



Thermal Mitigation of Stormwater Management Pond Outflows Using Geothermal Cooling

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The water component of STEP is a collaborative of:



Primary project funder:



Speaker and Organization



- STEP is collaborative initiative between TRCA , CVC, and LSRCA
- STEP **Energy**: Evaluates energy-efficiency technologies for buildings
- STEP **Water**: Evaluates technologies that protect water resources
 - e.g. erosion and sediment control, thermal mitigation, salt management, LID, etc.
- B.Sc. in Physics; M.A.Sc. in Engineering Physics
- Analyst with STEP **Energy** since 2013
- Scientific lead on pilot projects related to renewables and heat pumps
- STEP **Water** has done extensive work on thermal mitigation
- Lead this project: “**Energy**” technology applied it to a “**Water**” problem



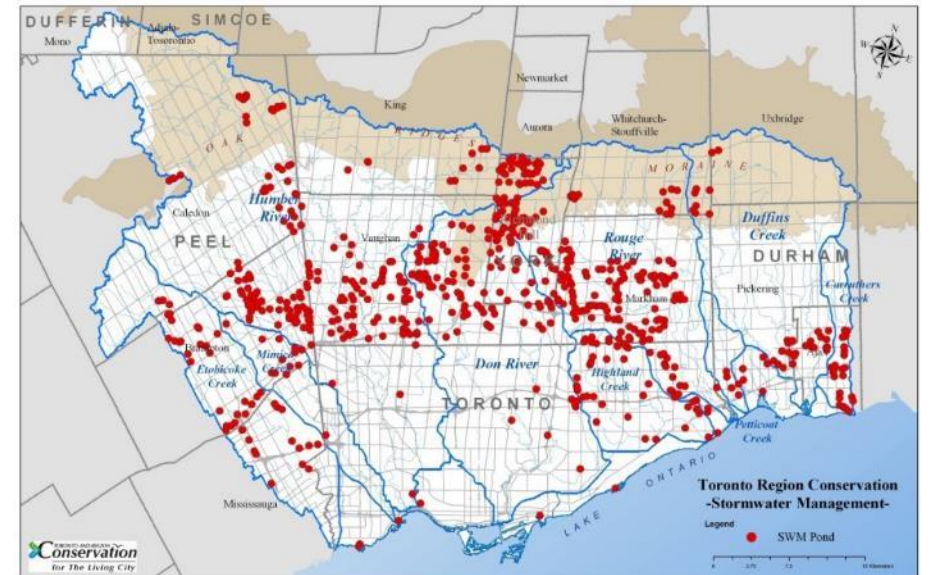
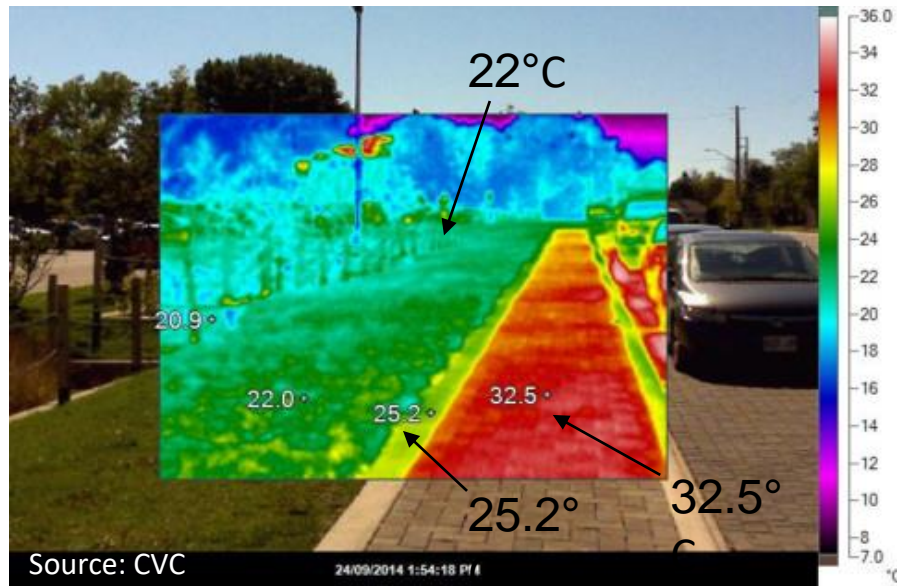
Outline

- The Issue: Thermal Pollution
- The Technology: Geothermal Cooling
- Modeling
- Results from Data Monitoring Pilot Funded By:



The Issue

- Stormwater management ponds are frequently used
- They get very hot



The Issue

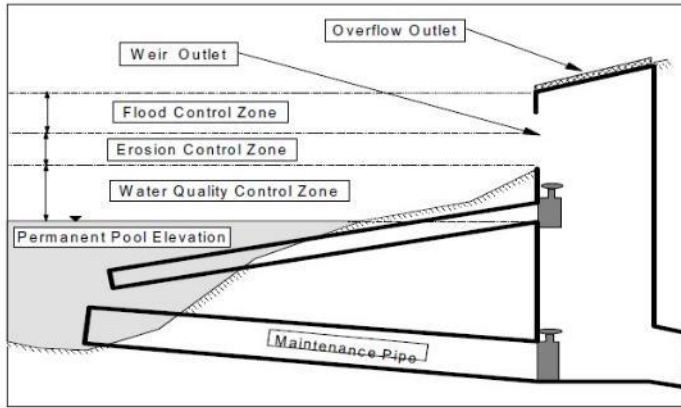
- Aquatic life are sensitive to small changes in temperature
- Problem for cool/cold water fisheries
- Endangered Species Act 2007 (MNRF) review - 24°C maximum target



Redside Dace

- Ontario reg 242/08 section 23.2 identifies pond retrofits as overall benefit action for species at risk

Thermal Mitigation Practices Evaluated



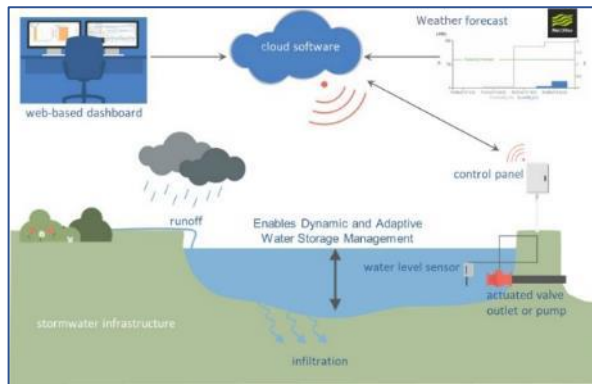
Subsurface Draw Outlet (n=18)



Cooling Trenches (n=18)



Vegetated Channels (n=1)



Night-time Release Outlet (n=1)

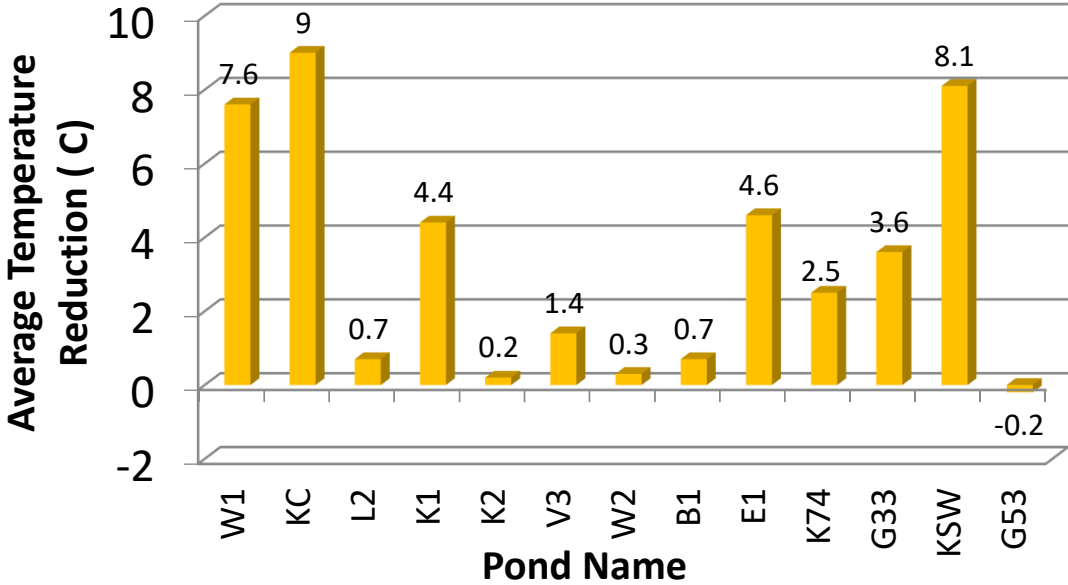


Low Impact Development Practices n=14



Floating Island (n=1)

Cooling Trench Performance

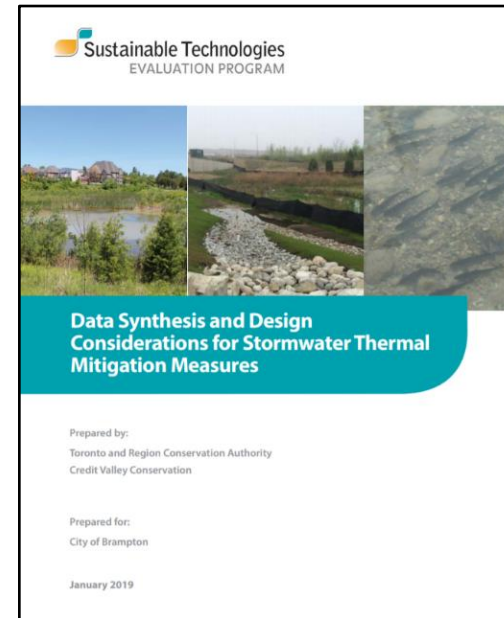


- Clear stone filled trenches downstream of pond outlet
- 9 out 16 didn't work well!
- Many important factors - initial temperature, outlet structure type, flow rate, ground interaction, system size
- In general, a passive standalone cooling trench needs to be very large to work

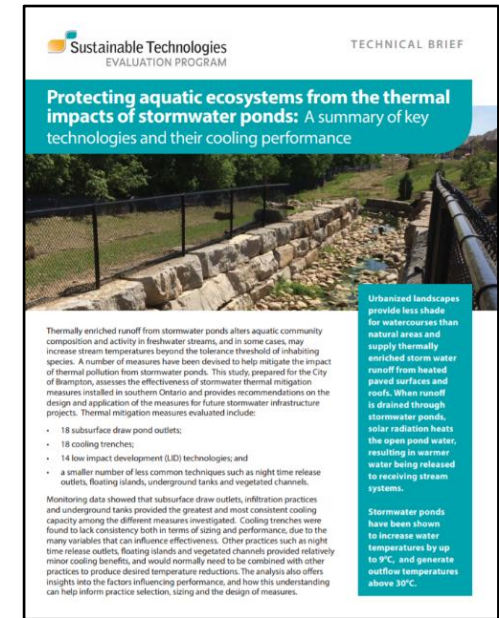
Takeaways

1. The thermal mitigation problem for new ponds is not solved
2. Need a solution for retrofits of existing systems that are underperforming

Full Report:



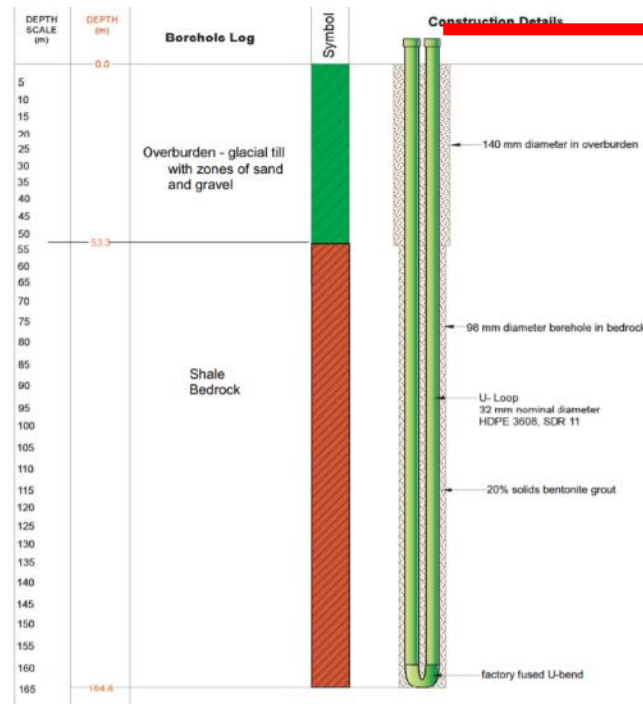
Short Whitepaper:



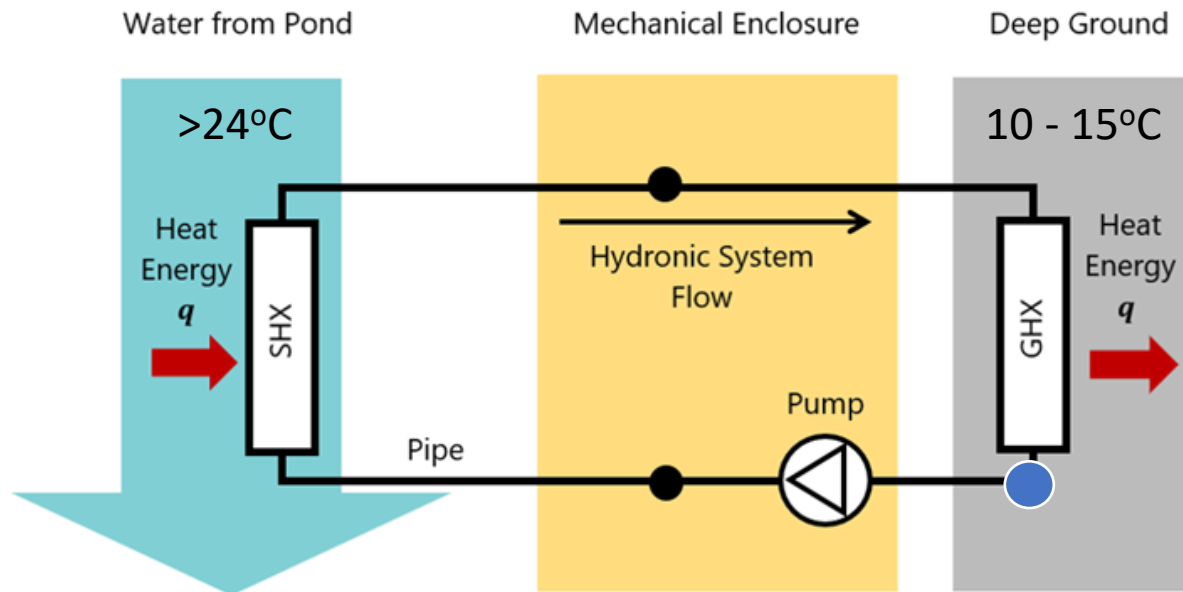
<https://sustainabletechnologies.ca/home/urban-runoff-green-infrastructure/thermal-mitigation/>

Geothermal

- Geothermal normally uses deep vertical boreholes - deep ground is $\approx 10^\circ\text{C}$
- Can also have pond-based systems



System Overview



- Closed loop of piping
- Circulating fluid - non-toxic (food-grade) propylene glycol for freeze protection
- **Surface water heat exchanger (SHX)** is placed in the path of the pond outflow
- **Ground heat exchanger (GHX)** is one or more deep vertical borehole
- The GHX supplies a cool fluid to the SHX
- SHX absorbs heat energy from the pond outflow
- GHX rejects that heat energy to the deep ground
- Only cools outflows (not the whole pond)

System Model

$$f(T_{p1}, T_{p2}, f_p, T_g, f_h, R_{GHX}, R_{SHX}, L_{GHX}, L_{SHX}) = 0$$

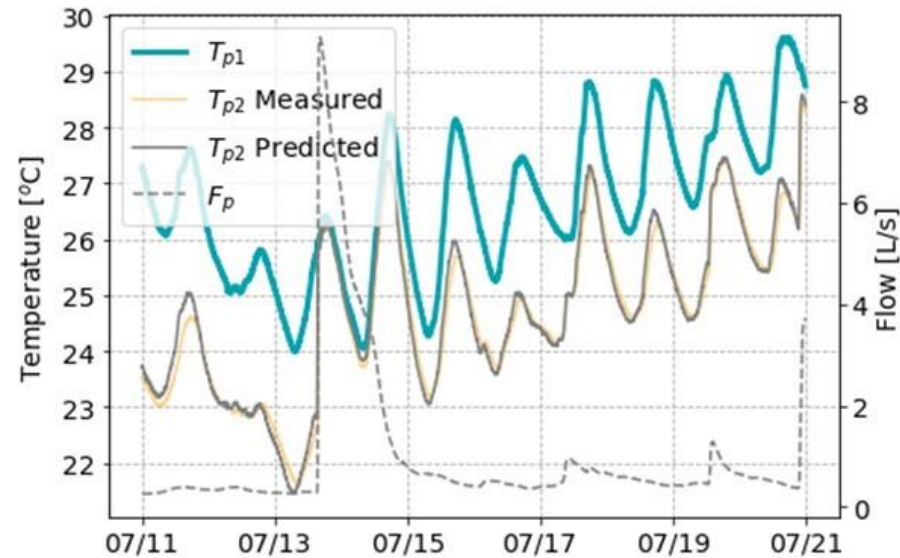
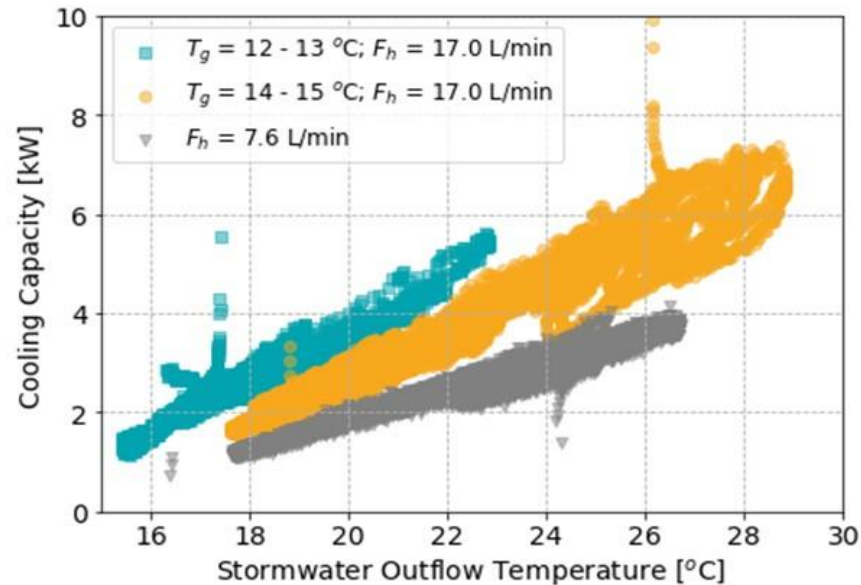
Parameter	Description
T_{p1}	Pond outflow temperature upstream of geo
T_{p2}	Pond outflow temperature downstream of geo
f_p	Pond outflow flowrate
T_g	Deep ground temperature
f_h	Hydronic flow rate of geothermal system
R_{GHX}	Thermal resistance of Ground Heat Exchanger (GHX)
R_{SHX}	Thermal resistance of Surface Heat Exchanger (SHX)
L_{GHX}	Borehole length (depth multiplied by # of boreholes)
L_{SHX}	Length of SHX

- Physics-based analytical steady-state heat transfer model (solved numerically)
- Design a system to meet a set-point T_{p2}
- Know T_{p1} and f_p
- Estimate (or measure) R_{GHX} , R_{SHX} and T_g
- Calculate L_{GHX} , L_{SHX} and f_h to achieve T_{p2}
- **Everything is well-defined mathematically!**

Brampton Pilot

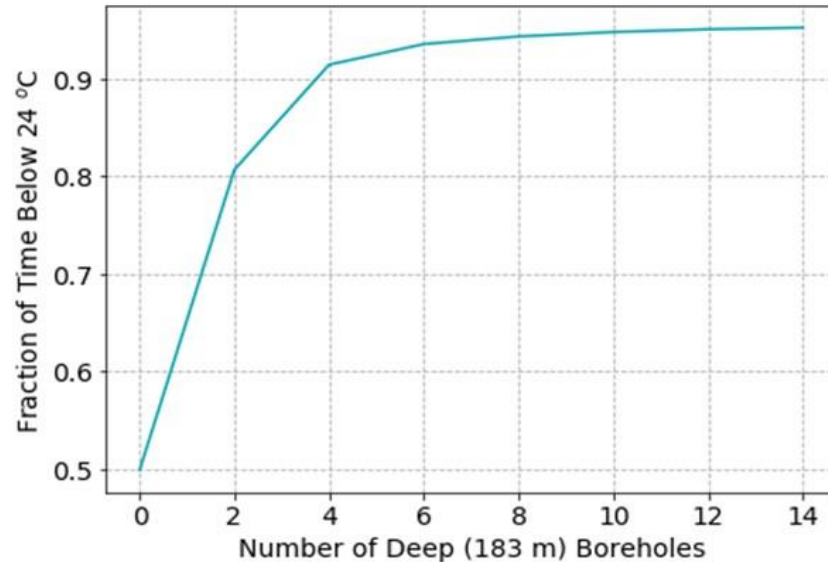


Data Results and Model Verification

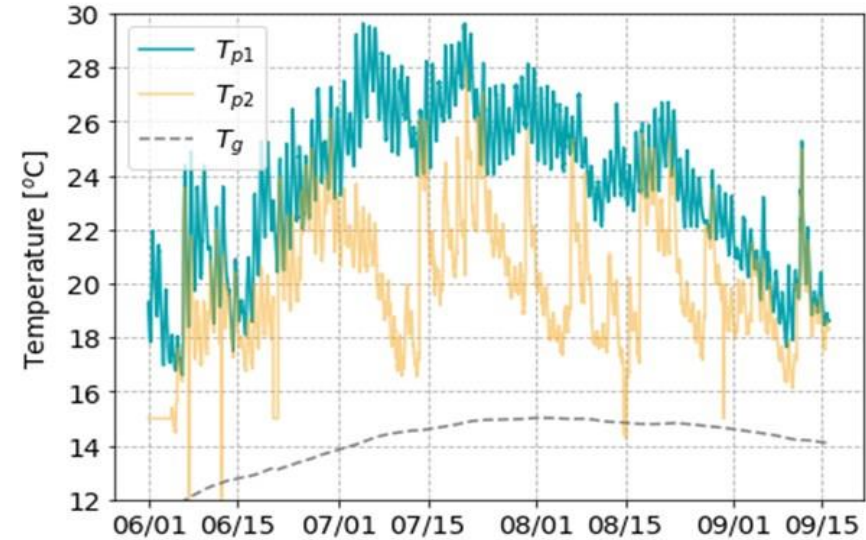


- Does the model predict the correct temperatures downstream of geothermal system (T_{p2})?
- Directly measured (or knew) other model parameters
- The model worked well!

Full-scale System Sizing



Modeled system with 6 boreholes:



- Model was used to size a full-scale system
- With no measures, outflow temperatures >24 °C 50% of the time
- 6 deep boreholes could keep temperatures below 24 °C 95% of the time
- Performance is not expected to vary greatly site-to-site within GTHA

Benefits and Drawbacks

Benefits

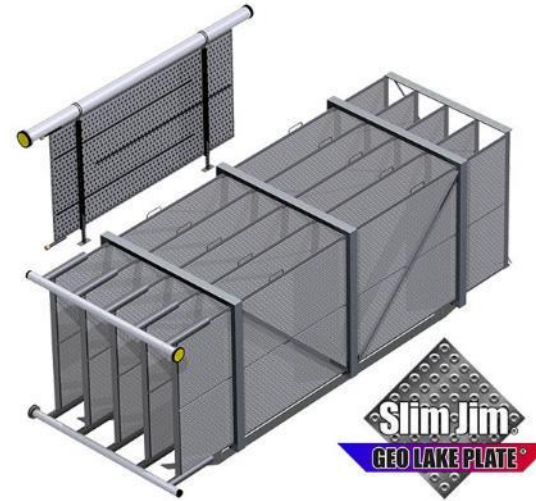
1. **Effective:** The pilot showed that it works
2. **Highly engineerable:** Can precisely design a system to meet a known cooling need
3. **Cost-effective:** Full-scale system for this pond is likely <200k\$
4. **No visual impacts:** System is mostly underground
5. **Space-efficient:** Only a minimal amount of area is required

Drawback

1. **Has a mechanical component:** Circulator pump may require periodic servicing
 - Not only thermal mitigation system to use mechanical components (controlled night-time release)
 - Pump is overall quite robust and inexpensive to replace
 - Can be winterized and re-commissioned with minimal work
 - Remote monitoring can automatically e-mail service people if there are issues

Opportunities for Improvement

- The SHX can be greatly improved
- Plastic pipe is bulky (6' dia. X 2' tall)
- Stainless steel plate much more compact (2' x 6' x 3/4" plate)
- Possible to implement SHX in the outflow pipe itself
- SHX could also be installed along length of a cooling trench
- Many different options
- Web-based sizing tool available soon



Thank You

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