Water Resource Management and Sustainability

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Outline

- What is sustainability?
- Key drivers of water sustainability
  - Water availability & costs
  - Environmental limitations
  - Air permits
- Water resource management
  - Water discharge options
  - Reduce – Reuse – Recycle
  - Zero Liquid Discharge (ZLD) overview
- Questions

What Is Sustainability?

- Corporate Sustainability is a business approach that creates long-term shareholder value by embracing opportunities and managing risks deriving from economic, environmental and social developments.
- Sustainable business practices are critical to the creation of long-term profitability and shareholder value in an increasingly resource-constrained world.
- Sustainability factors represent opportunities and risks that competitive companies must address.

Water impacts corporate economic, environmental, and social goals.

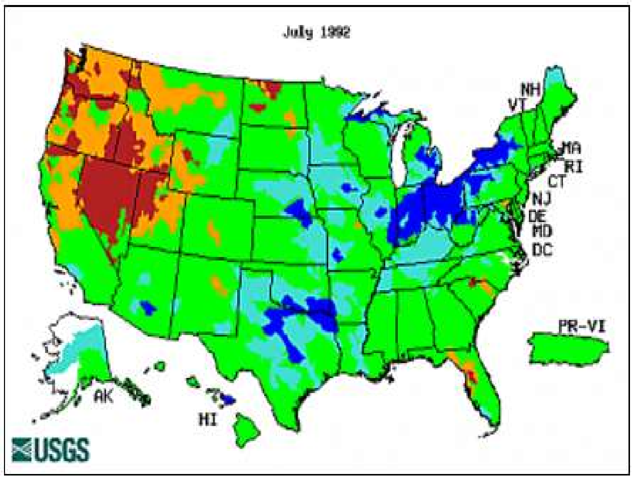
What's Driving Water Sustainability?

- Supply, Demand, and Quality of water resources
  - Increasing population (Water, Agriculture, Livestock)
  - Climate change or not?
  - Global industrial segment growth
- $ Increasing water and sewer costs
  - The price of water is increasing - Over the past 10 years, municipal water rates have increased by an average of 27% in the United States, 45% in Australia, 50% in South Africa, and 58% in Canada.
- $ Environmental compliance costs
  - NPDES effluent, sludge treatment requirements, air permits (PM 10)
- Political
  - Competition between users - Reduce both consumptive and intake requirements
- Image
  - "Green", Recycle, Reuse, LEED certification, NPDES Violations

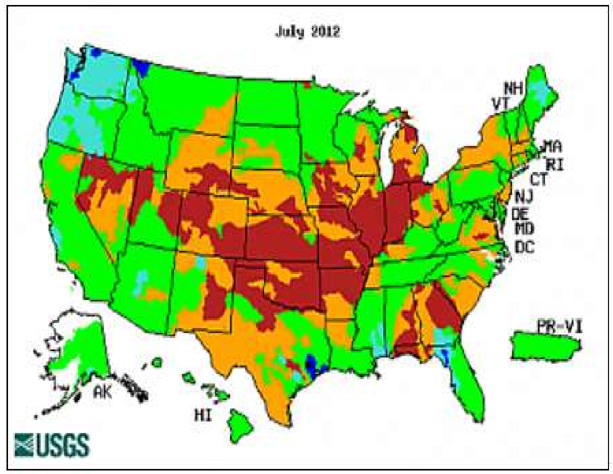
Water Scarcity?

USGS Drought Map Comparison

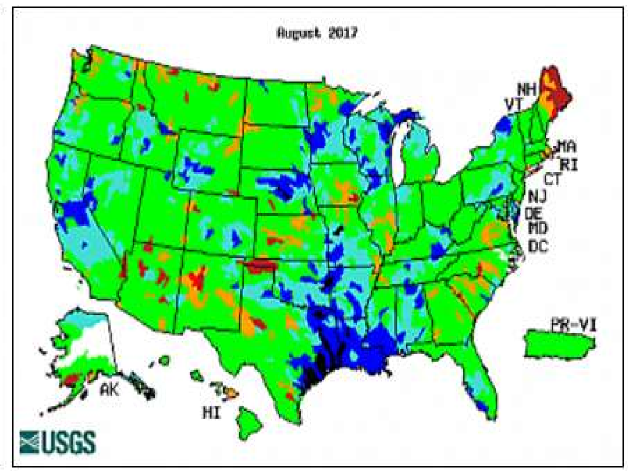
July, 1992



July, 2012



July, 2017



Explanation - Percentile classes						
Low	<10 Much below normal	10-24 Below normal	25-75 Normal	76-90 Above normal	>90 Much above normal	High

US Geological Services Data 2017

Water Cost Survey – Polling the Field

Geography	$$$/1000gals**
Michigan Area	$10.50 MU+WW
Georgetown, KY	$5.00 MU only
Chicago, IL	$7.90 MU+WW
Iowa Area	$13.00 MU+WW
West Virginia Area	$7.50 MU+WW
Southern Texas	$11.00 MU+WW
Maryland Area	$20.00 MU+WW
Lima, OH	$5.00 MU (w/10% annual increase)
Casa Grande, AZ	$2.27 MU+WW
Altavista, VA	$4.50 MU+WW
Columbus, OH	$8.00 MU+WW
Colorado Area	$9.00 MU+WW
Charleston, WV	$12.75 MU+WW
Detroit, MI	$11.00 MU+WW
North Carolina Area	$10.00 MU+WW
Kentucky Area	$6.80 MU+WW
Wichita, KS	$6.17 MU+WW
Front Royal, VA	$35.00 MU+WW
Northern KS	$8.50 MU+WW

**Geography given as reference only. Entities pay different prices based on agreements with municipalities.

US Water Cost Trends

	2008	2012	2016
Avg Water Rates:	$ 2.44	$ 3.02	$ 3.38
% Increase:		24%	12%
			39%
Avg W/W Rates:	$ 3.82	$ 4.26	$ 4.73
% Increase:		12%	11%
			24%
Avg Total Rates:	$ 6.26	$ 7.28	$ 8.11
% Increase:		16%	11%
			30%

***$$/kgal**

Water and Wastewater Annual Price Escalation Rates for Selected Cities across the United States, September 2017, U.S. Department of Energy, Office of Effeciency & Renewable Energy

Some Causes of H_2O Cost Increase

- Aging Water Infrastructure – Infrastructure Report Card, issued by the American Society of Civil Engineers (ASCE):
  - Dams: D
  - Drinking water: D
  - Wastewater: D+
- Inflation/Increase in Operations –
  - Inflation
  - Rising costs of electricity, chemicals, materials and equipment
  - Rising construction costs associated with replacing or upgrading aging utilities infrastructure
  - New regional, state and federal regulatory requirements for upgraded treatment processes also increase utility costs

You want to read this one!

https://www.fluencecorp.com/aging-water-infrastructure-in-the-us/

https://bouldercolorado.gov/water/utility-rates

Environmental Regulation Pressure

- Metals, O&G, TSS, Temperature, Toxicity
- Nutrient pollution from P and N
  - One of top causes of water quality degradation
    - Algal blooms, oxygen deficiency, decline in wildlife habitat
  - Rapidly Increasing Regulations

Cause of Impairment Group Name	Number of Causes of Impairment
Pathogens	9,743
Mercury	8,823
Metals (other than Mercury)	7,148
Nutrients	7,016
Sediment	6,583
Polychlorinated Biphenyls (PCBs)	6,083
Organic Enrichment/Oxygen Depletion	5,763
pH/Acidity/Caustic Conditions	3,737
Turbidity	3,050
Temperature	3,044
Cause Unknown - Impaired Biota	3,039
Salinity/Total Dissolved Solids/Chlorides/Sulfates	1,626
Pesticides	1,598

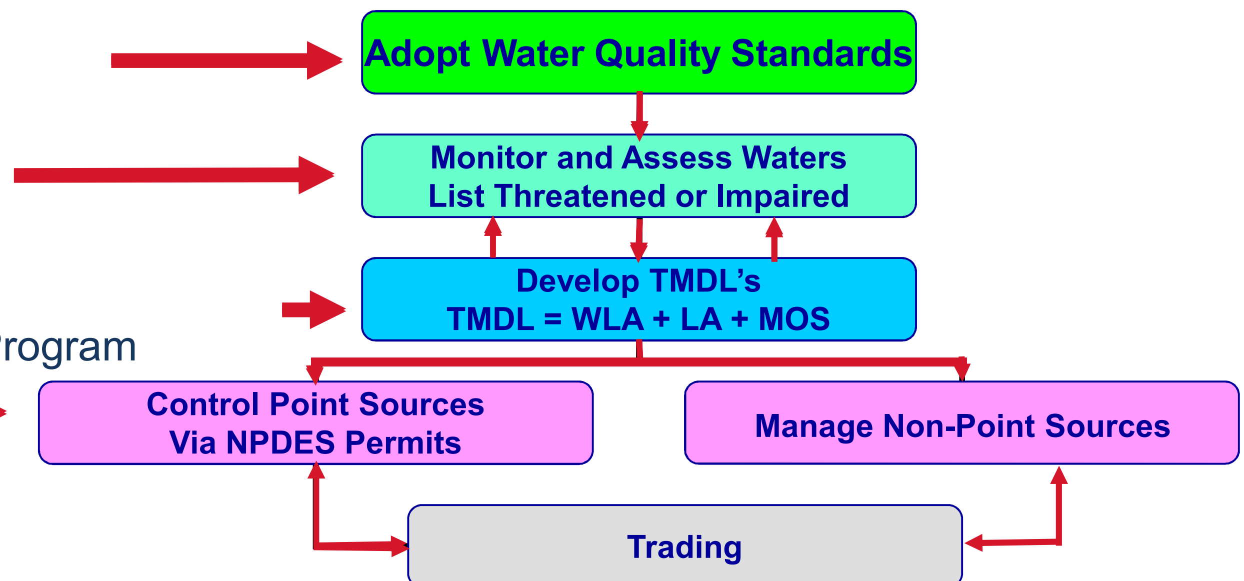
Source: USEPA http://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T#causes_303d

Regulating Nutrients

Total Maximum Daily Load (TMDL)

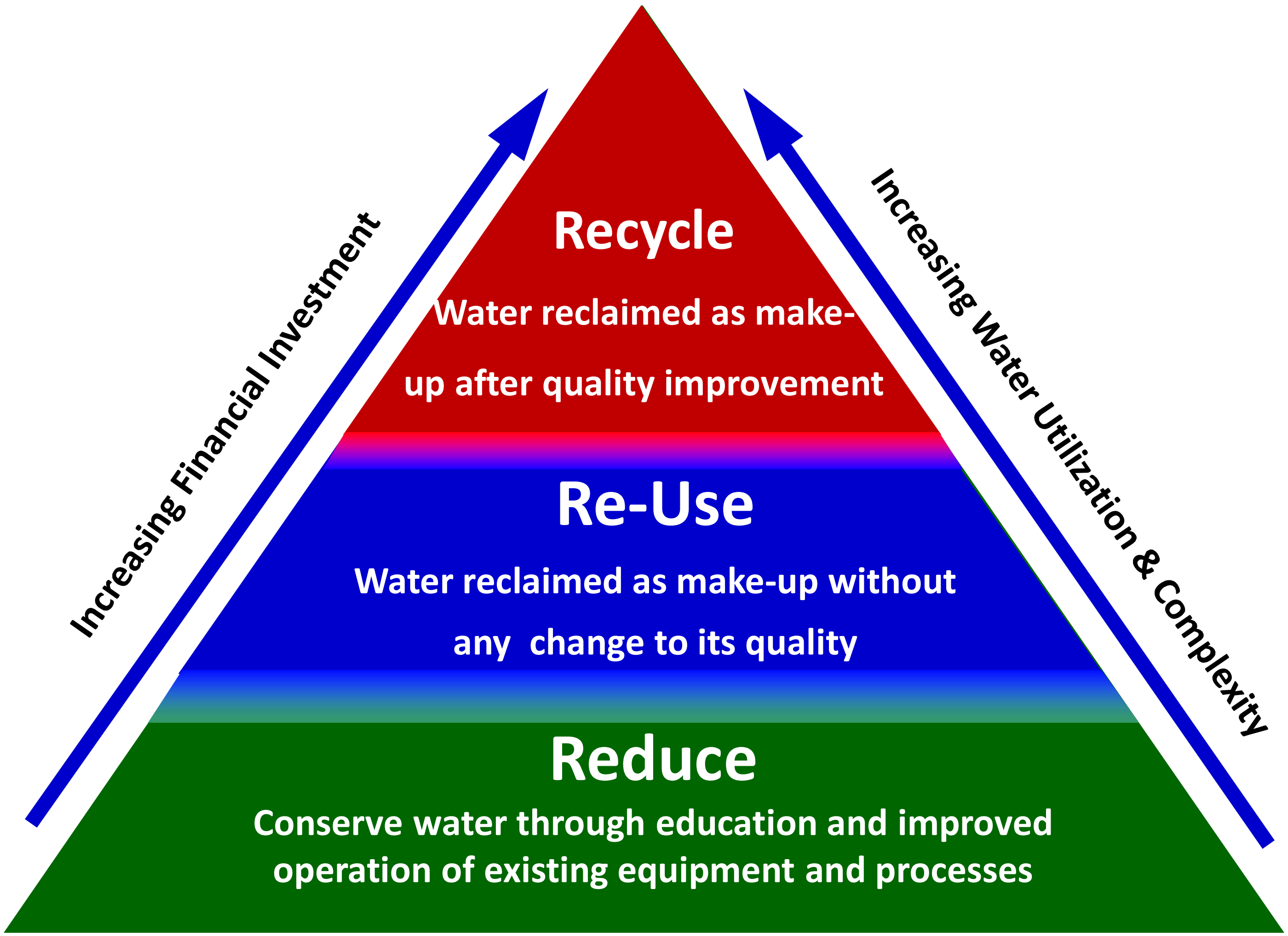
- Total input of each pollutant to a stream or watershed
- TMDL includes
  - Loading capacity calculation
  - Point Source contributions – Waste Load Allocation (WLA)
  - Non-Point Source contributions – Load Allocation (LA)
  - Margin of Safety (MOS)
- Incorporates a credit trading model

- Define the water quality goal
- Compile data and assess waterbody condition
- Section 303(d) Water Quality Program
- Implementation



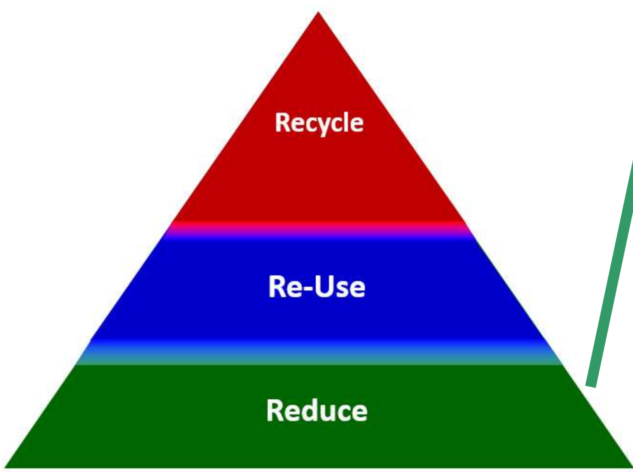
Source: USEPA http://www.epa.gov/owow/tmdl/intro.html

Water Resource Management



Reduce

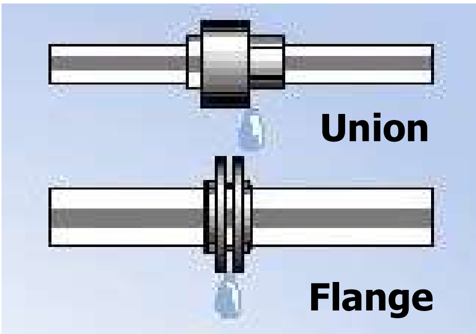
- **Strategy**
  - √ Review work practices
  - √ Improve efficiency
  - √ Share "Best Practices"
  - √ Education
- **Examples**
  - √ Containment
  - √ Reduce flows
  - √ Increase cycles
  - √ Closed loop cooling



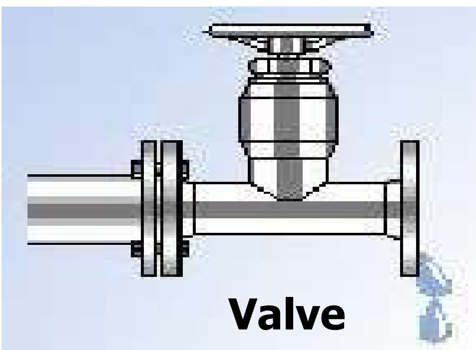
Reduce – Optimize Processes

- Operations and maintenance
- Keep Closed-Loops closed
  - Group Question : What are typical/acceptable closed loop losses
  - Heat exchangers, valves, pump seals, cross connects, wash down
- Steam Trap Surveys
- Utilize Low TDS and Nutrient loading chemicals
- Control CT COCs

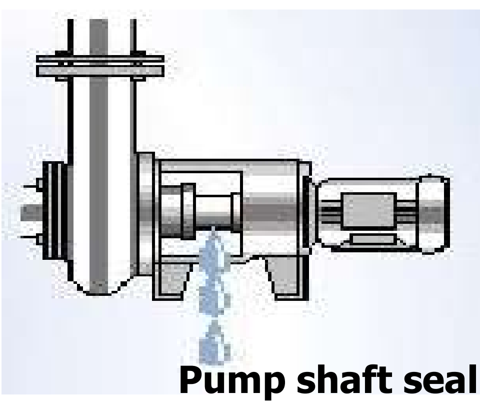
Reduce – Operations and Maintenance



Water Loss	One Drop/Sec
Hourly Loss	0.5 Liters
Annual Loss	1,321 gallons



Water Loss	0.1 L/min
Hourly Loss	6 Liters
Annual Loss	14,000 gallons



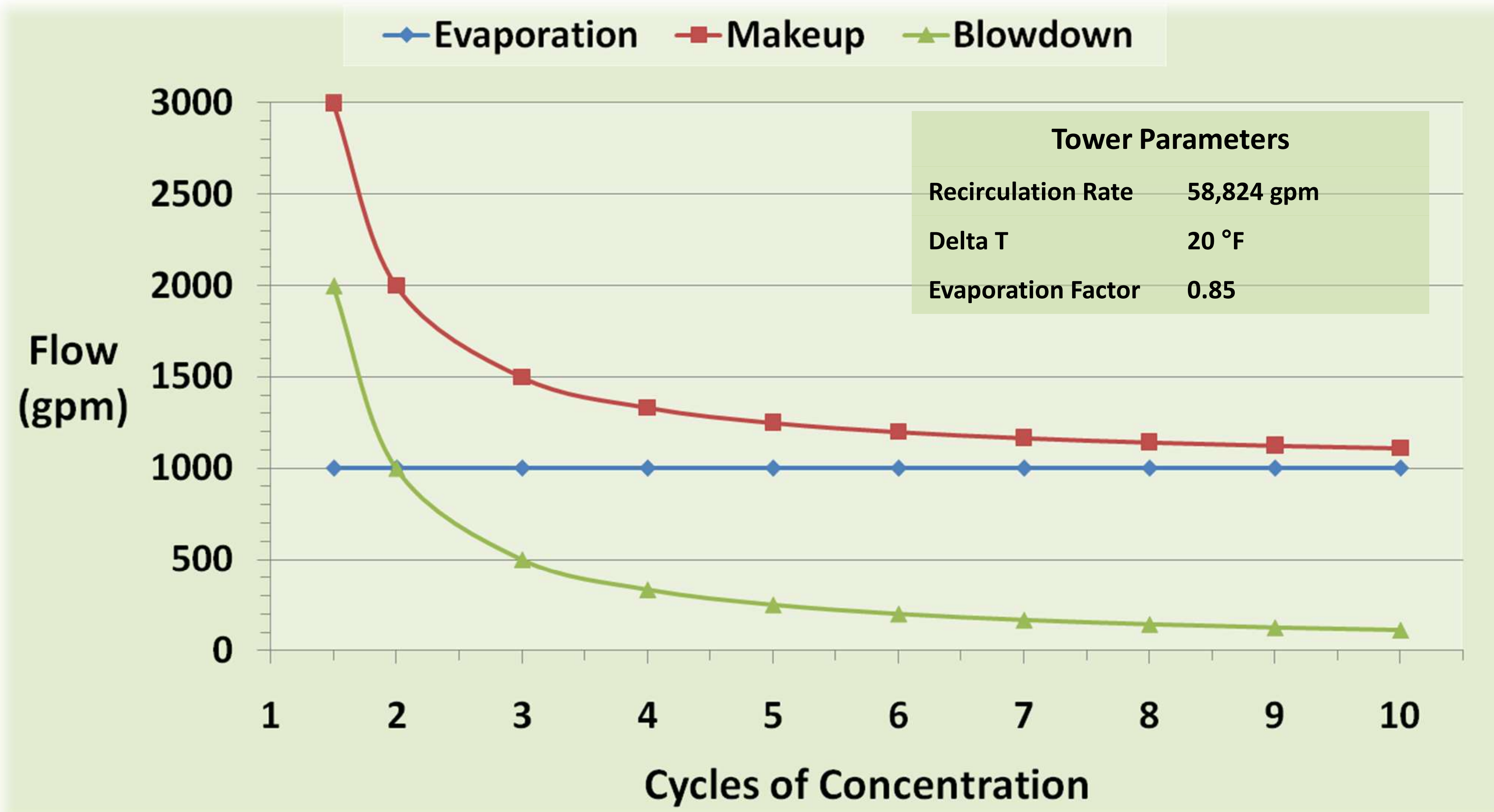
Water Loss	0-4 L/min
Hourly Loss	0-240 Liters
Annual Loss	0-554,760 gallons

Reduce - Low TDS & Nutrient Loading Chemicals

- Impact of bleach....
- Phosphorus.....
- Acid/caustic.....

So which chemistries are you currently using that could be substituted?

Reduce - Water Usage via Increasing CT COCs



Cycles = Makeup/Blowdown

BD = Evaporation/(Cycles – 1)

What Limits Your Cooling Water Chemistry?

- pH - Increases with cycles – may require acid feed
- Chloride (corrosive)
- Hardness - Scaling index
- Silica and iron in makeup
- Cooling tower design
  - Fill type
  - Uncovered distribution deck
  - Materials of construction (galvanized)
- Metallurgy
  - Stainless steel - Chlorides
  - Brasses - Ammonia
- Discharge limits
  - Total dissolved solids
  - Phosphate
  - Metals
- Heat exchanger or Process design
  - High skin temperature
  - Low flow

Monkey-Wrench in Increasing COCs

- PM-10/PM-2.5 becoming much more prevalent
  - Drift droplets contain same chemical impurities as recirc water
  - Particulate matter may be classified as an emission
- Magnitude of the drift loss influenced by the number and size of droplets which are determined by:
  - Tower fill design
  - Tower design
  - Air and water patterns
  - Design of the drift eliminators
- As an emission, regulated by EPA:
  - Lbs/yr (t/yr)
  - Limits COCs in CT by limiting lbs carried in recirc at any given time (translates to lower conductivity set point)
  - Increases MU and BD

Monkey-Wrench in Increasing COCs

- EPA's AP-42 is methodology for calculating
- Many problems with this method
- For example:

Heat Treat

COOLING TOWER

2 cells with 3,000 gallons per minute.
Estimated TDS concentration of 500 ppm.
Drift loss rate of 0.005%.

PM/PM_{10} (3,000 gals/min)(500/1,000,000)(8.345 lbs/gal)(0.00005)(60) = 0.038 lb/hr
(0.038 lb/hr)(8760 hrs/yr)(1 ton/2000 lbs) = 0.164 tpy

What is wrong with this calc?

Flaw #1 – TDS Measurements

- How are we calculating TDS?
  - Typically don't measure directly
  - Usually use Conductivity as surrogate (65% as TDS)
- Is this accurate?
- Does it depend on the conductivity contribution of each species?

Pre Column (1ppm)	Conductivity (umhos)
$CaCl_2$	2.44
$MgCl_2$	2.71
NaCl	2.16
$CaSO_4$	2.04
$MgSO_4$	2.21
Na_2SO_4	1.83
NaOH	6.39
NH_4OH	7.78
$CaCO_3$	2.57
Na_3PO_4	2.17
Na_2HPO_4	5.13
NaH_2PO_4	8.56

Flaw #2 – Calculating Drift Rate

- What drift rate are we using?
  - 0.0005%?
  - 0.02%?
- If unknown, some say to use 0.02%
- This can make a dramatic impact on overall solids *emission*

	Case #1	Case #2
Drift %	**0.0005%**	**0.02%**
RR gpm	50,000	50,000
Delta T f	15	15
Evap gpm	638	638
MU TDS ppm	300	300
COCs	8.0	8.0
CT TDS ppm	2,400	2,400
Drift gpm	0.25	10
Drift mmlbs/hr	0.0001251	0.005004
Drift Solids lbs/hr	0.30	12.01
Drift Solids lbs/yr	2,630	105,204
Difference		**39x**

Flaw #3 (but considered Best Practice) – Calculating Actual Solids

- Estimating Particle Size Distribution of PM_{TOTAL}

Based on Table

d_d = Drift droplet diameter, microns

C_{TDS} = Concentration of TDS in the circulating water, ppm x 10^{-6}

ρ_w = Density of Drift droplet, g/cm^3

ρ_{salt} = Density of particle, g/cm^3

$PM_{2.5}$:	$d_d = 30$	%Mass = 0.226%
PM_{10}:	$d_d = 110$	%Mass = 70.509%
TSP/PM:	$d_d = 270$	%Mass = 96.288%

Assumed to be 1.0g/cm3

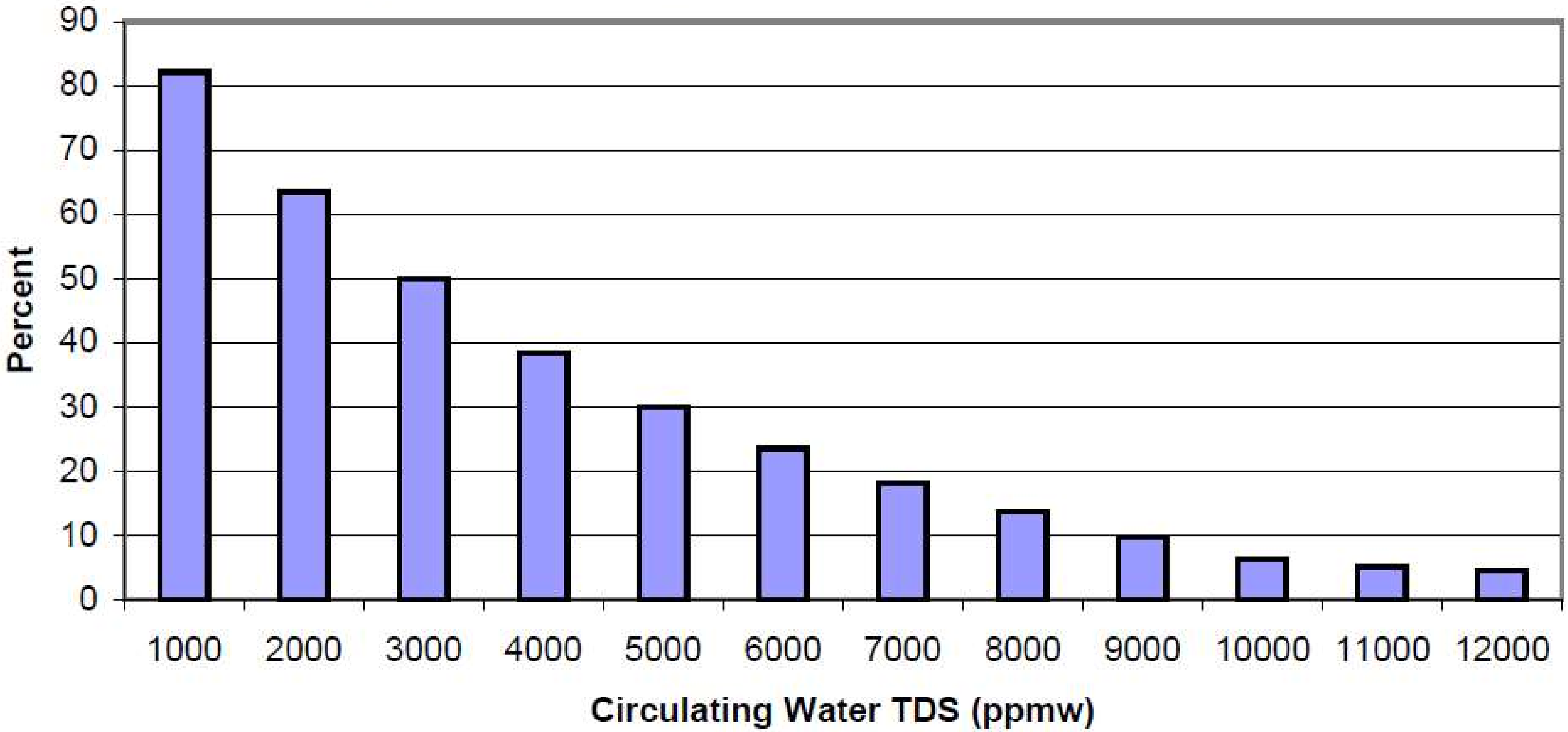
Based on density of constituents such as CaSO4, NaCl

The equation for determining particle size/diameter (d_p), in microns is:

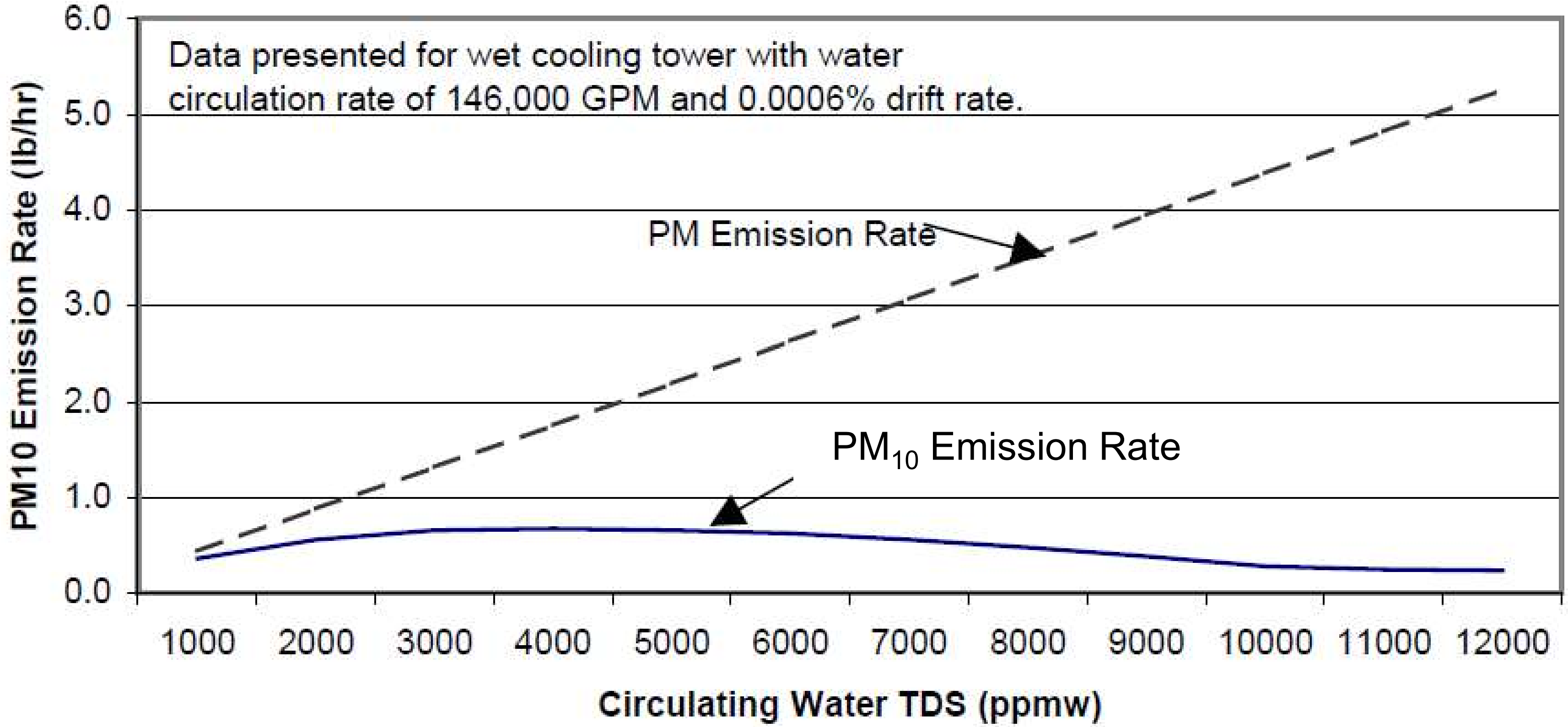
$$d_p = \frac{d_d}{(\rho_{salt} / \rho_w C_{TDS})^{1/3}}$$

Flaw #3 (but considered Best Practice) – Calculating Actual Solids

Figure 1: Percentage of Drift PM that Evaporates to PM10



Flaw #3 (but considered Best Practice) – Calculating Actual Solids



PM-10/2.5 Practical Application

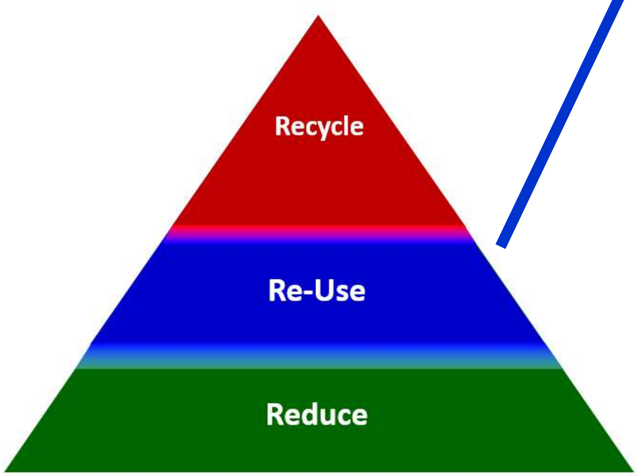
- So who cares? What does it mean to the plant?

	Original No Adjustment	New w/ Adjustment
Drift %	**0.0050%**	**0.0050%**
RR gpm	50,000	50,000
Delta T f	15	15
Evap gpm	638	638
COCs	2.6	3.8
BD gpm	***401***	***225***
MU gpm	***1,038***	***863***
MU TDS ppm	300	300
CT TDS ppm	777	1,149
Drift gpm	2.5	2.5
PM10 Drift mmlbs/hr	0.00125	0.00085
PM10 Drift Solids lbs/hr	0.97	0.97
PM10 Drift Solids lbs/yr	**8,515**	**8,525**

***assuming 8,500 lbs/yr limit*

Reduces BD by 44% and MU by 17%!!!

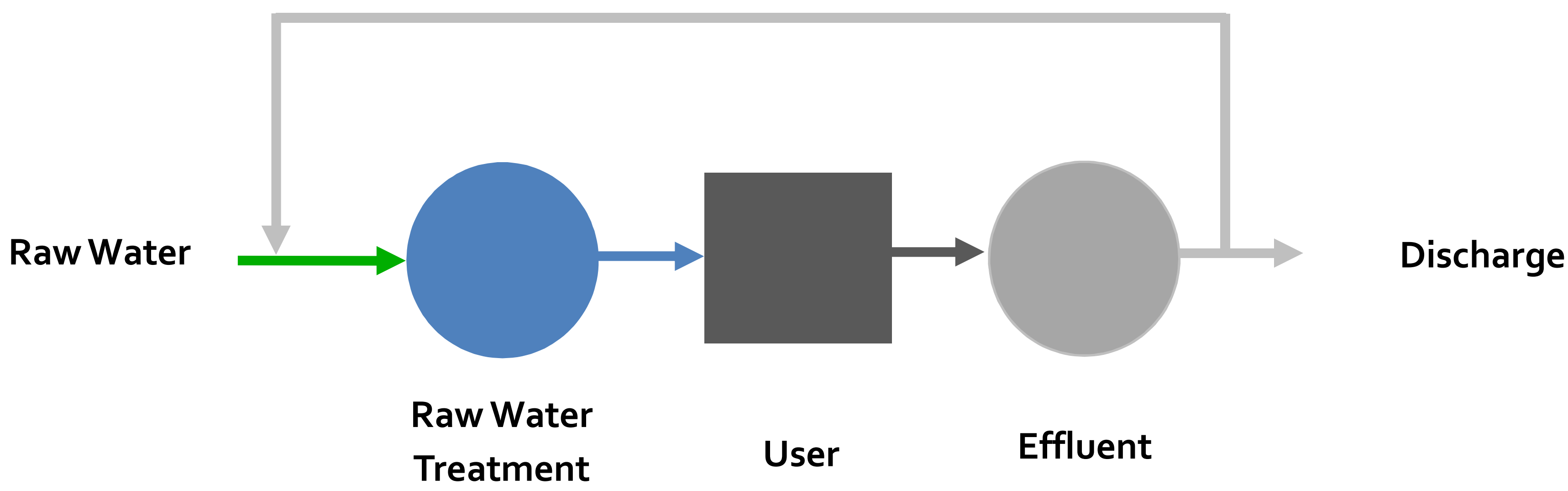
Re-Use



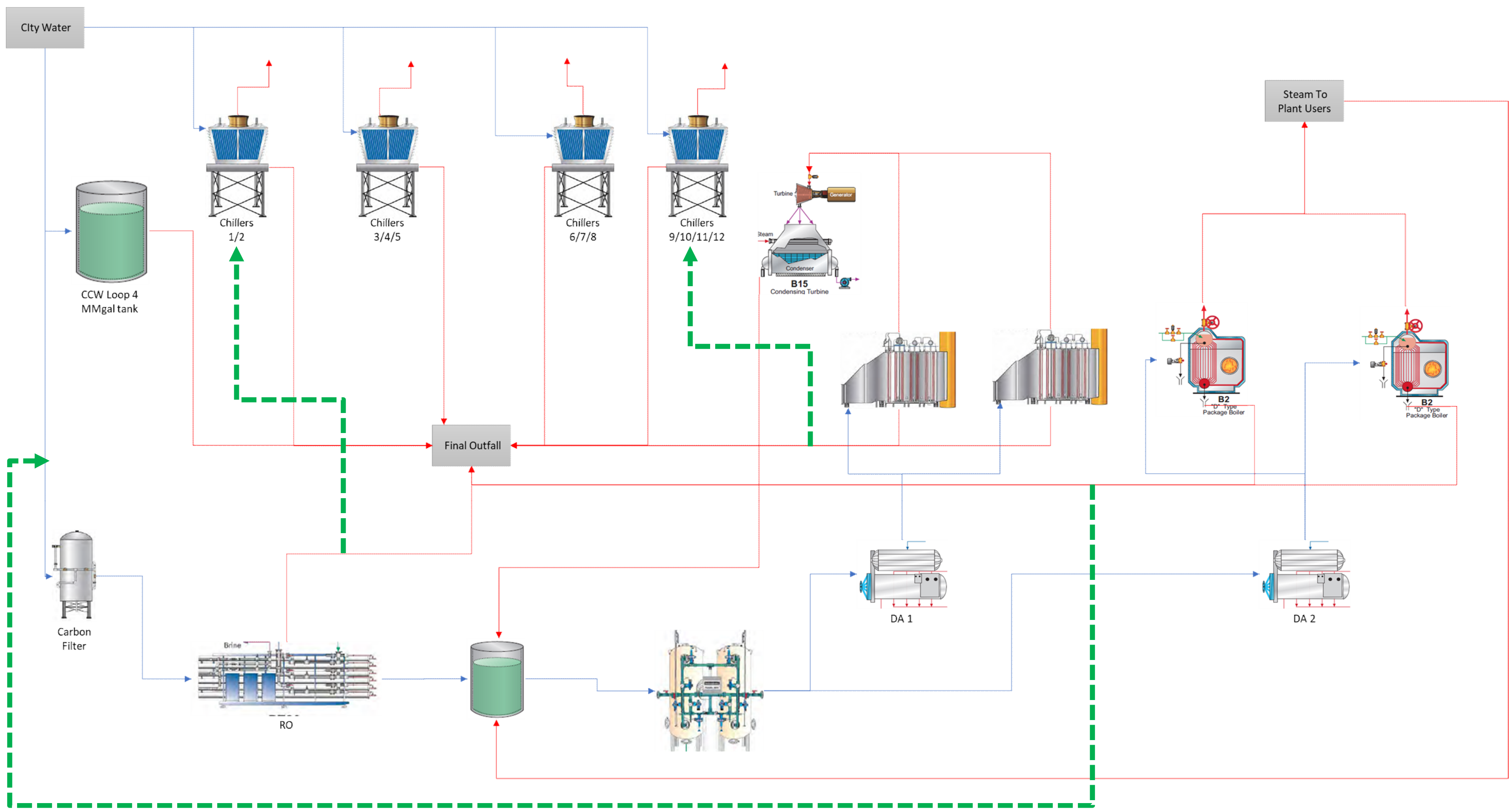
- **Strategy**
  - √ Segregation
  - √ Match Quality
- **Examples**
  - √ Cooling towers
  - √ RO reject
  - √ IX rinses
  - √ Boiler blowdown
  - √ Wash water
  - √ Condensate recovery

Water Re-Use Without Treatment

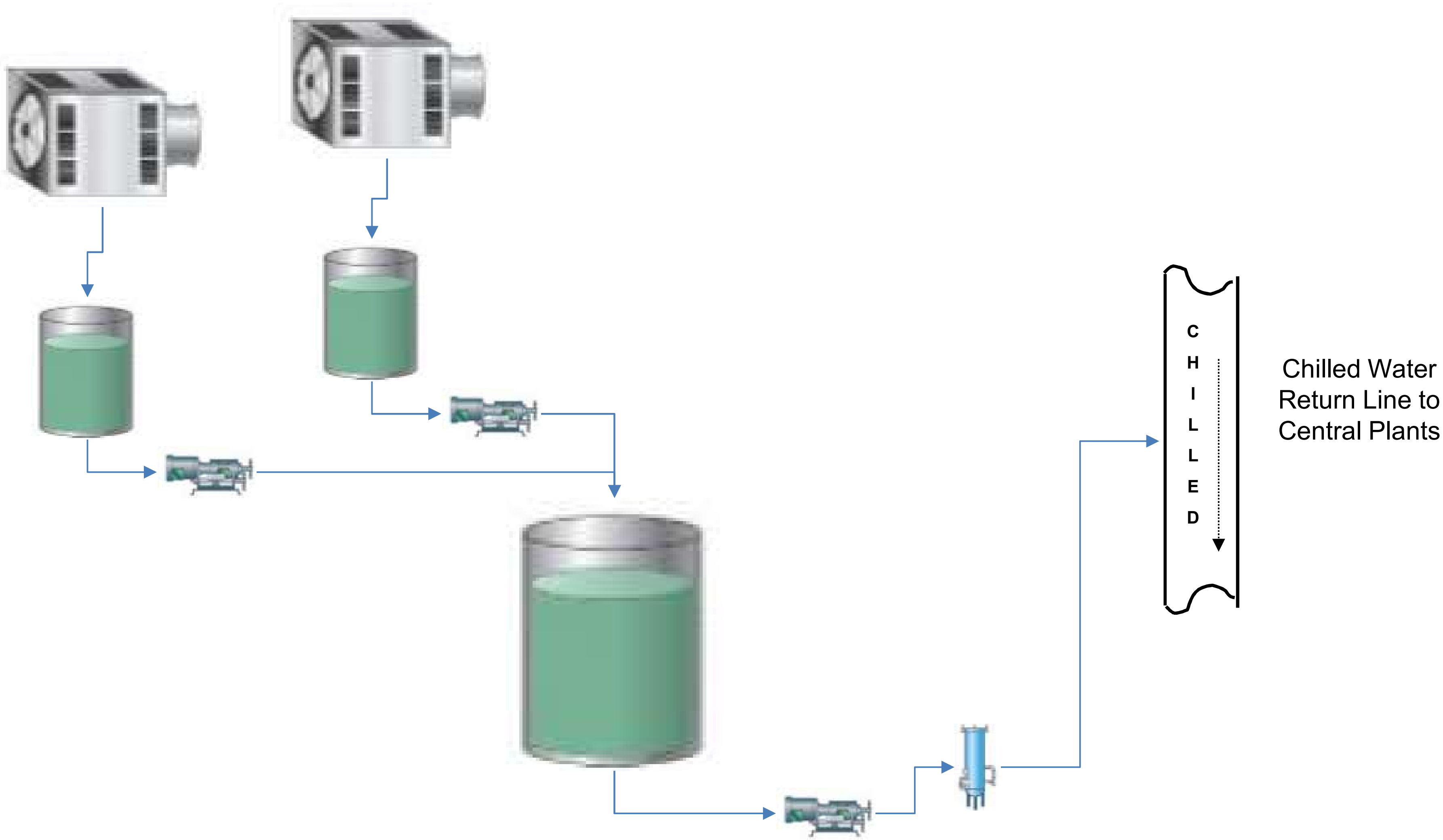
Low Cost Solution: ***<u>Higher Risk</u>***



Re-Use at the User – Rejects/BDs to CT



Re-Use at the User – AHU Condensate Recovery

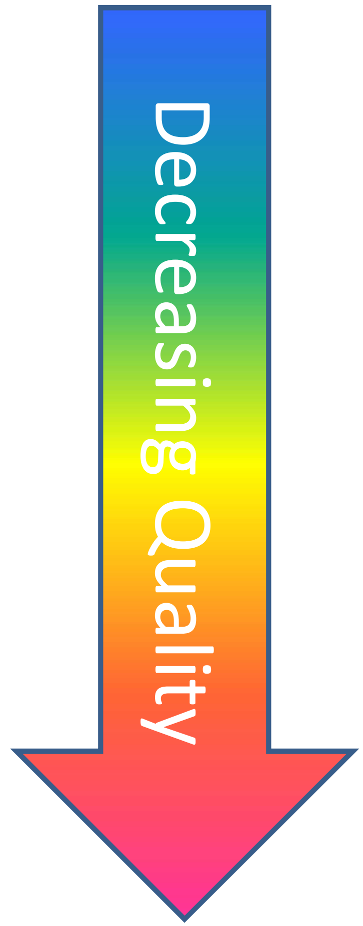


Re-Use on the Front-End – Different MU Sources

- Many alternative water sources can be used successfully with proper pretreatment
- Determine the chemistry, avg., min, max.
  - Specify the water quality in the contract!
- Determine the quantity available
- Evaluate system constraints
  - Stainless steels – chlorides
  - Copper alloys – ammonia
  - Carbon steel - corrosion
  - Plastic fill – organics, fibrous materials, biofouling
  - Temperatures – scaling
  - Heat exchanger type (plate and frame, tube diameter)
- Evaluate impact on discharge constraints
  - BOD, COD, ammonia, metals, priority pollutants,
  - sulfates, chlorides, phosphate, etc.

Potential Plant Water Sources

- City water
- Well water
- Lake water
  - Storm or Runoff Ponds
- River water
- Desalination water
- Grey water
  - Municipal effluent
  - Industrial process water
  - Industrial effluent
- Saline water
  - Brackish water
  - Sea water



Municipal Grey Water an Underutilized Resource

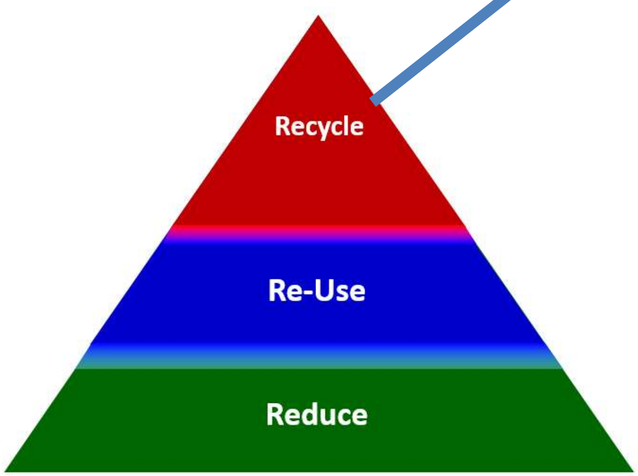
Advantages

- Lower cost, or free
  - Once you build the pipeline
- Reduces effluent discharge to receiving stream
- Lower salinity than many alternate sources
- Already treated
  - Low TSS
  - Chlorine residual
  - But, how well???

Challenges

- Long term variability in quality
  - Industrial process and treatment can change
- High organics
  - Nutrient for microorganisms
  - Increased chlorine demand
- High phosphate
  - Calcium phosphate deposition
  - Effluent nutrient
- Airborne pathogens
  - Legionella
  - Coliforms
- Ammonia
  - Chlorine demand
  - Nitrifying bacteria

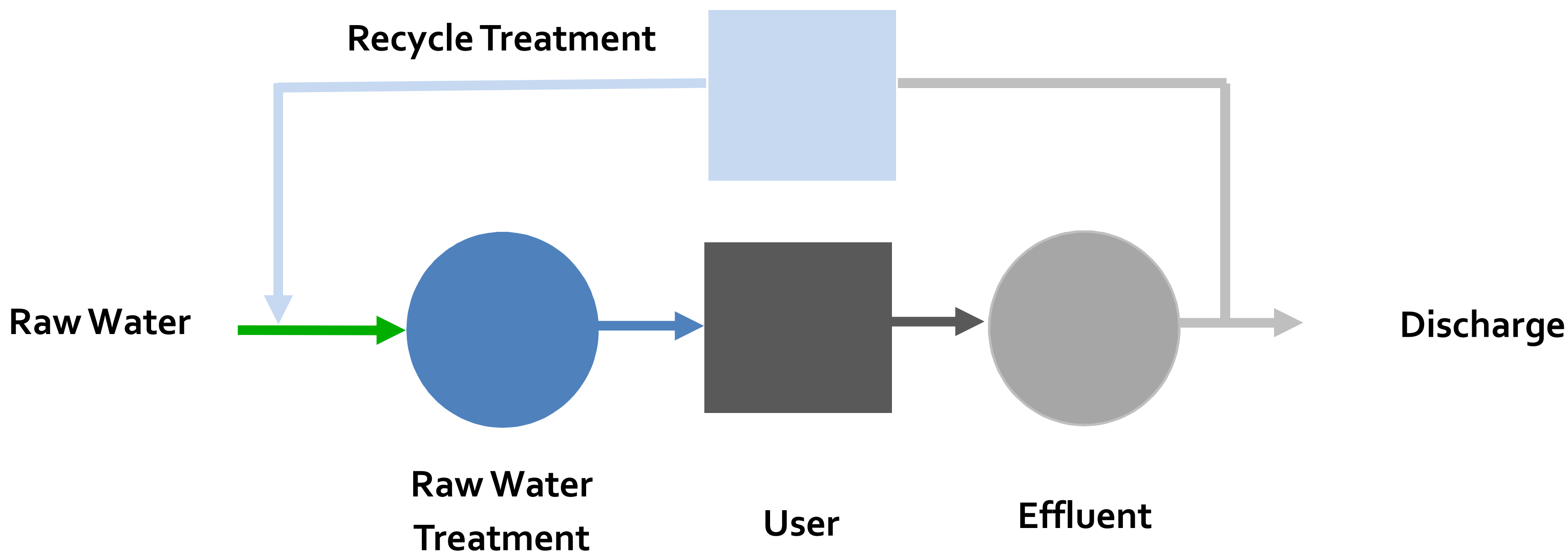
Recycle



- **Strategy**
  - √ Segregation
  - √ Improve Quality
- **Examples**
  - √ Cooling towers
  - √ Boilers
  - √ Process Uses
  - √ Wash water
  - √ Process water
  - √ Wastewater

Water Re-Use Without Treatment

Low Risk Solution: ***<u>High Cost</u>***



Recycle Treatments

- Clarification
- Filtration
- Membrane Solutions
- Zero Liquid Discharge – the ultimate in Recycle/Reuse

A wide variety of treatments available –

Campuses typically don't have all of these processes, but all are viable processes for any type of plant

ZLD Processes

- 5 Basic Processes
  1. Initial Concentration
  2. Hardness/Silica Removal or Stabilization
  3. Intermediate Concentration
  4. Final Concentration
  5. Solid Waste Production
- Processes may overlap or be eliminated entirely

How ZLD(ish) do you need to be?

ZLD Processes

- Cost of concentration generally proportional to TDS in concentrated streams
  - essentially free in cooling tower
  - As high as $40/gal in final step
- Volume of water to be concentrated lowers with each step of the process
- Designs focus on moving evaporation to the "front end" (less expensive)

#1: Initial Concentration

- Occurs in cooling tower or demin system
- Level of concentration obtainable depends on the incoming makeup water quality and its propensity to form scale
- Typically, makeup water can be concentrated from 3-10 times, raising TDS to 2500-8000 ppm
- Water high in scale-forming dissolved solids can be concentrated only a few times prior to being removed from the system via blowdown. Water low in scale-forming dissolved solids may be concentrated ten or more times prior to removal through blowdown

#1: Initial Concentration

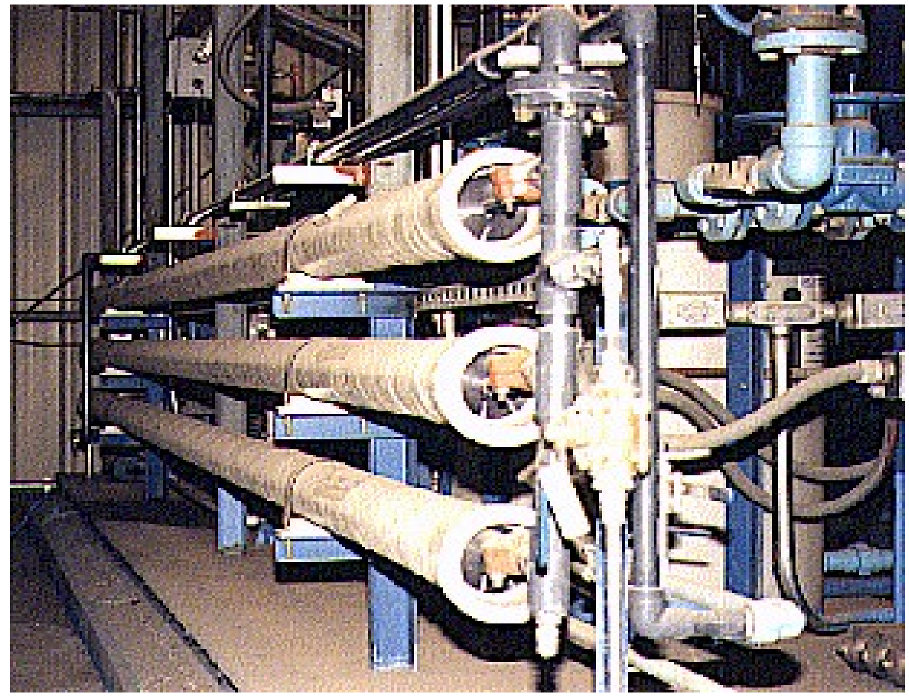
- "Front-end" removal of scale-forming minerals a good option to maximize initial concentration
- Initial concentration is least expensive and should be maximized

#2: Hardness/Silica Removal

- Goal is to replace less soluble species with more soluble species
- Can be accomplished after initial concentration (tower blowdown softening) or before initial concentration (make-up softening)
- Front-end softening usually most economical

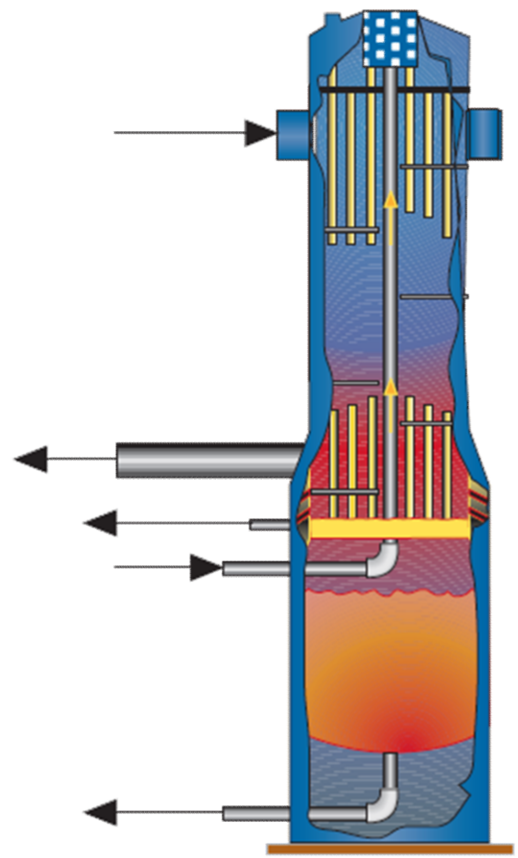
#3: Intermediate Concentration

- Utilizes RO to further concentrate TDS
- Limited by level of insoluble species in RO reject
- RO permeate reused, reject goes to Final Concentration
- Allows smaller Final Concentration equipment
- Typically raises TDS to the 20,000-60,000 ppm range



#4: Final Concentration

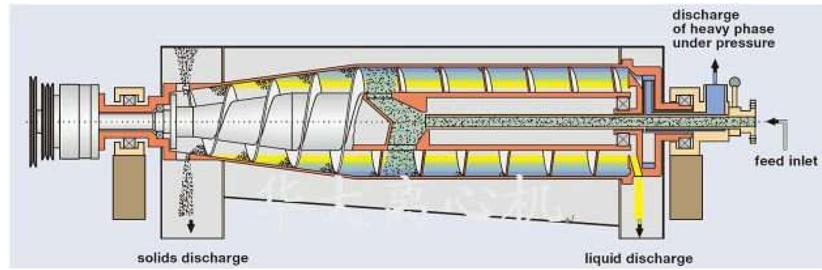
- Three Options (in various combinations)
  - Brine Concentrator
  - Crystallizer
  - Evaporation Ponds
- Uses thermal energy to evaporate incoming water
- Concentrated slurry sent to Solid Waste Production
- Focus shifts from TDS to TS (Total Solids), combination of TSS and TDS
- Can typically raise waste stream TS to the 150,000 to 500,000 range



Typical Brine Concentrator

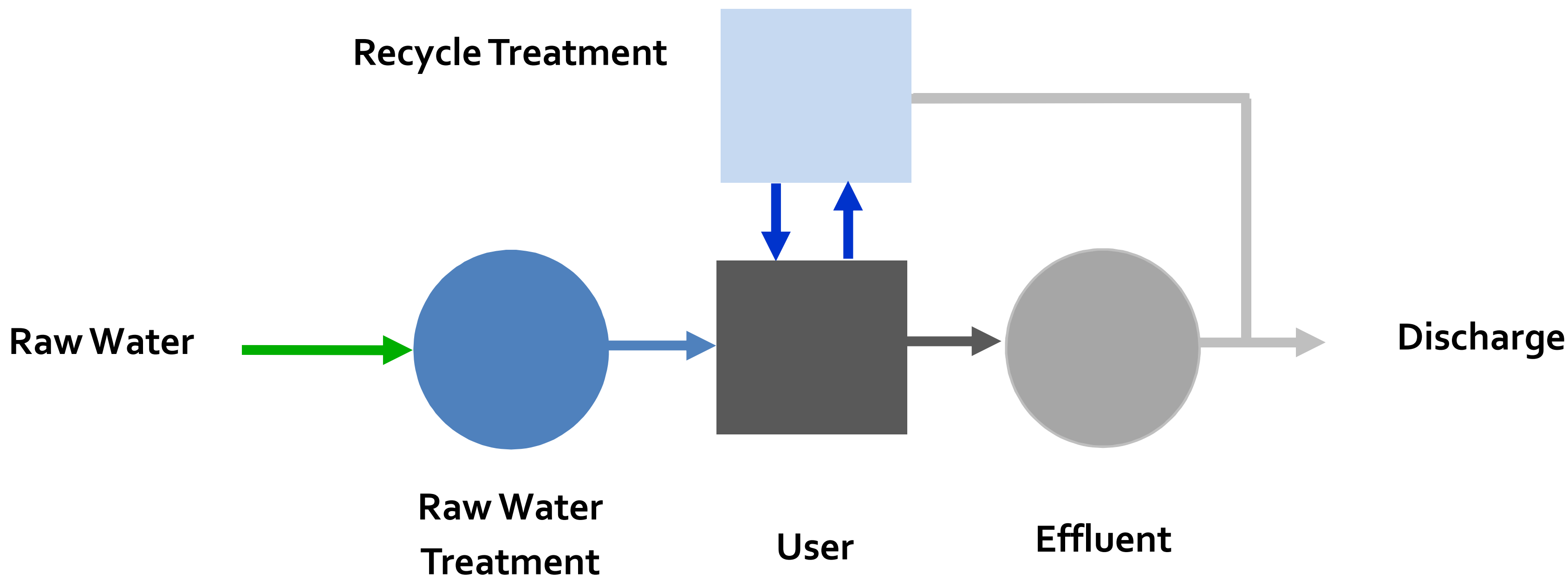
#5: Solid Waste Production

- Transforms concentrated brine into a damp solid
- Requires various combination of
  - Solar evaporation ponds
  - Filter presses
  - Centrifuges
  - Dryers
- Solid waste eventually hauled off-site

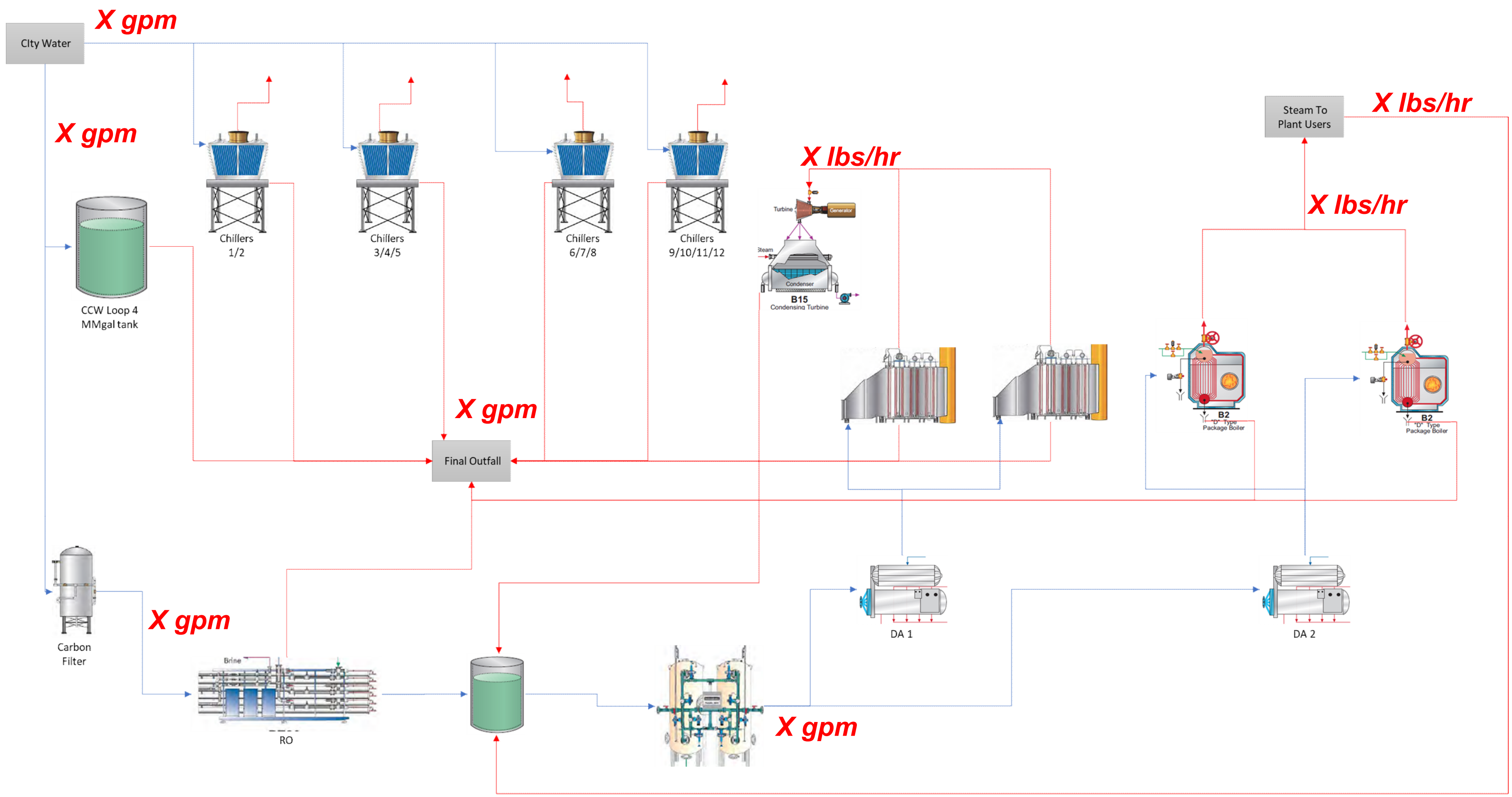


Water Resource Management Approach

Manage Benefit vs. Cost and Risk



Successful Management Starts w/ a Good Water Balance



Successful Management Starts w/ a Good Water Balance – Know Your Makeup Water

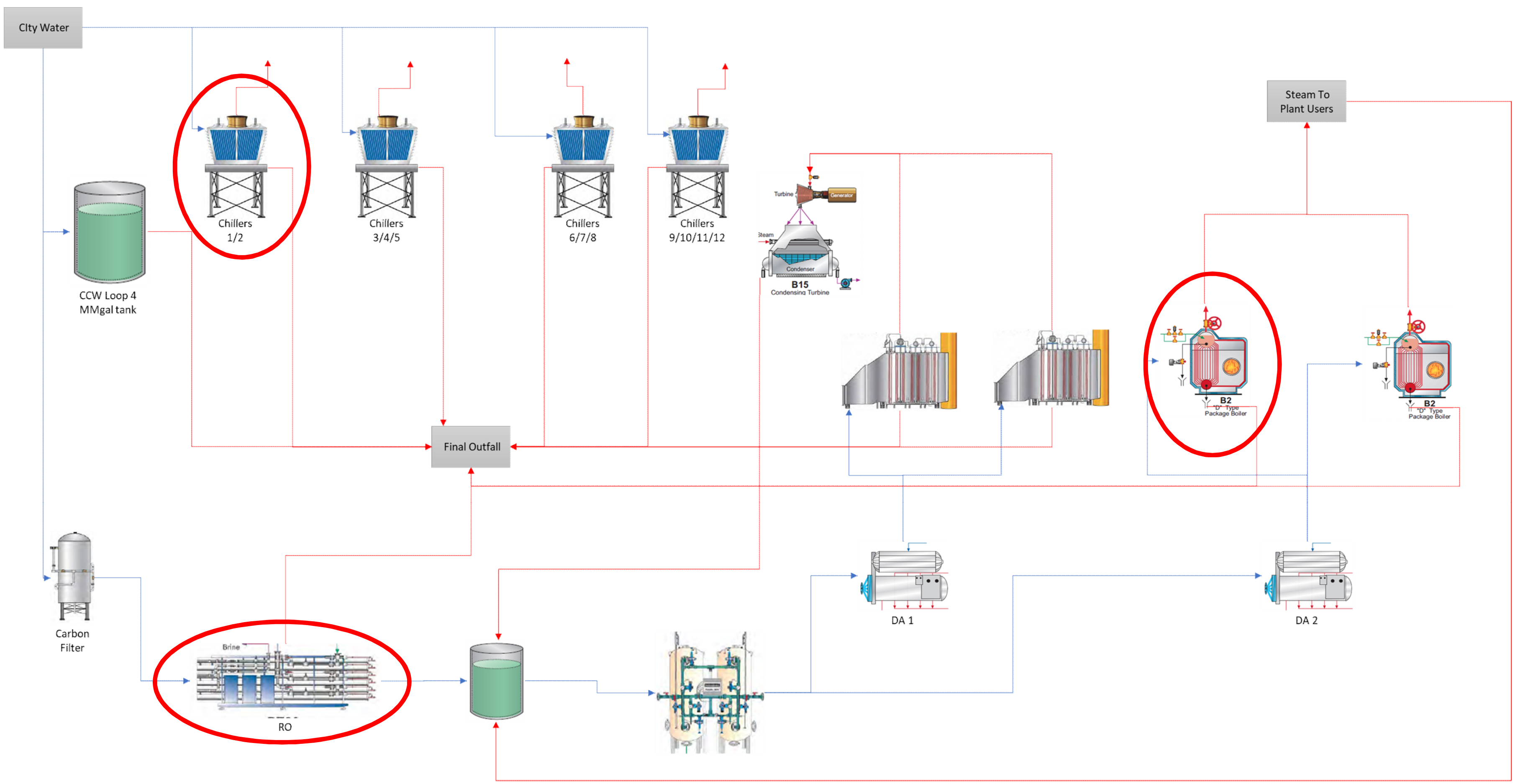
	City Makeup
pH	8.37
Conductivity, µmho	340
"M" Alkalinity, as CaCO3, mg/L	82
Calcium Hardness, as CaCO3, mg/L	2.6
Magnesium Hardness, as CaCO3, mg/L	1.3
Iron, as Fe, mg/L	0.01
Copper, as Cu, mg/L	0.03
Zinc, as Zn, mg/L	0
Sodium, as Na, mg/L	69
Potassium, as K, mg/L	0.25
Chloride, as Cl, mg/L	19
Sulfate, as SO4, mg/L	53
Nitrate, as NO3, mg/L	3.3
Ortho-Phosphate, as PO4, mg/L	0.69
Silica, as SiO2, mg/L	5.5
Total Organic Carbon, mg/L	
Turbidity, as NTU	
Total Suspended Solids, mg/L	
Total Dissolved Solids, by wt, mg/L	
Estimated TDS, mg/l	

Successful Management Starts w/ a Good Water Balance – Know Your Systems

	CT 1/2	CT 3/4/5	CT 6/7/8	CT 9/10/11/12	HRSG 1	HRSG 2	Aux Boiler 1	Aux Boiler 2	RO Reject	Total
MU Flow Rate gpm	340.0	340.0	340.0	340.0					300.0	1660
BD Flow Rate gpm	85.0	85.0	85.0	85.0	4.9	4.9	6.1	6.1	100.0	462
% Water Wastag										28%
BD as % of Total									%	100%
pH										
Conductivity, µm									20	1222
"M" Alkalinity, as									6	295
Calcium Hardnes										9
Magnesium Hard										5
Iron, as Fe, mg/L										0
Copper, as Cu, m										0
Zinc, as Zn, mg/L										0
Sodium, as Na, m									7	248
Potassium, as K,										1
Chloride, as Cl, m									7	68
Sulfate, as SO4,									9	190
Nitrate, as NO3,									)	12
Ortho-Phosphate										2
Silica, as SiO2, mg/L	22	22	22	22	0.1	0.1	0.1	0.1	17	20
Total Organic Carbon, mg/L	0	0	0	0	0.0	0.0	0.0	0.0	0	0
Turbidity, as NTU	0	0	0	0	0.0	0.0	0.0	0.0	0	0
Total Suspended Solids, mg/L	0	0	0	0	0.0	0.0	0.0	0.0	0	0
Total Dissolved Solids, by wt, mg/L	0	0	0	0	0.0	0.0	0.0	0.0	0	0
Estimated TDS, mg/l	884	884	884	884	4.4	4.4	4.4	4.4	663	794

	CT 1/2	CT 3/4/5	CT 6/7/8	CT 9/10/11/12
MU Flow Rate gpm	340.0	340.0	340.0	340.0
BD Flow Rate gpm	85.0	85.0	85.0	85.0
% Water Wastage				
BD as % of Total Flow	18%	18%	18%	18%
pH				
Conductivity, µmho	1360	1360	1360	1360
"M" Alkalinity, as CaCO3, mg/L	328	328	328	328
Calcium Hardness, as CaCO3, mg/L	10	10	10	10
Magnesium Hardness, as CaCO3, mg/L	5	5	5	5

Successful Management Starts w/ a Good Water Balance – Target Your Savings



Questions and Discussion