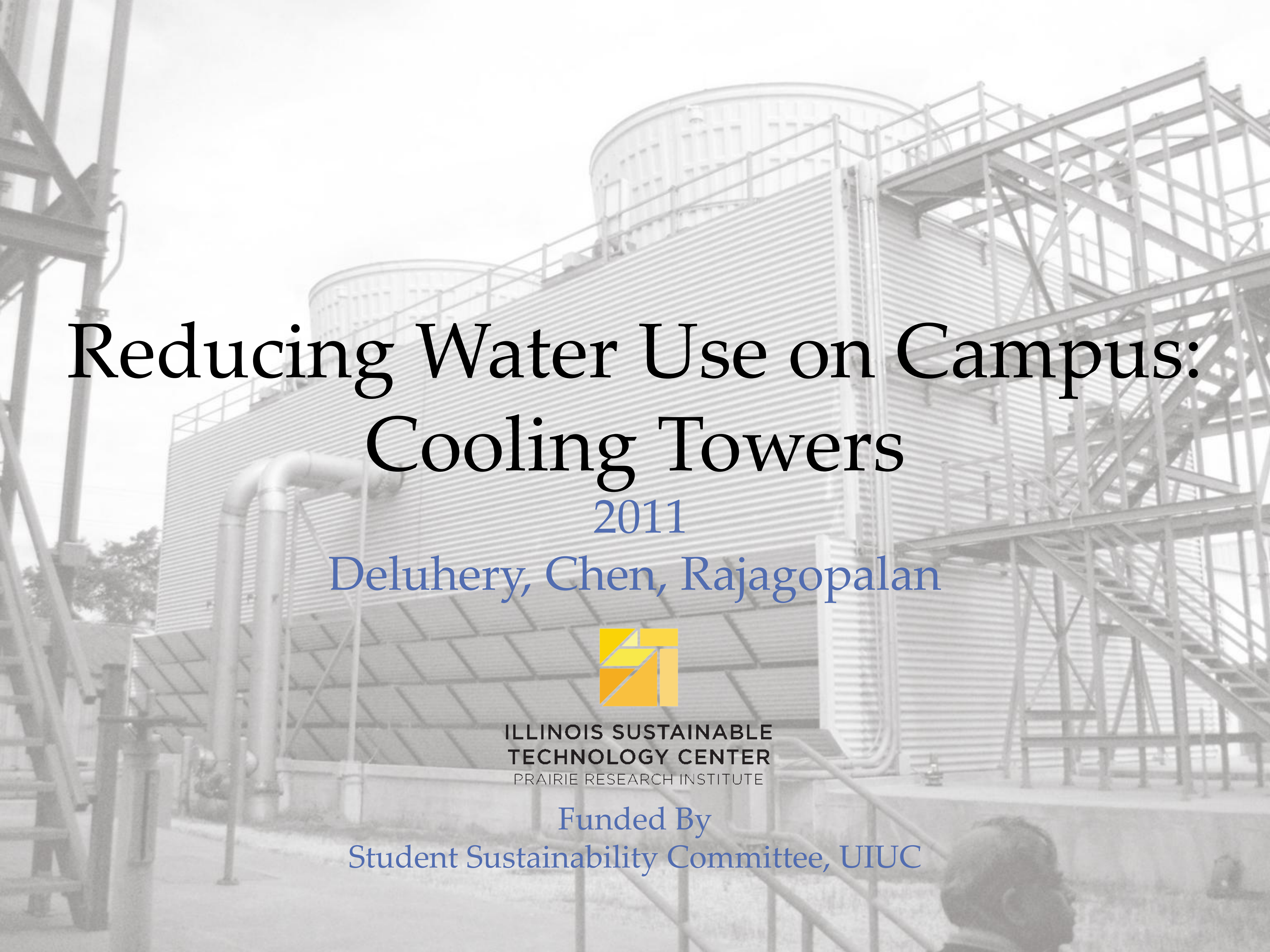


Reducing Water Use on Campus: Cooling Towers

2011

Deluhery, Chen, Rajagopalan

ILLINOIS SUSTAINABLE
TECHNOLOGY CENTER
PRAIRIE RESEARCH INSTITUTE

Funded By
Student Sustainability Committee, UIUC

Acknowledgements

- We would like to thank all of the people from Facilities and Services, in particular the Water Station and Utilities departments.

For Questions Contact:

- Dr. N. Rajagopalan
  nrajagop@illinois.edu
  217-244-8905
- Jennifer Deluhery
  deluhery@illinois.edu
  217-244-4314
- Morgan Johnston
  mbjohnst@illinois.edu
  217-333-2668

In 2008, the University of Illinois at Urbana Champaign signed on to the American College & University Presidents' Climate Commitment.

In 2010, the completed Illinois Climate Action Plan (iCAP) was published.

"Our intentions are clear and our goal remains ambitious: to be the model of sustainability for all universities in the nation."

-Robert A. Easter, *Chancellor* (iCAP)

The campus has made a commitment to reducing greenhouse gas emissions, energy and water use.

Where Do We Want to Be?

The University's goal is a 20% reduction of campus potable water consumption by 2015. A 40% reduction by 2025 is envisioned.

Where Are We Now?

The University has already achieved a 16% water reduction as of July 2011.

How Will We Get There?

Additional reductions in water consumption requires closely examining how water is currently used on campus and what opportunities are available for improvement.

All Campus Water Use FY 2011

When we start to look at how water is used on campus it is clear that the water used at Cooling Towers is a large percentage of the pie. Some advantages of focusing on water conservation at these locations is that they are (a) point sources and (b) actively managed by dedicated and trained personnel.

Units are given in 1,000 gallons (kgal)

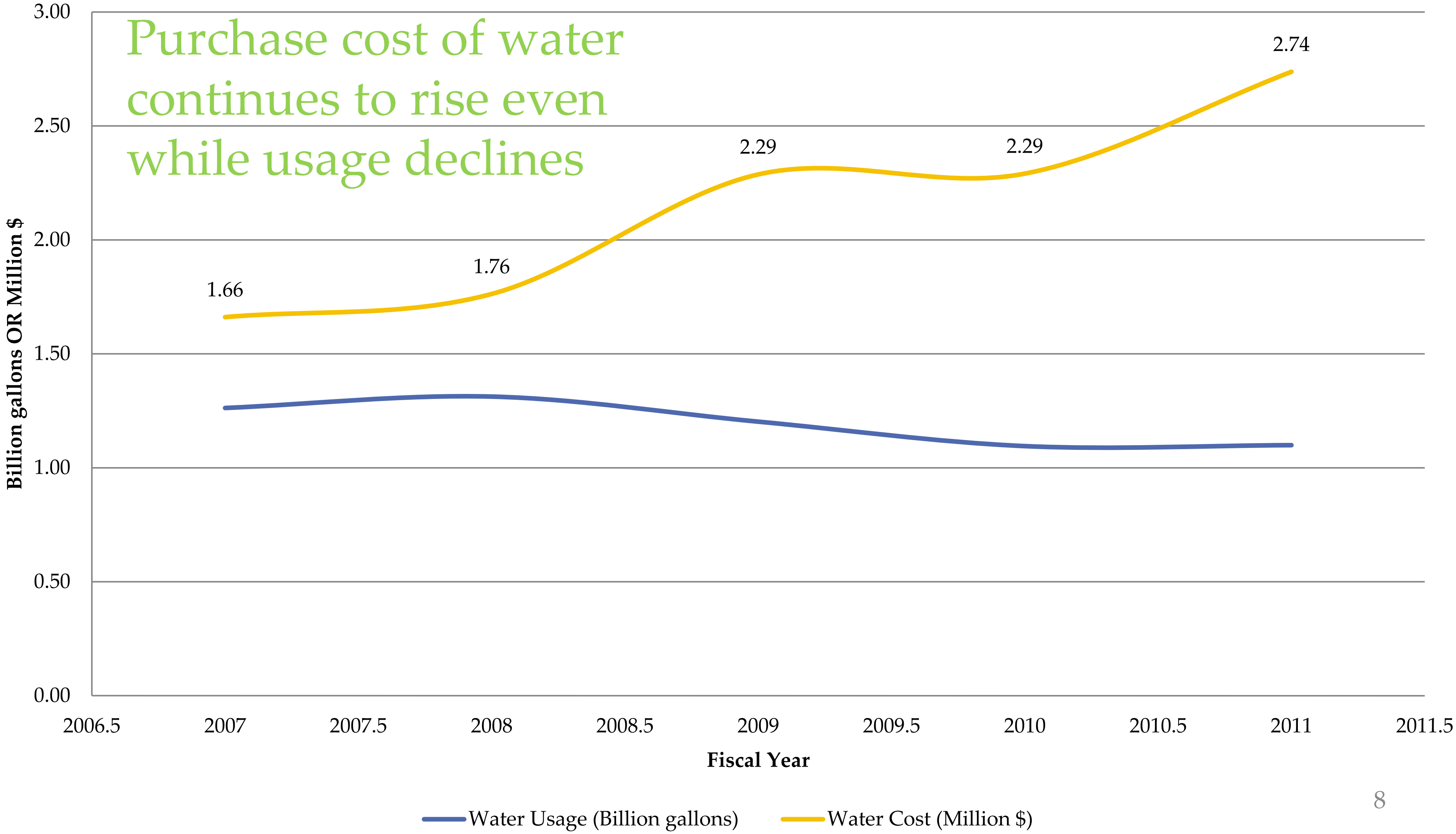
Project Goals

- Benchmark Water Use in Cooling Towers & at Abbott RO Plant
- Generate Ideas for Improving Water Use Efficiency

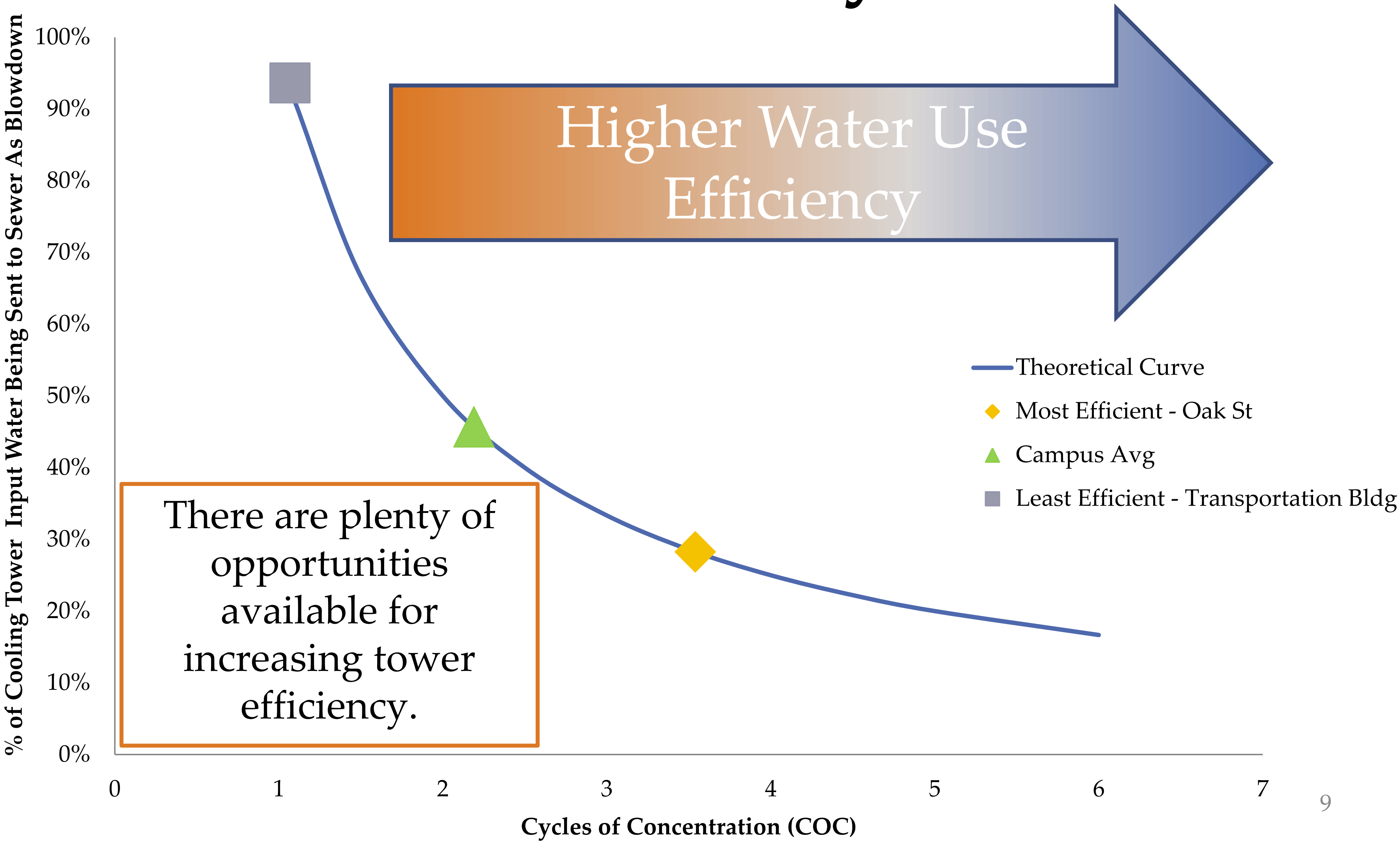
Customer/Collaborator – F & S

Project Sponsor – Student Sustainability Committee

Current Campus Water Use and Costs



Current Cooling Tower Efficiency



Summary
Benchmarking Results

- The largest amount of water is being used at Oak Street Chiller Plant (OSCP) and North Campus Chiller Plant (NCCP).
    - These locations are chemically treated
- Significant water use is occurring at
    - Abbott Power Plant – chemically treated
    - Vet Med Chiller Plant – untreated
    - Housing Food Storage – untreated
    - Natural Resources Studies Annex (NRSA) – untreated
    - Law Building – untreated
- More water, by volume, is going to the sewers from the smaller, lower COC towers than all of the large chiller plants.

Policy Recommendations

- Facilitate Information Access/Greater Campus Involvement/Innovations
  - Make available web-accessible campus wide monthly water use data in a format amenable to querying and analysis
  - Make available web-accessible monthly water quality reports at cooling towers
  - Encourage instructional use of data in campus courses on sustainability
  - Seek solutions from students/faculty/staff
- Raise the Bar on Water Conservation
  - Establish/Publicize anticipatory yearly goals for achieving water reduction
  - Establish/Publicize planning, progress, and barriers
  - Adopt a policy of 5 Cycles of Concentration for cooling towers at Centralized Chiller Plants
  - Amend existing policy of prohibiting once-through cooling to a minimum of 3 cycles of concentration at stand alone cooling towers
- Integrate Campus Wide Efforts on Energy Conservation with Water Conservation
  - Account for and take credit for associated water dollar savings and volume reductions associated with energy efficiency upgrades

Action-Items

Actions

- Install Trasar 3D monitoring at Oak St (Done) and Vet Med Chiller Plants
- Initiate engineering design and feasibility study of sulfuric acid dosing to increase COC at chiller plants
- Explore optimization of Abbott Cooling Tower and RO as a whole system
- Monitor the feed water going into the RO at Abbott to allow for independent determination of the RO efficiency
- Monitor any existing Cooling Tower blowdown meters to compare operation with the observed chemistry

Pilot Studies

- Initiate piloting of Nanofiltration of Oak Street Sub-soil drainage water as make-up for cooling tower
- Conduct pilot investigation of non-chemical water treatment (especially VRTX) technologies for stand-alone towers

UIUC Cooling Tower Location Map

http://goo.gl/maps/jf6K

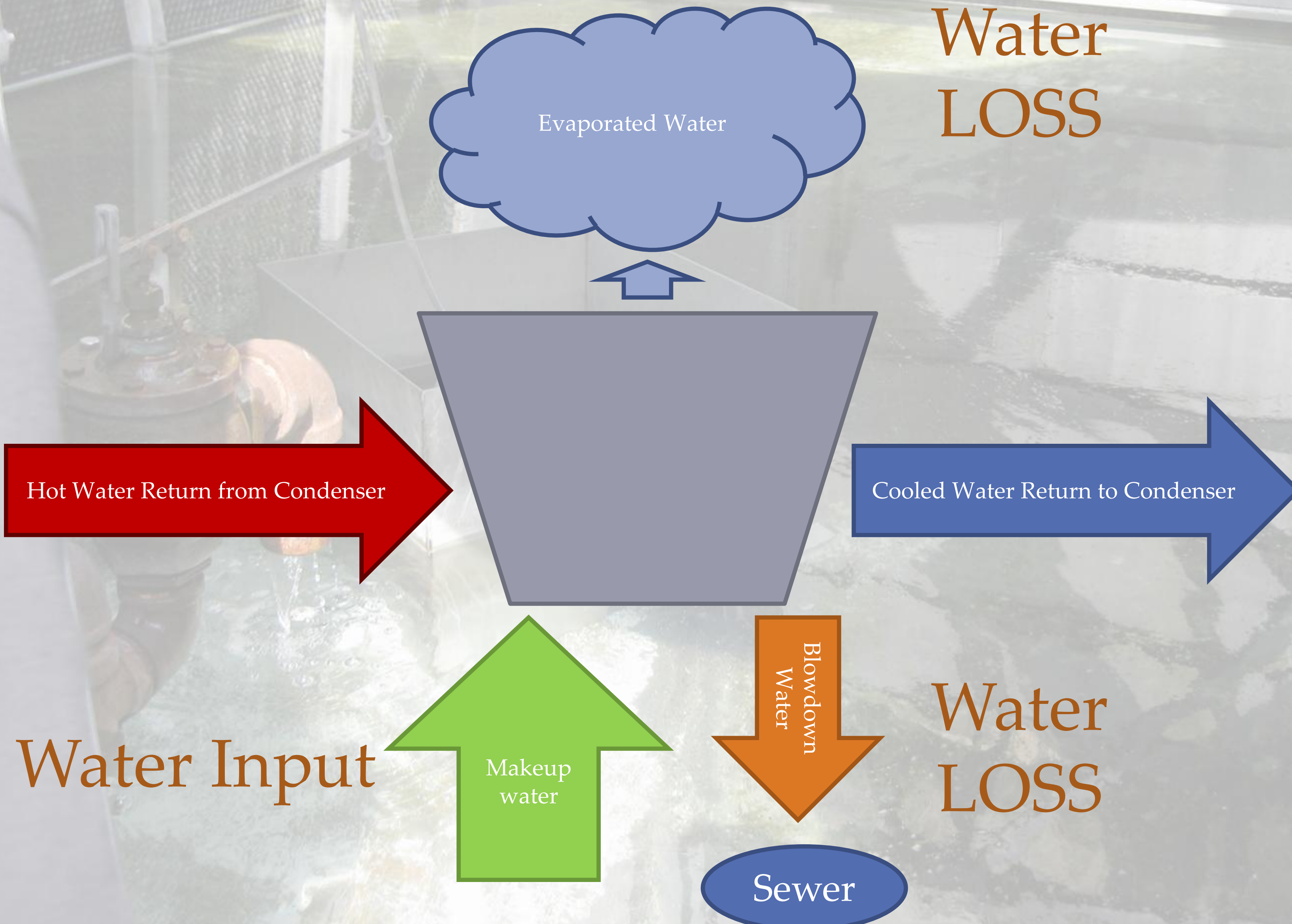
Cooling towers are spread all over the University of Illinois Urbana-Champaign Campus.

The spatial distribution of small towers makes close monitoring a challenge. The larger Chiller Plants, however, are closely monitored by on-site staffing on a daily basis. This means that 2 different strategies are needed to manage these towers. The smaller towers should continue to run with minimal attention while operations at the larger Chiller Plants are more amenable to closer monitoring and control.

What is a Cooling Tower?

- Equipment that cools water through evaporation
- On campus, primarily used to remove heat from buildings, especially in summer.

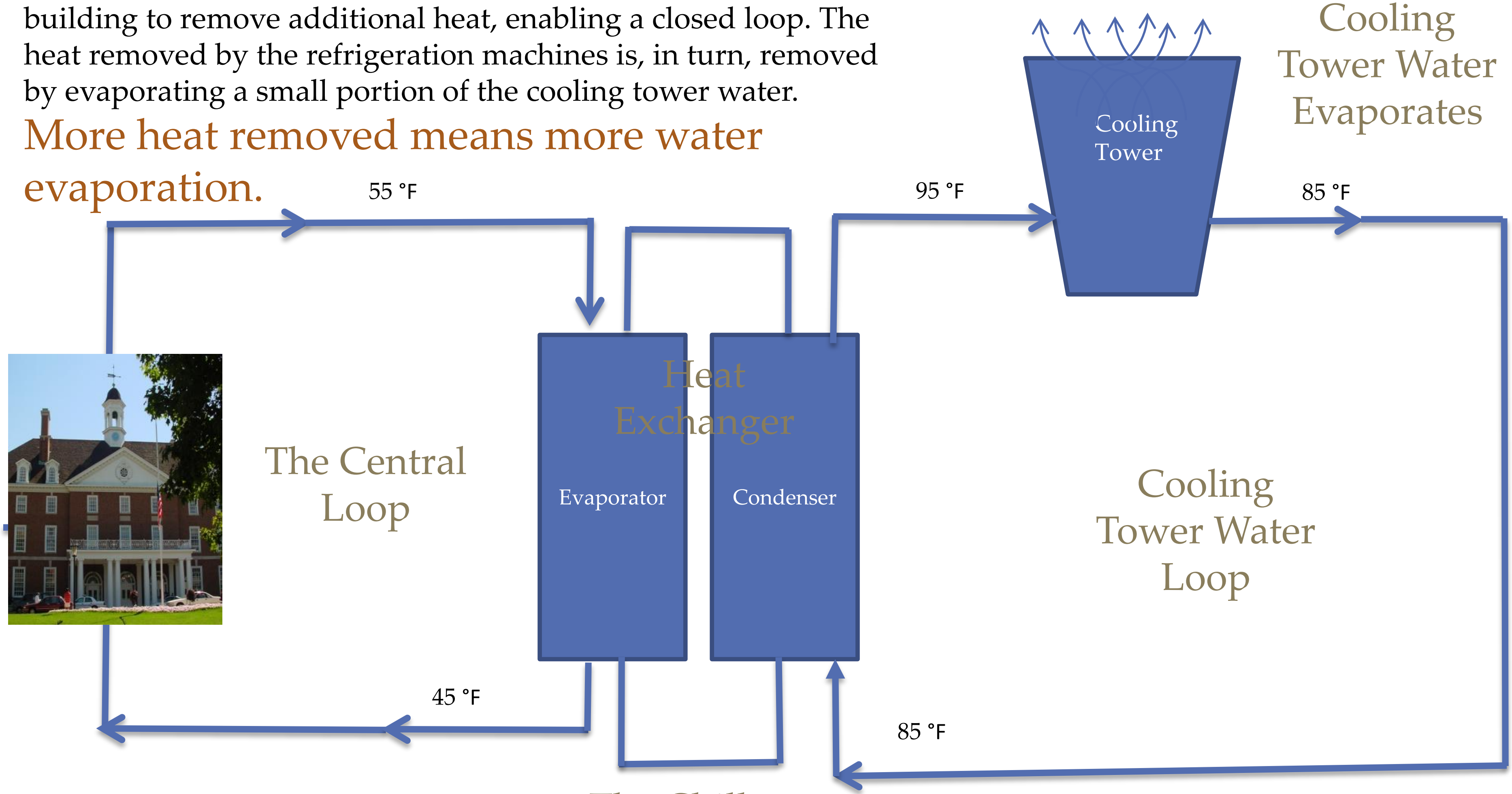
How is Water Lost in a Cooling Tower?



Where Does A Cooling Tower Fit?

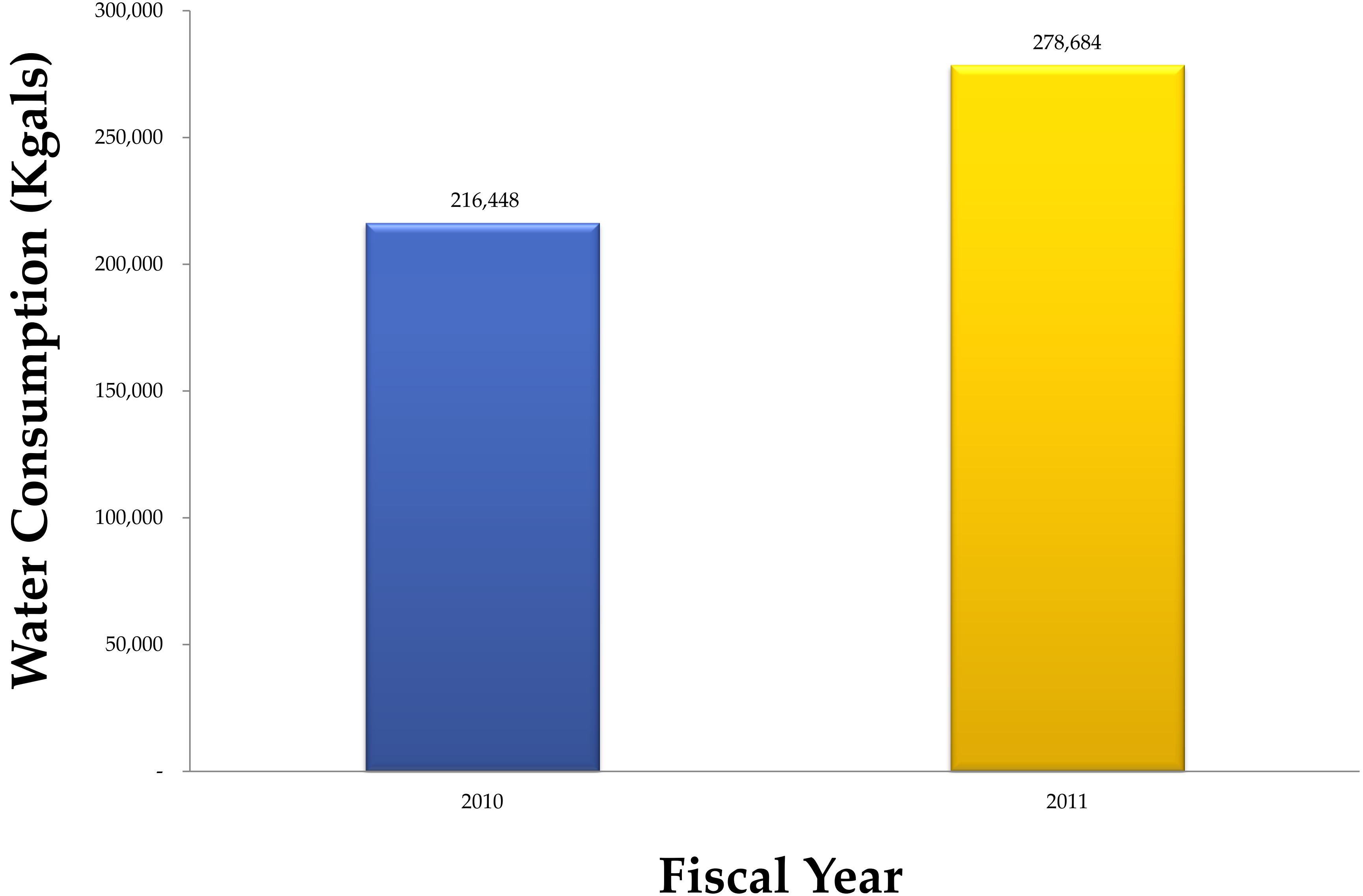
Building heat is removed by chilled water. Giant refrigeration machines remove heat from chilled water and send it back to the building to remove additional heat, enabling a closed loop. The heat removed by the refrigeration machines is, in turn, removed by evaporating a small portion of the cooling tower water.

More heat removed means more water evaporation.



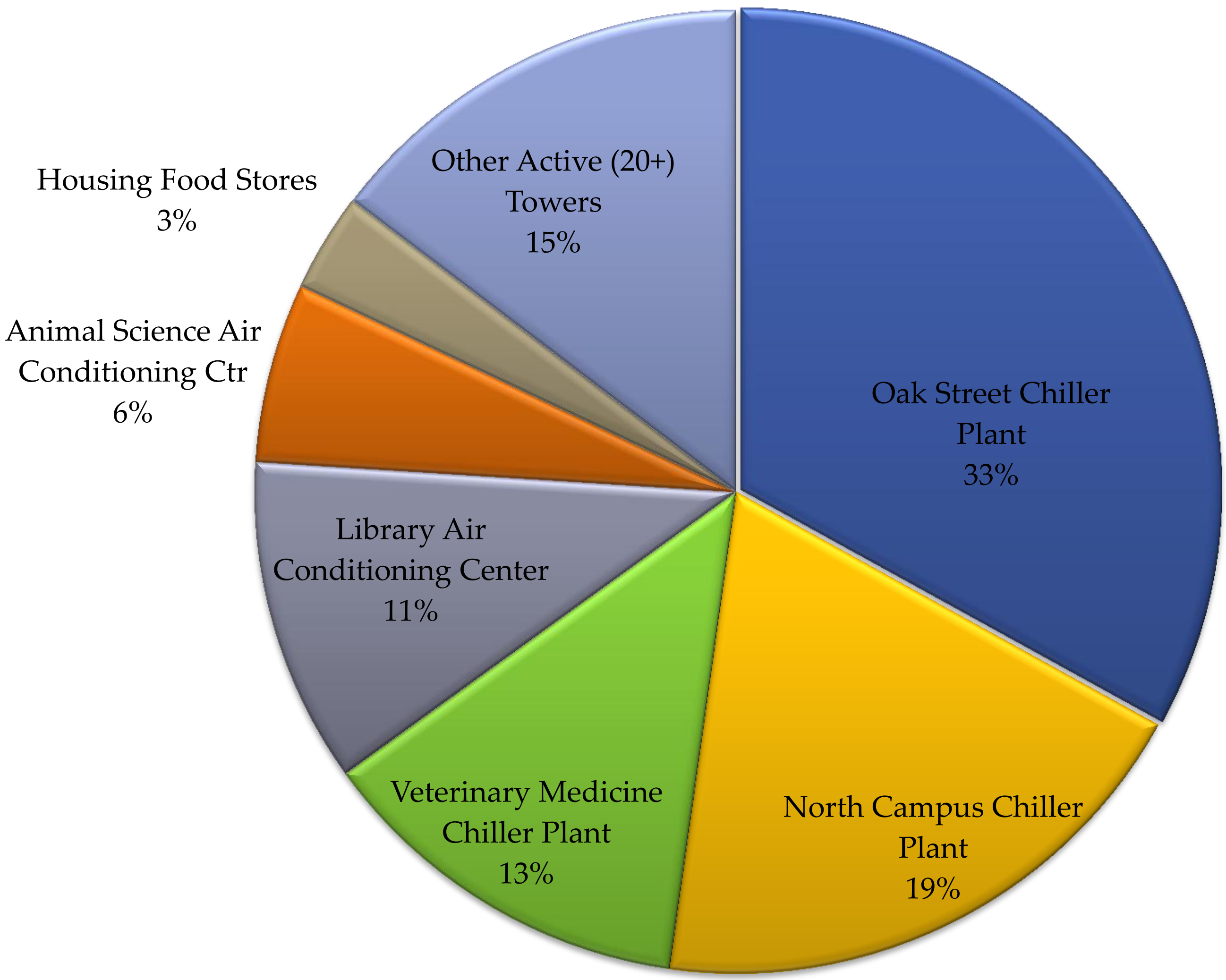
Parameters indicated are as an example; do not reflect campus settings.

Water Use Data For All Campus Cooling Towers
Fiscal Years 2010 & 2011



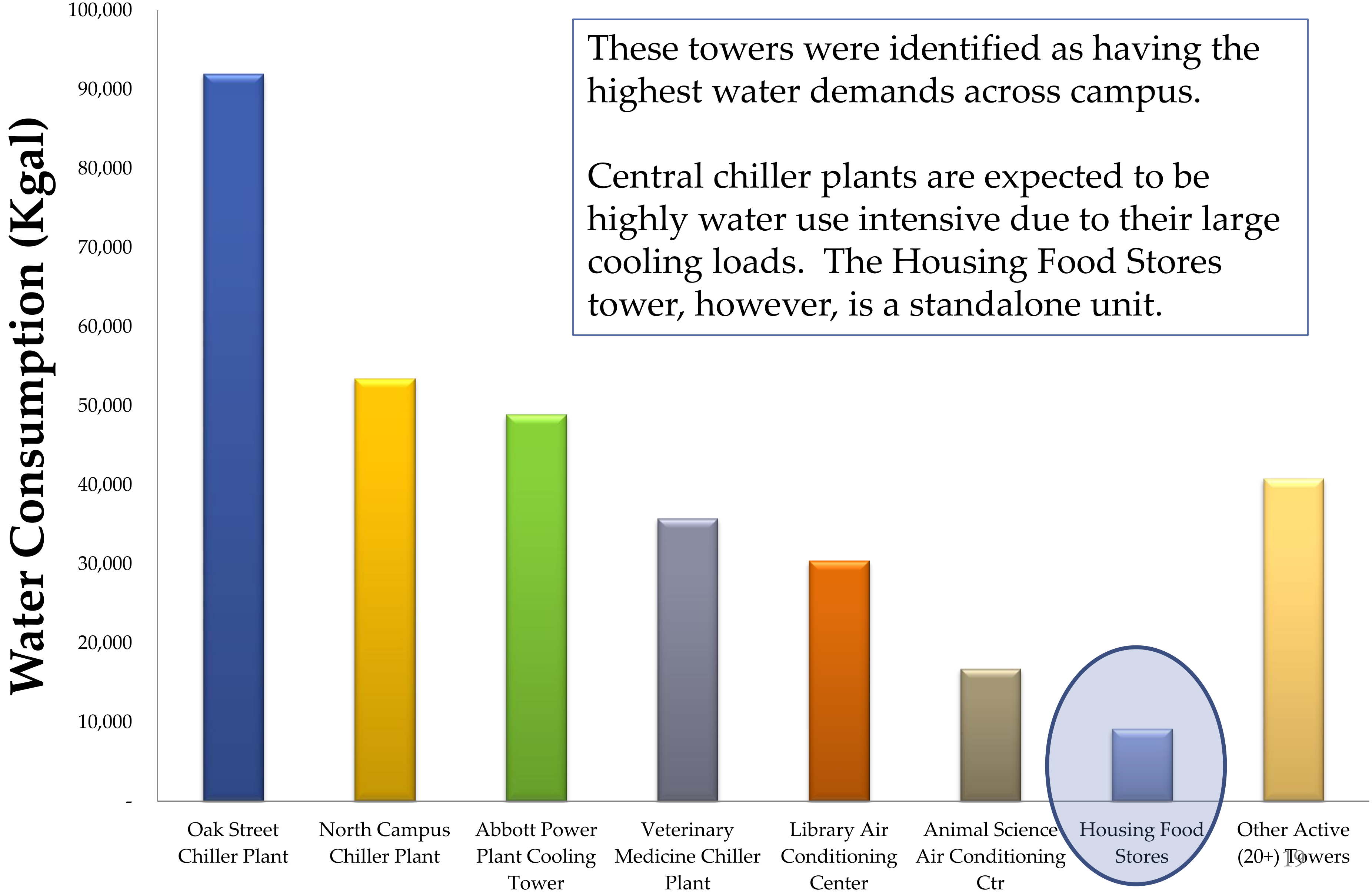
Does not include Abbott

Campus Cooling Tower Water Use FY 2011
Without Abbott Power Plant



* CLSL off for most of the year to bring it onto the loop as a booster chiller.

Campus Cooling Tower Water Consumption
FY 2011



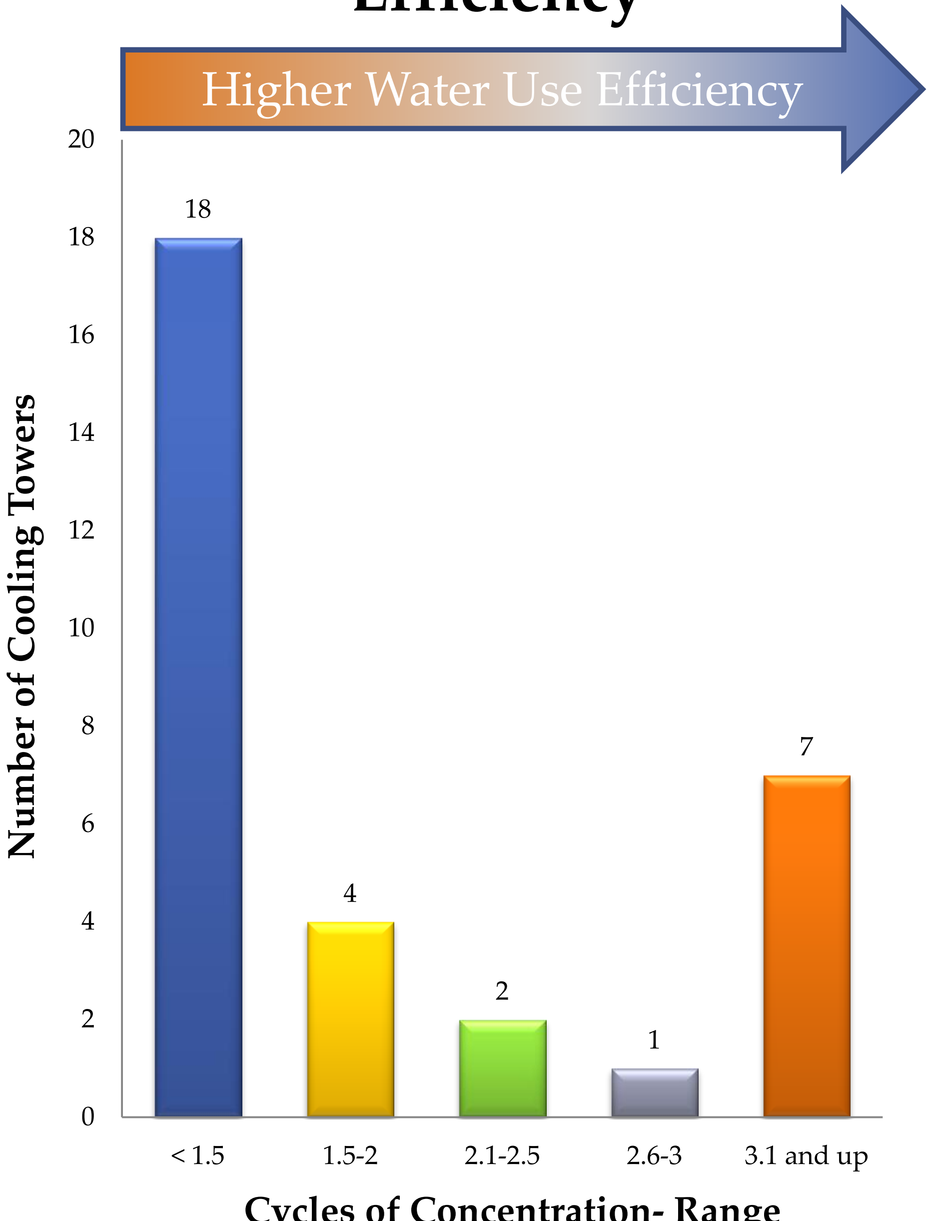
These towers were identified as having the highest water demands across campus.

Central chiller plants are expected to be highly water use intensive due to their large cooling loads. The Housing Food Stores tower, however, is a standalone unit.

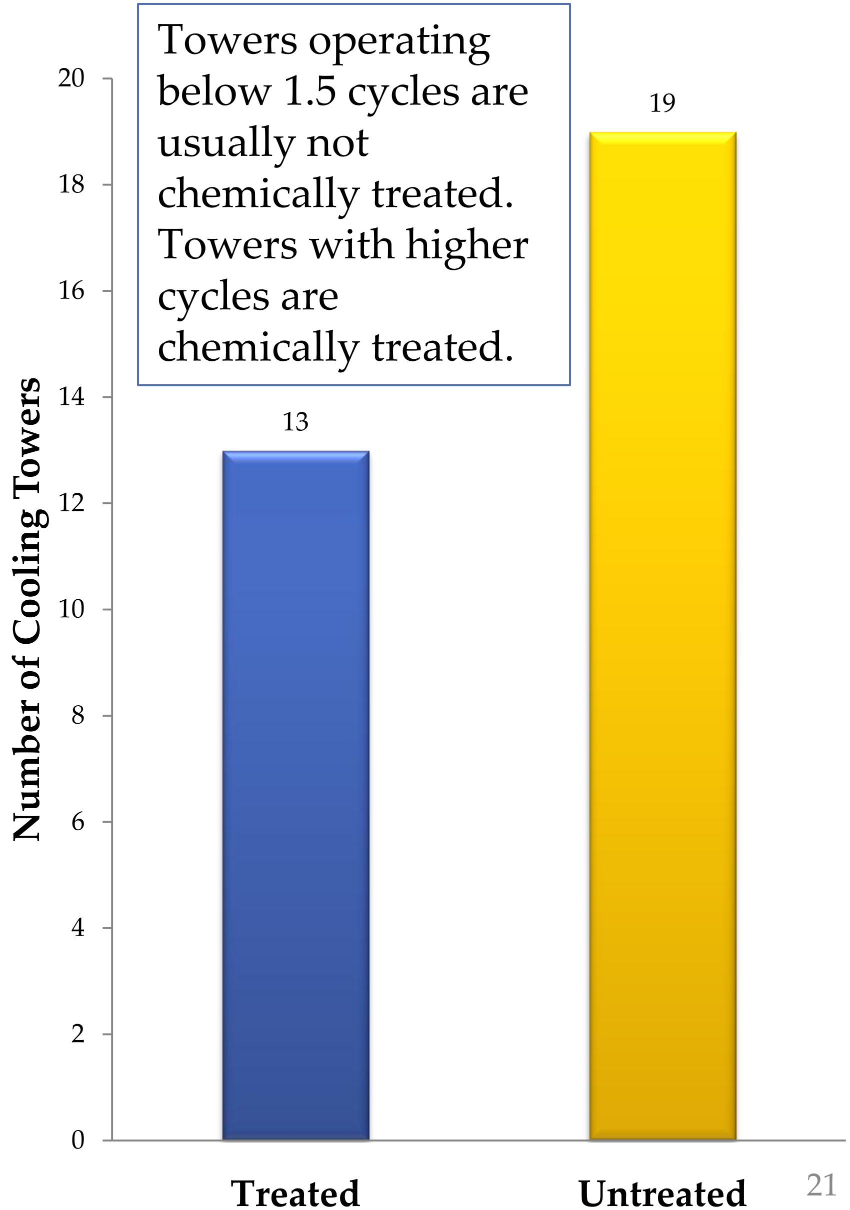
A Little Cooling Tower Jargon

- Cycles of Concentration (COC): A measure of water use efficiency
  - Bigger number is better
  - Typical target: 4-5
- COC dependent on water quality
  - Higher water quality into the tower allows higher target COC
  - Higher quality typically also means more water pretreatment/more $$$

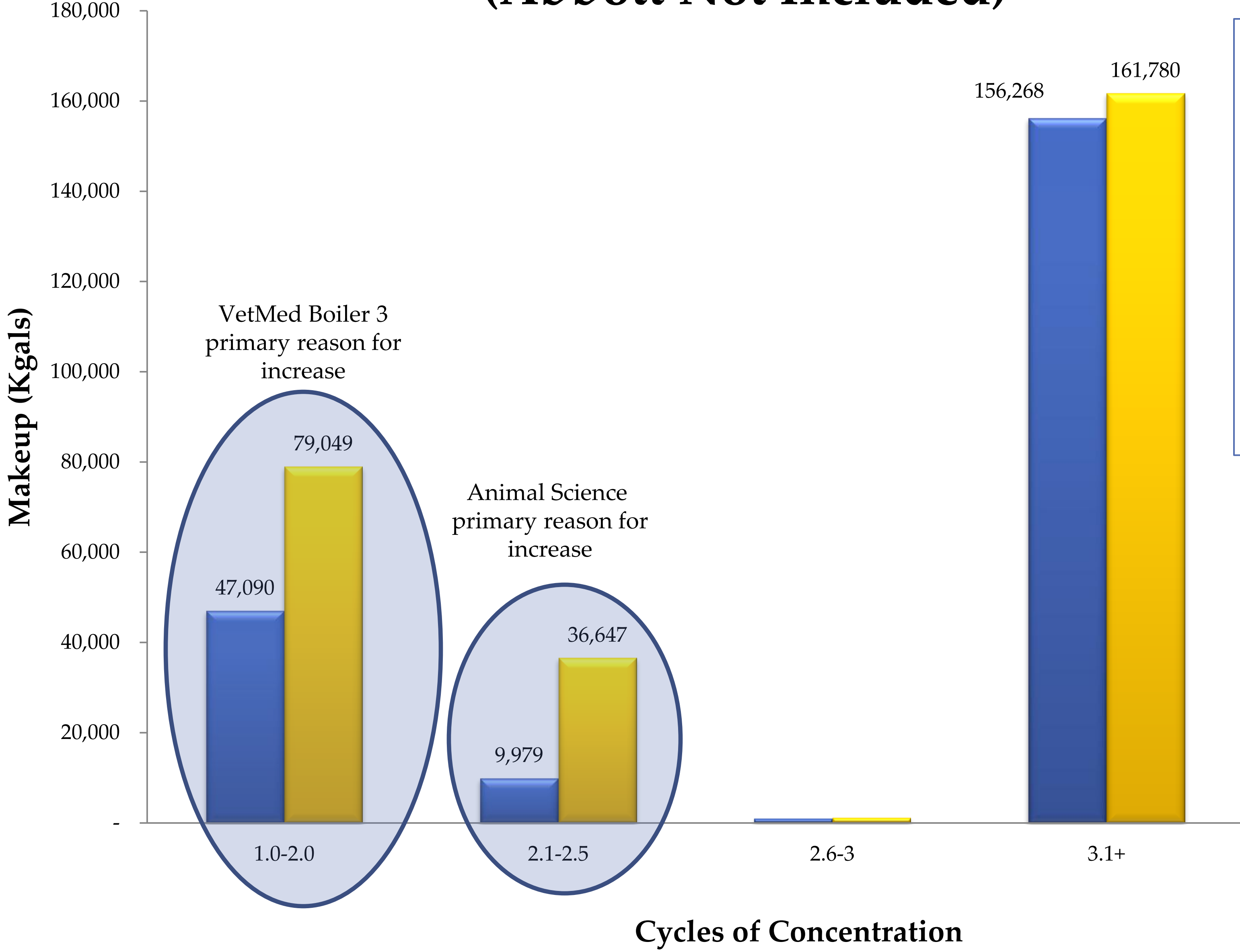
Cooling Towers vs Efficiency



Treated vs. Untreated CT

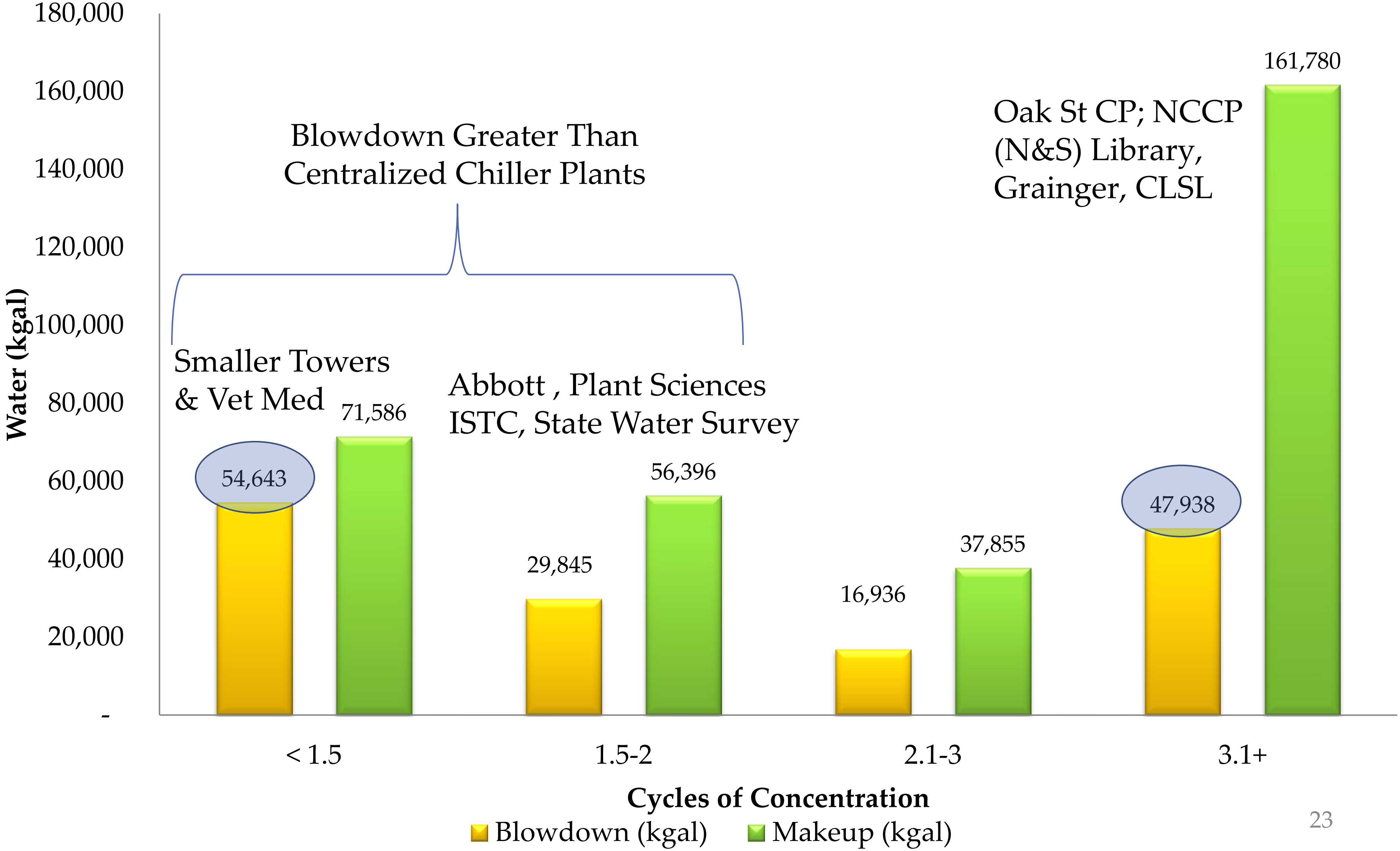


More Heat Removed, More Water Consumed (Abbott Not Included)

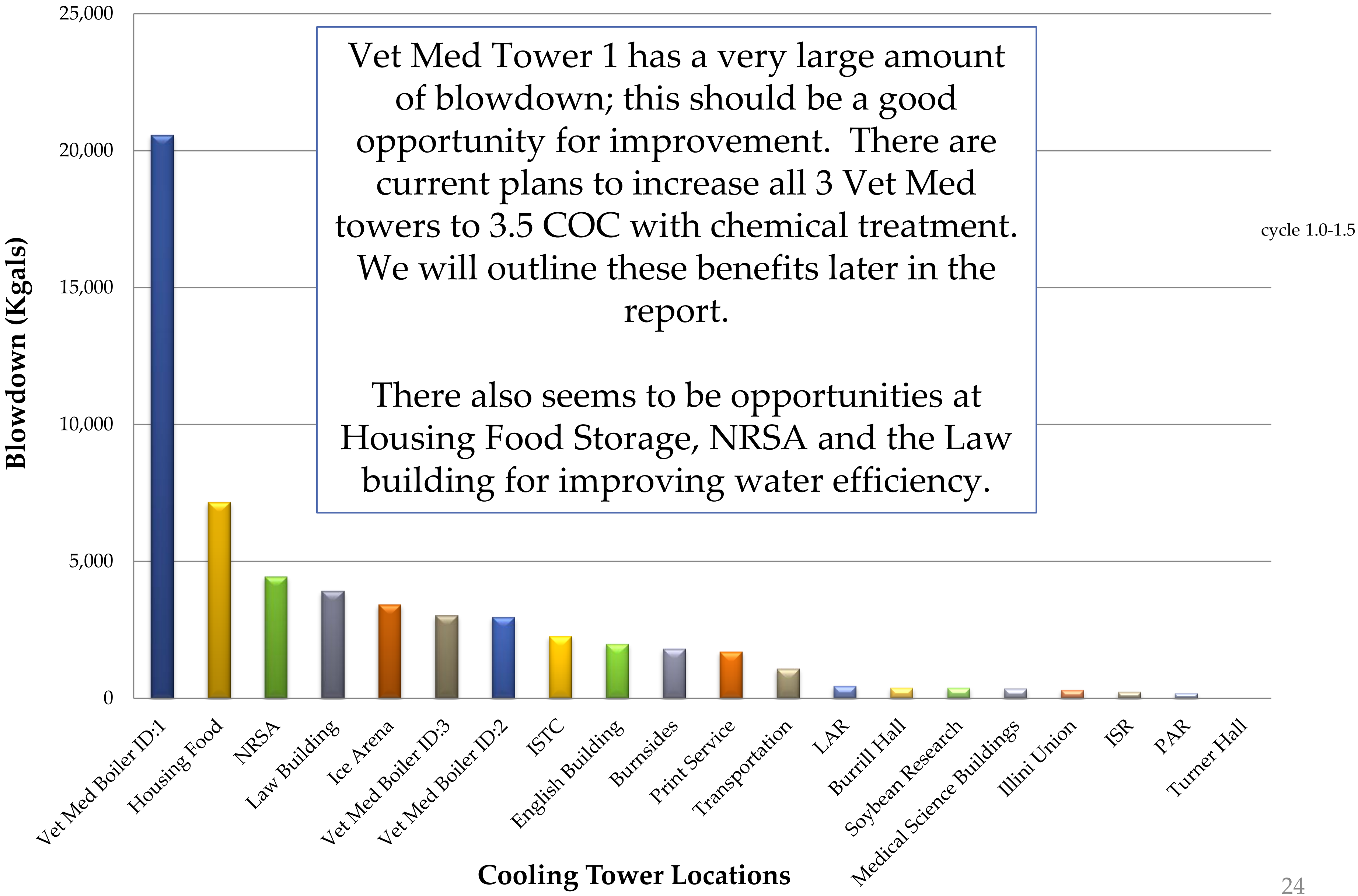


As expected, the largest water consumption occurs at the large chiller plants running at 3+ cycles

Lower Efficiencies Mean More Water Consumed



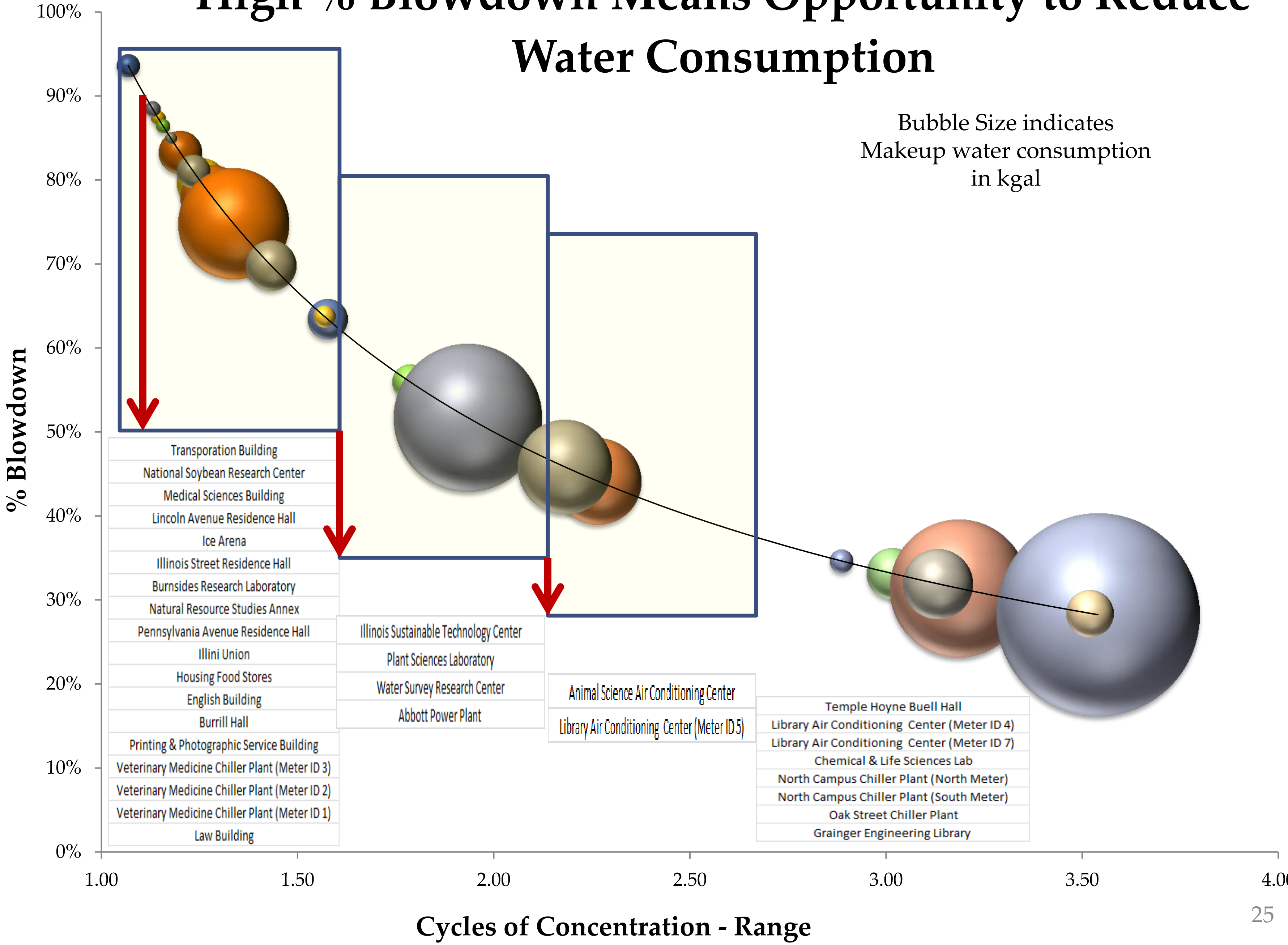
Blowdown - Untreated Towers (FY 2011)



Vet Med Tower 1 has a very large amount of blowdown; this should be a good opportunity for improvement. There are current plans to increase all 3 Vet Med towers to 3.5 COC with chemical treatment. We will outline these benefits later in the report.

There also seems to be opportunities at Housing Food Storage, NRSA and the Law building for improving water efficiency.

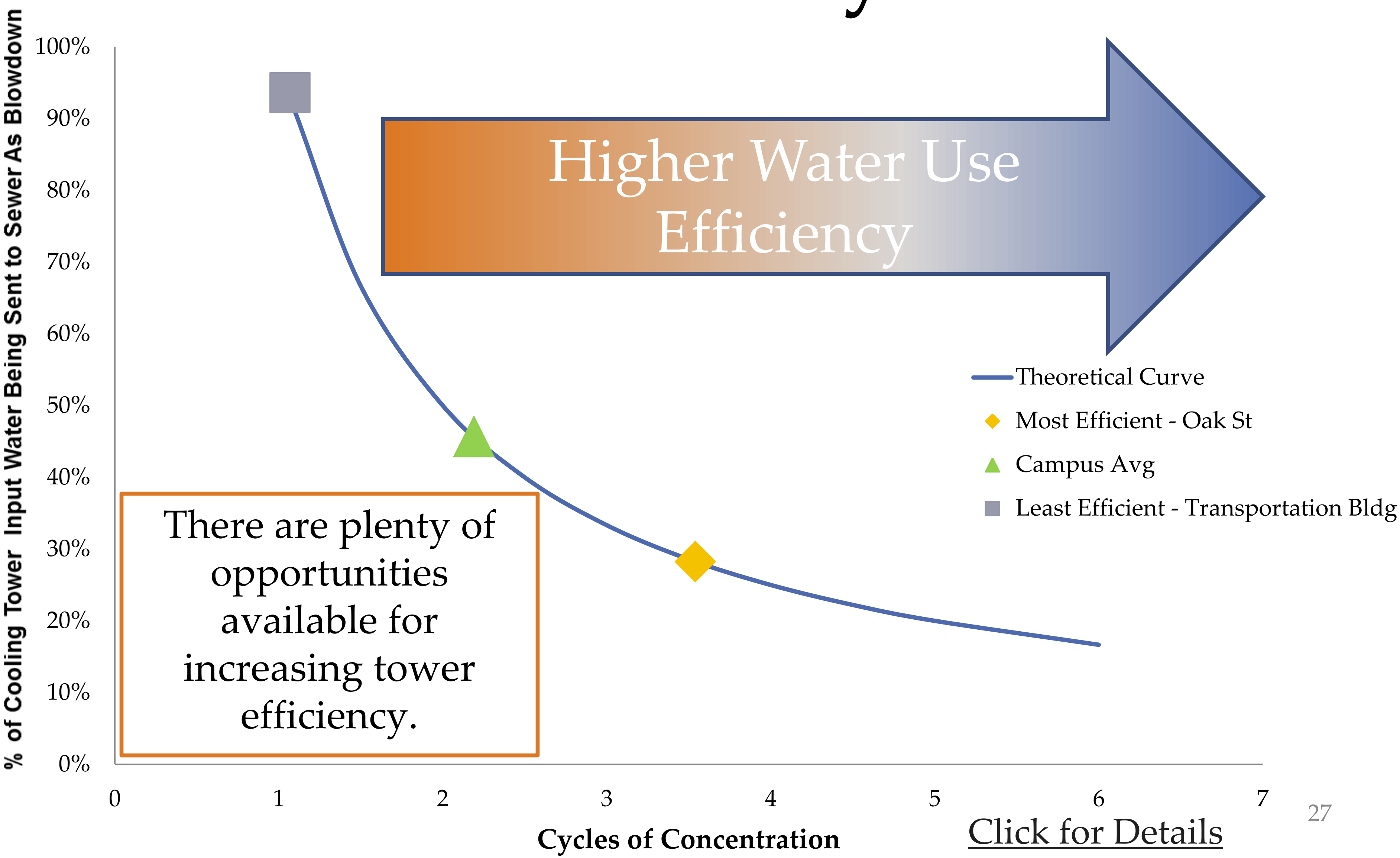
High % Blowdown Means Opportunity to Reduce Water Consumption



Summary
Benchmarking Results

- The largest amount of water is being used at Oak Street Chiller Plant (OSCP) and North Campus Chiller Plant (NCCP).
    - These locations are chemically treated
- Significant water consumption is occurring at
    - Abbott Power Plant – chemically treated
    - Vet Med Chiller Plant – untreated
    - Housing Food Storage – untreated
    - Natural Resources Studies Annex (NRSA) – untreated
    - Law Building – untreated
- More water, by volume, is going to the sewers from the smaller, lower COC towers than all of the large chiller plants.

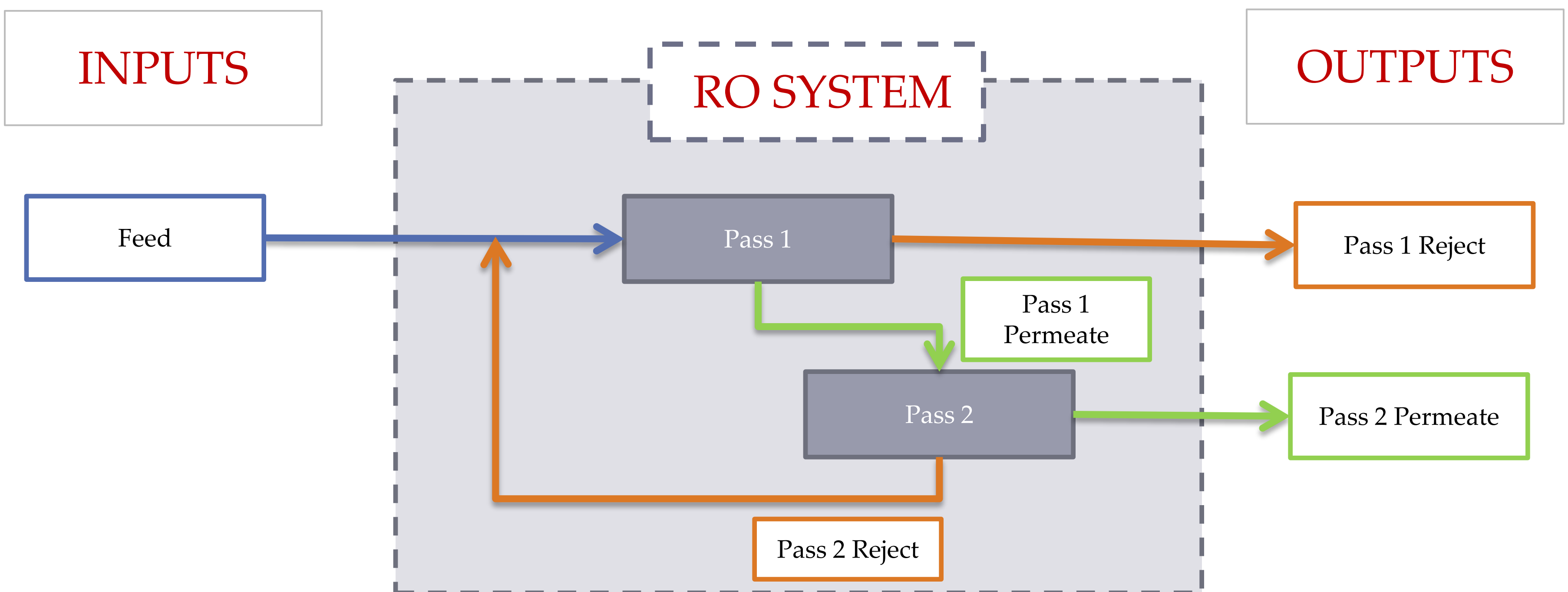
Current Cooling Tower Efficiency



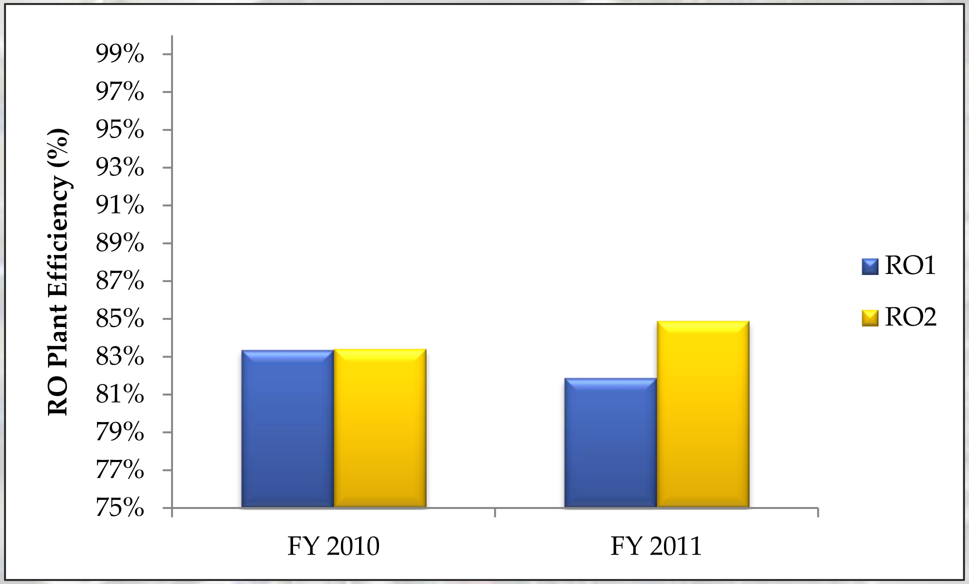
Click for Details

Benchmarking Abbott RO

- RO Flow rates at Abbott Power Plant were analyzed over a 2 fiscal year period.
- Based on the data provided we assumed that the Pass 2 reject went back as feed to Pass 1. This means that the system would look as diagramed below.



RO Plant Efficiency



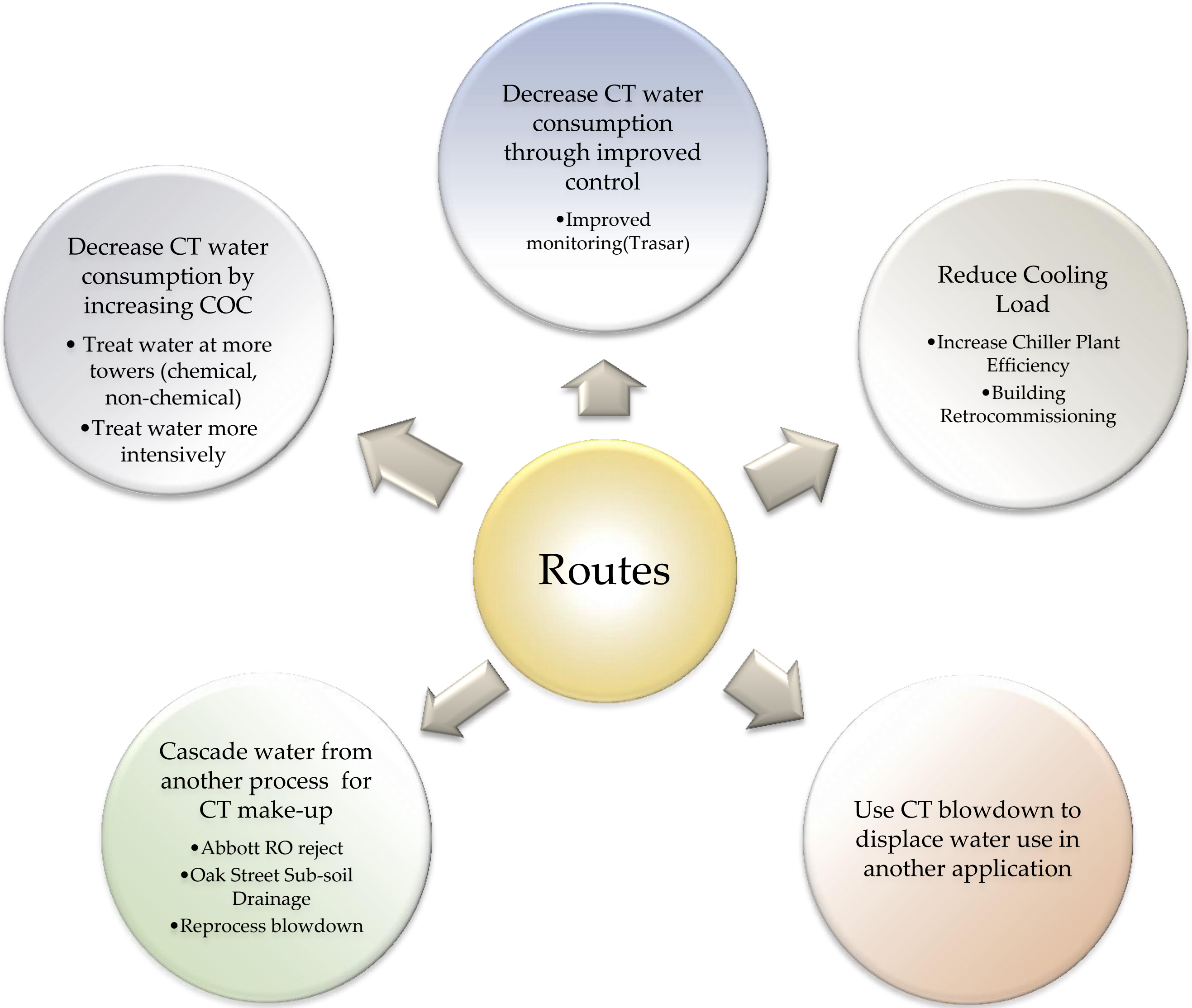
If we assume that the Feed is equal to the 2 Outputs (Pass 1 Reject and Pass 2 Permeate), we can estimate an efficiency.

RO plant efficiency calculated as ratio of permeate to (permeate + reject) as separate metering of feed not currently practiced.

Summary

- The data indicates that there has been little change between RO performance in FY 2010 and FY 2011.
- To allow an independent determination of RO efficiency, it is recommended that the feed flow rate to the RO be measured.
- While opportunities for optimization doubtless exist, large gains per unit effort are less likely.

Routes to Water Reduction



Route 1

ROUTE 1

Decrease CT water consumption by increasing COC

- Treat water at more towers (chemical, non-chemical)
- Treat water more intensively

Results of Cycle Changes at Cooling Towers (excl Abbott)

Route 1

- 57.3 Million Gallons total water savings (click to see details)
  - This would represent a 20% savings of total Campus Cooling Tower water consumption for 2011
  - It would represent a 5% savings of total Campus water Consumption for 2011
- In one year, cost savings could amount to **$136,000***!!

* (based on FY 2011 demands)

Results of Cycle Changes at Abbott

- 19 Million Gallons total water savings (click to see details)
- This would represent a ~40% savings of total Abbott Cooling Tower water consumption for 2011
  - It would represent a ~2% savings of total Campus Water Consumption for 2011
- In one year, cost savings could amount to **$71,000***!!

* (based on FY 2011 demands)

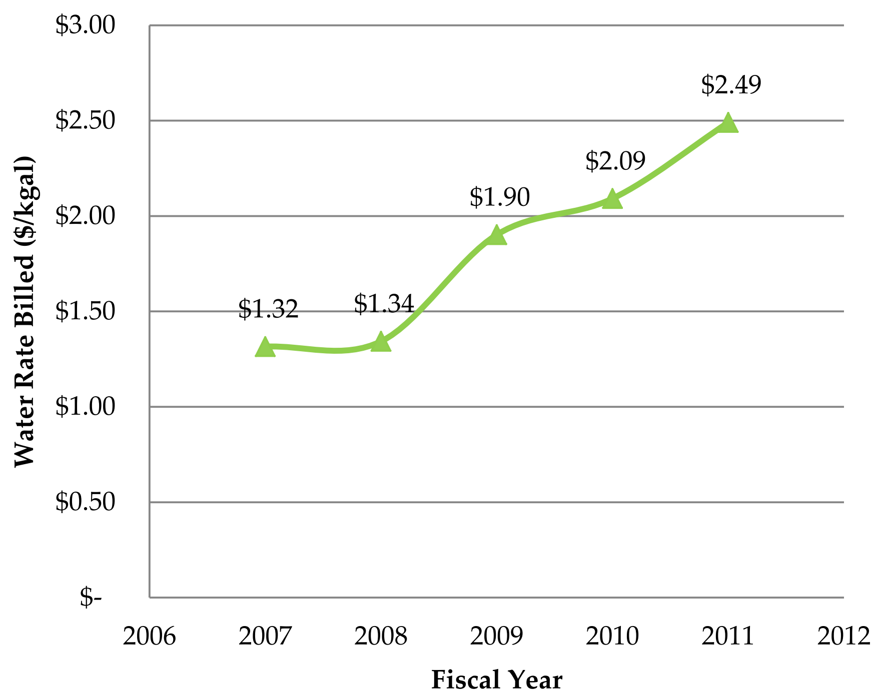
Evaluation of Increasing CT Cycles

- Cost calculated by estimating Makeup water demand based on observed cycles of concentration. Included in the cost are:
  - Chemical treatment of Makeup water
  - Water cost of Makeup
  - Sanitary costs of Expected Blowdown (assumed 25% of Makeup is billed for sewer*)

- *Based on billing practice; results in conservative $ savings number;

Isn't saving water only an environmental issue?

As overall costs of water used in cooling towers can be 200-300% higher than the incoming water cost at current water rates, water conservation is an economic issue as well.



True Cost of Water

Proper identification of all of the associated costs of running a system better enable you to make an accurate determination of the economic viability of an improvement.

Costs of water at Tower

1. Purchase price of water
2. Chemicals
3. Sewer fees
4. Maintenance of equipment – not included
5. Energy to run cooling tower – not included
6. Direct Labor, Supervision and Administration – not included

We are focusing on these 3 factors.

- Costs used (UIUC Internal Memo, June 28, 2010, Terry Ruprecht to Dempsey)
  - Energy Savings Rate for Water : $2.15/kgal
  - Energy Savings Rate for Sewer Disposal : $ 2.02/kgal
  - Chemical Treatment Costs :
    - $0/kgal for COC < 1.5; $1.08/kgal for 1.5<COC<4; $1.18/kgal for 4<COC<5

Example Calculation

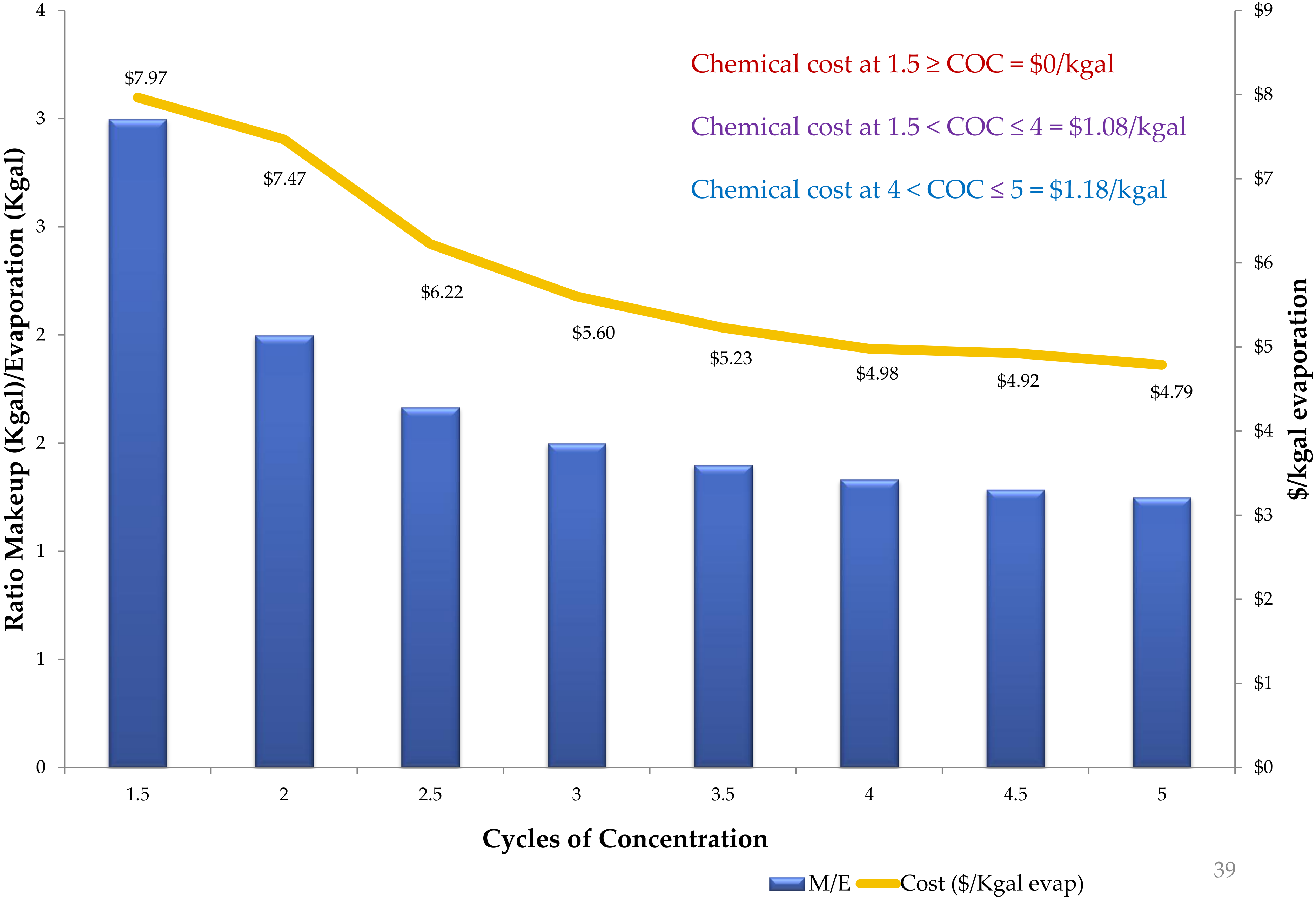
But if Chemicals add money doesn't treating a tower cost more?

Increased efficiency means

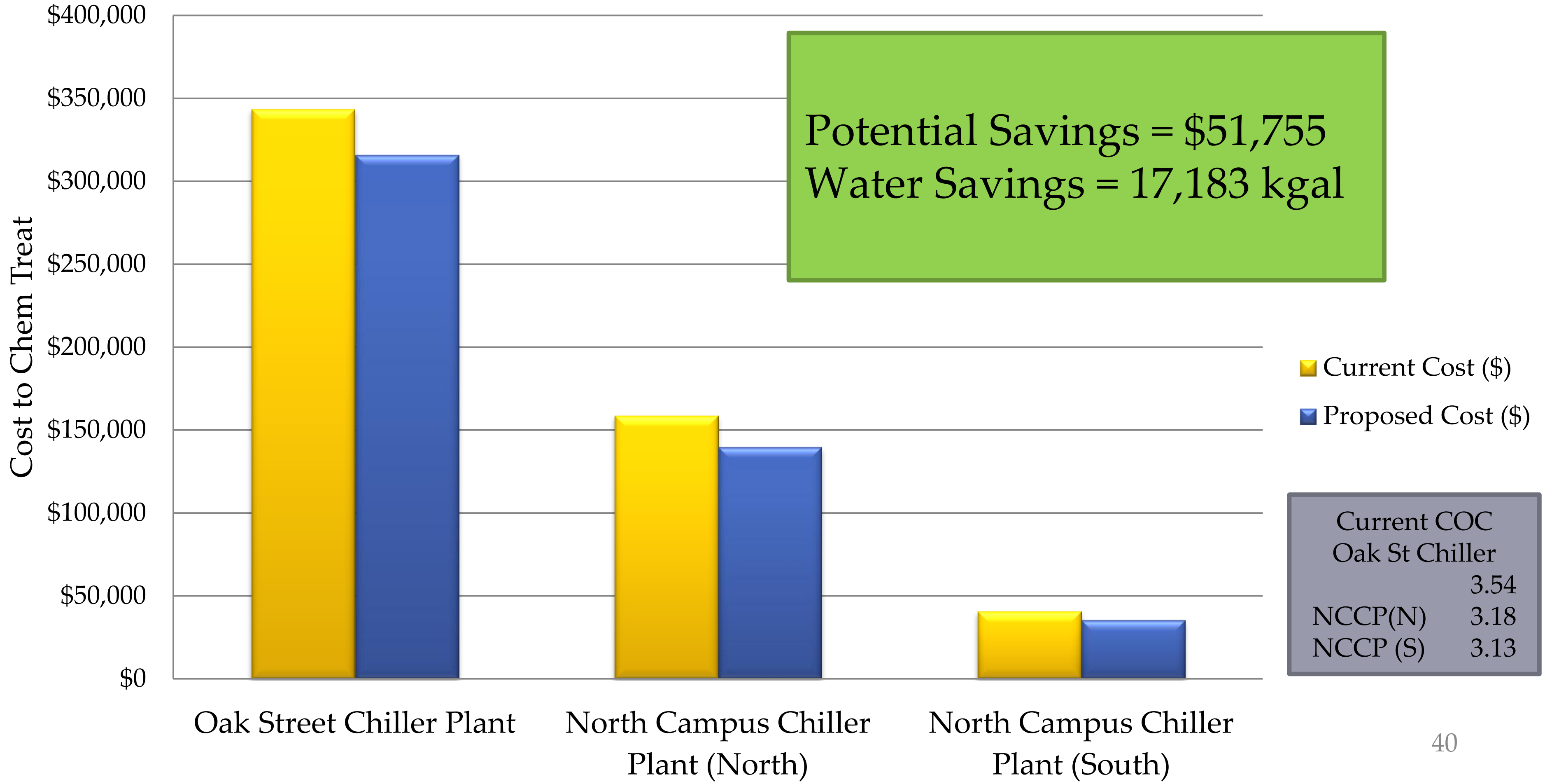
- less overall water consumed for the same amount of cooling
- less water going to the sewer.

A modest increase in chemical costs is more than offset by the money saved on incoming water and sewer fees.

Effect of COC on Water Costs



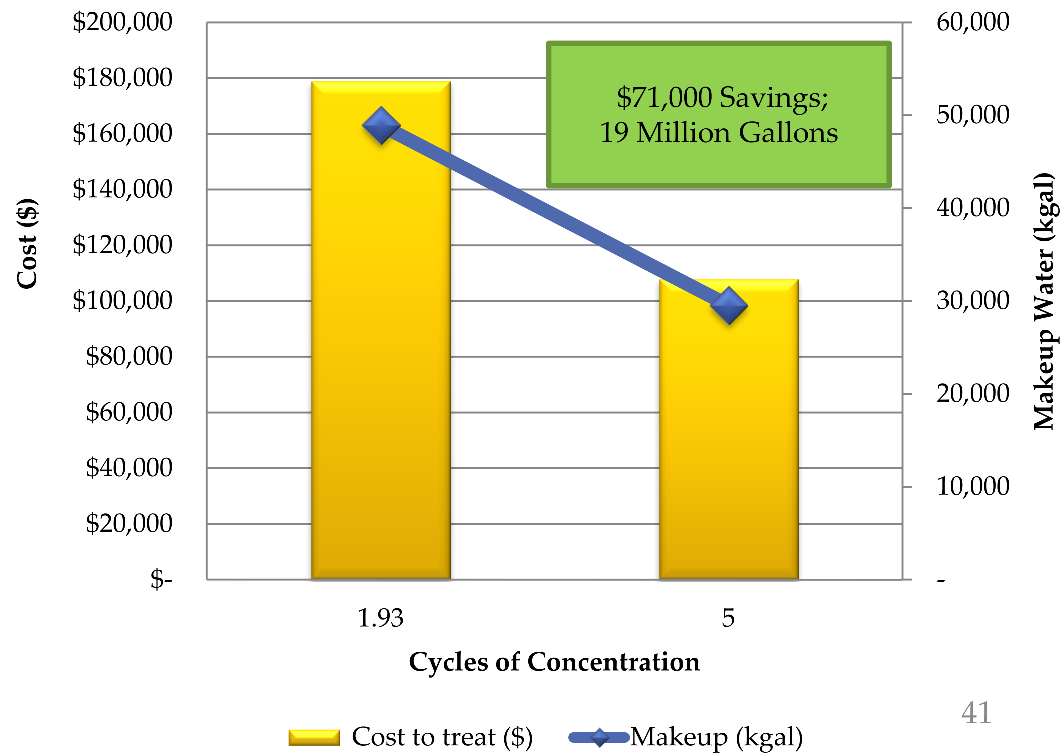
If cycles are increased from the ~3.5 to 5 cycles, estimated water and cost savings are:



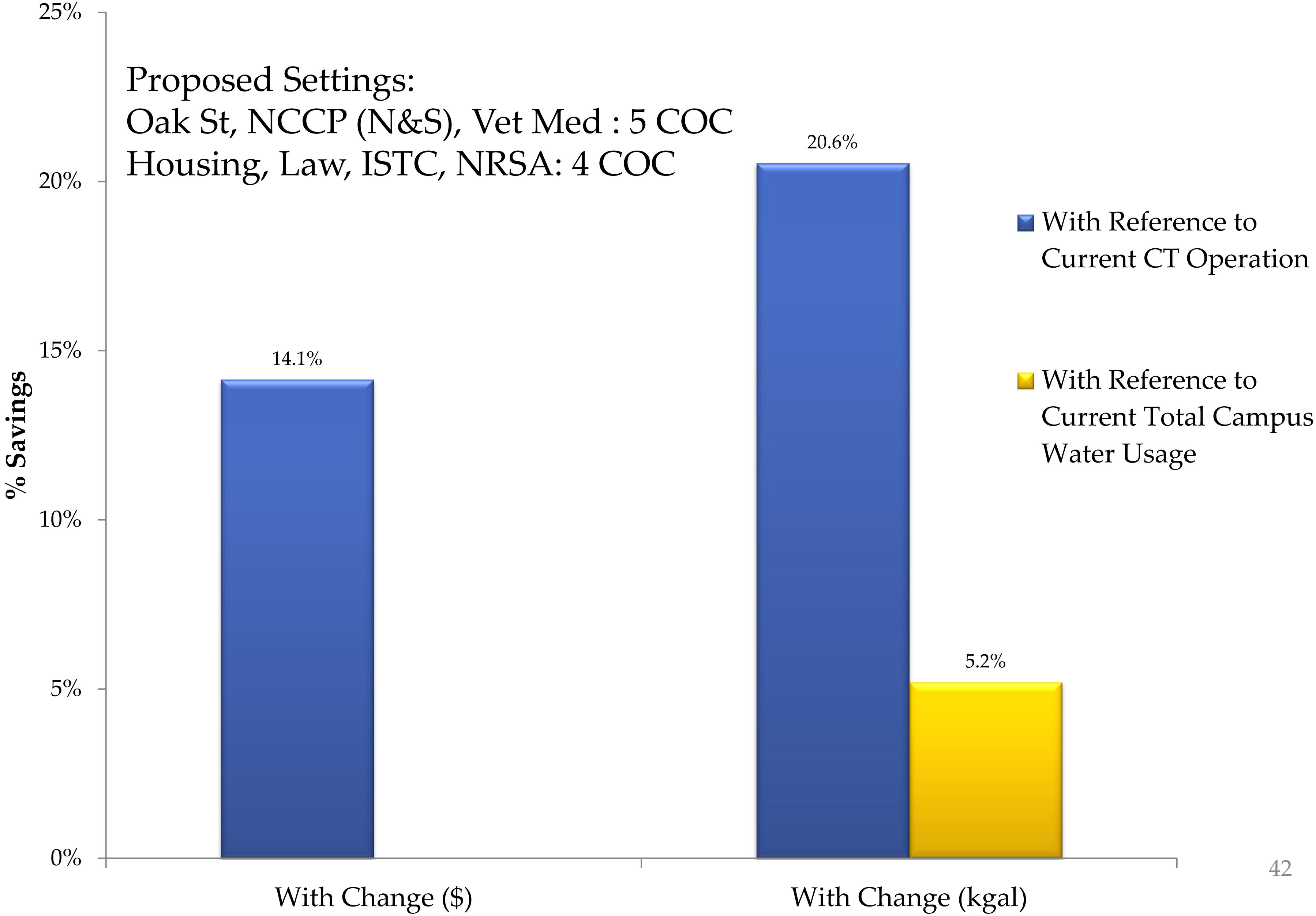
Improving Cycles at Abbott

- Current Chemical Management at Abbott is designed for 7 COC.
- The data provided indicates that the tower is running at ~2 COC.
- Improving controls to bring the cycles up to our target of 5 COC or the design of 7 COC can produce significant water and cost savings.

Abbott Power Plant
Cooling Tower Chemical Treatment
Assuming Chemical treatment cost and cooling load are constant



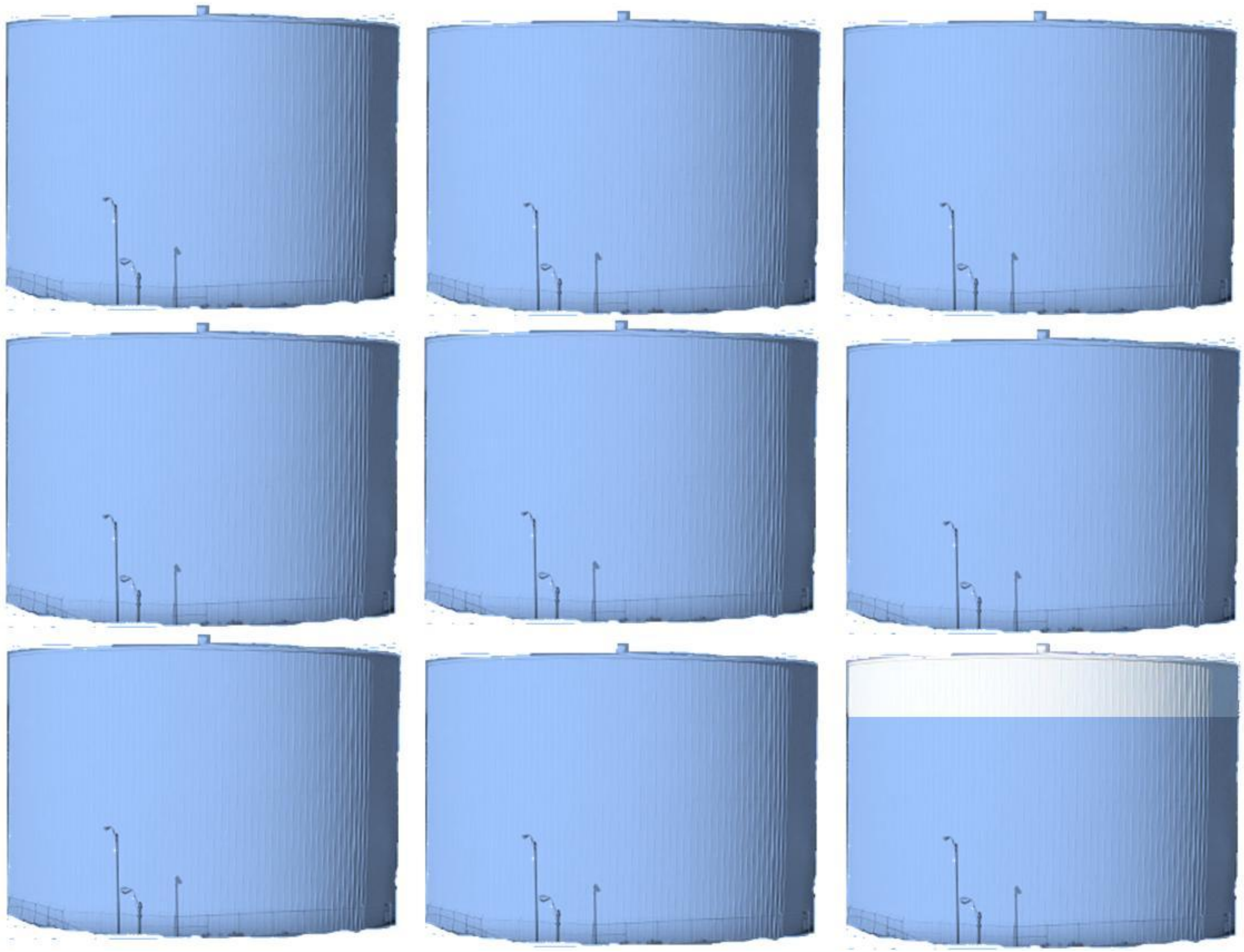
Improving CT COC Means



Route 1

Given Thermal Energy Storage Facility is…

Then the proposed water savings of these cycle changes would be like filling the TES almost 9 times



Potential Issues/Resolutions

- Increasing COC requires H_2SO_4 dosing
- Safety Concerns of Storing/Using Acid On-Site
- Resolution:
  - Would Need Robust System Design
    - Need Policies/Procedures for Receipts, Storage, Dispensing, Monitoring, & Containment (Environmental Compliance and DRS)
  - Environmental Regulations Impact Study
    - Modification to CT pre-treatment permits, Homeland Security related storage permits (Jim Marriott at DRS), OSHA regs (Tom Anderson at DRS)
    - http://safetyandcompliance.fs.illinois.edu

Route 1

Is there a way to avoid the use of Chemicals but still increase Cycles of Concentration?

Don't Like Chemicals?

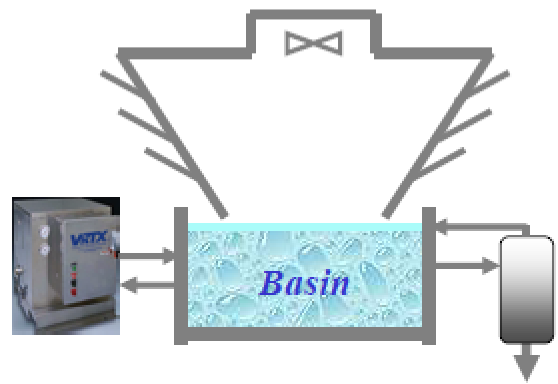
- Non-chemical cooling tower programs are available
- Many such programs are poorly documented and have questionable effectiveness
- One based on cavitation appears to have been more thoroughly vetted. This may be a good candidate for a pilot test.

VRTX Technology

Introduction to Non-Chemical Cooling Water Treatment

VRTX Technology - *How It Works*

- *VRTX unit and filtration system operate independently*
- *Both withdraw and return water to sump*
- *VRTX unit converts dissolved calcium into calcium carbonate colloids, kills bacteria, and removes corrosive gases from water*
- *Filter system removes suspended solids from recirculating water*

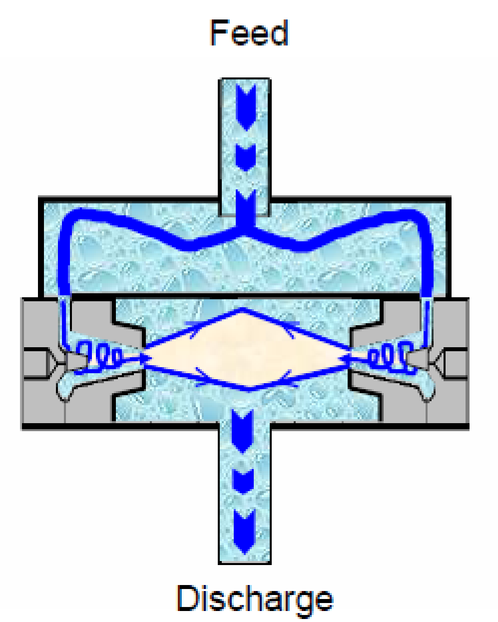


VRTX Cavitation Technology

How Does VRTX Generate Cavitation?

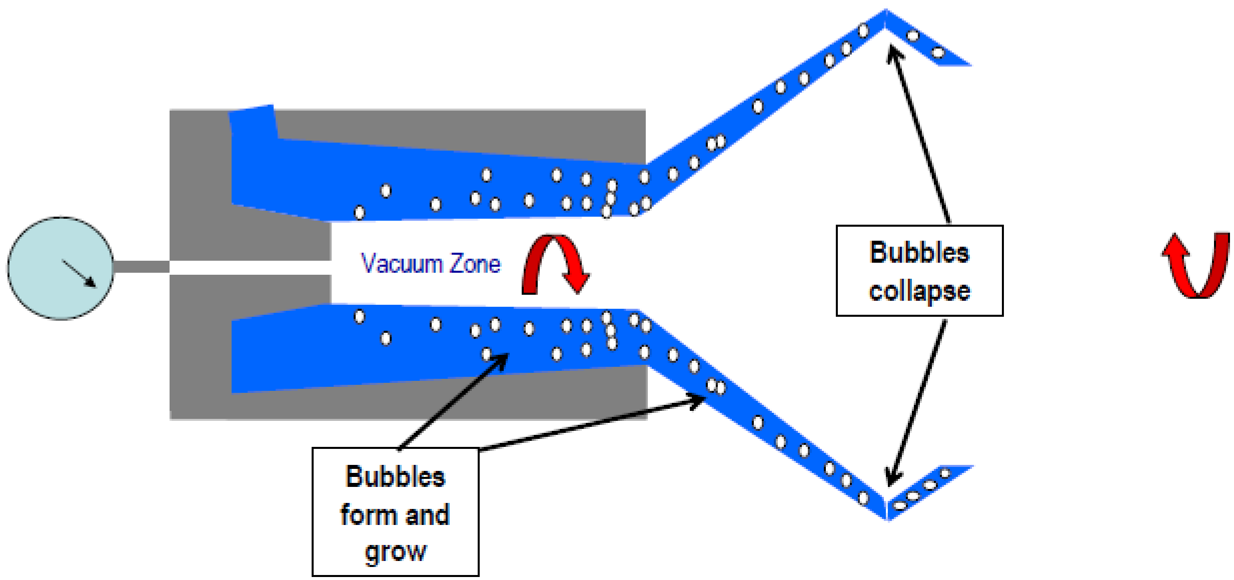
Mechanical device causes significant changes in static pressure in flowing fluid:

- **Vacuum condition is optimum for the formation and growth of bubbles**
- **Two opposite streams collide at the mid-point of chamber (no erosion to nozzle/chamber)**



VRTX Cavitation Technology

Fluid Flow Inside of VRTX Nozzle



VRTX Technology

System Description

System Components

- ***VRTX Unit:***
  VRTX chamber, pump
- ***Filtration system***
- ***Suction Strainers***
- ***Blow-down control system***

VRTX Technology - *How It Works*

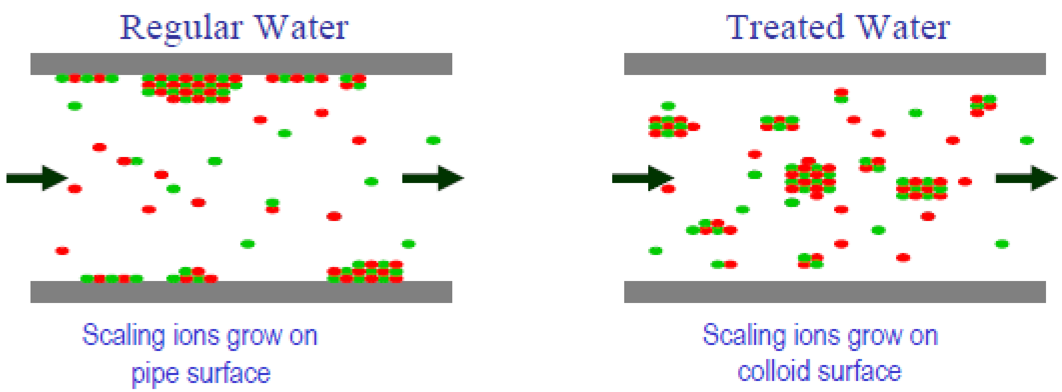
Chemical reactions

- ***Operating conditions force the dissolved calcium and carbonate ions to react and form colloidal, calcium carbonate crystals***
  - $Ca(HCO_3)_2 \rightarrow CaCO_3 + H_2O + CO_2$
  - solution $\rightarrow$ suspension
- ***Strong vacuum strips CO_2 gas from water and shifts chemical equilibrium to the right***
- ***Hydrodynamic cavitation creates extremely high temperature zone; and the solubility of $CaCO_3$ is decreased***
- ***Dissolved calcium and carbonate ions are dehydrated and combine to form $CaCO_3$***

VRTX Technology - *How It Works*

Chemical reactions

- ***$CaCO_3$ colloids act as incubation sites for dissolved calcium and carbonate ions to grow on***
- ***$CaCO_3$ colloidal crystal growth is thermo-dynamically favored over precipitation on equipment surfaces***

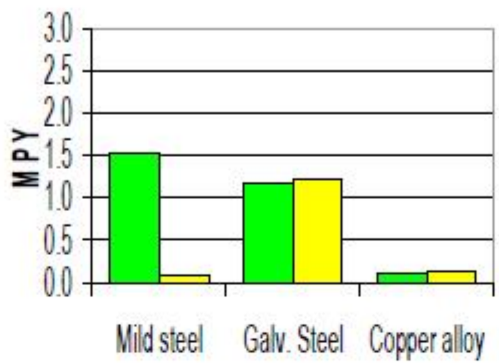


VRTX Technology - *How It Works*

Corrosion Control

- ***Maintaining water at high pH levels (pH > 8.5)***
- ***Removing corrosive dissolved gases***
- ***Controlling bacterial activity***
- ***Eliminating corrosive chemicals***
- ***Reducing suspended solids***

Days Exposed: 179

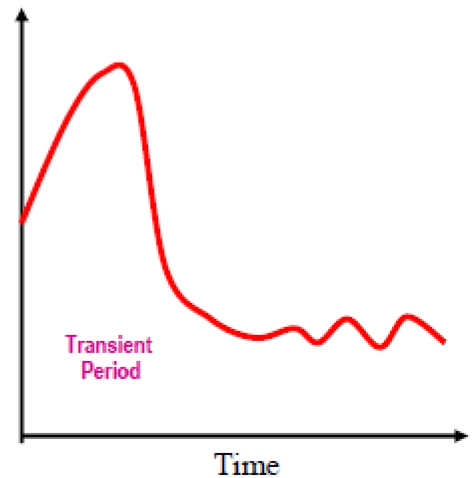


Days Exposed: 127

Bacterial Control

How It Works

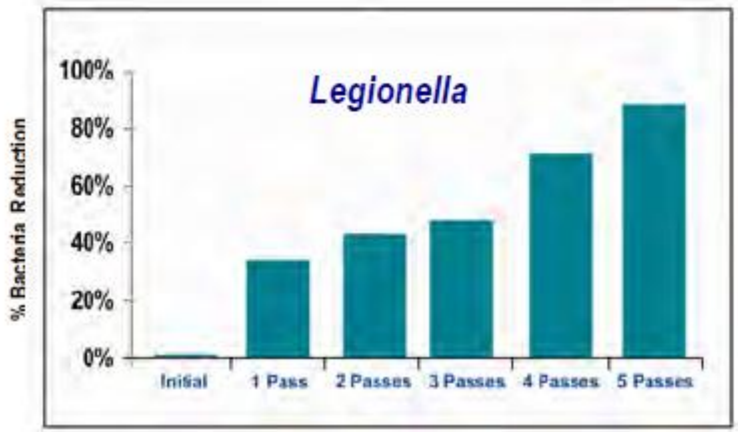
- Physically ruptures cell wall membranes
  - ✓ Dramatic changes in pressure and vacuum
  - ✓ Shear and collision forces created by the collision of water streams
  - ✓ High temperature and sonic wave produced by hydrodynamic cavitation



- A cumulative effect observed in various installations

Legionella Control

Lab Test Results on Bacteria Kill



VRTX System with ZGF Filtration

2006 AHR Expo
Innovation Award Winner

Most Innovative Product
Green Building Category

Leadership in Energy &
Environmental Design
***LEED* Certification**

US Green Building Council

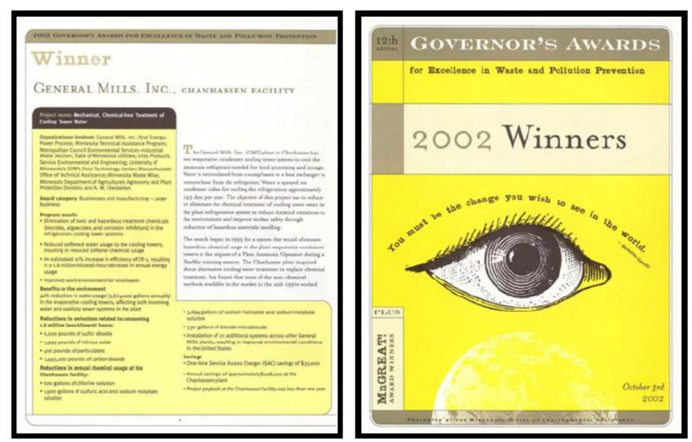
- *HDC Technology will give significant advantage toward LEED Goal Achievement and Advancement for buildings in pursuit of LEED.*
- *VRTX Awarded 2006 AHR Innovation Award in "Green Buildings" Category*

NREP
2005
National Registry
of Environmental Professionals

Environmental Award
Water, Wastewater, Storm Water Category

Plant Engineering
PRODUCT
of the **YEAR**
1999

Plant Engineering
Gold Medal Award Winner
February, 1999

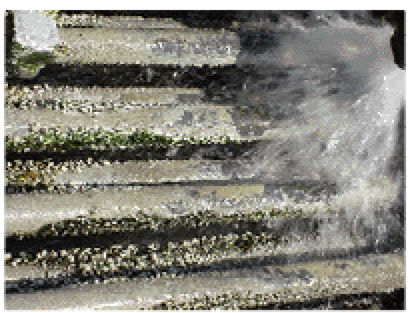


VRTX Technology – *Case History*

Food Processor

Chemical Treatment

- Softened water used as makeup
- Chemical treatment at a cost of $22K / yr
- Scale on condenser tubes 3/8 inches and in basin
- Bacteria counts 50,000 – 75,000 CFU / ml
- Cycles of concentration at 3.0
- Discolored water



VRTX Treatment

- Raw city water used as makeup
- Hard scale significantly reduce
- Bacteria counts 5,000 – 10,000 CFU/ml
- Corrosion 1.8 - 2.4 mpy for mild steel
- Cycles of concentration = 8
- Annual water savings 4.8 million gallons
- Makeup savings > 30%
- Blow-down reduction >70%

The STrategic Envirotechnology Partnership

Green Book Technology Summary Report

Utilizing:

VRTX Technology

A.W. Chesterton Company
5807 Business Park
San Antonio, TX 78218
(210) 661-8800 or (800) 722 0476
www.VRTX-Technologies.com

Prepared by:
Lisa Grogan, Rich Bizzozero, Jim Cain
Massachusetts Office of Technical Assistance
251 Causeway St. Suite 900
Boston, MA 02114-2119
(617) 626-1060
www.state.ma.us/ota

Table 2: VRTX Applications

Site	Industry Sector	Date of Implementation	Results
Pillsbury (MN)	Food Processing and Storage	2000	• Eliminated use, handling, and disposal of treatment chemicals • Substantial water savings • Cycles of concentration increased from 2.9 to 6.3
Richmond Cold Storage, Inc. (VA)	Cold Storage Warehouse	3 Units Installed, 1995, 1996, 1999	• No detectable scale or corrosion problems • Substantial water savings • Cycles of concentration increased from 4 to 18.9
Lancer, Corp (TX)	Plastic Injection Molding	1998	• No system shutdown related to cooling water • Substantial water savings • Cycles of concentration increased from 2.5 to 9
International Paper Co. (VA)	Technology Center	Sept. 1999	• Hazardous chemicals eliminated • Blowdown reduced to <250 GPD from ~1000 GPD • Old scale softened and removed • Cycles of concentration increased from 2.8 to 5.3
Fujitsu Corporation (OR)	Microchip Manufacturing	2 Units Installed, 1993, 1994	• Scale under control • Substantial water savings • Cycles of concentration increased from 4.6 to 33

Operational Parameters		Richmond Cold Stor.	Lancer	Internat'l Paper	Fujitsu	Pillsbury
Cooling Tower Capacity		1200 Ton + 900 Ton	2x350 Ton	1000 Ton	3x300 Ton	~ 1300 Ton
Material of Construction		Galvanized Steel	Galv. Steel	Galv. Steel	Galv. Steel	Galv. Steel
Corrosion Rate		2.0 mpy (mild steel)	Acceptable**	Acceptable**	Acceptable**	0.89 mpy
Function/Duty		Refrigeration	Hydraulic Oil	Test Lab A/C	Mfg. A/C	Refrigeration
Water Source		County Wells	City Wells	County Wells	City-Surface	City-Well
Sump Water Temperatures		Not Measured	90	82	88	75
Size of VRTX unit		3x40 gpm	40 gpm	60 gpm	3x30 gpm	60 gpm
Duration of Water Samples		6 months	13 months	24 months	12 months	3 months
Number of Water Samples		3	> 30	> 30	6	48
pH	Make-up	6.8	7.3	8.2	7.1	8
	Sump	9.3	8.8	9.2	8.9	9.08
Alkalinity (mg/L)	Make-up	24	198	326	38	350
	Sump	374	330	1498	454	1329
TDS (mg/L)	Make-up	34	364	866	68	400
	Sump	1377	1076	4531	2588	1600
Calcium (mg/L)	Make-up	4	174	142	22	73
	Sump	50	201	76	48	28
Magnesium (mg/L)	Make-up	2	72	48	4	34
	Sump	29	503	456	202	403
Chloride (mg/L)	Make-up	6	25	210	12	22
	Sump	113	226	1102	446	100
Cycle of Concentration - VRTX (Prior to VRTX Installation) *		18.9 (4)	9 (2.5)	5.3 (2.8)	33 (4.6)	6.3 (2.9)
Annual water savings (%)		20%	29%	17%	19%	41%
Annual Blowdown Water Savings	%	83%	82%	67%	88%	94%
	gallons	5.0 million	3.3 million	3.5 million	1.5 million	1.5 million

*The number of times non-volatile constituents in makeup water are concentrated by the evaporative cooling tower is the "Cycles of Concentration" (COC) for the cooling tower. If the COC factor is 3, the non-volatile constituents in the blowdown water are three times the concentrations of the makeup water. The blowdown volume (including any drift or leaks) is one third (33%) of the makeup water volume. If the COC increases to 10, then only one tenth (10%) of the makeup water is discharged as blowdown – a "calculated" water savings of 23% (33% - 10%).

**Acceptable: Not measured quantitatively by facility; however, no corrosion prevention chemicals have been added to date.

Pillsbury's VRTX unit, which has a flow rate of 60 gpm, was purchased for approximately $60,000 (including the cost of installation). The company did not provide any specific energy consumption information beyond that used by the system's two pumps (7.5 hp and 1.5 hp, as mentioned previously). Cost savings from water conservation documented in the previous section are listed in Table 7, as are cost savings stemming from the elimination of water softening and treatment chemicals. The Sewer Availability Charge is a one-time savings from the local sewer authority that resulted from Pillsbury's reduced water consumption. Based on these figures, first year savings were in excess of $60,000, indicating a pay back period of less than one year.

Controlling Cooling Tower Water Quality by Hydrodynamic Cavitation

W.A. Gaines B.R. Kim A.R. Drews

C. Bailey T. Loch S. Frenette

ABSTRACT

A field study was conducted to evaluate the performance of a hydrodynamic cavitation device (HCD) for disinfection, scaling, corrosion, and heat-transfer efficiency on a cooling-tower system at an automotive testing facility. Primary findings are: (1) The HCD unit performed as well as the chemical program that it replaced in terms of bacterial control without adding any chemicals (including disinfectants); the bacterial count was maintained at ~10^4 cfu/mL over the course of the study. (2) The HCD unit enabled the cooling system to be operated at comparable cycles of concentration (CoC) to that used during the chemical program, without adversely affecting pH, scaling, or corrosion. (3) The corrosion rates of copper and mild steel were either equivalent or better than those obtained during the chemical program. (4) The use of the HCD unit did not adversely affect heat-transfer efficiency. Long-term effectiveness of this technology was not evaluated as part of this study.

Table 1. Makeup Water Analysis

Calcium (Ca)	26.8 mg/L
Magnesium (Mg)	8.80 mg/L
Chloride (Cl^-)	7.5 mg/L
Sulfate (SO_4)	23.9 mg/L
pH	7.29 S.U.
Silica (SiO_2)	2.38 mg/L
Total alkalinity (as $CaCO_3$)	72 mg/L
Phosphorous (P)	0.29 mg/L
Conductivity	214 micro Siemens

Table 2. Cooling Water Cycles of Concentration Before and During the Study Period

	Previous Three Years	150-Day Pretrial	Trial
Average	3.5	4.7	4.9
Standard Deviation	1.4	0.4	0.3

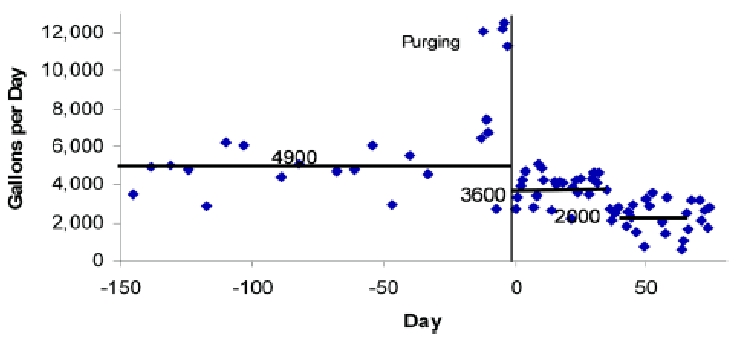
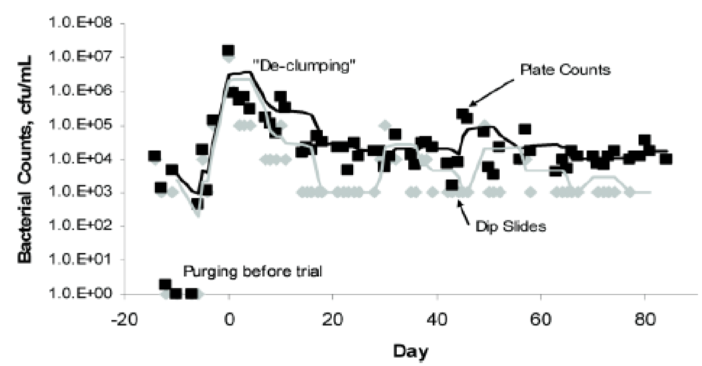


Table 4. Measured Corrosion Rates (mil/year) of Test Coupons

Date	Days Exposed	316L SS	Copper	Galvanized Steel	Untreated Mild Steel	Treated Mild Steel
Historic	23		<0.1		1.3	
Pretrial	61		<0.1			0.5
HCD	65	<0.1	<0.1	4.3	0.3	



References

- General Mills – New Albany IN: Ted Iverson – 812-941-4332; ted.iverson@genmills.com
- Ed Miniat Meats – South Holland IL: Randy Nelson – 708-589-2400; rnelson@miniat.com
- Preferred Freezer - Chicago IL: Phil Locher – 773-457-7839; plocher@preferredfreezer.com
- Appleton Medical Center – Appleton WI: Richard Helfrich – 920-731-4101
- Engineered Polymers – Mora MN: Tim Joy – 320-679-6786; tjoy@epcmolding.com
- Xavier University – Cincinnati OH: Rob Edwards – 513-745-3855

ROUTE 2

Decrease CT water consumption through improved control

- Monitoring

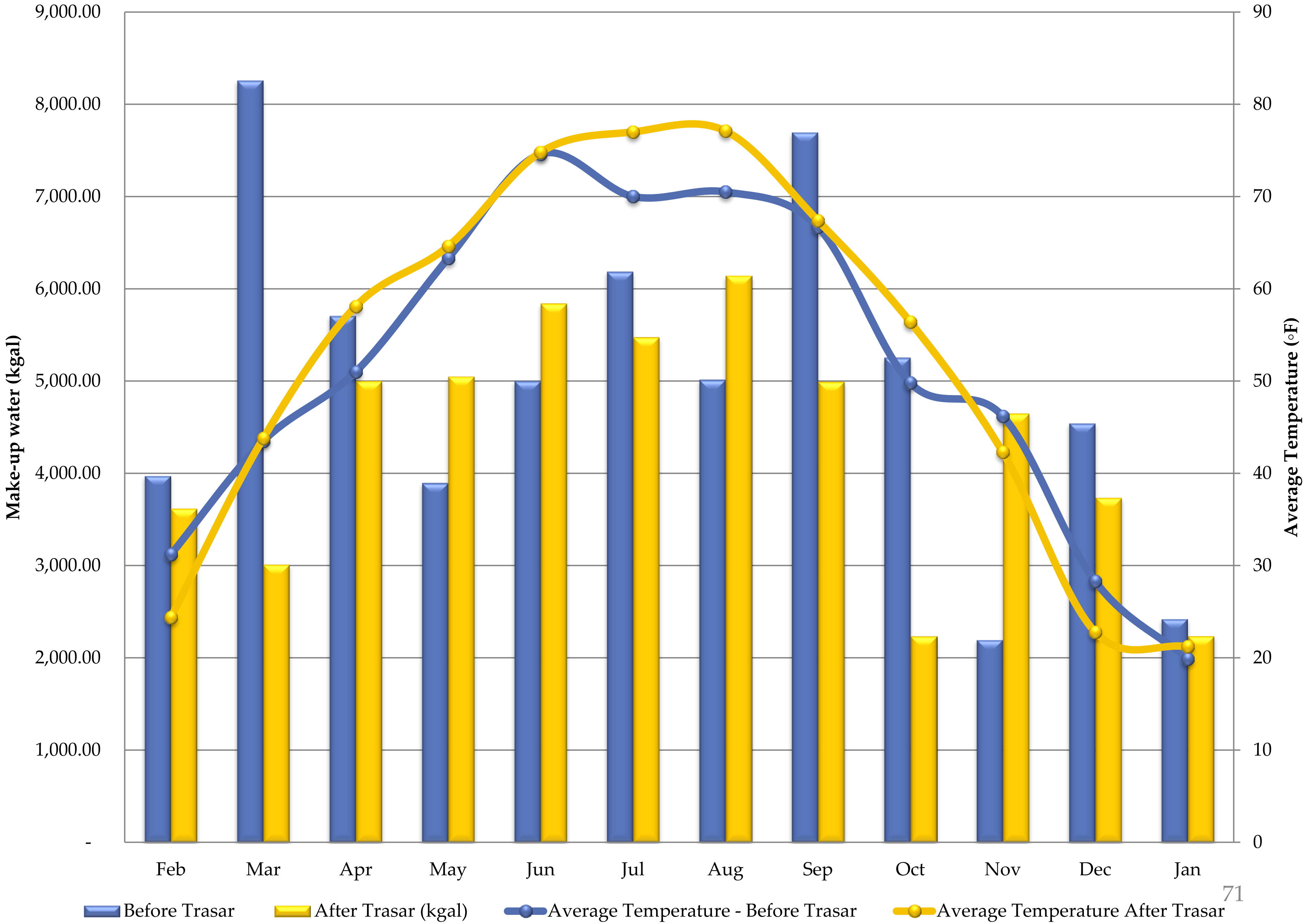
What is Improved Monitoring?

- Quantity of Blowdown is controlled by measurement of objective criteria such as conductivity
- Continuous monitoring is better than periodic monitoring – allows automated control
- Example of one such system – TRASAR 3D from Nalco

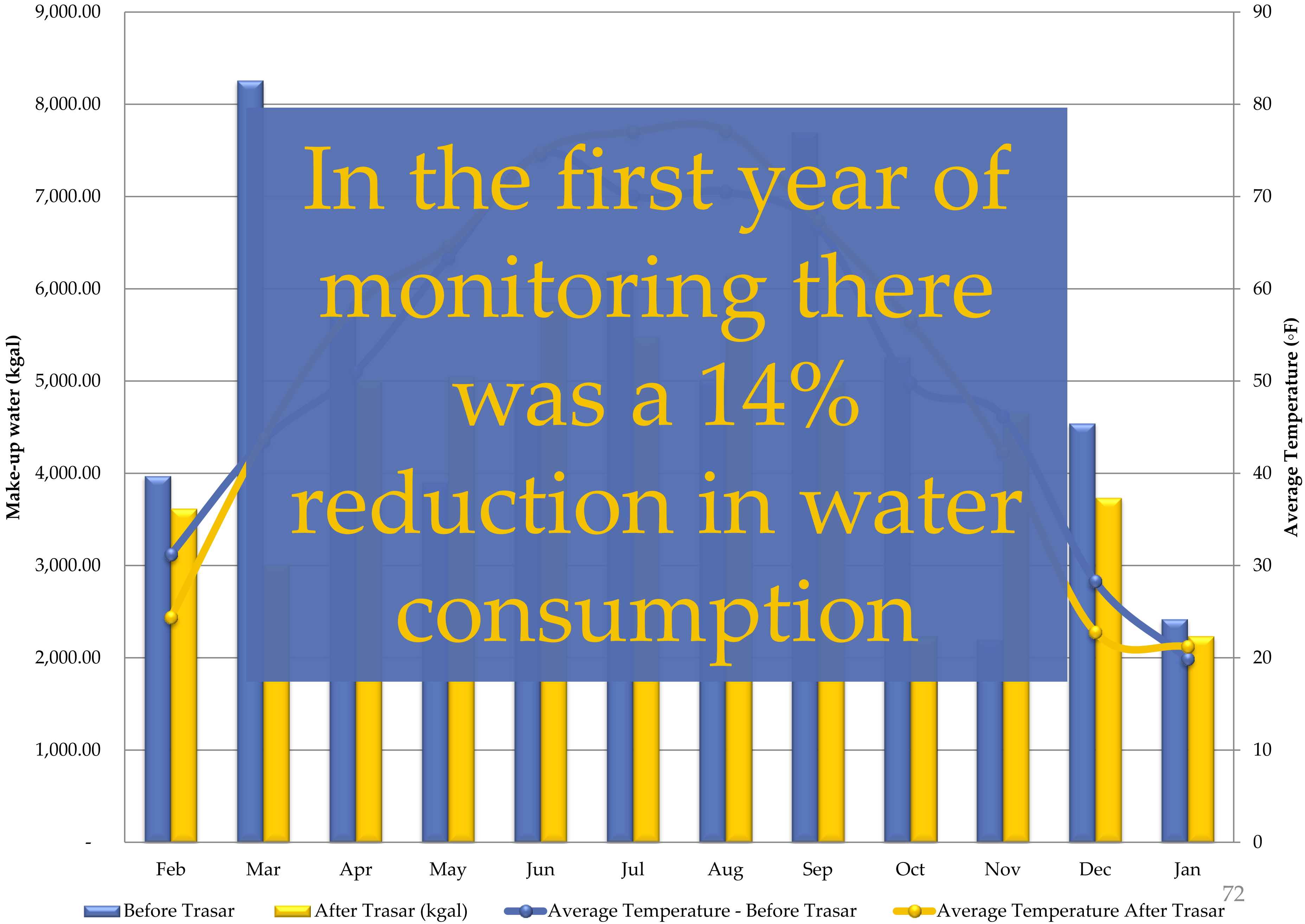
North Campus Chiller Plant Experience with Trasar 3D

What benefits, if any, due to improved monitoring?

Improved Monitoring Reduces Tower Makeup



Improved Monitoring Reduces Tower Makeup



In the first year of monitoring there was a 14% reduction in water consumption

Future of Trasar @ UIUC

The Nalco Representative indicated that units have already been purchased for Oak Street and Vet Med Chiller Plants but are awaiting installation. If additional units are needed for other locations:

– The expected cost of each unit would be $10,000; varies by unit

– Installations by Nalco have been completed for $2,000-$4,000 per unit.

Closer attention to water use numbers, metering, and prompt remedial action are likely to reduce water lost to malfunctioning hardware.

- At ISTC, during retrocommissioning, cooling tower blowdown control was found to be malfunctioning
- Similar situations have existed at Vet Med based on what we have heard anecdotally.

ROUTE 3

Reduce
Cooling Load

How Does One Reduce Cooling Load?

- Efficient energy use at buildings lowers cooling load
- Only campus efforts with retrocommissioning are highlighted but many pathways to improve efficiency exist; outside the scope of this project.
- Efficient energy use at chiller plant
  - optimization, condenser heat recovery; combined cooling/heating are all potential routes

An Example of The Energy-Water Nexus On Campus

- Building Retrocommissioning
  - The skilled analysis of a building's HVAC systems and maintenance program can play a part in reducing the thermal load that a building adds to the Campus Chilled Water System.

Retrocommissioning Energy Load Reduction in Select Locations

Retrocommissioned Buildings	Chilled Water Saved per year (MMBTU)
National Soybean Research Center	3,316
Turner Hall	6,223
Animal Sciences Laboratory	3,091
Bevier Hall	2,383
Psychology Building	3,032
Krannert Center for Performing Art	2,698
Chemical & Life Sciences Laboratory	13
	20,756
Data from Retrocommissioning website at http://www.fs.illinois.edu/retro/	

The cooling load reductions achieved by retrocommissioning reduces cooling tower water consumption as well. The example in the next slide calculates the cooling tower water that WOULD have been consumed if this energy had NOT been saved.

Result of these Retro-X projects

Route 3

Assumptions:

1. Compressor Power/ton : 0.08 kWh/1000 BTU cooling
2. Tower operates at 4 cycles

Cooling Load (MMBTU)	Added by Compressor (MMBTU)	Total Heat (MMBTU)	Water Consumption (Mgal)
20,756	5,665.79	26421.79	3.166

Evaporation (Mgal)	Makeup (Mgal)	Blowdown (Mgal)
3.166	4. 221	1.055

Route 3

Result of these Retro-X projects

Now that we have determined we are saving 4.221 Mgal of water, we can now calculate a cost savings.

Using the Energy Savings Rates:
Incoming Water: $2.15/kgal
Sewer Disposal: $2.02/kgal
Chemical treatment at 4 COC: $1.08/kgal

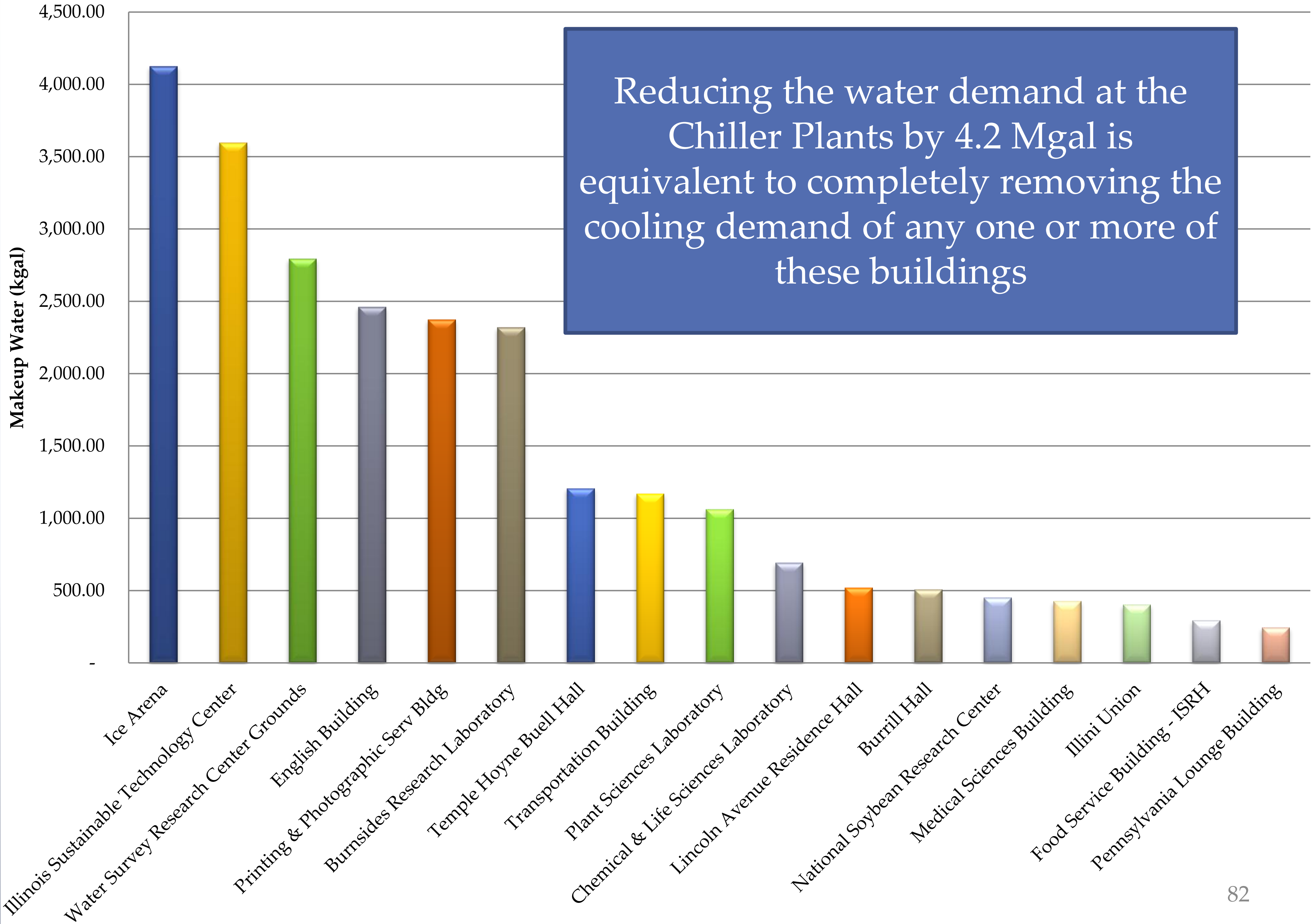
Assuming a Treated Tower at 4 COC	
Incoming Water Cost Abated ($)	$ 9,075.95
Chemical Cost Abated ($)	$ 4,599.08
Sewer Cost of Blowdown Abated($)	$ 2,131.79
Total Cost Abated($)	$ 15,766.82

Result of these Retro-X projects

Water associated costs at the Cooling Towers for FY 2011 (excl Abbott)	$ 959,438
Retro-X saved in cooling water expenses	$ 15,766.82
% $ savings of FY 2011	1.6%

FY2011 Campus water CT Only (excl Abbott)	278,684
Retro-X saved cooling water (Mgal)	4.2
% kgal CT FY 2011 savings (ex Abbott)	1.5%

FY 2011 Tower Water Consumption



Savings in Water As a Result of Retrocommissioning in Aggregate

If we add up the total first year energy savings from retrocommissioning of buildings served by the Chiller Plants

Retro Commissioning saved 106,666 MMBTU
After accounting for heat added by the compressors at the Chiller Plant, we estimate:
Total Heat saved 135,782 MMBTU

It would require
16.27 million gallons of water to be evaporated to remove this heat
At current operation, the Chiller Plants would consume 21.69 million gallons of water to provide this cooling.

Current Retrocommissioning projects have resulted in savings of ~21 Mgal water for cooling in the first year after Retrocommissioning

List of Retrocommissioned Buildings

Cost Savings As a Result of Retrocommissioning in Aggregate

	Savings Rate ($/MMBTU)	Cost Savings ($)
From Retro-X Energy Rate	$6.9300	$739,195.38
Savings from Cooling water	$0.7596	$81,026.39
Total Savings by Retrofit	$7.69	$820,221.77
% Added Savings Represented by Cooling Water		10%

The cost savings from water consumption abatement provides an additional 10% savings to the current calculation used to evaluate retrocommissioning projects.

This demonstrates a great potential for cost and water savings by the University through the continuation of the Retrocommissioning efforts.

The additional cost and fuel savings from reductions in mechanical load have not been included in our calculations and would represent further savings currently unaccounted for.

ROUTE 4

Cascade water from another process for CT make-up

- Abbott RO reject
- Oak Street Sub-soil Drainage
- Reprocessed blowdown

Oak Street Sub-soil Drainage

- Drainage of the order of 50 gpm
- Oak Street Chiller Plant make-up ~200 gpm
- Substantial reductions in cooling tower water usage possible if drainage can be used for make-up

Major Issue

Drainage water quality not suitable without recourse to treatment

Water Quality

Water Quality to Cooling Tower	
Parameters	Value
	mg/L
TDS	176
Calculated TDS	169
Cations	
Na	38
K	2.2
Ca	12.4
Mg	12.35
Sr	0.16
Fe	0
Barium	0.07
Anions	
Chloride	7
Sulfate	0
Bicarbonate as CaCO3	147
Carbonate as CaCO3	14
Fluoride	0.98
Si as SiO2	7.7
OH (mol/l)	0.00
pH at 8.4 C	9.08

Needs to be checked

Source: Illinois State Water Survey

Oak Street Drainage	
Parameters	Value
	mg/L
TDS	986
Calculated TDS	943
Cations	
Na	116
K	1.6
Ca	154
Mg	55
Sr	0.26
Fe	0.2
Barium	0.13
Anions	
Chloride	235
Sulfate	109
Bicarbonate as CaCO3	430
Carbonate as CaCO3	0
Fluoride	ND
Si as SiO2	13.7
pH at 23.6 C	7.6

Source: Report to Student Sustainability Committee
By E. Day, N. Grabowski, A. Rennegarbe
Title of Report: Design of a Sub-soil Drainage Water Distribution System
Date: 12/18/2009
Copy Obtained From: Jim Hopper, UIUC Water Station

Caveat: Water quality is likely to be variable; influenced by the precipitation pattern

Oak Street Sub-soil Drainage - Prior Study

- Report: *Design of a Sub-soil Drainage Water Distribution System*
  - By E. Day, N. Grabowski, A. Rennegarbe
  - Report to Student Sustainability Committee

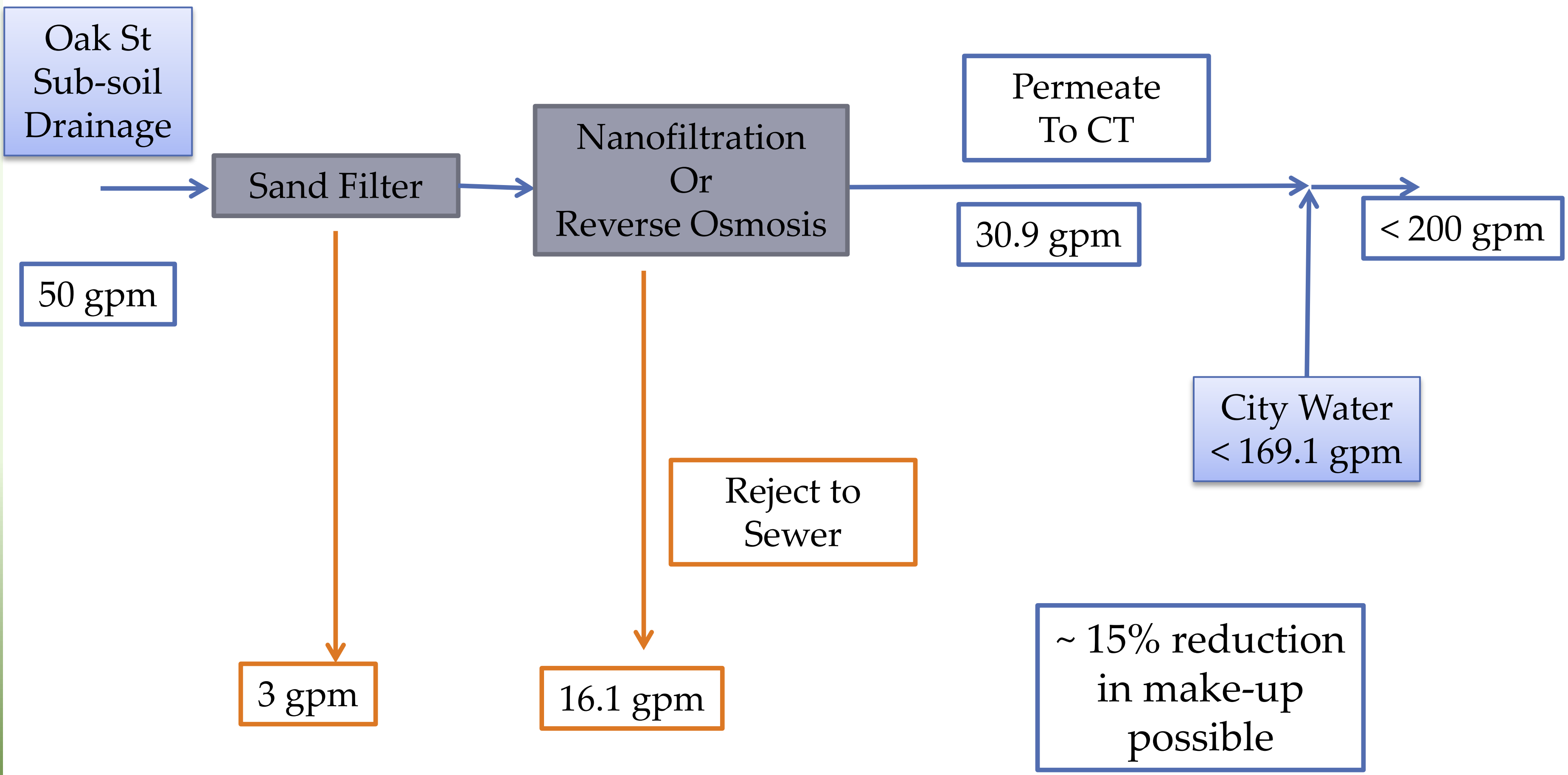
- Suggests that cost of treating Sub-soil Drainage water is excessive
  - Evaluated RO as treatment option; major costs identified in descending order
    - Disposal costs of RO reject flagged as major cost
    - pH adjustment of RO permeate was flagged as major cost
    - Energy for RO operation identified as significant cost component
    - Anti-scalant dosage costs were identified as significant

Prior Study…Observations

- The improved quality of tower water is not reflected in the COC

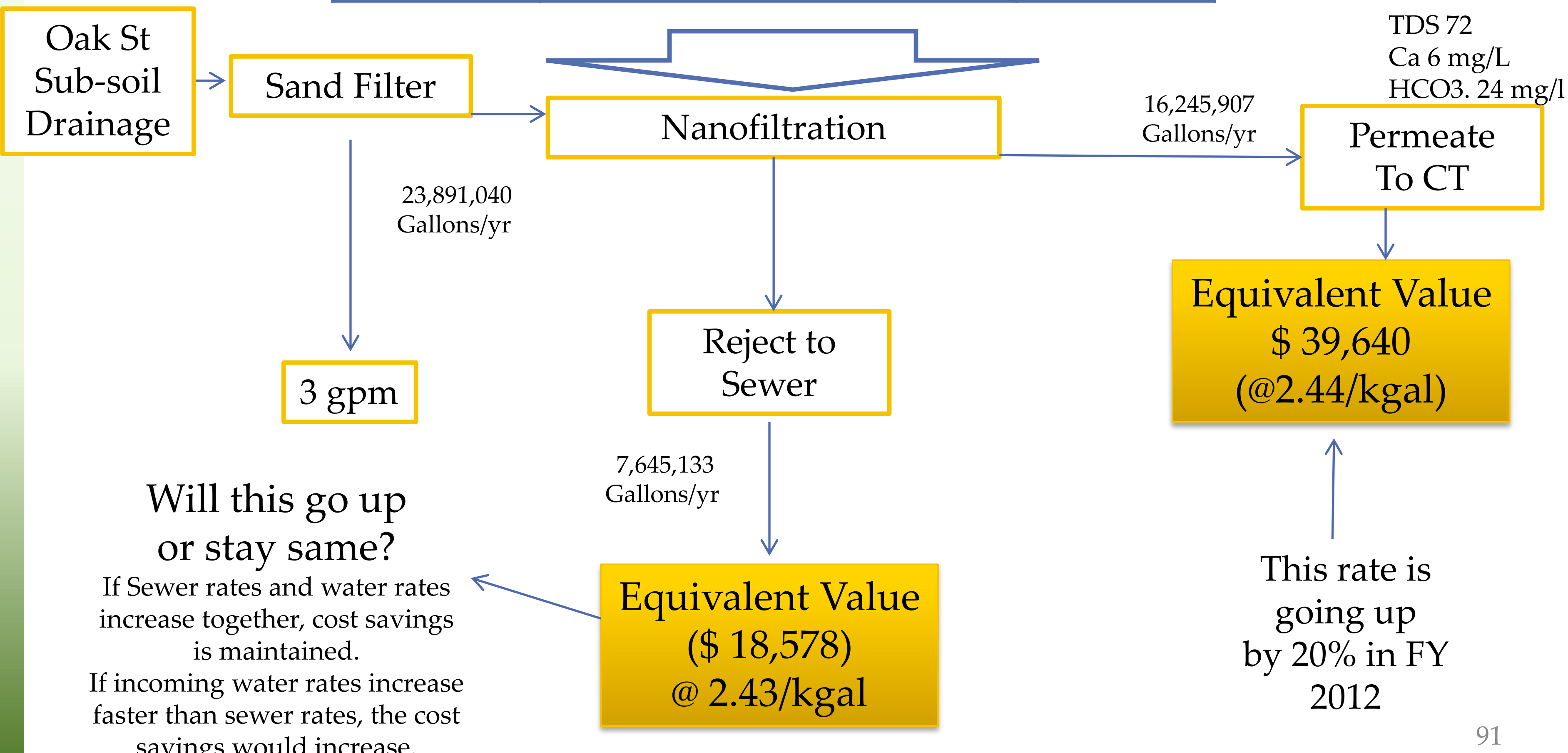
- Basis for chemical costs are unclear but likely incorrect (Appendix B, Fig 2 suggests that water input to cooling tower is 100% raw drainage water with sulfuric acid to control alkalinity rather than RO water)

Use of Alternative Water Sources



Tentative Estimates

Chemical (3,985?) (@5 ppm & $4/lb)	Other Costs ($16,000?)	Power ($ 1,253?) (@ 1.12 kWh/kgal permeate and $0.0689/kWh)
	Labor (10 hr/month*12*$25)- $3,000 Miscellaneous - $2,000 Membrane Replacement (5 yr life) - $2,000 Equipment Amortization (10 years) - $9,000	



Oak Street Sub-soil Drainage - Summary

- Suggest taking a second look at this opportunity
- Maybe economically neutral
- Uncertainties with water quality data need to be resolved (paper study/analytical data collection & pilot encouraged)
- If feasible, explore lease/contract option rather than ownership

ROUTE 5

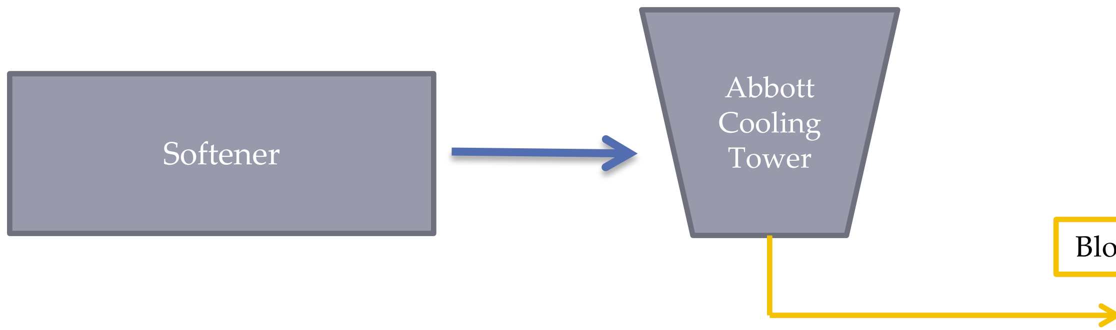
Use CT blowdown to displace water use in another application

Cooling Tower Blowdown as RO Input?

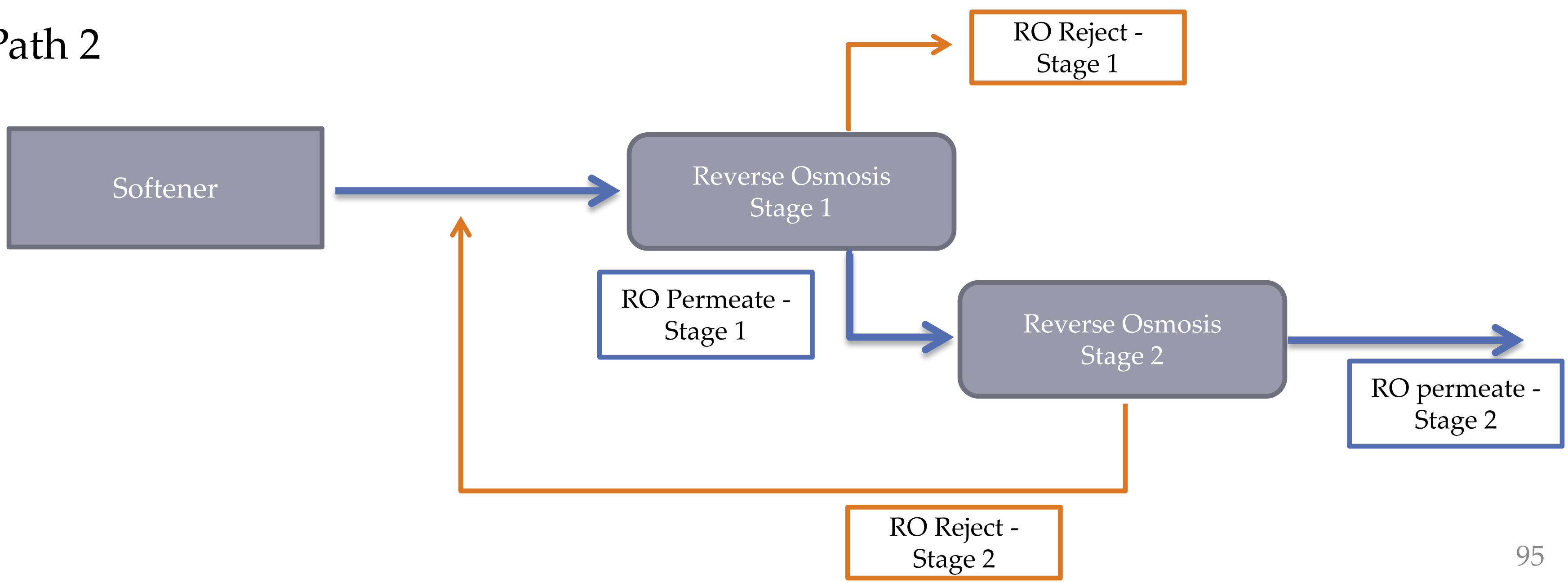
- Given the low COC at Abbott Tower and the large water consumption, does it make sense to use the CT blow down as RO input?
- In other words, what benefits might accrue if Tower/RO is optimized as a system?

Abbott Water Paths

Path 1



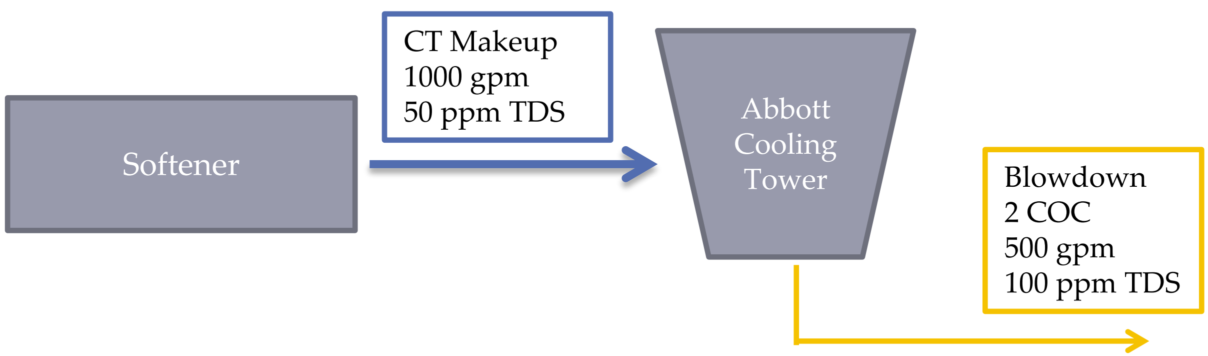
Path 2



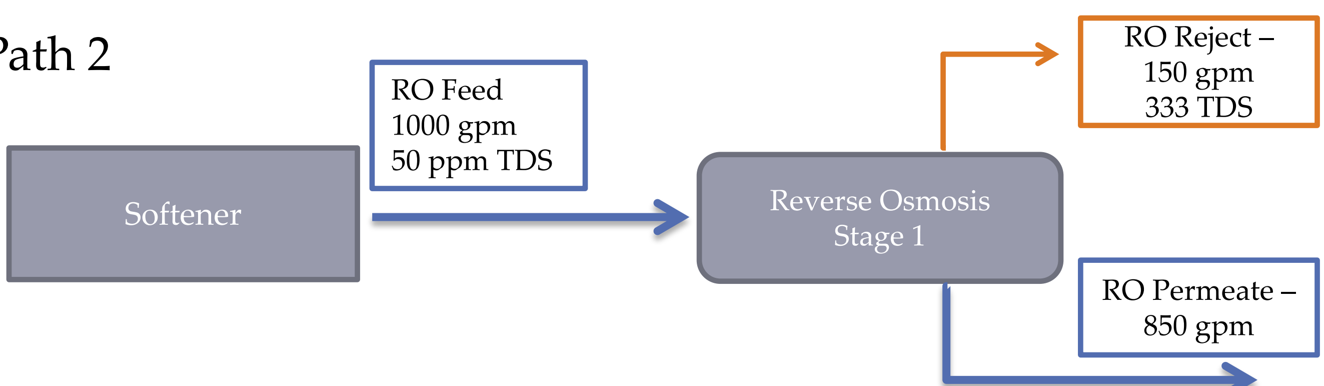
Example: Systems Designed Separately

Baseline
Incoming Water = 1000 (RO)+ 1000 (CT) = 2000 gpm
Total Effluent = 150 (RO) + 500 (CT) = 650 gpm

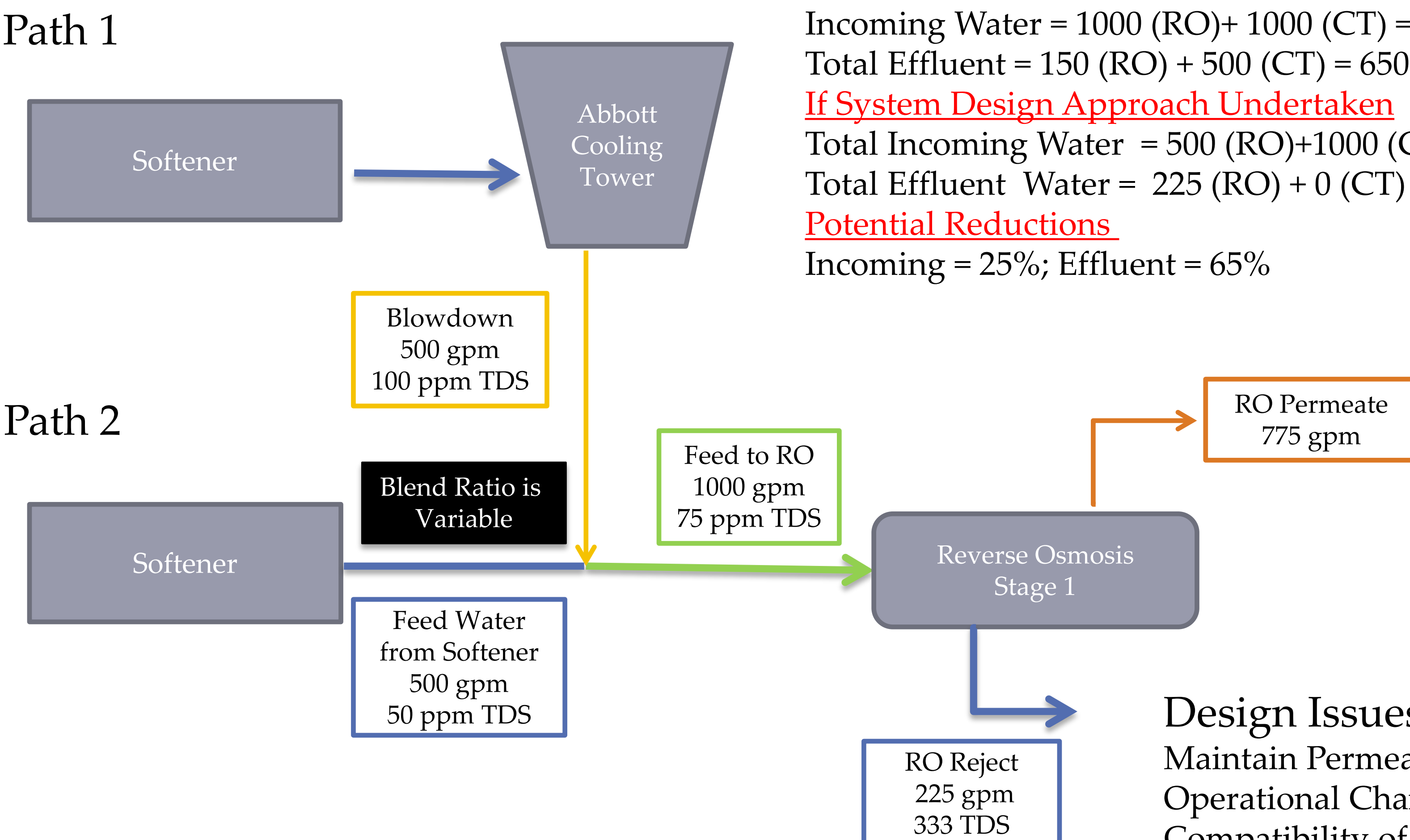
Path 1



Path 2



Example: Systems Designed as Parts of a Whole



<u>Base Case</u>

Incoming Water = 1000 (RO)+ 1000 (CT) = 2000 gpm
Total Effluent = 150 (RO) + 500 (CT) = 650 gpm

<u>If System Design Approach Undertaken</u>

Total Incoming Water = 500 (RO)+1000 (CT) = 1500 gpm
Total Effluent Water = 225 (RO) + 0 (CT) = 225 gpm

<u>Potential Reductions</u>

Incoming = 25%; Effluent = 65%

Design Issues

Maintain Permeate Production
Operational Changes to RO/CT
Compatibility of Chemicals
& so on

Appendix

- Campus Water Bill
- Untreated Towers – FY 2011 Operation
- Treated Towers – FY 2011 Operation
- COC Calculation
- True Cost of Water Calculation
- Campus Savings Calculation
  - Table of Values
  - Calculation of Incoming Water Savings (kgal)
  - Calculation of Total Water Cost Savings ($)
- Utility Rates for FY 2011 Memo from Terry Ruprecht – for Energy Savings Rates
- Retrocommissioned Buildings
- Abbott
  - Abbott Cooling Tower Makeup Flow Rates
  - Abbott RO Operation, 2 pages
- Oak Street Sub-soil Drainage Examination

Campus Water Bill

Usage Month	Calendar Year	Fiscal Month	Fiscal Year	TOTAL WATER COST ($)	TOTAL WATER USAGE (Kgals)	Cost ($/kgal)
Jul	2010	AUG	2011	$274,735	111,716	
Aug	2010	SEP	2011	$283,767	116,120	
Sep	2010	OCT	2011	$288,447	118,314	
Oct	2010	NOV	2011	$233,662	94,154	
Nov	2010	DEC	2011	$198,983	78,631	
Dec	2010	JAN	2011	$201,982	80,621	
Jan	2011	FEB	2011	$174,090	67,691	
Feb	2011	MAR	2011	$177,958	69,637	
Mar	2011	APR	2011	$209,207	83,012	
Apr	2011	MAY	2011	$213,736	85,270	
May	2011	JUN	2011	$224,150	90,067	
Jun	2011	JUL	2011	$256,968	104,060	
12 MO		TOTAL		$2,737,683	1,099,293	2.49

	Untreated Towers	Estimated Cycles (FY 2011)	Makeup (Kgal) (FY 2011)	Evaporation (kgal) (FY 2011)	Blowdown (kgal) (FY 2011)
1	Transporation Building	1.07	1,171	75	1,097
2	National Soybean Research Center	1.14	454	57	397
3	Medical Sciences Building	1.16	429	58	371
4	Lincoln Avenue Residence Hall	1.13	523	60	463
5	Ice Arena	1.20	4,128	689	3,438
6	Illinois Street Residence Hall	1.18	295	44	251
7	Burnsides Research Laboratory	1.27	2,322	498	1,824
8	Natural Resource Studies Annex	1.26	5,598	1,140	4,458
9	Pennsylvania Avenue Residence Hall	1.23	247	46	200
10	Illini Union	1.28	405	87	317
11	Housing Food Stores	1.28	9,219	2,033	7,186
12	English Building	1.23	2,464	467	1,997
13	Burrill Hall	1.27	511	109	402
14	Printing & Photographic Service Building	1.39	2,376	661	1,715
15	Veterinary Medicine Chiller Plant (Meter ID 3)	1.36	4,125	1,085	3,039
16	Veterinary Medicine Chiller Plant (Meter ID 2)	1.41	4,182	1,210	2,972
17	Veterinary Medicine Chiller Plant (Meter ID 1)	1.34	27,503	6,922	20,581
18	Law Building	1.43	5,635	1,700	3,935
19	Illinois Sustainable Technology Center	1.58	3,600	1,316	2,284
	Total	**1.32**	**75,186**	**18,259**	**56,927**

	Treated Towers	Estimated Cycles (FY 2011)	Makeup (Kgal) (FY 2011)	Evaporation (kgal) (FY 2011)	Blowdown (kgal) (FY 2011)
	Construction Engineering Research Lab	-	-	-	-
	State Regional Office Building	-	-	-	-
1	Plant Sciences Laboratory	1.57	1,065	385	679
2	Water Survey Research Center	1.79	2,798	1,231	1,567
3	Abbott Power Plant	1.93	48,934	23,619	25,314
4	Animal Science Air Conditioning Center	2.27	16,809	9,388	7,421
5	Library Air Conditioning Center (Meter ID 5)	2.18	19,838	10,741	9,097
6	Temple Hoyne Buell Hall	2.89	1,208	789	419
7	Library Air Conditioning Center (Meter ID 4)	3.12	4,822	3,276	1,546
8	Library Air Conditioning Center (Meter ID 7)	3.01	5,793	3,872	1,921
9	Chemical & Life Sciences Lab	3.24	696	481	215
10	North Campus Chiller Plant (North Meter)	3.18	42,568	29,202	13,365
11	North Campus Chiller Plant (South Meter)	3.13	10,939	7,445	3,494
12	Oak Street Chiller Plant	3.54	92,015	66,023	25,992
13	Grainger Engineering Library	3.52	4,948	3,542	1,406

COC Calculation

	Makeup (kgal)	Blowdown (kgal)	Evaporation (kgal)
Treated Towers	252,431	92,435	
Untreated Towers	75,186	56,927	
All Cooling Towers (incl Abbott)	327,617	149,362	178,255

M = E (COC/(COC-1))

E/B + 1 = COC

M = Makeup
B = Blowdown
E = Evaporation
COC = Cycles of Concentration

(178,255/149,362) + 1 = COC

COC = 2.19

Back to Presentation

True Cost of water Example Calculation

- Assume constant heat load; i.e., constant evaporation
- Blowdown (kgal/min) = Evaporation (kgal/min)/(COC-1)
- Make-up (kgal/min) = Evaporation (kgal/min)*[COC/(COC-1)]

- Make-up at COC of 3.5 = E*1.4; Blowdown at COC of 3.5 = E*0.4
- Make-up at COC of 5 = E*1.25; Blowdown at COC of 5 = E*0.25

- Costs at 3.5 COC = (E*1.4)*$2.15+ (E*0.4)[a]*$2.02+ (E*1.4)*$1.08 = $5.33*E
- Costs at 5 COC = (E*1.25)*$2.15+ (E*0.25) [a]*$2.02+ (E*1.25)*$1.18 = $4.67*E

- Relative costs $_{COC = 5/COC=3.5}$ = 0.875 (~10% savings)

- Incoming Water Savings $_{COC = 5/COC=3.5}$ = 1.25/1.4 = 0.89 (~10% savings)
- Discharged Water Savings $_{COC = 5/COC=3.5}$ = 0.25/0.4= 0.625 (~40% savings)

*. In previous slide, costs reflect blowdown fixed at 25% of makeup

Back to presentation

Campus Savings Calculation

	cost savings	Makeup water savings (kgal)	proposed cycles		
Oak St	$ 27,443.22	9,486.04	5		
NCCP -North	$ 19,117.27	6,064.86	5		
NCCP -South	$ 5,194.63	1,632.14	5		
Vet Med	$ 50,940.63	24,287.66	5		
Housing	$ 14,356.32	6,508.71	4		
Law Library	$ 6,497.48	3,368.29	4		
ISTC	$ 3,008.35	1,845.90	4		
NRSA	$ 9,187.20	4,077.91	4		
	Current (kgal)	With Changes (kgal)	$ Current	$ With Changes	
Total Cycle Change savings	0	57,271.51	-	135,745	Sum of cost savings listed above
FY 2011 Total Campus Water Use	1,099,293	1,042,021			
FY 2011 Total Campus Water Use – CT Only	278,684	221,412	959, 438 *	823,693	
	Savings wrt to All Campus due to changes (kgal)			Savings wrt to CT due to changes (ex Abbott) ($)	With Change (kgal)
Total Campus Water Use	1,042,021.24		Total CT (ex Abbott)	823,693	221,412
Total Campus Savings in Incoming Water Volume	5.2%		% Savings	14.1%	20.6%

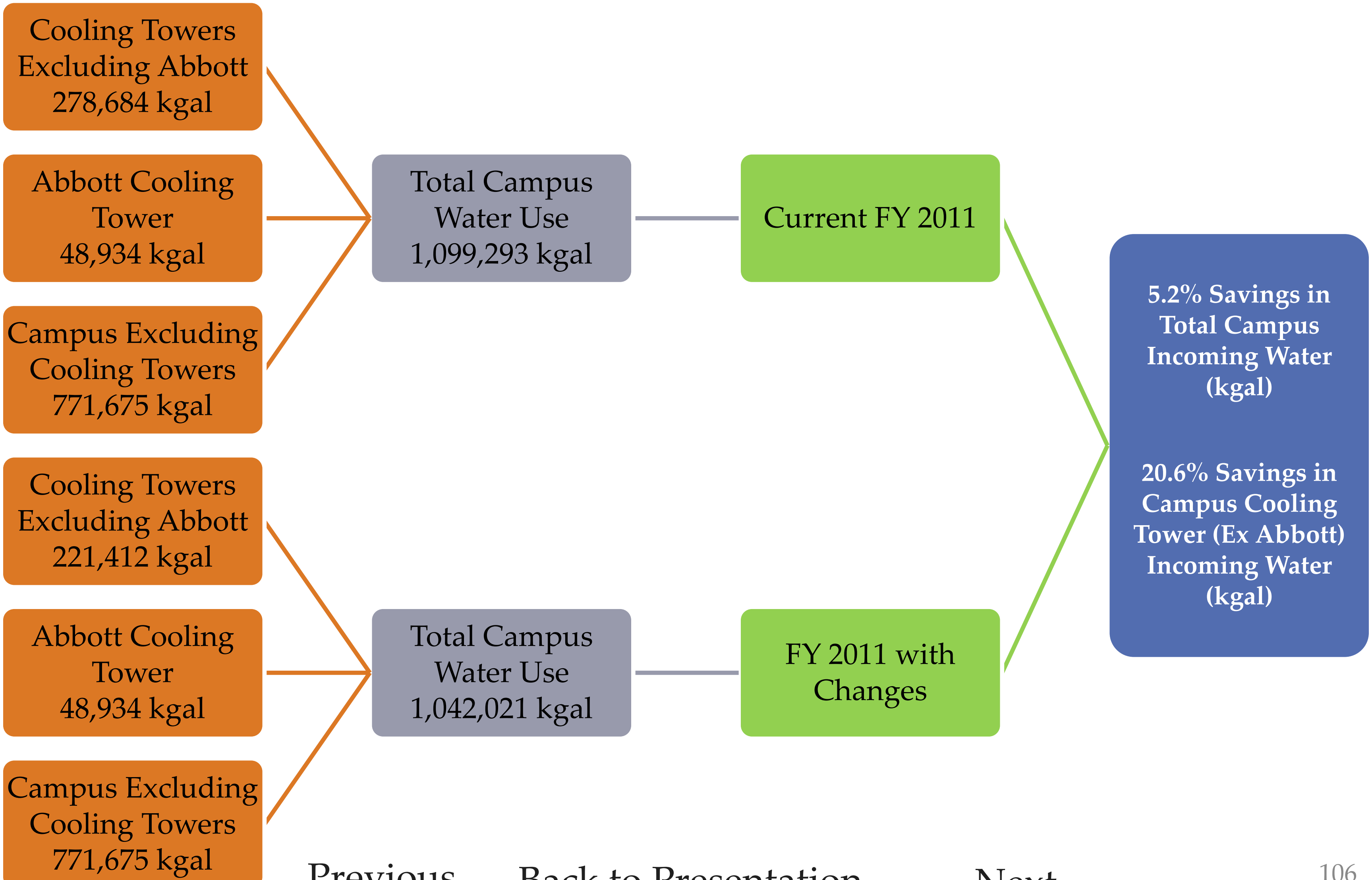
Back to Presentation Next

Abbott Cooling Tower Savings

	Proposed COC	Makeup (kgal)	Cost to treat ($)
Current Settings	1.93	48,933.66	$ 178,989.55
Proposed settings	5	29,524.02	$ 107,992.98
	Savings ($)	Savings (kgal)	% savings (kgal)
By changing Abbott CT to 5 COC	$ 70,996.58	19,409.64	39.7%
Total Campus water FY 2011 (kgal)		1,099,293	
% savings (kgal) by changing Abbott CT to 5 COC		1.8%	

Back to Presentation

Campus Savings Calculation Incoming Water (kgal)



Previous Back to Presentation Next

Campus Savings Calculation
Total Water Cost ($)

Cooling Towers Excluding Abbott
Incoming water : 278,684 kgal x $2.15/kgal = $599,170
Chemical treatment: 203, 497kgal x $1.08/kgal = $219,533
75,186 x $0.00/kgal = $0.00
Sewer : 278,684 kgal x 0.25 x $2.02/kgal = $140,735
TOTAL COST = $959,438

Abbott Cooling Tower
Incoming water : 48,934 kgal x $2.15/kgal = $105,207
Chemical treatment: 48,934 kgal x $1.08/kgal = $52,790
Sewer : 12,233 kgal x $2.02/kgal = $ 24,712
TOTAL COST = $182,709

Campus Excluding Cooling Towers
771,675 kgal x $2.15/kgal = $1,659,102

Total Campus Water Cost
$2,801,249

Current FY 2011 Settings

Cooling Towers Excluding Abbott
Incoming water : 221,412 kgal x $2.15/kgal = $476,036
Chemical treatment:
5 cycles : 139,861kgal x $1.18/kgal = $164,398
4 cycles : 66,227kgal x $1.08/kgal = $71,446
Untreated : 15,324 kgal x $0.00 = $0.00
Sewer : 221,412 kgal x 0.25 x $2.02/kgal = $111,813
TOTAL COST = $823,693

Abbott Cooling Tower - Unchanged
Incoming water : 48,934 kgal x $2.15/kgal = $105,207
Chemical treatment: 48,934 kgal x $1.08/kgal = $52,790
Sewer : 12,233 kgal x $2.02/kgal = $ 24,712
TOTAL COST = $182,709

Campus Excluding Cooling Towers - Unchanged
771,675 kgal x $2.15/kgal = $1,659,102

Total Campus Water Cost
$2,665,504

FY 2011 with Changes
Oak St, NCCP (N&S), Vet Med to 5 COC
Housing, Law, ISTC, NRSA to 4 COC

14.1% Savings wrt Campus Cooling Tower (Ex Abbott) Water Cost ($959,438)

Back to Presentation
Previous Back to Campus Savings Calculation

Using Energy Savings Rates for Sewer and Incoming Water

Utility Rates Memo

UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Facilities & Services
Physical Plant Service Building
1501 South Oak Street
Champaign, IL 61820

DATE: JUNE 28, 2010

TO: J.G. DEMPSEY
G. WAAS

FROM: TERRY RUFRECHT

RE: UTILITY RATES FOR FY 2011

For your information, the following is a summary of charge out rates for utilities at the Urbana-Champaign campus for the Fiscal Year ending 30-Jun-2011. These rates apply to all facilities not receiving direct billings from outside utility providers.

Commodity	Unit of Measure	Billing Rate *	Energy Savings Rate **
Steam	$/1000 lbs	$19.8309	$10.4730
Electricity	$/kwh	$0.0791	$0.0497
Chilled Water	$/Mmbtu	$12.8882	$6.9302
Water	$/1000 gal	$2.4435	$2.1521
Sanitary Sewer	$/1000 gal	$2.4368	$2.0262

*Billing Rate – The fully costed rate for billing utilities to campus units. Rates are pending approval by University Administration.

** Energy Savings rate – Fuel and consumable materials costs only. To be used to calculate energy savings for energy conservation projects.

Please do not hesitate to call me at 333-7900 if you have any questions with respect to this material.

CC: K. ERICKSON, T. TEMPLES, M. MARQUISSEE, C. TAYLOR, J. RIX, K. REIFSTECK

BACK

Retro-X: Buildings Completed

Building	After (MMBTU)	Before (MMBTU)
ACES Library Info. & Alumni Center	5,224	12,742
Animal Sciences Laboratory	6,852	9,943
Bevier Hall	8,921	11,304
Chemical & Life Sciences Laboratory	2,516	2,529
Coordinated Science Laboratory	12,886	20,704
Foellinger Auditorium	1,049	1,647
Foreign Languages Building	2,785	2,368
Henry Administration Building	3,390	5,170
Illini Union Bookstore	0	0
Krannert Center for Performing Arts	14,387	17,085
Loomis Laboratory of Physics	14,434	19,512
Madigan Laboratory Edward R	19,221	28,025
Mechanical Engineering Laboratory	14,132	22,944
Music Building	7,223	12,066
Nat Center for Supercomp Appl	8,265	16,270
National Soybean Research Center	5,710	9,026
Newmark Civil Engineering Building	11,028	21,964
Physical Plant Service Building	0	0
Psychology Laboratory	13,445	16,477
Siebel Center for Computer Science	18,832	32,241
Turner Hall	12,539	18,762
Undergraduate Library	7,282	6,961
Wohlers Hall	5,165	14,212
Grand Total	195,286	301,952

Back to presentation

The energy saved is 106,666 MMBTU

Abbott Cooling Tower Makeup Flow Rates

Month	Makeup (kgal)
FY 2011 Total	48,934
1	6,590
2	4,181
3	3,960
4	2,681
5	2,678
6	2,647
7	4,473
8	4,299
9	4,866
10	3,079
11	3,501
12	5,980
FY 2012 Total	12,843
7	2,880
8	3,532
9	2,292
10	2,231
11	1,908

Abbott RO Operation (pg 1 of 2)

RO RO1 1st Pass Permeate Flow	
	kgal
FY 2010	26,516
Jul-09	2,242
Aug-09	1,437
Sep-09	1,481
Oct-09	1,802
Nov-09	1,852
Dec-09	2,480
Jan-10	3,512
Feb-10	3,674
Mar-10	3,133
Apr-10	1,643
May-10	1,558
Jun-10	1,703
FY 2011	25,007
Jul-10	1,869
Aug-10	1,678
Sep-10	1,913
Oct-10	1,846
Nov-10	2,251
Dec-10	3,484
Jan-11	3,288
Feb-11	3,052
Mar-11	2,524
Apr-11	2,042
May-11	1,060

RO RO1 1st Pass Reject Flow	
	kgal
FY 2010	5,160
Jul-09	365
Aug-09	250
Sep-09	272
Oct-09	359
Nov-09	384
Dec-09	521
Jan-10	774
Feb-10	726
Mar-10	628
Apr-10	310
May-10	276
Jun-10	297
FY 2011	4,757
Jul-10	334
Aug-10	299
Sep-10	348
Oct-10	337
Nov-10	416
Dec-10	649
Jan-11	618
Feb-11	577
Mar-11	505
Apr-11	443
May-11	229

RO RO1 2nd Pass Permeate Flow	
	kgal
FY 2010	25,878
Jul-09	2,119
Aug-09	1,389
Sep-09	1,471
Oct-09	1,794
Nov-09	1,832
Dec-09	2,437
Jan-10	3,422
Feb-10	3,574
Mar-10	3,069
Apr-10	1,643
May-10	1,538
Jun-10	1,589
FY 2011	21,496
Jul-10	1,684
Aug-10	1,577
Sep-10	1,760
Oct-10	1,698
Nov-10	2,059
Dec-10	2,219
Jan-11	2,801
Feb-11	1,964
Mar-11	2,512
Apr-11	1,908
May-11	1,314

RO RO1 2nd Pass Reject Flow	
	kgal
FY 2010	2,569
Jul-09	178
Aug-09	139
Sep-09	133
Oct-09	161
Nov-09	176
Dec-09	242
Jan-10	363
Feb-10	386
Mar-10	320
Apr-10	151
May-10	143
Jun-10	176
FY 2011	2,769
Jul-10	230
Aug-10	151
Sep-10	203
Oct-10	202
Nov-10	254
Dec-10	432
Jan-11	407
Feb-11	382
Mar-11	251
Apr-11	174
May-11	83

Abbott RO Operation (pg 2 of 2)

RO RO2 1st Pass Permeate Flow	
	Sum of Flow (kgal)
FY 2010	24,682
Jul-09	2,784
Aug-09	2,162
Sep-09	1,847
Oct-09	1,696
Nov-09	1,808
Dec-09	1,636
Jan-10	1,427
Feb-10	1,500
Mar-10	1,540
Apr-10	2,184
May-10	2,479
Jun-10	3,621
FY 2011	22,788
Jul-10	2,982
Aug-10	2,078
Sep-10	2,630
Oct-10	1,965
Nov-10	1,191
Dec-10	1,823
Jan-11	1,954
Feb-11	1,586
Mar-11	1,598
Apr-11	2,208
May-11	2,772

RO RO2 1st Pass Reject Flow	
	Sum of Flow (kgal)
FY 2010	4,628
Jul-09	552
Aug-09	430
Sep-09	380
Oct-09	321
Nov-09	308
Dec-09	280
Jan-10	245
Feb-10	264
Mar-10	266
Apr-10	398
May-10	477
Jun-10	707
FY 2011	3,905
Jul-10	539
Aug-10	363
Sep-10	435
Oct-10	322
Nov-10	206
Dec-10	305
Jan-11	328
Feb-11	257
Mar-11	241
Apr-11	396
May-11	514

RO RO2 2nd Pass Permeate Flow	
	Sum of Flow (kgal)
FY 2010	23,278
Jul-09	2,588
Aug-09	2,013
Sep-09	1,712
Oct-09	1,615
Nov-09	1,727
Dec-09	1,572
Jan-10	1,360
Feb-10	1,438
Mar-10	1,485
Apr-10	2,084
May-10	2,338
Jun-10	3,348
FY 2011	21,959
Jul-10	2,801
Aug-10	1,964
Sep-10	2,512
Oct-10	1,908
Nov-10	1,314
Dec-10	1,756
Jan-11	1,895
Feb-11	1,534
Mar-11	1,543
Apr-11	2,112
May-11	2,619

RO RO2 2nd Pass Reject Flow	
	Sum of Flow (kgal)
FY 2010	2,537
Jul-09	298
Aug-09	228
Sep-09	194
Oct-09	200
Nov-09	196
Dec-09	165
Jan-10	129
Feb-10	134
Mar-10	136
Apr-10	209
May-10	250
Jun-10	397
FY 2011	2,187
Jul-10	313
Aug-10	206
Sep-10	243
Oct-10	177
Nov-10	120
Dec-10	177
Jan-11	173
Feb-11	140
Mar-11	128
Apr-11	211
May-11	298

Oak Street Sub-soil Drainage Examination of Appendix B Fig 2

- Water flow rate = 196 gallons/min = 1.03E5 kgal/yr (196*60*24*365)
- COC = 2.8 = Tower Ca (mg/l) (as modeled by NALCO/Input Ca (mg/l) = 431.2/154
- The Oak Street Sub-soil Drainage water has a Ca content of 154 mg/l; it is likely that Fig 2 uses raw Sub-soil Drainage not RO as input
- Furthermore, NALCO model assumes Tower Alkalinity to be at 1.86 meq/l
- Assuming that alkalinity cycles up at 2.8 COC, input alkalinity has to 1.86/2.8 = 0.665
- But Oak Street Sub-soil Drainage is at an Alkalinity of 8.59 meq/l
- Therefore, alkalinity has to be reduced by 7.925 meq/l (8.59-0.66)
- This requires sulfuric acid addition of 7.925 meq/l or 7.925 meq/l*48 mg/meq = 380.4 mg/l
- 380.4 mg/l = 1439.8 mg/gallon = 1439.8 g/kgal = 1.4398 kg/kgal =3.173 lb/kgal
- Sulfuric acid additions per year = 3.173 lb/kgal *1.03E5 kgal/yr = 3.2694E5 lb/yr
- At $ 0.25/lb, annual costs = $81,744 (this # is close to the number in NALCO spreadsheet in Fig 2)
- Therefore $/kgal = 81,744/1.03E5 = $0.79/kgal (reported in Table 1 Appendix B)

Source: Report to Student Sustainability Committee
By E. Day, N. Grabowski, A. Rennegarbe
Title of Report: Design of a Sub-soil Drainage Water Distribution System
Date: 12/18/2009
Copy Obtained From: Jim Hopper, UIUC Water Station