Health Consultation

Metals in Keyes Lake Private Wells
Town of Florence, Florence County, Wisconsin

Final Release with Public Comment

Prepared by the
Wisconsin Department of Health Services
Division of Public Health
Bureau of Environmental and Occupational Health[1]
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Summary and Statement of Issues

In July 2009, the Florence County Health Department requested assistance from the Wisconsin (WI) Department of Health Services (WDHS) to investigate elevated levels of arsenic in private wells around Keyes Lake, located in western Florence County. In 2010, DHS collected private well water samples from 66 homes and found elevated levels of metals in 26 of these wells, with arsenic the most commonly elevated (18 homes).

Conclusion. The Wisconsin (WI) Department of Health Services (WDHS) concludes that multiple homes in the vicinity of Keyes Lake, near the Town of Florence, WI, have levels of heavy metals in their private well water that pose a potential long-term health concern and *a public health hazard* to their residents.

Basis for decision. Analysis of water from 66 private wells around Keyes Lake revealed that 39% have levels of various metals (most commonly arsenic, manganese and lead) above the health advisory levels established by WDHS, the WI Department of Natural Resources (WDNR) or the United States Environmental Protection Agency (US EPA). Chronic ingestion of drinking water containing concentrations of chemicals above their health advisory level may result in adverse health effects.

Next steps. In order to protect community health and well-being, WDHS will continue to work with the Florence County Health Department (FCHD) to obtain safe drinking water for interested residential well owners.

Conclusion. WHDS cannot currently conclude whether other drinking water wells that have not been tested for metals in the area could be harming people's health.

Basis for decision. The basis for this conclusion is that many private wells near Keyes Lake and in Florence County have not been tested for metals, and due to the wide variability in the subsurface geology and individual well characteristics (e.g., age, depth, usage rates), it is difficult to predict the concentrations of metals or other contaminants in groundwater.

Next steps. WDHS will continue to promote awareness of the occurrence of metals, including arsenic, in Florence County wells, and encourage area residents to test their drinking water wells.

Background

Based upon local media reports of a prior WDHS investigation that found elevated levels of naturally occurring arsenic in private wells in Aurora (Florence County) and Niagara (Marinette County), WI, nearby residents living around Keyes Lake grew concerned about the arsenic content of the groundwater supplying their residential wells (*WDHS 2011*). In 2010, at the request of FCHD, WDHS performed metals testing on water samples from 66 private wells surrounding Keyes Lake in Florence County, WI. This investigation found 18 wells (27%) with arsenic levels above the US EPA Maximum Contaminant Level (MCL) and WI groundwater Enforcement Standard (ES) of 0.010 milligrams per liter (mg/L) (*WI Administrative Code 2012*). In addition to arsenic, three other metals (manganese, lead and nickel) were detected in private well samples at concentrations above the US EPA MCL for drinking water and/or the WI ES for groundwater. There are no known industrial or commercial sites in the vicinity that account for the elevated levels of arsenic and other metals detected in the groundwater around Keyes Lake. Geological evidence reviewed here supports the conclusion that elevated arsenic and other metals in these wells occur naturally in this area.

The FCHD, WDNR and WDHS jointly held a public meeting in July 2010 to discuss naturally occurring arsenic and the health effects associated with exposure to arsenic concentrations above the WI ES. WDNR representatives described the geology of the area and explained the natural processes that have resulted in elevated concentrations of arsenic in certain areas of northeastern WI. WDHS staff discussed the adverse health effects from chronic ingestion of water containing elevated concentrations of arsenic and other metals. The initial private well testing results from Keyes Lake were also presented by WDHS. Interested residents that had not yet submitted water samples were given sample kits and training on the proper technique for collecting a water sample. In total, 66 area residents submitted private well water samples for metals analysis at the WI State Lab of Hygiene (WSLH) between June 2010 and August 2010.

Demographics

Keyes Lake is a 195 acre lake located in Florence County, WI, approximately 5 miles from the Michigan border (***Appendix A***). Keyes Lake residents are part of the Town of Florence, which has a population of 2,002. The predominant racial makeup of the Town of Florence is 96.9% Caucasian, 0.1% Hispanic or Latino, and 0.1% American Indian and Alaska Native. In addition, 17.5% of Florence residents are under the age of 18, while 22.1% are over the age of 65. The median household income in the Town of Florence is $17,745; the statewide average is $49,993 (*US Census Bureau 2010*).

Results

Beginning in June 2010, 66 Keyes Lake residents provided samples of their private well water using water test kits provided by WDHS. Of these, 26 wells (39%) tested above a US EPA MCL and/or WI ES: 16 wells (24%) tested only above the arsenic MCL/ES of 0.010 mg/L; 4 wells (6%) tested only above the manganese ES of 0.300 mg/L; and one well tested only above the lead MCL/ES of 0.015 mg/L. Five additional wells tested above an MCL and/or ES for more than one metal. Test results from the private well water samples around Keyes Lake are summarized below in ***Table 1***.

Table 1: Florence County Private Well Testing
Comparison Value Exceedances
June 2010 to August 2010
All units in milligrams per liter (mg/L)

METAL	RANGE DETECTED	LABORATORY REPORTING LIMIT	COMPARISON VALUE	NUMBER OF WELLS (OUT OF 66) ≥ COMPARISON VALUE
Arsenic	nd – 0.086*	0.005	0.010[1]	18
Manganese	nd – 1.160*	0.001	0.300[2]	7
Lead	nd – 0.063*	0.003	0.015[1]	4
Nickel	nd – 0.895*	0.001	0.100[2]	2
Aluminum	nd – 0.072	0.003	0.200[2]	0
Cadmium	nd – nd	0.0005	0.005[1]	0
Chromium	nd – 0.003	0.001	0.100[1]	0
Cobalt	nd – 0.004	0.001	0.040[2]	0
Copper	nd – 1.090	0.002	1.300[1]	0
Vanadium	nd – 0.004	0.001	0.030[2]	0

Notes: nd – not detected
* exceeds WI ES
[1] US EPA MCL and WI ES
[2] WI ES

Discussion

Summary and Outreach

Previous testing of private wells in other areas of northeastern WI indicated that some residents in Florence County and neighboring Marinette County have consumed well water with levels of arsenic and other metals above WI drinking water standards (*WDHS 2011*). At the request of FCHD and local citizens, WDHS and WDNR collaborated to test additional private wells in Florence County around Keyes Lake, near the Town of Florence. WDNR records contain 1,565 well construction reports of private wells existing in Florence County. A public meeting to

discuss naturally occurring toxic metals and the health effects associated with exposure to them was held in July 2010. At this meeting, the WDNR discussed the geology of the Keyes Lake area and explained why elevated levels of naturally occurring metals are being found in some areas. WDHS discussed how arsenic, manganese and lead affect the body and the levels at which adverse health effects can begin to develop in those that are chronically exposed to these metals. Interested residents were given water sample test kits at the end of the meeting and proper sampling technique was demonstrated. The results of the testing showed that 39% (26 of 66) area wells had levels of arsenic, manganese, lead or nickel above their respective MCL and/or ES. These 26 wells expose the community to these metals, since they are used by the owners as their source of water for drinking and cooking. Assuming an average of 2.5 people per residence served by these 26 wells, approximately 65 people were being exposed to levels of metals in their drinking water that could harm their health.

WDHS sent letters to each of the investigation participants, explaining the results of their individual well water analysis. The letters contained advice and information specific to the metals found in their water. It is WDNR and WDHS policy to advise any private well owner with an exceedance of an MCL and/or ES to seek an alternative source of safe drinking water. WDHS also worked with WDNR to help interested residents determine the best available options to obtain a safe supply of drinking water. The results of this study, paired with the subsurface geology of the area, indicate the presence of geologic formations containing groundwater with elevated levels of toxic metals that is accessible in some, but not all, locations in Florence County.

In summary, WDHS found that an estimated 65 residents around Keyes Lake (served by 26 of 66 (39%) private wells) were being exposed to one or more of arsenic, lead, manganese or nickel at levels exceeding the WI DNR enforcement standard. Due to the possibility of health effects associated with long-term consumption of this water, WDHS has categorized the drinking water for these 65 residents as a *public health hazard*. Notably, most wells (around 1,500) in Florence County remain untested for metals. WDHS recommends that all well owners in Florence County have their well water tested for metals at least once, in addition to yearly tests for nitrates and bacteria.

Sources of Toxic Metals in Drinking Water

Approximately 30% of Wisconsin residents rely on their own private drinking water supplies (*WDNR 2012*). In contrast to public drinking water systems, private well water sources are not regularly tested for quality and safety. Industrial, agricultural and other human activities can impact the quality and safety of private water supplies. In addition, some naturally occurring metals present in underground rocks and sediments can be dissolved in groundwater and accumulate at high levels that are potentially harmful to humans. The sources and natural processes that likely contribute to the elevated metals concentrations most commonly detected in private water sources around Keyes Lake are described below.

Arsenic. Most of the arsenic found in groundwater is naturally occurring, deposited in the soil and bedrock layers over millions of years. Three general geochemical processes govern the release of arsenic to groundwater in WI: 1) oxidation of arsenic-bearing sulfide minerals; 2)

desorption of arsenic ions sorbed to aquifer sediments by competitive ions; or 3) reductive dissolution of arsenic-bearing iron and manganese mineral oxides (*Gotkowitz 2003*). Arsenic in WI groundwater is also often associated with elevated levels of iron and manganese. Arsenic can be released from dissolved iron and manganese oxides when the water pH is elevated (>8.5), and also from more neutral groundwater (pH 5.5-7.4) if the conditions are strongly reducing.

Manganese. Manganese is a naturally occurring element found in many types of rocks and soils, as well as groundwater. The level of manganese in groundwater from natural leaching processes can vary widely depending upon the types of rock and minerals present at the water table. Manganese will dissolve more readily in the presence of oxygen poor, slightly acidic groundwater (*Oregon DPH*), which is typical of deep aquifers that contain organic matter. Decomposition of the organic matter depletes oxygen in the water and promotes manganese release from soil or bedrock into groundwater. The amount of dissolved manganese in groundwater may also vary seasonally. For example, an influx of oxygenated surface water during periods of high recharge will prevent manganese dissolution and reduce manganese concentrations in well water. However, as oxygen in the recharge water is consumed, manganese dissolution will resume.

Lead. Lead is a naturally occurring toxic metal and may be found in its pure form or in combination with other minerals. Lead has no nutritional value, but is very valuable in manufacturing. Lead is used in the production of batteries, solder, paints, ammunition, sheet metal, and other metal alloys. Lead is often found in house paint sold before 1978. Since 1978, paint sold for residential use could contain no more than 600 parts per million (ppm) lead, which was further reduced to 90 ppm in 2009. Lead typically binds tightly to soil constituents and only minute amounts reach groundwater. The most likely source of lead in drinking water is from lead found in water pipes, leaded solder and brass faucets, which is most readily dissolved in the presence of acidic groundwater. A prohibition on lead in plumbing materials has been in effect since the mid-1980s as a result of the 1986 Amendments of the Safe Drinking Water Act, but lead may still be found in older household plumbing materials or in water service lines used to bring water from the main to the home.

Keyes Lake Exposure Assessment and Potential Health Concerns

While all drinking water standards are intended to safeguard human health, the degree of protection that exists between the established standard and any expected adverse health effects varies from contaminant to contaminant. The development of drinking water standards is the result of a rigorous evaluation of the available peer-reviewed literature to determine the highest dose at which no adverse effect is demonstrated. An acceptable exposure level is then calculated by dividing the No Observed Adverse Effect Level (NOAEL) by uncertainty factors of 10 (or sometimes 3) to account for limitations of the available data and differences between experimental conditions (e.g., population, exposure parameters) and potential real-world human exposures. When necessary, other technical or practical considerations are also factored into the final comparison value. Comparison values are used in the initial assessment phase, which is often followed by estimated exposure dose calculations that can then be used to guide actions and recommendations to minimize human exposure to contaminants. For drinking water contaminants, exposure estimates are compared to the appropriate ATSDR Minimum Risk Level

(MRL) or US EPA Reference Dose (RfD). As arsenic, manganese and lead were most commonly detected above their US EPA MCL and/or WI ES in private wells around Keyes Lake, an exposure assessment and the potential adverse health effects associated with their chronic ingestion are discussed in greater detail below:

Arsenic. Health guidance values typically indicate a threshold to halt drinking water consumption at contaminant levels well below those known to cause adverse health effects. However, there is only a 3-fold safety factor between the NOAEL and the ATSDR MRL and US EPA RfD of 3 x 10^{-4} mg As/kg-day (*ATSDR 2012; US EPA 1993*). In fact, children less than one year of age consuming water at the mean ingestion rate and the US EPA MCL and WI ES concentration (0.010 mg/L) would receive a Central Tendency Exposure (CTE) dose of 6.5 x 10^{-4} mg As/kg-day (***Appendix B***), more than twice the ATSDR MRL and US EPA RfD. Drinking water at the 95th percentile ingestion rate and an arsenic concentration of 0.010 mg/L would result in a Reasonable Maximum Exposure (RME) dose above the ATSDR MRL and US EPA RfD for all age groups and above the NOAEL for children less than 1 year of age. Thus, while WDHS always recommends that people reduce or eliminate their exposure to drinking water with a contaminant level at or above the US EPA MCL or WI ES, arsenic is of special concern.

Ingestion of inorganic arsenic has been linked to a number of adverse health effects. Of particular relevance to this investigation, long-term exposure to elevated arsenic levels in drinking water is known to increase risks of skin, bladder, lung, liver, colon and kidney cancer (*ATSDR 2007a*). The US EPA has classified inorganic arsenic as a "human carcinogen" based on studies demonstrating increased cancer mortality in multiple human populations following chronic inhalation of arsenic-containing dust and fumes (lung cancer) or ingestion of drinking water high in inorganic arsenic (liver, kidney, lung, bladder and skin cancers) (*US EPA 1998*). Locally, an investigation of the health outcomes of more than 2,000 WI families exposed to inorganic arsenic from private well water was conducted by WDHS in 2002 (*Knobeloch 2006*). Skin cancer rates were highest among people who had long-term exposure to arsenic-contaminated water and also smoked cigarettes. The combined effect of arsenic from water and cigarette use was slightly more than additive. In this investigation, the age-specific CTE- and RME-based excess cancer risks for all age groups in homes with arsenic concentrations at or above the US EPA MCL and WI ES are higher than the acceptable excess cancer risk (1 x 10^{-6} or 1 excess cancer per 1,000,000 population). Additionally, the cumulative lifetime cancer risks are 2 orders of magnitude higher than the acceptable excess cancer risk at the US EPA MCL and WI ES of 0.010 mg/L (CTE: 2.38 x 10^{-4}; RME: 5.75 x 10^{-4}) and 3 orders of magnitude higher at the maximum arsenic concentration (0.086 mg/L) detected at Keyes Lake (CTE: 2.05 x 10^{-3}; RME: 4.94 x 10^{-3}) (***Appendix B***).

In addition to increasing one's risk of cancer, chronic ingestion of inorganic arsenic may also result in a number of other adverse health effects, including blood vessel damage, high blood pressure, nerve damage, anemia, and skin changes (*ATSDR 2007a*). Drinking water containing arsenic between 0.300 and 30 mg/L can cause stomach ache, nausea, vomiting and diarrhea. Some recent studies have also linked arsenic with Type 2 diabetes mellitus. A study of US adults exposed to arsenic in drinking water found that elevated total urine arsenic was associated with an increased prevalence of type 2 diabetes (*Navas-Acien 2008*), and a large case-control study in Mexico found that people with drinking water sources containing inorganic arsenic

between 0.020 to 0.400 mg/L had an increased risk of diabetes (*Coronado-González 2007*). The most characteristic effect of long-term oral exposure to inorganic arsenic is a pattern of skin changes that include the development of patches of darkened skin and the appearance of small "corns" or "warts" on the palms, soles of feet and torso. Oral exposure data from population studies indicate that these lesions typically begin to manifest at arsenic exposure levels between 0.002 and 0.020 mg/kg-day (roughly 0.070 to 0.700 mg/L in drinking water, for an adult). The highest arsenic concentration detected in this study (0.086 mg/L) falls within this range. Drinking water at 0.086 mg/L would result in age-specific CTE and RME doses above the NOAEL for all age groups, with the RME for children under 1 year of age (1.23×10^{-2} mg As/kg-day) approaching the LOAEL (1.40×10^{-2} mg As/kg-day) (***Appendix B***). In conclusion, WDHS has categorized the drinking water from 18 private wells around Keyes Lake *"a public health hazard"* on the basis that average or greater ingestion would result in daily doses for all age groups above the ATSDR MRL and US EPA RfD, as well as a theoretical excess lifetime cancer risk in the range of 1-in-10,000 to more than 1-in-1,000.

Manganese. Evaluating the levels of manganese that are harmful to people is challenging because small amounts of the element are essential for normal physiological processes in both humans and animals. Among humans, adverse health effects have been linked to both manganese dietary deficiencies and excess exposures. Manganese is found in many foods, and is essential for good health. Manganese is important in the formation of bones, and in the metabolism of amino acids, cholesterol and carbohydrates. For adolescents and adults, the National Academy of Sciences (NAS) recommends a daily intake of manganese from 1.6 to 2.3 mg/day for adults, and 2.6 mg/day for women who are breast-feeding. For children between 1 and 8 years of age, the recommended daily intake for manganese is between 1.2 and 1.5 mg/day for children from 1 to 8 years of age, 0.6 mg/day for ages 7 to 12 months, and 0.003 mg/day for ages 0 to 6 months (NAS 2001). Due to its potential toxicity, the NAS has also determined the Tolerable Upper Intake (TUI) for manganese. The TUI for adolescents and adults is 6 to 11 mg/day, and 2 to 3 mg/day for children aged 1 to 8 years of age. For infants, NAS was unable to establish an acceptable upper level of manganese because of the inability of infants to handle excess amounts of the element. Consequently, NAS recommends that infants only drink purified water, such that their only source of manganese is from food or formula.

Long-term exposures to high levels of manganese can result in adverse health effects, but there is little evidence to indicate that manganese causes cancer in animals and no evidence it causes cancer in humans (*ATSDR 2008*). The US EPA has categorized manganese as a Class "D" carcinogen, which is "not classifiable as to human carcinogenicity" (*US EPA 2007*). With regard to noncancer toxicities, the central nervous system is the primary target of excess manganese levels. Most human studies have demonstrated notable systemic toxicities as a result of manganese inhalation. Occupational studies of workers who inhaled dust with very high amounts of manganese found higher rates of neurological effects than workers who inhaled lesser amounts of manganese. Unfortunately, there is limited information on the toxicity of oral manganese exposures in humans, although a Greek study of manganese in drinking water suggests an association between elevated manganese levels and decreased neurologic function (*Kondakis 1989*). Acute and chronic animal studies also confirm that the central nervous system is the primary target of manganese toxicity, and that the liver can also be adversely affected by high manganese concentrations in drinking water (*US EPA 2004*).

ATSDR has not developed a chronic oral MRL for manganese; however, US EPA has calculated an RfD of 0.140 mg/kg-day based on average dietary intakes and studies demonstrating central nervous system effects in humans via this route of exposure (*US EPA 2007*). Of note, the US EPA RfD is also equal to the NOAEL for manganese. Although 7 of the 66 wells tested (10.6%) in the vicinity of Keyes Lake had manganese levels in excess of the WI ES, calculations of age-specific CTE and RME doses found that only 2 wells had levels of manganese (1.020 and 1.160 mg/L) that would result in an RME dose over the US EPA RfD/NOAEL, and only for children under 1 year of age (***Appendix C***). Regardless, WDHS considers the drinking water of homeowners with concentrations of manganese over the WI ES of 0.300 mg/L as "*a public health hazard*" and suggest they follow the recommendations listed at the end of this Health Consultation, especially if children reside in the home.

Lead. Lead is a well-known developmental neurotoxin, and also affects the kidneys, blood, reproduction, humoral immunity and the peripheral nervous system (*ATSDR 2007b*). Long-term lead exposure for working adults is associated with decreased performance in some tests that measure functions of the nervous system. Lead exposure may also cause weakness in fingers, wrists, or ankles. Lead may also cause anemia. In pregnant women, high levels of exposure to lead may cause miscarriage. According to ATSDR there is no conclusive proof that lead causes cancer, although both the US Department of Heath and Human Services and US EPA have determined that lead is a probable human carcinogen. Children are more sensitive to the effects of lead than adults, and studies show that even low lead levels that do not affect adults can be detrimental to a child's cognitive development. The potential adverse health effects associated with childhood lead ingestion are expanded in the next section.

Neither ATSDR nor US EPA have developed an MRL or RfD for lead, but the US EPA MCL and WI ES for lead in water is 0.015 mg/L. In this study, 4 out of 66 wells tested (6.1%) had lead concentrations in excess of the 0.015 mg/L, which is of particular concern for those homes where children reside. Since the levels of lead being consumed in drinking water by 4 households were above the health guidance standards, WDHS further evaluated the potential lead exposure of these residents using the US EPA Integrated Exposure Uptake Biokinetic Model for children (IEUBK; *EPA 2010*). The model has 100 input parameters that account for various sources of ingested and inhaled lead in the environment. Default inputs and assumptions were used for all parameters except for ingestion of lead-contaminated drinking water. The IEUBK model predicts that 2 of the 4 Keyes Lake wells exceeding the US EPA MCL and WI ES for lead would result in child blood lead levels above 5 µg/dL, which is the new CDC public health reference value (*ATSDR 2012b*). However, as there is no known safe level of lead exposure for children, WDHS considers all drinking water sources over the US EPA MCL and WI ES to be *"a public health hazard."*

Child Health Considerations

In communities faced with air, water, or food contamination, the many physical differences between children and adults demand special emphasis. Children could be at greater risk than are adults from certain kinds of exposure to hazardous substances. Children play outdoors and sometimes engage in hand-to-mouth behaviors that increase their exposure potential. Children

are shorter than are adults; this means they breathe dust, soil, and vapors close to the ground. A child's lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage. Finally, children are dependent on adults for access to housing, for access to medical care, and for risk identification. Thus, adults need as much information as possible to make informed decisions regarding their children's health.

Children are exposed to arsenic in many of the same ways as adults. Since children tend to eat or drink a smaller variety of foods and beverages than do adults, ingestion of contaminated food or juice or infant formula made with arsenic-contaminated water may represent a significant source of exposure. Children who are exposed to inorganic arsenic may exhibit many of the same adverse health effects as adults, including irritation of the stomach and intestines, blood vessel damage, skin changes, and reduced nerve function. Prenatal and early childhood exposures to arsenic can increase the risk of lung cancer and respiratory disease in later life. There is some evidence that exposure to arsenic in early life (including gestation and early childhood) may increase mortality in young adults. There is also some evidence suggesting that long-term exposure to inorganic arsenic may result in lower IQ scores (*see* ***Appendix D***, for a child-specific public health statement).

Studies in children suggest that exposure to extremely high levels of manganese may produce undesirable effects on brain development, including changes in behavior and decreases in the ability to learn and retain information. Whether these changes were caused by manganese alone, or whether they are temporary or permanent is still unresolved. Although experiments in laboratory animals indicate that children may be more sensitive than adults to the adverse effects of manganese, it is unclear whether this is the case in humans. Studies of animals and workers exposed to elevated levels of manganese have not found increases in birth defects or decreases in birth weights.

Children are much more sensitive to the health effects of lead than adults, such that there is no blood lead level that is widely considered to be safe for children. Lead affects children in different ways depending upon their level of exposure. Exposure to high levels of lead may increase the risk of children developing anemia, kidney damage, colic, muscle weakness, and brain damage. Exposure to moderate levels of lead may affect development and behavior, while low levels can affect a child's cognitive abilities and physical growth. Fetal exposure to lead is associated with premature birth and low birth weight. Fetal and early childhood exposure to lead has also been linked to decreased cognitive development and reduced intelligence in early childhood, and evidence suggests that these effects may persist into adulthood (*see* ***Appendix E***, for a child-specific public health statement).

Conclusions

Regarding metals testing of residential drinking water wells in Florence County, WDHS reached two important conclusions:

- Because residents served by 26 private drinking water wells (39% of tested wells) in Florence County were identified as being exposed to arsenic, lead, manganese or nickel at levels associated with possible long-term health effects, WDHS concludes that the exposures from these wells could harm people's health.

- WDHS cannot currently conclude whether other private drinking water wells that have not been tested for metals in the area could be harming people's health. WDHS is working with the FCHD and WDNR to promote testing of drinking water wells for metals, especially arsenic, in the area.

Recommendations

WDHS and WDNR officials do not have regulatory authority over private residential wells. However, to protect the health of residents in the vicinity of Keyes Lake, WDHS recommends the following actions:

- WDHS recommends that all well owners in Florence County have their well water tested for metals at least once, in addition to yearly tests for nitrates and bacteria.
- WDHS recommends that well owners with elevated levels of metals discuss their well test results with their health care providers and have their exposure history recorded in their medical record.
- WDHS recommends that well owners with elevated levels of metals take actions to obtain a safe source of drinking water. Actions may include altering the depth of an existing well, drilling a new well, updating plumbing and fixtures, installing a water purification system or connecting to an existing municipal system.
- WDHS recommends well owners who make changes to their existing well or plumbing, conduct follow-up testing to ensure that the measures taken result in a safe source of drinking water.

Public Health Action Plan

The public health action plan (PHAP) identifies actions that have been or will be taken by public health agencies for well owners in Florence County. The PHAP ensures that public health hazards have been identified and that a plan of action is established to halt or prevent unsafe exposures to hazardous substances in the environment.

Actions that have been taken by agencies for this site include:

- WDHS sent individualized results letters to all the participants in this study containing advice and information specific to the metals found in their water.
- WDHS held an informational meeting in Florence County in July 2010 to discuss the results of the residential drinking water well testing conducted over the preceding months. Staff from the WDNR, WDHS and FCHD discussed the results of well water testing, options for residents affected by high levels of arsenic and other metals in their wells, and answered questions about the potential health effects associated with chronic ingestion of arsenic and other metals.
- WDNR and WDHS worked together to assist interested residents in determining the best available options to obtain a safe supply of drinking water.
- WDNR established a well advisory requiring that an arsenic test be conducted for all new wells in Florence County.
- WDHS has solicited comments on this Health Consultation from members of the public in local and state newspapers. **Appendix F** contains the official Public Comment Notice and the response of WDHS to all comments received.

Current and future actions to be implemented by agencies are:

- WDHS will continue to communicate and collaborate with the staff at the WDNR and local public health departments to address public health questions and concerns relating to arsenic in well water.
- WDHS will continue to promote awareness among area residents of the need to test their private wells due to the presence of arsenic and other metals in groundwater.

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References

ATSDR. 2007a. Toxicological Profile for Arsenic – Updated. Agency for Toxic Substances and Disease Registry, Atlanta, GA: US Department of Health and Human Services, Public Health Service. Available at URL: http://www.atsdr.cdc.gov/ToxProfiles/tp2.pdf

ATSDR. 2007b. Toxicological Profile for Lead – Updated. Agency for Toxic Substances and Disease Registry, Atlanta, GA: US Department of Health and Human Services, Public Health Service. Available at URL: http://www.atsdr.cdc.gov/ToxProfiles/tp13.pdf.

ATSDR. 2008. Draft Toxicological Profile for Manganese – Updated. Agency for Toxic Substances and Disease Registry, Atlanta, GA: US Department of Health and Human Services, Public Health Service. Available at URL: http://www.atsdr.cdc.gov/ToxProfiles/tp151.pdf

ATSDR. 2012a. Minimum Risk Levels (MRLs) for Hazardous Substances. Agency for Toxic Substances and Disease Registry, Atlanta, GA: US Department of Health and Human Services, Public Health Service.
Available at URL: http://www.atsdr.cdc.gov/mrls/pdfs/atsdr_mrls_february_2012.pdf

ATSDR. 2012b. CDC Response to Advisory Committee on Childhood Lead Poisoning Prevention Recommendations in "Low Level Lead Exposure Harms Children: A Renewed Call of Primary Prevention". Agency for Toxic Substances and Disease Registry, Atlanta, GA: US Department of Health and Human Services, Public Health Service.
Available at URL:
http://www.cdc.gov/nceh/lead/ACCLPP/CDC_Response_Lead_Exposure_Recs.pdf

Coronado-González JA, Del Razo LM, García-Vargas G, Sanmiguel-Salazar F and Escobedo-de la Peña J. 2007. Inorganic arsenic exposure and type 2 diabetes mellitus in Mexico. Environmental Research 104:(383-389).

Gotkowitz MB, Simo JA and Schreiber M. 2003. Geologic and Geochemical Controls on Arsenic in Groundwater in Northeastern WI. WI Geological and Natural History Survey. Available at URL: http://dnr.wi.gov/org/water/dwg/gw/research/reports/152.pdf

Knobeloch L, Zierold KM, Anderson HA. 2006. Association of arsenic-contaminated drinking water with prevalence of skin cancer in WI's Fox River Valley. Journal of Health, Population and Nutrition 24(2):206-213.

Kondakis, XG, N. Makris, M. Leotsinidis, M. Prinou and T. Papapetropoulos. 1989. Possible health effects of high manganese concentration in drinking water. Archives of Environmental Health 44(3):175-178.

National Academy of Sciences (NAS), Institute of Medicine, Food and Nutrition Board. 2001. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Available at URL: http://www.nal.usda.gov/fnic/DRI//DRI_Vitamin_A/vitamin_a_full_report.pdf.

Navas-Acien A, Silbergeld EK, Pastor-Barriusso R and Guallar E. 2008. Arsenic exposure and prevalence of type 2 diabetes in US adults. Journal of the American Medical Association 300(7):845-846.

Oregon Public Health Division. 2012. Iron (Fe) and Manganese (Mn) in Groundwater. Available at URL: http://public.health.oregon.gov/HealthyEnvironments/DrinkingWater/SourceWater/Documents/gw/FeMnInGroundwater.pdf

US Census Bureau. 2010. 2010 Census Interactive Population Search: WI – Florence County. Available at URL: http://2010.census.gov/2010census/popmap/ipmtext.php

US EPA. 1993. Arsenic, inorganic (CASRN 7440-38-2): Reference Dose for Chronic Oral Exposure (RfD). Available at URL: http://www.epa.gov/ncea/iris/subst/0278.htm

US EPA. 1998. Arsenic, inorganic (CASRN 7440-38-2): Carcinogenicity Assessment for Lifetime Exposure. Available at URL: http://www.epa.gov/ncea/iris/subst/0278.htm

US EPA. 2004. Drinking Water Health Advisory for Manganese. Available at URL: www.epa.gov/safewater/ccl/pdfs/reg_determine1/support_cc1_magnese_dwreport.pdf.

US EPA. 2007. Manganese (CASRN 7439-96-5) on the Integrated Risk Information System (IRIS). Available at URL: http://www.epa.gov/ncea/iris/subst/0373.htm

US EPA. 2010. Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBKwin v1.1 build 11). Available at URL: http://www.epa.gov/superfund/lead/products.htm

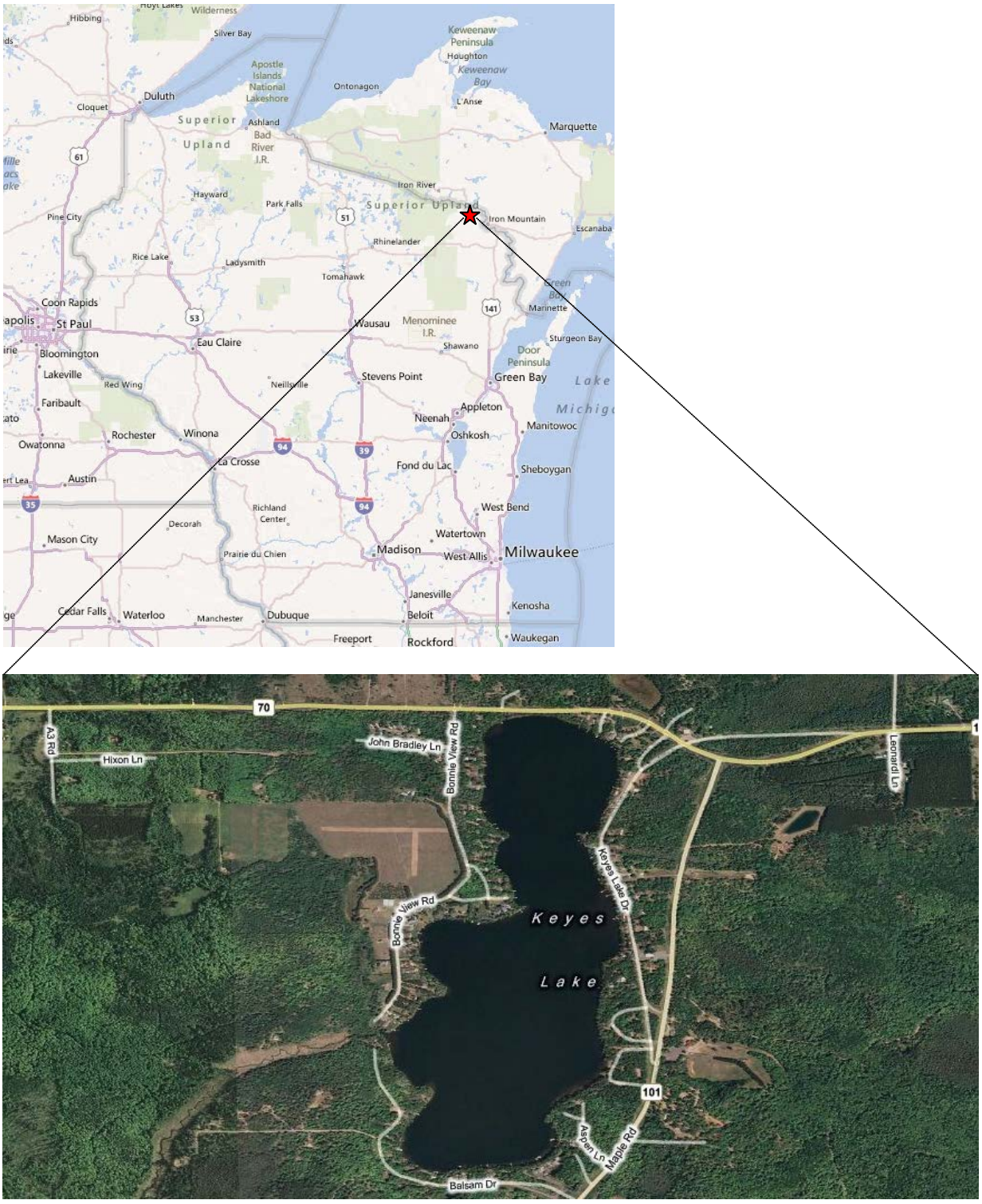
WI Administrative Code. 2012. Groundwater Quality – Chapter NR 140. Available at URL: www.legis.state.wi.us/rsb/code/nr/nr140.pdf

WDHS. 2011. Arsenic and Other Trace Metals in Private Wells: Florence and Marinette Counties, WI.

WDNR. 2012. Drinking Water and Groundwater. Available at URL: http://dnr.wi.gov/org/water/dwg/

Appendix

Appendix A. Map of Keyes Lake and surrounding area. Town of Florence, Florence County, WI.



Appendix B. Arsenic dose exposure calculations.

Keyes Lake Age-Specific Comparison Value Exposure and Cancer Risk

Age Range	Concentration (mg/L)	Ingestion Rate (L/day)		Exposure Factor	Body Weight (kg)	Exposure Dose (mg/kg-day)		Chronic Oral MRL (mg/kg-day)	Oral NOAEL (mg/kg-day)	Oral LOAEL (mg/kg-day)	Exposure Duration (yr)	CSF	Cancer Risk	
		Mean	95th Percentile			CTE	RME						CTE	RME
Birth to <1 year	0.010	0.504	1.113	1.0	7.8	0.00065	0.00143	0.00030	0.00080	0.01400	1	1.5	1.24E-05	2.74E-05
1 to <2 year	0.010	0.308	0.893	1.0	11.4	0.00027	0.00078				1	1.5	5.20E-06	1.51E-05
2 to <6 year	0.010	0.402	1.052	1.0	17.4	0.00023	0.00060				4	1.5	1.78E-05	4.65E-05
6 to <11 year	0.010	0.480	1.251	1.0	31.8	0.00015	0.00039				5	1.5	1.45E-05	3.78E-05
11 to <21 year	0.010	0.753	2.042	1.0	64.2	0.00012	0.00032				10	1.5	2.26E-05	6.12E-05
21 to <65 year	0.010	1.183	2.848	1.0	80.0	0.00015	0.00036				44	1.5	1.25E-04	3.01E-04
65+ year (78 avg.)	0.010	1.242	2.604	1.0	76.0	0.00016	0.00034				13	1.5	4.09E-05	8.57E-05
												Total	2.38E-04	5.75E-04

Keyes Lake Age-Specific Maximum Study Concentration Exposure and Cancer Risk

Age Range	Concentration (mg/L)	Ingestion Rate (L/day)		Exposure Factor	Body Weight (kg)	Exposure Dose (mg/kg-day)		Chronic Oral MRL (mg/kg-day)	Oral NOAEL (mg/kg-day)	Oral LOAEL (mg/kg-day)	Exposure Duration (yr)	CSF	Cancer Risk	
		Mean	95th Percentile			CTE	RME						CTE	RME
Birth to <1 year	0.086	0.504	1.113	1.0	7.8	0.00556	0.01227	0.00030	0.00080	0.01400	1	1.5	1.07E-04	2.36E-04
1 to <2 year	0.086	0.308	0.893	1.0	11.4	0.00232	0.00674				1	1.5	4.47E-05	1.30E-04
2 to <6 year	0.086	0.402	1.052	1.0	17.4	0.00199	0.00520				4	1.5	1.53E-04	4.00E-04
6 to <11 year	0.086	0.480	1.251	1.0	31.8	0.00130	0.00338				5	1.5	1.25E-04	3.25E-04
11 to <21 year	0.086	0.753	2.042	1.0	64.2	0.00101	0.00274				10	1.5	1.94E-04	5.26E-04
21 to <65 year	0.086	1.183	2.848	1.0	80.0	0.00127	0.00306				44	1.5	1.08E-03	2.59E-03
65+ year (78 avg.)	0.086	1.242	2.604	1.0	76.0	0.00141	0.00295				13	1.5	3.51E-04	7.37E-04
												Total	2.05E-03	4.94E-03

Abbreviations
CTE = Central Tendency Exposure
RME = Reasonable Maximum Exposure
MRL = Minimum Risk Level
NOAEL = No Observable Adverse Effect Level
LOAEL = Lowest Observed Adverse Effect Level
CSF = Cancer Slope Factor

Appendix C. Manganese dose exposure calculations.

Keyes Lake Age-Specific Comparison Value Exposure and Cancer Risk

Age Range	Concentration (mg/L)	Ingestion Rate (L/day)		Exposure Factor	Body Weight (kg)	Exposure Dose (mg/kg-day)		US EPA Oral RfD (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	Exposure Duration (yr)	CSF	Cancer Risk	
		Mean	95th Percentile			CTE	RME						CTE	RME
Birth to <1 year	0.300	0.504	1.113	1.0	7.8	0.01938	0.04281	0.14000	0.14000	None	1	N/A	0.00E+00	0.00E+00
1 to <2 year	0.300	0.308	0.893	1.0	11.4	0.00811	0.02350				1	N/A	0.00E+00	0.00E+00
2 to <6 year	0.300	0.402	1.052	1.0	17.4	0.00693	0.01814				4	N/A	0.00E+00	0.00E+00
6 to <11 year	0.300	0.480	1.251	1.0	31.8	0.00453	0.01180				5	N/A	0.00E+00	0.00E+00
11 to <21 year	0.300	0.753	2.042	1.0	64.2	0.00352	0.00954				10	N/A	0.00E+00	0.00E+00
21 to <65 year	0.300	1.183	2.848	1.0	80.0	0.00444	0.01068				44	N/A	0.00E+00	0.00E+00
65+ year (78 avg.)	0.300	1.242	2.604	1.0	76.0	0.00490	0.01028				13	N/A	0.00E+00	0.00E+00
												Total	0.00E+00	0.00E+00

Keyes Lake Age-Specific Maximum Study Concentration Exposure and Cancer Risk

Age Range	Concentration (mg/L)	Ingestion Rate (L/day)		Exposure Factor	Body Weight (kg)	Exposure Dose (mg/kg-day)		US EPA Oral RfD (mg/kg-day)	NOAEL (mg/kg-day)	LOAEL (mg/kg-day)	Exposure Duration (yr)	CSF	Cancer Risk	
		Mean	95th Percentile			CTE	RME						CTE	RME
Birth to <1 year	1.160	0.504	1.113	1.0	7.8	0.07495	0.16552	0.14000	0.14000	None	1	N/A	0.00E+00	0.00E+00
1 to <2 year	1.160	0.308	0.893	1.0	11.4	0.03134	0.09087				1	N/A	0.00E+00	0.00E+00
2 to <6 year	1.160	0.402	1.052	1.0	17.4	0.02680	0.07013				4	N/A	0.00E+00	0.00E+00
6 to <11 year	1.160	0.480	1.251	1.0	31.8	0.01751	0.04563				5	N/A	0.00E+00	0.00E+00
11 to <21 year	1.160	0.753	2.042	1.0	64.2	0.01361	0.03690				10	N/A	0.00E+00	0.00E+00
21 to <65 year	1.160	1.183	2.848	1.0	80.0	0.01715	0.04130				44	N/A	0.00E+00	0.00E+00
65+ year (78 avg.)	1.160	1.242	2.604	1.0	76.0	0.01896	0.03975				13	N/A	0.00E+00	0.00E+00
												Total	0.00E+00	0.00E+00

Abbreviations
CTE = Central Tendency Exposure
RME = Reasonable Maximum Exposure
RfD = Reference Dose
NOAEL = No Observable Adverse Effect Level
LOAEL = Lowest Observed Adverse Effect Level
CSF = Cancer Slope Factor

Appendix D. How can arsenic affect children? A public health statement from the Agency for Toxic Substances and Disease Registry's *Toxicological Profile for Arsenic* (ATSDR 2007).

1.6 HOW CAN ARSENIC AFFECT CHILDREN?

This section discusses potential health effects in humans from exposures during the period from conception to maturity at 18 years of age.

Children are exposed to arsenic in many of the same ways that adults are. Since arsenic is found in the soil, water, food, and air, children may take in arsenic in the air they breathe, the water they drink, and the food they eat. Since children tend to eat or drink less of a variety of foods and beverages than do adults, ingestion of contaminated food or juice or infant formula made with arsenic-contaminated water may represent a significant source of exposure. In addition, since children often play in the soil and put their hands in their mouths and sometimes intentionally eat soil, ingestion of contaminated soil may be a more important source of arsenic exposure for children than for adults. In areas of the United States where natural levels of arsenic in the soil and water are high, or in areas in and around contaminated waste sites, exposure of children to arsenic through ingestion of soil and water may be significant. In addition, contact with adults who are wearing clothes contaminated with arsenic (e.g., with dust from copper- or lead-smelting factories, from wood-treating or pesticide application, or from arsenic-treated wood) could be a source of exposure. Because of the tendency of children to taste things that they find, accidental poisoning from ingestion of pesticides is also a possibility. Thus, although most of the exposure pathways for children are the same as those for adults, children may be at a higher risk of exposure because of normal hand-to-mouth activity.

Children who are exposed to inorganic arsenic may have many of the same effects as adults, including irritation of the stomach and intestines, blood vessel damage, skin changes, and reduced nerve function. Thus, all health effects observed in adults are of potential concern in children. There is also some evidence that suggests that long-term exposure to inorganic arsenic in children may result in lower IQ scores. We do not know if absorption of inorganic arsenic from the gut in children differs from adults. There is some evidence that exposure to arsenic in early life (including gestation and early childhood) may increase mortality in young adults.

There is some evidence that inhaled or ingested inorganic arsenic can injure pregnant women or their unborn babies, although the studies are not definitive. Studies in animals show that large doses of inorganic arsenic that cause illness in pregnant females can also cause low birth weight, fetal malformations, and even fetal death. Arsenic can cross the placenta and has been found in fetal tissues. Arsenic is found at low levels in breast milk.

In animals, exposure to organic arsenic compounds can cause low birth weight, fetal malformations, and fetal deaths. The dose levels that cause these effects also result in effects in the mothers.

Appendix E. How can lead affect children? A public health statement from the Agency for Toxic Substances and Disease Registry's *Toxicological Profile for Lead* (ATSDR 2007).

1.6 HOW CAN LEAD AFFECT CHILDREN?

This section discusses potential health effects in humans from exposures during the period from conception to maturity at 18 years of age.

Studies carried out by the Centers for Disease Control and Prevention (CDC) show that the levels of lead in the blood of US children have been getting lower and lower. This result is because lead is banned from gasoline, residential paint, and solder used for food cans and water pipes. However, about 310,000 US children between the ages of 1 and 5 years are believed to have blood lead levels equal or greater than 10 μg/dL, the level targeted for elimination among young children in the Unites States by 2010.

Children are more vulnerable to lead poisoning than adults. Children are exposed to lead all through their lives. They can be exposed to lead in the womb if their mothers have lead in their bodies. Babies can swallow lead when they breast feed, or eat other foods, and drink water that contains lead. Babies and children can swallow and breathe lead in dirt, dust, or sand while they play on the floor or ground. These activities make it easier for children to be exposed to lead than adults. The dirt or dust on their hands, toys, and other items may have lead particles in it.
In some cases, children swallow nonfood items such as paint chips; these may contain very large amounts of lead, particularly in and around older houses that were painted with lead-based paint. The paint in these houses often chips off and mixes with dust and dirt. Some old paint contains as much as 50% lead. Also, compared with adults, a bigger proportion of the amount of lead swallowed will enter the blood in children.

Children are more sensitive to the health effects of lead than adults. No safe blood lead level in children has been determined. Lead affects children in different ways depending on how much lead a child swallows. A child who swallows large amounts of lead may develop anemia, kidney damage, colic (severe "stomach ache"), muscle weakness, and brain damage, which ultimately can kill the child. In some cases, the amount of lead in the child's body can be lowered by giving the child certain drugs that help eliminate lead from the body. If a child swallows smaller amounts of lead, such as dust containing lead from paint, much less severe but still important effects on blood, development, and behavior may occur. In this case, recovery is likely once the child is removed from the source of lead exposure, but there is no guarantee that the child will completely avoid all long-term consequences of lead exposure. At still lower levels of exposure, lead can affect a child's mental and physical growth. Fetuses exposed to lead in the womb, because their mothers had a lot of lead in their bodies, may be born prematurely and have lower weights at birth. Exposure in the womb, in infancy, or in early childhood also may slow mental development and cause lower intelligence later in childhood. There is evidence that these effects may persist beyond childhood.

Children with high blood lead levels do not have specific symptoms. However, health workers can find out whether a child may have been exposed to harmful levels of lead by taking a blood sample. They can also find out how much lead is in a child's bones by taking a special type of x-ray of the finger, knee, or elbow. This type of test, however, is not routine.

Appendix F. Response to comments from Public Comment Period.

This Public Comment Notice Appeared in the Wisconsin State Journal and Florence Mining News:
The Wisconsin Department of Health Services (WDHS) announces the beginning of a public comment period for a Health Consultation (HC) document regarding elevated levels of naturally-occurring metals, including arsenic, in the water of private well owners around Keyes Lake in Florence County, WI. The 30-day comment period begins July 23, 2012 and ends August 22, 2012. The HC is available for review at the Florence County Library (400 Olive Avenue, Florence, WI 54121) and on the WDHS website (http://www.dhs.wisconsin.gov/publications/P0/P00351.pdf).

Send written comments to:
Bureau of Environmental and Occupational Health
Attn: Superfund Section -- Keyes Lake HC
Wisconsin Division of Public Health
PO Box 2659
Madison, WI 53701-2659
Phone: (608) 266-1120
Email: DHSEnvHealth@wi.gov

Comment received

Date of submission: July 31, 2011

Comment:
"These are 'band-aid' solutions. Public water is available from Florence Utilities, approximately 3 miles [from Keyes Lake]. This could be done in phases. First phase – contact an engineering firm: a) to extend water to residents in Commonwealth Town, b) extend water line to Fern residents, [and] c) finally complete the loop for residents in the Town of Florence."

Response:
Extending municipal water to the residents of Keyes Lake is a permanent solution worthy of consideration and has been added to the Recommendations Section on page 11. However, WDHS has no authority to order such an extension. Connecting homes to an existing municipal system is a decision that would need to be made collectively by the residents of Keyes Lake and discussed with the municipalities mentioned. Extension of the municipal supply would require assessment and usage costs to residents, and there may be some who oppose such an action. Nonetheless, WDHS encourages this discussion among your fellow area residents and town council(s).