EXECUTIVE SUMMARY FOR

DRAFT REPORT ON
AQUIFER RECHARGE USING TREATED WASTEWATER
PRELIMINARY FEASIBILITY STUDY
WAUKESHA COUNTY, WISCONSIN

Prepared For

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INTRODUCTION

This report presents the results to date of a Christopher B. Burke Engineering, Ltd. (CBBEL) preliminary feasibility study of Aquifer Recharge (AR) using reclaimed water (highly treated wastewater) in Waukesha County, Wisconsin and focuses primarily on the regulatory and environmental issues associated with this injection into the deep sandstone aquifers that underlie the study area.

DRAWDOWN:

Wisconsin wells withdraw about 760 million gallons per day (mgd) of groundwater as of 2000. [1] In many areas, the withdrawal or discharge rate exceeds the natural recharge rate. Subsequently, severe drawdowns are occurring in the Lower Fox River Valley and Lake Winnebago watershed, in southeastern Wisconsin and in central Dane County. [1] A MODFLOW model created cooperatively by the United States Geological Survey (USGS) and the Wisconsin Geological Natural History Survey (WGNHS) has indicated a 450 foot drawdown occurring in the deep sandstone aquifers of Southeast Wisconsin since the onset of pumping in the late 1800's. [2] This drawdown is so significant, that it has reversed the natural flow of groundwater in parts of the region so that groundwater that used to flow to Lake Michigan now flows away from the lake.

PROJECT DESCRIPTION

Waukesha, WI lies west of the Great Lakes Basin and relies on groundwater for its drinking water supply. As drawdown continues to dewater the deep sandstone aquifers, levels of contaminates including gross alpha and radium have begun to exceed federal and state standards as set forth in the Safe Drinking Water Act (SDWA) and Wisconsin WDNR Chapter NR 809, Safe Drinking Water. In an effort to solve this developing water supply crisis, Waukesha has made a request to the Council of Great Lakes Governors for a diversion from Lake Michigan. However, since Waukesha is outside of the Great Lakes Basin, current US law would require that Waukesha get approval from the Governors of all 8 Great Lake States to make such a diversion. In addition, there is currently a move to limit or eliminate any new diversion outside of the basin under the Great Lakes Charter Annex 2001. It is likely that under the Charter, cities like Waukesha, who are just outside the Great Lakes Basin, will not be allowed to withdraw or divert any Great Lakes water.

The above is the framework for this study. Put simply, groundwater drawdown is the problem. It is causing drinking water sources to be non potable. Considering that drinking water demand is expected to increase with time, groundwater drawdown and water quality can only be expected to worsen unless the problem is addressed. AR is this project's pursued solution. However, it is **NOT** the intent of this study to claim that AR is an independent solution to this problem, but rather that in combination with conservation, water budgeting and other technologies, AR offers relief to declining aquifer water levels.

One of the objectives of GLPF Proposal #750 is to "demonstrate how current and future available sources of reclaimed water, stormwater and surface water can be used to enhance aquifer recharge." Pursuant to this objective, a target area for AR in the City of Waukesha, Wisconsin has been identified. It has been projected that AR in Waukesha using direct injection of reclaimed water from the Waukesha Waste Water Treatment Plant (WWTP) will meet the above stated objective. The Waukesha WWTP produces 10 to 12 mgd of reclaimed water which is currently discharged into the Fox River. It is the intent of this project to use 5 mgd of the reclaimed water and transform it into an asset. This asset will be potable water which meets or exceeds federal and state drinking water standards, state groundwater standards and ambient groundwater quality. This reclaimed water will then be used for AR in the deep sandstone aquifer. It is believed that AR will combat drawdown, help restore the natural groundwater flow regime, and improve drinking water quality all simultaneously.

REGULATORY ISSUES

There are two main issues associated with groundwater regulation, groundwater quality and groundwater quantity. At this point, there are no significant Wisconsin regulations regarding groundwater quantity. In terms of groundwater quality, all underground injection is regulated by the United States Environmental Protection Agency (USEPA) Underground Injection Control (UIC) Program. [5,6,7] The USEPA UIC program's main intent is to protect Underground Sources of Drinking Water (USDWs) from contamination as defined by the Safe Drinking Water Act (SDWA). The Wisconsin Department of Natural Resources (WDNR) is the agency responsible for administering the UIC program in the state. The governing regulation is Wisconsin Administrative Code Chapter NR 815, Injection Wells. [8] In addition to NR 815, there are separate regulations concerning drinking water quality (NR 809) and groundwater quality (NR 140). It follows that, the approach to gain regulatory approval in Wisconsin for a project of this nature is water quality. It will be imperative to be show that the reclaimed water quality meets or exceeds two criteria.

1. Drinking Water Standards as outlined in NR 809

2. Ground Water Standards as outlined in NR 140

NR 815 INJECTION WELLS

NR 815 is regulates any well used to place a fluid underground in Wisconsin. In NR 815.04 , injection wells are classified as Class I, II, II, IV or V. The proposed injection well would be considered a Class V well unless the reclaimed water is considered hazardous and then a Class IV designation would apply.

Under NR 815.06, Class I, II and III injection wells are strictly prohibited. Class IV injection wells are prohibited except in the case of soil or groundwater remediation projects. Class V injection wells require the approval of the WDNR, and are subject to additional regulation as outlined in NR 815.11. Discharge of liquid wastewaters is subject to NR 206, LAND DISPOSAL OF MUNICIPAL AND DOMESTIC WASTEWATERS. NR 206.07 (2)(d) reads, "The underground injection of municipal and domestic wastewaters through a well is prohibited." This is the main regulatory obstacle to the proposed AR using reclaimed water. It is evident that this regulation is intended to prohibit the direct injection of untreated wastewater, but the wording is ambiguous enough to draw concern. Some lenience is found in NR 206.06 stating that the owner of a proposed land disposal system can request alternative requirements if he feels that compliance with discharge prohibitions this chapter are impracticable.

NR 815 further stipulates in 815.07 - (4) that a regulatory agency may not approve the construction or use of any injection well that would:

1. Violate the provisions of chapter 160, Statutes (Groundwater Protection Standards)
2. Result in the endangerment of an USDW
3. Fail to comply with the other applicable requirements of this chapter (815)

NR 809 SAFE DRINKING WATER

NR 809 establishes drinking water quality standards and the procedures by which to measure and enforce these standards in Wisconsin. The regulations apply to all new and existing public water systems. NR 809 contains two levels of drinking water quality standards, Maximum Contaminant Levels (MCLs) and Maximum Contaminant Levels Goals (MCLGs). MCLs define the maximum permissible level of a contaminant in water which is delivered to any user of a public water system. The MCLs listed in NR 809 represent the minimum quality standards for any aquifer recharge project in Wisconsin, as indicated by the UIC program requirements. MCLGs are non enforceable health goals which define the maximum level of a contaminant in drinking water with no known or anticipated adverse health effects.

NR 140 GROUNDWATER QUALITY

NR 140 establishes groundwater quality standards and the procedures by which to measure and enforce these standards. The regulations apply to all facilities, practices and activities which may affect groundwater quality. NR 140 contains two classes of groundwater quality standards, public health related standards and public welfare standards. For both standards there are two tabulated sets of values, enforcement standards and preventive action limits (PALs).

The enforcement standards in NR 140 are analogous to the MCLs in NR 809. They define when a violation has occurred. When an enforcement standard is attained or exceeded, the source activity is subject to immediate enforcement action, in that a regulatory agency must prohibit the continuation of the activity, unless it is demonstrated that an alternative response will achieve compliance.

The preventive action limits in NR 140 are analogous to the MCLGs in NR 809. However, unlike MCLGs, PALs are enforceable. PALs are set to 10%, 20%, or 50% of the corresponding enforcement standard. PALs represent the most stringent regulatory standards associated with the proposed project.

Enforcement Standards and PALs are measured at a point of standards application (PSA). A PSA is any of the following:

1. Any point of present groundwater use
2. Any point beyond the property boundary
3. Any point beyond a design management zone
4. Any monitoring point established by permit for sites with hazardous waste
5. For ASR wells the PSA is 1,200 feet from the well

As alluded to above, PALs are very conservative, but exemptions can be granted. These exemptions, and the subsequent requirements for the exemptions, are organized in four basic categories. The categories address the quality of the background or native water. They are as follows:

1. Exemption where background concentration is below PAL
2. Exemption where background concentration is above PAL
3. Exemption where background concentration is above enforcement standard
4. Temporary exemption for remedial action

Categories 1, 2 and 3 are further separated into exemptions for substances of public health concern and substances of public welfare concern. For both classes of substances, the general guidelines are public safety and technical/financial feasibility.

Category 4, remedial action, could potentially be pursued if the project included treatment of the radium contaminated groundwater. Remedial action would require treatment of the contaminated groundwater followed by re-injection of that treated water into the same aquifer from which it was pumped. This type of exemption is valid for up to five years and can be reissued.

It should be noted that exemptions might not be necessary if the recharge water does not contain any substance that meets or exceeds any PAL or enforcement standard at a point of standards application, or cause a change in the native groundwater resulting in an exceedance.

ENVIRONMENTAL ISSUES

There are two basic areas of environmental concern associated with the injection of reclaimed water into a USDW. The first area of concern is the use of **reclaimed water** as the source water. The "Toilet to Tap" fear is likely the largest obstacle in a project of this nature. [11] This fear takes the form of public opinion/resistance and therefore needs to be addressed in terms of a public relations campaign more so than in terms of engineering. The second area of environmental concern is the **injection effects** on the aquifer as a result of injecting non-native water.

EXAMPLE OF TYPICAL ENVIRONMENTAL CONCERNS

Wisconsin recognizes the need to develop new and innovative solutions to the increasing demand for drinking water. To that end, the WDNR has allowed pilot studies of a technology known as Aquifer Storage and Recovery (ASR). Pilot studies have been initiated in both Green Bay and Oak Creek. The Oak Creek ASR has received WDNR approval as of October 2004. The only major operational difference between an ASR well and a typical AR well as proposed under GLPF Proposal #750, is that an AR well is not intended to retrieve the water that it injects into the aquifer. Therefore, it follows that a Wisconsin based operational ASR well is an excellent model for addressing local environmental injection effect concerns.

Four basic principals of ASR operation have been established by the WDNR:

1. Injected water must meet federal and state drinking water standards.

2. Recovered water must meet federal and state drinking water standards.

3. Water stored around an ASR well must meet federal and state drinking water standards and cannot exceed groundwater enforcement standards at any property boundary.

4. At the end of each ASR cycle, any water remaining in the “displacement zone” around an ASR well must not exceed the Enforcement Standards for Fe, Mn, Cu, Pb, fluoride, nitrate, nitrite, asbestos, and trihalomethanes (THMs), or the Preventive Action Limits for other substances.

The following are four environmental concerns raised during Oak Creek and Green Bay ASR Pilot operations.

1. **Introduction of Contaminants into the Aquifer**

2. **Fate of Disinfection By-Products (DBPs)**

3. **Geochemical Reactions in the Aquifer**

4. **Lack of Hydraulic Control**

Introduction of Contaminants into the Aquifer

This concern can be alleviated by treating any injected water to Safe Drinking Water Act (SDWA) standards or WDNR 809 standards. However, the method of treatment can affect the second concern.

Fate of Disinfection By-Products (DBPs)

Disinfection through inactivation usually involves the use of disinfectants such as chlorine, ozone, and chlorine dioxide, and a combination of chlorine and ammonia (chloramines). In drinking water systems there is typically a residual amount of chlorine or other disinfection product intentionally left in the water to protect against pathogens during storage and delivery. Disinfection byproducts (DBPs) are formed when the disinfectants used in a water treatment react with bromide and/or natural organic matter present in the source water. The risks associated with DPBs and the risks associated with pathogens must be balanced. Regulated DBPs include: trihalomethanes (THMs), haloacetic acids (HAA5), bromate, and chlorite.[12]

For THMs, Wisconsin groundwater standards WDNR 140 are more stringent than the drinking water standards WDNR 809. These standards are summarized in Table 1.

Table 1

THMs Standards		
Contaminant	**WDNR 140** Enforcement Standard (mg/L)	**WDNR 809** MCL (mg/L)
Chloroform	0.006	0.08 total trihalomethanes
Bromodichloromethane	0.0006	0.08 total trihalomethanes
Bromoform	0.0044	0.08 total trihalomethanes
Dibromochloromethane	0.06	0.08 total trihalomethanes

Standard treatment technologies such as chlorination and ozonation might not be suitable for AR especially if the WDNR 140 regulations are strictly enforced. However, this concern can be addressed by using alternative treatment technologies. Currently, Waukesha Waste Water Treatment Plant (WWTP) uses ultraviolet (UV) disinfection as part of its tertiary treatment process. UV disinfection produces no DBPs of consequence.

Geochemical Reactions in the Aquifer

Geochemical reactions in an AR system are caused by differences between native water and injected water. Groundwater chemistry is dominated by reactions with the in situ aquifer solids. [14] It is important to identify potential changes to both the native mineralogy and aquifer water chemistry when assessing the potential for geochemical reactions. An abbreviated list of water quality characteristics of concern includes: pH, redox state, ionic strength, dissolved oxygen (DO) and total organic carbon (TOC). There are two main areas of concern with geochemical reactions in the aquifer: microbial contamination and trace element contamination.

Microbial reactions have two main mechanisms. The first is simply the introduction of non-native microbes. This is addressed by treatment methods used to ensure drinking water quality as previously discussed. The second mechanism involves oxygen, carbon or nutrients introduced with the non-native water thereby stimulating indigenous microbes. [14] This is avoided by careful monitoring and treatment of source water to ensure that it complies with native groundwater quality.

Trace elements are mobilized largely by a change in the redox state of the system with the introduction of non-native water. [14] Of particular interest are observed geochemical reactions at the Green Bay pilot study. These reactions included the release of arsenic, nickel, cobalt, gross alpha and uranium due to high levels of dissolved oxygen (DO) in the injected water. [12] Also, at the Oak Creek pilot study, injection water quality has caused the dissolution of manganese to levels above groundwater standards. [12]

CBBEL has obtained a protocol from St. Johns River Water Management District in Florida to test for key properties in the proposed recharge source water chemistry, native groundwater chemistry and geologic mineralogy that could trigger geochemical reactions. Initial testing is scheduled to begin May, 2005. Adherence to this protocol coupled with an aggressive monitoring program should limit unwanted geochemical interactions.

Lack of Hydraulic Control

The concern with hydraulic control deals with the difficulty associated with the prediction of the groundwater flow in a reliable and accurate manner as the result of direct injection through a well. In order to predict the effect on the groundwater flow regime, it is necessary to conduct in depth analysis of the aquifer formations and their associated hydraulic properties including hydraulic conductivity. Also, fractured formations and formations with high hydraulic conductivity create preferential flow zones which greatly impact the groundwater flow regime. [14]

Procedures for maintaining hydraulic control adapted from *A Review of Aquifer Storage Recovery Techniques* [14] are included in the full draft report. Also, the Wisconsin Geological and Natural History Survey (WGNHS) is an excellent source for more information regarding existing studies/models for Waukesha's geology and groundwater flow. Assuming the hydraulic properties can be established to a certain level of confidence for the injection area and affected aquifers, the injection well(s) can then be designed with injection points, well screen lengths and casing parameters in order to attain predictable hydraulic behavior in the aquifer(s). An in-depth analysis of well design is not included in this report.

SUMMARY

Groundwater depletion threatens available groundwater drinking sources in Waukesha County, Wisconsin. One method of reversing this trend is Aquifer Recharge. Aquifer Recharge using reclaimed water is an ideal scenario because it not only addresses the problem of groundwater depletion, but it also turns a waste into an asset. However, in order to gain approval from the WDNR for the design, construction and operation of an aquifer recharge well using reclaimed water as its primary source in Waukesha County, a carefully crafted and well documented argument will be necessary. The reclaimed water will need to meet or exceed drinking water and groundwater quality standards while not imposing any significant risk of geochemical reactions with the aquifer itself. However, not only will the regulatory and environmental issues addressed in this paper need to be satisfied, but also public opinion will need to be won. Even though all water is recycled, it is definitely not viewed that way in the public eye. This public opinion has been won in places like Orange County California. It will need to happen in Waukesha Wisconsin in order to successfully implement a project of this nature.

REFERENCES

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3. USGS 2003. USGS Fact Sheet-103-03. *Ground-Water Depletion Across the Nation.*

4. University of Wisconsin Water Resources Institute. Wisconsin Water Issues Fact Sheet. *Arsenic.*

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8. Wisconsin Department of Natural Resources 2005. Wisconsin Administrative Code. *Chapter NR 815, Injection Wells.*

9. St. Johns River Water Management District, 2004. *Aquifer Storage and Recovery (ASR) Issues and Concepts*

10. Wisconsin Groundwater Coordinating Council 2004. *Meeting Minutes from August 20, 2004 - Wisconsin Department of Transportation*. Available online at: http://www.dnr.state.wi.us/org/water/dwg/gcc/082004mn.pdf

11. Waldie, D.J. December 1, 2002. *Toilet-to Tap Fear Factor*. Los Angeles Times.

12. U.S. EPA. *Disinfection Byproduct Information*. Available online at: http://www.epa.gov/enviro/html/icr/dbp.html

13. City of Waukesha WWTF, 2004. City of Waukesha Wastewater Treatment Process. *wastewater_treatment_process.doc/4-04*

14. Aquifer Storage Recovery Technical Advisory Group, March 2002. *A Review of Aquifer Storage Recovery Techniques.* Submission to WDNR.

1. Table of facilities using wastewater reuse.

Operational Facilities Injecting Reclaimed Water		
AR / ASR	**Sites**	**Relevance**
AR	Orange County, Ca - Factory 21	Direct Injection Seawater Barrier
AR	Orange County, Ca - Groundwater Replenishment System (GWRS)	Direct Injection Seawater Barrier
AR	El Paso, TX	Aquifer recharge direct injection
AR	St. Petersburg, Florida	Saltwater barrier and other uses
ASR	Sun Lake City, Az	3 ASR Wells storing 2.4mgd for irrigation
ASR	Glendale, Az	4 ASR Wells storing reclaimed water
ASR	Mt. Pleasant Waterworks & Sewer Commission, SC	ASR using reverse osmosis treatment

Operational Facilities Injecting Non-Reclaimed Water		
AR / ASR	**Sites**	**Relevance**
ASR	Des Moines Water Works, Ia	Dolomite/sandstone formations 2100-2600 feet
ASR	Oak Creek, Wi	Pilot Study near the Waukesha area
AR/ASR	Goleta Water District, Ca	ASR and Injection Wells
AR/ASR	Las Vegas Valley Water District, Nv	33 ASR Wells and injection wells
AR/ASR	Salt Lake County Water Conservancy District, Ut	1 ASR and 1 injection

Operational Facilities Using Reclaimed Water (Non-Injection)	
Sites	**Relevance**
Upper Occaquan Sewage Authority Alexandra, Va	blended for conversion to potable water
Los Angeles, Ca	40 years of operation for GW recharge
Perth Amboy, NJ	Open water recharge
Clayton County, Ga	Land application
Windhoek, Namibia	Potable water
Singapore NEW Water Project	Potable water
Monterey, California	Irrigation
Mexico City	Irrigation
Dan Region, Israel	Irrigation
Virginia, Australia	Irrigation
Irvine Ranch, California	Irrigation and other uses
South Bay, California	Urban, industrial and agricultural
Rouse Hill Australia	Toilet flushing and garden water
Homebush Bay, Australia	Toilet flushing and irrigation
Mawson Lakes, Adelaide, Australia	Toilet flushing and irrigation
Phoenix, Arizona - Palo Verde Power Station	Cooling water
Australia - Eraring Power Station at Lake Macquarie	Steam
Australia - Port Kembla Steelworks	Cooling and quenching

Australia - BP Oil Refinery	Process water
South Africa	Law requires WWTP to return flow to stream of origin

Cancelled Reclaimed Injection Facilities		
AR / ASR	**Sites**	**Relevance**
AR	San Diego, Ca	Cancelled by City Council
AR	Tampa Bay, Fl	Cancelled due to public opposition
Cancelled Non-Reclaimed Injection Facilities		
AR / ASR	**Sites**	**Relevance**
ASR	Green Bay, Wi	ASR - Cancelled due to arsenic mobilization