LAKE MEADOW WATER TRUST
RADIUM COMPLIANCE REPORT

CITY OF MUSKEGO
WAUKESHA COUNTY, WISCONSIN

FEBRUARY/2008

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LAKE MEADOW WATER SYSTEM
RADIUM COMPLIANCE REPORT

I. BACKGROUND AND PURPOSE

This report presents the results of a preliminary study to evaluate issues related to radium compliance for the Lake Meadow Water Trust (LMWT). Specifically, this report is designed to present the results of a project to:

1. Collect available data on the water system, wells, pumping stations and work completed to date from the water trust and their contractors.

2. Evaluate radium compliance options including:

   - Connection to Muskego system
   - Construction of blending well
   - HMO treatment
   - Ion selective resins
   - Logging and lining of well
   - New private home wells
   - New water softeners at each home

3. Prepare a list of benefits of each option.

4. Prepare opinions of probable cost for each option.

5. Present the results of all investigations in a letter report to the City.

The LMWT serves approximately 223 (per DNR website) connections in the Lake Meadows Subdivision with groundwater. The LMWT is one of three systems in the Southeast District that is not in compliance with the Radionuclide Rule. A meeting was held between the Department of Natural Resources (DNR), the City of Muskego, and LMWT on January 23, 2008 to discuss compliance schedule and the possibility of cooperative assistance from the City of Muskego. LMWT is evaluating options available with regard to compliance and the City of Muskego is concerned regarding the future provision of water to the area. As a result of the meeting, it was determined that an independent review of the potential solutions to the issues facing the LMWT would be commissioned by the City. The LMWT consist of two wells and about three miles of distribution mains. Well 1 is 95 feet deep and capable of producing 200 GPM. Well 2 is 973 feet deep and capable of producing 700 GPM. Water from Well 2 does not meet radionuclide maximum contaminant levels (MCL's) specified in DNR code. Well 3, a test well, has been drilled in proximity to Well 2 and is intended to be developed into a production well for blending purposes. It is 192 feet deep and has not been completely analyzed for use as a public water source.

Attachment A contains available water quality data related to radionuclides for the existing wells.

II. ALTERNATIVE DESCRIPTIONS

The LMWT has limited data available for the amount of water pumped to the system or delivered to customers. The Trust is not required to report to the Wisconsin Public Service Commission and, therefore, is not required to track water pumped. Likewise, the Trust charges customers based on a flat quarterly fee and does not meter water delivered to homes.

A flow meter was recently installed at Well 2 to perform a one-week test recording flows every minute for the seven-day test. During this week-long test, the average flow in the system was 30.6 GPM and the highest daily average was 40.9 GPM. The highest flow rate for any minute during the test was 120 GPM. The preceding flows discount three incidents when the well pump was shut down during the testing and had instantaneous higher flows while being restarted. If it is assumed that 40.9 GPM is equivalent to the average daily flow in summer, then typical peaking factors can be applied to this figure. The City of Muskego's peak day to average day peaking factor is 2.5:1. The Southeastern Wisconsin Regional Planning Commission (SEWRPC) recommends a peak hour to peak day ratio of 2:1 for small water systems. If these two peaking factors are applied to the 40.9 GPM average flow above, the actual calculated peak hour demand for the LMWT would be approximately 205 GPM. Any system leakage could increase the number. For the purposes of this report, a 20 percent safety factor will be used.

Theoretical flows are significantly lower than this figure. Using a SEWRPC value of 70 gallons per capita per day and a regional average of 3.0 person/household, an average water demand of 32.5 GPM is derived. After applying the peak flow factors identified above, the theoretical peak hour flow rate is calculated to be 164 GPM. Given the above estimations and calculations, it is reasonable to assume a value of 220 GPM for peak hourly demand.

Seven alternatives to gain radionuclide compliance have been identified and are discussed in this report. These include:

a. Connection to Muskego public water system

b. Construction of a blending well

c. Construction of an HMO treatment system

d. Construction of an ion selective media treatment system

e. Modification of Well 2 by logging high radionuclide sections and lining those areas

f. Install new private wells at each residence served by the LMWT

g. Installation of individual softeners at residential customer homes

This section of this report describes these options.

A. Connection to the City of Muskego Public Water System

The City of Muskego has long-term plans to include water service to the area of the Lake Meadows Subdivision as identified in their water system master plan completed in late 2007. To accomplish this in the short term, prior to anticipated timing of other developments, such a connection would require that a 12 inch water main be run from the intersection of North Shore Drive and Kelsey Drive to an existing water main in Racine Avenue near Parker Road. If this option were instituted, the City would most likely oversize the new water main to a 16 inch water main in Racine Avenue to meet expected future water needs in the area. The City of Muskego would most likely recover the cost of the base pipe size needed from customers at the LMWT and fund the oversizing charges through impact fees or connection charges when future connections are made. It is assumed that the City of Muskego would then become responsible to provide compliant water to the residents of Lake Meadows Subdivision on a retail basis, although a wholesale agreement could be developed.

B. Blending

Blending consists of mixing water with high radionuclide content with water of low content to achieve a final product which meets the drinking water standard. The DNR has indicated that the required method of blending is physically mixing the water at each well site to form an acceptable product prior to pumping into the distribution system. This can be achieved through a discharge of well water from two or more wells into a common reservoir. It could also be achieved by in-line mixing on pressurized well discharge lines.

For some water systems which do not have enough existing radionuclide free well capacity, blending water from existing high radionuclide wells with water from new wells low in radionuclides prior to pumping into the distribution may be the preferred method of the radionuclide reduction. For example, a new sand and gravel producing water low in radium content could be drilled on the same site or near the site of an existing sandstone well producing water high in radionuclide content. Water from the two sources could be blended at the well site prior to pumping into the distribution system to obtain a final product which meets the standards.

Radionuclide reduction by blending has limiting factors. The production rate needed from a blending source to blend with the volume of water produced from an existing high radionuclide source may be the most limiting factor. The needed production rate from a blending well depends upon the capacity of the existing high radionuclide source, on the concentration of radionuclides in the water and the target level of radionuclides in the final blended water product.

1. Recommended Blending Plan

It has been previously noted that Well 1 currently provides radionuclide compliant water. Wells 2 and Well 3 (the test well) are located on the same site. The production capacity of Well 1 is about 200 gallons per minute (gpm).

Under the proposed blending alternative, water from Well 3 would be directly routed to the discharge pipe of Well No. 2 and mixed with water from Well 2 before entering the distribution system. The radionuclide concentration in the final blended water product is determined by the supply rate of radionuclide compliant water that would be used for blending.

The DNR has indicated in their approval letter dated July 14, 2006 that the blending ratio needs to be 4.4:1 (Well No. 3 to Well No. 2) to meet the gross alpha emission requirements. In order to meet a 4.4:1 blending ratio, the flow of Well No. 3 would have to be approximately 179 GPM and be blended with a flow of 41 GPM from Well No. 2 to meet required demand. DNR requires that the peak hourly demand be met with the highest capacity well out of service. It is estimated that Well No. 3 will produce in excess of 220 GPM when developed. Given the fact that Well No. 1 produces 200 GPM, a larger pump is required in Well No. 1 to meet the peak hourly flow. Peak hourly flows could then be met with either Well No. 1 or Well No. 3. Well No.2 could be set at a limited flow to maintain a blend ratio of 4.4:1 except during fire emergencies.

The recommended blending plan would consist of the following components:

- A new 12 inch diameter dedicated transmission main would be constructed to deliver water discharged from Well 3 to the discharge line for Well 2. This new main would connect to the Well No. 2 discharge main outside of the Well No. 2 pump house.

- A mechanical mixing device would be installed on the Well No. 2 discharge main downstream from the connection to the new transmission main. The mixing device is recommended to insure that the water from the two sources is sufficiently blended to provide sufficient radionuclide reduction prior to the water being delivered to customers.

- A underground metering and control vault would be constructed on the site of Wells 2 and 3. This vault would be constructed as part of the dedicated blending water transmission main. It would include devices which would be used to meter and control the rate of blending water being delivered to Well No. 2. It will allow the blending water flow rate to be adjusted based on the radionuclide quality and quantity of water being supplied from Well No. 3.

The blending ratio recommended above by DNR is based on the average of three samples taken from Well 2 over approximately a seven year period. The latest of these samples indicate that gross alpha emissions are within the compliant range. If this sample result is accurate, the blending ratio would be based on radium samples and could be reduced to 1.2:1 (Well 3:Well 2). This blending ratio allows significantly more of Well 2 water to be used, which is of higher quality in several respects when compared to Wells 1 and 3. It is recommended that prior to any significant investment in blending equipment that additional radionuclide sampling and testing be done to confirm the required blending ratio.

Wells No. 1 and 3 are significantly lower in radionuclide concentration than Well No. 2, hence the ability to blend water described above. It must be noted, though, that Well No. 1 and 3 are of poorer quality in some respects than Well No. 2. Depending more heavily on these wells will deter significantly the water quality in the distribution system and delivered to customers.

Arsenic concentrations in both wells are elevated. Well No. 3 arsenic level has been measured at 8.6 μ/L, which is lower than the Maximum Containment Level (MCL) for arsenic of 10 μ/L. While the tested value is not in excess of the MCL, it is relatively high and could go up or down after Well No. 3 is put in service. Blending this well discharge with Well No. 2 will reduce arsenic levels in the distribution system. Well No. 1 has one sample that tested with a detectible amount for arsenic. This test must be confirmed and treatment may be needed if the arsenic level in Well No. 1 rises above the MCL.

The concentration of iron in Wells No. 1 and 3 is also elevated. There is no MCL for iron, but iron causes many aesthetic and practical problems in water. Staining of clothing, colored water, and staining of fixtures are all problems associated with water that contains the concentration measured in Wells No. 1 and 3. Blending of Well No. 3 water with Well No. 2 water will not substantially help reduce iron levels in the distribution system due to Well No. 2 elevated iron concentrations.

C. HMO Treatment

HMO filtration uses conventional treatment processes for iron and removal from well water. It has long been recognized that a limited amount of radium may be removed as a consequence of iron - manganese treatment processes, as a result of sorption to the metal oxides produced. Sorption is the adhesion of a molecule to the surface of a solid. Removals have generally been observed to increase in the presence of increasing manganous ion and have been attributed primarily to the sorption of radium to hydrous manganese oxides (HMOs) and not to iron oxides, which appear to have a much lower radium sorption potential under typical water treatment conditions.

The sorptive capacity depends on the conditions under which the HMOs are formed, the chemicals used to form them, and the chemistry of the water being treated. Sorption will also depend on the pH and the presence of competing ions such as calcium and barium, which are expected to reduce sorption of radium.

Sorption to freshly precipitated HMOs has been specifically exploited to remove radium from water. High dosages of HMOs have been used to remove very high concentrations of radium from effluents associated with uranium mining and from drinking water.

HMO addition involves the application of a controlled dosage of manganese dioxide to the well water prior to filtration. This is typically accomplished by mixing manganous sulfate and potassium permanganate. The resulting manganese dioxide is used to adsorb the radium. The HMOs, along with iron and manganese, and adsorbed radium are filtered out using a conventional sand filter media.

This treatment alternative should be effective in reducing radionuclide levels in water from Well No. 2. This alternative could be implemented by using a conventional pressure filtration process. Pilot studies would need to be completed in order to determine the optional chemical dosages, pretreatment steps and the order of application. However, the general approach would be as follows: the well water would be pumped directly from the well to a horizontal pressure style filter. Chlorine is usually applied first, followed by pressure aeration, HMO addition, and filtration. The HMO forming chemicals are manganous sulfate and potassium permanganate. The chemical combination of these forms hydrous manganese oxide which absorbs the radium. The manganese oxide adsorbs radium and raw water iron are filtered out using a conventional sand filter.

HMO holds the advantage of removing iron and, to a lesser extent, arsenic; both of which are present in Wells No 1 and 3.

1. Recommended HMO Treatment Plan

   Based on the above description, the HMO treatment alternative plan would consist of the following recommended components:

   - Pilot plant studies would be initially conducted to determine the optimum treatment steps for water from well No. 2. The pilot plant studies would determine optimum chemical dosages and locations, order of pretreatment steps, filter loading rates, and other parameters.

   - Filtration equipment would consist of a horizontal style pressure filter. The filter would have four cells that could be operated and backwashed independently. The equipment would include chemical feed systems and pressure aerator.

- Mechanical piping additions and modifications to the existing building would be constructed. Primarily, these modifications would be constructed to provide for the ability of the well to discharge directly through the filter and to the distribution system.

- A building addition would be constructed to house the filters and mechanical equipment. The estimated size of the addition is 20 feet by 40 feet, or about 800 square feet. The addition would be constructed to be aesthetically compatible with the existing building.

- A large capacity sanitary sewer connection would be constructed from the Well No. 2 pump house to the gravity sewer in the easement for Well 2 which drains to the sanitary sewage lift station serving the subdivision. This connection is needed to convey the wastewater flow rates produced by the filtration.

2. Operation and Maintenance

The most significant operational costs associated with the HMO filtration process are the costs for chemicals and wastewater disposal. The chemical costs are incurred continuously. The wastewater disposal costs are incurred each time the filters are backwashed.

Backwashing frequency can be based upon a maximum fixed run time, head loss through the filter media, or on finished water quality. Backwashing is accomplished by using water from the distribution system and providing a compressed air source simultaneously.

D. Ion Selective Media Treatment

Z-88 Radium Selective Media is a proprietary granular media for radium reduction. It is marketed by Water Remediation Technology, LLC (WRT) of Denver, Colorado. The media product is mined, processed and formulated by WRT. The media is contained within a steel pressure vessel. The system is added to an existing or new well pumping and discharge piping system. Water is passed through the media in an upflow direction which fluidizes the media bed. The radium is removed by means of an ion exchange process.

1. Recommended Selective Media Plan

In a typical WRT Z-88 removal system the raw groundwater is fed into the pressure vessels from the bottom. The vessel contains the WRT media. As water passes through the media, the radium transferred to the media by ion exchange. Water exits the vessel from the top and is subsequently delivered to the distribution system.

Raw groundwater is delivered to the WRT media vessel without any pretreatment. The media is effective at removing radium while not altering other water characteristics. The resulting passive treatment only requires monitoring and sampling. No chemicals are added and no backwash or regeneration of the media is required. When the media reaches its design capacity for radium removal, it is disposed of in a licensed facility and replaced with new material. The process generates no liquid waste streams containing concentrated levels of radium that need disposal. Under a long term contract with the city, WRT would provide the equipment, media, replacement and disposal of the spent media, and maintenance of the process.

The contract duration is typically 20 years. The Trust would purchase the equipment from WRT which furnishes the pressure vessel, media, process piping, controls and instrumentation for the process. This equipment would be furnished for installation by an outside contractor. The media would remain the property of WRT throughout the contract period. At the end of the contract period, a new contract may be negotiated. In the event that a new contract is not negotiated for whatever reason, WRT would presumably remove the media from the pumping facility.

2. Operation and Maintenance

Part of WRT's responsibility during the contract period is to provide services to remove and legally dispose of the spent media, and provide new media. This is not the case for some other similar systems.

Under a long term contract with WRT for use of its media, WRT would be responsible for all media disposal and replacement arrangements and associated costs.

It should be noted that the WRT process will not remove iron or arsenic. In fact, the iron levels in these wells may hinder treatment by WRT.

E. Well Logging and Lining

In many cases, it is possible to reduce radium and gross alpha levels in well water by casing off or backfilling portions of a well bore that produce water with elevated levels of these substances. Radium levels may also be reduced by selectively stimulating portions of the borehole that produce water with low radium levels. The success of this approach depends on the presence of high radium zones in the formation and the presence of shale layers in the formation to act as vertical barriers to prevent migration around the sealed off portions of the well. Geophysical well logging is needed to determine the degree of radium reduction that may be achieved and how much the specific capacity will change. In some cases, the specific capacity is reduced but the pumping rate of the well can be maintained by setting the pump deeper.

This process usually involves removing the well pump and installing a temporary submersible pump, and purging the well. Two sets of geophysical logs are collected. One set of logs is performed during static (non-pumping) conditions. The other set is performed during pumping conditions. Sampling of ground water at various depths is also completed during the pumping conditions. This approach to logging and sampling allows for the assessment of the formation conditions including flow, quality and physical structure. This assessment allows for the determine of which zones, if any, are suitable for treating, sealing off, or lining to reduce flow of radium rich water into the well column. Reduction in radium of any level would potentially reduce blending and/or treatment costs. Because the required level of effort to rehabilitate the well cannot be defined until the logging is completed, the estimated cost of rehabilitation is presented as a rather wide range. The approach is to conduct logging studies on the well. Then, based upon the results of the logging studies, a plan for well lining, backfilling, selective stimulation, or some combination of these can be prepared of the logging studies indicate these could be successful.

Past experience indicates that radium is likely to vary throughout the formations penetrated by the well. Experience has demonstrated that uranium and thorium levels in the formation are not directly correlated to elevated radium and gross alpha levels in the ground water those zones produce. Logging studies that focus on measuring the changes in water production and water quality with depth in the borehole while pumping under normal operating conditions are effective at identifying zones of the aquifer that produce elevated levels of radionuclides and predicting the change in water quality and well capacity that can be achieved by isolating those zones.

If proper testing is conducted, it may be possible to identify and isolate zones of the well that produce poor quality water. It may also be possible to identify and selectively stimulate portions of the well that produce good water quality. With proper analysis, logging information can be used to determine the change in water quality and well capacity that can be expected by rehabilitating the well.

1. Description of Geophysical Logging

Two sets of geophysical logs are run as part of this alternative. One set is run under static (non-pumping) conditions. The other is run under pumping conditions. A description of the static logs is as follows:

- Televising Log - A submersible video camera is lowered down the well and the image is tape recorded in a mobile studio at the surface. The televising is used to determine where the borehole diameter changes due to the use of explosives, where borehole surfaces are rough and irregular, and/or where the borehole may substantially deviate from vertical. The existence of these features needs to be known in order to accurately interpret logging data.

- Natural Gamma Log - This log measures the natural gamma radiation produced by the clay minerals in shale units. This measurement may be used to determine the location and extent of shale rich intervals which may act as vertical confining units that separate the various permeable zones in the aquifer.

- Borehole fluid temperature and resistivity - The bore hole temperature log measures the temperature of the water within the borehole. The fluid resistivity log measures the conductivity (inverse of resistivity) of the water in the borehole. This information is useful in determining how certain water quality parameters change with depth.

- Short and long normal resistivity - These logs measure formation resistivity at various depths. The short resistivity values are more influenced by the volume of water in the borehole. The long resistivity values provide a more accurate measurement of formation resistivity. In aquifer units with similar rock type, changes in formation resistivity will be largely a measurement of the resistivity of the fluid filling the pore spaces.

- Heat pulse flow log - The heat pulse flow meter makes sensitive measurements of flow at distinct depth points by creating a pulse of heated water and recording the transit time to detectors above and below the heating unit. The tool can measure fluid flow at very low velocities and distinguish between upward or downward flow.

A description of the pumping logs is as follows:

- Borehole fluid temperature and resistivity - these are the same as above, except that they are run again while the well is being pumped.

- Spinner log - a spinner flow meter is used to measure the change in production with depth in the borehole while pumping. The spinner flow meter uses an impeller to make continuous flow measurements as the tool is lowered down the well. It can identify distinct flow zones within the well.

- Downhole water sampling - water samples are collected at distinct depths in the well while it is being pumped, using a two inch diameter sampler with an automated sampling port. The samples are analyzed for general water chemistry and radionuclides.

2. Recommended Well Reconstruction Plan

Based on the above descriptions and past experience, the well reconstruction plan would consist of the following recommended components:

- The necessary background data on historical water quality would be acquired and reviewed. Current representative data of interest includes general water chemistry including major ions, combined radium and gross alpha. Most of this information is already on hand. It would be reviewed and updated as necessary.

- The existing well pump would be removed and the initial geophysical logs would be performed. These are the static logs described previously.

- A temporary submersible purge pump would be installed in the well to purge mixed water from the well bore and formation. When a sandstone well is idle, water flows among the different hydraulic zones of the aquifer through the vertical conduit created by the well bore. The head difference between hydraulic zones can exceed 50 feet. This is sufficient to cause millions of gallons of flow between zones in a few days. The net result is an invasion of low head zones by water from higher head zones, which displaces the native formation water in the low head zones. The invaded water must be purged from the formation before accurate water samples can be obtained from every hydraulic zone. This is accomplished by installing a temporary pump that produces enough drawdown to overcome the natural head differences and purges the full aquifer.

- The pumping geophysical logging would be performed. These are the logs previously described.

- Downhole water samples would be collected at selected depths. The data from the dynamic logs is used to select depths where major changes in flow or water quality appear to occur. Water samples would be collected from those depths in the water column in the well while pumping. The water samples would be analyzed for major ions, radium and gross alpha. By using the change in water quality and the measured change in flow in the borehole, the water quality of each interval can be calculated using mass balance equations. The interval water quality and interval water production calculations will be used to identify target zones to isolate or stimulate.

- The data would be analyzed and a report would be prepared with recommendations. The recommended reconstruction program may consist of isolating zones by backfilling or lining, selective stimulation of other intervals, a modification in pumping rate to accommodate head differences between hydraulic zones in the aquifer, or some combination of these. The recommendations will be presented in report that includes the logging data and a discussion of the relevant findings and conclusions.

- A program for well construction would be implemented if appropriate. It is possible that after completion of logging and sampling, it would be determined that well reconstruction is not a viable option for reducing radionuclide levels.

3. Operation and Maintenance

Operation and maintenance costs associated with well reconstruction would be minimal. The most significant O&M cost would be the cost of additional electrical energy required to pump water from the well. This would be due to a decrease in specific capacity of the well caused by the reconstruction. A decrease in specific capacity means that the pumping water level in the well is lower for the same flow rate. This requires that the water be "lifted" a greater distance in order to pressurize the water to distribution system pressures. This means that for the same volume of water pumped, a higher electrical energy cost results. Depending on the exact reconstruction method(s) that may be used, the specific capacity of the well may only decrease slightly, or it may actually increase. Therefore, this increase on O&M costs is not a certain thing.

F. New Private Wells at Homes

Radionuclides are typically found in water drawn from deep sandstone aquifers. Shallow wells are less likely to contain concentrations above the MCL for radionuclides, private, on-site wells serving individual homes are likely to be shallow and in aquifers that do not contain significant concentrations of radionuclides. Private home wells do not undergo the same level of oversight that public water systems do. Reverting to each home having their own well and disbanding the LMWT would eliminate the current non-compliance issues facing the LMWT. Regardless of who funds the initial drilling of the private wells, the cost will ultimately be born by the residents of the LMWT.

The estimated cost to each homeowner would be $12,000. This equates to $2.6 million for the entire subdivision.

G. Installation of Individual Softeners at Residential Customer Homes

One of the Best Available Technologies (BAT) identified by the Environmental Protection Agency (EPA) to treat radionuclide contamination is technically called point-of-entry (POE) treatment with ion exchange water softeners. Under this treatment scenario water softeners are installed in each home to treat all water entering the home.

While EPA lists POE treatment with water softeners as a BAT, the DNR does not consider such treatment to be an option. The ongoing maintenance issues for this type of treatment is not under the direct control of the water provider and therefore water quality may not be in compliance in homes where maintenance is not maintained. Regulations also require regular sampling at each treatment unit. The cost of such testing is typically considered prohibitive. This option was not considered for economic analysis due to the unknown implementation.

III. ADVANTAGES AND DISADVANTAGES OF SYSTEMS

The following chart summarizes the advantages and disadvantages inherent in each of the systems studied.

Advantages and Disadvantages
Radionuclide Treatment Options

Treatment Method	Advantages	Disadvantages
Connection to Muskego Public Water System	1. Assuming retail sales, it makes water system part of municipal water system. 2. In congruence for long-term plans to provide area with water. 3. Opens areas between Lake Meadow and Muskego to water service. 4. Removes water quality compliance obligations from LMWT 5. Fire protection will be available to the area. 6. System O&M becomes responsibility of City. 7. Muskego City water is lower in iron than that produce by LMWT.	1. Long, dead end water main. 2. Highest capital cost.
Construction of a Blending Well	1. Increases water producing capability of system. 2. Employs similar technologies to those currently used. 3. Lowest capital cost. 4. Blending will improve arsenic levels.	1. Total water production limited by shallow well production. 2. Radionuclide concentration in Well #2 may increase. 3. Blending test well contains relatively high (but within existing code) amount of arsenic. 4. Well No. 3 very high in iron.

Treatment Method	Advantages	Disadvantages
Construction of HMO Treatment System	1. Controllable treatment process that can be adjusted to future radionuclide water quality changes. 2. Process also removes iron from well water.	1. High amount of waste generated. 2. Significant amount of operations and maintenance required. 3. Limited capacity in sewers require storage of wastes and slow release. 4. Land requirement may be more than is available on site.
Construction of ION Selective Media Treatment System	1. Highly efficient removal that is selective to radionuclides. 2. Very little operations and maintenance requirements for operators. 3. No chemical addition required for radium removal.	1. Long-term contract that contains minimum charges and locks community to one supplier. 2. Media may be considered low-level radioactive waste. 3. Land requirement may be more than is available on site. 4. High iron concentration may interface with treatment.
Well Logging and Lining	1. Operations and maintenance requirements relatively unchanged after well is modified. 2. Other treatment options exist after well is modified.	1. Effectiveness not known until after logging. 2. Potential to decrease well output. 3. Well out of service while well is being logged, tested, and lined.

Treatment Method	Advantages	Disadvantages
New Private Wells at Homes	1. Responsibility of well operation, maintenance, and compliance taken away from municipality.	1. Distributed contamination potential. 2. Increased number of wells. 3. Future connection to City system doubtful 4. Potential increased health hazard due to lower scrutiny of regulatory agency on water quality. 5. Potential for added site erosion due to many sites. 6. Relatively high cost.
Installation of Water Softeners at Each Home	1. Relatively low installation cost. 2. Other contaminants (hardness) also removed.	1. Not allowed by DNR. 2. High cost of sampling required. 3. Unknown effectiveness due to homeowner controlled maintenance.

IV. COST ESTIMATES

The following pages include charts estimating the capital investment needed for alternative a-e. These estimates are for planning purposes.

V. SUMMARY

This report was commissioned by the City of Muskego to assist the LMWT in their decision-making process as they deal with compliance with radionuclide standards. It is expected that residents of the Lake Meadow Subdivision and the LMWT will take the information contained herein and decide on a compliance plan that meets all parties needs and desires.

From a cost perspective, the least costly alternative appears to be the blending alternative studied. It should be noted that these are planning level estimates and can contain a great deal of variability. Operations and maintenance charges in the LMWT and the City are very similar. The only alternatives that could be expected to have a significant impact on operations and maintenance costs are the two centralized treatment options. Given the imperative nature of this project, the emphasis in this report is on capital costs and not long-term maintenance costs.

It is expected that cost estimates will be refined for the alternative selected as the project progresses.

Table C-1
Connection to City of Muskego Water System Planning Cost Opinion
Lake Meadows Water Trust
Waukesha County, Wisconsin

Proposed Route: Commencing at the south edge of Woodland Creek Subdivision in Racine Avenue, thence south in Racine Avenue to Kelsey Drive, thence west in Kelsey Drive to North Shore Drive for connection.

OPTION 1: 12-Inch Water Main

800 L.F.	12-inch water main in granular backfill	@	$112.00/L.F.	=	$ 89,600.00
400 L.F.	12-inch water main in slurry backfill	@	$140.00/L.F.	=	$ 56,000.00
10,600 L.F.	12-inch water main in spoil backfill	@	$100.00/L.F.	=	$ 1,060,000.00
30 EA.	Hydrants with hydrant valve	@	$3,100.00/EA.	=	$ 93,000.00
500 L.F.	6-inch hydrant lead	@	$60.00/L.F.	=	$ 30,000.00
16 each	12-inch water valves	@	$1,800/EA.	=	$ 28,800.00
200 S.Y.	Pavement replacement	@	$22.00/S.Y.	=	$ 4,400.00
40,000 S.Y.	Restoration	@	$4.00/S.Y.	=	$ 160,000.00
12,000 L.F.	Silt fence	@	$3.00/L.F.	=	$ 36,000.00
			Subtotal	=	$ 1,557,800.00
	30% Contingencies, Administration, and Engineering			=	$ 467,340.00
			Total	=	**$ 2,025,140.00**

OPTION 2: 16-Inch Water Main (Shown for oversizing purposes)

800 L.F.	16-inch water main in granular backfill	@	$132.00/L.F.	=	$ 105,600.00
400 L.F.	16-inch water main in slurry backfill	@	$165.00/L.F.	=	$ 66,000.00
10,600 L.F.	16-inch water main in spoil backfill	@	$122.00/L.F.	=	$ 1,293,200.00
30 EA.	Hydrants with hydrant valve	@	$3,100.00/EA.	=	$ 93,000.00
500 L.F.	6-inch hydrant lead	@	$60.00/L.F.	=	$ 30,000.00
16 each	16-inch water valves	@	$3,100.00/EA.	=	$ 49,600.00
200 S.Y.	Pavement replacement	@	$22.00/S.Y.	=	$ 4,400.00
40,000 S.Y.	Restoration	@	$4.00/S.Y.	=	$ 160,000.00
12,000 L.F.	Silt fence	@	$3.00/L.F.	=	$ 36,000.00
			Subtotal	=	$ 1,837,800.00
	30% Contingencies, Administration, and Engineering			=	$ 551,340.00
			Total	=	**$ 2,389,140.00**

Table C-2
Well No. 2 Radionuclide Reduction
Blending Alternative Planning Cost Opinion
Lake Meadows Water Trust
Waukesha County, Wisconsin

Item No.	Description	Quantity	Unit	Unit Price	Estimated Item Cost
1	New Well Construction	1	Each	93,750	$93,750
2	12 inch Water Main	200	L.F.	120	$24,000
3	Pumping Equipment	1	Each	12,500	$12,500
4	12 inch Isolation Valves	3	Each	1,500	$4,500
5	Building Construction and Internal Piping	1	Each	25,000	$25,000
6	Mechanical Mixing Device	1	Each	9,375	$9,375
7	Metering and Control Vault	1	Each	37,500	$37,500
8	Control System	1	Each	12,500	$12,500
9	Water Quality Analysis	10	Each	500	$5,000
				Subtotal	$224,125
	30% Contingencies, Administration, and Engineering				67,238
				Total Estimated Cost	$291,363

Differential
Operation and Maintenance

Item	Description	$/1,000 Gallons of Finished Water
1	Electricity	0.01[2]

(1) Based on estimate from municipal well and pump dated 3/14/04. Values have been updated to reflect the difference in the Engineering News Record Construction Cost Index for February 2008.
(2) Assumes gravel backfill and pavement replacement.
(3) Based on additional friction loss due to dedicated pipeline and control devices constructed to convey water from Well 3, and an electricity cost of $0.075/kwhr.

Table C-3
Well No. 2 Radionuclide Reduction
HMO Filtration Alternative Planning Cost Opinion
Lake Meadows Water Trust
Waukesha County, Wisconsin

Item No.	Description	Quantity	Unit	Unit Price	Estimated Item Cost
1	Pilot Plant Studies	1	Each	18,750	$18,750
2	Treatment Equipment	1	Each	350,000	$350,000
3	Mechanical and Process Piping	1	Each	75,000	$75,000
4	Building Addition Including Electrical & HVAC	800	Sq. Ft.	250	$200,000
5	Sanitary Sewer Connection	200	L.F.	160	$32,000
6	10'6" x 15' x 30' Backwash Tank and Pump (40,000 gal.)	1	Each	70,000	$70,000
7	Chemical Addition Equipment	1	Each	15,000	$15,000
8	Water Quality Analysis	20	Each	500	$10,000
				Subtotal	$770,750
	30% Contingencies, Administration, and Engineering				231,225
				Total Estimated Cost	$1,001,975

Operation and Maintenance

Item	Description		$/1,000 Gallons(1) of Finished Water
1	Wastewater Disposal		0.02(2)
2	Electricity		0.02(3)
3	Chemicals		0.08(4)
		Total	$0.12

(1) Based on 80 hours of well operation between filter backwashes.
(3) Based on a volumetric wastewater disposal charge of $3.06 per thousand gallons and 21,600 gallons of wastewater produced per backwash.
(3) Includes incremental electricity cost for operation of equipment and for wastewater pumping, with an electricity cost of $0.075/kwhr.
(4) Based on HMO dosage of 1 mg/l.

Table C-4
Well No. 2 Radionuclide Reduction
Ion Selective Media Alternative Planning Cost Opinion
Lake Meadows Water Trust
Waukesha County, Wisconsin

Item No.	Description	Quantity	Unit	Unit Price	Estimated Item Cost
1	Pilot Plant Studies	1	Each	18,750	$18,750
2	Treatment Equipment Contract Payment	1	Each	400,000	$400,000
3	Mechanical and Process Piping	1	Each	75,000	$75,000
4	Building Addition Including Electrical & HVAC	800	Sq. Ft.	250	$200,000
5	Sanitary Sewer Connection	200	L.F.	160	$32,000
6	New Control Center with Variable Frequency Drive	1	Each	75,000	$75,000
7	Water Quality Analysis	20	Each	500	$10,000
				Subtotal	$810,750
	30% Contingencies, Administration, and Engineering				243,225
				Total Estimated Cost	$1,053,975

Operation and Maintenance

Item	Description	$/1,000 Gallons(1) of Finished Water
1	Base Treatment Charge	2.17(2)
2	Electricity	0.02(3)
3	Chemicals	0.08(4)
	Total	2.27(5)

(1) Based on 80 hours of well operation between filter backwashes.
(3) Based on 213 connections and 70,000 gal. Usage per home.
(3) Includes incremental electricity cost for operation of equipment and for wastewater pumping, with an electricity cost of $0.075/kwhr.
(4) Based on HMO dosage of 1 mg/l.
(5) Equates to approximately $40 per quarter additional per home.

Table C-5
Well No. 2 Radionuclide Reduction
Well Reconstruction Alternative Planning Cost Opinion
Lake Meadows Water Trust
Waukesha County, Wisconsin

Item No.	Description	Quantity	Unit	Unit Price	Item Amount
1	Remove Existing Pump and Install Purge Pump	1	Each	$18,000	$18,000
2	Static and Dynamic Logging	1	Each	10,000	$10,000
3	Logging Equipment Rental	1	Each	8,500	$8,500
4	Logging Data Interpretation and Report	1	Each	7,500	$7,500
5	Water Quality Analyses	20	Each	400	$8,000
6	Well Reconstruction	1	Each	200,000	$200,000
7	Test Pumping, Purge Pump Removal, Reinstall Permanent Pump	1	Each	45,000 (1)	$45,000
			Subtotal		$297,000
	Contingencies, Administration, and Engineering 30 percent of Items 1, 6 and 7				$ 78,900
			Total Estimated Cost		$375,900

Differential
Operation and Maintenance

Item	Description	$/1,000 Gallons of Finished Water
1	Electricity	0.03 (2)

(1) This cost is variable based on the specific reconstruction procedure used. The estimate shown is on the high end of the cost range. It is possible that Item 7 would not be implemented, as completion of Items 1-5 may show that well reconstruction may not be sufficiently effective in reducing radionuclides.

(2) Based upon a specific capacity reduction of 30 percent due to well reconstruction, a current specific capacity of about seven gpm per foot of drawdown, and electricity cost of $0.075/kwhr.

Attachment A

Radionuclide Analyses Results
Lake Meadow Water Trust
Waukesha County, Wisconsin

Sample Date	Radium-226 (pCi/l)	Radium-228 (pCi/l)	Combined Radium (pCi/l)	Gross[1] Alpha (pCi/l)
Well No. 1				
3/12/2002	0.29	0.4	0.26	0.6
10/3/2007	1	0.47	1.47	-.35
Well No. 2				
3/12/2002	5.2	2.4	7.6	40
12/10/2002	5.8	2.9	8.7	32
10/3/2007	3.8	2.8	6.6	10.7
Well No. 3				
1/15/2007	0.4	0.9	1.3	3.1[1]
MCL	5	5	5	15

Arsenic and Iron Analysis Results (Maximum Levels)
Lake Meadow Water Trust
Waukesha County, Wisconsin

Samples Site	Arsenic (µg/L)	Iron (mg/L)
Well No. 1	1.8	1.7
Well No. 2	ND	1.5
Well No. 3	8.6	2.7
MCL	10.0	NA

Notes:
(1) Excludes contributions from uranium and radium.