

PURDUE CALUMET WATER INSTITUTE REPORT

December 14, 2006

The purpose of the Purdue University Calumet Water Institute (PWI) is to use fresh water from the great lakes as a competitive advantage to attract and retain companies that depend on the availability of abundantly clean and secure sources of water for the success of their businesses. The mission of PWI is to conduct research, offer education programs in water resources, and assist local, regional/state agencies, as well as the private sector in solving water-related problems. The PWI also provides an interdisciplinary approach to complex issues dealing with water quality, water efficiency, water security and water/energy interrelations. Since its creation in 2005, PWI has identified and engaged in three major areas necessary to accomplish the mission and goal of the institute. These are: (1) development of real-time online water sensing technique for detection of low-level contaminants, (2) economic development studies in Northwest Indiana (NWI) using water resource as a “catalyst,” and (3) professional assistance to local industry and utility companies in solving water-related problems. This report provides a synopsis of the preliminary exploits in these three areas.

A. WATER SENSORS

Distribution Systems have been recognized as the part of water supply systems that is most vulnerable to deliberate contamination. In order to be truly innovative, new monitoring systems need to be able to operate unattended, online, in real time and be integrated into a distributed sensor network that minimizes false positives and negatives. A conceptual design for an innovative monitoring system to monitor water storage tanks is proposed and described here. This proposed monitoring system is of particular interest in the Mid-West because of the widespread presence of water towers. The presence of a headspace above the aqueous phase in storage tanks provides a significant opportunity to scan for unwanted volatile organic chemicals, some of which are a significant terror threat but are also commonly found pollutants. This “scan” would complement standard monitoring of the aqueous phase in various points of the distribution system (using multi-parameter monitors, for instance).

This conceptual design illustrates a system composed of (1) on-line multi-parameter detection systems, already commercially available and well known by water utilities. These sensors are connected to a network that will transmit findings to a central location. To avoid flooding the system with uneventful data, each node would have the capability of processing specific data and be programmed to send the parameters of interest for that particular node; (2) In addition to the multi-parameter control points, the water towers will be instrumented with new, innovative sensors used to detect possible volatile gases/contaminants in the head space. Remote photoacoustic sensors and/or millimeter wave sensors are chosen for this application. Both exhibit high degrees of detection sensitivity, can be adapted for online use, and can be interfaced with the proposed data processing network.

Multiparameter sensing

A multiparameter sensing system will monitor water quality on line, real time. Sensors will be located at inlet (1) of water tower and elsewhere in water distribution system (2) (see drawing for location). Potential anomalies will be reported as deviations from historic multi-parameter trend line. Parameters to be detected includes: chlorine (free+combined chlorine), conductivity, pH, temperature, pressure, flow, and turbidity. Other possibilities include DO, TOC, hardness, and nitrate.

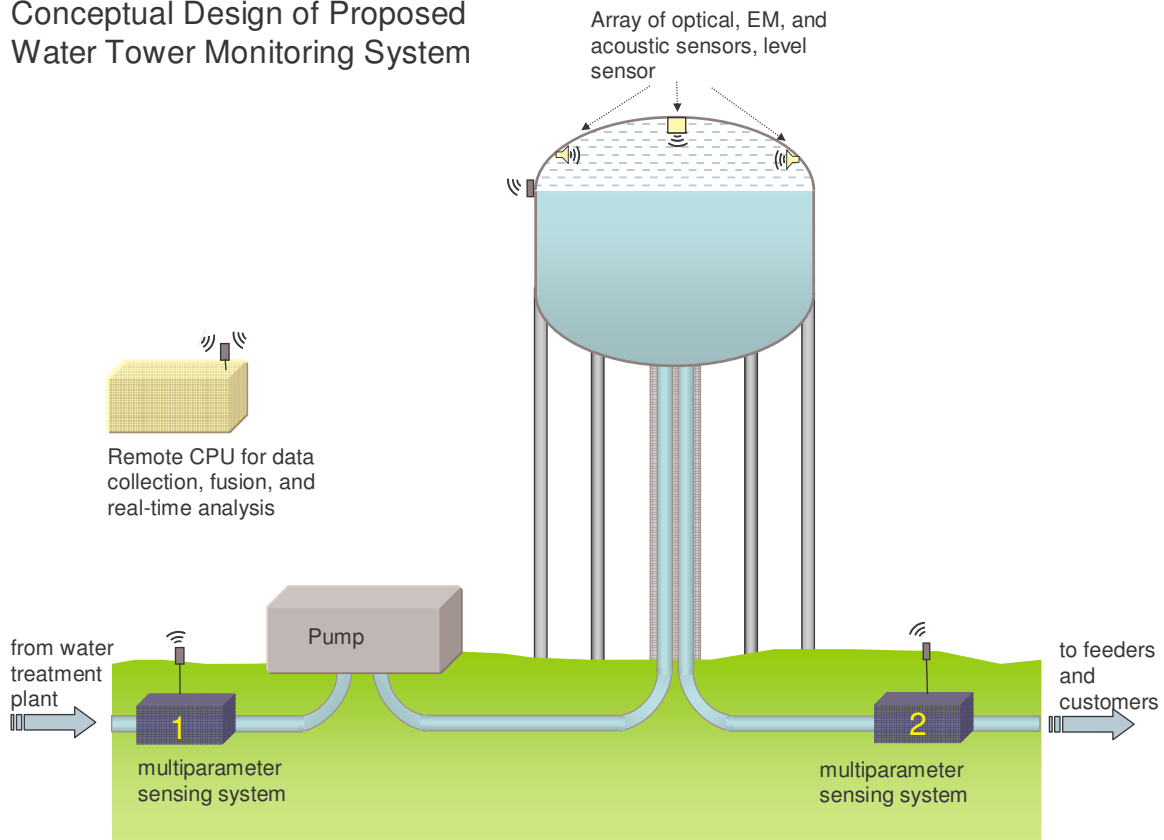
EM Sensor Technologies

A non-contact electromagnetic (EM) level sensor will be installed to monitor the change in the level of water inside the tank. The EM level sensor would operate at the microwave frequency range based on the Doppler principle and measures the change in the phase shift between the transmitted and received signal in order to

continuously monitor the level of water. Employment of low-power solid-state microwave sources and integrated circuit technology allows construction of rugged, compact and battery-operated devices.

A millimeter wave (mmW) spectroscopic sensor will be installed to monitor the air above the water for presence of organic molecules of interest. The swept-frequency active mmW sensor will measure the rotational energy transitions of polar molecules in gaseous phase at atmospheric pressures. As a direct consequence of operating at longer wavelengths in comparison to its optical counterparts, the mmW sensor will be less affected by harsh environmental conditions within the tank such as presence of significant amount of moisture and fluctuations in ambient temperature. Measurement of rotational absorption by polar molecules further allows one to identify chemical species of interest with high degree of specificity. The system will employ backward oscillator technology as the mmW source, which provides high output power and wide operating bandwidth. Solid-state passive components will be employed for detection and amplification of signals. Acquisition and analysis of data will be performed in real time using specialized hardware and software developed for this purpose.

Conceptual Design of Proposed Water Tower Monitoring System



Argonne National Laboratory - December 2006

Photoacoustic Infrared Spectroscopy

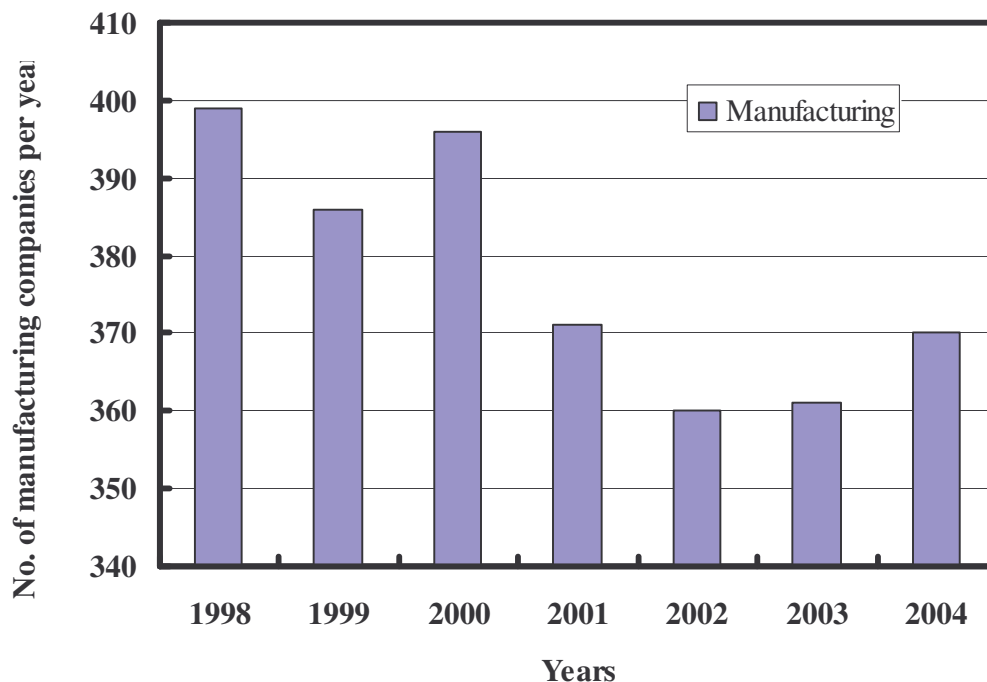
Photoacoustic infrared spectroscopy (PAIS) can be the practical technique for in-situ water-quality analysis (headspace in the water tower). PAIS has been applied to characterization of both condensed phases and gases

with high sensitivity and spectroscopic selectivity. Compared with conventional absorption spectroscopy, the PAIS offers many distinct advantages such as minimal sample preparation, suitability for opaque materials, nondestructive, high sensitivity, ppbV level with a CO₂ laser and can detect ammonia, ethylene, propylene, methanol, ethanol, chloro-compounds, and benzene/toluene at the level of < 100 ppbV.

B. ECONOMIC IMPACT OF FRESH AND WASTE WATER IN NWI

Water is an essential resource during the production process of various manufactured products. Industrial water use includes water used for such purposes as fabricating, processing, washing, diluting, cooling, or transporting a product; incorporating water into a product; or for sanitation needs within the manufacturing facility. Some industries that use large amounts of water produce such commodities as food, paper, chemicals, refined petroleum, or primary metals. The community of Northwest Indiana (NWI) is located in the vicinity of the Lake Michigan which is the second largest Great Lake by volume with just under 1,180 cubic miles of water, with a registered water flow averaged at 2176.8 billion gallons or approximately 6 billion gallons per day in 2005. The lake is 321 miles (517 km) long (north to south); it has a maximum width of 118 miles (190 km), and an average of 279 feet in depth, the lake reaches 925 feet at its deepest point. According to a 1994 Indiana Department of Natural Resources report, the Lake Michigan region, which includes most of Lake, Porter, and LaPorte counties, uses Lake Michigan surface water for almost 99 percent of its daily 3 billion gallon need. Of this total, 60 percent are for industrial uses, 37 percent for energy production purposes, and the remaining 3 percent for public supply, agriculture, or other uses.

NW Indiana has experienced a significant decline in manufacturing jobs as shown in Fig. 1 for the Lake County. This region is now one of the most economically depressed regions in the country and is in desperate need of economic transformation. The need is for new industries that create new jobs, revive the economy, and improve the quality of life. Fresh water from the Great Lake represents the most significant natural resource in NW Indiana.

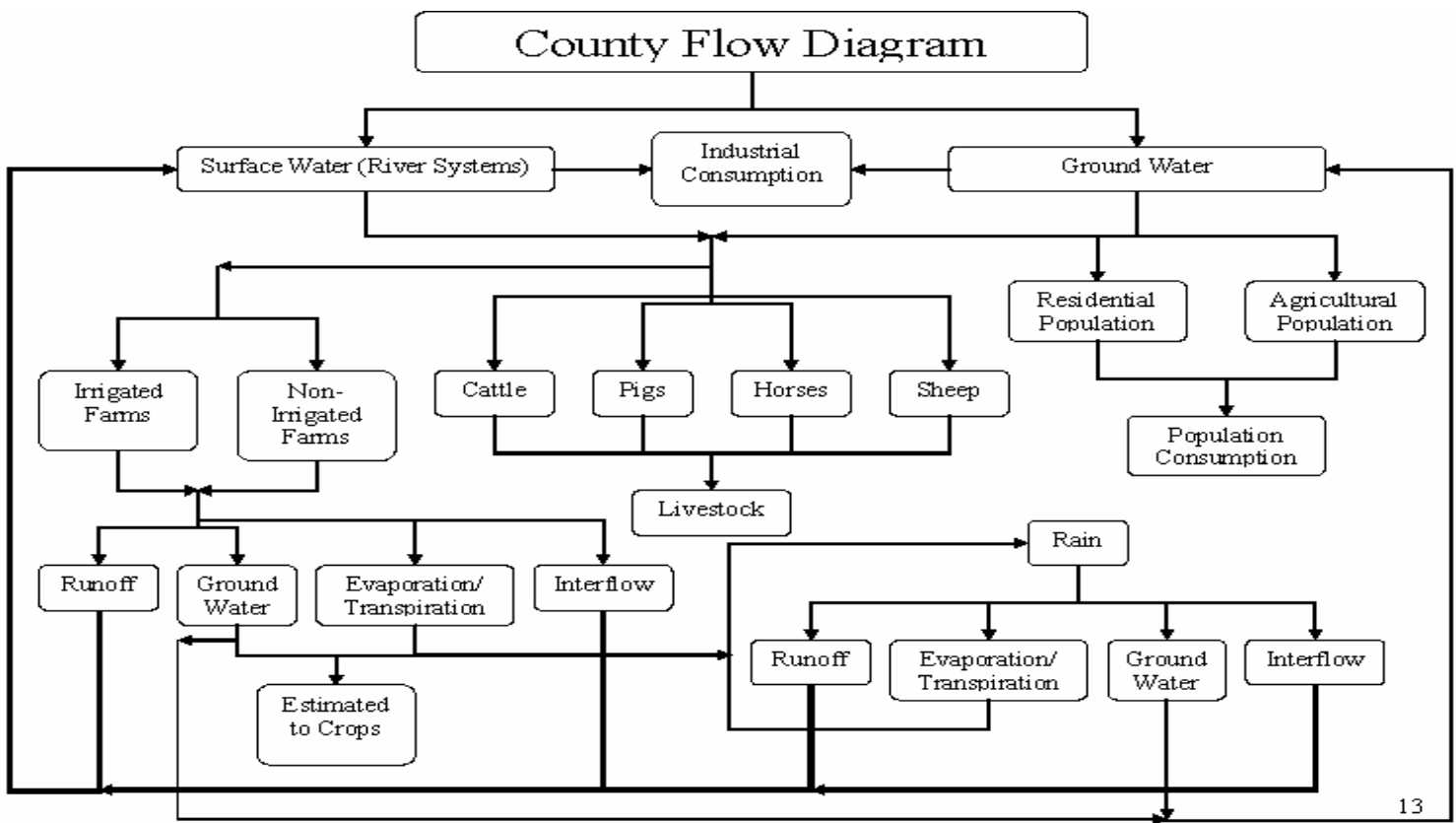


The purpose of the Purdue University Calumet Water Institute (PWI) is to use water resource as a competitive advantage to attract and retain companies that depend on the availability of abundantly clean and secure sources of water for the success of their businesses. The aim of this preliminary project is to investigate the use of water resource as a catalyst for economic development in Northwest Indiana. The project is focused on three key areas:

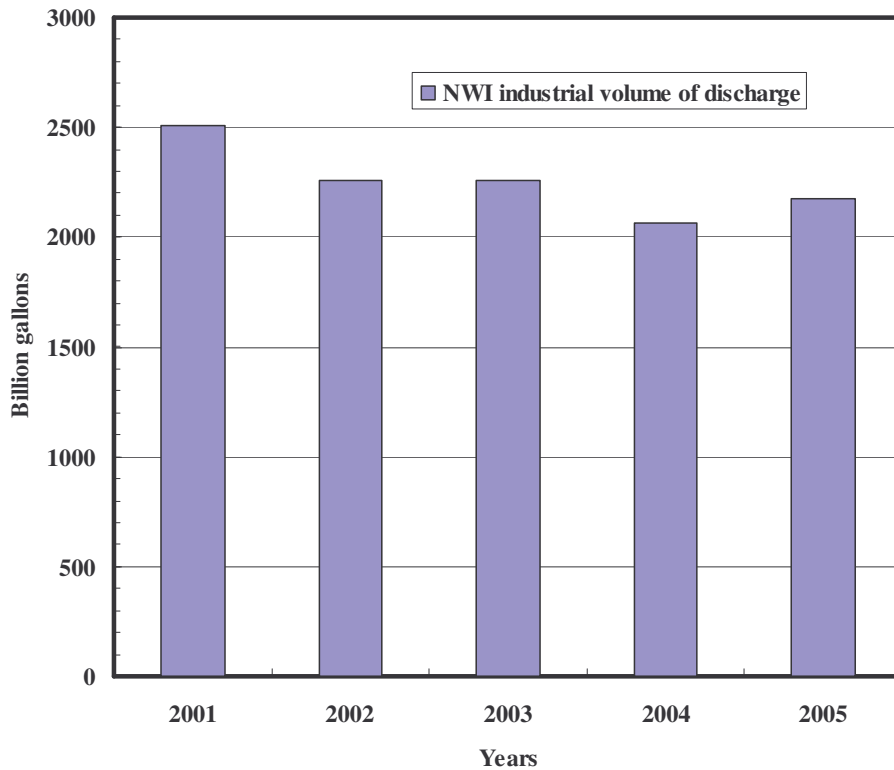
- An assessment of waste water reuse in NWI
- Evaluation of industries outside of the region that depends heavily on water and volume of water consumed

The waste water assessment is performed through statistical analyses of the amount of wastewater generated in the Northwest Indiana region that is being treated and reused for other requirements on a county by county basis. Information on the volume of wastewater is imperative since if properly treated could potentially reduce the amount of freshwater drawn from Lake Michigan for everyday tasks. The data used in this analysis are the amount of water that is currently being consumed by agriculture, industry, and residential/commercial groups and their corresponding sources. All of the data is obtained using statistical method based mainly on United States Census data. The industrial evaluation is based on volume of water discharged to the Lake Michigan by various companies for the last five years. This data was provided by the Indiana Department of Environmental Management.

Based on evaluation of the data, a flow diagram depicted in Fig. 3 is developed to show various sources and sinks that are associated with each county. Using a mass balance type of analysis, which is done by equating the amount of water into a county by the amount of water out, an estimate of wastewater generation, is obtained. According to the mass balance analysis the amount of water supplied to a given group should match the amount coming out of that particular group.



According to our detailed analysis which is not presented in this report for brevity, it was found that the water usage in the agriculture and residential/commercial groups is much lower than that of the industrial/energy group. Therefore, only the industrial data will be presented. The histogram in Fig. 4 shows the volume of water discharge to Lake Michigan by various industries for the last five years. It reveals a decline in water discharge with the range from 2.5 Trillion gallons to 2.0 Trillion gallons per year. These variations could be attributed to reduction in production capacity, improvement in water usage, or other parameters.



Assuming that 20% of the surface area (321 miles by 118 miles) of Lake Michigan is in the NWI region, with average water depth of 279 feet in depth, NWI has approximately 88.3 Trillion gallons of fresh water from Lake Michigan. According to data in Fig. 4, only 2.5 Trillion of industrial water is used per year. This obviously shows that fresh water in NWI is underutilized.

It has been demonstrated that NWI has the potential to support more industries such as microelectronics, beverage, food processing, and paper mills that rely heavily on water resource. In Table 1, various industries have been identified that may benefit from the profusion of water in NWI. It shows that volume of water used in the last five years. It should be noted that they are other factors that companies will take into account before considering relocation to the NWI region. These factors including availability of water will be considered in its entirety in the future.

Table 1. Volume of water used by potential companies in the last five years

Name	(millions of gallon)					
	GPM	2000	2001	2002	2003	2004

AG PROCESSING INC	2550.0	257.9	292.7	280.3	231.0	259.9
AG PROCESSING INC	2550.0	255.2	283.0	252.1	282.2	229.4
BLANDIN PAPER CO	30000.0	7985.0	7040.9	6350.2	6428.4	6088.1
FORD MOTOR CO	600.0	231.0	195.5	161.8	214.4	186.9
GENERAL MILLS INC	3700.0	131.0	163.5	195.0	1.5	1.1
GEORGIA PACIFIC CORP	2500.0	559.6	409.2	408.3	415.1	448.3
GREAT RIVER ENERGY	50000.0	13884.3	12838.3	11280.0	12933.0	12675.8
HIBBING TACONITE COMPANY	10376.0	7383.4	7395.1	7365.5	6957.9	6367.3
HORMEL FOODS CORP	5250.0	501.3	399.6	342.4	321.1	248.3
INTERNATIONAL PAPER CO	9722.0	3493.4	3482.4	3533.4	3714.7	3577.3
INTERSTATE POWER&LIGHT CO	70000.0	5643.7	5354.0	6910.5	8091.3	3118.0
MATHY CONSTRUCTION CO	6400.0	784.1	1163.3	986.5	999.3	694.4
NORTHSHORE MINING COMPANY	95000.0	47433.6	46008.0	45878.4	47304.0	46998.9
UNITED STATES STEEL CORP	22000.0	1757.1	2234.0	1930.8	2050.5	1728.8
UNITED TACONITE LLC	7000.0	2835.5	3118.0	3811.6	2550.8	2400.0

C. PWI ASSISTANCE TO LOCAL INDUSTRIES

- The PWI has provided professional service to the Gary Sanitary District and US EPA in the development of “remediation plan” for the “Ralston Street Lagoon.”
- Technical discussions with BP on ways to improve water quality
- Collaboration with Quansor, a water security company, on development of sensors for monitoring low-level contaminants

D. Development of Water Resource Management Certification Program

A list of courses for the Water Resource Management Certification Program has been identified based on the need assessment survey from local companies and organizations. A graduate level course “Environmental Chemistry” has been offered in Fall 2006. Two graduate level courses “Environmental Microbiology” and “Foundations in Homeland Security Studies” will be offered in Spring 2007. All these courses include a large

portion of water resources, wastewater treatment, and water security issues. In addition, a new course “Water and Society” is under development.

FUTURE WORK

The next phase of this project is to perform a more detailed economic study on the additional factors that may attract water-based companies to NWI region including tax incentives. Also, the local governments, Northern Indiana Regional Planning Commission (NIRPC), and even the state of Indiana should be involved in this phase of economic studies.

The second phase of the water sensors investigation includes: model the hydrodynamics and chemistry of the two-phase water tower control volume for various flow conditions, mixing conditions, and contaminant concentrations; construct laboratory-scale water tank test system setup, instrumentation of the water tower lab test system with the monitors of choice, and testing headspace sensors on various contaminants.