Sustainable Water is an Integrated Solution

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Drawing a water balance

Why is this important?

- Baseline current water usage
- Identify sources of waste (leakage, compliance, high volumes)
- Encapsulates cost of water & water treatment

Water related costs

- **Direct** - Water use, wastewater discharge fees, pretreatment technology, energy costs associated with water use, Regulatory, water management measures
- **Indirect** - Site location limitations, license to operate or grow, relationships with stakeholders , loss or damage of ecosystem/species

How to do it?

- Capture incoming & outgoing flow capacities for every water consuming entity on site
- Classify entity under a category and sum up all entities under category
- Document related cost structure
- Consult a water expert

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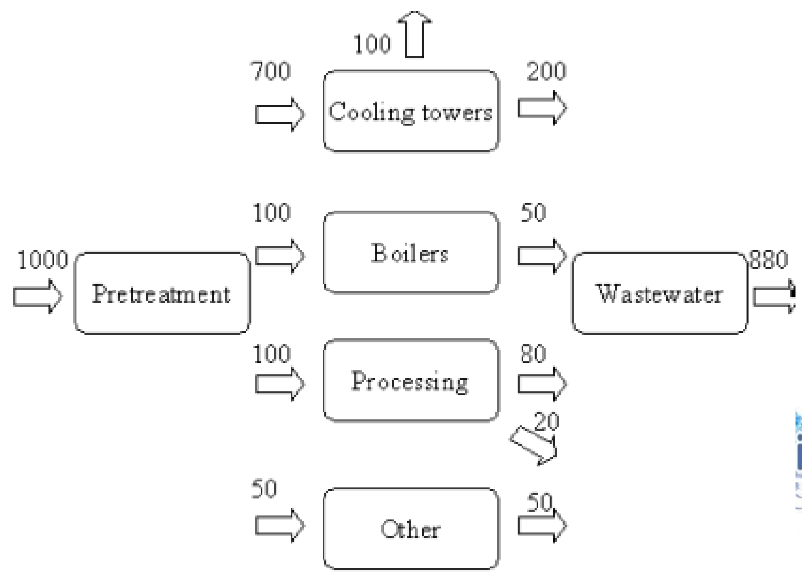
Water balance elements



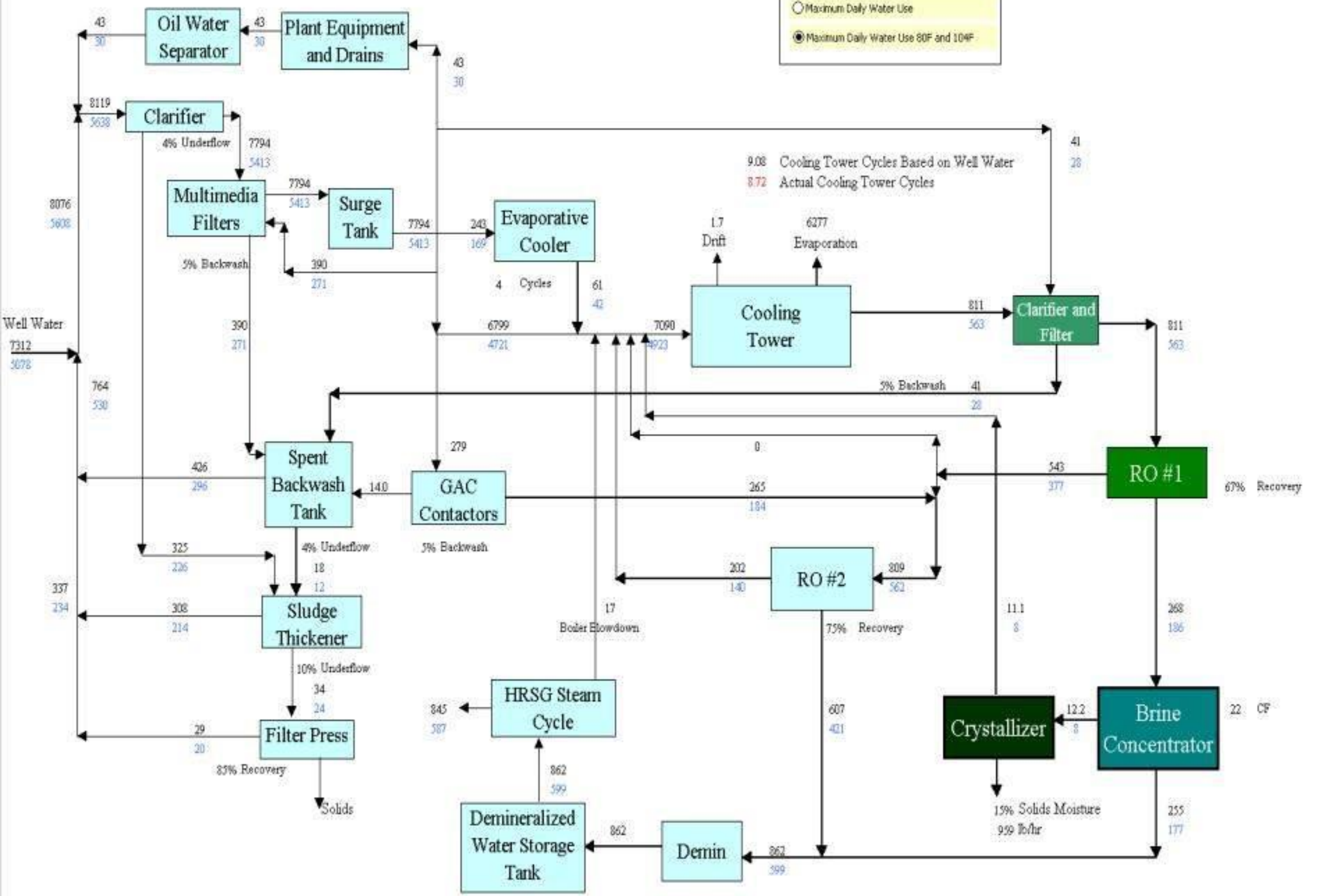
LA PALOMA PROJECT ZERO LIQUID DISCHARGE SYSTEM

ALL VALUES IN KGAL/DAY

Maximum Daily Water Use 80F and 104F

Flow Condition

- ○ Average Daily Water Use
- ○ Maximum Daily Water Use
- ◉ Maximum Daily Water Use 80F and 104F



Get The Basic Costs

Water & Energy Value Calculator			
Flow (GPM)	100		
Heat Cost ($/MBTU)	5		
Electricity Cost ($/KWH)	0.07		
Water Cost ($/1000 Gal)	2		
Discharge Cost ($/1000 Gal), (Treatment, Hauling, Sewer)	2		
Ambient Temperature ©	20		
Condensate Temperature ©	71		
Savings	Year 1	Year 2	Year 3
Heating Savings	$ 198,226	$ 198,226	$ 198,226
Water Make-up Savings	$ 103,680	$ 103,680	$ 103,680
Water Discharge Savings	$ 105,120	$ 105,120	$ 105,120
Total Savings per year	*$ 407,026*	*$ 407,026*	*$ 407,026*

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Integrating The Solutions

Water Reuse Value Calculator - HPI/CPI Tertiary Waste Treatment

Input Required	Assumed/Calculated Data	Output

Customer Name
Customer Location

Plant Economic Data			**Effluent Operating Data**	**Average**	**Minimum**
Raw Water Costs	0.57	$/1000 gal	Total Suspended Solids (TSS)		
Makeup Demin Water Cost =	1.86	$/1000 gal	Turbidity (NTU)		
Sewer/Discharge Charge =	3.75	$/1000 gal	Chemical Oxygen Demand		
Fuel Cost =	9	$/mcf (10 therms) if fuel is natural gas	Total Dissolved Solids (TDS)		
Fuel Cost =	8	$/MMBtu if fuel is something other than natural gas	Conductivity		

Plant Operating Calculations (Current)				
Wastewater Discharge	1000.0	gpm	1.4	MGD
Makeup Water Flowrate	2000.0	gpm	2.9	MGD

Plant Operating Calculations (Desired)				
Wastewater Discharge	280.0	gpm	0.4	MGD
Makeup Water Flowrate	280.0	gpm	0.4	MGD
Demin Water Produced	720.0	gpm	1.0	MGD
RO Concentrate (as Makeup)	180.0	gpm	0.3	MGD

Calculated Savings						
Makeup Water	1720.0	gpm	866880	kgal/yr	494122	$/yr
Wastewater Discharge	720.0	gpm	362880	kgal/yr	1360800	$/yr
Demin Water Treatment	720.0	gpm	362880	kgal/yr	674957	$/yr
Total Calculated Savings					**2529878**	$/yr

Additional Savings		
Additional Fines/Levies		$/yr
RO Concentrate Used as Raw Water Makeup =	51710.4	$/yr
Total Additional Savings	**51,710**	$/yr

Savings Summary		
Water Reuse (Demin Water)	0.67	$MM/yr
Wastewater Discharge Minimization	1.36	$MM/yr
Makeup Water	0.49	$MM/yr
Additional Savings	0.05	$MM/yr
Total Savings	**2.58**	$MM/yr

Starting a Water Conservation Program?

Baseline
water footprint

Identify
Efficiency
opportunities

Prepare
an optimization
Plan
&
Engage
stakeholders

Execute
&
Celebrate

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Reuse and Conservation

R.C. Krichten, P. DiFranco, E. Greenwood

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Our Objective—
Industrial Water Conservation

- What can be done?
- How quickly?
- What's the impact versus cost to change?

Total Site Water Management

- **Optimization**
- **Internal Reuse**
- **Alternative Water Sources**
- **Site WW Reuse**

Water Reuse is like Heat Exchange

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It works best in countercurrent mode…

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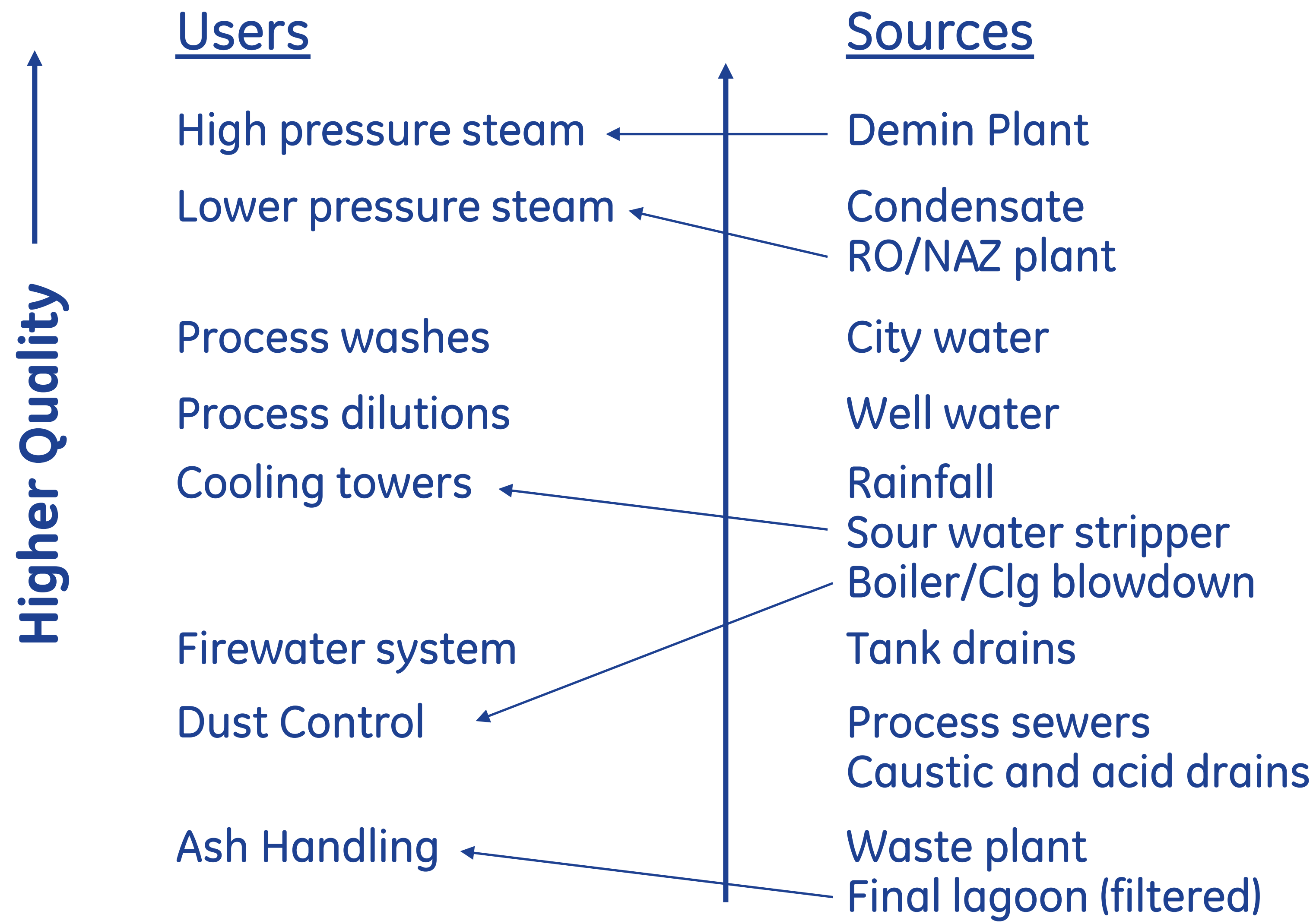
Think about water reuse as a counter current exchange of high-to-low quality sources and users



Think about water reuse as a material balance –- Look for losses and segregate highly concentrated wastewaters.

- Recoverable steam or condensate (steam vents and traps)
- Recoverable pump seal waters
- “Arkansas” coolers, CW losses

THE GOLDEN RULE

MAXIMIZE USE BEFORE BLOWDOWN….AND SEGREGATE HIGH TDS, IF POSSIBLE

Everything Starts with a Water Balance

-Intake meters and users
-Primary user is often the evaporative cooling systems
-In some plants process/wash waters are primary
-In some plants steam/condensate losses are high

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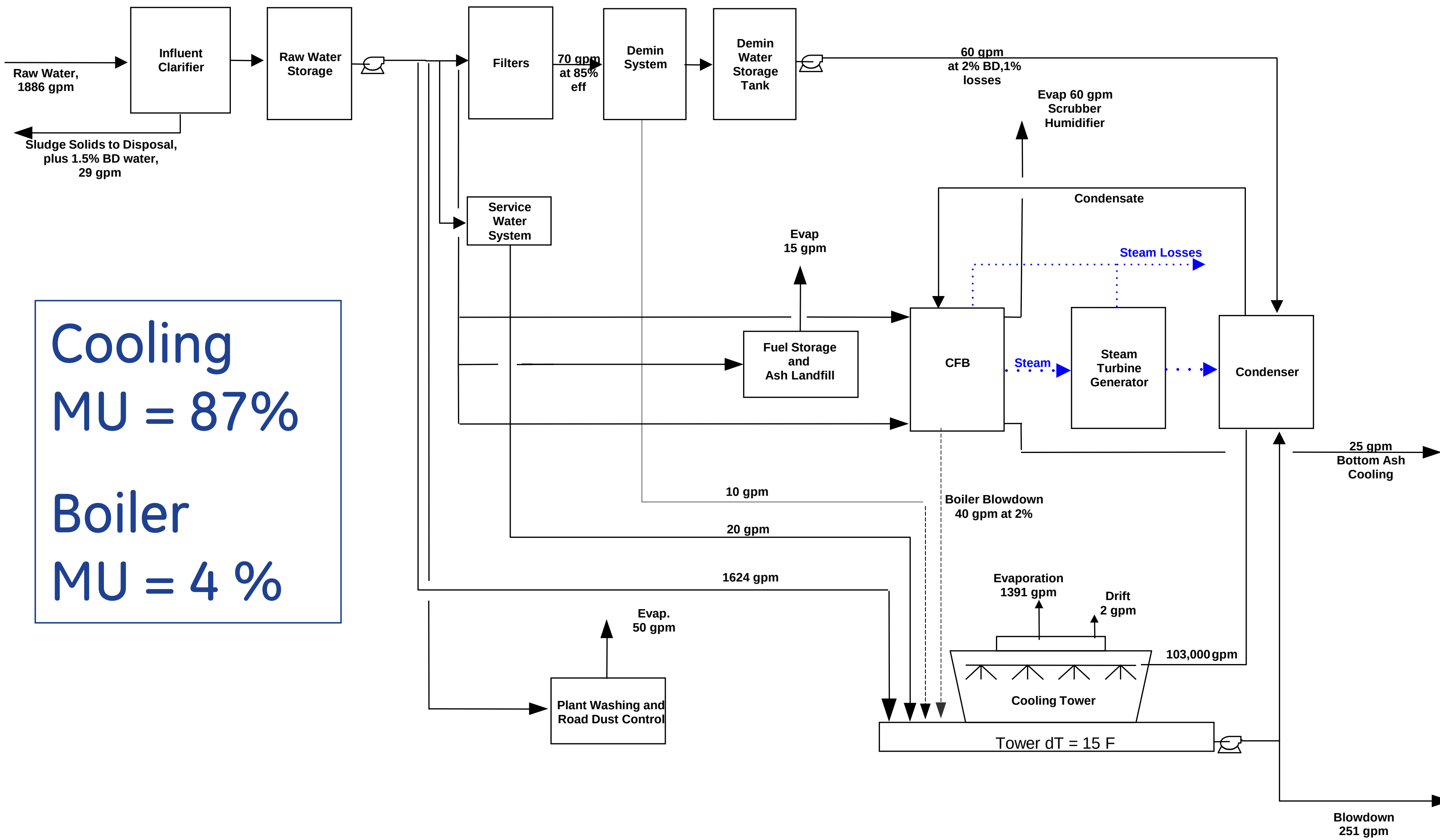
Power Plant Balance



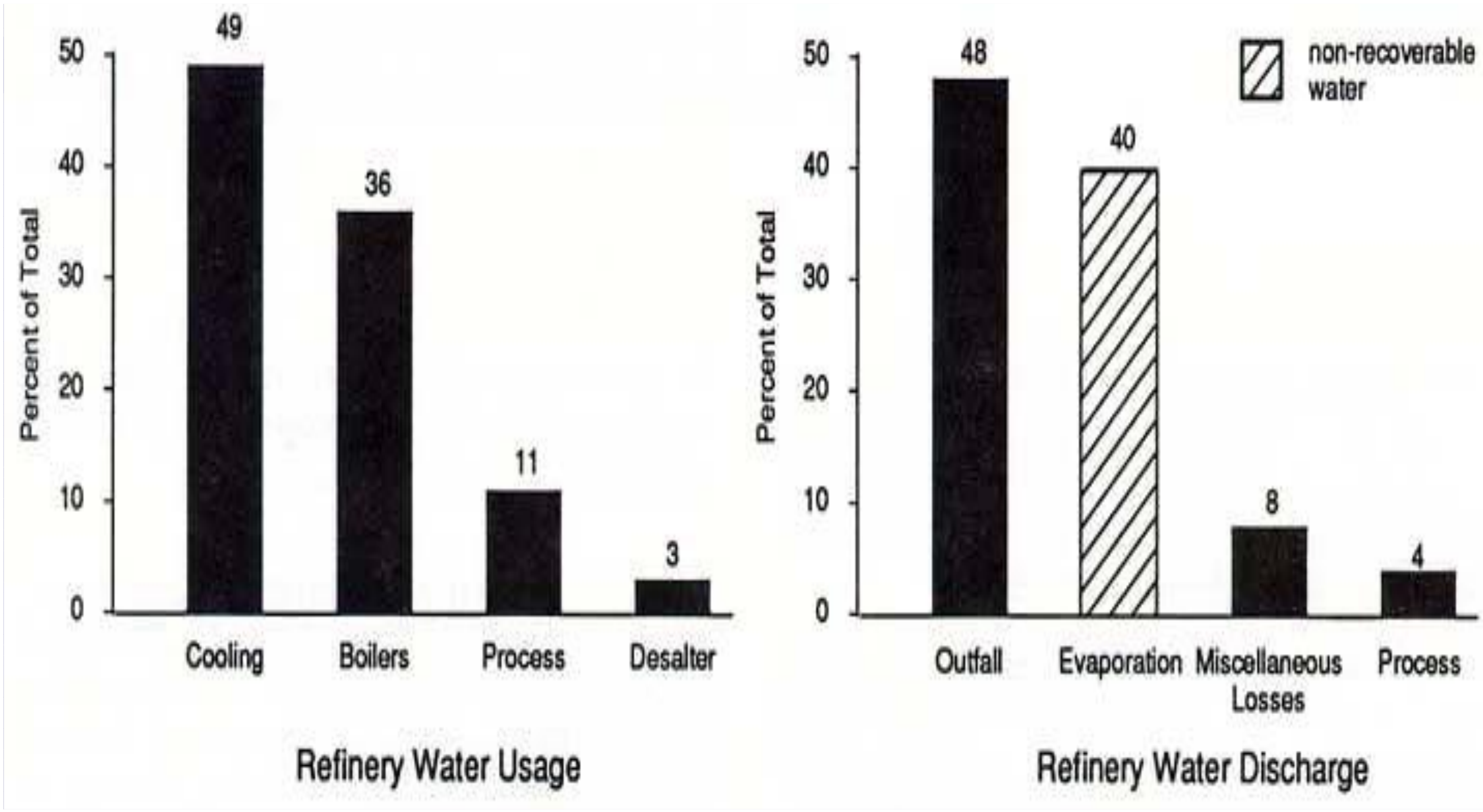
Cooling

MU = 87%

Boiler

MU = 4 %

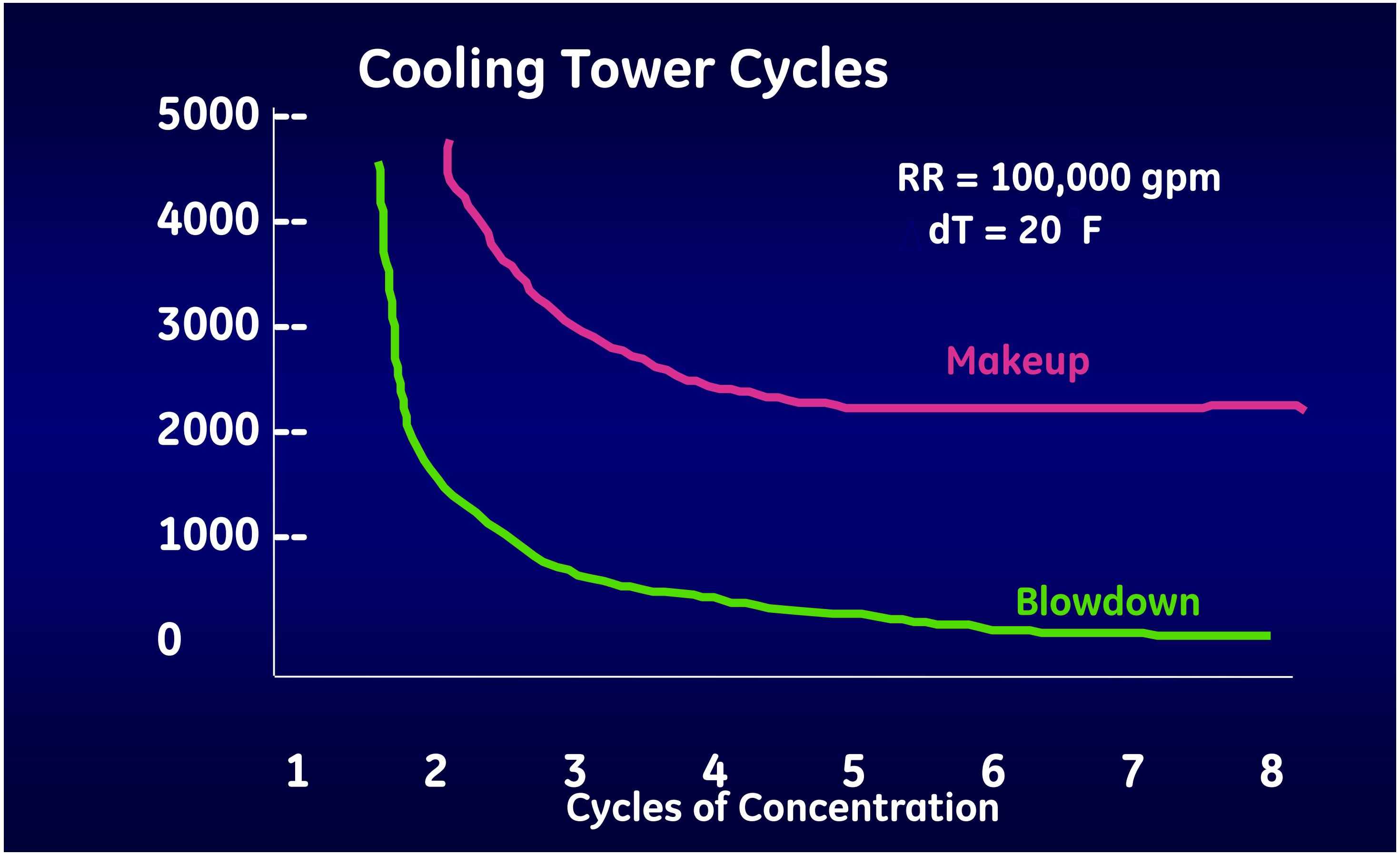
Refinery Water Balance



Water as a Heat Transfer Medium

- Steam/condensate recovery
- Minimize BTU reject to cooling water
- Consider process influent/effluent ex
- Consider expansion turbines, rather than surface condenser
- Trim cool with fin fans

Internal Water Conservation



Recycle Sources

- Demin Rinse Water
- Process Wash Waters
- ZLD Distillate
- RO Reject
- Boiler/Cooling Blowdown
- *Municipal WW Effluent*

Ion Exchange

- In water terms ion exchange is efficient
- Typically 88 to 95% of intake water becomes produced water
- The other 5 to 12% is regen waste, backwash, and rinse water
- The highest volume is rinse, which can be recovered direct to the front of the IX

RO Reject

- Older RO plants might be designed with conservative % recovery (perhaps 75%)
- RO Reject at 75% is only 4 cycle water, easy to reuse as cooling makeup
- Or perhaps a secondary RO to concentrate the reject to 8 cycle water and achieve 88% recovery

Ingredient Water Systems-

Concentrate Recovery Performance

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ecomagination Water Technologies Concentrate Recovery

- GE Water has installed 28 systems that recover 50-70% of RO concentrate (reject/brine)
- Customers include Cadbury-Schweppes, Coca-Cola, Nestle, Niagara Water, Nor-Cal Beverage, and PepsiCo
- These 28 systems recover more than 750 Million Gallons per Year *(18 hours per day, 300 days per year operation)*

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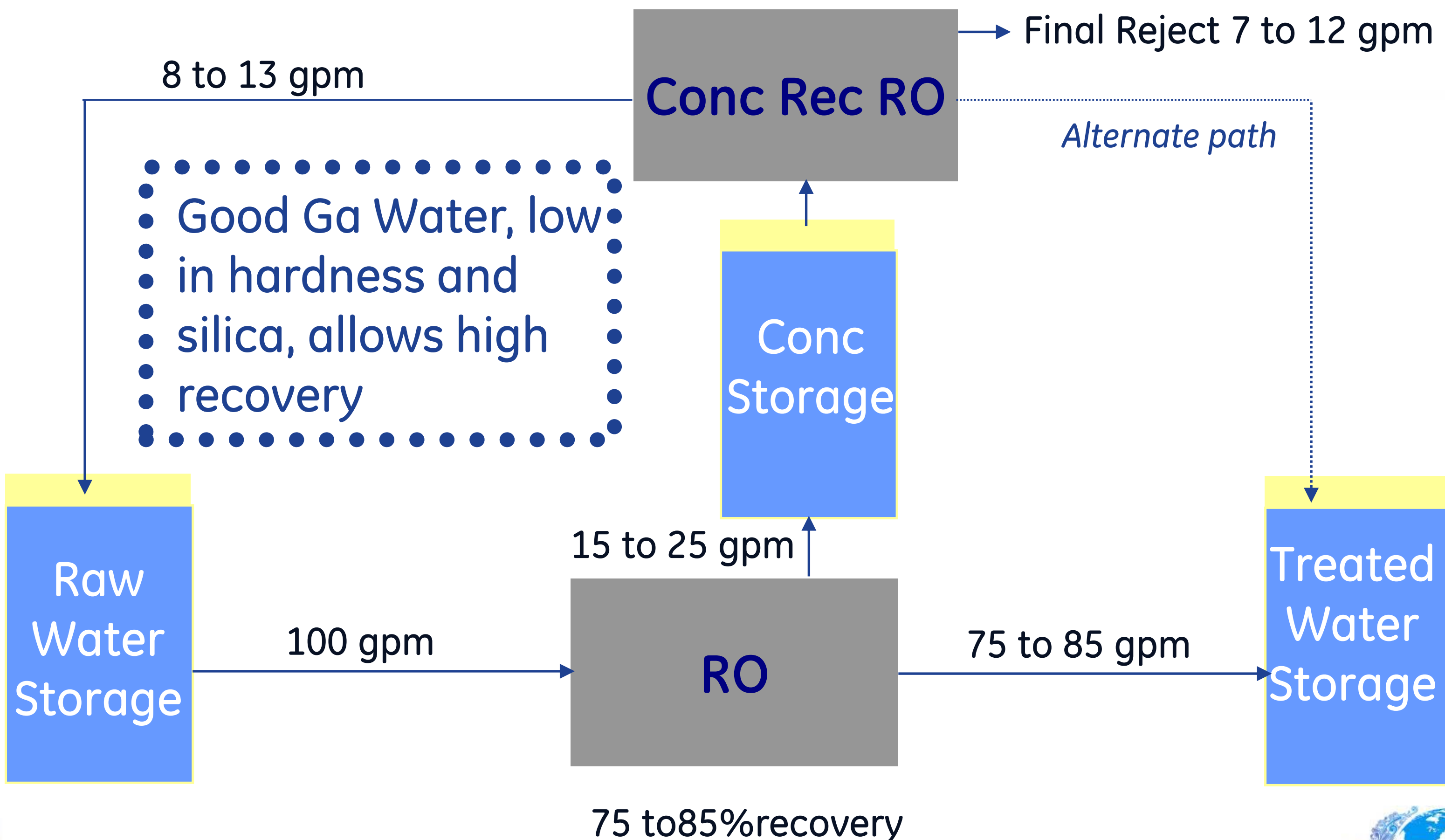
RO Concentrate Recovery

Resultant Savings of $2.3MM per year based on combined Influent + Sewer Cost of $3/kGal

Makes Existing Equipment More Efficient (Greater Product Water Flow)

RO Concentrate Recovery

Over all Recovery is 88 to 93%+



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Muni Effl Water Reuse

Drivers

Water scarcity

- Rising water prices
- Threatening economic stability
- Threatening quality of life

Environmental

- Businesses and governments needing to respond

Water discharge and reuse solutions are needed

Situation

- Limited applicability for reuse, especially industrial reuse, with simple filtration
- Industrial reuse emerging

Newer Technologies

- MBR, UF, RO/NF, EDR, ZLD, Ozone… but: Often need to combine technologies for best total solution

Municipal Examples

Source	Users
Hyperion, LAX	Chevron, Mobil
Phoenix	Palo Verde Nuclear
Contra Costa County	Shell, Unocal
Guayama PR	AES

Petro Canada – Edmonton Gold Bar Municipal WWT Plant

1.3 MGD Muni Effl to UF to RO for Boiler Makeup

Use of Industrial Plant Effluent

Improving effluent quality:

- **Segregation of high salt, high organic streams**
- **Tertiary Treatment**
  - **Minimum = dual media filtration, or ultrafiltration, and bio-oxidation**
  - **Options = PO_4, NH_3 removal lime softening activated carbon specific metals removal sulfide removal reverse osmosis**

Typical Users of Industrial WW Recycle:

- Non-critical process users, wash water systems
- Fire water/emergency standby
- Non-critical cooling systems

Key gotcha's:

- **Final effluent Bio assay/toxicity**
- **Final effluent dissolved solids**
- **Final effluent phenols and other difficult organics**
- **Final effluent metals**

On-site/Internal Reuse

Various Unit Operations

- Filtration/Ultrafiltration
- Nanofiltration/EDR
- Lime/soda Softening
- Reverse Osmosis

Ultrafiltration

- Perfect barrier for suspended solids
- The best pretreatment for reverse osmosis

Lime Softening/Filtration

- Calcium reduction
- Magnesium reduction
- Alkalinity reduction
- Silica reduction

Reverse Osmosis

- Influent, sidestream or blowdown
- High removal efficiency
- No dependence on ionic charge of solids
- Concentrated reject stream
- Pretreatment required

In conclusion, Total Site Water Management involves:

- Optimization
- Internal Reuse
- Alternative Water Sources
- Site WW Reuse

What’s quick and easy?

- Increase cooling cycles with dispersant chemistry
- Increase cooling cycles with sidestream hardness removal, lime softening or EDR
- Recover more steam condensate
- Recover IX rinse waters
- Recover filter backwash

What's not so quick and easy?

- Recover high pressure boiler BD to cooling
- Install fin fans for heat rejection
- Recover/treat process rinse water with filters, UF, other special operations
- Reuse muni or industrial waste water effluent streams

Utilities

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Cooling Systems

Paul DiFranco

Global Technical Marketing

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Evaporative Cooling Towers

Can be:

A large consumer of scarce fresh water

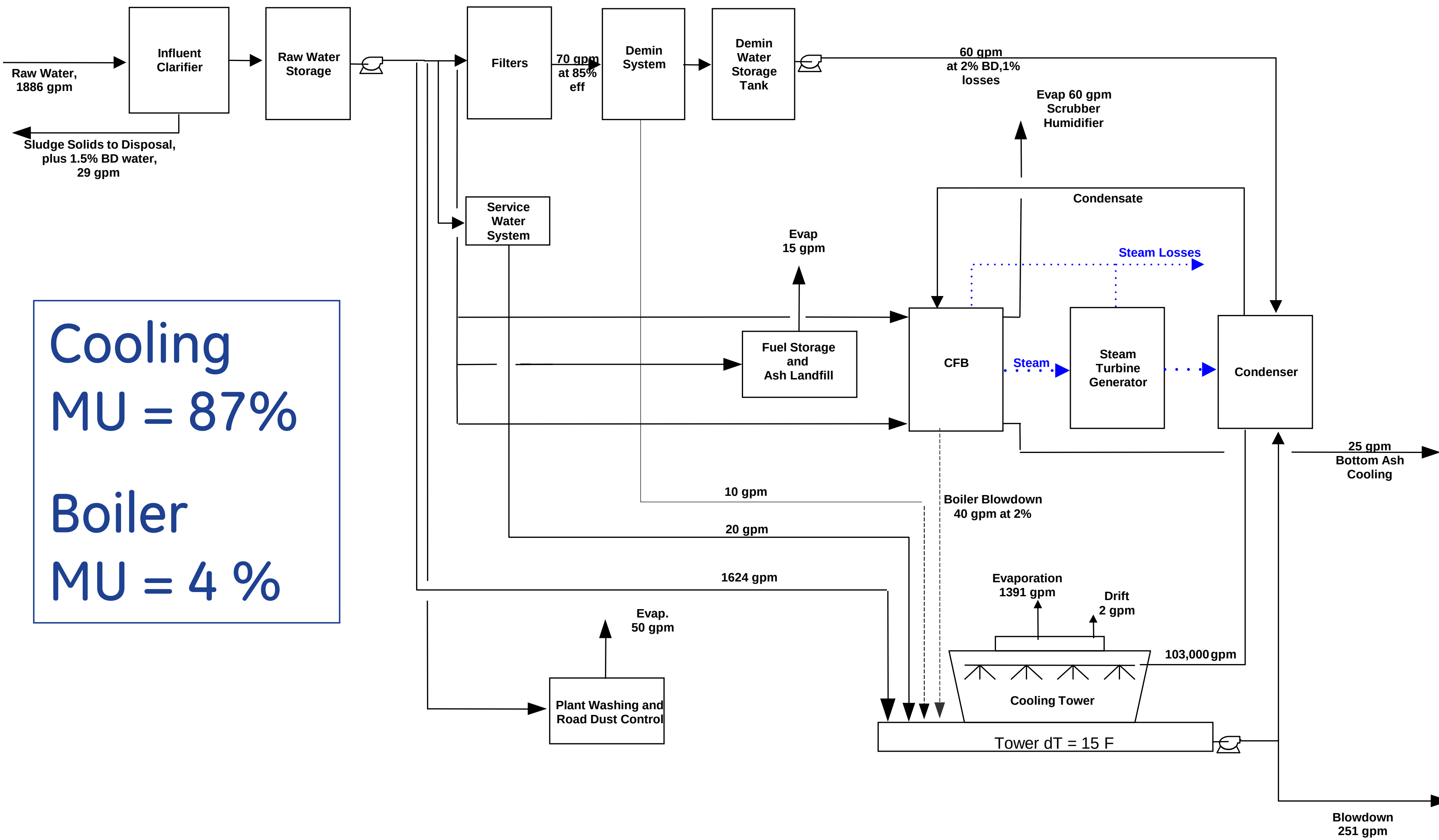
A significant environmental impact with high blowdown flow esp. at low cycles

Or could be:

An evaporative reuse concentrator

- Concentrates liquid process wastewater **reducing blowdown**
- Consumes municipal "grey water" instead of fresh water **reusing poor quality water**

Power Plant Balance



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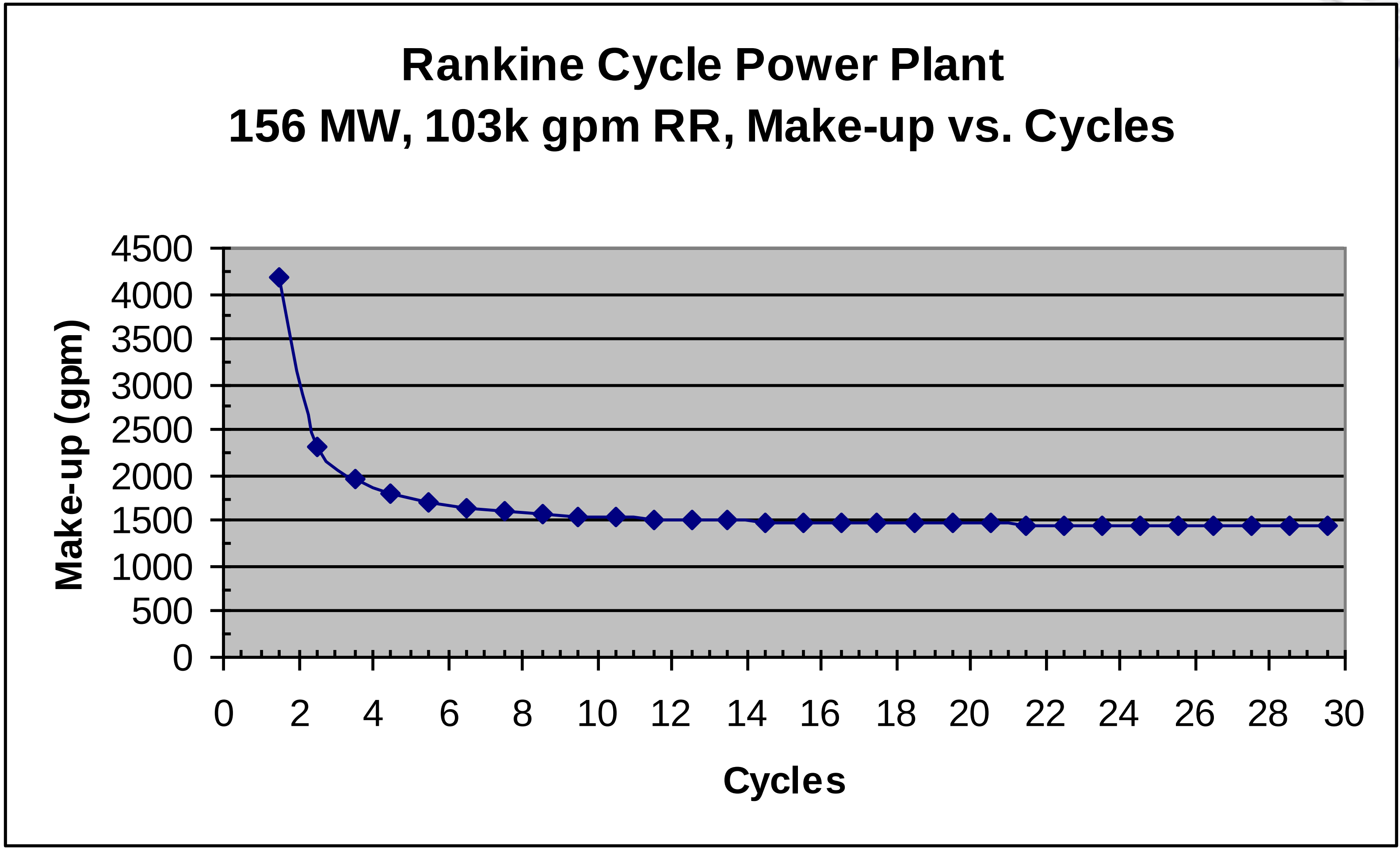
Cycle-up



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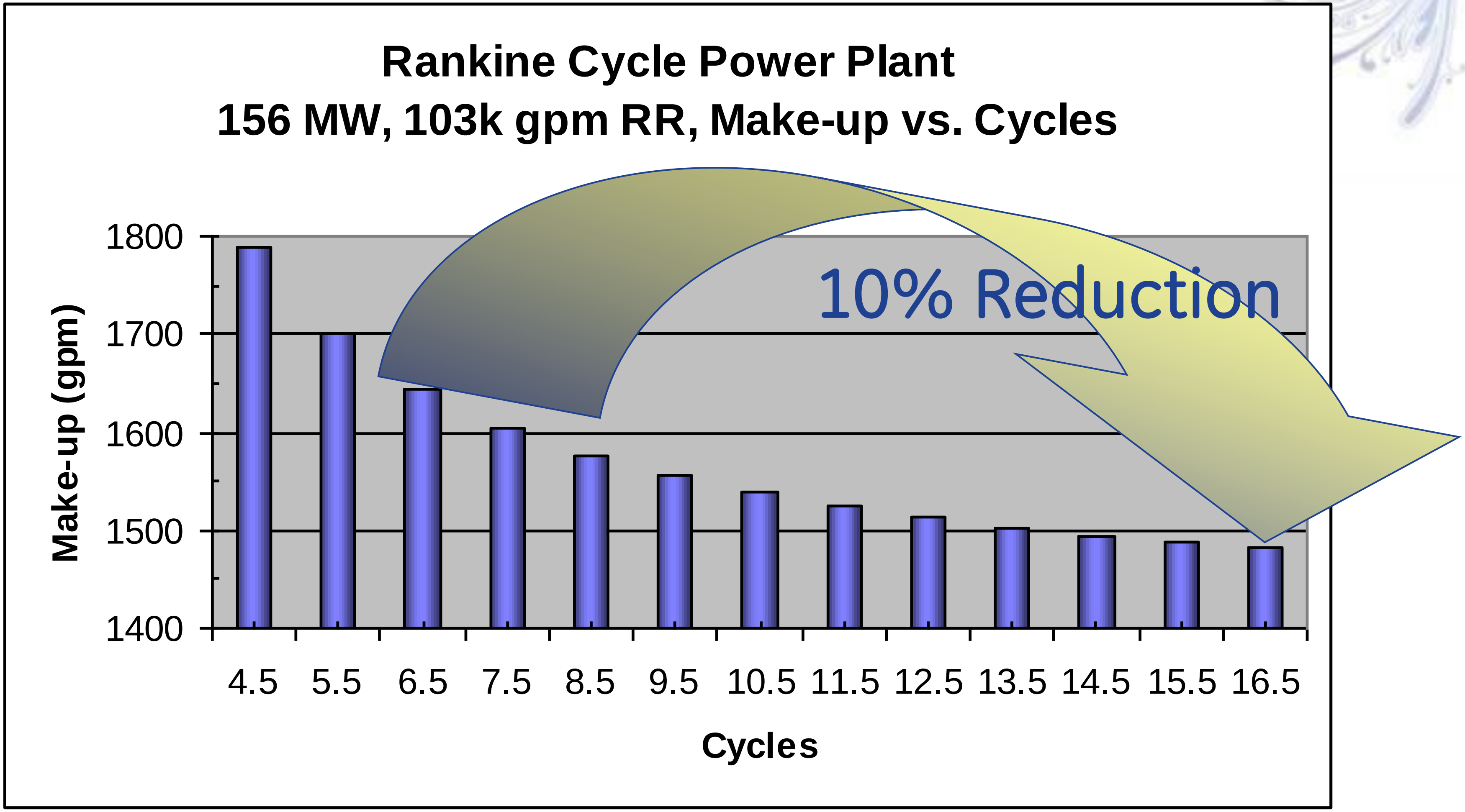
Cycle-up


Rankine Cycle Power Plant
156 MW, 103k gpm RR, Make-up vs. Cycles
10% Reduction
Make-up (gpm)
1800
1700
1600
1500
1400
4.5
5.5
6.5
7.5
8.5
9.5
10.5
11.5
12.5
13.5
14.5
15.5
16.5
Cycles

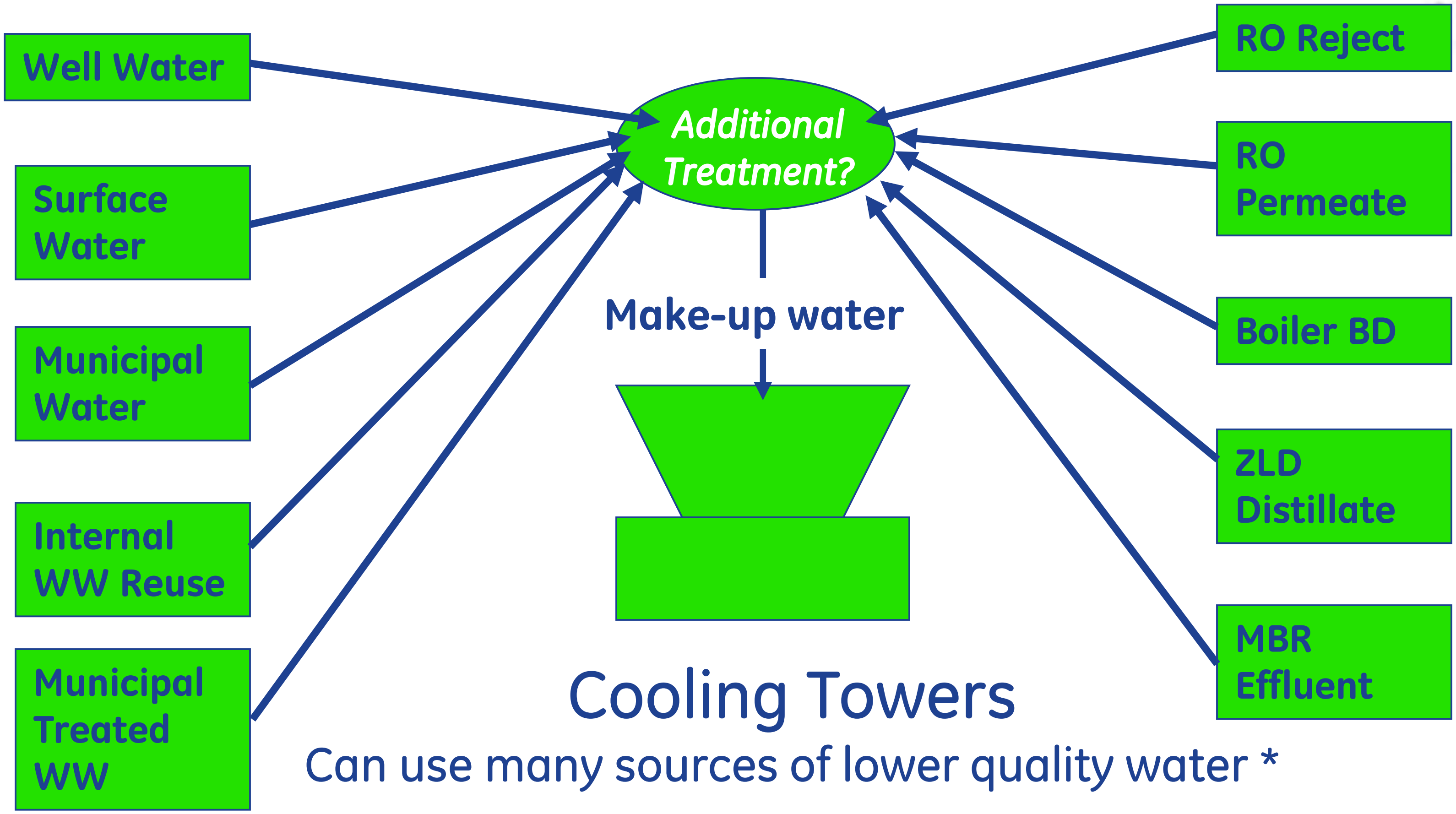
Cycle-up Chattahoochee River

CYCLES	pH	M-ALK (ppm as CaCO3)	Ca (ppm as CaCO3)	Mg (ppm as CaCO3)	SiO2 (ppm as SiO2)	COND (umhos)	Cl (ppm as Cl)	SO4 (ppm as SO4)	LSI CaCO3 Index	MgSi	CMSi	RT75 (Retention Time in days)	B.D. (gpm)	M.U. (gpm)
										***** = Exceeds Limit ok = Under Sat.				
MAKEUP	6.90	30	21	8	9	113	8	13	-1.58	ok	ok			
1.50	7.04	41	32	12	14	170	12	20	-1.16	ok	ok	0.35	2,782	4,174
2.50	7.45	68	53	20	23	283	20	33	-0.34	ok	ok	1.04	927	2,319
3.50	7.71	95	74	28	32	396	28	46	0.20	ok	ok	1.73	556	1,948
4.50	7.92	122	95	36	41	509	36	59	0.60	ok	ok	2.42	397	1,789
5.50	8.08	149	116	44	50	622	44	72	0.92	ok	ok	3.11	309	1,700
6.50	8.21	176	137	52	59	735	52	85	1.19	ok	ok	3.81	253	1,644
7.50	8.32	203	158	60	68	848	60	98	1.42	ok	ok	4.50	214	1,605
8.50	8.42	230	179	68	77	961	68	111	1.62	ok	ok	5.19	185	1,577
9.50	8.51	257	200	76	86	1074	76	124	1.80	ok	ok	5.88	164	1,555
10.50	8.59	284	221	84	95	1187	84	137	1.96	ok	ok	6.57	146	1,538
11.50	8.67	311	242	92	104	1300	92	150	2.10	ok	ok	7.26	132	1,524
12.50	8.73	338	263	100	113	1413	100	163	2.24	ok	ok	7.96	121	1,512
13.50	8.79	365	284	108	122	1526	108	176	2.36	ok	ok	8.65	111	1,502
14.50	8.85	392	305	116	131	1639	116	189	2.47	ok	*****	9.34	103	1,494
15.50	8.90	419	326	124	140	1752	124	202	2.58	ok	*****	10.03	96	1,487
16.50	8.95	446	347	132	149	1865	132	215	2.68	ok	*****	10.72	90	1,481
22.50	9.20	608	473	180	*****	2543	180	293	*****	*****	*****	14.87	65	1,456
28.50	9.39	770	599	228	*****	3221	228	371	*****	*****	*****	19.03	51	1,442

Cycle-up Etowah River

CYCLES	pH	M-ALK (ppm as CaCO3)	Ca (ppm as CaCO3)	Mg (ppm as CaCO3)	SiO2 (ppm as SiO2)	COND (umhos)	Cl (ppm as Cl)	SO4 (ppm as SO4)	LSI CaCO3 Index	MgSi	CMSi	RT75 (Retention Time in days)	B.D. (gpm)	M.U. (gpm)
										***** = Exceeds Limit ok = Under Sat.				
MAKEUP	7.10	39	21	6	9	68	5	5	-1.25	ok	ok			
1.50	7.25	53	32	9	14	102	8	8	-0.82	ok	ok	0.35	2,782	4,174
2.50	7.66	88	53	15	23	170	13	13	0.00	ok	ok	1.04	927	2,319
3.50	7.92	123	74	21	32	238	18	18	0.53	ok	ok	1.73	556	1,948
4.50	8.13	158	95	27	41	306	23	23	0.94	ok	ok	2.42	397	1,789
5.50	8.29	193	116	33	50	374	28	28	1.26	ok	ok	3.11	309	1,700
6.50	8.42	228	137	39	59	442	33	33	1.53	ok	ok	3.81	253	1,644
7.50	8.53	263	158	45	68	510	38	38	1.75	ok	ok	4.50	214	1,605
8.50	8.63	298	179	51	77	578	43	43	1.96	ok	ok	5.19	185	1,577
9.50	8.72	333	200	57	86	646	48	48	2.13	ok	ok	5.88	164	1,555
10.50	8.80	369	221	63	95	714	53	53	2.29	ok	*****	6.57	146	1,538
11.50	8.88	404	242	69	104	782	58	58	2.44	ok	*****	7.26	132	1,524
12.50	8.94	439	263	75	113	850	63	63	2.57	ok	*****	7.96	121	1,512
13.50	9.00	474	284	81	122	918	68	68	2.70	ok	*****	8.65	111	1,502
14.50	9.06	509	305	87	131	986	73	73	2.81	ok	*****	9.34	103	1,494
15.50	9.11	544	326	93	140	1054	78	78	*****	*****	*****	10.03	96	1,487
16.50	9.16	579	347	99	149	1122	83	83	*****	*****	*****	10.72	90	1,481
22.50	9.41	790	473	135	*****	1530	113	113	*****	*****	*****	14.87	65	1,456
28.50	9.60	1000	599	171	*****	1938	143	143	*****	*****	*****	19.03	51	1,442

Possible Make-up Water Sources



Cooling Towers

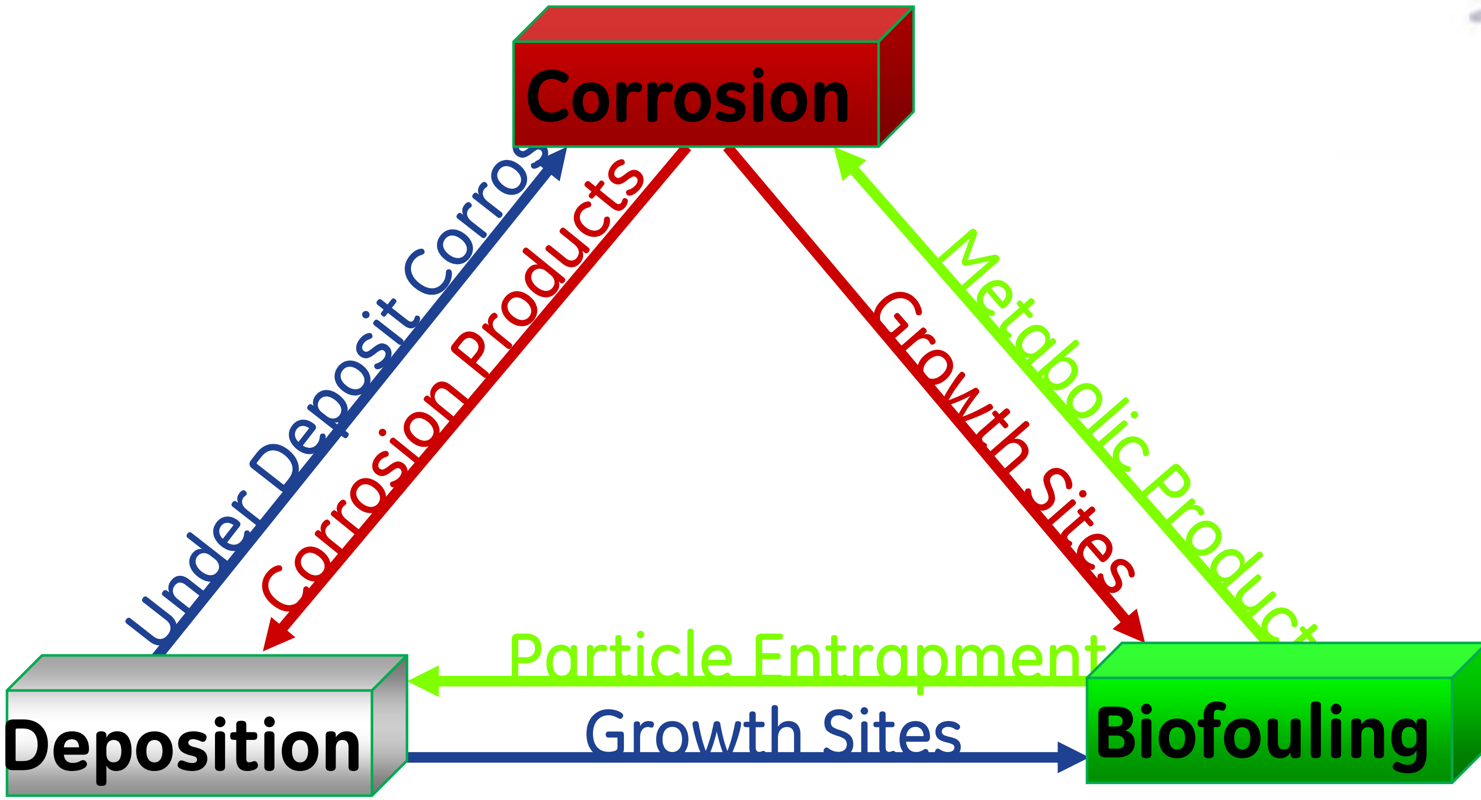
Can use many sources of lower quality water *

* With proper system design and chemical treatment

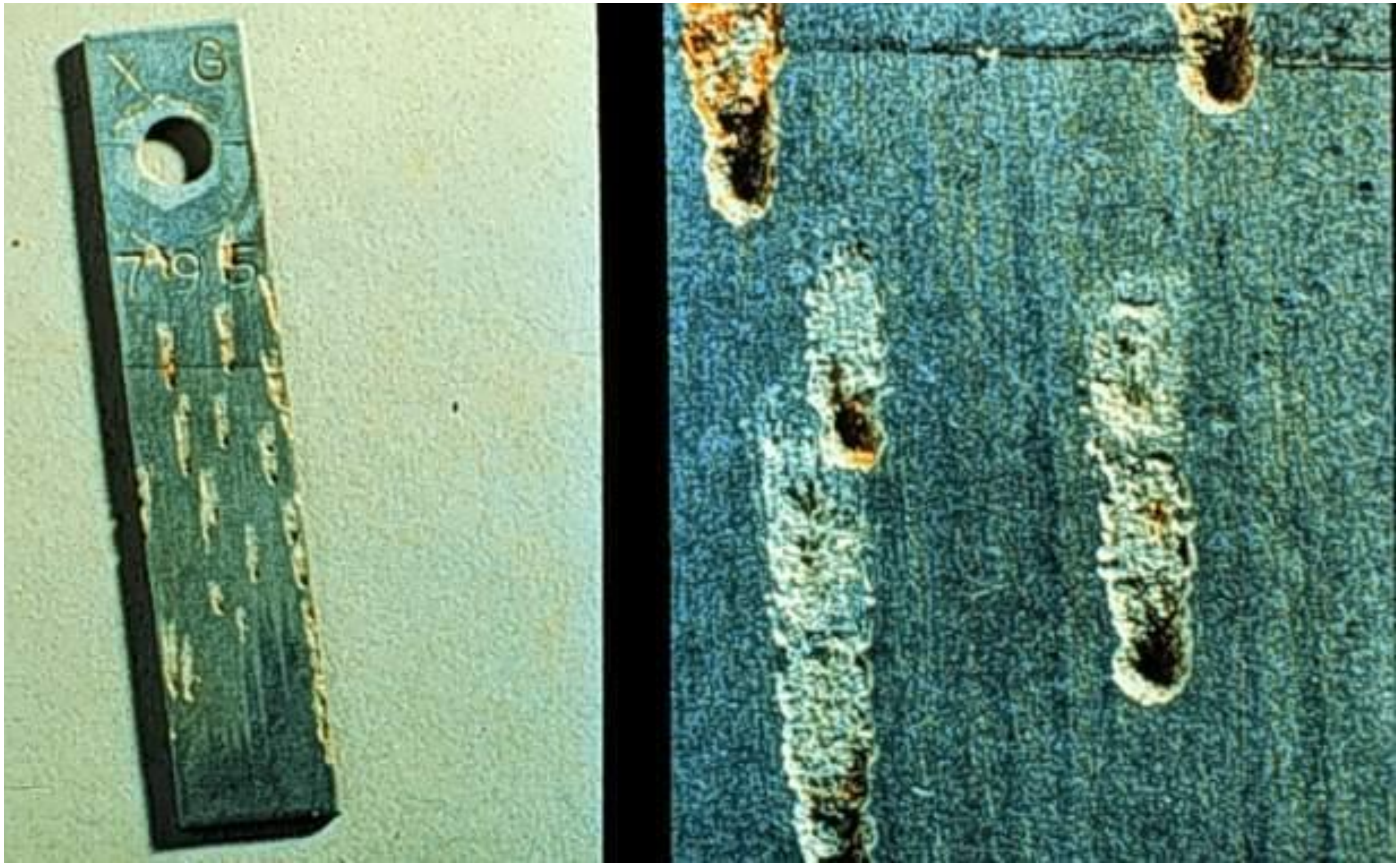
Water Sources Benefits and Limitations

Water Source	Benefits	Limitations
Well, Surface and Municipal	Known and consistent, conventional treatment	Limited quantities, scarce
Municipal treated WW, MBR Effluent, internal WW reuse	Water Conservation, Ready Source, Win for the municipality	Contaminants, Organics, Variability, CT Chemical Treatment difficult
RO Reject, Boiler BD	Easy Reuse	Already cycled, Chemical treatments compatibility
RO Permeate, ZLD Distillate	Clean low TDS, No Contaminates	Not Free, Used to balance contaminant loading of combined makeup

Water Treatment Concerns



Pitting Corrosion



Mineral Solubility Limits
Can Be Exceeded As Cycles Increase

Calcium carbonate
Calcium phosphate
Magnesium silicate
Calcium sulfate
Silica

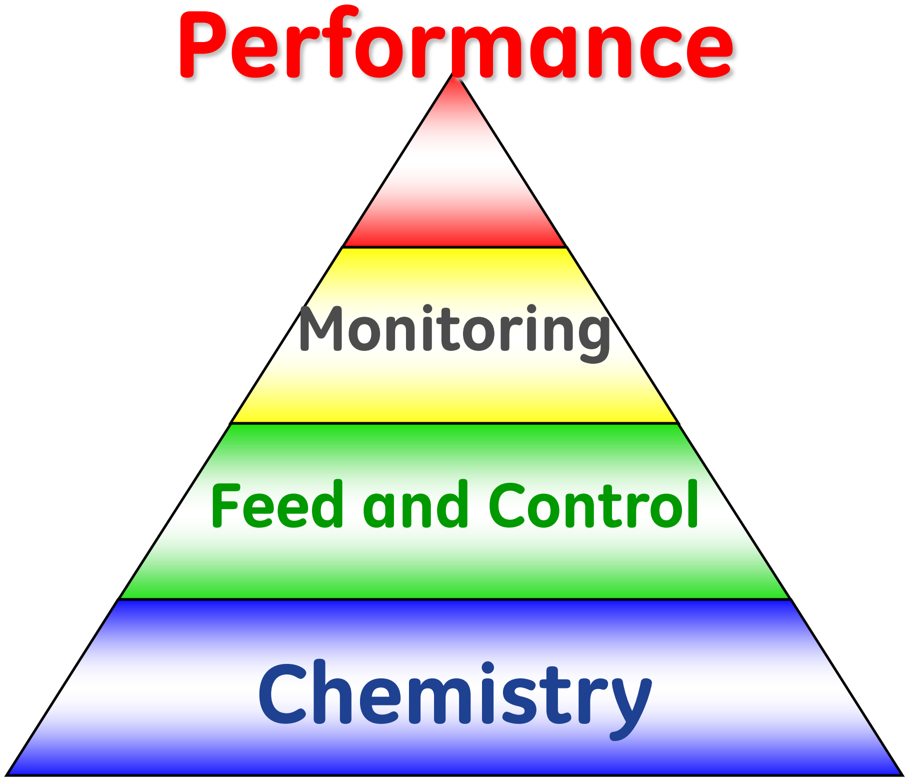
Heat Exchanger Deposition

Cooling Tower Fill

Fill before cleaning

Fill after cleaning

How to Overcome These Concerns



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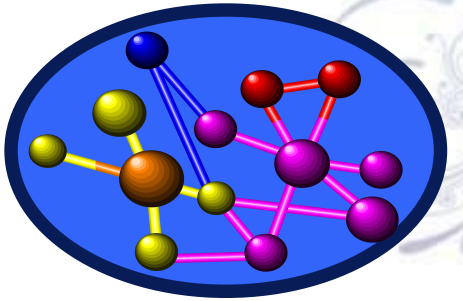
Corrosion Control

- Chloride, sulfate and ammonia are problems
- Superior inhibitors required for carbon steel and copper alloy protection
- Provide general and pitting protection
- Persistent protective film
- Halogen stable
- No harmful odors

Deposition Control



- $CaPO_4$ solubility critical
- $CaCO_3$, $MgSiO_3$, silica, manganese, iron and TSS are concerns
- Superior dispersants required
  - Superior calcium carbonate protection
    - ➢ Effective at high LSI
    - ➢ Non-Phosphorus
- Halogen stable
  - No Degradation; no loss in deposition control

Biological Control

- Reuse/recycle water can add nutrients (Organics, NO_2, NO_3) and microorganisms
- MB control is difficult and the #1 treatment challenge
- Loss of MB control is rapid
- Recovery of MB control is slow and costly
- Successful control requires:
  - Proper make-up water treatment
  - Proper tower water treatment
    - Oxidizing/Non-Oxidizing Biocides + Biodispersant

Cooling Water Treatment

- Major challenge to success:
  - Simultaneous risk potential
  - Corrosion, Deposition & MB Control
- Requirements for success:
  - Improved water treatment
  - Effective system monitoring
  - Tight system control
- Problem areas
  - Critical exchangers
    - High temperature
    - Low velocity
  - Cooling tower film fill

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Feed & Control Systems

Configurations tailored to fit the application.

Basic to advanced control and monitoring systems

Custom algorithms tailored for specific process control requirements.

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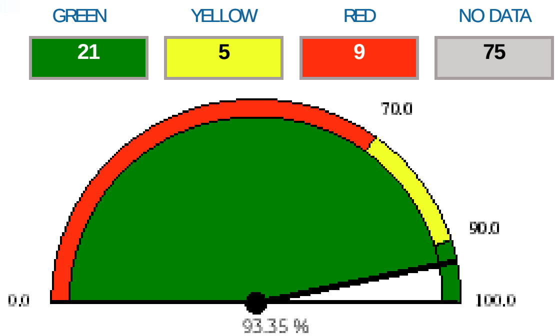
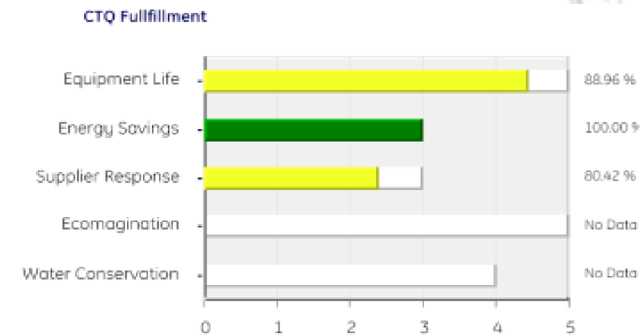
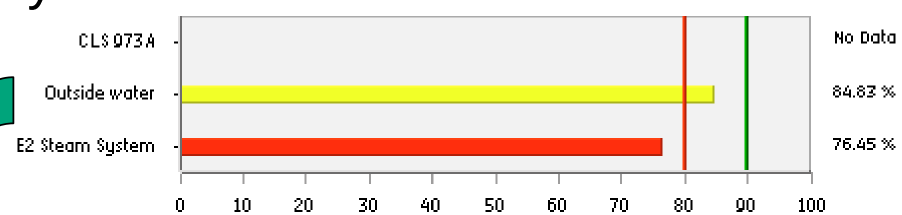
Performance Monitoring





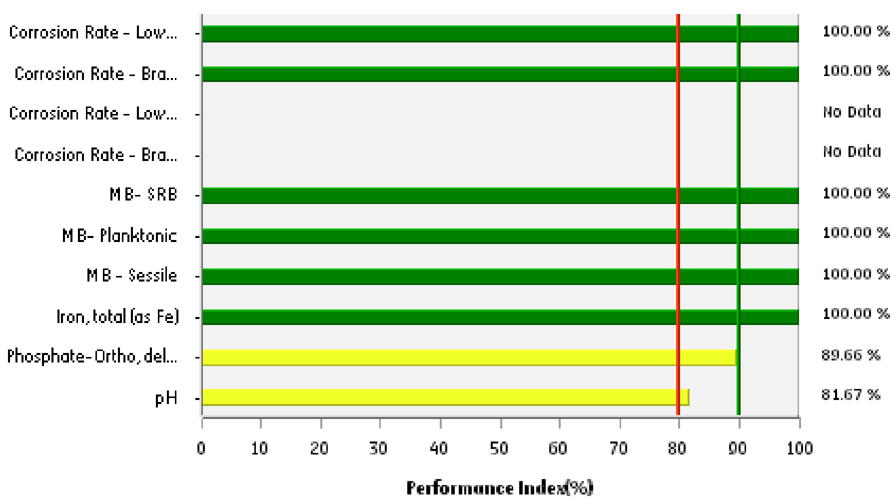
Systems Scorecard

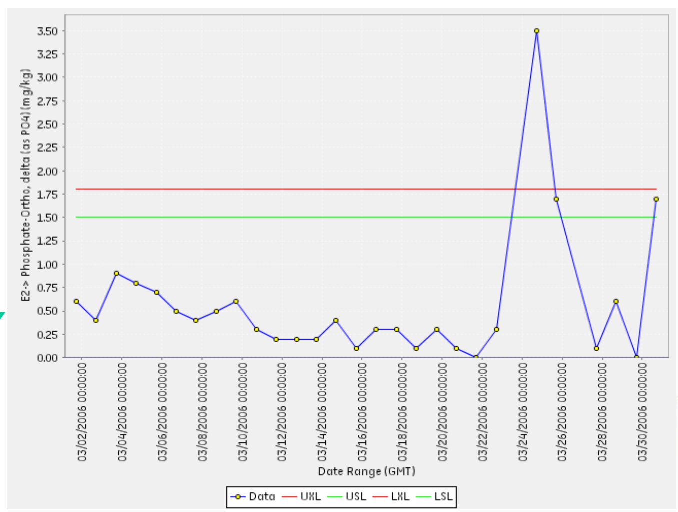
Performance against Business Objectives



Single System KPI's

If online can drill down to raw data





Challenges

Excessive Water and Energy Usage

Corrosion and Fouling of Piping and Equipment

Reduced Heat Transfer Efficiency

Waste Production

Solutions

Improved Scale Inhibitors

Deposit Control Agents

Performance Monitoring

Total Internal Reuse Example:

Coal-fired ZLD Power Plant

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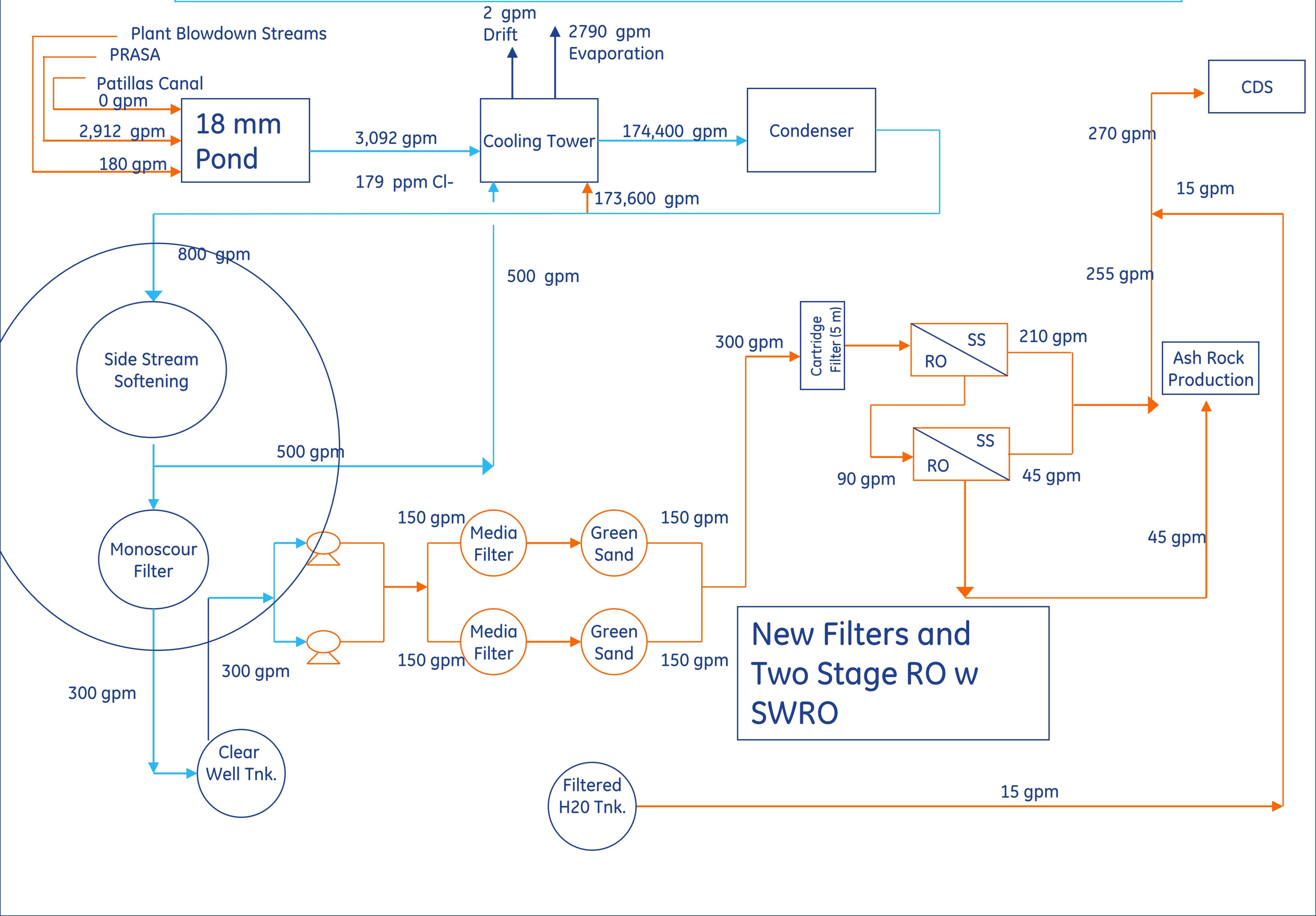
85% Recovery of SSRO with Permeate to CDS & Reject to ASH Rock



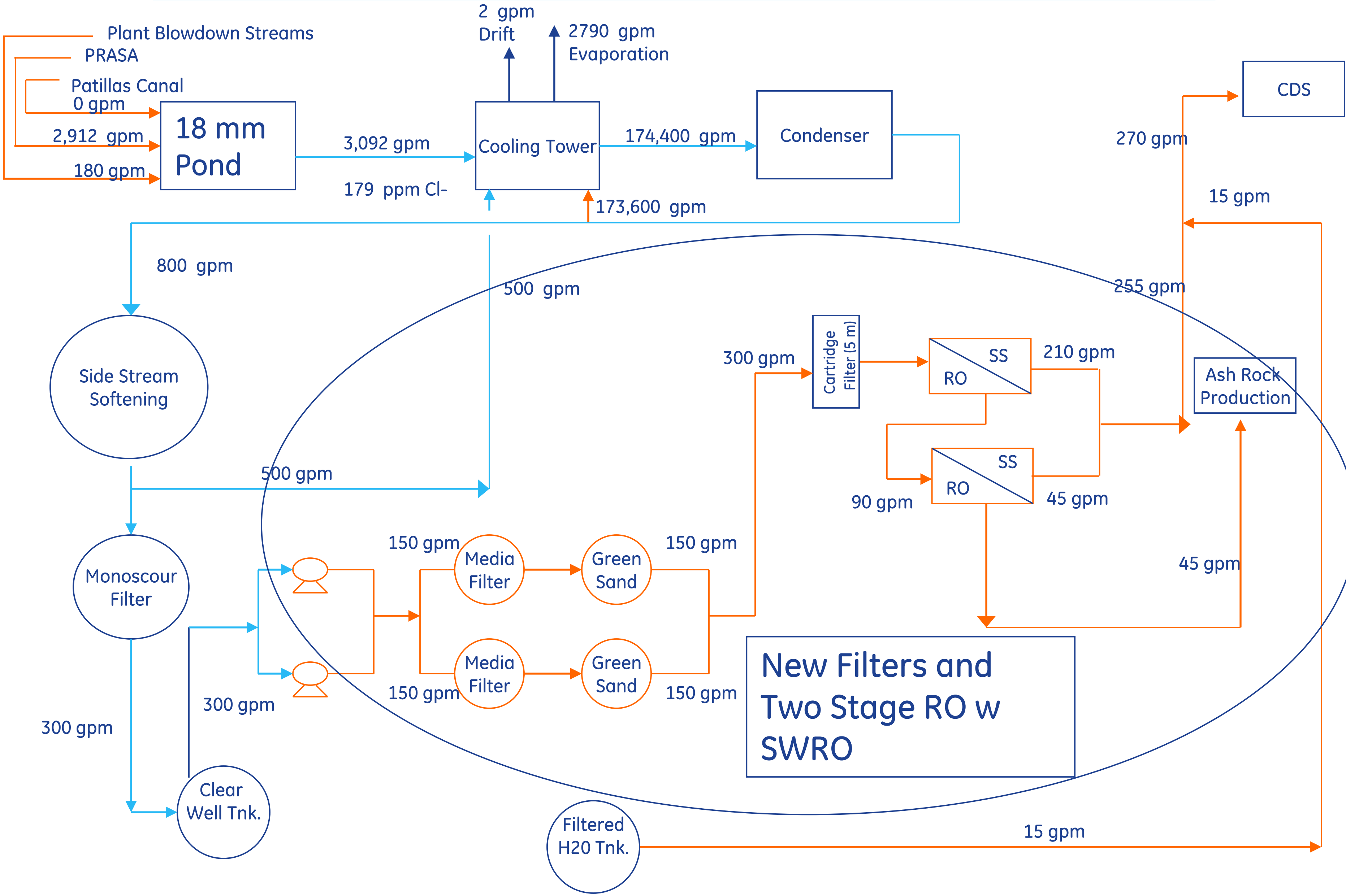
Generic Options For ZLD

- Sidestream Warm Lime Softening for Hardness, Silica Control
- EDR or RO For Concentration of Salts
- Deep Well Injection
- Evaporation Pond
- Brine Concentrator/Evaporator
- Crystallizer = Final Dry Salt Cake

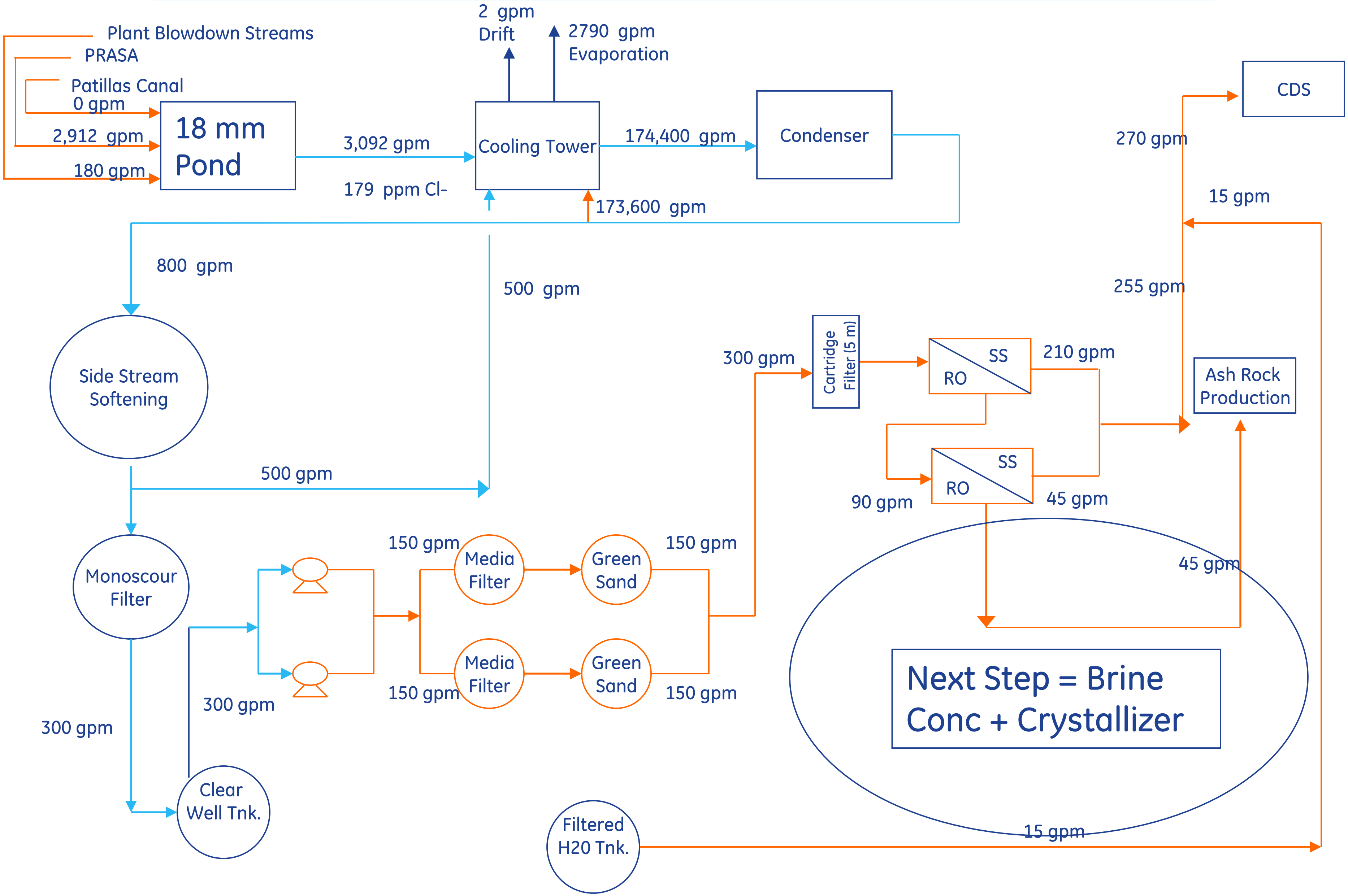
Zero Liquid Discharge Common Operations

- ZLD means all incoming TDS goes out as a sludge/solid
- Internal cooling reuse is normally warm lime for hardness, silica
- Additional BD concentration via RO or EDR
- Then evaporation, and crystallizer

85% Recovery of SSRO with Permeate to CDS & Reject to ASH Rock



85% Recovery of SSRO with Permeate to CDS & Reject to ASH Rock

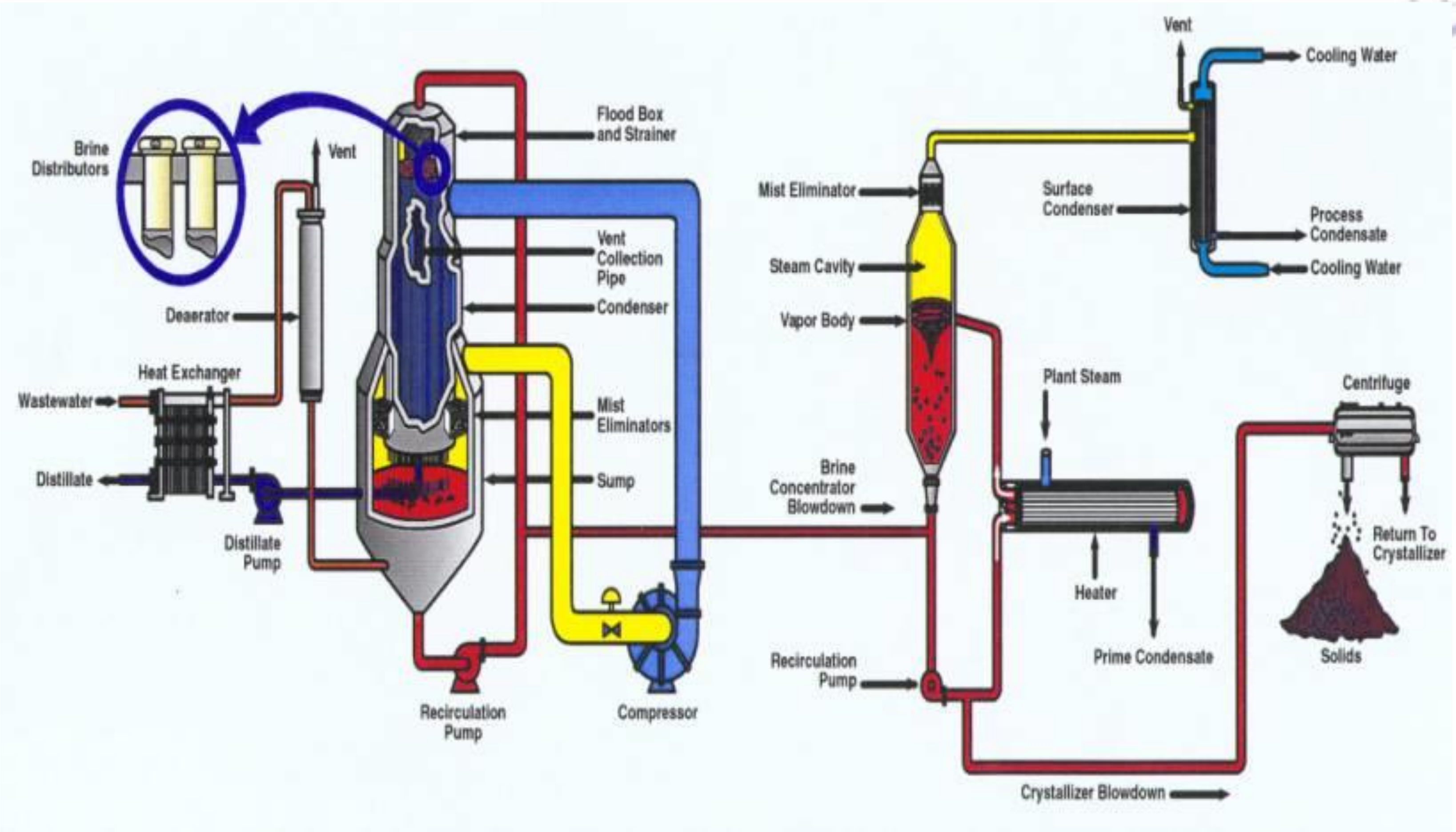


Evaporation Crystallization

FUNCTION | OPERATION | LIMITATIONS | STRENGHS

TOTAL COST

Brine Concentrator/Crystallizer PFD



EXAMPLE OF PROJECT OBJECTIVES

Complete Plant Material Balances by ion including all chemicals which impact total salt discharge

Working Balance Models To Analyze Impact of Process Options On Salt Discharge

Processing Options With Capability Limits Defined

Budgetary Cost/Economic Impact of Options Considered

Choices/Decision Required For Design Basis

Projected Characteristics of Water

Parameter	Lime Softened Water		2 Stage RO Permeate
Conductivity	12,003 mmhos		414 mmhos
pH	7.2		7.5
Calcium	304 ppm		3.5 ppm
Magnesium	58 ppm		0.8 ppm
Sulfates	2258 ppm		51.1 ppm
Chlorides	1762 ppm		80.7 ppm
Phosphate	1 ppm		0 ppm
Sodium	2269 ppm		82.4 ppm

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Inputs to chemical usages

Chemical	**Composition as purchased**	**User**	**Use rate**			**Calculations**
Sulfuric Acid	98% H_2SO_4	Demin + CT	10,000 gal/mo	329 gpd	13.7 gph	
	15.02 lb/gal	Clarifier	4378 gal/mo	144 gpd	6 gph	
		Totals	14378	473		
Caustic	50% NaOH	Clarifier		288 gpd		
	6.36 lb NaOH/gal	MU demin		48 gpd		regen 1/da
		Combined MB		240 gpd		regen 1/da
		Org. Trap		21.7 gpd		65 gal ea 3 da
		Totals		597.7 gpd		
Soda Ash	100% Na_2CO_3	Clarifier	834 T/yr	2.28 T/da	4570 lb/da	
Brine/ Salt	100% NaCl	Org. Trap	65 gpm of 25%	1950 gal	4836 lb NaCL	
	1.2 SG as 25% brine		for 30 min		per 3 days =	
	2.48 lb NaCl/gal		every 3 days		1612 lb/da	
Chlorine gas	100% Cl_2	CT + SSRO	900 lb/da			

TOTAL SALTS BALANCE

Salt	Municipal Effl, ppm	Canal ppm	Acid	NaOH	Soda Ash	Bleach	Cl2 gas	Muni lbs/d	Canal lbs/d	Total lbs/d
Flow gpm	2629	700								
Flow lbs/d			7174	4571	3720	10200	500	31573238	8406720	40006124
Ca	106	24						3,347	202	3549
Mg	64	21						2,021	177	2197
Na	169	18		2629	1614	394		5,336	151	10124
Cl	204	14				599	500	6,441	118	7658
SO4	96	28	7028					3,031	235	10294
PO4	6.8	0.2						215	2	216
SiO2	26	23						821	193	1014

68.3% SO4 from acid	45.8% Na from caustic and soda and bch	14.4% Cl from gas and bch	21,211 lbs salt	1,078 lbs salt	35052 Total lbs/d of salts

63.6% of salts come from inlet waters

Salts Entering The Plant

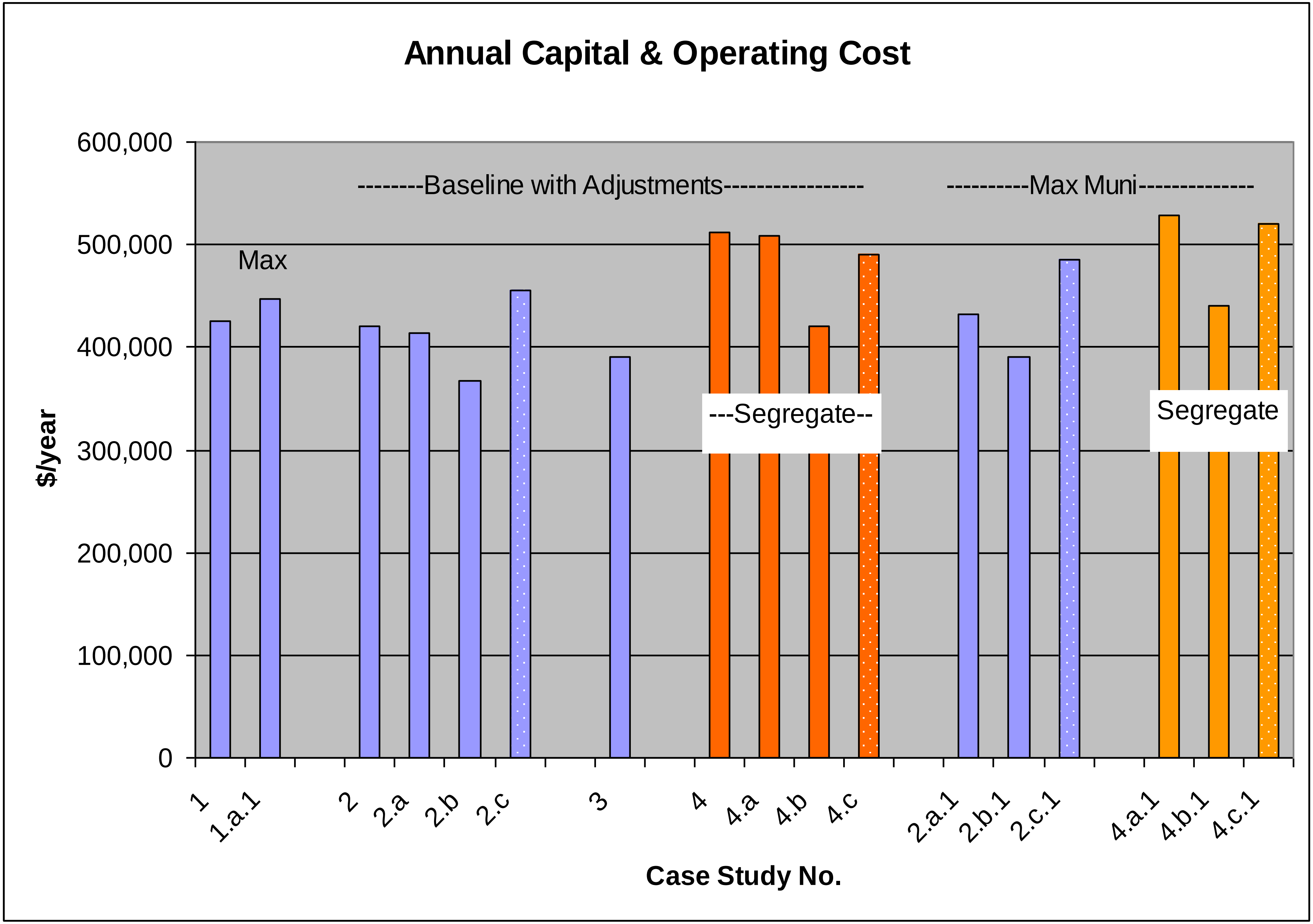
Salt	Prasa	Canal	Wells	Chemicals	Coal Pond	Tot. Mass per Ion
Flow, gpm	2,781	1,200	138	N/A	23	
Flow, MM#/day	33.4	14.4	1.7	N/A	0.28	
Conductivity, mmhos	1,132	147	603	N/A	34,950	
TDS as ppm	702	91	374	N/A	N/A	
Potassium, lb/day	261	13	1.2	0	195	**470**
Nitrate, lb/day	1,670	N/A	N/A	0	41	**1,711**
Calcium, lb/day	1,369	144	53	0	102	**1,668**
Magnesium, as lb/day	501	62	25	0	9	**597**
Sodium, lb/day	4,008	164	94	4,810	1,994	**11,070**
Chloride, lb/day	4,642	159	58	1,873	2,030	**8,762**
Bicarbonate, lb/day	3,908	418	240		36	**4,602**
Carbonate, lb/day	0	0	0	2,587	0	**2,587**
Sulfate, lb/day	2,371	159	71	6,959	2,356	**11,916**
Phosphate, lb/day	200	3	0	0	5	**208**
Silica, lb/day	935	317	53	0	9	**1,314**
Total salts, Lb	**19,865**	**1,439**	**595**	**16,229**	**6,777**	**44,905**
Total salts, Ton	**9.93**	**0.72**	**0.30**	**8.11**	**3.39**	**22.45**
% of Total	**44**	**3**	**1**	**36**	**15**	**100.0**

Salts Leaving (Accumulating In) The Plant

Salt	Clarifier	SSRO	Cooling Tower	Tot. Mass per Ion	Net Balance
Flow, gpm	700	45	190,000		
Flow, MM#/day	8.4	0.5	2,281.8		
Conductivity, mmhos					
TDS as ppm					
Potassium, lb/day	0	419	0.0	**419**	**51**
Nitrate, lb/day	0	814	0	**814**	**897**
Calcium, lb/day	1,550	176	0	**1,726**	**-58**
Magnesium, as lb/day	242	13	0	**255**	**342**
Sodium, lb/day	0	8,910	0	**8,910**	**2,160**
Chloride, lb/day	0	6,464	0	**6,464**	**2,298**
Bicarbonate, lb/day	0	171	4,779	**4,950**	**-348**
Carbonate, lb/day	2,203	0	0	**2,203**	**384**
Sulfate, lb/day	0	9,639	0	**9,639**	**2,277**
Phosphate, lb/day	193	6	0	**199**	**9**
Silica, lb/day	***1,084***	64	0	**1,148**	**166**
Total salts, Lb	**5,272**	**26,676**	**4,779**	**36,727**	**8,178**
Total salts, Ton	**2.64**	**13.34**	**2.39**	**18.36**	**4.09**
% of Total	**14**	**73**	**13**	**100**	**N/A**

Economic Basis for ZLD

1) 15 year Straight Line Capital
2) Electrical Cost : $0.03/KwH
3) Chemical Cleaning Frequency : 1/ year
4) Antifoam for Evaporator/Brine Concentrator
5) No Operating or Maintenance Labor included
6) No Replacement Parts Components



Annual Capital & Operating Cost
$/year
600,000
500,000
400,000
300,000
200,000
100,000
0
--------Baseline with Adjustments----------------
----------Max Muni--------------
Max
---Segregate--
Segregate
1
1.a.1
2
2.a
2.b
2.c
3
4
4.a
4.b
4.c
2.a.1
2.b.1
2.c.1
4.a.1
4.b.1
4.c.1
Case Study No.

Boiler and Steam Systems

Rick Krichten

Global Technical Marketing

Presented by

GE
Water & Process Technologies

GE

What’s quick and easy?

- Recover more steam condensate

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What's quick and easy?

- Recover IX rinse waters
  - 4 to 6% of inlet right back to the front
- Recover filter backwash
  - 2 to 4% of inlet back to the clarifier

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Boiler Feedwater Purification

- Boiler feedwater water and steam purity requirements

- Methods of pretreatment of feedwater

- Pretreatment Equipment for boilers
  - RO in front of demineralizers
  - RO replacement of softeners

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Impact of feedwater quality on boiler operational efficiency

- Blowdown Heat Transfer Losses
- Effect of boiler cycles
  - At 10 cycles have 10% blowdown
  - At 20 cycles have 5% blowdown
  - At 50 cycles have 2% blowdown

Impact of feedwater quality on boiler operational efficiency

BTU Value of Blowdown Heat

				BD Heat Lost, $/yr		
Cycles	% BD	FW	BD	With No Heat Recovery	With Flash Tank Bottoms	With Flash Tank and Heat Exch
		klb/hr	klb/hr			
10	10%	111,111	11,111	$367,531	$147,947	$11,836
20	5%	105,263	5,263	$174,093	$70,080	$5,606
50	2%	102,041	2,041	$67,506	$27,174	$2,174

Basis

Steam	100,000	lb/hr
Pressure	600	psi

50 cycles versus 10 cycles saves $300,000/yr

50 cycles versus 10 cycles saves $120,000/yr

50 cycles versus 10 cycles saves $10,000/yr

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Boiler feedwater quality considerations

Boiler pressure and superheater/turbine steam purity requirements generally define pretreatment and feedwater quality requirements.

In general –

- Softened or single pass RO-quality make-up < **600** psig
- Generally demineralized/MB or RO/EDI make-up > **900** psig

RO – Reverse Osmosis

EDI - Electrodeionization

Resin Based Pretreatment Performance

System	Typical Effluent Quality	Typical Boiler Operating Pressure (psig)
Softener	0.2-1.0 ppm hardness (no TDS reduction)	0 to 600
Dealkalizer	50 to 90% alkalinity reduction (no TDS reduction)	0 to 600
Standard two-bed demineralizer	<10 μmho <200 ppb silica	400 to 900
Two-bed demineralizer with counterflow regeneration	<5 μmho <50 ppb silica	900 to 1,200
Two-bed demineralizer with mixed bed polisher	<0.1 μmho <10 ppb silica	1,200+

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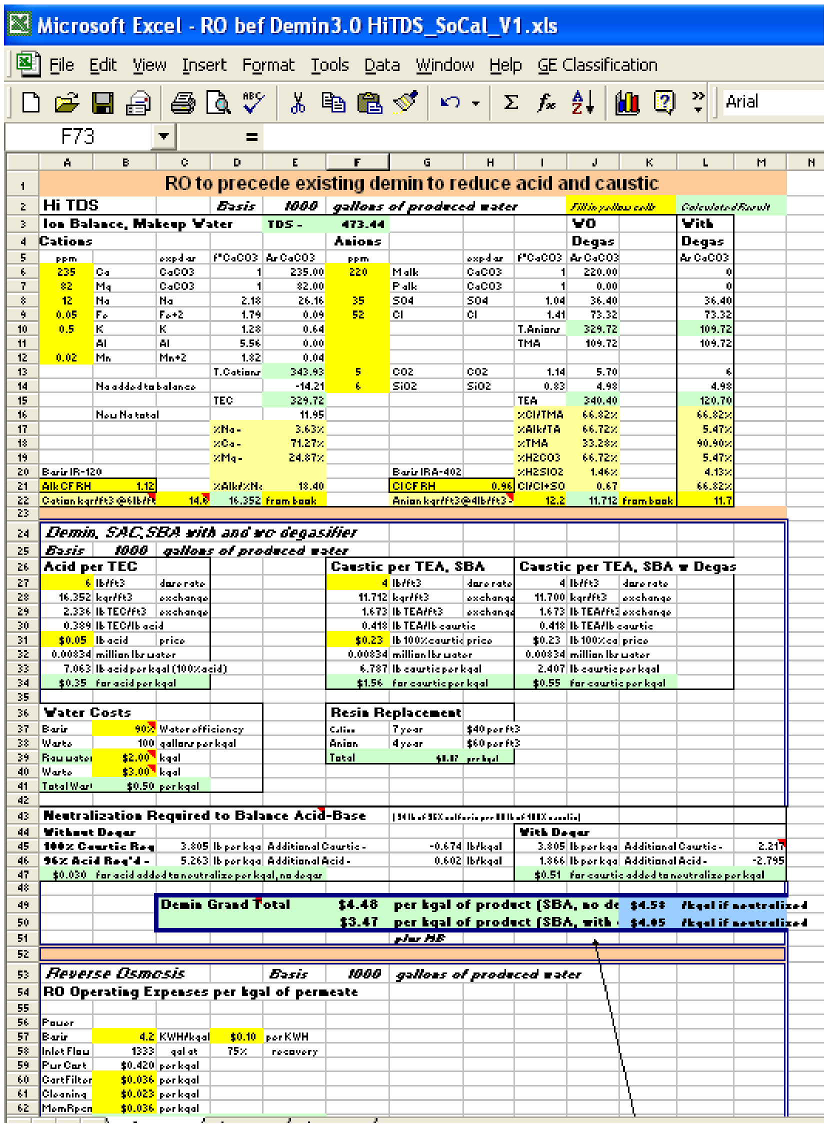
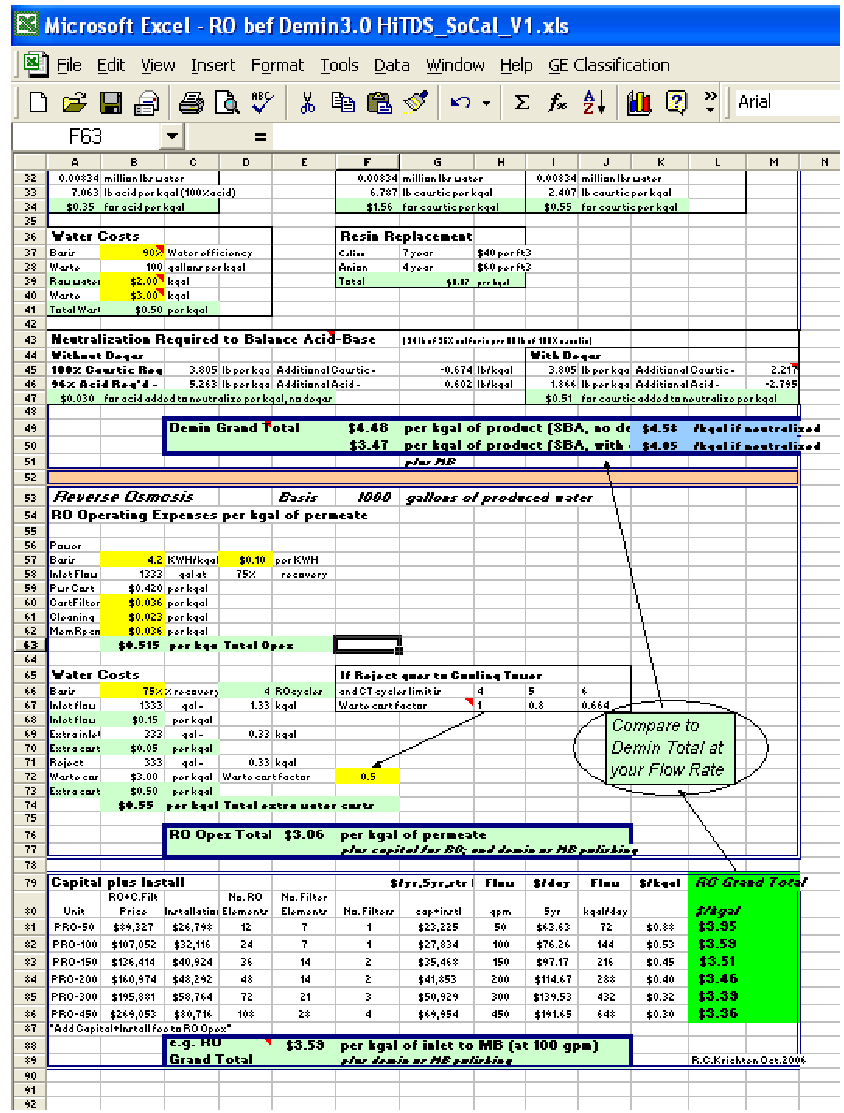
Addition of RO ahead of Existing Demin

- Reduced acid & caustic regenerant costs
  - 90 – 95% reduction in regenerant usage is typical
- 10 to 15% more feedwater production each month
- But not less intake water due to RO reject, unless reuse the reject stream
- 90% less high TDS regenerant waste
- Extended ion exchange resin life
  - Much longer regen. cycles & reduced iron/organic fouling
- Improved feedwater & steam quality

Detailed economic & environmental benefit analysis and modeling is required

Economic models must account for <u>all</u> relevant variables which impact cost, as well installed RO costs



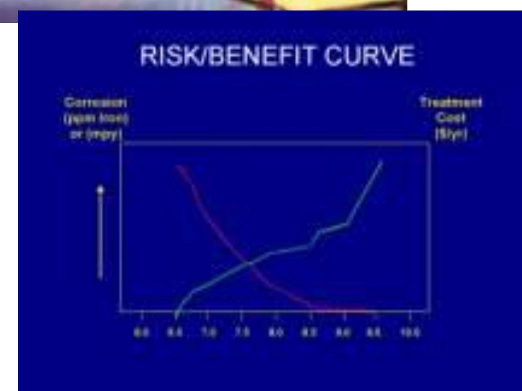


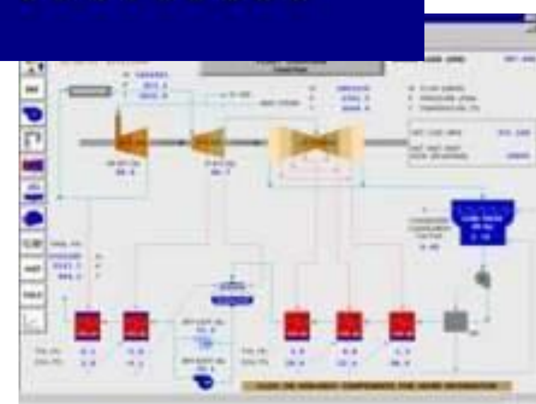
RO preceding Demineralizer Approximate TDS Breakeven

Raw Water, $/kgal	Waste Water, $/kgal	Flow, 50 gpm	Flow, 450 gpm
$.50	$.50	380	230
$.50	$1.00	405	275
$.50	$2.00	470	310
$1.50	$2.00	500	360

Conversion from NaZ Softened to RO make-up

- **Improved steam purity**
  > Process/Turbine
- **Improved condensate corrosion control**
  > High-alkalinity waters
- **Minimizes operating and maintenance expenses**
  > Boiler waterside and steamside failures
- **Maintains optimal thermal performance**
  > Boiler and steam heat transfer efficiency
- **Reduced chemical treatment costs**
  > Higher cycles operation – less wastage
  > Lower steam system treatment requirements





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Logical candidates for analysis Softener and/or Dealkalizer to RO

- Boiler cycles limited to 15 or less (7% or more blowdown)
- High alkalinity and/or high silica waters - cycles limiting or scale-forming
- Steam treatment costs excessive due to high alkalinity make-up
- Steam purity is critical – turbines; steam contact with process; clean steam generators
- Amine feed is not permitted or desired
- Systems without blowdown heat recovery (or inoperable/inefficient blowdown HX)

Blowdown Rate and Heat Savings Available

BaseCase

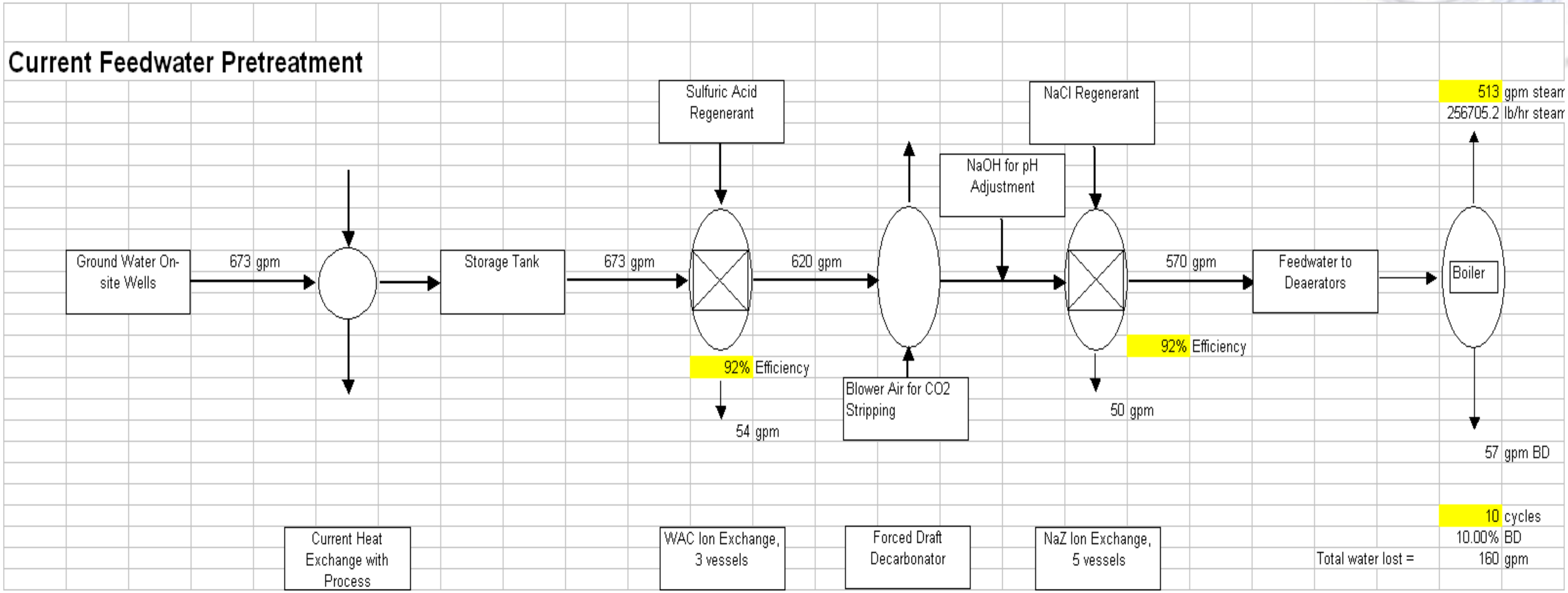
Steam Pressure psi	Steam Rate lb/hr	BaseCase Cycles	% BD	FW lb/hr	BD lb/hr	LiqBTU Btu/lb	BD Heat Lost BTU/hr
600	10,000	3.6	28%	13,846	3,846	475	1,603,846
450	80,000	8	13%	91,429	11,429	441	4,377,143
120	190,000	14	7%	204,615	14,615	321	3,843,846
50	52,000	14	7%	56,000	4,000	267	836,000
			Sum	365,890		**Sum**	**10,660,835**
						$/yr	**$878,955**

High Cycles w RO, NaZ

Steam Pressure psi	Steam Rate lb/hr	Cycles	% BD	FW lb/hr	BD lb/hr	LiqBTU Btu/lb	BD Heat Lost BTU/hr
600	10,000	50	2%	10,204	204	475	85,102
450	80,000	50	2%	81,633	1,633	441	625,306
120	190,000	50	2%	193,878	3,878	321	1,019,796
50	52,000	50	2%	53,061	1,061	267	221,796
			Sum	338,776		**Sum**	**1,952,000**
						$/yr	**$160,937**

Feedwater Savings =	**27,115**	**lb/hr**
	54	**gpm**
Blowdown Heat Savings =	**$718,018**	**per year**

Impact of RO on Water Balance



570 gpm out with 673 in

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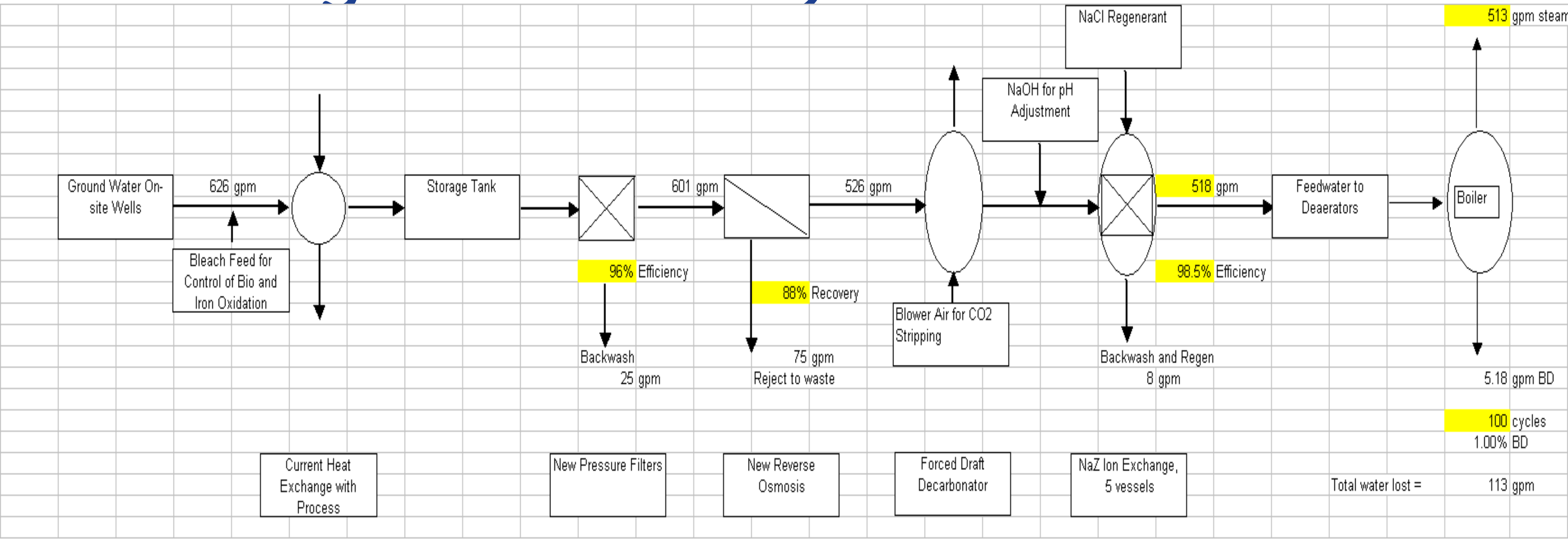
Impact of RO on Water Balance, with Higher Boiler Cycles



518 gpm out with 626 in

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Industrial Waste Water Treatment and Reuse

Ed Greenwood

Presented by

GE
Water & Process Technologies

GE

Wastewater Treatment for Reuse

Challenges

Variable wastewater flow and concentration

Fugitive emissions

High operating cost

Solids Disposal

Compliance

Solutions

Advanced separations technologies

Production Process modification

Segregation of waste streams

Zero liquid discharge

Sell effluent

Economic Benefits

Reduced raw water costs

Reduced discharge costs

Increased sustainability

New Revenue source

Faster permitting time

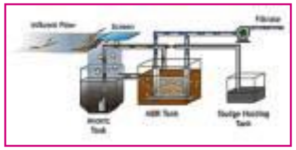
Separations Technologies

Pretreatment (UF, Chemical)

DAF / EAF (Enhanced Air Floatation)

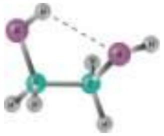
Membrane Systems (RO, NF)

Membrane Bio Reactor (MBR)



Electro Dialysis Reversal (EDR)

Mem-Chem Enhancements



Zero Liquid Discharge (ZLD)

Cartridge Filters

Almost Always in Combination

Technology Exists to Reuse Wastewater

Inorganic Waste

UF + RO
UF + EDR

Organic Waste

MBR + RO
MBR + EDR

Heavy Metals / Complex Waste

ZLD

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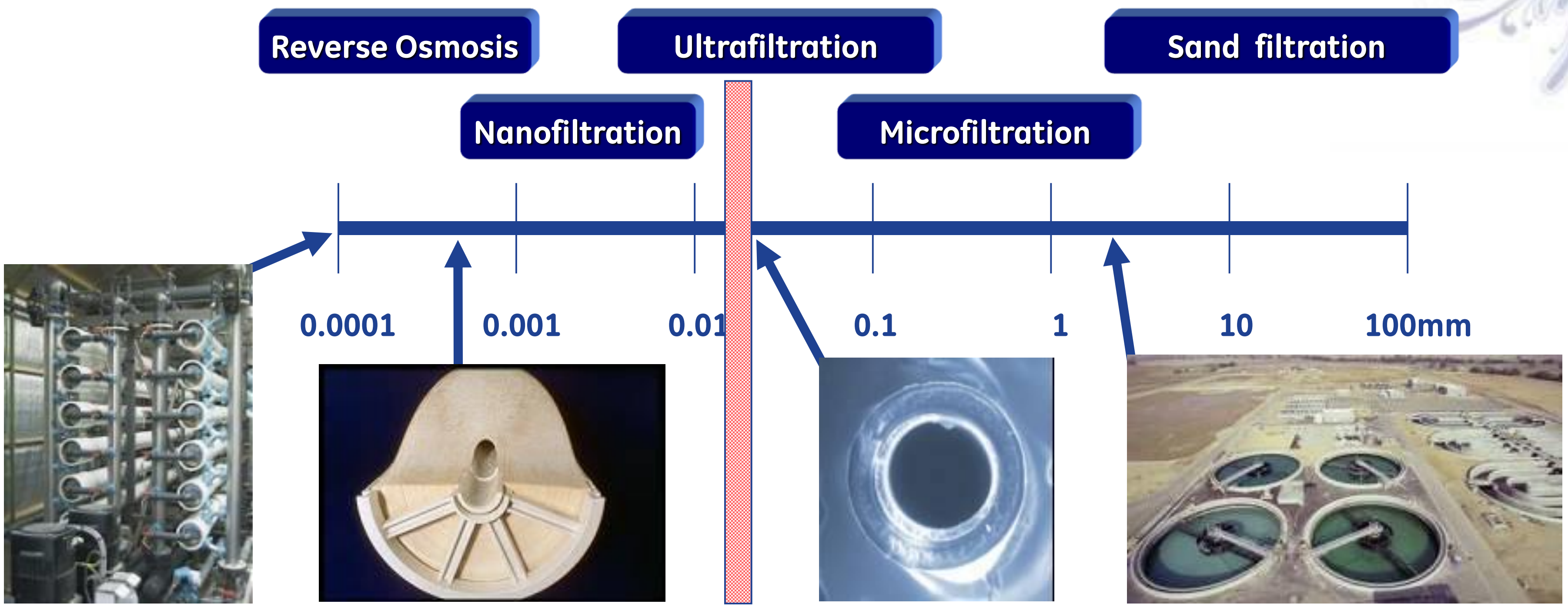
Why UF for Reuse?



Reverse Osmosis

Spiral Wound/Tubular best suited for NF/RO

Immersed Hollow Fiber best suited for UF

Conventional

Increasing pressure requirements

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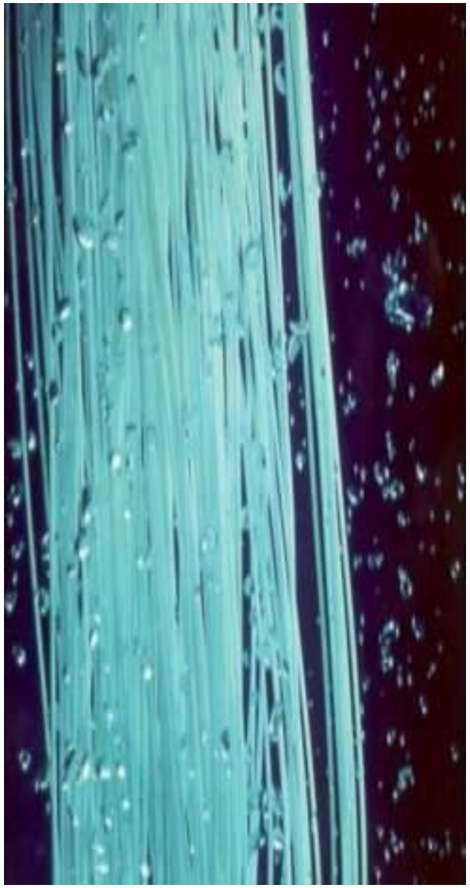
When to use a UF?

- Removal of Suspended Solids (TSS, Turbidity, SDI)
- Removal of Colloidal Material (i.e. Silica)
- Removal of Organics (TOC) using a coagulant (i.e Alum, FeCl2)
- Removal of metals using an oxidant (i.e Iron)

The *Industrial-Strength* Solution



Reinforced Structure
- No Fiber Breaks even with TSS > 20,000 ppm

Ultrafiltration Membrane
- Absolute Barrier providing SDI < 3

Immersed Membrane
- Low Trans Membrane Pressure

Outside-In Hollow Fiber
- Very Low Fouling Rates

PVDF Chemistry
- Resistant to Chlorine and Acids

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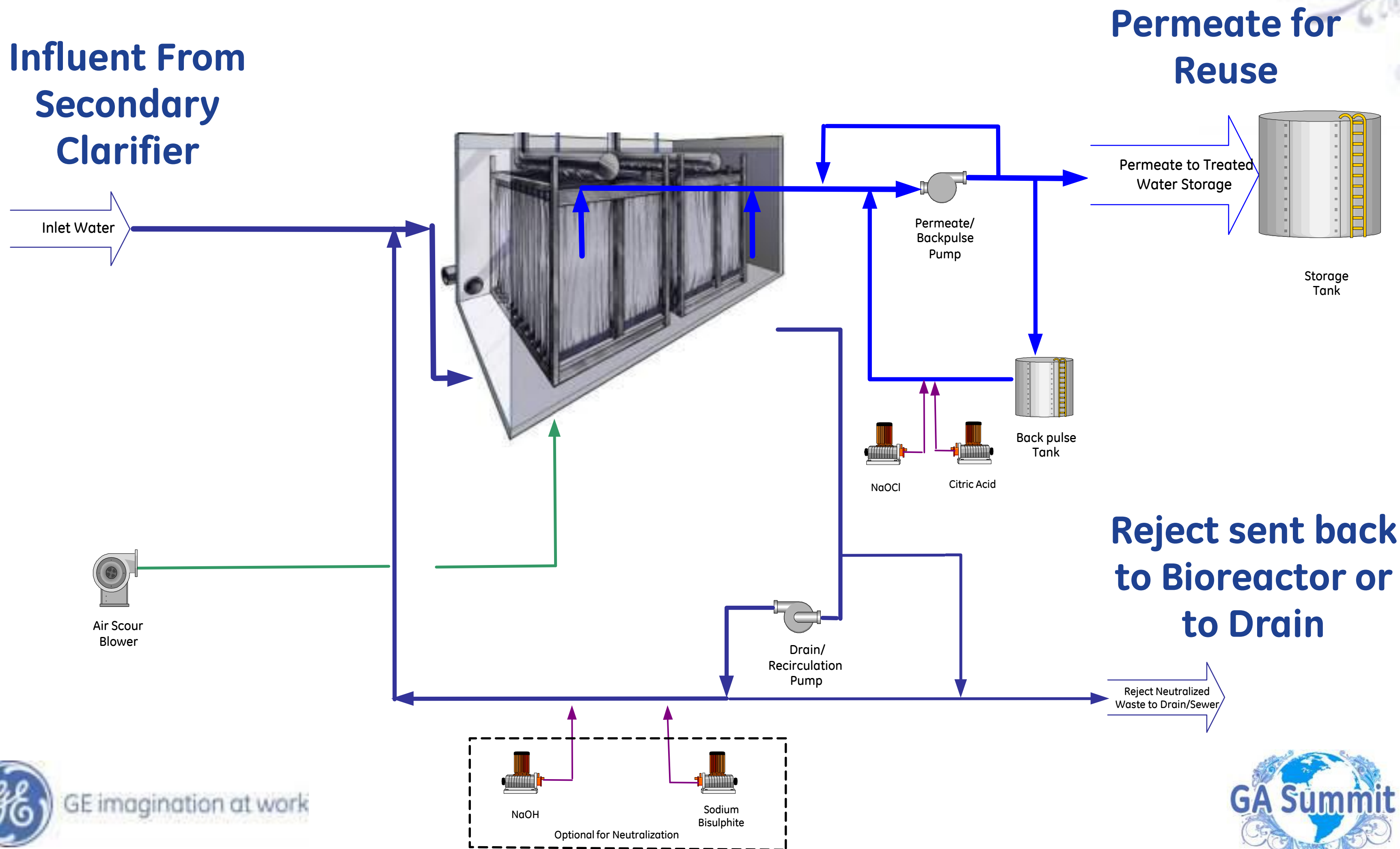
Tertiary Filtration PFD



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PEMEX Refinery, Veracruz, Mexico

ZeeWeed® UF 7,000,000 US gpd

Refinery Wastewater (Secondary Effluent) is treated and reused as RO Feed (Boiler Make-Up)

Commissioned September 2001

Petro Canada / Gold Bar, Alberta

ZeeWeed® UF

1,300,000 US gpd

Municipal Secondary Effluent is treated and reused for CT Make-Up and RO Feed (Boiler Make-Up)

Commissioned January 2006

Archer Daniels Midland (ADM), IL

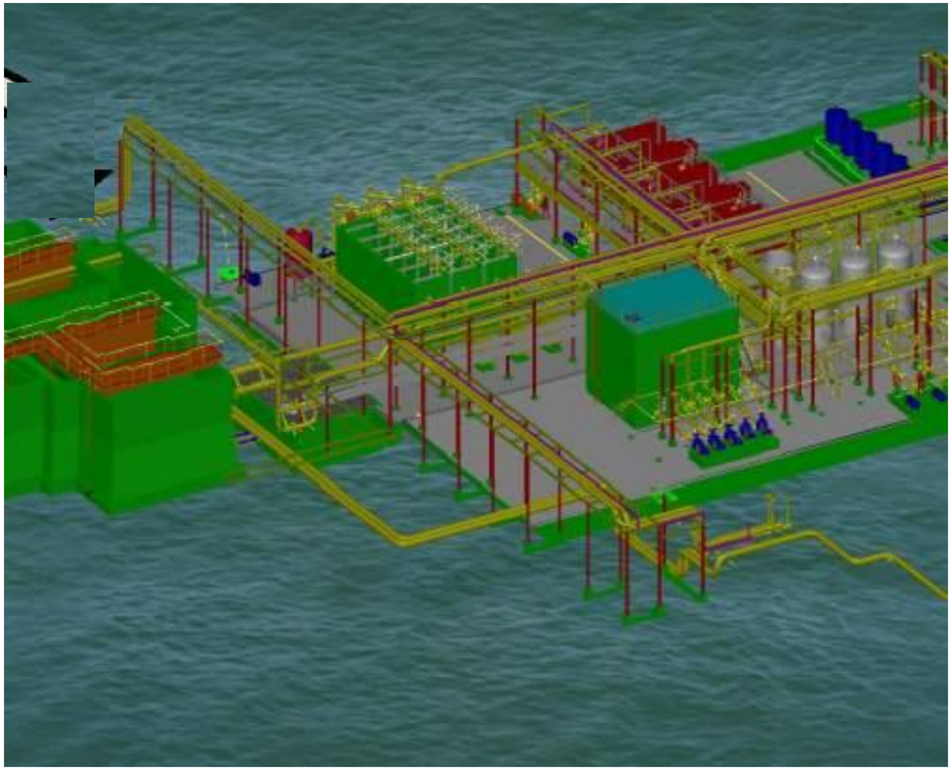
ZeeWeed® UF

5,000,000 US gpd

Grain Processor treats Secondary Effluent wastewater for reuse as CT Make-Up

Commissioned March 2004

Sasol, South Africa



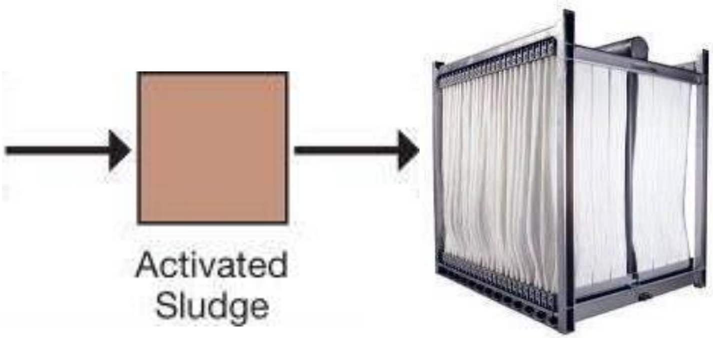
ZeeWeed® UF

Synthetic Fuels Manufacturer treats CTBD for RO Feed (Boiler Make-Up and CT Make-Up

3,200,000 US gpd

Commissioned June 2006

When to use an MBR?



- Removal of Organics (BOD, COD)
- Removal of Organic Nutrients (NH_3, TKN, NO_2/3, TN, TP)
- Removal of Suspended Solids (TSS, Turbidity, SDI)

MBR Effluent Quality

ZeeWeed® MBR Series UF
Provides Consistent Effluent Quality for RO Pretreatment

- SDI < 3
- Turbidity < 0.2 NTU
- BOD < 2 mg/L
- TSS < 2 mg/L
- TN < 3 mg/L*
- TP < 0.05 mg/L*

* With appropriate biological design and/or chemical addition

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MBR - Other Key Benefits

Reliable Performance

- Better control of biological process
- Independent of sludge settling
- 100% TSS Removal
- Readily adaptable for TN/TP reduction
- Long Membrane Life (>10 years)

Aerobic – no offensive odor (compared to anaerobic)

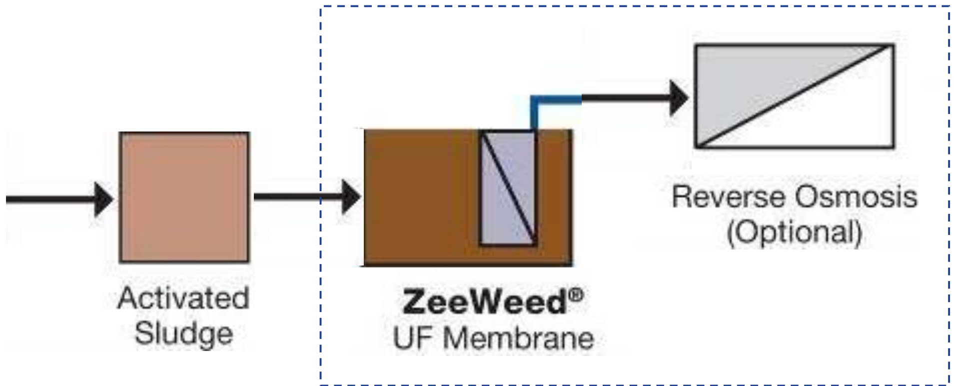
Compact – Smaller bioreactor, no clarifiers, no sand filters

Retrofit – Adaptable to existing tanks (minimize civil works)

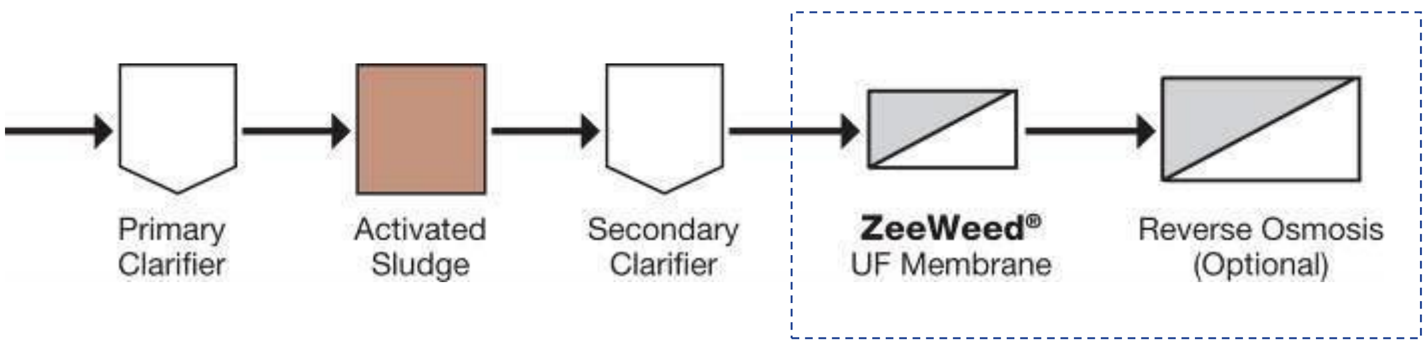
→ Best Available Technology for Water Reuse

MBR vs. Tertiary Treatment

MBR Process



Tertiary Filtration Process



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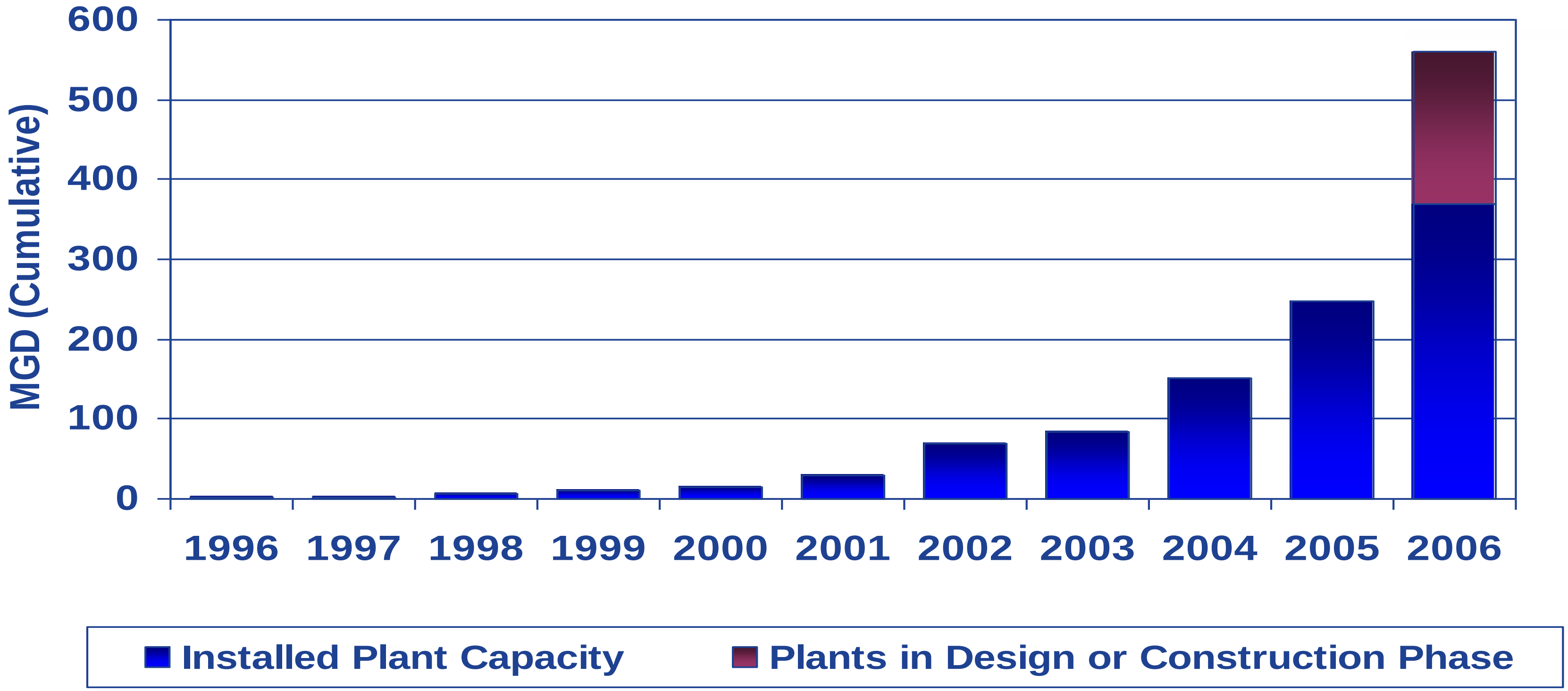
Total Installed ZeeWeed® MBR Wastewater Treatment Capacity*



*Average Day Flow as of February 2007

GE imagination at work

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Papeterie du Rhin, Europe

ZeeWeed® MBR

240,000 US gpd

Pulp and Paper (recycled paper) wastewater is treated and reused as Process Water Make-Up

Commissioned February 2000

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Coca Cola, Puerto Rico

Permaflow® MBR

121,000 US gpd

Beverage bottling plant wastewater reused in a variety of ways including RO Feed and CT Make-Up

Commissioned January 2004

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ENI Refinery, Italy

ZeeWeed® MBR

1,900,000 US gpd

Refinery wastewater treated and reused as RO Feed

Commissioned March 2007

Saving Water & Energy
is a Big Win in Every Way,
and the creative use of Water Recycle
(both Internal and External) can help you to
make it happen at your facility!

Thank you for your time & attention

GE imagination at work

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Case Study – Michelin Opelika

Mr. George Harrison

Background

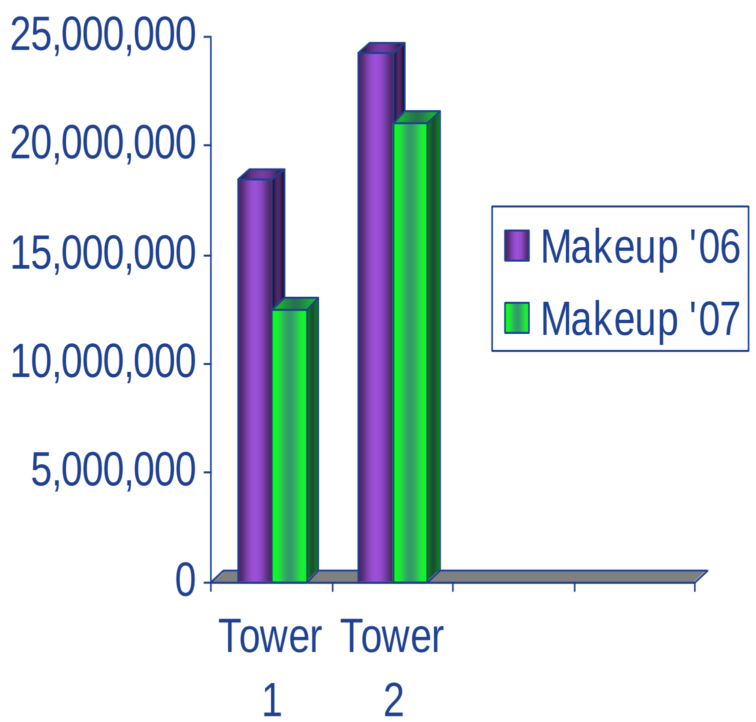
- Early in 2007 Michelin started an initiative to reduce water consumption with a goal of 3 to 4 MM Gallon per year reduction

- After performing a site wide water audit, GE and Michelin identified three projects that could offer immediate water savings

Quick Hit Projects

1. Increase Tower Cycles – Potential 5 MM Gallons per year savings.
2. Add biocide to tuber tanks to eliminate the need for constant overflow.
3. Convert to Molybdate free tower chemistry to allow tower blowdown to be sent to the fire pond as source of make eliminating the need for city water make-up in the summer

Project 1: Tower Savings



- Increase cycles from 4 to 6 cycles
- Convert from a neutral pH to an AEC alkaline pH program
- Corrosion and scale inhibition results are similar with the new program
- No impact to production
- Net savings of 5 MM gallons per year and $ 9000.

Project 2: Tuber Tanks

For the last 6 months a trial has been ran adding a GE biocide to a tuber tank to control microbiological activity and eliminate the need for constant water over flow. To date the results are promising and could result in 500,000 gallon per year water savings.

Project 2: Molybdate Free Chemistry

When the tower chemistry was changed in Project 1 to achieve higher cycles, we converted to a molybdate traced cooling water product.   We are now looking at a removing the molybdate, which may allow us to send the tower blowdown to our fire water ponds. This would fully eliminate the need for city water make in the summer due to the high evaporation rates. Estimated savings of 250,000 to 500,000 gallons per years savings.

Session Objective

To provide practical ideas utilizing process equipment & treatment chemistries to take back to your industrial plants/companies to help reduce water consumption and create new sustainable sources of water through reduce/recover/recycle