Design of a Cooling Water Pipeline from Lake Ontario to Queen's University

APSC100 Module 3 – Group #63C
Preliminary Report

Project Sponsors: **Dr. Heather Jamieson**
Dr. Vicki Remenda, P.Eng

Project Manager: **Matheiu Poulin**

By:
Donald Marwick, Andrew Mansfield,
Edward Rothschild and Justin Ross

October 23, 2003

Table Of Contents

Abstract:

Deep water system cooling (DWSC) is an environmentally friendly alternative to traditional air conditioning systems. Most air conditioners work by using a compressor to drive the heat from coolant fluid which is then circulated over water, reducing its temperature. This water is then pumped past fans in the air conditioning ducts, allowing cool air to circulate through the building. It takes a great deal of energy to sufficiently reduce the temperature of the coolant so that it can be circulated through the system. The coolant also contains Chlorofluorocarbons (CFCs) which, when released into the atmosphere cause ozone depletion. DWSC replaces the coolant with water acquired from a source with a constantly low temperature, usually a lake where the deeper waters maintain a temperature around four to five degrees Celsius. [1] The water is pumped to the surface and used to replace the coolant in the system. The energy saved by this can reduce the power cost of cooling by up to 90 percent in ideal conditions.[2] This creates environmental benefits such as reduced emissions of greenhouse gases and pollutants from power stations feeding the system, as well as the elimination of the threat to the ozone from CFCs. DWSC is already being successfully implemented in places like Cornell University and the city of Toronto. It works ideally in areas with a deep body of water close by and a central cooling system, which decreases the number of locations to which lake water is sent.

Introduction:

Constructing a system to utilize DWSC at Queens University will require changes from most of the standard models already in place. However, the basic concept would remain the same. Implementing the system would require the construction of a pipeline out into Lake Ontario from a pumping station on the shore with the intake placed at a location of suitably cold water. Since Queen's University does not have a central circuit of water flowing throughout the campus between all the buildings, it will not be possible to model Cornell University's method of cooling the water at the pumping station itself. Instead, the water will need to be pumped to each building's cooling system individually. Ideally, the water will then replace the coolant in these systems and then be pumped back to the lake where it will be returned into the lake ecosystem. This project will require significant construction both under water and on land. There are four major issues concerned with the feasibility of implementing a DWSC system for the campus that have been considered and addressed:

- Location of Intake
- Environmental Impact
- Geotechnical Feasibility
- Integration with current infrastructure

[1] http://www.howstuffworks.com/news-item137.htm
[2] ibid.

Location of Intake:

The waters of Lake Ontario surrounding the Queen's University campus reach a maximum depth of approximately 22 metres. Due to the narrowness of the lake in this region, there is sufficient current to keep the waters from maintaining a stable temperature, and as such, no site for the int ake of cold water is available. The Dupont Canada chemical plant is 8 km west of campus, and they use lake water to the south of their facility to cool their machinery, but not for the use of air conditioning. Depth at their intake site is between 25 and 30 metres.

The deepest water within a reasonable proximity to Queen's University is off the northwest end of Amherst Island, reaching maximum depths of 75 to 80 metres (see Appendix A). Despite being at least 27 kilometres from campus, with additional piping distance due to changes in depth on the lake bottom, this is the only site for water deep enough to be suitable for the temperature requirements of DWSC. Even at this depth, temperatures are estimated to be between 6 - 8vC.[3]

Environmental Assessment:

Significant changes have occurred in the Lake Ontario ecosystem over the last century due to the effects of toxic pollution and habitat loss resulting from the rapid development of the Lake Ontario basin. The extent of these changes was fully realized in the 1960s and 1970s, when Lake Ontario colonial water birds experienced nearly total reproductive failures due to high levels of toxic contaminants in the food chain. In 1972, Canada and the United States took actions to ban and control contaminants entering the Great Lakes, and, in 1987, renewed the Great Lakes Water Quality Agreement with the goal to restore the overall health of the Great Lakes ecosystem. Today, as a result of these actions, levels of toxic contaminants in the Lake Ontario ecosystem have decreased significantly. However, bio-accumulative toxins persist in sediment, water, and biota at levels of concern for some fish species.[4] The conservation and health of the Lake Ontario ecosystem is of the utmost importance when considering any new industrial project concerning the lake, and is therefore crucial to the feasibility of implementing a Deep Water Source Cooling system at Queen's University.

With the environmental history of Lake Ontario in mind, the central issues of concern identified by our committee were the potential effects of DWSC on:

- Lake water temperatures and thermal structure;
- Phosphorus moved from deep to shallow water with possible effects on primary production and algae species composition;
- Entrainment and destruction of small fish;
- Redistribution during construction of any toxicity contained in lake sediments;

[3] Gilbert, Robert, Prof., Geography Department. Personal Interview, October 15 2003.
[4] http://www.epa.gov/glnpo/lakeont/summary.html

- The need to control zebra mussel settlement and the impact of control measures on other components of the lake ecosystem.

Clearly, the implementation of a DWSC system in Lake Ontario is inevitably going to have some sort of an impact on the lake ecosystem; however, with these issues being considered, the impact should be minimal. First of all, with the projected scale for this project, the difference in temperature bet ween the water coming out of the lake and the water going back in to the lake will be small enough in the perspective of volume to have little to no effect whatsoever on the thermal structure of the lake. Secondly, phosphorous addition to the surface waters from the outflow will likely be measurable directly adjacent to the source, but will diffuse rapidly and is unlikely to have a detectable effect on algal species composition.[5] The projected depth and flow rate of the intake should both be sufficiently low to expect minimal entrainment of small fish. The redistribution of the toxicity contained in the lake sediment during construction can be minimized by using state -of-the art machinery designed to minimize sediment, having a contained or "curtained" dredging site, and the disposal of dredged sediments away from the lake. These methods, however, will add additional costs to the project. And finally, according to Professor Bruce C. Anderson, a Civil Engineering Professor at Queen's University whose expertise includes water pollution and ecological and environmental engineering, at the projected depth of intake, there should be no need f or Zebra Mussel control at all, as they do not survive at those depths. In conclusion, at the site of Queen's University on Lake Ontario the implementation of a Deep Water Source Cooling system is entirely feasible from an environmental assessment aspect.

Geological Feasibility:

The ground surface on campus and near campus is mainly a thin clay plain deposit that covers the limestone bedrock. The clay deposit was measured on the construction site of what is now the Stauffer Libra ry. It was measured to be 2m deep.[6] Based on this information, the piping would be run mainly through clay, which is soft and would be a relatively cheap material to run our pipes through. Under this clay is limestone bedrock, which has been measured half a kilometer from campus and is approximately 50m in depth. [7] Limestone is also a soft rock and a relatively cheap material to run a pipe through. Also, the system would have to be run through the limestone near the lake as to avoid having the piping affected by the ice on Lake Ontario in the winter. The pipe would be required to be about 4m underground to avoid the ice. [8] Judging by this data, it is geologically feasible to run the piping from campus to the intake location at the lake. The soft material below the surface is adequate for cost - effective digging.

For the final report, a detailed survey of the current underground piping system and planned route of our pipes will be included.

---

[5] http://www.utilities.cornell.edu/LSC/News/GuestCol/IJ-06-05-98.htm
[6] A Rock Mass Characterization of the Foundation Rock at the Joseph S. Stauffer Library Site by Lisa C. Coyne 1993. pp. 8-11
[7] ibid.
[8] Gilbert, Robert, Prof., Geography Department. Personal Interview, October 15 2003.

Integration at Queen's University:

The integration of lake water into the present cooling system at Queens University is a very complicated matter. In areas where cooling is done by one large loop of chilled water, integration is only a mater of replacing the refrigerant at the cooling station with the lake water. Since Queen's University lacks such a system, however, and the construction of one could be as large a project as the addition of a deep water cooling system, the water must be sent to each building's individual cooling systems. This puts the project on a much larger scale, and adds both cost and complexity as a full new network of pipes must be added.

Once the water arrives it will be circulated thro ugh the coolant loop. This is the portion of the cooling system that refrigerant usually flows through. By passing through this loop the lake water will cool the closed loop of water within each building. This water is then pumped through the buildings ventilation system where air is blown past it, cooling the air and warming the water. The cool air is blown throughout the building by the air conditioning system and the warmed water is circulated back to be cooled again.[9]

The primary problem with integration is getting the lake water into the refrigerant loop. Aside from the issues of transporting the water to each individual building to be cooled, the refrigerant loops are designed to be completely closed systems. While some alterations to the system will be necessary to accommodate for the outside flow, the infrastructure may be so specialized in some cases that it will have to be removed and replaced with a more practical system, according to Eric Neuman, a mechanical engineer working with Physical Plant Services. Such a replacement will create a new score of problems concerning the accuracy of the cooling system. The existing cooling system is precisely calibrated for highly efficient energy transfer. Even if water of a constant temperature could be guaranteed we would have to accept either a loss in the efficiency of the system, or the costly recalibrating of the new temperature of coolant. Since energy would no longer be spent on cooling the water, the consequences of efficiency loss would either be the need for more water to be pumped through the system, or accepting slightly warmer buildings.

There must also be a system added to export the used water back to the lake. While this could be put in with the original transport system it would need to be monitored separately. After passing through the coolant loop there could be issues of decreased water pressure throughout the system. If the water is not clearly flowing downhill all the way to the lake it could stall and holdup the entire system. The addition of a set of smaller pumping stations might be necessary to maintain flow and offset this problem.

While it will not be a simple task the integration of cool lake water into the current cooling system at Queens University is possible, providing all the abov e issues are addressed. The primary benefit of this project would be a great drop in the power draw of each building that has their cooling system altered. Without the need to maintain the refrigerant loop, malignance costs would decrease as well. If accomplished, the integration would be of great benefit to the University.

---

[9] Neuman, Eric, Mechanical Engineer. Physical Plant Services, Queen's University. Personal Interview, October 15, 2003.

Conclusion

From the findings of our research, it is clear that Deep Water Source Cooling would be a great improvement to the means by which buildings on the campus of Queen's University are cooled. In addition to the benefits of cost reduction and elimination of the use of refrigerants (and consequently, CFCs) in the cooling loop, approval of the community at large would also be a positive factor. An undertaking of this scale will hel p to ensure the University comes into accordance with the Kyoto Agreement and furthers its reputation as an institution that stands for innovation and environmental responsibility.

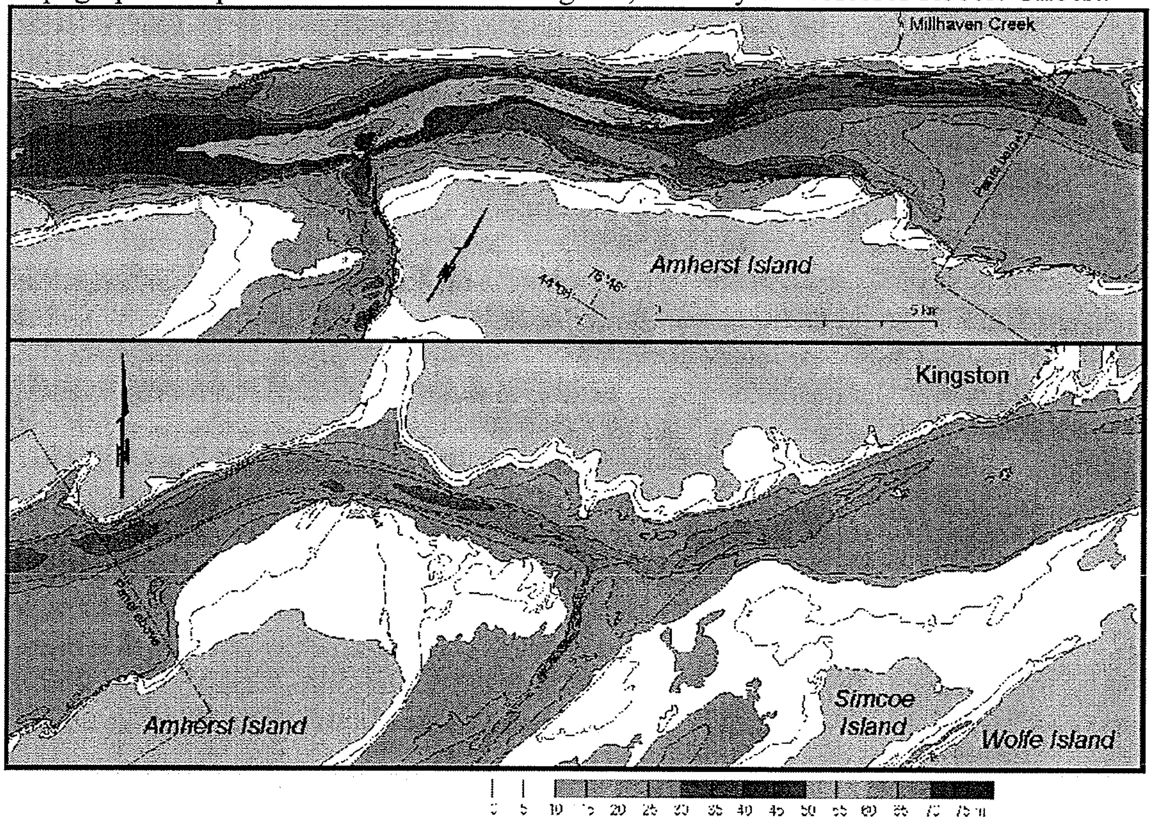
Although the DWSC concept is fairly straightforward, there are still some fundamental requirements that will make it impossible for the implementation of such a system at Queen's. This is due to the fact that there is no location for the intake of water cold enough to support the cooling requirements of the system. Even if we determined the costs for installing a near-30 km submarine pipeline and pumping large amounts of water across that great a distance were within the constraints of the budget, water at between 6 - 8vC is already at the upper end of the acceptable range of temperatures. Although no calculations for heat exchange have been carried out, it is implicitly obvious that the water could not remain at this temperature as the pipe ran through many kilometres of more shallow and warm water. Since there is no possible means of bringing in water at an ideal temperature of 4 vC, alternate solutions involving the use of cool lake water closer to campus will have to instead be explored. Alternatives include:

- Using chillers to cool the lake water to an acceptable temperature, thereby still requiring the use of refrigerants;
- Using lake water to cool the cooling machines, which currently is accomplished using water in a closed loop that runs from the basement machine room to the roof of the building and operates at temperature ranges of 95-105 vF;
- Using lake water as an integral part of a new "Co-Gen" plant that would be constructed at a site near the lake for the generation of electricity using gas turbines and the generation of steam for the campus' hot water.

This final alte rnative seems to be the most promising, as electricity prices will soon be deregulated, at which point the cost of purchasing electricity will be more expensive than the generation of our own electricity from natural gas. Although all of these alternative s may help to lower our consumption of electricity (and hence, our contribution to the emission of greenhouse gasses), they will not eradicate the use of refrigerants. The alternatives c annot be considered to be forms of Deep Water Source Cooling, and thusly may not fall within the scope of this project. In conclusion, although there are clear benefits to the implementation of DWSC at Queen's, it is simply not possible given the nature of the depths of Lake Ontario in the region surrounding Queen's University.

Appendix A:

Topographic map of Lake Ontario near Kingston, courtesy of Professor Robert Gilbert.



Appendix B:

Source data to be obtained in the near future:

- Data of temperatures of the water in Lake Ontario at certain depths.
  - Already acquired surface temperature chart
- Map of underground piping and electrical wires.
- Cost analysis of system:
  - Construction costs:
    - Piping system
    - Manual Labor
    - Pumping system
  - Consumption costs:
    - Maintenance
    - Power

Bibliography

Anderson, Bruce C., Professor. Queen's University. Personal Interview, October 20, 2003.

Coyne, Lisa C. A Rock Mass Characterization of the Foundation Rock at the Joseph S. Stauffer Library. 1993.

http://www.utilities.cornell.edu/LSC/News/GuestCol/IJ-06-06-98.htm, October, 2003.

http://www.epa.gov/glnpo/lakeont/summary.htm, United States Environmental Protection Agency. October, 2003.

http://www.energy.rochester.edu/idea/cooling/1995/dwsc/concept.htm, Cornell Lake Source Cooling, October, 2003.

http://www.howstuffworks.com/news-item137.htm, Howstuffworks "Lake Water Creates Natural Air Conditioner". August 4, 2000.

http://www.utilities.cornell.edu/LSC/Mailer?HowLSCWorks.htm, Lake Source Cooling For the Environment. Cornell University Utilities Department. May, 1999.

http://binational.net/sogl2001/03eng.pdf, State of the Great Lakes, 2001. October, 2003.

http://www.electricalline.com/images/mag_archive/25.pdf, Constantine Eliadis, October, 2003.

http://www.on.ec.gc.ca/solec/nearshore-water/paper/part1.html, Near Shore Waters of the Great Lakes, Environment Canada, October, 1996.

http://www.makai.com/p-swac.htm, Cold Sea Water Air Conditioning, Makai Ocean Engineering Inc., October, 2003.

http://www.warmair.com/html/duct_dynamics.htm, Duct Design and Dynamics, October, 2003.

Gilbert, Robert, Professor. Queen's University. Personal Interview, October 15, 2003

Neuman, Eric. Civil Engineer. Physical Plant Services, Queen's University. Personal Interview, October 15, 2003.