Reducing Water Use on Campus: Cooling Towers

2011

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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.
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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.

<table>
<thead>
<tr>
<th>Where Do We Want to Be?</th>
<th>The University’s goal is a <strong>20%</strong> reduction of campus potable water consumption by 2015. A <strong>40%</strong> reduction by 2025 is envisioned.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Where Are We Now?</td>
<td>The University has already achieved a <strong>16%</strong> water reduction as of July 2011.</td>
</tr>
<tr>
<td>How Will We Get There?</td>
<td>Additional reductions in water consumption requires closely examining how water is currently used on campus and what opportunities are available for improvement.</td>
</tr>
</tbody>
</table>
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.
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
Purchase cost of water continues to rise even while usage declines.
There are plenty of opportunities available for increasing 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
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?

- **Water Input**
  - Makeup water

- **Evaporated Water**

- **Water LOSS**
  - Blowdown water
  - Sewer
  - Hot Water Return from Condenser
  - Cooled Water Return to Condenser
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

Water Consumption (Kgals)

2010: 216,448
2011: 278,684

Fiscal Year

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.
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

Higher Water Use Efficiency

Towers operating below 1.5 cycles are usually not chemically treated. Towers with higher cycles are chemically treated.

Number of Cooling Towers vs Cycles of Concentration - Range

- < 1.5: 18
- 1.5 - 2: 4
- 2.1 - 2.5: 2
- 2.6 - 3: 1
- 3.1 and up: 7

Number of Cooling Towers

- Treated: 13
- Untreated: 19
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 Greater Than Centralized Chiller Plants

Smaller Towers & Vet Med

Abbott, Plant Sciences

ISTC, State Water Survey

Oak St CP; NCCP
(N&S) Library,
Grainger, CLSL

Water (kgal)

Cycles of Concentration

Blowdown (kgal)  Makeup (kgal)

< 1.5  1.5-2  2.1-3  3.1+

54,643  29,845  16,936  47,938

71,586  56,396  37,855  161,780
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

Bubble Size indicates Makeup water consumption in kgal

Transporation Building
National Soybean Research Center
Medical Sciences Building
Lincoln Avenue Residence Hall
Ice Arena
Illinois Street Residence Hall
Burnside's Research Laboratory
Natural Resource Studies Annex
Pennsylvania Avenue Residence Hall
Illini Union
Housing Food Stores
English Building
Burrill Hall
Printing & Photographic Service Building
Veterinary Medicine Chiller Plant (Meter ID 3)
Veterinary Medicine Chiller Plant (Meter ID 2)
Veterinary Medicine Chiller Plant (Meter ID 1)
Law Building
Illinois Sustainable Technology Center
Plant Sciences Laboratory
Water Survey Research Center
Abbott Power Plant
Animal Science-Air Conditioning Center
Library Air Conditioning Center (Meter ID 4)
Library Air Conditioning Center (Meter ID 7)
Chemical & Life Sciences Lab
North Campus Chiller Plant (North Meter)
North Campus Chiller Plant (South Meter)
Oak Street Chiller Plant
Grainger Engineering Library
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
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• 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

There are plenty of opportunities available for increasing tower efficiency.

Higher Water Use Efficiency
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**

- **Decrease CT water consumption by increasing COC**
  - Treat water at more towers (chemical, non-chemical)
  - Treat water more intensively

- **Reduce Cooling Load**
  - Increase Chiller Plant Efficiency
  - Building Retrocommissioning

- **Cascade water from another process for CT make-up**
  - Abbott RO reject
  - Oak Street Sub-soil Drainage
  - Reprocess blowdown

- **Use CT blowdown to displace water use in another application**

- **Decrease CT water consumption through improved control**
  - Improved monitoring (Trasar)
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)

- **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

• 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

Chemical cost at $1.5 \geq COC = $0/kgal

Chemical cost at $1.5 < COC \leq 4 = $1.08/kgal

Chemical cost at $4 < COC \leq 5 = $1.18/kgal
If cycles are increased from the ~3.5 to 5 cycles, estimated water and cost savings are:

Potential Savings = $51,755
Water Savings = 17,183 kgal
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.
Improving CT COC Means

Proposed Settings:
Oak St, NCCP (N&S), Vet Med : 5 COC
Housing, Law, ISTC, NRSA: 4 COC

With Reference to
Current CT Operation

With Reference to
Current Total Campus
Water Usage

% Savings

With Change ($) 14.1%
With Change (kgal) 20.6%

With Change ($) 5.2%
Given Thermal Energy Storage Facility is...

6.5 million Gallons
Then the proposed water savings of these cycle changes would be like filling the TES almost 9 times.
Potential Issues/Resolutions

• Increasing COC requires $\text{H}_2\text{SO}_4$ 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
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
  - $\text{Ca(HCO}_3\text{)}_2 \rightarrow \text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_2$
  - 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

- CaCO₃ colloids act as incubation sites for dissolved calcium and carbonate ions to grow on
- CaCO₃ colloidal crystal growth is thermodynamically favored over precipitation on equipment surfaces

Regular Water

Scaling ions grow on pipe surface

Treated Water

Scaling ions grow on colloid surface
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
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

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%

![Image of water treatment process](image_url)
The STTrategic 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

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(617) 626-1060
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<table>
<thead>
<tr>
<th>Site</th>
<th>Industry Sector</th>
<th>Date of Implementation</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pillsbury (MN)</td>
<td>Food Processing and Storage</td>
<td>2000</td>
<td>• Eliminated use, handling, and disposal of treatment chemicals</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Substantial water savings</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Cycles of concentration increased from 2.9 to 6.3</td>
</tr>
<tr>
<td>Richmond Cold Storage, Inc. (VA)</td>
<td>Cold Storage Warehouse</td>
<td>3 Units Installed, 1995, 1996, 1999</td>
<td>• No detectable scale or corrosion problems</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Substantial water savings</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Cycles of concentration increased from 4 to 18.9</td>
</tr>
<tr>
<td>Lancer, Corp (TX)</td>
<td>Plastic Injection Molding</td>
<td>1998</td>
<td>• No system shutdown related to cooling water</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Substantial water savings</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Cycles of concentration increased from 2.5 to 9</td>
</tr>
<tr>
<td>International Paper Co. (VA)</td>
<td>Technology Center</td>
<td>Sept. 1999</td>
<td>• Hazardous chemicals eliminated</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Blowdown reduced to &lt;250 GPD from ~1000 GPD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Old scale softened and removed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Cycles of concentration increased from 2.8 to 5.3</td>
</tr>
<tr>
<td>Fujitsu Corporation (OR)</td>
<td>Microchip Manufacturing</td>
<td>2 Units Installed, 1993, 1994</td>
<td>• Scale under control</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Substantial water savings</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Cycles of concentration increased from 4.6 to 33</td>
</tr>
<tr>
<td>Operational Parameters</td>
<td>Richmond Cold Stor.</td>
<td>Lancer</td>
<td>Internat’l Paper</td>
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<tr>
<td>-----------------------------</td>
<td>---------------------</td>
<td>--------</td>
<td>------------------</td>
</tr>
<tr>
<td>Cooling Tower Capacity</td>
<td>1200 Ton + 900 Ton</td>
<td>2x350 Ton</td>
<td>1000 Ton</td>
</tr>
<tr>
<td>Material of Construction</td>
<td>Galvanized Steel</td>
<td>Galv. Steel</td>
<td>Galv. Steel</td>
</tr>
<tr>
<td>Corrosion Rate</td>
<td>2.0 mpy (mild steel)</td>
<td>Acceptable**</td>
<td>Acceptable**</td>
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<tr>
<td>Function/Duty</td>
<td>Refrigeration</td>
<td>Acceptable**</td>
<td>0.89 mpy</td>
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<td>Water Source</td>
<td>County Wells</td>
<td>Hydraulic Oil</td>
<td>Test Lab A/C</td>
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<tr>
<td>Sump Water Temperatures</td>
<td>Not Measured</td>
<td>90</td>
<td>82</td>
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<tr>
<td>Size of VRTX unit</td>
<td>3x40 gpm</td>
<td>40 gpm</td>
<td>60 gpm</td>
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<tr>
<td>Duration of Water Samples</td>
<td>6 months</td>
<td>13 months</td>
<td>24 months</td>
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<tr>
<td>Number of Water Samples</td>
<td>3</td>
<td>&gt; 30</td>
<td>&gt; 30</td>
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<tr>
<td>pH</td>
<td>Make-up 6.8</td>
<td>7.3</td>
<td>8.2</td>
</tr>
<tr>
<td></td>
<td>Sump 9.3</td>
<td>8.8</td>
<td>9.2</td>
</tr>
<tr>
<td>Alkalinity (mg/L)</td>
<td>Make-up 24</td>
<td>198</td>
<td>326</td>
</tr>
<tr>
<td></td>
<td>Sump 374</td>
<td>330</td>
<td>1498</td>
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<tr>
<td>TDS (mg/L)</td>
<td>Make-up 34</td>
<td>364</td>
<td>866</td>
</tr>
<tr>
<td></td>
<td>Sump 1377</td>
<td>1076</td>
<td>4531</td>
</tr>
<tr>
<td>Calcium (mg/L)</td>
<td>Make-up 4</td>
<td>174</td>
<td>142</td>
</tr>
<tr>
<td></td>
<td>Sump 50</td>
<td>201</td>
<td>76</td>
</tr>
<tr>
<td>Magnesium (mg/L)</td>
<td>Make-up 2</td>
<td>72</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>Sump 29</td>
<td>503</td>
<td>456</td>
</tr>
<tr>
<td>Chloride (mg/L)</td>
<td>Make-up 6</td>
<td>25</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td>Sump 113</td>
<td>226</td>
<td>1102</td>
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<tr>
<td>Cycle of Concentration</td>
<td>18.9 (4)</td>
<td>9 (2.5)</td>
<td>5.3 (2.8)</td>
</tr>
<tr>
<td>VRTX (Prior to VRTX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Installation)</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual water savings (%)</td>
<td>20%</td>
<td>29%</td>
<td>17%</td>
</tr>
<tr>
<td>Annual Blowdown</td>
<td>% 83%</td>
<td>82%</td>
<td>67%</td>
</tr>
<tr>
<td>Water Savings</td>
<td>gallons 5.0 million</td>
<td>3.3 million</td>
<td>3.5 million</td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium (Ca)</td>
<td>26.8 mg/L</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>8.80 mg/L</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>7.5 mg/L</td>
</tr>
<tr>
<td>Sulfate (SO₄)</td>
<td>23.9 mg/L</td>
</tr>
<tr>
<td>pH</td>
<td>7.29 S.U.</td>
</tr>
<tr>
<td>Silica (SiO₂)</td>
<td>2.38 mg/L</td>
</tr>
<tr>
<td>Total alkalinity (as CaCO₃)</td>
<td>72 mg/L</td>
</tr>
<tr>
<td>Phosphorous (P)</td>
<td>0.29 mg/L</td>
</tr>
<tr>
<td>Conductivity</td>
<td>214 micro Siemens</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th>Previous Three Years</th>
<th>150-Day Pretrial</th>
<th>Trial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>3.5</td>
<td>4.7</td>
<td>4.9</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>1.4</td>
<td>0.4</td>
<td>0.3</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Date</th>
<th>Days Exposed</th>
<th>316L SS</th>
<th>Copper</th>
<th>Galvanized Steel</th>
<th>Untreated Mild Steel</th>
<th>Treated Mild Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historic</td>
<td>23</td>
<td>&lt;0.1</td>
<td>1.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pretrial</td>
<td>61</td>
<td>&lt;0.1</td>
<td></td>
<td></td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>HCD</td>
<td>65</td>
<td>&lt;0.1</td>
<td>4.3</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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

Make-up water (kgal)

Average Temperature (°F)

Before Trasar  After Trasar (kgal)  Average Temperature - Before Trasar  Average Temperature After Trasar

Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec  Jan

0 10 20 30 40 50 60 70 80 90

1,000.00 2,000.00 3,000.00 4,000.00 5,000.00 6,000.00 7,000.00 8,000.00 9,000.00

Average Temperature - Before Trasar

Average Temperature After Trasar
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

<table>
<thead>
<tr>
<th>Retrocommissioned Buildings</th>
<th>Chilled Water Saved per year (MMBTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Soybean Research Center</td>
<td>3,316</td>
</tr>
<tr>
<td>Turner Hall</td>
<td>6,223</td>
</tr>
<tr>
<td>Animal Sciences Laboratory</td>
<td>3,091</td>
</tr>
<tr>
<td>Bevier Hall</td>
<td>2,383</td>
</tr>
<tr>
<td>Psychology Building</td>
<td>3,032</td>
</tr>
<tr>
<td>Krannert Center for Performing Art</td>
<td>2,698</td>
</tr>
<tr>
<td>Chemical &amp; Life Sciences Laboratory</td>
<td>13</td>
</tr>
<tr>
<td>Data from Retrocommissioning website at</td>
<td></td>
</tr>
<tr>
<td><a href="http://www.fs.illinois.edu/retro/">http://www.fs.illinois.edu/retro/</a></td>
<td></td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Cooling Load (MMBTU)</th>
<th>Added by Compressor (MMBTU)</th>
<th>Total Heat (MMBTU)</th>
<th>Water Consumption (Mgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20,756</td>
<td>5,665.79</td>
<td>26421.79</td>
<td>3.166</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaporation (Mgal)</th>
<th>Makeup (Mgal)</th>
<th>Blowdown (Mgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.166</td>
<td>4.221</td>
<td>1.055</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th>Cost Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assuming a Treated Tower at 4 COC</td>
<td></td>
</tr>
<tr>
<td>Incoming Water Cost Abated ($)</td>
<td>$9,075.95</td>
</tr>
<tr>
<td>Chemical Cost Abated ($)</td>
<td>$4,599.08</td>
</tr>
<tr>
<td>Sewer Cost of Blowdown Abated ($)</td>
<td>$2,131.79</td>
</tr>
<tr>
<td>Total Cost Abated ($)</td>
<td>$15,766.82</td>
</tr>
</tbody>
</table>
Result of these Retro-X projects

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water associated costs at the Cooling Towers for FY 2011 (excl. Abbott)</td>
<td>$ 959,438</td>
</tr>
<tr>
<td>Retro-X saved in cooling water expenses</td>
<td>$ 15,766.82</td>
</tr>
<tr>
<td>% $ savings of FY 2011</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY2011 Campus water CT Only (excl. Abbott)</td>
<td>278,684</td>
</tr>
<tr>
<td>Retro-X saved cooling water (Mgal)</td>
<td>4.2</td>
</tr>
<tr>
<td>% kgal CT FY 2011 savings (ex Abbott)</td>
<td>1.5%</td>
</tr>
</tbody>
</table>
Reducing the water demand at the Chiller Plants by 4.2 Mgal is equivalent to completely removing the cooling demand of any one or more of these buildings.
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
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.

### Cost Savings As a Result of Retrocommissioning in Aggregate

<table>
<thead>
<tr>
<th></th>
<th>Savings Rate ($/MMBTU)</th>
<th>Cost Savings ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>From Retro-X Energy Rate</td>
<td>$6.9300</td>
<td>$739,195.38</td>
</tr>
<tr>
<td>Savings from Cooling water</td>
<td>$0.7596</td>
<td>$81,026.39</td>
</tr>
<tr>
<td>Total Savings by Retrofit</td>
<td>$7.69</td>
<td>$820,221.77</td>
</tr>
</tbody>
</table>

% Added Savings Represented by Cooling Water: 10%
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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDS</td>
<td>176</td>
</tr>
<tr>
<td>Calculated TDS</td>
<td>169</td>
</tr>
</tbody>
</table>

**Cations**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (mg/L)</th>
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</thead>
<tbody>
<tr>
<td>Na</td>
<td>38</td>
</tr>
<tr>
<td>K</td>
<td>2.2</td>
</tr>
<tr>
<td>Ca</td>
<td>12.4</td>
</tr>
<tr>
<td>Mg</td>
<td>12.35</td>
</tr>
<tr>
<td>Sr</td>
<td>0.16</td>
</tr>
<tr>
<td>Fe</td>
<td>0</td>
</tr>
<tr>
<td>Barium</td>
<td>0.07</td>
</tr>
</tbody>
</table>

**Anions**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride</td>
<td>7</td>
</tr>
<tr>
<td>Sulfate</td>
<td>0</td>
</tr>
<tr>
<td>Bicarbonate as CaCO3</td>
<td>147</td>
</tr>
<tr>
<td>Carbonate as CaCO3</td>
<td>14</td>
</tr>
<tr>
<td>Fluoride</td>
<td>0.98</td>
</tr>
<tr>
<td>Si as SiO2</td>
<td>7.7</td>
</tr>
<tr>
<td>OH (mol/l)</td>
<td>0.00</td>
</tr>
<tr>
<td>pH at 8.4 C</td>
<td>9.08</td>
</tr>
</tbody>
</table>

### Oak Street Drainage

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TDS</td>
<td>986</td>
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<tr>
<td>Calculated TDS</td>
<td>943</td>
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**Cations**

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<tr>
<th>Parameter</th>
<th>Value (mg/L)</th>
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</thead>
<tbody>
<tr>
<td>Na</td>
<td>116</td>
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<tr>
<td>K</td>
<td>1.6</td>
</tr>
<tr>
<td>Ca</td>
<td>154</td>
</tr>
<tr>
<td>Mg</td>
<td>55</td>
</tr>
<tr>
<td>Sr</td>
<td>0.26</td>
</tr>
<tr>
<td>Fe</td>
<td>0.2</td>
</tr>
<tr>
<td>Barium</td>
<td>0.13</td>
</tr>
</tbody>
</table>

**Anions**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride</td>
<td>235</td>
</tr>
<tr>
<td>Sulfate</td>
<td>109</td>
</tr>
<tr>
<td>Bicarbonate as CaCO3</td>
<td>430</td>
</tr>
<tr>
<td>Carbonate as CaCO3</td>
<td>0</td>
</tr>
<tr>
<td>Fluoride</td>
<td>ND</td>
</tr>
<tr>
<td>Si as SiO2</td>
<td>13.7</td>
</tr>
<tr>
<td>pH at 23.6 C</td>
<td>7.6</td>
</tr>
</tbody>
</table>

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

Source: Illinois State Water Survey

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
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

- Oak St Sub-soil Drainage
- Sand Filter
- Nanofiltration Or Reverse Osmosis
  - 50 gpm
  - 3 gpm
  - 16.1 gpm
  - 30.9 gpm
- Permeate To CT
- < 200 gpm
- City Water < 169.1 gpm
- ~ 15% reduction in make-up possible
Tentative Estimates

**Chemical Costs ($3,985?)**
- 5 ppm & $4/lb

**Other Costs ($16,000?)**
- Labor (10 hr/month*12*$25) - $3,000
- Miscellaneous - $2,000
- Membrane Replacement (5 yr life) - $2,000
- Equipment Amortization (10 years) - $9,000

**Power Costs ($1,253?)**
- @ 1.12 kWh/kgal permeate
- $0.0689/kWh

---

**Oak St Sub-soil Drainage**

**Sand Filter**

**Nanofiltration**

**Reject to Sewer**

**Permeate To CT**

**Equivalent Value**
- $39,640 ($@2.44/kgal)

---

**Equivalent Value**
- $18,578 (@2.43/kgal)

---

**Will this go up or stay same?**
- If Sewer rates and water rates increase together, cost savings is maintained.
- If incoming water rates increase faster than sewer rates, the cost savings would increase.

---

**TDS 72**
- Ca 6 mg/L
- HCO3, 24 mg/l

**16,245,907 Gallons/yr**

**7,645,133 Gallons/yr**

**This rate is going up by 20% in FY 2012**
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

1. Softener
2. Abbott Cooling Tower
   - Blowdown

Path 2

1. Softener
2. Reverse Osmosis Stage 1
   - RO Permeate - Stage 1
   - RO Reject - Stage 1
3. Reverse Osmosis Stage 2
   - RO Permeate - Stage 2
   - RO Reject - Stage 2
Example: Systems Designed Separately

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

Path 1

Softener
CT Makeup
1000 gpm
50 ppm TDS
Abbott Cooling Tower
Blowdown
2 COC
500 gpm
100 ppm TDS

Path 2

Softener
RO Feed
1000 gpm
50 ppm TDS
Reverse Osmosis Stage 1
RO Reject – 150 gpm
333 TDS
RO Permeate – 850 gpm
Example: Systems Designed as Parts of a Whole

Path 1

Softener ➔ Abbott Cooling Tower

Blowdown
500 gpm
100 ppm TDS

Feed Water from Softener
500 gpm
50 ppm TDS

Path 2

Softener ➔ Reverse Osmosis Stage 1

Feed to RO
1000 gpm
75 ppm TDS

Feed Water from Softener
500 gpm
50 ppm TDS

RO Permeate
775 gpm

RO Reject
225 gpm
333 TDS

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

If System Design Approach Undertaken
Total Incoming Water = 500 (RO)+1000 (CT) = 1500 gpm
Total Effluent Water = 225 (RO) + 0 (CT) = 225 gpm

Potential Reductions
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

<table>
<thead>
<tr>
<th>Usage Month</th>
<th>Calendar Year</th>
<th>Fiscal Month</th>
<th>Fiscal Year</th>
<th>TOTAL WATER COST ($)</th>
<th>TOTAL WATER USAGE (Kgals)</th>
<th>Cost ($/kgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul</td>
<td>2010</td>
<td>AUG</td>
<td>2011</td>
<td>$274,735</td>
<td>111,716</td>
<td></td>
</tr>
<tr>
<td>Aug</td>
<td>2010</td>
<td>SEP</td>
<td>2011</td>
<td>$283,767</td>
<td>116,120</td>
<td></td>
</tr>
<tr>
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<td>OCT</td>
<td>2011</td>
<td>$288,447</td>
<td>118,314</td>
<td></td>
</tr>
<tr>
<td>Oct</td>
<td>2010</td>
<td>NOV</td>
<td>2011</td>
<td>$233,662</td>
<td>94,154</td>
<td></td>
</tr>
<tr>
<td>Nov</td>
<td>2010</td>
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<td>2011</td>
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<td>FEB</td>
<td>2011</td>
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<tr>
<td>Feb</td>
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<td>JUL</td>
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<td>12 MO TOTAL</td>
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<td></td>
<td>$2,737,683</td>
<td>1,099,293</td>
<td>2.49</td>
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<td>1.13</td>
<td>523</td>
<td>60</td>
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<tr>
<td>5 Ice Arena</td>
<td>1.20</td>
<td>4,128</td>
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<td>6 Illinois Street Residence Hall</td>
<td>1.18</td>
<td>295</td>
<td>44</td>
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<td>7 Burnsides Research Laboratory</td>
<td>1.27</td>
<td>2,322</td>
<td>498</td>
<td>1,824</td>
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<td>8 Natural Resource Studies Annex</td>
<td>1.26</td>
<td>5,598</td>
<td>1,140</td>
<td>4,458</td>
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<td>9 Pennsylvania Avenue Residence Hall</td>
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<td>247</td>
<td>46</td>
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<td>10 Illini Union</td>
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<td>87</td>
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<td>11 Housing Food Stores</td>
<td>1.28</td>
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<td>12 English Building</td>
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<td>1,997</td>
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<td>13 Burrill Hall</td>
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<td>511</td>
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<td>14 Printing &amp; Photographic Service Building</td>
<td>1.39</td>
<td>2,376</td>
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<td>Veterinary Medicine Chiller Plant (Meter ID 3)</td>
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<td>Veterinary Medicine Chiller Plant (Meter ID 2)</td>
<td>1.41</td>
<td>4,182</td>
<td>1,210</td>
<td>2,972</td>
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<td>Veterinary Medicine Chiller Plant (Meter ID 1)</td>
<td>1.34</td>
<td>27,503</td>
<td>6,922</td>
<td>20,581</td>
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<td>18 Law Building</td>
<td>1.43</td>
<td>5,635</td>
<td>1,700</td>
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<td>19 Illinois Sustainable Technology Center</td>
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<td>3,600</td>
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<td><strong>Total</strong></td>
<td><strong>1.32</strong></td>
<td><strong>75,186</strong></td>
<td><strong>18,259</strong></td>
<td><strong>56,927</strong></td>
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<tr>
<td>Construction Engineering Research Lab</td>
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<td>State Regional Office Building</td>
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<td>-</td>
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<td>Plant Sciences Laboratory</td>
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<td>1,065</td>
<td>385</td>
<td>679</td>
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<td>Water Survey Research Center</td>
<td>1.79</td>
<td>2,798</td>
<td>1,231</td>
<td>1,567</td>
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<td>Abbott Power Plant</td>
<td>1.93</td>
<td>48,934</td>
<td>23,619</td>
<td>25,314</td>
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<td></td>
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<td>Animal Science Air Conditioning Center</td>
<td>2.27</td>
<td>16,809</td>
<td>9,388</td>
<td>7,421</td>
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<td>Library Air Conditioning Center (Meter ID 5)</td>
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<td>19,838</td>
<td>10,741</td>
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<tr>
<td>Temple Hoyne Buell Hall</td>
<td>2.89</td>
<td>1,208</td>
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<td>419</td>
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<tr>
<td>Library Air Conditioning Center (Meter ID 4)</td>
<td>3.12</td>
<td>4,822</td>
<td>3,276</td>
<td>1,546</td>
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<tr>
<td>Library Air Conditioning Center (Meter ID 7)</td>
<td>3.01</td>
<td>5,793</td>
<td>3,872</td>
<td>1,921</td>
<td></td>
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<tr>
<td>Chemical &amp; Life Sciences Lab</td>
<td>3.24</td>
<td>696</td>
<td>481</td>
<td>215</td>
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<td></td>
</tr>
<tr>
<td>North Campus Chiller Plant (North Meter)</td>
<td>3.18</td>
<td>42,568</td>
<td>29,202</td>
<td>13,365</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Campus Chiller Plant (South Meter)</td>
<td>3.13</td>
<td>10,939</td>
<td>7,445</td>
<td>3,494</td>
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<tr>
<td>Oak Street Chiller Plant</td>
<td>3.54</td>
<td>92,015</td>
<td>66,023</td>
<td>25,992</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grainger Engineering Library</td>
<td>3.52</td>
<td>4,948</td>
<td>3,542</td>
<td>1,406</td>
<td></td>
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</tr>
<tr>
<td>Total</td>
<td>2.73</td>
<td>252,431</td>
<td>159,996</td>
<td>92,435</td>
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</tbody>
</table>
COC Calculation

<table>
<thead>
<tr>
<th></th>
<th>Makeup (kgal)</th>
<th>Blowdown (kgal)</th>
<th>Evaporation (kgal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treated Towers</td>
<td>252,431</td>
<td>92,435</td>
<td></td>
</tr>
<tr>
<td>Untreated Towers</td>
<td>75,186</td>
<td>56,927</td>
<td></td>
</tr>
<tr>
<td>All Cooling Towers (incl Abbott)</td>
<td>327,617</td>
<td>149,362</td>
<td>178,255</td>
</tr>
</tbody>
</table>

\[
M = E \left(\frac{\text{COC}}{\text{COC} - 1}\right)
\]

\[
E/B + 1 = \text{COC}
\]

\[
(178,255/149,362) + 1 = \text{COC}
\]

\[
\text{COC} = 2.19
\]
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)*$2.02+ (E*1.4)*$1.08 = $5.33*E
• Costs at 5 COC = (E*1.25)*$2.15+ (E*0.25)*$2.02+ (E*1.25)*$1.18 = $4.67*E

• Relative costs \( \frac{\text{COC}=5}{\text{COC}=3.5} = 0.875 \) (~10% savings)

• Incoming Water Savings \( \frac{\text{COC}=5}{\text{COC}=3.5} = 1.25/1.4 = 0.89 \) (~10% savings)
• Discharged Water Savings \( \frac{\text{COC}=5}{\text{COC}=3.5} = 0.25/0.4= 0.625 \) (~40% savings)
  *

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

Back to presentation
## Campus Savings Calculation

<table>
<thead>
<tr>
<th></th>
<th>cost savings</th>
<th>Makeup water savings (kgal)</th>
<th>proposed cycles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oak St</td>
<td>$ 27,443.22</td>
<td>9,486.04</td>
<td>5</td>
</tr>
<tr>
<td>NCCP -North</td>
<td>$ 19,117.27</td>
<td>6,064.86</td>
<td>5</td>
</tr>
<tr>
<td>NCCP -South</td>
<td>$ 5,194.63</td>
<td>1,632.14</td>
<td>5</td>
</tr>
<tr>
<td>Vet Med</td>
<td>$ 50,940.63</td>
<td>24,287.66</td>
<td>5</td>
</tr>
<tr>
<td>Housing</td>
<td>$ 14,356.32</td>
<td>6,508.71</td>
<td>4</td>
</tr>
<tr>
<td>Law Library</td>
<td>$ 6,497.48</td>
<td>3,368.29</td>
<td>4</td>
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<tr>
<td>ISTC</td>
<td>$ 3,008.35</td>
<td>1,845.90</td>
<td>4</td>
</tr>
<tr>
<td>NRSA</td>
<td>$ 9,187.20</td>
<td>4,077.91</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Current (kgal)</th>
<th>With Changes (kgal)</th>
<th>$ Current</th>
<th>$ With Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cycle Change savings</td>
<td>0</td>
<td>57,271.51</td>
<td>-</td>
<td>135,745</td>
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<tr>
<td>FY 2011 Total Campus Water Use</td>
<td>1,099,293</td>
<td>1,042,021</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FY 2011 Total Campus Water Use – CT Only</td>
<td>278,684</td>
<td>221,412</td>
<td>959,438*</td>
<td>823,693</td>
</tr>
</tbody>
</table>

- Savings wrt to All Campus due to changes (kgal)
- Savings wrt to CT due to changes (ex Abbott) ($)
- With Change (kgal)

<table>
<thead>
<tr>
<th></th>
<th>Total Campus Water Use</th>
<th>Total CT (ex Abbott)</th>
<th>Total Campus Savings in Incoming Water Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1,042,021.24</td>
<td>823,693</td>
<td>5.2%</td>
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</tbody>
</table>

- % Savings
- 14.1%
- 20.6%
## Abbott Cooling Tower Savings

<table>
<thead>
<tr>
<th></th>
<th>Proposed COC</th>
<th>Makeup (kgal)</th>
<th>Cost to treat ($)</th>
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</thead>
<tbody>
<tr>
<td>Current Settings</td>
<td>1.93</td>
<td>48,933.66</td>
<td>$178,989.55</td>
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<tr>
<td>Proposed settings</td>
<td>5</td>
<td>29,524.02</td>
<td>$107,992.98</td>
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<tr>
<td><strong>Savings ($)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>By changing Abbott CT to 5 COC</td>
<td>$70,996.58</td>
<td>19,409.64</td>
<td>39.7%</td>
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<tr>
<td><strong>Total Campus water FY 2011 (kgal)</strong></td>
<td></td>
<td>1,099,293</td>
<td></td>
</tr>
<tr>
<td><strong>% savings (kgal) by changing Abbott CT to 5 COC</strong></td>
<td></td>
<td>1.8%</td>
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</table>
### Campus Savings Calculation

#### Incoming Water (kgal)

<table>
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<tr>
<th>Description</th>
<th>Current FY 2011</th>
<th>FY 2011 with Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Campus Water Use</td>
<td>1,099,293 kgal</td>
<td>1,042,021 kgal</td>
</tr>
<tr>
<td>Current FY 2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Towers Excluding Abbott</td>
<td>278,684 kgal</td>
<td></td>
</tr>
<tr>
<td>Abbott Cooling Tower</td>
<td>48,934 kgal</td>
<td></td>
</tr>
<tr>
<td>Campus Excluding Cooling Towers</td>
<td>771,675 kgal</td>
<td></td>
</tr>
<tr>
<td>Excluding Abbott</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Campus Water Use</td>
<td>1,042,021 kgal</td>
<td></td>
</tr>
<tr>
<td>Current FY 2011</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling Towers Excluding Abbott</td>
<td>221,412 kgal</td>
<td></td>
</tr>
<tr>
<td>Abbott Cooling Tower</td>
<td>48,934 kgal</td>
<td></td>
</tr>
<tr>
<td>Campus Excluding Cooling Towers</td>
<td>771,675 kgal</td>
<td></td>
</tr>
<tr>
<td>Excluding Cooling Towers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Campus Water Use</td>
<td>1,042,021 kgal</td>
<td></td>
</tr>
<tr>
<td>Total Campus Water Use</td>
<td>1,099,293 kgal</td>
<td></td>
</tr>
<tr>
<td>5.2% Savings in Total Campus Incoming Water</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20.6% Savings in Campus Cooling Tower (Ex Abbott)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Changes in Water Use

- **Current FY 2011 Total Campus Water Use**: 1,099,293 kgal
- **Total Campus Water Use with Changes**: 1,042,021 kgal
### Campus Savings Calculation

#### Total Water Cost ($)

- **Cooling Towers Excluding Abbott**
  - Incoming water: 278,684 kgal x $2.15/kgal = $599,170
  - Chemical treatment: 203,497 kgal x $1.08/kgal = $219,533
  - 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

- **Cooling Towers Excluding Abbott**
  - Incoming water: 221,412 kgal x $2.15/kgal = $476,036
  - Chemical treatment:
    - 5 cycles: 139,861 kgal x $1.18/kgal = $164,398
    - 4 cycles: 66,227 kgal 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

---

**Current FY 2011 Settings**

**Total Campus Water Cost**

- **Campus Water Cost**
  - $2,801,249

- **Cooling Towers Excluding Abbott**
  - $959,438

- **Abbott Cooling Tower**
  - $182,709

- **Campus Excluding Cooling Towers**
  - $1,659,102

---

**FY 2011 with Changes**

- Oak St, NCCP (N&S), Vet Med to 5 COC
- Housing, Law, ISTC, NRSA to 4 COC

**Total Campus Water Cost**

- **Campus Water Cost**
  - $2,665,504

- **Cooling Towers Excluding Abbott**
  - $823,693

- **Abbott Cooling Tower - Unchanged**
  - $182,709

- **Campus Excluding Cooling Towers - Unchanged**
  - $1,659,102

---

**14.1% Savings wrt Campus**

**Cooling Tower (Ex Abbott)**

**Water Cost** ($959,438)

---

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[Back to Campus Savings Calculation](#)
Utility Rates Memo

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 families not receiving direct billings from outside utility providers.

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Unit of Measure</th>
<th>Billing Rate *</th>
<th>Energy Savings Rate **</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam</td>
<td>$/1000 lbs</td>
<td>$19.8300</td>
<td>$10.4750</td>
</tr>
<tr>
<td>Electricity</td>
<td>$/kwh</td>
<td>$0.0791</td>
<td>$0.0497</td>
</tr>
<tr>
<td>Chilled Water</td>
<td>$/Mbtu</td>
<td>$12.8882</td>
<td>$6.9302</td>
</tr>
<tr>
<td>Water</td>
<td>$/1000 gal</td>
<td>$2.4635</td>
<td>$2.1521</td>
</tr>
<tr>
<td>Sanitary Sewer</td>
<td>$/1000 gal</td>
<td>$2.4635</td>
<td>$2.0362</td>
</tr>
</tbody>
</table>

*Billing Rate – The fully encumbered 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. DECKEN, J. TEMPLES, M. MARQUEZ, C. TAYLOR, J. RIX, K. REIPSTECK
## Retro-X: Buildings Completed

<table>
<thead>
<tr>
<th>Building</th>
<th>After (MMBTU)</th>
<th>Before (MMBTU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACES Library Info. &amp; Alumni Center</td>
<td>5,224</td>
<td>12,742</td>
</tr>
<tr>
<td>Animal Sciences Laboratory</td>
<td>6,852</td>
<td>9,943</td>
</tr>
<tr>
<td>Bevier Hall</td>
<td>8,921</td>
<td>11,304</td>
</tr>
<tr>
<td>Chemical &amp; Life Sciences Laboratory</td>
<td>2,516</td>
<td>2,529</td>
</tr>
<tr>
<td>Coordinated Science Laboratory</td>
<td>12,886</td>
<td>20,704</td>
</tr>
<tr>
<td>Foellinger Auditorium</td>
<td>1,049</td>
<td>1,647</td>
</tr>
<tr>
<td>Foreign Languages Building</td>
<td>2,785</td>
<td>2,368</td>
</tr>
<tr>
<td>Henry Administration Building</td>
<td>3,390</td>
<td>5,170</td>
</tr>
<tr>
<td>Illini Union Bookstore</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
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The energy saved is 106,666 MMBTU
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## Abbott RO Operation (pg 1 of 2)

### RO RO1 1st Pass Permeate Flow

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### RO RO1 2nd Pass Permeate Flow

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### Abbott RO Operation (pg 2 of 2)

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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)

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