

Caledonia Groundwater Molybdenum Investigation Southeast Wisconsin

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ABBREVIATIONS AND ACRONYMS

BGS = Below Ground Surface
BRRTS = WDNR Bureau for Remediation and Redevelopment Tracking System (A WDNR electronic data storage and access system for contaminated properties)
CERCLA = Comprehensive Environmental Response Compensation Liability Act of 1980, also known as the federal Superfund program
CGMI = Caledonia Groundwater Molybdenum Investigation
EADA = We Energies Early Ash Disposal Areas
EPL = Emerald Park Landfill
ERP = Environmental Repair Program
ES = Enforcement Standard from Wisconsin's Groundwater Quality administrative code (ch. NR 140, Wis. Adm. Code)
GEMS = Groundwater and Environmental Monitoring System (A WDNR electronic data storage and access system for environmental monitoring data)
GIS = Geographical Information System
HRS = Hazard Ranking System
HSRG = Hunts Site Remediation Group
HT and HTO = Tritium in air and Tritium in water, respectively
MCL = federal Maximum Concentration Level for substances in drinking water
MEK = Methyl Ethyl Ketone
MIBK = Methyl Isobutyl Ketone
MSL = Mean Sea Level
NPL = National Priorities List (part of the federal Superfund program)
OCN = We Energies Oak Creek North Ash Landfill
OCS = We Energies Oak Creek South Ash Landfill
PA = Preliminary Assessment
PAH = Polycyclic Aromatic Hydrocarbon
PCB = Polychlorinated Biphenyl
RCRA = Resource Conservation and Recovery Act
SARA = Superfund Amendments and Reauthorization Act of 1986
SEWRPC = Southeast Wisconsin Regional Planning Commission
SVOC = Semi-Volatile Organic Compound
U.S. EPA = United States Environmental Protection Agency
USGS = United States Geological Survey
VOA = Volatile Organic Analyte, sometimes called VOC
VOC = Volatile Organic Compound, sometimes called VOA
WGNHS = Wisconsin Geological and Natural History Survey
WDHS = Wisconsin Department of Health Services
WDNR = Wisconsin Department of Natural Resources (department)
WSLOH = Wisconsin State Laboratory of Hygiene

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Executive Summary

Elevated molybdenum concentrations have been found in water from several dozen private water supply wells located in the Village of Caledonia, in northern Racine County, Wisconsin, and in wells several miles to the west in northwestern Racine County. Several of the private wells have molybdenum concentrations above the Wisconsin groundwater quality standard of 40 micrograms per liter (ug/L). In addition, two of these private wells produce water containing boron at concentrations above its groundwater quality standard of 1,000 ug/L. Molybdenum and boron are naturally occurring elements found typically in low concentrations in the Earth's crust and waters. Both also enter the environment from man-made (i.e. anthropogenic) sources, such as coal ash or other industrial waste.

Two potential anthropogenic sources of molybdenum and boron located within relatively close proximity of the contaminated private wells are the We Energies ash fill areas, located in Oak Creek and Caledonia and the Hunts Landfill located in Caledonia.

In 2011 department staff collected groundwater samples from private water supply wells and groundwater monitoring wells near the We Energies and the Hunts Landfill properties. In addition to the well samples, coal ash and leachate samples were collected from both ash fill areas and the Hunts Landfill. These water, ash and leachate samples were collected and tested in an attempt to determine the source(s) of the elevated molybdenum and boron concentrations. All of the samples were analyzed for a suite of organic and inorganic parameters. Samples were also analyzed for tritium and for isotopes of boron, strontium and molybdenum. Boron and strontium isotope studies, and to a lesser extent, molybdenum isotope studies have been used in other states to help identify contaminant sources.

As part of their investigation, department staff made efforts to obtain a better understanding of the groundwater flow paths in the region. Staff discovered that the flow paths are fairly complex and that the area of molybdenum affected wells is either much larger than previously thought or there are multiple affected areas separated by several miles. The extent of the affected area increases the likelihood that the observed impacts are due to naturally occurring molybdenum or multiple man-made sources, rather than a single source near the We Energies power plant. The boron and strontium isotope data appear to have helped answer the question of the boron source(s), but the molybdenum isotope data are not as well understood at this time. Molybdenum isotopes are more susceptible to changes along the flow path than are boron isotopes.

The sampling project appears to eliminate the Hunts Landfill as a source of the molybdenum. The sampling project is inconclusive on whether the molybdenum is naturally occurring and whether molybdenum is from the We Energies ash fill areas.

SECTION 1.0 INTRODUCTION AND BACKGROUND

1.1 Description of the Problem

A number of private home water supply wells have been identified in southeastern Wisconsin as producing water containing molybdenum and, in two cases boron, at concentrations above state groundwater quality standards. The area of concern is predominately rural, residential and agricultural land located between the cities of Milwaukee to the north and Racine to the south. The area lies predominately in Racine County near the border with Milwaukee County and extends a short distance into Milwaukee and Waukesha Counties (see Figures 6, 7 & 18). It is mostly flat topography. The study area is primarily served by individual private water supply wells and individual septic systems. A public water supply well serving a school in the area has also been found to contain molybdenum concentrations above the state's groundwater quality standard.

The United States Environmental Protection Agency (U.S. EPA) has not established Public Water System Maximum Contaminant Level (MCL) drinking water standards for molybdenum. The agency has established a Life-time Health Advisory level for the substance and has placed it on its current Contaminant Candidate List (CCL). Substances on EPA's CCL are unregulated contaminants reviewed by EPA for possible future national drinking water regulation under the Safe Drinking Water Act. EPA uses the CCL list to prioritize research and data collection efforts including nationwide testing for CCL contaminants in public water systems under the Unregulated Contaminant Monitoring Program.

The Department of Natural Resources, in conjunction with the Department of Health Services, establishes groundwater quality standards for substances detected in, or having a reasonable probability of entering the groundwater resources of the state. The standards are based on studies of actual health effects with safety factors built in according to a scientific protocol. These groundwater quality standards are used by state agencies to make recommendations related to the safety of home water supplies, and in oversight of groundwater contamination cleanup cases and similar activities, minimizing health risks and the need for often costly home water treatment. Wisconsin groundwater quality standards are established at two levels, a preventive action limit (PAL) level and an Enforcement Standard (ES) level with different response options specified in Chapter NR 140, Wis. Adm. Code.

Private well owners are issued a drinking water health advisory if testing of their water shows that it is above a groundwater quality ES level, or above an established health advisory level. Health based groundwater quality ESs and established health advisory levels are concentrations at which a compound is considered to become a health risk if an individual consumes water

contaminated with that compound over a lifetime. [Ref. (2)] Drinking water containing a compound at a concentration below its ES or health advisory level is not considered to pose a health risk. [Ref. (2)] Enforcement Standards are based on recommendations from the State's Department of Health Services (DHS) and established in Wisconsin Administrative Code. [Ref. (3)] Health advisory levels are established by DHS or the U.S. EPA.

Many of the private wells in the study area have been found to contain molybdenum, a naturally occurring element in some types of soil and rock. At least forty four (44) private wells located in the study area have shown molybdenum concentrations above Wisconsin's groundwater quality ES of 40 micrograms per liter (ug/L). [Refs. (4), (5), (4)] Molybdenum is a necessary dietary nutrient in small quantities. [Ref. (2)] Too much molybdenum intake can cause health problems. Some health problems associated with too much molybdenum intake include digestive problems and gout. [Ref. (2)] Molybdenum is found in coal ash, has uses in the steel industry and may sometimes be used as a pigment in paints. [pgs.106-107, Ref. (6), Refs. (7), (8)]

Two private wells sampled in the study area have been found to contain boron concentrations above the ES of 1000 ug/L. Like molybdenum, boron is a naturally occurring element. Boron minerals are associated with a variety of rock types. Boron is also used in household cleaning products and can be present in sewage and certain industrial wastes, including coal ash. [Refs. (9), (10), (8)] Boron is commonly found in groundwater. [Ref. (11)] Studies in animals indicate that the male reproductive organs, especially the testes, are affected if large amounts of boron are ingested for short or long periods of time. [Ref. (10)] The doses that produced these effects in animals are more than 1,800 times higher than the average daily intake of boron in food by adults in the U.S. population [Ref. (10)], and are well above the boron intake that would result from drinking water with boron concentrations noted in the private wells in this study.

Some of the private wells in the study area have also been found to contain lead, copper, zinc and iron. Lead has been detected in nine private wells above the state's drinking water standard of 15 ug/L. Follow-up sampling from one of the private wells showed that the lead may be coming from a brass fitting in the plumbing. Lead, copper, zinc and iron all occur naturally in groundwater; however, lead, copper and zinc can often be attributed to household plumbing or plumbing fixtures.

1.2 Prior Molybdenum Sampling

In 1989 We Energies began sampling private water supply wells located near its property in the town of Caledonia. This sampling is being carried out as part of the local land-use agreement We Energies had completed with the Village of Caledonia for the construction of the We Energies Caledonia Ash Landfill. The wells were sampled for metals and other inorganic compounds, some of which are also found in coal ash. In 1993 molybdenum was added to the parameter list and was detected in 14 private water supply wells out of 20 wells that were sampled. [Ref. (12)] Molybdenum continues to be analyzed in water samples collected from private wells by We Energies. [Ref. (4)]

In December, 2006 the Wisconsin Department of Natural Resources established a groundwater quality ES of 40 ug/L for molybdenum in Chapter NR 140, Wisconsin Administrative Code in response to its regular query process for substances detected in, or having a reasonable probability of entering the groundwater resources of the state. [Ref. (3) & (13)]

Molybdenum concentrations found in at least 21 private well samples were above the Wisconsin groundwater ES of 40 ug/L [Ref. (12)] Since there was no groundwater standard established for molybdenum in 1993, the molybdenum concentrations found at that time did not cause concern. In August 2009, We Energies reported to the department that the measured molybdenum concentrations in water samples being collected from nearby private water supply wells were above the 2006 established groundwater ES. On September 4, 2009, We Energies submitted a work plan to investigate this issue. [Ref. (12)]

In 2010, the DHS offered free sample kits to private well owners in the study area to sample their private wells and have the samples analyzed at the Wisconsin State Laboratory of Hygiene (WSLOH). The WSLOH analyzed the water samples for a suite of 19 metals and inorganic compounds, including molybdenum. [Ref. (5)]

Of the 124 wells sampled by well owners using the free DHS sampling kits, there were 20 private water supply wells with a molybdenum ES exceedance (above 40 ug/L), two wells with a boron ES exceedance (above 1000 ug/L) and eight wells with a lead ES exceedance (above 15 ug/L).

At the eight homes with the high lead sampling results it is not known at what location in the household water distribution system the samples were collected or how long the water was flushed in each house before the owner collected the sample. In addition, lead and copper concentrations appeared to be correlated in the sample results: systems with high lead levels also had relatively high copper levels, and systems that were resampled and showed lead below the standard also showed reduced copper levels in the same sample. (see Appendix A.) This direct lead-copper relationship suggests some leaching from water supply pipes and/or fixtures in the house. Resampling those eight private wells would be needed to determine whether plumbing system leaching is the likely source of the lead exceedances.

1.3 WDNR Investigation

The department began its investigation of the occurrence of molybdenum and boron in 2010. The elements of the study included:

- Assessment of groundwater monitoring data from known potential sources, and review of groundwater studies completed as part of monitoring and remediation plans for potential sources.

- Collection and testing of well water samples from private water wells and monitoring wells in proximity to WE Energies and Hunts Landfill sites to determine levels and patterns of contamination.
- Coal ash and landfill leachate testing to compare the nature and patterns of chemical parameters with those noted in groundwater.
- Study of contaminant isotopes and tritium to help identify the source of the contaminants and whether the water containing the contaminants pre-dates the industrial activities that might have produced them.
- Assembly of data and studies on the occurrence of molybdenum in groundwater in Wisconsin, nationally and globally.
- Study well construction reports of groundwater monitoring wells, private water supply wells and public water supply wells and review past geological studies of the area to obtain knowledge of the geology and the groundwater flow paths.
- Consultation with experts on various aspects of hydrogeology, geochemistry, and isotope interpretation.

1.4 Potential Sources

The molybdenum found in area private wells may be naturally occurring or coming from an unknown source(s). Boron and molybdenum can both be found in coal ash. Boron is a typical contaminant associated with coal ash contamination of groundwater. However the presence of boron in groundwater does not prove that the source of contamination is coal ash. Borax, or sodium borate, is commonly found in a variety of commercial and household products such as detergents, cosmetics, glass, pesticides, photographic materials, as a fire retardant and as a food additive. [Ref. (10)] Therefore boron can sometimes be found in municipal solid waste landfills and in the environment from septic systems. Boron is also known to be a common naturally occurring element, found in the ocean and in sedimentary rock such as shale. [Refs. (11) & (10)] Groundwater sampling in southeast Wisconsin has found boron to be fairly common. [Ref. (4)] Less is known about molybdenum in groundwater in southeast Wisconsin. Both boron and molybdenum may become dissolved and transported in groundwater.

Three industrial facilities were identified through department records as known potential sources of molybdenum and boron:

1. The We Energies Oak Creek and Caledonia property, containing two coal fired power plants and associated coal ash landfills, located along the Lake Michigan shoreline in

the City of Oak Creek, Milwaukee County, and in the Village of Caledonia, Racine County. This property is just east of the main area of private homes with well water documented as containing elevated concentrations of molybdenum.

2. The Hunts Disposal Landfill (Hunts) located about 1.5 miles southwest of the We Energies property in the Village of Caledonia. Hunts is a closed and capped municipal and industrial waste landfill. It has been designated as an EPA Superfund site. [Ref. (14)]
3. The PPG Industries (PPG) property located approximately three miles west of the We Energies property, in the City of Oak Creek. PPG Industries is a manufacturer of paint and coating products. [Refs. (15) & (16)]

In the fall of 2011, the department conducted a sampling project involving groundwater sampling at selected private wells, groundwater monitoring wells for the We Energies property, monitoring wells for the Hunts property, leachate from the ash landfills and from the Hunts Landfill, and analysis of samples collected from We Energies coal ash. In addition the groundwater was evaluated to determine if other parameters such as metals and organic compounds known or believed to be potential releases from these facilities are present at concentrations above their Wisconsin ES.

1.5 Regulatory and Operational History

1.5.1 We Energies Oak Creek and Caledonia Property

The We Energies Oak Creek Power Plant property is located to the east of the intersection of Foley Road and County Line Road and lies along the Lake Michigan shoreline (see Fig. 7). The property straddles the City of Oak Creek in Milwaukee County to the north and the Village of Caledonia in Racine County to the south. The plant address is 4801 East Elm Road, Oak Creek, Wisconsin. [Ref. (17)]

The Oak Creek power plant began commercial power production in 1953. [p.2-4, Ref. (17)] A second power plant on the property was constructed between 2005 and 2010. There are several areas on the We Energies property where coal ash from the power plant is disposed of. The first areas that were used for ash disposal are now called the “Early Ash Disposal Areas” (EADAs). The EADAs are scattered, in formerly low lying areas on the property. Soil borings on the property show that the coal ash thicknesses in the EADAs range from 6 to about 20 ft. [pp. 2-4, Ref. (17)]

The extent of one of the EADAs, was discovered when a bluff failed on October 31, 2011, showing that coal ash was disposed of in a former ravine along the Lake Michigan shoreline on the south side of the property. The ravine was up to 35 feet deep at some locations. [p., Ref.

(18)] The EADAs are estimated to comprise about 61 acres, based on the 1993 Groundwater Investigation Report. [pp. 2-4, Ref. (17)]

We Energies also owns two closed, licensed coal ash landfills and one licensed active coal ash landfill located on the property. The two closed ash landfills are the Oak Creek North Ash Landfill (OCN) and the Oak Creek South Ash Landfill (OCS). The Caledonia Landfill is the only active coal ash landfill on the property. The OCN Landfill is approximately 45 acres in area and the OCS Landfill is approximately 130 acres in area. [pp. 2-2 & 2-3, Ref. (17)]

Disposal of coal ash in the EADAs started in 1953, before the State's solid waste regulations came into effect, and continued until the late 1960s. [p. 2-3, Ref. (17)] The OCN Landfill accepted coal ash from 1969 until 1976. [p. 2-6, Ref. (17)] The OCS Landfill accepted ash from 1974 until 1992. [p. 2-5, Ref. (17)] The Caledonia Landfill went through Wisconsin's landfill feasibility siting and plan of operation approval process in 1985 through 1987 [Refs. (19) & (20)], began accepting coal ash in 1991, and remains active today. [p. 2-9, Ref. (17)]

The Caledonia Landfill has a 5-foot compacted clay liner and an active leachate collection system. [Ref. (20)] The newest cell of the Caledonia Landfill was approved in 2010 for construction of a 4-foot compacted clay liner overlain by a 60-mil HDPE liner. [Ref. (21)] This new composite liner meets the standards for Wisconsin's municipal solid waste landfill design and federal sub-title D requirements under the Resource Conservation and Recovery Act (RCRA). [Ref. (3)] The EADAs, OCN and OCS do not have liners or leachate collection systems consistent with today's industrial waste landfill standards. [Ref. (17)] The lack of liners in these older landfills may be mitigated by the thick silty clay soil upon which they are constructed. They are capped with clay soil covers. The OCN Landfill also has an asphalt parking lot covering it, while the OCS Landfill has several feet of clay cover soil that was excavated from elsewhere on the property and laid in place in 2005 and 2006 during excavation for the new power plant. [Refs. (22) & (23)]

We Energies collects water samples from groundwater monitoring wells located on its Oak Creek and Caledonia property semi-annually and submits the data to the department in an electronic format where the data are stored in the department's groundwater and environmental monitoring system (GEMS). [Ref. (4)] The parameters that are analyzed include boron, sulfate, selenium and starting in 2010, molybdenum. [Ref. (4)] The ash landfills are also inspected by the assigned WDNR Waste and Materials Management engineer annually.

1.5.2 Hunts Disposal Landfill

The Hunts Disposal Landfill is an inactive 35-acre landfill which is part of an 84-acre parcel located to the west of the majority of the molybdenum affected private water supply wells, in the Village of Caledonia. [p.8, Ref. (14)] The landfill is located in the site of an old sand and gravel

quarry. [p.9, Ref. (14)] The landfill reportedly accepted municipal and industrial wastes from 1959 to 1974. [p.9, Ref. (14)] The parcel is currently owned by the Racine County Park System, but the landfill continues to be managed and cared for by the Hunts Site Remediation Group (HSRG) which consists of a number of responsible parties. [p.9, Ref. (14)] The Hunts property borders the Root River, located along the western property line. [Ref. (14)] The landfill is located south of County Line Road and is approximately 1.5 miles west of Highway 32, in the northeast quarter of Section 3, Township 4, Range 22 East, in the Village of Caledonia. (see Fig. 7)

In the mid 1990s, the landfill was capped with clay soil and a bentonite slurry containment wall was constructed around the limits of waste. An active groundwater/leachate extraction system was installed at the landfill, consisting of five extraction wells. [Ref. (14)] The Hunts Landfill is a federal Superfund Site. [Ref. (14)]

Inorganic contaminants that have been found in soil and groundwater at the Hunts Facility include arsenic, barium, chromium, manganese, and nickel. Organic contaminants that have been found include vinyl chloride, trichloroethene, 1,1-dichloroethene, 1,1-dichloroethane, benzene, naphthalene, and xylene. [Ref. (14)]

1.5.3 PPG Industries

PPG Industries is located at 10800 South 13th St. in the NW ¼ of the SW ¼ of Section 32, Township 5 North, Range 22 East, in the City of Oak Creek, Milwaukee County. [p. 3, Ref. (15)] The facility is located approximately three miles west of the intersection of Foley Road and County Line Road (see Fig. 18). The PPG manufacturing facility was constructed between 1973 to 1975 and began producing both solvent and water-based coatings for the automotive, industrial, and consumer sectors in December, 1975. [p. 9, Ref. (15)] PPG Industries is a RCRA hazardous waste generator and as a result is subject to inspections by department hazardous waste specialists. [Ref. (15)]

Raw materials used in the manufacturing process are received in bags, cans, various sized fiber, plastic and metal drums, tank wagons and historically in rail cars. [p. 9, Ref. (15)] The major raw materials used in the paint are water, aromatic solvents (e.g., xylene, toluene, ethyl benzene, mineral spirits, VM&P naphtha), ketones, (e.g., methyl ethyl ketone & methyl isobutyl ketone), glycol ethers (e.g., butyl cellosolve), ether acetones (e.g., cellosolve acetate), alcohols (e.g., butanol, isopropyl & isobutyl), pigments (predominantly titanium dioxide, although zinc oxide, iron oxide, carbon black, toluene red and heavy metal pigment usage is significant), additives (e.g., lecithin, hydroxyethyl cellulose) and extenders (e.g., calcium carbonate, silica, talc, bentonite, aluminum silicates, clay). [p. 11, Ref. (15)]

The major waste streams produced from paint manufacturing are spent solvents and wash water used to clean vessels and equipment, used filter media, quality assurance and quality control sample waste, pigment dust and off-specification products. [p.10, Ref. (15)]

The facility is currently in the process of monitoring the groundwater and remediating a release of solvents from its previous underground tank farm. [Ref. (24)]

1.6 Hydrogeological and Geochemical Background

1.6.1 Aquifers and Groundwater Flow

Three groundwater aquifers are recognized in southeastern Wisconsin [Ref. (25)]: a complex of glacial clay till and alluvial sand and gravel deposit at or near the surface, the Silurian aged dolomite bedrock that underlies the glacial/alluvial deposits, and a deeper aquifer consisting of older sandstone, dolomite and siltstone bedrock of Ordovician and Cambrian age. The aquifers in the glacial/alluvial deposits and Silurian dolomite bedrock are hydraulically connected and are sometimes referred to as the “shallow aquifer.” Below the Silurian dolomite bedrock a relatively thick shale bedrock layer, the Maquoketa Shale, is present. This shale layer acts as an aquitard confining unit and separates the shallow aquifer from the “deeper aquifer” in the Ordovician - Cambrian bedrock units.

The uppermost glacially deposited till layer in the area of investigation is the Oak Creek Formation. [Ref. (25)] The Oak Creek glacial till formation is composed of fine grained sediments, i.e., silty sand, silt and clay deposits. Fractures have been observed in the Oak Creek Formation extending from near the surface to a depth of approximately 30 feet. Below the Oak Creek Formation lie older glacially deposited till sediments and sediments associated with alluvial melt water deposited between periods of glacial advance. Silurian dolomite bedrock underlies the unconsolidated sedimentary deposits.

In the area of investigation, a major bedrock valley exists within the Silurian dolomite bedrock. [Ref. (25)] This bedrock valley, a part of the Troy Bedrock Valley, lies in a predominantly east-west orientation in southern Milwaukee and Waukesha Counties, just to the north of their borders with Racine County (see Fig. 20). This segment of the Troy Bedrock Valley contains up to 500 feet of glacial sediment fill (see Fig. 21). [Ref. (1)] These glacially deposited sediments include both dense clay and coarse sand and gravel deposits. The bedrock valley sand and gravel deposits form a locally significant glacial aquifer.

The geology of glacially deposited sediments in the Troy Bedrock Valley is considered to be extremely complex and groundwater flow within the Valley aquifer does not appear to be well understood [Refs. (1) & (26)]. The Valley aquifer has been modeled as consisting of four layers, including an upper sand unit about 50 feet to 100 feet thick, and a lower discontinuous sand unit separated from the upper sand by a layer of fine grained glacial till (reported to be up to 200' thick in some places, but absent in other places). [Ref. (1)] Deeper Valley glacial units truncate against the bedrock walls along the sides of the Valley. Water discharging from springs in the

Valley near the City of Mukwonago has been shown to come from both glacial sand and gravel and bedrock sources. [Ref. (1)] Horizontal hydraulic conductivity in the east-west portion of the Troy Bedrock Valley has been reported as high as 100 feet per day. [Ref. (26)]

Regional groundwater flow in the shallow glacial/alluvial and dolomite bedrock aquifers in the area of investigation is predominately west to east toward Lake Michigan. [Ref. (25)] Local shallow groundwater flow within the glacial/alluvial aquifer may, however, follow surface contours and groundwater may flow locally towards lake and stream discharge areas. Groundwater flow within the deep Ordovician – Cambrian aquifer, below the Maquoketa shale, has been greatly influenced by high capacity groundwater pumping that started in the beginning of the 20th century. This high rate pumping from the deep Ordovician – Cambrian aquifer has created downward vertical gradients through the Maquoketa Formation and has also changed general regional flow within the aquifer system. Prior to the heavy pumping, the major discharge area for the deep aquifer system was Lake Michigan. Now flow in the system is toward areas of drawdown created by deep high capacity pumping wells.

A water table groundwater divide is present at the We Energies site, with local groundwater flow in the glacial till aquifer at the site both to the east and to the west/northwest [Fig. 3, Ref. (17) and Plate No. 6, Ref. (12)]. Water table elevations measured on the western side of the We Energies site (690' - 710') and at the Hunts Landfill site (656' to 664'), which is located approximately 1.5 miles to the west, appear to support the concept of local groundwater flow in the glacial till aquifer from the We Energies site to the west.

Groundwater flow in an “intermediate sand” layer at the We Energies site has been calculated to be toward the southeast. As discussed later in this report, because not all site monitoring wells thought to monitor this layer were used, and as some of the wells used for the calculation are screened at different elevations in an aquifer with significant vertical gradients present [Ref. (12)], these flow direction calculations may not be accurate.

Similarly, groundwater flow in the Silurian dolomite aquifer at the We Energies site has been calculated to be to the northeast; but, because some of the wells used for the calculations have sensing zones at different elevations within the aquifer and significant vertical gradients appear to be present [Ref. (12)], these flow direction calculations in the dolomite aquifer may not be accurate.

1.6.2 Molybdenum in groundwater

The concentration of dissolved molybdenum in natural water samples depends on molybdenum geochemistry, which is tied closely to pH and redox conditions in the groundwater. At pH levels above 5, molybdenum in groundwater is expected to exist mostly as molybdate ion, (MoO_4^{2-}). [Ref. (11)] Under certain specific geochemical conditions molybdenum in groundwater may

become occluded to mineral oxides (iron, manganese, aluminum) or soil clay minerals, or may precipitate out as solid mineral deposits. Molybdenum adsorption to clay minerals has been shown to take place at relatively low pH levels (maximum around pH =3), while adsorption to metal oxide minerals has been shown to take place at higher pH levels (approximate pH range of 4 to 8). [Ref. (27)]

Aquifer reduction/oxidation (redox) conditions can greatly affect the speciation and mobilization of molybdenum in groundwater. Oxidizing conditions in groundwater are characterized by the presence of relatively higher concentrations of redox sensitive parameters such as dissolved oxygen, nitrate nitrogen and sulfate, while reducing conditions are characterized by relatively higher concentrations of redox sensitive parameters such as dissolved iron, dissolved manganese and arsenic (and relatively low levels of dissolved oxygen, nitrate nitrogen and sulfate). [Ref. (28)] Under oxidizing conditions, iron and manganese oxyhydroxides may form in an aquifer and soluble molybdenum may be sorbed to these minerals. As geochemical conditions become more reducing, solid phase iron and manganese oxyhydroxides may undergo dissolution and sorbed molybdenum may be released back into groundwater. Under euxinic reducing conditions (anoxic conditions with hydrogen sulfide present), soluble molybdenum may precipitate out of solution along with iron sulfide minerals. In addition to affecting dissolved molybdenum concentrations, molybdenum release into, or removal from, water due to changing redox conditions has been shown to have characteristic effects on measured molybdenum isotope ratios. [Ref. (29)]

Geochemical redox conditions in the most of the glacial till and Silurian dolomite aquifer system in the area of investigation appear to be relatively oxic. Reported dissolved oxygen levels are in the 2.1 to 7.0 mg/L range, well above the 0.5 mg/L threshold level often used to classify an aquifer as oxic. [Ref. (28)] Other redox sensitive parameters analyzed for also suggest oxic conditions in the glacial till/dolomite groundwater system. Dissolved iron levels are relatively low (iron generally < 0.100 mg/L) and sulfate levels relatively high (> 4 mg/L) compared to what are often considered “reducing redox condition” threshold levels. [Ref. (28)]

1.6.3 Naturally occurring molybdenum in groundwater, soil and rock

Reported concentrations of molybdenum in groundwater around the country and in Wisconsin are generally much lower than the levels reported from the wells in this study area. Levels in groundwater in the United States have been reported as “usually < 1 ug/L”. [Ref. (30)] In 3,063 samples collected for a United States Geological Survey (USGS) study evaluating trace elements in groundwater across the United States, molybdenum levels were reported at a median level of 1.0 ug/L and a 90th percentile level of 8.0 ug/L. [Ref. (31)] In a USGS study evaluating trace elements in the glacial aquifer system in the northern United States, molybdenum levels were reported at a median level of 1.4 ug/L, and a 90th percentile level of 7.9 ug/L. [Ref. (32)]

Molybdenum was sampled for in private water supply wells in northern Wisconsin by the USGS

for the National Uranium Resource Evaluation (NURE) program. The NURE program was conducted between 1973 and 1980 in the United States to identify potential uranium resources. A total of 2,735 Wisconsin NURE well samples were analyzed for molybdenum. Approximately 78% of those samples were reported as below the analytical detection limit of 4 ug/L and approximately 20% were reported as between 4 ug/L and 20 ug/L. [Ref. (33)]

Molybdenum in groundwater has been reported possibly associated with shale bedrock in several locations in North America. In a USGS study of arsenic in groundwater in glacial till, glacial buried valley and Silurian carbonate aquifers in southwest Ohio, a "highly significant" correlation between molybdenum, arsenic and iron in groundwater was reported. [Ref. (34)] The mechanism suggested in the study for mobilization these elements in this area is reducing conditions in the groundwater environment, causing reductive dissolution of iron oxide minerals and subsequent release of co-precipitated and sorbed accessory minerals, such as arsenic and molybdenum.

Molybdenum in groundwater was reported in a study of the sand and gravel aquifer in a buried bedrock valley, the Mahomet Buried Bedrock Valley, in central Illinois. [Ref. (35)] The bedrock adjacent to and underlying the Mahomet Buried Bedrock Valley is black shale with coal, pyrite and limestone. Groundwater sampling results suggest that the Valley aquifer is being recharged from the underlying bedrock and that reducing redox conditions are present. Molybdenum levels in groundwater are reported at 1.8 to 14.6 ug/L.

A study conducted in northern Alberta, Canada, evaluated high arsenic levels found in "deeper" domestic water supply wells in three areas. [Ref. (36)] The three study areas are underlain by bedrock containing marine shale deposits and the shale is thought to be the source of iron, arsenic and molybdenum found in groundwater in the study areas. Median molybdenum levels in the study were reported from 2.5 to 4.5 ug/L.

In soil in the USA molybdenum has been reported at 1.2 mg/kg, with a range of 0.1 to 40 mg/kg. [Ref. (30)] In 664 soil samples analyzed for a USGS study evaluating trace elements in Wisconsin surface soils, molybdenum was reported as not detected in 91% of samples, and between 1.0 and 8.5 mg/kg in detected samples. [Ref. (37)] Average levels for molybdenum in various sedimentary rock types reported by the USGS are 4.2 parts per million (ppm) for shale, 0.50 ppm for sandstone and 0.75 for carbonates. [Ref. (11)] Note that mg/kg is equivalent to ppm.

SECTION 2.0 FIELD INVESTIGATION ACTIVITIES

2.1 Past Environmental Investigations

2.1.1 We Energies Oak Creek and Caledonia Property

In 1992, We Energies (known as Wisconsin Electric Power Company, or WEPCO, at that time) hired Woodward and Clyde Consultants to conduct a hydrogeological investigation of the Oak Creek power plant property and associated ash fill areas. This was done to address concerns over elevated groundwater levels of boron and sulfate that were reported to the department at the time and to respond to concerns from some residential neighbors after work was done on the OCS Landfill. WEPCO also wanted a better understanding of the geological and hydrogeological conditions for each ash fill area as well as for the entire property. The results of the hydrogeological investigation were submitted to the department dated July 28, 1993. [Ref. (17)]

The report showed that the property is underlain by the glacially deposited Oak Creek Formation Till consisting of clay and silty clay soil. The Oak Creek Formation under the property ranges from about 150 to 200 feet in thickness and is inter-bedded with seams of silt, sandy silt and fine sand. The upper portion contains fractures that affect the hydraulic conductivity. Measured vertical hydraulic gradients in the glacial till were larger than horizontal gradients, and the vertical gradients in the deeper (unit 1B) well nests were greater than in the shallower (unit 1A) well nests. Hydraulic conductivity in the till ranged from 2.2×10^{-6} to 1.0×10^{-3} cm/sec. The hydraulic conductivity tended to decrease with depth, partly due to decreasing effectiveness of fractures in controlling hydraulic conductivity with depth. A sand layer was encountered in the screened interval of boring W-37C, on the west side of the OCS Landfill beginning at a depth of approximately 43 feet below ground surface and at an elevation of 654 ft. above sea level. [Ref. (17)]

The 1993 hydrogeological investigation reported that a shallow groundwater divide is present on the east side of the OCS Landfill. Shallow groundwater west of the divide, beneath most of the OCS Landfill, flows to the west. Shallow groundwater on the east of the divide flows east toward Lake Michigan. There is a shallow drainage ditch on the west side of the OCS Landfill that probably receives some shallow groundwater. Some groundwater in the Oak Creek Formation, west of the divide, may flow under the drainage ditch toward tributaries of the Root River, where it may discharge. [Ref. (17)]

Table 5 in the 1993 report shows average, high and low concentrations of 22 analytical parameters from samples collected in 6 monitoring wells on the property (W-01A, W-02A, W-31A, W-28, W-29 & W-32B). Molybdenum was among the 22 parameters analyzed. Molybdenum concentrations measured in the 6 wells ranged from 0.02 mg/L to 0.05 mg/L with an average concentration of 0.02 mg/L. The specific molybdenum concentrations for each well and sampling event were not provided in the 1993 report.

We Energies has since submitted a paper documenting a new review of the 1993 report, highlighting sections of the report that need to be updated or corrected. [Ref. (38)] We Energies will amend the 1993 report.

In 2009 and 2010 We Energies investigated the molybdenum found in area private wells to try determine if the source may be from its ash fill areas and reported its findings in a report to the department dated March 30, 2010. [Ref. (12)] In the report, We Energies hypothesized that the molybdenum could be coming from one or more of the following sources: (1) naturally occurring background, (2) an anthropogenic source that is not the We Energies Oak Creek property, or (3) a release from coal ash on the We Energies Oak Creek or Caledonia property.

The 2010 We Energies report documents thick layers of glacially deposited clay and silty clay till of the Oak Creek Formation underlying the property; however, sand seams were identified within the till unit. A sand seam that is approximately 5 to 10 feet thick was found at an elevation between 660 and 650 ft. Another sand seam was encountered at an elevation between 640 and 600 ft. and is approximately 35 to 40 feet thick. The report calls this thicker sand seam an intermediate sand seam. Based on cross section B-B' contained in the 2010 report and based on cross section A-A' in Figure 8 contained in the 1993 report, it appears that monitoring well W-37C, located on west side of the OCS Landfill, is screened in the intermediate sand seam. [Plate No. 2, Ref. (12) and Figure 8, Ref. (17)]

The 2010 We Energies report also confirms the presence of a shallow groundwater divide on the east/southeast side of the OCS Landfill. [Plate No. 6, Ref. (12)] According to the report, shallow groundwater on the west side of the divide flows west/northwest and shallow groundwater on the east side of the divide flows east/southeast. This divide appears to represent the local divide between the Root River drainage and the Lake Michigan drainage in the upper, shallow aquifer. [Map 21, Ref. (25); see also Figure 12] Measured groundwater elevations in the dolomite bedrock aquifer show groundwater flow in the bedrock to the northeast. [Plate No. 8A, Ref. (12) & Plate No. 2, Ref. (39)] Groundwater elevations measured in wells screened in the intermediate sand seam appear to show groundwater flow in the intermediate sand towards the east/southeast. [Plate No. 1, Ref. (39)]

In its March 30, 2010, report, We Energies concluded that there are no data indicating leachate from coal ash disposal areas on the We Energies property is migrating to the private wells located west of the property. [p. 12, Ref. (12)] The report states that the geologic materials underlying the power plant and property largely consist of a thick sequence of low-permeability clays that do not readily convey groundwater. In addition, the report states that low permeability of the till and low molybdenum concentrations in till monitoring wells west of the landfills, including the wells in the intermediate sand seam, indicate that westward migration through the till is not occurring and measured groundwater elevations of bedrock wells show that westward groundwater flow in the bedrock is not occurring.

2.1.2 Hunts Disposal Landfill

A groundwater contamination investigation at the Hunt's Disposal Landfill was conducted in

1992 and 1993 to address known groundwater contamination at the property. [Ref. (40)] Shallow groundwater on the parcel flows towards the Root River. Groundwater monitoring wells are used to monitor the groundwater quality around the landfill. The investigation showed that four main hydrostratigraphic units exist at the property. These units consist of an upper sand outwash unit, a lower clayey till unit, a lower silty outwash unit and the Silurian Niagara Dolomite. The lower silty outwash is hydraulically connected to the bedrock aquifer (the dolomite). The upper sandy outwash is hydraulically connected to the surface water and the lower clayey till separates the upper sandy outwash unit from the lower silty outwash and bedrock units. [p. 22, Ref. (40)]

The water table occurs in the upper sand outwash and flows from northeast to the southwest, discharging to the adjacent Root River. The groundwater in the bedrock aquifer flows toward the north, parallel to the slope of the top of bedrock. The extent of groundwater contamination at Hunts appears to be confined to the upper sandy outwash unit and does not appear to extend across the Root River. [p.22, Ref. (40)]

The thickness of glacial sediments ranged from 45 feet on the south end of the landfill to 85 feet on the northeast end. Bedrock was encountered at 45 feet below ground surface (bgs) near the south end of the Hunts property and 85 feet bgs near the northeast corner of the property. Bedrock slopes at a rate of approximately 0.03 feet per foot to the north/northeast. [p. 21, Ref. (40)]

2.1.3 PPG Industries

There are several reported releases of volatile organic compounds (VOCs) to the soil and groundwater from the PPG Industries facility. [Ref. (15) & (16)] An environmental investigation was conducted at PPG Industries and results from the investigation were reported in a July 31, 1997 report prepared by ICF Kaiser Engineers, Inc. [Ref. (16)] The investigation found low level VOC contamination in the area around PPG's former underground tank farm. The extent of groundwater contamination appeared to be limited due to the hydrogeological setting and a tank farm underdrain system whose underdrain system influenced groundwater flow in the area. PPG elected to close the underground tank farm and replace it with new above ground tanks. [Ref. (16)]

On March 30, 2011 department staff interviewed PPG staff regarding past manufacturing processes at PPG. [Ref. (41)] According to the PPG staff member, PPG has not used metal pigments such as chromium and molybdenum during his employment at PPG, beginning in the early 1980s.

2.2 The 2011 Sampling Plan and Field Events

On September 26 and 27, 2011 department staff collected water samples from 24 private water

supply wells in the study area and from 18 groundwater monitoring wells and piezometers located on or adjacent to the We Energies property (see Figs. 7, 8a & 8b for sampling locations). All samples were collected according to the sampling plan contained in the 2011 Sampling Plan. Samples were analyzed for water quality indicator parameters, metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), molybdenum isotopes, strontium isotopes, boron isotopes and tritium.

Because of budget limitations, not all of the private wells and monitoring wells in the area could be sampled. Wells were selected for sampling based on location, concentration of molybdenum and boron in previous sampling, and available well construction information. The sampling strategy was to target private water supply wells with elevated concentrations of molybdenum or boron that provided spatial representation of the area or wells that could potentially provide background data and wells for which well construction reports could be found. A well construction report could not be found for some of the private wells sampled. These wells were included because the molybdenum concentration was elevated or the well was located in an area that would help provide spatial representation or background information. Three private water supply wells that were in the original plan could not be sampled, because the home owner was unavailable at the time of sampling. PW-26 was sampled in place of PW-25. Only samples for tritium and isotope analysis could be collected from PW-21 because the home owner was not available on the days of the scheduled sampling event and there was a specified time frame when the other water samples could be sent to the laboratories. That specified time frame did not exist for the tritium and isotope samples which allowed for PW-21 to be sampled at an alternate date for tritium and isotopes.

On October 27, 2011, We Energies drilled two leachate head monitoring wells in the Oak Creek North (OCN) Ash Landfill. Coal ash samples were collected from both wells at varying depths. These samples were labeled CA-01 through CA-09 and analyzed for molybdenum, boron and strontium isotopes.

On November 4, 2011, four coal ash samples were collected from the October 31, 2011, bluff slide on the We Energies Oak Creek property, which had exposed buried ash from one of the Early Ash Disposal Areas on the We Energies property. These samples were labeled CA-10 through CA-13 and were also analyzed for molybdenum, boron and strontium isotopes.

On November 28 and 29, 2011, the department collected leachate samples from one leachate headwell located in the OCN Landfill, LH-05; three leachate headwells located in the OCS Landfill, LH-07, LH-08 and LH-09; and a leachate sample from the Caledonia leachate collection system, LH-10.

On November 28 and 29, 2011 the department collected water samples from 15 monitoring wells and piezometers located on the Hunts Disposal Landfill property and off the property but controlled by Hunts. The Department also collected liquid samples from three leachate/groundwater extraction wells located within the Hunts Landfill limits of waste.

Because of a limited budget, time and staff resources, samples were not collected from the monitoring wells located at the PPG Industries property. The department determined that the Hunts Disposal Landfill and the We Energies property presented a greater potential of being a source of molybdenum to the specific area than the PPG Industries property, based on location and prior knowledge of facility operations.

2.3 Discussion of the Sample Analytical Data

Laboratory analytical summary tables for all of the private water supply wells, groundwater monitoring wells and leachate/groundwater extraction wells sampled in 2011 as part of the study are summarized in Tables 1 through 10.

2.3.1 Private Water Supply Wells

Tables 1, 2 and 7 provide a summary of the analytical results for the private well samples.

Molybdenum: The location of most of the private wells with samples that showed molybdenum ES exceedances are found within 1-mile of the intersection of Foley Road and County Line Road; however, there are private wells located several miles outside of this area that also have molybdenum ES exceedances. Some of these include PW-14, PW-15, PW-18 and PW-26. The samples collected from PW-18 showed the second highest molybdenum concentration in the private well samples at 121 ug/L. PW-18 is located approximately 5 miles to the southwest from the Foley Road and County Line Road intersection. The sample collected from PW-26 also showed a molybdenum ES exceedance at 70 ug/L. PW-26 is located approximately 3.5 miles west from the intersection.

Boron: Only two private wells showed boron ES exceedances, above 1,000 ug/L. These are PW-12 and PW-13 at 1,470 ug/L and 1,740 ug/L, respectively. Both wells are located on Michna Road, south of the We Energies property and south of monitoring well MW-19 which is located between the We Energies property and PW-12. Monitoring well MW-19 is open in the dolomite and does not show a boron or a molybdenum ES exceedance.

Sulfate: Sulfate ES exceedances, above 250 ug/L, were observed in only two private wells. Samples collected from PW-12 and PW-18 showed sulfate concentrations of 300 ug/L and 255 ug/L, respectively.

Other Contaminants:

Bis (2-ethylhexyl) phthalate was detected at a concentration of 1.7 ug/L in PW-17 and at 9.4 ug/L in PW-18. A duplicate sample collected from PW-18 (labeled PW-29) contained a concentration of 15 ug/L. Bis (2-ethylhexyl) phthalate is also known as di (2-ethylhexyl)

phthalate and has a Wisconsin ES of 6 ug/L. It was also detected in two field blanks, PW-31 (1.0 ug/L) and MW-22 (3.9 ug/L). Bis (2-ethylhexyl) phthalate is associated with plastics and PVC pipe. [Ref.14] Since it was detected in field blanks, it may be a laboratory contaminant or residual from the plastic bailers or plastic carboy containers used to store the distilled/deionized rinse water. Bis (2-ethylhexyl) phthalate was not detected in any of the monitoring wells sampled. It was detected in E-07, a leachate/groundwater extraction well installed through the waste at the Hunts Landfill, at a concentration of 1,100 ug/L.

Private well PW-18 was resampled on June 18, 2012 for bis (2-ethylhexyl) phthalate; the concentration was 16 ug/L. Department staff observed during resampling that some of the piping for the household water supply is made of PVC pipe.

Lead was not detected in any of the private well samples at concentrations above its ES of 15 ug/L, except for the sample collected from PW-19. The lead concentration in the PW-19 sample was 25.1 ug/L. The sample was collected from the sample tap in the basement of the house, at a point in the water supply distribution system before the pressure tank. It was observed that a brass fitting is part of the basement sample tap. A follow-up sample collected from this well on September 9, 2010, did not show a lead detection. The owner stated that he collected the September 9, 2010, sample from the outside tap. Follow-up samples from PW-19 were collected on June 19, 2012, and July 10, 2012. The June 19, 2012 sample, again collected from the sample tap in the basement, showed a lead a concentration of 45 ug/L. The July 10, 2012 samples were collected from the basement sample tap, the outside sample tap and from the kitchen faucet. Lead was not detected from either the outside tap or the kitchen faucet. Lead was detected in the sample collected from the sample tap in the basement at a concentration of 7.9 ug/L.

Most of the lead concentrations in the private well samples were less than 1 ug/L. Six private well samples had a lead concentration above 1 ug/L but less than 15 ug/L. These wells are PW-04, PW-07, PW-10, PW-16, PW-22 and PW-26.

Arsenic was detected in six private wells. All of the arsenic concentrations detected in the private well samples were less than 1 ug/L, except for PW-24 and PW-26 with arsenic concentrations of 3.36 ug/L and 3.58 ug/L, respectively. Arsenic is commonly found in soil and groundwater in southeast Wisconsin from naturally occurring minerals; it has an NR 140 ES of 10 ug/L. [Ref. (42)]

Cadmium was detected in only one private well sample, PW-07, at a concentration of 0.27 ug/L. The ES for cadmium is 5.0 ug/L. [Ref. (3)]

Mercury was detected in the samples collected from PW-01 at a concentration of 0.2 ug/L and from PW-10 at a concentration of 0.4 ug/L. The ES for mercury is 2.0 ug/L. [Ref. (3)]

Aluminum was detected in the sample collected from private well PW-13 at a concentration of 57.9 ug/L. Aluminum has an NR 140, Wis. Adm. Code ES of 200 ug/L [Ref. (3)]

Iron concentrations above the Wisconsin Public Welfare ES of 300 ug/L were observed in 14 of the 24 private wells sampled. Iron concentrations in the private wells ranged from 51.5 ug/L in PW-23 to 6,240 ug/L in PW-7. Iron exceedances are relatively common in private water supplies in Wisconsin. [Ref. (43)]

2.3.2 Monitoring Wells and Leachate/Groundwater Extraction Wells

Several analytes from monitoring and leachate well samples were flagged with the qualifier “UJ”. This qualifier means that the analyte was not detected above the reported sample quantitation limit; however, the reported quantitation limit is approximate and may or may not represent the action limit of quantitation necessary to accurately and precisely measure the analyte in the sample.

We Energies Coal Ash Leachate

Significant concentrations of molybdenum, boron, aluminum, iron and sulfate were found in samples collected from the We Energies coal ash leachate wells. Tables 5, 6 and 9 provide a summary of the analytical results for all of the leachate samples collected.

Molybdenum concentrations in leachate samples collected from the We Energies landfills ranged from 1,650 to 16,700 ug/L. Boron concentrations range from 6,490 to 23,200 ug/L, aluminum concentrations from 651 to 171,000 ug/L, iron from 46 to 120,000 ug/L, and sulfate from 1,130 to 16,700 ug/L.

Of the RCRA listed metals, arsenic, chromium, lead, mercury and selenium were all detected in one or more of the samples collected from the We Energies ash leachate samples. The two highest lead concentrations were from LH-07 at 682 ug/L and LH-09 at 173 ug/L.

We Energies Monitoring Wells

Samples collected from six We Energies monitoring wells (out of 18 wells sampled) had molybdenum concentrations above the ES. All of the monitoring well samples had boron detections, but only two were above the ES, at MW-06 (W-12B) and MW-07 (W-12C). These wells were drilled through an EADA located on the south side of the property.

Iron concentrations above Wisconsin’s Public Welfare ES of 300 ug/L were observed in only

four of the We Energies monitoring wells sampled, at MW-17 (W-45A) and MW-18 (W-45B) at 4,660 ug/L and 3,960 ug/L, respectively. MW-17 and MW-18 are located in a farm field to the west of the We Energies property (see Figure 5). Samples from MW-17 and MW-18 also had the two highest aluminum concentrations at 4,300 ug/L and 4,680 ug/L, respectively.

In general, significant sulfate concentrations were not observed in the monitoring wells. Two We Energies monitoring wells, MW-06 (W-12B) and MW-07 (W-12C), had sulfate ES exceedances, above 250 ug/L.

Arsenic was detected in the sample collected from MW-01 (W-26CR) at a concentration of 16 ug/L, which above the ES of 10 ug/L.

Caprolactam was found in water samples collected from eight of the We Energies monitoring wells and from one of the Hunts Landfill monitoring wells. Caprolactam is an organic compound used in the manufacturing of nylon. Some of the rope tied to the bailers for sampling the monitoring wells was made of nylon. Caprolactam was not found in leachate samples collected from the We Energies landfills or from the Hunts leachate/groundwater extraction wells. It is likely that the caprolactam detected in the water samples is a result of small particles or shavings of the nylon rope that may have entered the bailers during sample collection.

Hunts Landfill Leachate

The Hunts leachate showed only small concentrations of molybdenum, ranging from 1.28 ug/L in E-05 to 16 ug/L in E-07. Sample E-07 is a duplicate sample from extraction well E-05. Boron concentrations in Hunts leachate samples ranged from 163 ug/L in E-02 to 2,850 ug/L in E-04. Aluminum concentrations in the Hunts leachate samples ranged from 578 ug/L in E-02 to 6,130 ug/L in E-04. The boron and aluminum concentrations from the We Energies leachate samples were almost ten times higher than from the Hunts Landfill leachate samples.

Hunts Landfill leachate samples had sulfate concentrations ranging from 3.02 ug/L in E-05 to 71.8 ug/L in E-02. The two highest arsenic concentrations were in samples from E-04 and E-07 at 1620 ug/L and 1090 ug/L, respectively.

Total chromium was detected in the sample from E-05 at a concentration of 48.3 ug/L. This concentration is much lower than the chromium concentration found in the duplicate sample collected from E-05 which was named E-07. The total chromium concentration in the E-07 was 617 ug/L.

The Hunts Landfill leachate samples contained several organic analytes such as bis (2-ethylhexyl) phthalate, vinyl chloride, 1,1-dichloroethane, 1,1-trichloroethane, tetrachloroethylene and other VOCs.

Hunts Landfill Monitoring Wells

The Hunts monitoring well samples did not have any ES exceedances for molybdenum. Boron was detected in all of Hunts monitoring well samples but only MW-34 (P-4BR) and MW-43 (MW-14S) had boron concentrations above the ES. The boron concentrations in MW-34 (P-4BR) and MW-43 (MW-14S) were 1640 ug/L and 1480 ug/L, respectively. Both wells are shallow monitoring wells screened in sandy till, located on the west side the Hunts Landfill.

Samples collected from two Hunts monitoring wells, MW-41 (MW-11D) and MW-42 (MW-13B), had aluminum concentrations of 218 ug/L and 615 ug/L, respectively. The sample collected from MW-34 (P-4BR) had no detection of aluminum; however, the duplicate sample (MW-47) collected from MW-34 (P-4BR) had an aluminum concentration of 299 ug/L. The Wisconsin ES for aluminum is 200 ug/L

Arsenic was detected in the sample collected from MW-34 (P-4BR) at 10.9 ug/L. The duplicate sample (MW-47) collected from MW-34 had an arsenic concentration of 15.1 ug/L. The ES for arsenic is 10 ug/L.

Iron concentrations above the Public Welfare Standard of 300 ug/L were observed in 14 of the 15 Hunts monitoring wells sampled. Iron concentrations in the Hunts monitoring wells ranged from 61.9 ug/L in MW-36 (MW-6D) to 26,500 ug/L in MW-37 (P-3B). Three of the Hunts monitoring wells, MW-31 (P-1B), MW-32 (P-2B) & MW-37 (P-3B), had iron above 10,000 ug/L.

Vinyl chloride was detected in MW-39 (MW-10S) at a concentration of 180 ug/L. The ES for vinyl chloride is 0.2 ug/L. Other VOCs such as 1,1-dichloroethane, trans-1,2-dichloroethene, cis-1,2-dichloroethene and benzene were detected in samples from MW-39. MW-39 is a shallow monitoring well located on the west side of the Hunts Landfill, at the window of the containment wall around the landfill, near the Root River. Shallow groundwater on this side of the Hunts Landfill flows west towards the Root River.

Low levels of VOCs were also detected in monitoring wells MW-34 (P-4BR) and MW-35 (MW-4D).

2.4 Isotopes and Tritium: Background Information

Isotopes are atoms of the same element that have the same number of protons and electrons, but a different number of neutrons in the nucleus of the atom. The protons and neutrons in the nucleus of the atom provide the atom's weight or mass. The electrons are in orbit around the

nucleus and have virtually no weight or mass. The protons provide a positive charge, the electrons a negative charge and the neutrons have no charge. The number of protons and electrons in an atom define its elemental characteristics and properties. A change in the number of protons in an atom changes the element itself. For example, hydrogen has one proton; adding a proton creates helium.

Because neutrons have no charge, atoms of a single element can have a varying number of neutrons in the nucleus. Variations in the number of neutrons change the atomic weight of the atom. Isotopes of an element are distinguished by their differing atomic weights.

Some isotopes are stable and some are not stable. Unstable isotopes are called radioactive isotopes. Their nuclei disintegrate over time to form other isotopes or other elements and in the process emit a subatomic particle or a form of energy known as a gamma ray. The subatomic particles that may be emitted are alpha particles or beta particles. Alpha particles, beta particles and gamma rays are all referred to as atomic nuclear radiation. Stable isotopes do not emit any nuclear radiation.

As the earth was created and evolved over time, there were physical, chemical and biological processes or reactions that allowed isotopes of the same element to fractionate or change their relative proportions in the composition of different materials, such as rock, water and organic material. The isotopic composition of an element that makes up a particular material can be indicative of the source or of the processes that formed that material. This is the basis of isotope analysis.

Isotope compositions are simply a ratio of the heavy isotope to the lighter isotope. In the scientific community isotope compositions are commonly referenced to a standard of known composition and reported in per mil (‰). Note, per mil is a portion of 1000 just as percent is a portion of 100 (%).

The per mil (‰) value of a sample compared to the standard is calculated by using the following formula:

$$(\text{In } \text{‰}) = (R_{\text{sample}}/R_{\text{standard}} - 1)/1000$$

where “R” is the ratio of heavy to light isotope in the sample or standard. Reporting the isotope composition of a sample in this way is also known as its “delta” (d or δ) value in parts per thousand relative to a standard of known composition. A positive delta value means that the sample contains more of the heavy isotope than the standard and a negative delta value means that the sample contains less of the heavy isotope than the standard. [Ref. 42]

2.4.1 Boron Isotopes

Boron has two stable isotopes. They are Boron-10 (^{10}B) and Boron-11 (^{11}B). Boron-10 has 5 protons and 5 neutrons and Boron-11 has 5 protons and 6 neutrons. The delta value for $^{11}\text{B}/^{10}\text{B}$ can be written as $\delta^{11}\text{B}$. The environmental abundance of ^{11}B is approximately 80.1 % of all boron and the abundance of ^{10}B is approximately 19.9 %. [Ref. (9)]. The stable isotope ratio of boron in coal ash and coal ash leachate can vary significantly from the boron ratio found in naturally occurring groundwater. Stable boron isotope ratios have been used in previous studies as an indicator of the source of boron found in the environment around coal ash disposal sites. Published studies have found $\delta^{11}\text{B}$ values between -40 ‰ and $+6.6\text{ ‰}$ in coal ash samples. [Refs. (9), (44) & (45)] Studies have found that most natural waters have a $\delta^{11}\text{B}$ value between $+10$ and $+30\text{ ‰}$. [Refs. (9), (44) & (45)] Possible fractionation of boron isotopes by 30 to 40, caused by preferential adsorption of ^{10}B in dissolved boron to clay minerals, has been noted in the literature. [Ref. (46)]

2.4.2 Strontium Isotopes

Strontium can be found in coal ash and in naturally occurring minerals such as sphalerite. Strontium has four stable isotopes. They are ^{84}Sr , ^{86}Sr , ^{87}Sr and ^{88}Sr . The environmental abundance of these strontium isotopes out of all strontium is as follows: ^{84}Sr (0.56%), ^{86}Sr (9.86%), ^{87}Sr (7.0 %) and ^{88}Sr (82.58%). [Ref. 43] The ratio of $^{87}\text{Sr}/^{86}\text{Sr}$ is what is commonly used in geologic investigations. Past studies have found $^{87}\text{Sr}/^{86}\text{Sr}$ values for coal ash in the range of 0.71091 to 0.71169 and $^{87}\text{Sr}/^{86}\text{Sr}$ values in naturally occurring groundwater in the range of 0.708 to 0.709. [Ref. (47)]

2.4.3 Molybdenum Isotopes

Molybdenum has 33 isotopes but only six are stable. The stable isotopes of molybdenum are ^{92}Mo , ^{94}Mo , ^{95}Mo , ^{96}Mo , ^{97}Mo and ^{98}Mo . The most environmentally abundant molybdenum isotope is ^{98}Mo , comprising 24.14 % of all molybdenum. [Ref. (48)]

2.4.4 Past Boron and Strontium Isotope Studies

Boron and strontium isotopes have successfully been used to trace coal ash releases by researchers at Duke University and at the USGS and U.S. EPA. Duke University researchers found that boron is a sensitive indicator for coal combustion residue leaching. [Refs. (44) & (45)] Their study showed a distinctive boron isotope fingerprint in coal ash residue that is significantly different than that of boron in the upstream rivers. In their study, downstream rivers revealed a

$\delta^{11}\text{B}$ of -11‰ and -12‰ while most natural waters have a more positive $\delta^{11}\text{B}$ value. [Ref. (45)]

Researchers for the USGS and the U.S. EPA conducted a sampling project to determine if boron and strontium isotopes can be used to indicate the source of elevated boron concentrations found in private water supply wells located in Beverly Shores, IN. They also used tritium to try to obtain a relative age of the groundwater. Coal ash disposal has been a source of local surface and groundwater contamination in areas east and west of Beverly Shores. The researchers sampled private wells drilled in two separate aquifers, a deep confined aquifer and a shallower surficial aquifer. Past studies in the area showed that elevated boron levels occur naturally in the deep, confined aquifer, but not in the shallow aquifer. The USGS study showed distinctive $\delta^{11}\text{B}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values in the coal combustion products (CCP) affected water samples that are different from the $\delta^{11}\text{B}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ values in water samples collected from wells in the deeper, confined aquifer, consistent with $\delta^{11}\text{B}$ values obtained in the Duke University study. [Ref. (9)]

2.4.5 Tritium

Tritium is a radioactive isotope of hydrogen with a half-life of approximately 12.3 years. [Ref. (9)] Tritium contains a proton, an electron and two neutrons. This gives tritium an atomic mass of 3. Tritium can be written as ^3H . Tritium in air can be abbreviated as HT and tritium as water can be abbreviated HTO.

Tritium has been used in past studies to date groundwater in order to determine if it is younger than 1953. Natural tritium is not very common, but tritium can be created as a result of atomic nuclear reactions. [Ref. (9)] From the 1950s through the 1970s, atomic bomb testing distributed large amounts of tritium into the atmosphere. Cosmic rays from the sun caused tritium in the atmosphere to combine with oxygen to create tritium water. The tritium water fell to the earth in the form of rain or snow and was absorbed by the ground or collected in surface water. Tritium levels in precipitation were measured at stations in Chicago, IL, and Ottawa, Canada, until 2002. Knowing the tritium levels that were in precipitation and the half-life of tritium, one can determine if the water was likely formed before or after 1953. Tritium amounts for this project were measured in Tritium Units (TU). $1\text{ TU} = 3.221\text{ Picocuries/Liter}$. A picocurie is a unit of radioactivity.

Based on past tritium studies, at the time the groundwater samples for this project were collected in 2011, it is believe that if the water contained detectable amounts of tritium ($>0.8\text{ TU}$) then the water is likely younger than 1953. Most groundwater that is under a 100 to 200 foot confining layer, such as clay, is hundreds, if not thousands, of years old. Groundwater that is younger than 1953 means that it is likely either shallow or there is a pathway for younger groundwater and any contaminants that may be in it to enter the deeper aquifer within that 58 year time span.

Over time, man-made tritium levels in the atmosphere have declined because above ground

atomic bomb testing ended in the 1970s and the tritium from past atomic bomb testing has been radioactively decaying. In an aquifer, “old” groundwater may mix with “young” groundwater which may further lower tritium amounts, because of dilution. The result is these factors may diminish the effectiveness of using tritium to detect “young” water, if the “young” water is present in small amounts.

2.5 Discussion of the Isotope and Tritium Analytical Data

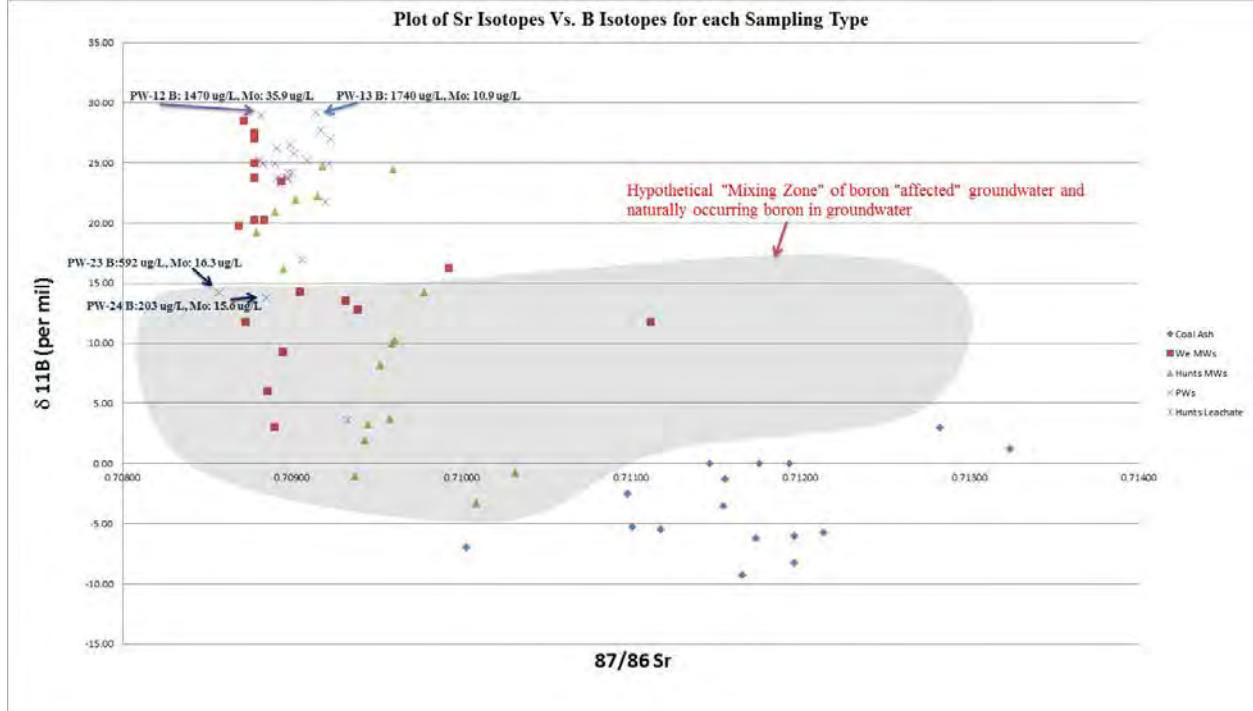
2.5.1 Strontium and Boron Isotopes Analysis

All samples for boron and strontium isotope analysis were shipped, via Fed Ex, to the United States Geological Survey (USGS) Laboratory in Menlo Park, California.

Because of the presence of petroleum product in samples collected from the Hunts leachate/groundwater extraction wells, the USGS laboratory was unable to analyze these samples for boron and strontium isotopes. The consultant for Hunts, TRC, Inc., was able to get their liquid sample collected from E-05 analyzed for $\delta^{11}\text{B}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ at ALS Isotech Laboratories, Inc., in Scandinavia.

Figure 1, below is a plot of $^{87}\text{Sr}/^{86}\text{Sr}$ versus $\delta^{11}\text{B}$ for all of the sample types. The sample types include leachate samples collected from the We Energies coal ash landfills (blue diamonds), one leachate sample from the Hunts Landfill (blue star), the We Energies groundwater monitoring wells (red squares), the Hunts Landfill groundwater monitoring wells (green triangles) and the 24 private wells sampled (blue Xs).

Figure 1:



The plot shows that the coal ash leachate is generally isotopically light for boron and isotopically heavy for strontium, compared to the other sample types. This is consistent with other boron and strontium isotope studies. [Refs. (9), (44), (45) & (49)] The coal ash samples (blue diamonds) are generally located in the bottom, right of the plot.

The isotope expert for the USGS who looked at the $^{87}\text{Sr}/^{86}\text{Sr}$ Vs. $\delta^{11}\text{B}$ plot indicated that the plot is a classic data set and a sample with a $\delta^{11}\text{B}$ value less than +15 ‰ is likely “affected”. [Ref. (50)]

The private well samples (blue Xs) are generally located in the top, left corner of the plot. This means that the water samples collected from the private wells were generally isotopically heavy for boron and isotopically light for strontium. The two private wells with the highest boron concentrations, PW-12 (B at 1,470 ug/L) and PW-13 (B at 1,740 ug/L), had the heaviest boron isotope composition compared to all other samples and are located in the upper, left end of the plot.

In the middle of the plot is a hypothetical mixing zone where naturally occurring boron in groundwater would hypothetically be mixing with groundwater containing boron from a potential source such as the coal ash landfills or the Hunts Landfill. The hypothetical “mixing zone” is the shaded area on the plot. The area drawn is an estimate of the mixing zone. Above this “mixing zone” the samples would represent “non-affected” boron groundwater or groundwater from a different source than the coal ash or Hunts.

While the majority of the private well samples lie well outside the mixing zone, several monitoring wells and two private wells appear to lie within the “mixing zone”.

The two private wells within the “mixing zone” are PW-23, located approximately two miles northwest from the intersection of County Line Rd. and Foley Rd. and PW-24, located approximately 3.5 miles due west from the intersection of County Line Rd., and Foley Rd. The boron concentration in the sample collected from PW-23 was 592 ug/L and the molybdenum concentration was 16.3 ug/L. The boron concentration in the sample collected from PW-24 was 203 ug/L and the molybdenum concentration was 70.6 ug/L. Well construction information for these two private wells was not available. In neither case was the boron concentration at a level that would be considered elevated above potential naturally occurring levels.

Eight of the We Energies monitoring wells appear to lie within the “mixing zone.” Of these wells, only MW-18 (W-45B) is open in the dolomite.

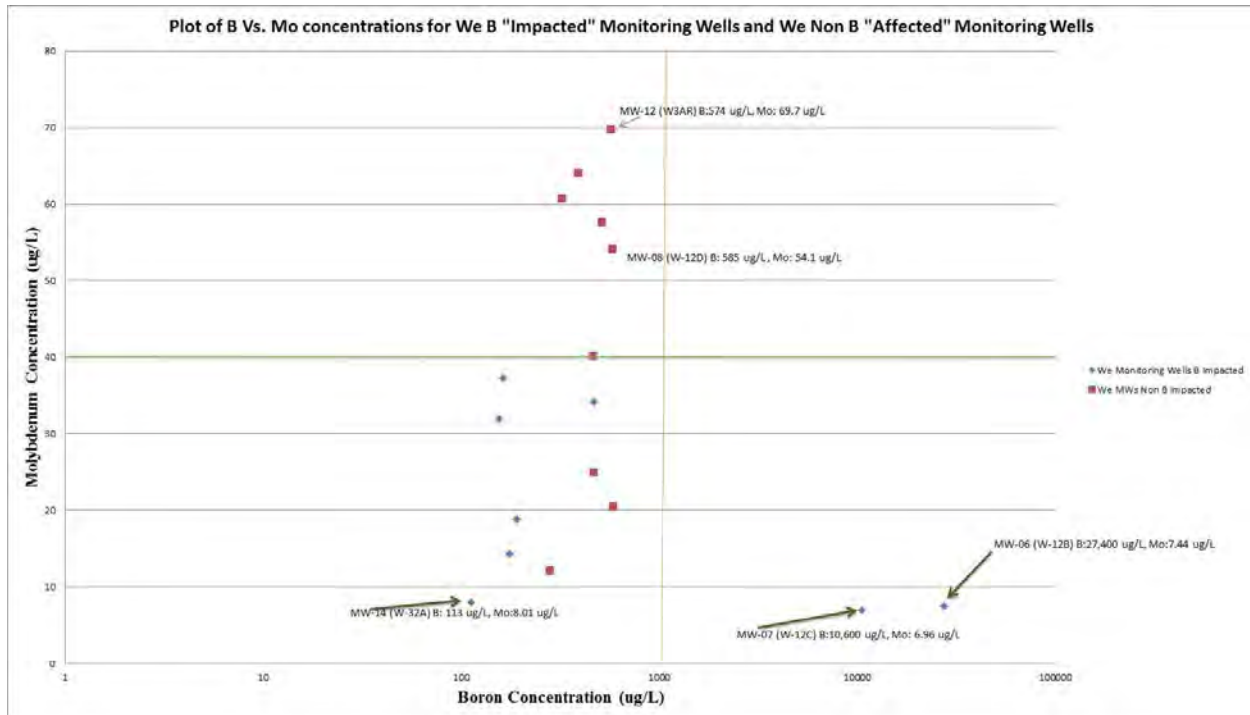
Three of the We Energies wells are part of a well nest that goes through an EADA located on the south side of the We Energies property. MW-07 is the shallowest of these wells, screened between 11.5 and 21.5 ft. bgs, just below the ash. The boron concentration in MW-07 was 10,600 ug/L and the molybdenum concentration was 6.96 ug/L. MW-06 is screened at a depth between 39 and 49 ft. bgs. The boron concentration in MW-06 was 27,400 ug/L and the molybdenum concentration was 7.44 ug/L. MW-08 is open to the top of the dolomite at a depth of 168 to 173 ft. bgs. The boron concentration in MW-08 dropped significantly to 585 ug/L and the molybdenum concentration increased to 54.1 ug/L, compared to the shallower wells in this nest. The plot of $^{87}\text{Sr}/^{86}\text{Sr}$ Vs. $\delta^{11}\text{B}$ places MW-08 outside of the “mixing zone” which would appear to indicate that it is not an “affected” well from the coal ash based on boron isotope characteristics. In addition, the molybdenum in MW-08 samples does not appear to be coming from this specific EADA because the molybdenum concentrations in the shallower wells of this well nest have much lower molybdenum concentrations than in samples collected from MW-08.

Eight Hunts Landfill monitoring wells lie within the “mixing zone.” These wells all screened less than 30 ft. deep. Wells MW-31, MW-32, MW-34 and MW-37 are all located within the containment wall around the landfill. MW-39 (MW-10S) is located at the discharge window of the containment wall.

Figure 2, below is a plot of the boron concentration versus the molybdenum concentration for the We Energies boron affected monitoring wells (blue diamonds) and the We Energies boron non-affected monitoring wells (red squares). Again, the boron “affected” monitoring wells were distinguished from the boron non-affected monitoring wells based on the $^{87}\text{Sr}/^{86}\text{Sr}$ versus $\delta^{11}\text{B}$ plot (Figure 1). On the plot in Figure 2 the molybdenum ES (40 ug/L) is marked with the green line and boron ES (1000 ug/L) is marked with the orange line. The plot shows that the boron affected We Energies monitoring wells generally have lower or similar molybdenum concentrations compared to the boron non-affected monitoring wells. In other words, there does not appear to be a relationship between the boron affected We Energies monitoring wells and

elevated molybdenum concentrations (Mo > 40 ug/L).

Figure 2:



2.5.2 Molybdenum Isotope Analysis

Samples for molybdenum isotope analysis were sent, via Fed Ex, to the Arizona State University Earth and Space Exploration Laboratory in Tempe, Arizona. Department staff deferred to the expertise of the molybdenum isotope research scientists to determine which molybdenum isotopes to analyze.

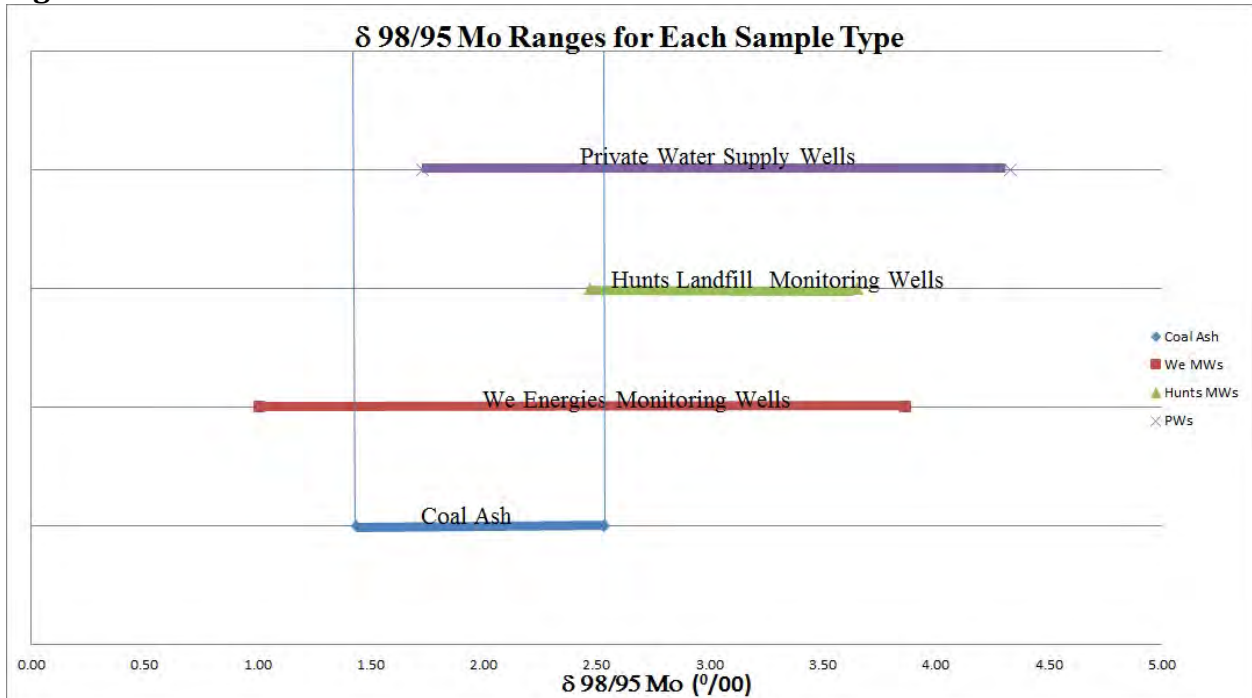
Using molybdenum isotopes as an indicator of the source can be difficult because molybdenum can fractionate under oxic conditions in the aquifer to iron oxide and organic material. [Refs. (51), (29) & (52)] Dissolved molybdenum can also adsorb to the walls of the plastic sample bottles. [Ref. (51)] Iron oxide and particulates were noted in several of the samples. [Ref. (51)] The result may be that the molybdenum isotope changes along the flow path in the aquifer with distance from the source. [Ref. (51)]

Experiments were conducted by the laboratory to evaluate how the processes described above may have affected the Mo isotope ratios. The experiments involved comparing sub-samples of the coal ash leachate samples that were (1.) unacidified, filtered, (2.) unacidified, unfiltered, and

(3.) acidified, unfiltered. The results of the experiments are contained in Table 9.

Figure 3, below is a chart that shows the relative $\delta^{98/95}\text{Mo}$ ranges for each sample type. The $\delta^{98/95}\text{Mo}$ ranges for each sample type are summarized below:

Figure 3:



Coal ash (includes leachate samples): 1.44 – 2.53 ‰

We Energies Groundwater Monitoring Wells: 1.01 – 3.87 ‰

Hunts Landfill Groundwater Monitoring wells: 2.47 – 3.65 ‰

Private Water Supply Wells: 1.73 – 4.33 ‰

The private wells that had a $\delta^{98/95}\text{Mo}$ value in the same range as the We Energies monitoring wells are PW-01, PW-06, PW-10, PW-14, PW-15, PW-18, PW-19, PW-24 and PW-26. Wells PW-24 and PW-26 are located approximately four miles west of the We Energies property and PW-14 and PW-15 are located approximately two miles west of the We Energies property.

The two private wells with the highest molybdenum concentrations, PW-10 with a Mo concentration of 145 ug/L and PW-18 with a Mo concentration of 121 ug/L, had $\delta^{98/95}\text{Mo}$ values in the same range as the coal ash samples. PW-10 is located within ¼ mile from the We Energies property, to the west, and PW-18 is located approximately 5.5 miles from the We Energies property to the southwest. PW-18 is open to the underlying Makoqueta Shale. The

well construction information for PW-10 was not available.

The private wells that had $\delta 98/95$ Mo values outside but close to the coal ash range, are PW-02 ($\delta 98/95$ Mo 2.68) and PW-20 ($\delta 98/95$ Mo 2.58). Private wells PW-05, PW-09, PW-12, PW-13, PW-16, PW-17, PW-22 and PW-23 all had $\delta 98/95$ Mo values outside of the range of the coal ash samples. (see Table 7 for Mo isotope values) Unfortunately Mo isotope data were unavailable for PW-03, PW-04, PW-11 and PW-21. It is not known why the laboratory was not able to achieve values for these samples.

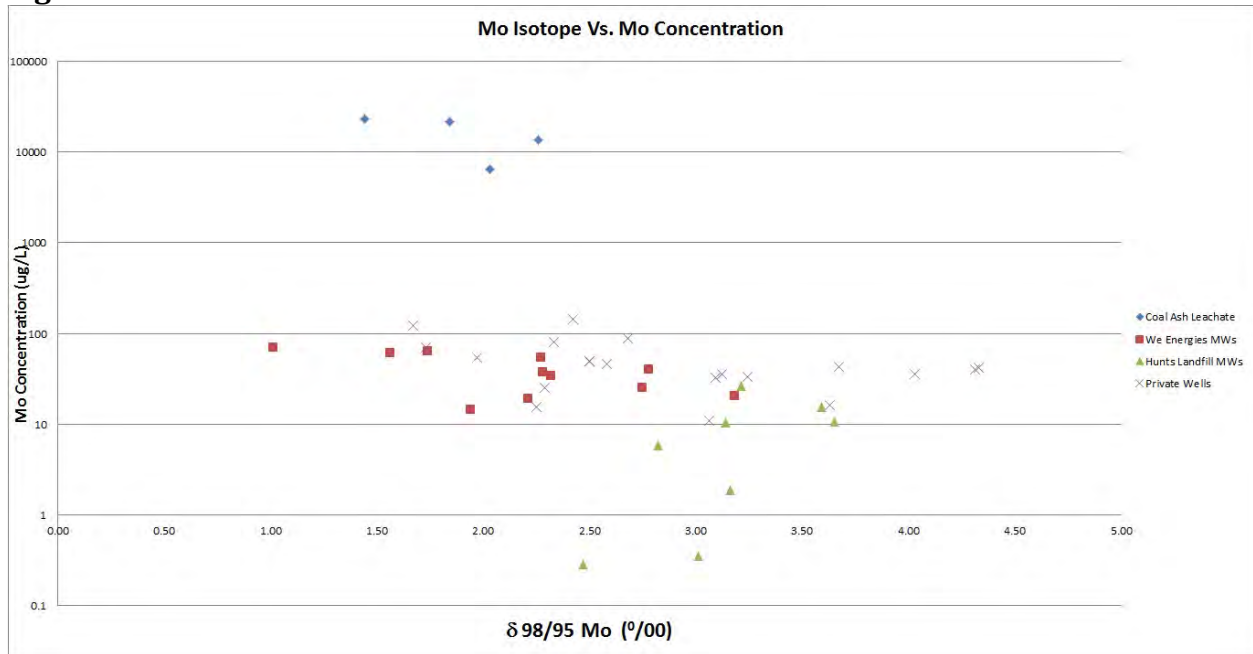
The private wells PW-14, PW-15, PW-18, PW-19, PW-24 and PW-26 that had a $\delta 98/95$ Mo value within the same range as the coal ash samples are farther away from the We Energies property than the private wells that do not (PW-05, PW-09, PW-16, PW-17 and PW-22). In addition some of the farther wells, such as PW-18, PW-21 and PW-26 have higher molybdenum concentrations than some of the closer wells. Some of the variations may be attributable to varying well depths. However, the fact that PW-09, PW-16 and PW-17 all have elevated molybdenum concentrations, and $\delta 98/95$ Mo values outside the range of the coal ash on the high end, suggests that something may be occurring with the molybdenum isotopes that is not understood at this time and/or there is another molybdenum source.

Much of the molybdenum isotope data do not appear to correlate well with the boron isotope data in the private wells and in the We Energies monitoring wells. Of the private wells, only PW-24, which had a molybdenum concentration of 15.6 ug/L and a boron concentration of 203 ug/L, had both boron and molybdenum isotope values in the same range or “mixing zone”. Of the We Energies monitoring wells, only 5 of the 18 wells sampled correlated. This may mean that (1.) either the Mo or the B isotope data are unreliable or both are unreliable, (2.) there is another unidentified source influencing the data or (3.) the boron and molybdenum are acting independently.

Regarding reliability of the isotope data, molybdenum appears to be more susceptible to fractionation in the aquifer along the flow path than boron does, which could change its isotopic ratio from its original state. Boron isotope ratios have appeared to be reliable in past studies of coal ash.

Figure 4 below compares molybdenum concentrations with measured molybdenum $\delta 98/95$ isotope values in collected samples.

Figure 4:



It appears from this graph that all sample $\delta 98/95$ isotope values except one fall within the $\delta 98/95$ isotope value range of coal ash leachate (about 1.44 to 2.26 ‰) or show a "heavier" isotopic value. The graph also seems to show, for both the We Energies site monitoring well samples and the private water supply well samples, that molybdenum concentrations are decreasing as $\delta 98/95$ isotope values for those monitoring points become "isotopically heavier".

Research has shown that under oxic geochemical conditions molybdenum will adsorb to iron and manganese oxyhydroxides, and that the lighter isotopes of molybdenum (^{95}Mo) will be preferentially adsorbed relative to the heavier isotopes of molybdenum (^{98}Mo). [Ref. (29)] This preferential adsorption of lighter molybdenum isotopes should then result in a heavier isotopic molybdenum signature in groundwater under oxic geochemical conditions. As sample results for redox sensitive parameters suggest that oxic redox conditions are present in the shallow aquifer system in the area of investigation, a possible explanation for the observed heavier isotopic values seen with decreasing molybdenum concentrations in Figure 4 is that the lighter molybdenum isotopes are being preferentially adsorbed to aquifer oxyhydroxides.

Research has also shown that under certain reducing redox conditions that molybdenum might be removed from solution with the formation of iron sulfide minerals. It has been suggested that this process will result in an isotopically lighter molybdenum isotope signature as under these redox conditions heavier isotopes of molybdenum may be preferentially removed. [Ref. (29)] It appears that at the Hunts Landfill site reducing conditions may be present in the aquifer, possibly due to the past release of organic contaminants into groundwater. On Figure 4, for some of the Hunts

landfill monitoring well samples, it appears that a lighter molybdenum isotopic signature is associated with reduced molybdenum concentrations. This might be explained by the preferential “loss” of heavier molybdenum isotopes associated with reducing aquifer conditions in this area.

At this time, there are no known or obvious additional potential man-made sources. Two borings that were drilled in 1953 and archived by the WGNHS had detections of both molybdenum and boron in the clay till and in the Maquoketa Shale.

Regarding the relationship between boron and molybdenum, both occur in coal ash at high concentrations and both may be mobile in the groundwater. Boron was higher in concentration than molybdenum in 3 of the 4 coal ash leachate samples. In LH-05, the boron concentration was 13 times higher than the molybdenum concentration and in LH-10, the boron concentration was 6.8 times higher. Monitoring wells MW-06 and MW-07, both drilled through an EADA are screened just below the ash and had very high boron concentrations but very little molybdenum. The Hunts Landfill leachate also had elevated boron concentrations but very little molybdenum. If the isotope data are suggesting that boron from the coal ash is not impacting the private wells but molybdenum is, then there would need to be a flow mechanism to transport the molybdenum several miles to the west and southwest from the We Energies property, but not the boron. At this time, there is no known flow mechanism with this capability.

2.5.3 Tritium Analysis

All water samples for tritium analysis were shipped via Fed Ex to the University of Waterloo Isotope Laboratory in Waterloo, Canada.

In this project none of the samples collected from the five We Energies monitoring wells that are open in the dolomite had detectable amounts of tritium. These monitoring wells are MW-05 (W-39C), MW-08 (W-12D), MW-16 (W-44), MW-18 (W-45B) and MW-19 (W-47). The other We Energies monitoring wells that did not have a detectable amount of tritium are MW-03 (W-3CR), MW-12 (W-3AR) and MW-17 (W-45A). Of these the shallowest well is MW-12 (W-3AR) which is screened between 27.1 and 32.1 feet bgs in till and the deepest well is MW-17 (W-45A) which is screened between 55 and 60 feet. bgs. This screened interval is also in the intermediate sand layer.

The remaining ten We Energies monitoring wells sampled in this project showed detectable amounts of tritium, which would suggest that some of the groundwater in these wells is younger than 1953. The shallowest of these wells with a measurable amount of tritium is MW-02 (W-3BR) which is screened between 7.5 and 17.5 feet bgs in clay till and deepest is MW-01 (W-26CR) which is screened between 59 and 64 feet bgs in till.

Unlike the We Energies monitoring wells in the dolomite, the three monitoring wells that were sampled at the Hunts Landfill that are open in the dolomite all showed measurable amounts of

tritium. The dolomite is shallower at the Hunts site than at the We Energies property. The shallowest Hunts dolomite well sampled is MW-42 (MW-13B) which is open between 47.8 and 53 ft. bgs. The deepest dolomite well sampled at Hunts is MW-44 (MW-16B) which is open between 88.8 and 94 ft. bgs. Only two Hunts monitoring wells did not have detectable amounts of tritium. These two wells are MW-36 (MW-6D), screened between 42.1 and 47.1 ft. bgs. and MW-41 (MW-11D), screened between 22.1 and 27 ft. bgs.

The remaining ten monitoring wells sampled at Hunts all showed measurable amounts of tritium. The shallowest of these wells is MW-39 (MW-10S) which is screened between 2.7 and 12.7 ft. bgs. and the deepest is MW-34 (P-4BR) which is screened between 20 and 30 ft. bgs.

Of the 24 private wells sampled for tritium, only four private wells showed a detectable amount. These private wells are PW-01, PW-03, PW-04 and PW-11. The tritium levels in these four private wells ranged from 0.9 to 1.1 TU. The lack of detectable tritium in the majority of private water supply wells suggests that they are less likely to have received water that is younger than 1953.

2.6 Follow-up 2012 Sampling

2.6.1 Emerald Park Landfill Groundwater Monitoring Well Samples

On October 18, 2012 the department collected water samples from six groundwater monitoring wells located on the Emerald Park Landfill (EPL) property in Muskego, WI. EPL is located approximately eleven miles west of Lake Michigan, in southeast Waukesha County. EPL is an approved and licensed, active municipal solid waste landfill. It began accepting solid waste in 1994. [Ref. (53)]

EPL has an engineered composite liner consisting of four feet of compacted clay overlain with a 60 mil thick high density polyethylene (HDPE) liner. The landfill also contains an engineered leachate collection system consisting of a 12-inch stone drainage layer over the liner and perforated leachate collection pipes laid in trenches that collect and drain leachate to sumps where it is pumped out. Under the composite liner is a 12-inch sand gradient control layer that routes shallow groundwater away from the bottom of the liner. Older portions of the landfill are capped with a composite cap consisting of clay and a plastic geomembrane. EPL is surrounded by groundwater monitoring wells at different depths that are sampled semi-annually.

The monitoring wells that were sampled are nested at different depths. Five of the wells sampled, MW-303B, MW-305A, MW-305B, MW-305C and MW-305D are located approximately 1,500 feet south of the existing limits of waste, along Union Church Drive (8-Mile Road; see fig. 18 for location of EPL). One well, MW-313D, is located approximately 150 feet south of the existing limits of waste.

Molybdenum concentrations of 300 ug/L and 321 ug/L were found in samples collected from MW-303B and MW-305B, respectively. MW-303B is screened in the glacial clay till at an elevation interval of 708.5 to 703.5 feet msl and MW-305B is also screened in the glacial clay till at an elevation interval of 687.9 to 682.9 feet msl. Molybdenum was found in the samples from the other four EPL wells at concentrations between 27 ug/L in the shallowest monitoring well (MW-305A) to 165 ug/L in a well screened in a silty sand layer (MW-305C) at an elevation interval of 653.8 to 648.8 feet msl.

Groundwater elevations in monitoring wells on the EPL property show that the shallow groundwater generally flows from east to west and groundwater in the outwash sand unit below the glacial clay till generally flows towards the north/northeast. [Refs. (54) & (55)]

Strontium was also detected in some of the samples at elevated concentrations, particularly in MW-305A.

Table 11 below summarizes the October 18, 2012, sample data from the EPL monitoring wells:

Table 11:

	MW-303B	MW-305A	MW-305B	MW-305C	MW-305D	MW-313D
Screened Elevation Interval (ft. msl)	708.5 – 703.5	774.9 – 764.9	687.9 – 682.9	653.8 – 648.8	611.06 – 606.06	592.91 – 587.91
Screened Depth Interval (ft/ bgs)	69.0 – 74.0	4.0 – 14.0	91.0 – 96.0	125 - 130	167.6 – 172.6	189.2 – 194.2
Geologic Unit of Screened Interval	Clay Till	Clay Till	Silty Sand (Outwash)	Silty Sand to Sandy Silt (Fluvial)	Dolomite Bedrock	Dolomite Bedrock
Boron (ug/L)	459	371	490	457	381	427
Molybdenum(ug/L)	300	27	321	165	77	117
Aluminum (ug/L)	9	7	5	5	6	6
Arsenic (ug/L)	ND	ND	ND	ND	ND	ND
Cadmium (ug/L)	ND	ND	ND	ND	ND	ND
Calcium (mg/L)	38.0	240	50	29.3	16.7	22.8
Chromium (ug/L)	ND	ND	ND	ND	ND	ND
Cobalt (ug/L)	ND	ND	ND	ND	ND	ND
Copper (ug/L)	3	4	ND	ND	ND	ND
Iron (mg/L)	ND	ND	ND	0.1	ND	ND
Lead (ug/L)	ND	ND	ND	ND	ND	ND
Magnesium (mg/L)	12.7	153	19.8	10.9	9.1	11.9
Manganese (ug/L)	3	20	14	14	2	10
Nickel (ug/L)	1	7	ND	ND	ND	ND
Vanadium (ug/L)	ND	ND	ND	ND	ND	ND
Zinc (ug/L)	ND	ND	ND	ND	ND	ND
Strontium (ug/L)	1280	4090	1660	898	357	828
Hardness (mg/L)	147	1230	206	118	79.2	106

EPL is not considered to be a source of the molybdenum found in these wells because:

- 1) EPL is a relatively young landfill. Waste filling began in 1994. [Ref. (53)]
- 2) EPL is an engineered, lined landfill with a leachate collection and removal system. It also has a groundwater gradient control system that routes groundwater away from the liner. [Ref. (53)]
- 3) Other contaminants such as VOCs normally associated with municipal solid waste landfills have not been detected in these monitoring wells and are not being detected in other EPL monitoring wells. [Ref. (4)]
- 4) The general shallow groundwater flow direction across this property is from east to west. [Refs. (54) & (55)]

The Future Parkland landfill is a closed and capped foundry sand landfill located approximately 2,800 feet north of MW-303B and MW-305B. It was constructed in the mid 1980s and has a four foot clay liner and a leachate collection system. [Ref. (56)] Molybdenum can sometimes be found in foundry sand. Therefore molybdenum was analyzed in the leachate from Future Parkland on two separate occasions by Future Parkland.

The May 11, 2012 leachate sample had a molybdenum concentration of 110 ug/L and the August 22, 2012 sample had a molybdenum concentration of 87.6 ug/L [Ref. (57)] Both of these concentrations are lower than the concentrations found in four of the six monitoring wells. Therefore, based on available leachate sampling results, the Future Parkland Landfill is not considered to be a likely source of the molybdenum.

Some recent water samples collected from private wells located to the south of EPL have shown elevated molybdenum concentrations, above the NR 140 ES. These wells are generally open to the dolomite.

2.6.2 WGNHS samples (shale & till)

Department staff obtained samples from two borings drilled on the We Energies property in 1953, before most if not all ash filling activities began on the property. The WGNHS had maintained these soil and rock samples in its archive. The samples were analyzed for molybdenum, boron and other metals. The samples included both clay till and the Maquoketa shale at different depths in the two borings.

Boron was found in all of the samples and molybdenum was found in four of the six samples. The highest boron concentration was 32 milligrams per kilogram (mg/Kg) in a sample of the Maquoketa Shale at a depth of 440 to 445 feet bgs. The highest molybdenum concentration was

2.4 mg/Kg in a sample of the clay till at a depth of 80 to 85 feet bgs.

The concentrations in these two samples do not appear to be relatively high when compared to average values reported for these elements in shale rock, 4.2 ppm for molybdenum and 194 ppm for boron [Ref. (11)], and considering that the reported molybdenum concentrations are below the laboratory analytical level of quantitation; however, the data show the presence of these compounds in the overlying clay till and shale bedrock which underlies the Niagara Dolomite.

Table 12 below summarizes the sample data from the WGNHS 1953 borings.

Table 12:

	ML330	ML330	ML330	ML331	ML331	ML331
Sample Depth Interval (ft/ bgs)	105 - 110	440 – 445	645 - 650	80 - 85	335 - 340	535 - 540
Geologic Unit of Screened Interval	Clay Till	Maquoketa Shale	Lower Maquoketa Shale	Clay Till	Maquoketa Shale	Lower Maquoketa Shale
Boron (mg/Kg)	19	32	21	20	25	22
Molybdenum (mg/Kg)	2.0	1.3	ND	2.4	1.1	ND
Aluminum (mg/Kg)	10,700	8,860	7,360	10,500	10,400	9,680
Arsenic (mg/Kg)	2	ND	ND	2	ND	ND
Barium (mg/Kg)	57.0	9.8	8.0	54.3	12.0	10.6
Cadmium (mg/Kg)	ND	ND	ND	ND	ND	ND
Calcium (mg/Kg)	112,000	59,900	126,000	92,300	60,300	64,200
Chromium (mg/Kg)	19.1	14	10.7	19.1	16.1	15.4
Cobalt (mg/Kg)	7.9	6.8	8.4	9.7	12.4	12.0
Copper (mg/Kg)	20.1	9.0	14.8	18.5	17.4	19.8
Iron (mg/Kg)	19,000	23,000	16,000	18,000	24,400	20,300
Lead (mg/Kg)	10	7	3	8	6	3
Magnesium (mg/Kg)	52,000	36,800	78,600	45,100	38,500	40,900
Manganese (mg/Kg)	424	172	253	460	335	323
Nickel (mg/Kg)	20	16	17	21	25	25
Vanadium (mg/Kg)	22.5	17.4	10.2	22.5	13.5	12.2
Zinc (mg/Kg)	41	27	30	39	31	32
Strontium (mg/Kg)	96	46	53	84	84	68

2.6.3 Public Water Supply Sampling

On January 8, 2013 the Raymond Elementary and the Drought Elementary School wells were sampled for molybdenum, boron and a suite of metals. The Raymond Elementary School is located at 2659 South 76th Street in Franksville and the Drought Elementary School is located at 21016 Seven Mile Road in Franksville, in Racine County. (see figure 18 for school locations)

The molybdenum concentration in the Raymond Elementary school water sample was 101 ug/L, which above the NR 140 ES of 40 ug/L. The molybdenum concentration in the Drought Elementary school water sample was 7 ug/L.

The boron concentration at the Drought Elementary School sample was 965 ug/L and the boron concentration in the Raymond elementary School sample was 919 ug/L. While these concentrations are below the NR 140 ES of 1,000 ug/L for boron, the concentrations are high compared to the other water samples collected in the area.

The Raymond School well is drilled to a depth of 1,400 feet bgs. It is constructed with a protective steel casing to a depth of 485 feet bgs which is below the Maquoketa Shale Formation. The grout material around the steel casing, which provides seal between the casing and the surrounding soil or rock, is at a depth of only 40 feet bgs.

The well for the Drought School is 389 feet deep and is open in the dolomite (limestone on the well report), with a protective steel casing and grout (puddled clay) that is 261 feet deep.

SECTION 3.0 MIGRATION PATHWAYS

3.1 Groundwater

In the unconsolidated deposits in the area of the study, migration pathways for contaminants in groundwater include horizontal and vertical flow in the clay till, flow in the coarser sand seams inter-bedded within the till, flow within the outwash sand above the Niagara Dolomite, flow among the unconsolidated units and flow from the unconsolidated units to the bedrock. The clay till unit displays some fracturing, especially in the top 30 feet, which may promote vertical movement of water. With increasing depth, the frequency of fractures appears to reduce and the hydraulic conductivity decreases. The thick clay and silty clay till deposits tend to be more protective of the aquifer below, where the private wells obtain their drinking water, than other soil types because of the relatively low hydraulic conductivity of clay compared to other soil types such as sand. [Ref. (25)]

The aquifer just below the clay till consists of Silurian age fractured dolomite bedrock and basal sand and gravel just on top of the dolomite. [Ref. (17) and Ref. (25)] The dolomite bedrock tends to increase in depth closer to Lake Michigan in the local area. [Map 13, Ref. (25)] (see Fig. 16)

The groundwater flow direction in the bedrock has been calculated to be generally to the east. [Ref. (25)] (see Figs. 11 & 12) An east-west bedrock valley, the Troy Bedrock Valley, is located along the boundary between Milwaukee and Racine County. [Map 17, Ref. (25)] (see Figs. 14, & 20) Bedrock depth in this valley, and thicknesses of unconsolidated sediments, are greater than in areas outside the valley. Most of the molybdenum affected private wells appear to lie in or near the bedrock valley. [See Fig. 14 and Fig. 7]

Intermediate Sand Layer: In 1993, We Energies identified a sand layer embedded in the clay till that is approximately 30 feet thick and 70 feet deep. The sand layer runs east-west and has been found under the We Energies property at varying depths. [Refs. (12) & (58)] This sand layer has been the focus of efforts to determine whether it represents a migration pathway for coal ash contaminants originating on the We Energies property.

The western extent of the sand layer has not been fully identified. Some private well logs suggest that the sand layer extends to the west and contacts the dolomite bedrock. [Cross Section C-C' of Figure 4, Ref. (59)] The groundwater flow direction in this sand layer is not well defined, but the 2010 We Energies report concluded that the flow direction is to the southeast. [Ref. (39)]

However, if additional site monitoring wells W-26CR and W-3CR are included in an evaluation of groundwater flow direction, a groundwater divide appears to be present in the sand layer, and there is groundwater flow in the sand layer to the west/northwest. The presence of a groundwater divide in the sand layer is consistent with the east – west water table groundwater divide that has been found to be present at the site. [Fig. 3, Ref. (17) & Plate 6, Ref. (12)]

Soil boring information was not collected when monitoring well W-26CR was constructed so it is unknown whether the screened interval of well W-26CR intersects the sand layer or not. Well W-26CR, however, has been shown to be screened (640' - 635' MSL) at approximately the elevation that the sand layer exists in neighboring wells (top of sand 645' to 635' MSL), and has exhibited the same hydraulic response to installation of the new site dewatering system as nearby wells screened in the sand layer. Soil boring information was also not collected for well W-3CR when it was constructed, but well W-3CR replaced site well W-3C and the boring log for well W-3C [Ref. W-3C Soil Boring Log] shows the existence of a silty fine sand layer between approximately elevations 650' and 644' MSL. Well W-3CR is screened between approximately elevations 648' and 643' MSL, and therefore appears to be monitoring the sand layer at the site.

In 2005, We Energies constructed a new power plant generating unit at a site along the lake shore to the east of the existing site North Ash Landfill. The new power unit project included extensive bluff excavation and construction of a substantial drainage dewatering system [Ref. (60)]. The installation of this dewatering system appears to have significantly reduced the hydraulic heads in a number of sand layer monitoring wells at the We Energies site. After installation of the new power unit site dewatering system the hydraulic heads measured in site wells W-26CR, W-28BR, W-37C and W-39B dropped approximately 10' to 15' [Figure 5, below]. Site well W-26CR appears to have responded hydraulically the same as site wells

known to be screened in the sand layer.

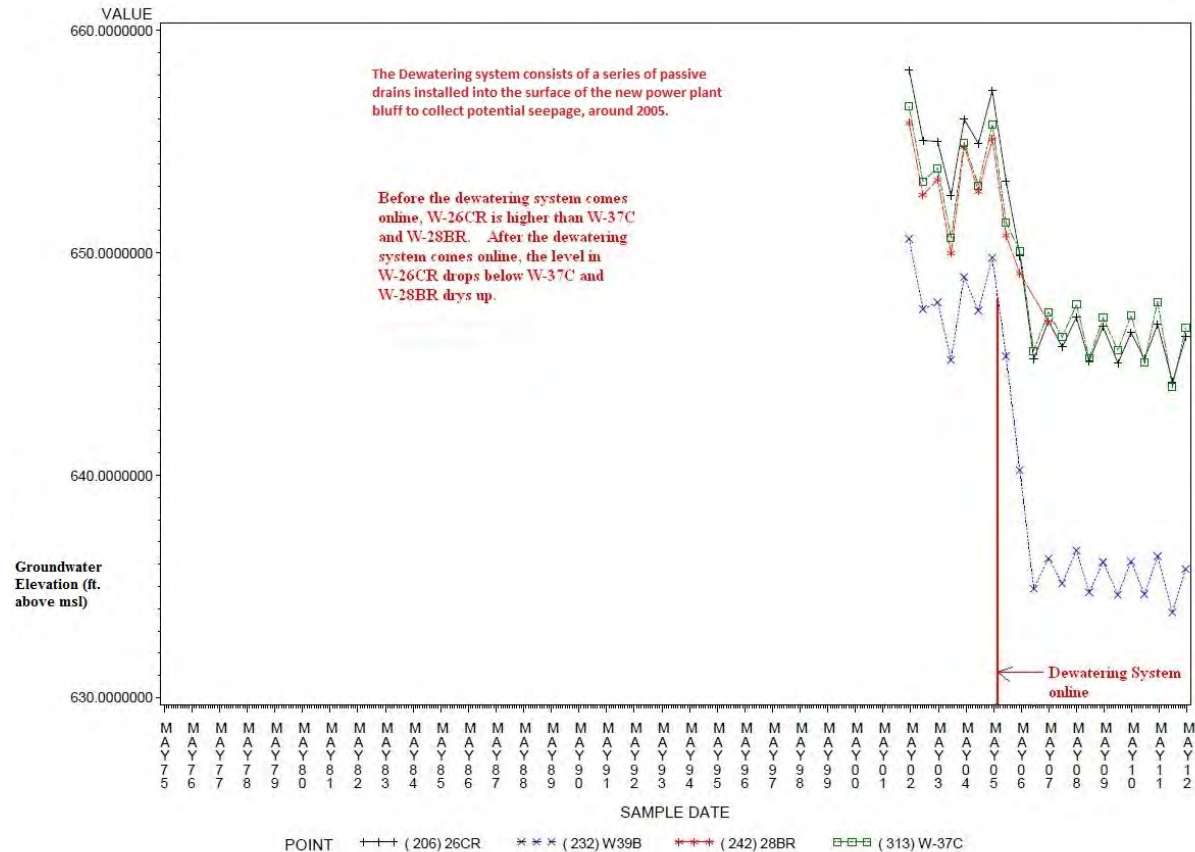
In the fall of 2012, We Energies drilled two borings on the site at the request of the department in an attempt to find the sand layer at other locations under the property. At one of the two boring locations, sand was encountered at two intervals. The location of this boring is in the vicinity of the W-16 well nest. A 5 foot "poorly graded sand" layer was encountered at elevation 652.5' to 647.5', MSL, and a 15 foot "poorly-graded sand with silt" layer was encountered at elevation 628.5' to 613.5' MSL [Ref. (58)]. Monitoring well W-16D was constructed with a screened elevation (624.5' to 619.5' MSL) in the in the lower of these two sand layers.

After W-16D was developed and the groundwater elevations allowed to reach steady state, We Energies measured the groundwater elevations in the sand wells across the site, but excluded monitoring wells W-26CR and W-3CR when evaluating the sand layer groundwater flow direction in the November, 2012 groundwater elevation measurement events and therefore did not show flow at the site in the sand layer toward the west/northwest. [Ref. (58)]

Well W-26CR is located between site monitoring wells W-25CR (to the west) and W-39B (to the east) on the north side of the OCS Landfill. The screened elevation of well W-26CR, 640' - 635' MSL, appears to be at approximately the same elevation as the sand layer in wells W-25CR (top of sand layer at 645' MSL) and W-39B (top of sand layer at 635' MSL).

Figure 5:

Time Vs. Groundwater Elevation for We Energies Monitoring Wells W-26CR, W-39B, W-28BR and W-37C



Because W-26CR appears to be screened at approximately the same elevation that the sand layer exists in neighboring wells and because it is exhibiting the same hydraulic response to the new site dewatering system as nearby wells screened in the sand layer, it seems reasonable to conclude that well W-26CR is likely screened in the sand layer and should therefore be included in assessments of site groundwater flow in the sand layer.

It is possible that the higher sand layer (top at 652.5' MSL) encountered at the W-16 well nest location is hydraulically connected to the sand layer encountered at other site "sand layer" monitoring wells (top of sand encountered between approximately 652' – 635' MSL in other site wells). At the time that W-16D was established, it seemed reasonable to set the well screen at the lower sand interval. Upon further review, well W-16D may not be monitoring the same sand layer as other site "sand layer" monitoring wells and it may not be appropriate to include groundwater elevations measured in this well when evaluating groundwater flow in the sand layer at the We Energies site. Other borings also show two sand layers, an upper thin layer (5' to 10' thick) and a lower layer (15' to 30' thick).

Shallow groundwater at the We Energies property on the east side of the OCS Landfill flows towards Lake Michigan and shallow groundwater on the west side of the OCS landfill flows towards a drainage ditch located on the west side of the OCS Landfill. [Ref. (17) & Ref. (12)] Shallow groundwater at the Hunts Landfill flows towards the adjacent Root River on the west side of the landfill. [Ref. (59) & Ref. (40)]

While the thick deposit of glacial till, consisting of silty clay, is protective of the deeper aquifer, some natural groundwater migration pathways that may exist include fractures in the clay that may connect to inter-bedded sand layers. Measured $^{18}\text{O}/^{16}\text{O}$ and $^2\text{H}/^1\text{H}$ isotope levels at a piezometer installed near the We Energies property as part of a past study conducted by Wisconsin geologists Simpkins, Bradbury and Mickelson indicated relatively recent recharge of groundwater. [Ref. (61)] If the inter-bedded sand layers are connected to each other, then any potential contamination that enters them can migrate. Also if the sand layers connect to the bedrock or a water supply well, then the bedrock and water supply well may potentially become contaminated.

Other groundwater pathways that may exist include deteriorating water supply wells that have perforations in the well casing, improperly constructed water supply wells, unsealed well caps, water supply wells that are not deeply grouted and improperly abandoned or unabandoned water supply wells that are no longer in use. A water supply well can become contaminated if the protective outer layers of the well, which consist of the steel casing and the annular space seal (e.g., bentonite or grout) around the casing, become perforated or are not deep enough. If the contaminated well is open into the bedrock the well can potentially contaminate the bedrock aquifer and other water supply wells in the area.

3.2 Surface Water

Surface water was not sampled as part of this assessment. The area is overlain with poorly drained silty clay soils. [Ref. (25) & (62)] (see Figures 10a & 10b) Surface water in the area drains to the Root River and to tributaries of the Root River. [Ref. (25) & (62)] (see Figures 9a & 9b) The Root River drains to Lake Michigan, located to the east. [Ref. (25)] Both the Hunts Landfill and the We Energies OCS landfill have clay soil caps and grass vegetation. [Refs. (14), (17) & (23)] The caps prevent surface water from coming into contact with waste and then flowing to the surrounding surface water drainage basin.

There is a drainage ditch located on the west side of the OCS Landfill that connects to a tributary of the Root River. [Ref. (17)] (see Fig. 9a) If shallow groundwater on the west side of the OCS Landfill is contaminated, it may be entering the drainage ditch on that side of the landfill and flowing into the tributary. However, there is little evidence of significant surface water contamination into this system through discharge of contaminated groundwater. Historic water samples collected by We Energies from monitoring well P28A, located on the west side of the OCS Landfill, showed elevated concentrations of boron and sulfate above the ES. [Ref. (4)]

Well P-28A was screened at a depth of approximately 23 feet. [Ref. (4)] P-29A was damaged, so it was abandoned and replaced with P-28AR in 1995. P-28AR is also screened at a depth of approximately 23 feet below ground surface. Since 1995, the boron and sulfate conditions in P-28AR have significantly decreased. The boron concentration has remained below the ES (1000 ug/L) since 2009 and the sulfate concentration is slightly above the ES (250 mg/L). [Ref. (4)] The molybdenum concentration in semi-annual sampling from P-28AR conducted by We Energies has ranged from 1.5 ug/L to 11 ug/L since April, 2010. [Ref. (4)]

The Root River lies approximately 100 feet from the limits of waste, adjacent to the west side of the Hunts Landfill and surface water on the west side of Hunts flows to the Root River. [Refs. (59) & (40)] A large pond lies adjacent to the limits of waste on the north side of the Hunts Landfill and another pond also lies to the west of the Hunts Landfill approximately 1,800 ft. away. (see Fig. 8b)

Surface water and the shallow groundwater do not appear to be migration pathways to the dolomite water supply wells. In this area, surface water is more likely to act as a shallow groundwater discharge point rather than a recharge point because the groundwater flow appears to be toward the surface water bodies rather than away from them. In addition, it appears that vertical migration in the upper portion of the clay till may be more dominant than horizontal migration. Once the groundwater reaches the sand and the dolomite bedrock, below the clay till, then horizontal movement may be more significant.

SECTION 4.0 GENERAL DISCUSSION

The purpose of this study was to investigate some of the potential sources of the observed elevated molybdenum concentrations in private water supply wells near the We Energies Caledonia and Oak Creek coal ash facilities. The scope included sampling a select number of private water supply wells and monitoring wells near to, or associated with, the We Energies facilities or the nearby Hunts Landfill. This study was necessarily limited in its scope due to resource constraints. In addition to limiting the sampling of water supply wells in the area, the assessment did not include sampling monitoring wells associated with the PPG Industries facility.

In addition to sampling for the standard analytical list of parameters including metals, VOCs, SVOCs, pesticides, and PCBs, the study attempted to use isotopes of the elements of concern as indicators of their origin and to use tritium as an indicator of the relative age of the groundwater.

As the project unfolded and the geology of the area became more clear, the data and the geological information led the department to conduct additional sampling far to the west in wells located in the east-west bedrock valley and to find historic samples of the clay till and Maquoketa Shale in the WGNHS archive that could be analyzed. Two private water supply wells, PW-18 and PW-26, located several miles west of the We Energies property, turned out to

have elevated molybdenum concentrations, and the till and shale samples were shown to contain moderate amounts of molybdenum and boron that likely predated coal combustion activities at the We Energies facility.

Logic suggested that if the molybdenum and boron are naturally occurring in the Troy Bedrock Valley, these elements would be found in the groundwater at other locations in the Valley besides in the area around the intersection of Foley Rd. and County Line Road. The nested groundwater monitoring wells south of EPL appeared to be good sampling points because the nested wells provided the opportunity to sample the groundwater at discrete depth intervals and they are located in the bedrock valley, approximately eleven miles to the west. EPL was never considered a likely source of the molybdenum and boron because of the young age of the landfill and the state-of-the-art engineering features of the landfill. Leachate data from the Future Parkland foundry sand landfill, located just north of EPL, showed elevated molybdenum concentrations, but they are lower than the concentrations found in the EPL monitoring wells.

The molybdenum concentrations found in two of the EPL monitoring wells sampled are almost twice as high as the highest molybdenum concentrations found in the groundwater near the We Energies property. The fact that higher concentrations have not been seen in wells between the We Energies property and the EPL property is evidence that the We Energies ash fill areas are not the source of the molybdenum found in the EPL monitoring wells. Concentrations of groundwater contaminants decrease with distance from a source due to dilution and other attenuation processes.

If the clay till is a natural source of the molybdenum, then it is likely migrating down to the underlying dolomite bedrock where it is pumped to the surface by the private water supply wells. If the molybdenum is naturally occurring, it may not be distributed equally throughout the till or in the aquifer. Concentrations in a given well would also depend on other chemical characteristics of the aquifer at that specific well location. Oxidation-reduction in the aquifer is a chemical process that may affect the ability of the soil to release or retain certain compounds. The full extent of the molybdenum in the groundwater is still not known, but it may be following the bedrock valley where thick sequences of glacial till are deposited.

Based on the sampling data, it appears the Hunts Landfill can be ruled out as a source of the private well molybdenum because the molybdenum concentrations in Hunts leachate and groundwater monitoring samples are low.

If the We Energies coal ash landfills are the source of the molybdenum in the private water supply wells to the west of the We Energies property, there would need to be a flow path for the molybdenum to have traveled from the ash fill areas to the private wells. The flow path is not likely through surface water or even shallow groundwater in the clay till because the molybdenum would need to migrate vertically through at least approximately 70 to 100 feet of clay soil and withstand substantial dilution in order to reach the private water supply wells in the concentrations that have been observed. If coal ash leachate entered nearby surface water, then

the leachate likely would have stayed in the surface water and followed the tributaries to the nearby Root River, and ultimately to Lake Michigan. If the coal ash leachate entered the very shallow groundwater, clay soils present in the aquifer likely would have hindered any significant horizontal movement.

One flow path may be by vertical migration under the ash fill areas to the sand layer(s) under the We Energies property; however, there are no definitive data showing how the groundwater in the sand layer(s) flowed historically or how continuous the layers are across the area. Some of the contaminated private wells are several miles away from the We Energies property. In order for the ash fill areas to be a source in those private wells, the flow system would need to be fairly significant in horizontal extent and velocity. Since the sand layer(s) does not appear to be continuous several miles to the west, a flow path through the sand layer(s) does not appear to explain how the private wells several miles to the west became affected at the observed concentrations. Therefore that would mean that (1) either there is one or more unknown man-made source(s) in the region contaminating a large area, or (2) there is a more widespread naturally occurring source.

The pattern of affected wells and the chemical characteristics of the water from the sampling project do not provide conclusive evidence that the We Energies Oak Creek facility is the source of the molybdenum. There does not appear to be significant vertical migration in the MW-07, MW-06 and MW-08 monitoring well nest.

4.1 Isotopes and Tritium

Analysis of the tritium data appears to show that some of the monitoring wells for both the Hunts Landfill and We Energies Landfill are receiving relatively young water. Therefore the contaminants in the groundwater at these sites did not originate before 1953. This is supported by some VOC detections such as vinyl chloride in samples collected from Hunts monitoring well MW-39 (MW-10S) at a concentration of 180 ug/L.

In addition, the boron isotope data appear to be showing boron from the Hunts Landfill and boron from the ash fill areas to be affecting the monitoring wells associated with each site, respectively. The boron affected monitoring wells at Hunts are either located within the containment wall surrounding the landfill or close to the landfill. The leachate samples from both Hunts and the coal ash showed elevated boron concentrations.

The tritium data in the private wells did not show relatively young water except for the possibility of some proportion of young water in four of the private wells sampled. Interpreting the tritium results in the private wells is more difficult than in the monitoring wells because the private wells tend to be deeper. The deeper aquifer wells tend to have older water than the shallower aquifer wells and therefore tritium levels may be diluted in the deeper aquifer wells.

The boron isotope data for the private wells appear to be showing that most of the boron in the

private well samples is naturally occurring. Samples from PW-23 and PW-24 had boron isotope ratios just within the hypothetical mixing zone of naturally occurring boron and boron from the coal ash or Hunts; however, both of these wells are located miles from the We Energies property and Hunts, in different directions. In addition, both of these wells have low molybdenum concentrations. PW-24 also has a relatively low boron concentration. Boron is contained in household cleaners and detergents. It is not known why the boron isotope values are within this range when the values for all of the other private wells are not; however, it is possible that there are local, isolated sources of boron affecting these two wells. The boron and strontium isotope data do not appear to strongly support the concept that the We Energies facility is the likely source of the molybdenum in the private wells.

The attempt was made to use molybdenum isotopes because it is the element of concern in most of the private wells. The molybdenum isotope data do not appear to conclusively identify a groundwater molybdenum source at this time. Conditions in the aquifer may affect the molybdenum isotope ratios along the flow path. The attempt was made to use molybdenum isotopes because it is the element of concern in most of the private wells.

4.2 Private Water Supply Wells PW-12 and PW-13

Private water supply wells PW-12 and PW-13 are the only two private wells with boron concentrations above the ES of 1,000 ug/L. Both wells are located south of the We Energies property, along the Lake Michigan shoreline and both wells are constructed to the Maquoketa Shale, under the dolomite bedrock. While both of these private wells have the highest boron concentrations of all of the private well samples, PW-12 and PW-13 also have the highest $\delta^{11}\text{B}$ values and are the farthest from the coal ash points on the $^{87}\text{Sr}/^{86}\text{Sr}$ versus $\delta^{11}\text{B}$ plot (Fig. 1).

Monitoring well MW-19 (W-47B), which is cased to the top of the dolomite bedrock, is located south of the We Energies property, between the coal ash fill areas and PW-12 and PW-13. MW-19 has a lower boron concentration than both PW-12 and PW-13. Moreover, monitoring wells MW-06 (W-12B) and MW-07 (W-12C), which are located on the south side of the We Energies property and are drilled through an EADA, have the highest boron concentrations found in the monitoring wells at 27,400 ug/L and 10,600 ug/L respectively. Both MW-06 and MW-07 are nested monitoring wells screened at different depths, along with MW-08 (W-12D). MW-07 is the shallowest well, followed by MW-06 which is deeper and MW-08 is the deepest, screened at the top of the dolomite. This monitoring well nest does not show significant vertical migration of the boron to the dolomite. In addition, the $\delta^{11}\text{B}$ value for MW-08 is outside of the “mixing zone,” suggesting it is naturally occurring, and tritium was not detected in MW-08 but was detected in both MW-06 and MW-07, suggesting that the water in the deepest well is more reflective of pre-ash-disposal conditions.

The groundwater elevation levels measured in the dolomite bedrock monitoring wells for We

Energies during the September, 2011, sampling event showed the groundwater in the dolomite to be flowing to the east (see Fig. 19).

PW-12 and PW-13 are similar in their location and well depth. Both wells appear to be exposed to the underlying Maquoketa Shale. Both wells also have high concentrations of iron. The boron isotope data, the boron concentrations in MW-08 and MW-19 and the measured groundwater flow direction in the dolomite monitoring wells do not appear to support the theory that the boron in these two private wells is coming from the coal ash.

4.3 Other Sampling Data

Lead was detected in all of the 2011 samples collected from the private wells at low concentrations, except at PW-19 where it was found at a concentration above its ES of 15 ug/L. The sample collected from PW-19 in 2010 did not have a lead detection. Lead was found above the ES in eight other private wells that were sampled in 2010. The lead in all these instances seems likely attributable to pipes and/or household plumbing fixtures.

Bis (2-ethylhexyl) phthalate was detected in samples collected from PW-18 at concentrations above the ES of 6.0 ug/L and from PW-17 at a concentration below the ES. Based on information from the well driller at PW-18, it appears that the drop pipe for the pump in the well at PW-18 is made of CPVC and the pump has a plastic cover. [Ref. (63)] Since bis (2-ethylhexyl) phthalate was also detected in field blanks, it is possible that some of the bis (2-ethylhexyl) phthalate in the samples at this location may have originated as a lab contaminant introduced to the samples during transportation or analysis.

Aluminum and iron were found in several monitoring wells above Wisconsin's groundwater enforcement standard for aluminum of 200 ug/L and Wisconsin's or public welfare standard for iron of 300 ug/L. The highest iron concentrations were found in monitoring wells associated with the Hunts Landfill. Iron was also found in several samples collected from private wells above Wisconsin's public welfare standard. The highest aluminum concentrations were 4,300 ug/L and 4,680 ug/L from monitoring wells MW-17 (W-45A) and MW-18 (W-45B), respectively. These aluminum concentrations are very high compared to aluminum concentrations in samples from all of the other wells. The source of aluminum in these two wells is not known.

All of the RCRA metals except mercury and silver were found in the samples collected at one or more monitoring wells. Arsenic was detected in MW-01 and MW-34 above its ES of 10 ug/L.

SECTION 5.0 SUMMARY

The molybdenum concentrations from the Hunts Landfill leachate samples do not support the hypothesis that the Hunts Landfill is the source of the molybdenum. The data are not as conclusive with regard to the ash landfills. This study has produced some evidence that tends to support the hypothesis that the observed elevated concentrations of molybdenum in local wells reflect naturally occurring molybdenum in the groundwater, and other evidence that tends to suggest the molybdenum is due to an anthropogenic source, possibly the We Energies facilities near Caledonia and Oak Creek, or some other source(s).

5.1 Evidence For Considering A Naturally Occurring Molybdenum Source

- 1) There are elevated levels of molybdenum found in monitoring wells and private well samples located approximately eleven miles west of the We Energies property. Some of the highest concentrations in the study area are in the western most sample locations. It appears unlikely that the ash fill areas are the source of the elevated molybdenum levels found eleven miles to the west. Other man-made sources of these elevated molybdenum levels are not apparent.
- 2) Elevated molybdenum concentrations observed in groundwater are widespread, over a distance of several miles. A single man-made source that could cause elevated molybdenum levels in multiple directions is not apparent at this time. (see Fig. 18)
- 2) The boron and strontium isotope data do not appear to support coal ash as a source of the boron in most of the private wells. Some of the boron that was found in the monitoring wells, and most of the boron found in private water supply wells appears to be naturally occurring, based on boron/strontium isotope analysis.
- 3) Molybdenum concentration gradients seen between We Energies site monitoring wells and molybdenum affected private wells appear very different from molybdenum concentration gradients seen between monitoring wells and affected private wells at other ash landfills that are known to be causing groundwater contamination.
- 4) Two We Energies site monitoring wells with very high boron levels show low levels of molybdenum.
- 5) Analysis of drill cuttings from two We Energies site wells drilled in 1953 before significant deposition of coal ash shows the presence of molybdenum and boron in

glacial till and in shale bedrock at this location.

- 6) Groundwater monitoring at known coal ash affected sites typically shows elevated levels of boron and sulfate associated with elevated molybdenum levels. The boron and sulfate concentrations in the private wells in the study area, generally are within background concentrations.
- 7) Groundwater flow in glacial till on site calculated by We Energies shows flow across the We Energies property in the glacial aquifer “intermediate sand layer” towards the east/northeast and southeast, away from the private wells where elevated molybdenum concentrations were documented.
- 8) Similarly, groundwater flow in the dolomite bedrock, calculated by We Energies and by the department during the 2011 sampling event, shows groundwater flow in the bedrock towards the east/northeast, away from the private wells where elevated molybdenum concentrations were documented.
- 9) There is an absence of vertical concentration reductions in the nested wells that we would expect from a contaminant with a surface source, and of significant concentration gradients between the proximal We Energies monitoring wells and more distal private wells. A private well five miles to the southwest (PW-18) has the second highest molybdenum concentration found in private wells, while some closer private wells have a much lower molybdenum concentrations.
- 10) The close correlation with other coal ash contaminants (boron, sulfate) we would expect from a coal ash source are absent in this case.
- 11) The We Energies property is generally underlain by a significant clay till soil layer that tends to have a very low hydraulic conductivity, thus limiting horizontal contaminant movement in the till.

5.2 Evidence For Considering We Energies or Another Anthropogenic Molybdenum Source

- 1) Although glacial till and shale bedrock (drill cuttings) sample analysis from two We Energies site wells drilled in 1953 show the presence of molybdenum in glacial till and shale bedrock, the levels were not particularly high (2 – 2.4 ppm in the till and 1.1 – 1.3 ppm in the shale) at that location. These sample results are below the 3 ppm laboratory limit of quantitation (LOQ), and also below the 4.5 ppm average for shale rock [p. 5, Ref. (11)].
- 2) It appears to be unusual to find naturally occurring elevated levels of molybdenum in

groundwater because naturally occurring levels of Mo in groundwater in Wisconsin glacial aquifers in Mid-West, and in various aquifers around the country are reported low. [pgs. 7-8, Ref. (30)]

- 3) Naturally occurring molybdenum concentrations in groundwater, potentially associated with shale bedrock sources (Ohio, Illinois, Alberta CA), are lower than the concentrations seen in Caledonia/Oak Creek area of investigation, and occur under reducing redox conditions in groundwater. [Refs. (64), (34), (35) & (36)] Based on sample results of redox sensitive parameters, it does not appear that there are reducing redox conditions in groundwater in area of investigation.
- 4) One potential source for molybdenum and boron would be shale bedrock (the Maquoketa Formation), but the Maquoketa Shale lies below dolomite bedrock and gradients measured at locations where elevated molybdenum found in monitoring well samples are vertically downward.
- 5) Sites around the country with molybdenum levels as high as those seen in the area of investigation have been linked to contamination site releases, not naturally occurring conditions.
- 6) There are multiple areas of unlined ash fill on the We Energies Oak Creek property.
- 7) There are very high levels of molybdenum (boron, sulfate) in site ash landfill (OCS Landfill and OCN Landfill) leachate head wells.
- 8) Some glacial till and dolomite bedrock monitoring wells on the We Energies property show high levels of molybdenum (> 40 ug/L) in addition to boron and sulfate.
- 9) Shallow groundwater flow in glacial till across the property is documented to flow to the west/northwest and to the east, showing evidence of a shallow groundwater divide.
- 10) A bedrock monitoring well (W-44) installed by We Energies at a proposed “background” location, if groundwater flow in the dolomite is to the east/ northeast, did not show elevated molybdenum concentrations.
- 11) Elevated levels of molybdenum (and boron and sulfate) in groundwater have been found associated with releases from coal ash landfill sites in WI and in other parts of the country (e.g. IN, IL, PA). [Refs. (9), (65), (8), (64) & (44)]
- 12) It is possible that the molybdenum isotope results indicate coal ash as the source of molybdenum found in groundwater in area of investigation. Literature for molybdenum isotope values for naturally occurring molybdenum generally appear to be relatively low (-0.3 to 1.4 per mil) while samples in area of investigation are generally greater than 1.4

per mil. [Refs. (51), (29) & (52)]

- 13) Fractures documented in glacial clay till (Oak Creek Till) deposits would promote more mobility for dissolved contaminants than might be expected in a clay till formation.
- 14) Measured $^{18}\text{O}/^{16}\text{O}$ and $^2\text{H}/^1\text{H}$ isotope levels at a piezometer installed near the We Energies property as part of past study conducted by Wisconsin geologists Simpkins, Bradbury and Mickelson indicated relatively recent recharge of groundwater. [Ref. (61)]

SECTION 6.0 CONCLUSIONS

- 1) The Hunts Landfill does not appear to be a source of the molybdenum in area private wells.
- 2) The data remain inconclusive on whether the We Energies coal ash fill areas are a significant molybdenum source.
- 3) The data appear to be more conclusive regarding boron. While the monitoring wells may have been affected, the boron isotope data and other evidence appear to show that the boron in most of the private wells is naturally occurring. Boron may also be coming from other man-made sources. There is more available boron data for the area's groundwater resources than molybdenum data. Boron is known to occur naturally in area groundwater.
- 4) The hydrogeological flow path is complex and the affected area is very large (several miles). The full extent of the affected area is still not known. The elevated molybdenum concentrations appear to correlate with a natural buried bedrock valley that is oriented in an east-west direction across northern Racine County, but a causal relationship between the observed concentrations and the buried valley could not be determined.
- 5) Because the primary contaminants of concern, molybdenum and boron, occur naturally in the area, determining the source(s) of what appear to be elevated concentrations may not be possible with the data collected to date. Additional groundwater sampling and analysis of additional samples of the clay till and shale bedrock could increase the understanding of the extent of the elevated concentrations and may contribute to determining a cause.

SECTION 7.0 REFERENCES

1. **Southeastern Wisconsin Regional Planning Commission.** *Troy Bedrock Valley Aquifer Model Waukesha and Walworth Counties, Wisconsin.* November 2009. Memorandum Report Number 188.
2. **Wisconsin Department of Health Services.** *Human Health Hazards, Molybdenum in Drinking Water: Wisconsin Department of Health Services.* February, 2010. fact sheet .
3. **Wisconsin Department of Natural Resources.** Wisconsin Administrative Code, chs. NR 140 and NR 500.
4. —. WDNR Groundwater and Environmental Monitoring System (GEMS). [Online] <http://dnr.wi.gov/topic/Landfills/gems.html>.
5. Wisconsin Department of Health Services 2010 Private Well Sampling Data. 2010.
6. **Polyak, Desiree E.** *2008 Minerals Yearbook.* U.S. Geological Survey. 2008.
7. **Kosson, D. and Sanchez, F. and Kariher, P. and Turner, L.H. and Delapp, R. and Seignette, P.** *Characterization of Coal Combustion Residues from Electric Utilities - Leaching and Characterization Data.* December, 2009. Technical Report prepared for the U.S. EPA.
8. **Zillmer, Michael and Fauble, Philip.** *Groundwater Impacts from Coal Combustion Ash Disposal Sites in Wisconsin.* Wisconsin Department of Natural Resources Waste and Materials Management Program. Technical Report.
9. **Buska, Paul M., Fitzpatrick, John and Watson, Lee R. and Kay, Robert T.** *Evaluation of Ground-Water and Boron Sources by Use of Boron Stable-Isotope Ratios, Tritium, and Selected Water Chemistry Constituents near Beverly Shores, Northwestern Indiana, 2004.* U.S. Geological Survey Scientific Investigations Report 2007-5166. 2007.
10. **U.S. Department of Health and Human Services Agency for Toxic Substances and Disease Registry (ATSDR).** *Publication on Boron (CAS#7440-42-8).* November, 2010.
11. **Hem, John D.** *Investigation Study and Interpretation of the Chemical Characteristics of Natural Water.* 1989. United States Geological Survey Water-Supply Paper 2254. Third Edition.
12. **Natural Resources Technology Environmental Consultants.** *Investigation Plan Summary*

Analysis, Dolomite Aquifer Groundwater Evaluation, Oak Creek Power Plant. prepared for We Energies. March 30, 2010.

13. **Wisconsin Department of Health and Family Services.** *Scientific Support Documentation for Cycle 8 Revisions of NR140.10 Groundwater Enforcement Standard & Preventative Action Limit.* Recommendations . March, 2005 (revised August, 2005).

14. **Wisconsin Department of Natural Resources.** *Second Five-Year Review Report, Hunts Disposal Landfill, Caledonia, Wisconsin: U.S. EPA ID No. WID980511919.* prepared for U.S. EPA Region 5. September, 2006.

15. **Warzyn, Inc.** *RCRA Facility Investigations: I. Description of Current Conditions and II. Pre-Investigation Evaluation of Corrective Measures Technologies, PPG Industries, Inc., 10800 South 13th St, Oak Creek, Wisconsin.* prepared for PPG Industries. September, 1992.

16. **ICF Kaiser Engineers, Inc.** *RCRA Facility Investigation Report for the PPG Industries, Inc., Oak Creek Facility, Permit No. EPA ID WID 059972935.* prepared for PPG Industries. July 31, 1997.

17. **Woodward-Clyde Consultants, Inc.** *NR 140 Groundwater Investigation, Oak Creek Property, South Oak Creek, Caledonia, North Oak Creek, Early Ash Disposal Areas, Oak Creek Power Plant, Oak Creek, Wisconsin, Project Number 93C5439.* prepared for Wisconsin Electric Power Company. July 28, 1993. 3 volume report.

18. **Wisconsin Department of Natural Resources.** *We Energies Oak Creek Power Plant Air Quality Control System NR 216 Construction Site Storm Water Discharge Permit Bluff Collapse Assessment.* February 28, 2012. Technical Report.

19. —. *Feasibility Approval for Wisconsin Electric Power Company's Proposed Caledonia Fly and Bottom Ash Landfill.* Bureau of Solid Waste Management. February 6, 1986. Approval Document for FID#: 252108450.

20. —. *Wisconsin Electric Power Company (WEPCO) Caledonia Landfill Plan of Operation Approval.* August 27, 1987. Bureau of Solid Waste Management Approval Document For FID#: 252108450.

21. —. *Plan of Operation, We Energies (WE) Caledonia Ash Landfill, Landfill Design Enhancement and Other Modifications, License # 3232.* Waste and Materials Management Program. May 19, 2010. Solid Waste Approval Document.

22. **Natural Resource Technology, Inc.** *Exemption Request for Development as a Licensed Landfill, Oak Creek North Ash Landfill, Oak Creek, Wisconsin, Project No. 1514.* prepared for We Energies. October 10, 2003.

23. —. *Exemption Request for Development as a Licensed Landfill, Oak Creek South Ash Landfill, Oak Creek, Wisconsin, Project No. 1611.* prepared for We Energies. November 14, 2003.
24. **Wisconsin Department of Natural Resources.** Bureau for Remediation and Redevelopment Tracking System (BRRTS). [Online] <http://dnr.wi.gov/topic/Brownfields/botw.html>.
25. **Southeast Wisconsin Regional Planning Commission (SWRPC) and The Wisconsin Geologic and Natural History Survey (WGNHS).** *Technical Report Number 37 - Groundwater Resources of Southeastern Wisconsin.* June, 2002.
26. **Mickelson, David M. and Anderson, Mary P., and Dunlke Kallina.** *Hydrostratigraphic and Groundwater Flow Model: Troy Valley Glacial Aquifer, Southeastern Wisconsin.* September 2008. UW Project Number 144-QJ26.
27. **Goldberg, S. and Forster, H. S., and Godfrey, C.L.** Molybdenum Adsorption on Oxides, Clay Minerals, and Soils. *Soil Science Society of America Journal.* March-April 1996, Vol. 60, no.2, pp. 425-432.
28. **Thomas, Mary Ann.** *The Association of Arsenic With Redox Conditions, Depth, and Ground-Water Age in the Glacial Aquifer System of the Northern United States.* U.S. Geological Survey. 2007. Scientific Investigations Report 2007-5036.
29. **Chappaz, Anthony and Lyons, Timothy W. and Gordon, Gwyneth W. and Anbar, Ariel D.** Isotopic Fingerprints of Anthropogenic Molybdenum in Lake Sediments.
30. **Eisler, Ronald.** *Molybdenum Hazards to Fish, Wildlife and Invertebrates: A synoptic Review.* Patuxant Wildlife Research Center, U.S. Department of Interior, Fish and Wildlife Service. Laurel, MD 20708 : s.n., August, 1989.
31. **Ayotte, Joseph D. and Gronberg, Jo Ann M., and Apodaca, Lori E.** *Trace Elements and Radon in Groundwater Across the United States, 1992-2003.* U.S. Geological Survey. 2011. Scientific Investigations Report 2011-5059.
32. **Groschen, George E. and Arnold, Terri L. and Morrow, William S., and Warner, Kelly L.** *Occurrence and Distribution of Iron, Manganese, and Selected Trace Selected Trace Elements in Ground Water in Glacial Aquifer System of Northern United.* U.S. Geological Survey. 2009.
33. **Mudray, M.G. Jr. and Bradbury K.R.** *Evaluation of NURE Hydrogeochemical Data for Use in Wisconsin Groundwater Studies.* Wisconsin Geological and Natural History Survey. 1992. Open-File Report 93-2.

34. **Thomas, Mary Ann and Schuman, Thomas L. and Pletsch, Bruce A.** *Arsenic in Groundwater in Selected Parts of Southwestern Ohio, 2002-03*. U.S. Geological Survey, U.S. Department of Interior. 2005. Scientific Investigations Report 2005-5138.
35. **Warner, Kelly L.** Arsenic in Glacial Drift Aquifers and the Implication for Drinking Water – Lower Illinois River Basin. *Groundwater*. May-June 2001, Vol. 39, No. 3, pp. 433-442.
36. **Alberta Health and Wellness.** *Arsenic in Groundwater from Domestic Wells in Three Areas of Northern Alberta, CA*. October 2000.
37. **Stensvold, Krista A.** *Distribution and Variation of Arsenic in Wisconsin Surface Soils, With Data on Other Trace Elements*. U.S. Geological Survey . 2012. Scientific Investigations Report 2011-5202.
38. **We Energies.** DRAFT Review of 1993 NR 140 Report Oak Creek Power Plant. October 30, 2012.
39. **Natural Resources Technology Environmental Consultants.** *Review of Analytical Results from New Sample Points: Dolomite Aquifer Groundwater Quality Evaluation, Oak Creek Power Plant*. prepared for We Energies. August 11, 2010. Technical Memorandum.
40. **Warzyn, Inc.** *Groundwater Extent of Contamination Investigation, Hunt's Disposal Landfill, Town of Caledonia, Racine County, Wisconsin*. prepared for the Hunts Site Remediation Group. April 22, 1993. Technical Memorandum.
41. **Wyche, Phil.** *Technical Assistant at the PPG Industries Facility*. [interv.] Joe Lourigan. March 30, 2011.
42. **Wisconsin Department of Natural Resources.** Arsenic in Drinking Water. [Online] 2006. <http://dnr.wi.gov/org/water/dwg/gw/pubs/arsenic.pdf>.
43. —. *Groundwater Retrieval Network (GRN)*. electronic data system of water supply wells in Wisconsin.
44. *A Twenty-Month Geochemical and Isotopic Investigation into Environmental Impacts of the 2008 TVA Coal Ash Spill, – May*. **Ruhl, Laura S. and Vengosh, Avner and Dwyer, Gary S. and Hsu-Kim, Heileen and Deonarine, Amrika.** Denver, CO, USA : s.n., 2011. 2011 World of Coal Ash (WOCA) Conference - May 9-12, 2011.
45. *Boron and Strontium Isotopic Characterization of Coal Combustion Residuals: Validation of Novel Environmental Tracers, Paper No. 30616-208920*. **Ruhl, Laura.** Charlotte, NC : s.n., 2012. 2012 Geological Society of America Annual Meeting and Exposition, 4-7 November.

46. **Coplen, T. B. , et. al.** *Compilation of Minimum and Maximum Isotope ratios of Selected Elements in Naturally Occurring Terrestrial materials and Reagents*. U.S. Geological Survey. 2002. Water-Resources Investigations Report 01-4222.
47. **United States Geological Survey, Menlo Park, CA.** Resources on Isotopes – Periodic Table-Strontium. [Online] http://wwwrcamnl.wr.usgs.gov/isoig/period/sr_iig.html.
48. **Bullen, Thomas D.** Handbook of Environmental Isotope Geochemistry, Advances in Isotope Geochemistry. M. Baskaran (ed.). 2011, Chapter 10, Stable Isotopes of Transition and Post Transition Metals as Tracers in Environmental Studies.
49. *Geochemical and Isotopic Characterization of the Environmental Impacts of Coal Combustion Products: Lessons from the Tennessee Valley Authority Coal Ash Spill , Paper No. 166-2.*, **Ruhl, Laura.** Minneapolis, MN, USA : s.n., 2011. Geological Society of America Annual Meeting, 9-12 October.
50. **Bullen, Thomas D.** e-mail to Joseph Lourigan at the Wisconsin Department of Natural Resources. October 26, 2012.
51. **Gordon, Gwyneth W.** *Mo Isotope Analyses of Samples from the Wisconsin Department of Natural Resources*. Arizona State Earth and Space Exploration Laboratory. Tempe, AZ : s.n., November, 2012. Technical Report.
52. **Uri, Ryb, et. al.** Large Molybdenum Isotope Variations Trace Subsurface Fluid Migration Along the Dead Sea Transform. *Geological Society of America*. May 2009, Vol. 37, No. 5, pp. 463-266.
53. **Wisconsin Department of Natural Resources.** *Plan of Operation Approval, Emerald Park Landfill, Facility No. 3290:*. Bureau of Solid Waste Management. June 3, 1994. Approval Document for FID#: 268244130.
54. **RMT, Inc.** *Feasibility Report –Southwestern Horizontal Expansion, Veolia ES Emerald Park Landfill, LLC, Muskego, Wisconsin,, Inc.* prepared for Veolia ES. January 30 2009.
55. —. *Addendum No. 1, Feasibility Report – Southwestern Horizontal Expansion, Veolia ES Emerald Park Landfill, LLC, Muskego, Wisconsin.* prepared for Veolia ES, Inc. January 22, 2010.
56. **Wisconsin Department of Natural Resources.** *Future Parkland Development, Inc., Landfill Plan of Operation Approval.* Bureau of Solid Waste Management. March 13, 1987. Approval document for FID#: 268219930.

57. Future Parkland Landfill Leachate Sample Laboratory Analytical Report. 2011.
58. **Natural Resources Technology Environmental Consultants.** *Fall 2012 Intermediate Sand Field Investigation and Results, Oak Creek South and Caledonia Ash Landfills, Oak Creek Power Plant.*: prepared for We Energies. December 3, 2012. Technical Memorandum.
59. **RMT, Inc.** *Hunt's Site (Re: Molybdenum in Groundwater).* prepared for the Hunts Site Remediation Group. April 13, 2011. Technical Memorandum.
60. **Natural Resources Technology Environmental Consultants.** *Groundwater Elevation and Inferences for Flow, Intermediate Sand Unit, Oak Creek Power Plant South Landfill.* prepared for We Energies. September 20, 2012. Technical Memorandum .
61. **Simpkins, William W., Bradbury, Kenneth R. and Mickelson, D.M.** Methods for Evaluating Large-Scale Heterogeneity in Fine-Grained Glacial Sediment: In: Molz, F.J., Melville, J.G., and Guven, O., Proceedings of the Conference on New Field Techniques for Quantifying the Physical and Chemical Properties of Aquifers. 1989, pp. 53-75.
62. **Wisconsin Department of Natural Resources.** *Electronic GIS Data Layers and electronic data systems.*
63. **McManama, Zoe.** *WDNR Drinking and Groundwater Specialist - Southeast Region.* [interv.] Joe Lourigan. 2012.
64. **Bayless, Randall E. and Greeman, Theodore K. and Harvey, Colin.** *Hydrology and Geochemistry of a Slag-Affected Aquifer and Chemical Characteristics of Slag-Affected Ground Water, Northwestern Indiana and Northeastern Illinois.*: U.S. Geological Survey. Indianapolis, IN : s.n., 1998. Water Resources Report 97-4198.
65. **AECOM Environment.** *Remedial Investigation Report, Pines Area of Investigation, AOC II, Docket No. V-W-'04-C-784.* March 5, 2010.
66. —. *Plan of Operation Modification, We Energies Caledonia Landfill WDNR License No. 032326 – AECOM Project No. 10532-011.* prepared for We Energies. April 17, 2009.
67. **Wisconsin Department of Natural Resources.** *Future Parkland Development, Inc., Landfill Plan of Operation Modification Approval to dispose of nine additional waste streams from the Briggs & Stratton Plants.* Bureau of Solid Waste Management. April 26, 1991. Approval Document for FID#: 268219930.
68. **Luczaj, John A.** A Mineralized Breccia Pipe Near Racine, Wisconsin: Evidence For Post-Silurian Igneous Activity.
69. **Natural Resources Technology Environmental Consultants.** *Results of Residential Well*

and Monitoring Well Sampling South of Oak Creek Power Plant in the Vicinity of Michna Road. prepared for We Energies. June 27, 2012. Technical Memorandum.

70. **Polyak, Desiree E.** *U.S. Geologic Survey, Mineral Commodity Summaries.* United States Geological Survey . January, 2012.

71. **Wisconsin Department of Natural Resources.** *Future Parkland Development, Inc., Landfill Feasibility Determination.* Bureau of Solid Waste Management. August 1, 1986. Approval Document for FID#: 268219930.

72. United States Census Bureau. [Online] <http://quickfacts.census.gov/qfd/states/00000.html>.

73. **United States Geological Survey, Menlo Park, CA.** Resources on Isotopes – Fundamentals of Stable Isotope Geochemistry. [Online] <http://wwwrcamnl.wr.usgs.gov/isoig/res/funda.html>.

74. **Wisconsin Department of Natural Resources.** *Problems Associated with bis(2-ethylhexyl)phthalate Detections in Groundwater Wells.* Waste and Materials Management Program. 2002. Pub. – WA 1011-2002.

75. **Natural Resources Technology Environmental Consultants.** *Response to Statements by Environmental Integrity Project Regarding the Oak Creek Power Plant in the Report “In Harm’s Way: Lack of Federal Coal Ash Regulations Endangers Americans and Their Environment.* prepared for We Energies. November 30, 2010. Technical Memorandum.

76. —. *Sampling Plan for Private Wells on North Michna Road.* prepared for We Energies. January 19, 2011. Technical Memorandum.

77. —. *Commentary and Response to Technical Memorandum Prepared by RMT, Hunts Site, Dated April 13, 2011.* prepared for We Energies. June 3, 2011. Letter.

78. —. *Results of Private Well Sampling and Recommendations for Additional Groundwater Monitoring South of the Oak Creek Power Plant in the Vicinity of Michna Road.* May 19, 2011. Technical Memorandum.

79. *Laboratory Analytical Data Reports for the 2011 Sampling Project.*

80. Private Well Construction Reports from WDNR .

81. Groundwater Monitoring Well Construction Reports and Borings from We Energies.

82. Groundwater Monitoring Well Construction Reports for the Hunts Landfill.

83. The 2011 Caledonia Investigation Sampling Plan. 2011.

84. USGS Menlo Park, CA Laboratory Isotope Analytical Methods.

85. Environmental Isotope Laboratory, Department of Earth Sciences, University of Waterloo.
Tritium.

86. WGNHS Shale and Till Sample Laboratory Analytical Report. 2012.

Tables

Table 1: Summary of Private Well Inorganic Parameter Sample Data

Table 1: Summary of Private Well Inorganic Parameter Sample Data																																					
NA = Not Analyzed ND = Not Detected																																					
Molybdenum, Boron and Strontium										Indicators										RCRA Metals								Other Metals and Inorganics									
Sample ID	Well Depth (ft BGS) Casing Depth (ft BGS) Geologic Unit Well Open in	Sample Date	Molybdenum Concentration (ug/L)	Previous Mo Concentrations (ug/L)	Boron Concentration (ug/L)	Previous Boron Concentrations (ug/L)	Strontium Concentration (ug/L)	Total Dissolved Solids (mg/L)	Hardness (mg CaCO ₃ /L)	Total Alkalinity (mg CaCO ₃ / L)	Chloride (mg/L)	Calcium (ug/L)	Barium (ug/L)	Mercury (ug/L)	Lead (ug/L)	Selenium (ug/L)	Arsenic (ug/L)	Cadmium (ug/L)	Chromium (ug/L)	Silver (ug/L)	Aluminum (ug/L)	Iron (ug/L)	Sulfate as SO ₄ (mg/L)	Magnesium (ug/L)	Potassium (ug/L)	Sodium (ug/L)	Thallium (ug/L)	Thorium (ug/L)	Uranium (ug/L)	Vanadium (ug/L)							
			NR 140 ES: 40 ug/L		NR 140 ES: 1000 ug/L		NR 140 ES: None	NR 140 ES: None	NR 140 ES: None	NR 140 ES: None	NR 140 ES: 250 mg/L	NR 140 ES: None	NR 140 ES: 2000 ug/L	NR 140 ES: 2 ug/L	NR 140 ES: 15 ug/L	NR 140 ES: 50 ug/L	NR 140 ES: 10 ug/L	NR 140 ES: 5 ug/L	NR 140 ES (Total): 100 ug/L	NR 140 ES: 50 ug/L	NR 140 ES: 200 ug/L	NR 140 ES: 300 ug/L	NR 140 ES: 250 mg/L	NR 140 ES: None	NR 140 ES: None	NR 140 ES: None	NR 140 ES: 2 ug/L	NR 140 ES: None	MCL: 30 ug/L	NR 140 ES: 30 ug/L							
PW-01	225 150 Limestone	09/26/2011	80	66, 62	448	471, 455	525	242	90.3	130	10.2	19800	31.1	0.2	0.069	ND	ND	ND	ND	ND	ND	ND	542	52.4	9930	864	51500	ND	0.23	ND	ND						
PW-02	250 150 Limestone	09/26/2011	88.2	85, 83	387	399, 394	716	262	136	130	10.9	31300	16.9	ND	0.195	ND	ND	ND	ND	ND	ND	112	83.7	14100	1930	44900	ND	0.077	ND	ND	ND						
PW-03	220 153 Limestone	09/26/2011	66.8	70, 67	458	480, 470	355	230	81.4	120	8.7	19500	33.6	ND	0.148	ND	ND	ND	ND	ND	ND	191	52.5	7950	833	50500	ND	0.282	0.077	ND	ND						
PW-04	175 140 Limestone	09/26/2011	64	65	463	450	644	234	83.1	120	7.91	19200	32.8	ND	4.26	ND	ND	ND	ND	ND	ND	ND	384	59.2	8510	1060	51300	ND	0.099	ND	ND	ND					
PW-05	325 145 Limestone	09/26/2011	33.2	37, 35	799	859	581	356	104	180	31.3	24400	22.6	ND	2.82	ND	ND	ND	ND	ND	ND	ND	343	76.6	10600	3680	98100	ND	0.299	ND	ND	ND					
PW-06	216 143 Limestone	09/26/2011	54.1	61, 59	470	508, 535	753	236	90.1	130	10.7	20200	38.2	ND	0.265	ND	0.376	ND	ND	ND	ND	ND	51.5	45.9	9620	881	47300	ND	0.108	ND	ND	ND					
PW-07	Info Not Available	09/27/2011	32.4	45, 27, 39	431	540, 420, 420	975	250	97.2	140	7.65	21100	46.9	ND	6.12	ND	0.616	0.27	ND	ND	ND	ND	6240	49.7	10800	944	49900	ND	0.071	ND	ND	ND					
PW-08	222 180 Limestone																																				
PW-09	190 176 Limestone	09/26/2011	42.5	31.5, 42	550	532, 482	519	234	66.6	130	11	15600	28.7	ND	0.125	ND	ND	ND	ND	ND	ND	ND	84.1	51.9	6730	797	63300	ND	ND	ND	ND	ND	ND				
PW-10	Info Not Available	09/27/2011	145	124, 89.4	581	532, 482	1720	424	132	77	11.1	32900	34.1	0.4	1.47	ND	ND	ND	ND	ND	ND	213	222	12200	858	96600	ND	ND	ND	ND	ND	ND	ND				
PW-11	Info Not Available	09/26/2011	41.1	58, 42, 33, 56	551	720, 570, 520, 520	540	250	70.1	130	11.1	16200	32.2	ND	0.487	ND	ND	ND	ND	ND	ND	ND	531	51.2	7180	815	63300	ND	ND	ND	ND	ND	ND				
PW-12	305 143 Limestone	09/27/2011	35.9	44	1470	1190	1950	786	184	210	83.6	44600	5.54	ND	0.35	ND	ND	ND	ND	ND	ND	ND	800	300	17700	4080	228000	ND	0.055	0.088	ND	ND	ND				
PW-13	325 114 Red Shale	09/27/2011	10.9	24	1740	1040	466	764	61.3	310	113	15500	1.65	ND	0.113	ND	ND	ND	ND	ND	ND	57.9	127	179	5480	5270	290000	ND	0.225	0.127	ND	ND	ND	ND			
PW-14	Info Not Available	09/26/2011	49.3	50	323	302	718	308	182	150	4.06	40500	23.7	ND	0.218	ND	1.07	ND	ND	ND	ND	ND	1210	110	19700	2220	43100	ND	0.359	0.221	ND	ND	ND	ND			
PW-15	125 75 Limestone	09/26/2011	48.9	50	337	327	777	306	185	150	9.18	40900	25.3	ND	0.198	ND	1.17	ND	ND	ND	ND	ND	387	103	20100	1940	45400	ND	0.075	0.165	ND	ND	ND	ND			
PW-16	Info Not Available	09/27/2011	40.2	43	487	470	975	264	92.6	140	7.96	18400	29.1	ND	0.663	ND	ND	ND	ND	ND	ND	ND	442	55.6	11300	826	59900	ND	0.053	ND	ND	ND	ND	ND			
PW-17	Info Not Available	09/26/2011	41.7	37, 43	489, 477	473	990	256	94.4	150	7.92	18800	28.9	ND	1.22	ND	ND	ND	ND	ND	ND	ND	283	54.4	11600	818	59800	ND	ND	ND	ND	ND	ND	ND			
PW-18	198 141 Red Shale	09/27/2011	121	120	582	540	1360	476	183	90	3.24	44200	37.6	ND	0.236	ND	ND	ND	ND	ND	ND	ND	202	255	17700	1270	91400	ND	ND	ND	ND	ND	ND	ND			
PW-19	Info Not Available	09/26/2011	25.1	26	344	359	972	310	184	190	2.53	41700	66.7	ND	25.1	ND	0.464	ND	ND	ND	ND	ND	625	71.6	19400	1650	37600	ND	ND	ND	ND	ND	ND	ND	ND		
PW-20	Info Not Available	09/27/2011	45.6	46	303	300	677	318	190	150	3.85	43200	23.1	ND	0.355	ND	0.592	ND	ND	ND	ND	ND	596	113	19800	2840	42300	ND	ND	ND	ND	ND	ND	ND	ND		
PW-21	Owner said well at -300', Water at -50', Pump at -98'	09/29/2011	NA	55	NA	460	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		
PW-22	Info Not Available	09/26/2011	35.6	36, 35	509	542, 523	710	212	80.7	140	9.56	18900	28.2	ND	8.06	ND	ND	ND	ND	ND	ND	ND	441	49.1	8100	837	62200	ND	0.19	ND	ND	ND	ND	ND			
PW-23	Info Not Available	09/26/2011	16.3	16	592	604	2610	216	76.2	150	11.7	15000	108	ND	0.361	ND	ND	ND	ND	ND	ND	ND	54.6	37.1	9430	1130	60200	ND	0.208	ND	ND	ND	ND	ND	ND		
PW-24	100 57 Limestone	09/27/2011	15.6	NA	203	NA	2110	422	341	330	6.78	61600	70.2	ND	0.43	ND	3.36	ND	ND	ND	ND	ND	1070	58.2	45500	1970	23800	ND	0.06	0.446	ND	ND	ND	ND			
PW-25	157 85 Limestone																																				
PW-26	Info Not Available	09/27/2011	70.6	NA	412	NA	956	352	151	130	3.12	33500	20.5	ND	1.12	ND	3.58	ND	ND	ND	ND	ND	360	124	16300	1340	54900	ND	ND	ND	ND	ND	ND	ND	ND		
R-01		09/27/2011	ND	NA	12.2	NA	0.4	NA	ND	ND	0.3	70.9	ND	ND	ND	ND	0.327	ND	ND	ND	ND	ND	ND	ND	ND	53	ND	ND	ND	ND	ND	ND	ND	0.38	ND		
PW-27	Duplicate for PW-07	09/27/2011	29.5	NA	431	NA	984	260	97.5	140	7.78	21100	46.6	ND	5.58	ND	0.303	0.235	ND	ND	ND	ND	5590	48.5	10900	1000	51500	ND	ND	ND	ND	ND	ND	ND	ND		
PW-28	Duplicate for PW-13	09/27/2011	10.7	NA	1740	NA	476	818	61.9	320	112	15700	1.67	ND	0.284	0.217	ND	ND	ND	ND	ND	44.2	113	178	5500	5170	290000	ND	0.115	0.126	ND	ND	ND	ND	ND		
PW-29	Duplicate for PW-18	09/27/2011	114	NA	580	NA	1360	480	182	90	3.21	44000	36.3	ND	0.479	ND	ND	ND	ND	ND	ND	ND	191	256	17500	1310	92100	ND	ND	ND	ND	ND	ND	ND	ND		
PW-30	Field Blank		ND	NA	ND	NA	ND	NA	ND	NA	NA	ND	0.065	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND	ND	ND	70.3	ND	0.18	0.13	ND	ND	ND	ND	ND		
PW-31	Field Blank		ND	NA	7.2	NA	ND	NA	ND	NA	NA	ND	5.99	ND	0.077	ND	ND	ND	ND	ND	ND	ND	NA	ND	ND	ND	56.1	ND	ND	ND	ND	ND	ND	ND	ND		

Table 2: Summary of Private Well Organic Parameter Sample Data – Detections Only							
			NA = Not Analyzed ND = Not Detected				
			Organics				
Sample ID	Well Depth (ft BGS) Casing Depth (ft BGS) Geologic Unit Well Open in	Sample Date	Bis(2-ethylhexyl) phthalate (ug/L)	Acetone (ug/L)	Methylene Chloride (ug/L)	Toluene (ug/L)	Comment
			NR 140 ES: 6 ug/L	NR 140 ES: 1000 ug/L	NR 140 ES: 5 ug/L	NR 140 ES: 1000 ug/L	
PW-01	225 150 Limestone	09/26/2011	ND	ND	ND	ND	
PW-02	250 150 Limestone	09/26/2011	ND	ND	ND	ND	
PW-03	220 153 Limestone	09/26/2011	ND	ND	ND	ND	
PW-04	175 140 Limestone	09/26/2011	ND	ND	ND	ND	
PW-05	325 145 Limestone	09/26/2011	ND	ND	ND	ND	
PW-06	216 143 Limestone	09/26/2011	ND	ND	ND	ND	
PW-07	Info Not Available	09/27/2011	ND	ND	ND	ND	
PW-08	222 180 Limestone						Not Sampled
PW-09	190 176 Limestone	09/26/2011	ND	ND	ND	ND	
PW-10	Info Not Available	09/27/2011	ND	ND	ND	ND	
PW-11	Info Not Available	09/26/2011	ND	ND	ND	ND	
PW-12	305 143 Limestone	09/27/2011	ND	ND	ND	ND	
PW-13	325 114 Red Shale	09/27/2011	ND	ND	ND	ND	
PW-14	Info Not Available	09/26/2011	ND	ND	ND	ND	
PW-15	125 75 Limestone	09/26/2011	ND	ND	ND	ND	
PW-16	Info Not Available	09/27/2011	ND	ND	ND	ND	
PW-17	Info Not Available	09/26/2011	1.7	ND	ND	ND	
PW-18	198 141 Red Shale	09/27/2011	9.4	ND	ND	ND	
PW-19	Info Not Available	09/26/2011	ND	ND	ND	ND	
PW-20	Info Not Available	09/27/2011	ND	ND	ND	ND	
PW-21	Owner said well at -300', Water at -50', Pump at -98'	09/29/2011	ND	ND	ND	ND	
PW-22	Info Not Available	09/26/2011	ND	ND	ND	ND	
PW-23	Info Not Available	09/26/2011	ND	ND	ND	ND	
PW-24	100 57 Limestone	09/27/2011	ND	ND	ND	ND	
PW-25	157 85 Limestone						Not Sampled
PW-26	Info Not Available	09/27/2011	ND	ND	ND	ND	
R-01		09/27/2011	ND	ND	ND	ND	
PW-27	Duplicate for PW-07	09/27/2011	ND	ND	ND	ND	
PW-28	Duplicate for PW-13	09/27/2011	ND	ND	ND	ND	
PW-29	Duplicate for PW-18	09/27/2011	15	8.4	3.5	ND	
PW-30	Field Blank		ND	4.6	3.9	ND	
PW-31	Field Blank		1.0	7.6	3.5	0.55	

Table 3: Summary of Monitoring Well Inorganic Parameter Sample Data																																
Sample ID	Description or Name given to monitoring pt by the facility	Geologic Unit Well Screened In	Screened Interval (ft above MSL and Depth (ft. BGS))	Sample Date	Sample Time	Indicators																	Other Metals and Inorganics									
						Molybdenum Concentration (ug/L)	Boron Concentration (ug/L)	Strontium Concentration (ug/L)	Total Dissolved Solids (mg/L)	Hardness (mg CaCO ₃ /L)	Total Alkalinity (mg CaCO ₃ /L)	Chloride (mg/L)	Calcium (ug/L)	Barium (ug/L)	Mercury (ug/L)	Lead (ug/L)	Selenium (ug/L)	Arsenic (ug/L)	Cadmium (ug/L)	Chromium (ug/L)	Silver (ug/L)	Aluminum (ug/L)	Iron (ug/L)	Sulfate as SO ₄ (mg/L)	Magnesium (ug/L)	Potassium (ug/L)	Sodium (ug/L)	Thallium (ug/L)	Thorium (ug/L)	Uranium (ug/L)	Vanadium (ug/L)	
We						NR 140 ES: 40 ug/L	NR 140 ES: 1000 ug/L	NR 140 ES: None		NR 140 ES: None	NR 140 ES: none	NR 140 ES: 250 mg/L	NR 140 ES: None	NR 140 ES: 2000 ug/L	NR 140 ES: 2 ug/L	NR 140 ES: 15 ug/L	NR 140 ES: 50 ug/L	NR 140 ES: 10 ug/L	NR 140 ES: 5 ug/L	NR 140 ES (Total): 100 ug/L	NR 140 ES: 50 ug/L	NR 140 ES: 200 ug/L	NR 140 ES: 300 ug/L	NR 140 ES: 250 mg/L	NR 140 ES: None	NR 140 ES: None	NR 140 ES: None	NR 140 ES: 2 ug/L	NR 140 ES: None	NR 140 ES: 30 ug/L		
MW-01	W-26CR	Till/Sand Seam	640 - 635 59 - 64	09/26/2011	15:15	14.3	176	2390	370	308	340	2.88	39,000	95	ND	0	1	16	ND	ND	ND	ND	ND	43	35.6	51,100	1,590	23,000	ND	0.224	0.246	0.437
MW-02	W-3BR	Till/Clay	683.83 - 673.83 7.5 - 17.5	09/27/2011	11:00	37.3	163	580	224	441	380	6.98	62,100	32	ND	0	ND	0	ND	ND	ND	ND	ND	90.3	69,400	1,490	14,600	ND	0.983	6.86	0.93	
MW-03	W-3CR	Till/Clay-Sand	646.3 - 641.3 45.5 - 50.4	09/27/2011	11:30	57.6	515	1050	396	141	57	3.41	35,900	12.3	ND	0	ND	4	ND	ND	ND	ND	79.2	79.7	219	124000	988	70100	ND	0.313	0.402	0.507
MW-04	W-27RR	Till/Silty Clay	694.9 - 684.9 10 - 20	09/27/2011	11:25	24.9	469	597	686	552	440	8.58	92000	39.6	ND	0.062	ND	0.536	ND	1.5	ND	ND	ND	19.6	182	78400	1890	31300	ND	0.087	3.84	1.47
MW-05	W-39C	Dolomite	512.14 - 507.14 205 - 210	09/26/2011	11:35	40.1	466	648	252	73.8	140	6.84	16800	32.2	ND	0.053	0.308	0.306	ND	ND	ND	ND	ND	17.7	44.1	7720	756	51900	ND	0.06	ND	0.222
MW-06	W-12B	Till/Clay - just below ash	657 - 647 39 - 49	09/27/2011	8:47	7.44	27400	2730	1530	1140	470	24.8	199000	26.1	ND	ND	0.37	0.886	ND	1	ND	ND	ND	1520	651	156000	2000	23400	ND	0.309	1.46	0.908
MW-07	W-12C	Till/Clay	684 - 674 11.5 - 21.5	09/27/2011	9:23	6.96	10600	864	2380	1740	480	119	373000	24	ND	ND	0.449	0.394	0.111	1.1	ND	ND	ND	23.2	1110	197000	2130	58200	ND	0.144	9.12	1.37
MW-08	W-12D	Dolomite	527.18 - 522.18 168 - 173	09/27/2011	10:03	54.1	585	1430	296	98.3	120	4.22	25600	24.5	ND	ND	0.229	ND	ND	ND	ND	ND	ND	107	100	8380	895	58500	ND	ND	0.137	0.496
MW-09	W-16AR	Till/Silty Clay	685.1 - 680.1 29 - 34	09/27/2011	14:20	60.7	324	1930	564	199	350	2.38	29100	37.4	ND	0.109	0.316	5.64	ND	ND	ND	ND	77.3	82.9	141	30700	1740	139000	ND	ND	9.4	1.23
MW-10	W-16BR	Till/Silty Clay	703.5 - 693.5 46 - 53	09/27/2011	14:11	32	156	1250	612	430	430	1.98	74600	40.1	ND	0.806	0.28	1.65	ND	1.2	ND	ND	ND	115	59100	2150	49000	ND	ND	8.53	0.774	
MW-11	W-16CR	Till/Silt	666.7 - 661.7 46 - 53	09/26/2011	11:05	18.9	191	2730	426	388	420	2.27	46800	97.6	ND	ND	ND	0.555	ND	ND	ND	ND	ND	42.1	65700	1700	20300	ND	ND	0.066	0.578	
MW-12	W-3AR	Till/Sand	663.7 - 658.7 27.1 - 32.1	09/27/2011	11:22	69.7	574	1450	478	196	90	4.02	45400	12.8	ND	0.178	0.254	3.44	ND	1.3	ND	ND	336	301	231	20100	1110	63900	ND	0.197	1.6	1.84
MW-13	W-9C	Till/Clay	? - ? 42 - 48	09/27/2011	14:21	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-14	W-32A	Till/Clay	? - ? 7 - 30.5	09/26/2011	10:14	8.01	113	1530	554	478	330	29.6	80000	101	ND	0.062	ND	2.8	ND	1.1	ND	ND	50.7	66.4	143	67600	1590	17800	ND	ND	0.225	0.652
MW-15																																
MW-16	W-44	Dolomite	526.6 - 516.6 168 - 168	09/26/2011	14:50	12	282	1550	204	157	190	1.63	25400	69.4	ND	ND	ND	1.86	ND	ND	ND	ND	ND	65.7	16.6	22600	888	23400	ND	0.31	0.271	0.662
MW-17	W-45A	Till/Sand Seam	637.1 - 632.1 55 - 60	09/26/2011	14:05	64	383	473	216	104	140	2.67	24600	37.9	ND	2.98	0.374	1.66	0.101	7.2	ND	ND	4300	4660	30.6	10300	2290	48200	ND	1.11	1.71	9.14
MW-18	W-45B	Dolomite	508.3 - 503.3 184 - 189	09/27/2011	8:08	34.2	471	405	306	161	140	11	36900	50.5	ND	1.17	0.387	0.528	0.075	8.4	ND	ND	4690	3960	70.6	16800	3780	49200	ND	1.33	0.854	8.97
MW-19	W-47B	Dolomite	522.2 - 516.7 143.5 - 149	09/27/2011	13:46	20.5	589	2240	464	185	190	5.1	44600	23.3	ND	ND	0.301	ND	ND	1.1	ND	ND	56	156	174	17900	1700	90000	ND	0.064	0.068	0.667
MW-20	Dup for MW-03	Till		09/27/2011	11:30	56.7	526	1070	430	140	57	3.31	35800	13.2	ND	0.06	0.363	3.65	ND	ND	ND	ND	ND	212	12300	1080	70400	ND	ND	0.258	0.611	
MW-21	Dup for MW-08	Dolomite		09/27/2011	10:03	56	560	1470	276	101	120	4.26	26400	24.2	ND	0.06	ND	ND	ND	ND	ND	ND	ND	109	101	8640	928	60900	ND	ND	0.191	0.388
MW-22	Field Blank	-		09/27/2011	15:00	0.065	14.4	0.3	NA	ND	NA	NA	25.6	0.062	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND	ND	ND	89.6	ND	ND	ND	ND	
R-02	Rinse for Monitoring Well	-		09/27/2011	14:20	ND	14.5	ND	ND	ND	ND	ND	36.8	ND	0.2	0.349	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	39.3	ND	0.073	ND	ND
Notes																																
MW-30	P-1A	till/sand	? - ? 7 - 17	11/28/2011	10:42	1.88	83.8	251	496	439	280	42.7	116000	53.6	ND	ND	ND	1.16	ND	2.1	ND	ND	40.9	2390	121	36200	3450	22300	ND	ND	0.615	ND
MW-31	P-1B	till/clay	? - ? 14 - 24	11/28/2011	10:28	0.355	709	674	808	678	570	73.2	140000	322	ND	1.08	5.75	1.97	ND	4.3	ND	ND	81.2	26500	181	79600	16400	44900	ND	ND	0.167	0.729
MW-32	P-2B	till/sand	? - ? 19.8 - 29.8	11/29/2011	10:15	0.299	550	554	896	736	830	83.9	178000	430	ND	ND	1.61	0.669	ND	4.3	ND	ND	18500	22.5	70700	20300	77000	ND	ND	ND	2.24	
MW-33																																
MW-34	P-4BR	till/sand	? - ? 20 - 30	11/28/2011	15:44	1.62	1640	802	1480	735	910	164	69500	505	ND	0.328	3.87	10.9	ND	12.1	ND	ND	6460	486	136000	111000	284000	ND	ND	ND	2.97	
MW-35	MW-4D	till/sand & gravel	644.4 - 639 17.1 - 22.1	11/29/2011	10:36	1.61	98.2	494	704	602	380	38.8	141000	124	ND	ND	ND	0.37	ND	3.2	ND	ND	3570	258	60900	4140	29300	ND	ND	0.335	0.369	
MW-36	MW-6D	till/sand	621.2 - 616.2 42.1 - 47.1	11/28/2011	13:12	6.02	109	1090	250	248	240	4.41	52300	61.6	ND	ND	ND	0.442	ND	ND	ND	ND	ND	61.9	20.7	28400	948	16600	ND	ND	0.079	ND
MW-37	P-3B	till/sand	? - ? 18.4 - 28.4	11/29/2011	10:41	0.288	496	749	1150	1230	950	44	304000	473	ND	0.052	7.63	3.17	ND	7	ND	ND	23000	185	113000	33600	37000	ND	ND	ND	4.77	
MW-38	MW-8D	till/sand	643.4 - 638.4 18.7 - 23.7	11/29/2011	9:38	2.39	161	1680	846	643.4	380	131	154000	334	ND	ND	0.248	0.303	ND	3.2	ND	ND	36	4460	216	69800	1820	57300	ND	ND	0.077	0.273
MW-39	MW-10S	till/sand	655.5 - 645.5 2.7 - 12.7	11/28/2011	12:10	0.345	258	322	604	465	440	95.1	105000	168	ND	ND	1.02	0.789	ND	2.5	ND	ND	1370	46.7	49100	16400	59100	ND	ND	0.383	0.908	
MW-40	MW-10D	till/silt	638 - 633 20.9 - 25.9	11/28/2011	12:15	15.6	245	1020	314	180	120	114	44200	29.1	ND	ND	0.295	1.62	ND	ND	ND	ND	ND	31.6	17000	2760	60400	ND	ND	2.37	0.878	
MW-41	MW-11D	till/sand	638.9 - 634.0 22.1 - 27.0	11/29/2011	11:11	26.2	310	687	310	203	160	32	48100	50.6	ND	0.234	ND	0.798	ND	ND	ND	ND	218	356	88.6	20100	2490	47200	ND	ND	0.094	0.919
MW-42	MW-13B	Dolomite	610.9 - 605.6 47.8 - 53	11/28/2011	14:03	5.82	157	708	440	369	260	57.8	83000	68.2	ND	0.462	ND	1.89	ND	3.1	ND	ND										

Table 4: Summary of Monitoring Well Organic Parameter Sample Data – Detections Only																										
Sample ID	Description or Name given to monitoring pt by the facility	Geologic Unit Well Screened In	Screened Interval (ft above MSL) and Depth (ft. BGS)	Sample Date	Sample Time	Organics																		Comment		
						NA = Not Analyzed ND = Not Detected																				
						Bi(2-ethylhexyl)phthalate (ug/L)	D-n-butylphthalate (ug/L)	Acetone (ug/L)	Methylene Chloride (ug/L)	Caprolactam (ug/L)	Toluene (ug/L)	4-Methylphenol (ug/L)	2,4-Dimethylphenol (ug/L)	Naphthalene (ug/L)	Vinyl Chloride (ug/L)	1,1-Dichloroethane (ug/L)	1,1,1-Trichloroethane (ug/L)	trans-1,2-Dichloroethane (ug/L)	cis-1,2-Dichloroethane (ug/L)	Benzene (ug/L)	Tetrachlorethene (ug/L)	Chlorobenzene (ug/L)	Ethylbenzene (ug/L)		o-xylene (ug/L)	m,p-xylene (ug/L)
We						NR 140 ES: 6 ug/L	NR 140 ES: None	NR 140 ES: 1000 ug/L	NR 140 ES: 5 ug/L	NR 140 ES: None	NR 140 ES: 1000 ug/L	NR 140 ES: None	NR 140 ES: None	NR 140 ES: 100 ug/L	NR 140 ES: 0.2 ug/L	NR 140 ES: 850 ug/L	NR 140 ES: 200 ug/L	NR 140 ES: 100 ug/L	NR 140 ES: 70 ug/L	NR 140 ES: 5 ug/L	NR 140 ES: 5 ug/L	NR 140 ES: None	NR 140 ES: 700 ug/L	NR 140 ES: 10000 ug/L	NR 140 ES: 10000 ug/L	NR 140 ES: None
MW-01	W-26CR	Till/Sand Seam	640 - 635 59 - 64	09/26/2011	15:15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-02	W-3BR	Till/Clay	683.83 - 673.83 7.5 - 17.5	09/27/2011	11:00	ND	ND	ND	1.3	180	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-03	W-3CR	Till/Clay-Sand	646.3 - 641.3 45.5 - 50.4	09/27/2011	11:30	ND	ND	ND	ND	1100	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-04	W-27RR	Till/Silty Clay	694.9 - 684.9 10 - 20	09/27/2011	11:25	ND	ND	ND	ND	140	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-05	W-39C	Dolomite	512.14 - 507.14 205 - 210	09/26/2011	11:35	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-06	W-12B	Till/Clay - just below ash	657 - 647 39 - 49	09/27/2011	8:47	ND	ND	ND	ND	3600	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-07	W-12C	Till/Clay	684 - 674 11.5 - 21.5	09/27/2011	9:23	ND	ND	ND	ND	64	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-08	W-12D	Dolomite	527.18 - 522.18 168 - 173	09/27/2011	10:03	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-09	W-16AR	Till/Silty Clay	685.1 - 680.1 29 - 34	09/27/2011	14:20	ND	ND	ND	ND	310	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-10	W-16BR	Till/Silty Clay	703.5 - 693.5 10 - 20	09/27/2011	14:11	ND	ND	ND	ND	3500	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-11	W-16CR	Till/Silt	666.7 - 661.7 46 - 53	09/26/2011	11:05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-12	W-3AR	Till/Sand	663.7 - 658.7 27.1 - 32.1	09/27/2011	11:22	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-13	W-9C	Till/Clay	? - ? 42 - 48	09/27/2011	14:21	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-14	W-32A	Till/Clay	? - ? 7 - 30.5	09/26/2011	10:14	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-15																										Not Used
MW-16	W-44	Dolomite	526.6 - 516.6 158 - 168	09/26/2011	14:50	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-17	W-45A	Till/Sand Seam	637.1 - 632.1 55 - 60	09/26/2011	14:05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-18	W-45B	Dolomite	508.3 - 503.3 184 - 189	09/27/2011	8:08	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-19	W-47B	Dolomite	522.2 - 516.7 143.5 - 149	09/27/2011	13:46	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-20	Dup for MW-03	Till		09/27/2011	11:30	ND	ND	ND	ND	670	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-21	Dup for MW-08	Dolomite		09/27/2011	10:03	ND	ND	ND	ND	2.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-22	Field Blank	-		09/27/2011	15:00	1.9	ND	7.1	3.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R-02	Rinse for Monitoring Well	-		09/27/2011	14:20	1.5	ND	7.5	ND	ND	0.57	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Hums																										
MW-30	P-1A	till/sand	? - ? 7 - 17	11/28/2011	10:42	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-31	P-1B	till/clay	? - ? 14 - 24	11/28/2011	10:28	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-32	P-2B	till/sand	? - ? 19.8 - 29.8	11/29/2011	10:15	NA	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-33																										Not Sampled
MW-34	P-4BR	till/sand	? - ? 20 - 30	11/28/2011	15:44	<25	23	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.7	ND	1.5	ND	ND	ND
MW-35	MW-4D	till/sand & gravel	644.4 - 639 17.1 - 22.1	11/29/2011	10:36	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3.6	3	2.3	ND	ND	ND	ND	ND	ND	ND
MW-36	MW-6D	till/sand	621.2 - 616.2 42.1 - 47.1	11/28/2011	13:12	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-37	P-3B	till/sand	? - ? 18.4 - 28.4	11/29/2011	10:41	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-38	MW-8D	till/sand	643.4 - 638.4 18.7 - 23.7	11/29/2011	9:38	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-39	MW-10S	till/sand	655.5 - 645.5 2.7 - 12.7	11/28/2011	12:10	ND	ND	ND	ND	ND	ND	ND	ND	180	9.1	ND	5	29	0.71	ND	ND	ND	ND	ND	ND	ND
MW-40	MW-10D	till/silt	638 - 633 20.5 - 25.5	11/28/2011	12:15	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-41	MW-11D	till/sand	638.9 - 634.0 22.1 - 27.0	11/29/2011	11:11	ND	ND	ND	ND	16	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-42	MW-13B	Dolomite	610.8 - 605.8 47.8 - 53	11/28/2011	14:03	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-43	MW-14S	till/sand	659.2 - 649.2 8.2 - 18.2	11/28/2011	14:00	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-44	MW-16B	Dolomite	575.0 - 568.8 88.8 - 94.0	11/29/2011	12:23	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-45	MW-17B	Dolomite	605.7 - 600.5 59.1 - 64.3	11/28/2011	15:10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
MW-46	Dup for MW-39	till/sand		11/28/2011	12:10	ND	ND	ND	ND	ND	ND	ND	ND	180	ND	ND	5.1	28	0.67	ND	ND	ND	ND	ND	ND	20
MW-47	Dup for MW-34	till		11/28/2011	15:44	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.6	ND	ND	ND	ND	20
R-01	Rinse for Monitoring Well	-		11/29/2011	12:30	2.5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
R-02	Rinse for Monitoring Well	-		11/29/2011	12:39	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
T-01	Blank					ND	ND	3.9	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.53	ND	ND

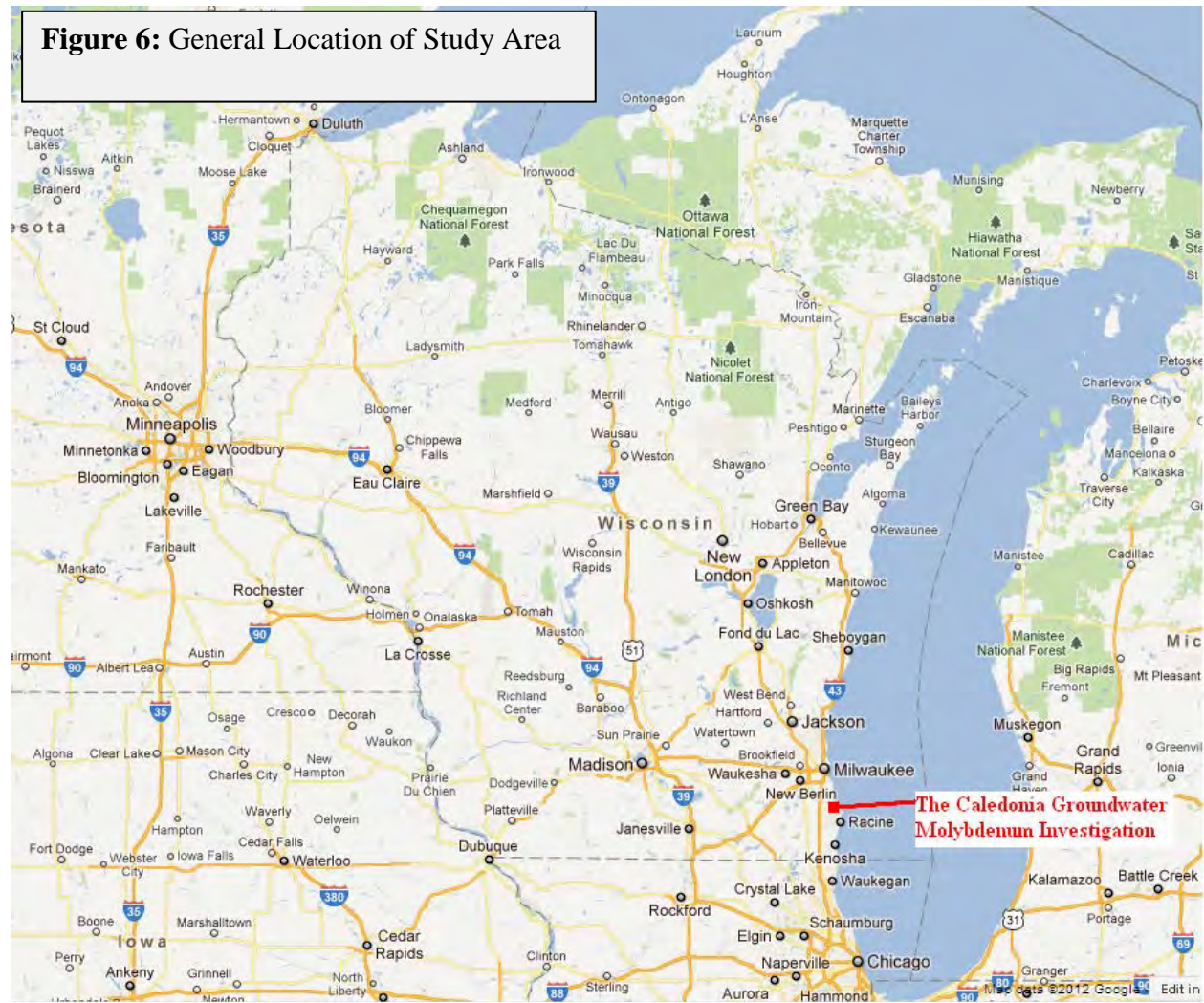
Table 7: Summary of Private Well Molybdenum, Boron & Strontium Isotopes and Tritium Data														
		NA = Not Analyzed		ND = Not Detected		Tritium, Molybdenum, Boron & Strontium								
Sample ID	Well Depth (ft BGS) Casing Depth (ft BGS) Geologic Unit Well Open in	Sample Date	Tritium (TU) 1TU = 3.221 Picocuries/L	Tritium ± 1σ	Molybdenum Concentration (ug/L)	Previous Mo Concentrations (ug/L)	Molybdenum Isotope (δ 98/95 Mo) (per mil)	2sd	n (# of repetitions)	Boron Concentration (ug/L)	Previous Boron Concentrations (ug/L)	Boron Isotope (δ ¹¹ B) (per mil)	Strontium Concentration (ug/L)	Strontium Isotope 87/86 Sr
					NR 140 ES: 40 ug/L					NR 140 ES: 1000 ug/L			NR 140 ES: None	
PW-01	225 150 Limestone	09/26/2011	1.1	0.3	80	66, 62	2.16 & 2.33	0.06 & 0.03	5 & 3	448	471, 455	24.23	525	0.70900
PW-02	250 150 Limestone	09/26/2011	<0.8	0.4	88.2	85, 83	2.68	0.01	3	387	399, 394	16.98	716	0.70906
PW-03	220 153 Limestone	09/26/2011	0.9	0.4	66.8	70, 67	NA	NA	NA	458	480, 470	25.22	355	0.70909
PW-04	175 140 Limestone	09/26/2011	1.0	0.4	64	65	NA	NA	NA	463	450	23.73	644	0.70898
PW-05	325 145 Limestone	09/26/2011	<0.8	0.4	33.2	37, 35	3.24	0.03	3	799	859	21.73	581	0.70920
PW-06	216 143 Limestone	09/26/2011	<0.8	0.4	54.1	61, 59	1.97	0.16	6	470	508, 535	23.23	753	0.70893
PW-07	Info Not Available	09/27/2011	<0.8	0.3	32.4	45, 27, 39	3.09 leach from PW-07: 2.91	0.17 leach from PW-07: 0.02	4 leach from PW-07: 4	431	540, 420, 420	23.73	975	0.70891
PW-08	222 180 Limestone													
PW-09	190 176 Limestone	09/26/2011	<0.8	0.3	42.5	31.5, 42	3.57 & 3.67	0.05 & 0.05	3 & 4	550	532, 482	24.23	519	0.70898
PW-10	Info Not Available	09/27/2011	<0.8	0.3	145	124, 89.4	2.42 & 2.31	0.11 & 0.02	3 & 4	581	532, 482	25.22	1720	0.70881
PW-11	Info Not Available	09/26/2011	0.9	0.4	41.1	58, 42, 33, 56				551	720, 570, 520, 520	23.48	540	0.70895
PW-12	305 143 Limestone	09/27/2011	<0.8	0.4	35.9	44	3.12	0.01	3	1470	1190	28.97	1950	0.70882
PW-13	325 114 Red Shale	09/27/2011	<0.8	0.4	10.9	24	3.06	0.07	3	1740	1040	29.22	466	0.70914
PW-14	Info Not Available	09/26/2011	<0.8	0.3	49.3	50	2.50	0.01	3	323	302	26.97	718	0.70923
PW-15	125 75 Limestone	09/26/2011	<0.8	0.4	48.9	50	2.50	0.02	3	337	327	27.72	777	0.70917
PW-16	Info Not Available	09/27/2011	<0.8	0.3	40.2	43	4.11 & 4.31	0.03 & 0.05	4 & 3	487	470	24.98	975	0.70883
PW-17	Info Not Available	09/26/2011	<0.8	0.3	41.7	37, 43	4.33	0.1	4	489, 477	473	24.98	990	0.70883
PW-18	198 141 Red Shale	09/27/2011	<0.8	0.3	121	120	1.67	0.07	4	582	540	26.22	1360	0.70891
PW-19	Info Not Available	09/26/2011	<0.8	0.3	25.1	26	2.29	0.20	5	344	359	25.72	972	0.70901
PW-20	Info Not Available	09/27/2011	<0.8	0.3	45.6	46	2.58	0.04	4	303	300	24.98	677	0.70922
PW-21	Owner said well at -300'. Water at -50'. Pump at -98'	09/29/2011	<0.8	0.4	NA	55	NA	NA	NA	NA	460	23.73	NA	0.70897
PW-22	Info Not Available	09/26/2011	<0.8	0.3	35.6	36, 35	4.03	0.03	3	509	542, 523	24.98	710	0.70890
PW-23	Info Not Available	09/26/2011	<0.8	0.3	16.3	16	3.63	0.07	3	592	604	14.24	2610	0.70857
PW-24	100 57 Limestone	09/27/2011	<0.8	0.3	15.6	NA	2.25 & 2.22	0.19 & 0.16	6 & 5	203	NA	13.74	2110	0.70885
PW-25	157 85 Limestone													
PW-26	Info Not Available	09/27/2011	<0.8	0.3	70.6	NA	1.73	0.03	3	412	NA	26.47	956	0.70899
R-01		09/27/2011	12.9	1.0	ND	NA	NA	NA	NA	12.2	NA	NA	0.4	NA
PW-27	Duplicate for PW-07	09/27/2011	NA	NA	29.5	NA	NA	NA	NA	431	NA	NA	984	NA
PW-28	Duplicate for PW-13	09/27/2011	NA	NA	10.7	NA	NA	NA	NA	1740	NA	NA	476	NA
PW-29	Duplicate for PW-18	09/27/2011	NA	NA	114	NA	NA	NA	NA	580	NA	NA	1360	NA
PW-30	Field Blank		NA	NA	ND	NA	NA	NA	NA	ND	NA	NA	ND	NA
PW-31	Field Blank		NA	NA	ND	NA	NA	NA	NA	7.2	NA	NA	ND	NA

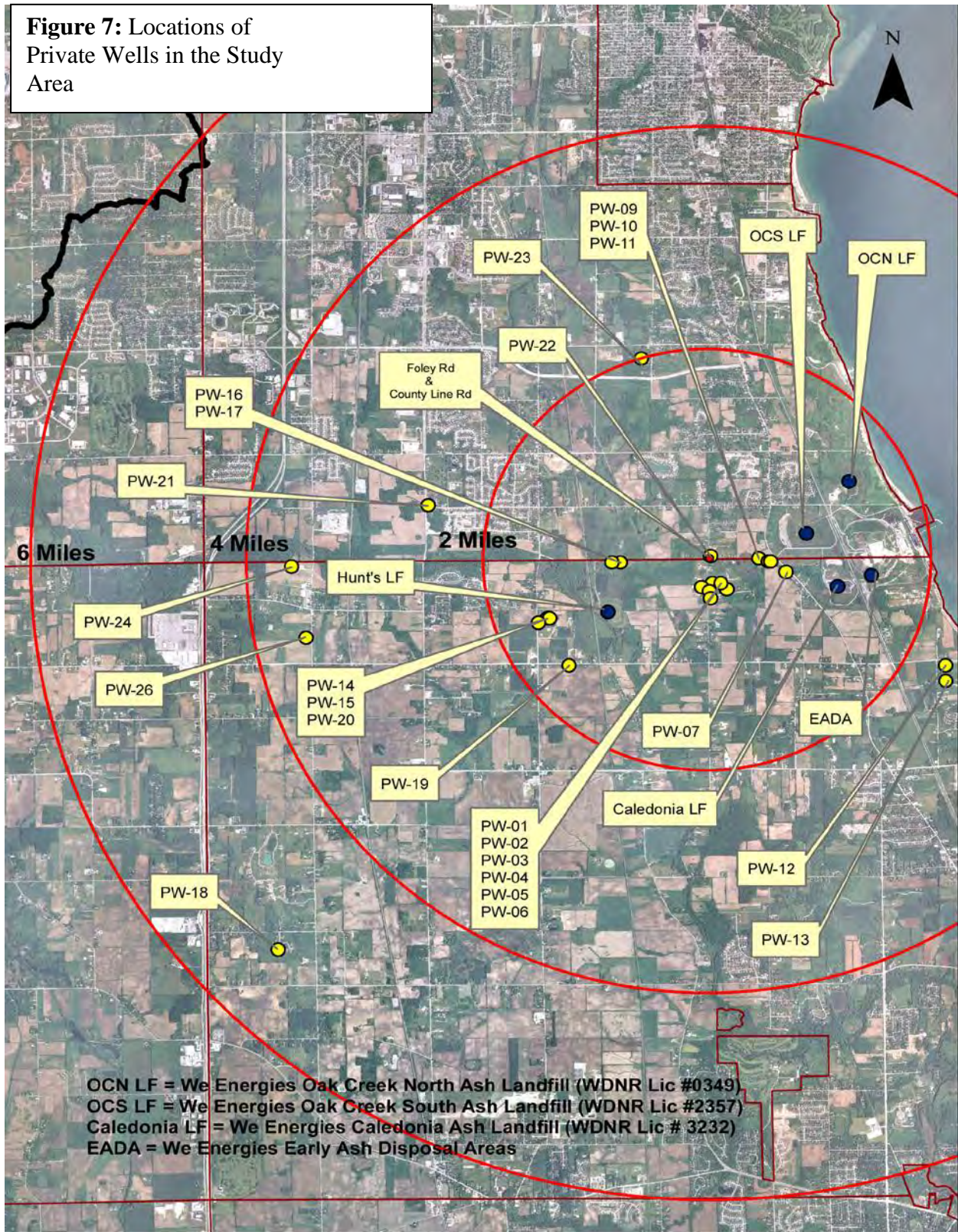
Table 8: Summary of Monitoring Well Molybdenum, Boron & Strontium Isotopes and Tritium Sample Data															
NA = Not Analyzed		ND = Not Detected		Tritium, Molybdenum, Boron & Strontium											
Sample ID	Description or Name given to monitoring pt by the facility	Geologic Unit Well Screened In	Screened Interval (# above MSL and Depth (ft. BGS))	Sample Date	Sample Time	Tritium (TU) 1TU = 3.221 Picocuries/L	Tritium ± 1σ	Molybdenum Concentration (ug/L)	Molybdenum Isotope (# 98/95 Mo) (per mil)	2sd	n	Boron Concentration (ug/L)	Boron Isotope (# 11B) (per mil)	Strontium Concentration (ug/L)	Strontium Isotope 87/86 Sr
We								NR 140 ES: 40 ug/L				NR 140 ES: 1000 ug/L		NR 140 ES: None	
MW-01	W-26CR	Till/Sand Seam	640 - 635 59 - 64	09/26/2011	15:15	1.4	0.4	14.3	1.94	0.05	3	176	5.99	2390	0.70886
MW-02	W-3BR	Till/Clay	683.83 - 673.83 7.5 - 17.5	09/27/2011	11:00	5.6	0.5	37.3	2.28	0.06	4	163	12.74	580	0.70939
MW-03	W-3CR	Till/Clay-Sand	646.3 - 641.3 45.5 - 50.4	09/27/2011	11:30	<0.8	0.4	57.6	NA	NA	NA	515	26.97	1050	0.70878
MW-04	W-27RR	Till/Silty Clay	694.9 - 684.9 10 - 20	09/27/2011	11:25	6.9	0.6	24.9	2.52 & 2.75	0.07 & 0.08	4 & 3	469	16.23	597	0.70993
MW-05	W-39C	Dolomite	512.14 - 507.14 205 - 210	09/26/2011	11:35	<0.8	0.3	40.1	2.78	0.05	3	466	23.48	648	0.70894
MW-06	W-12B	Till/Clay - just below ash	657 - 647 39 - 49	09/27/2011	8:47	5.3	0.5	7.44	NA	NA	NA	27400	14.24	2730	0.70905
MW-07	W-12C	Till/Clay	684 - 674 11.5 - 21.5	09/27/2011	9:23	8.6	0.8	6.96	NA	NA	NA	10600	11.74	864	0.71112
MW-08	W-12D	Dolomite	527.18 - 522.18 168 - 173	09/27/2011	10:03	<0.8	0.3	54.1	2.27 & 2.04 & 2.23	0.11 & 0.02 & 0.01	3 & 4 & 3	585	24.98	1430	0.70878
MW-09	W-16AR	Till/Silty Clay	685.1 - 680.1 29 - 34	09/27/2011	14:20	1.6	0.3	60.7	1.56	0.02	3	324	19.73	1930	0.70869
MW-10	W-16BR	Till/Silty Clay	703.5 - 693.5 10 - 20	09/27/2011	14:11	4.7	0.5	32	NA	NA	NA	156	9.24	1250	0.70895
MW-11	W-16CR	Till/Silt	666.7 - 661.7 48 - 53	09/26/2011	11:05	3.1	0.4	18.9	2.21	0.04	4	191	11.74	2730	0.70873
MW-12	W-3AR	Till/Sand	663.7 - 658.7 27.1 - 32.1	09/27/2011	11:22	<0.8	0.3	69.7	1.01	0.03	3	574	28.47	1450	0.70872
MW-13	W-9C	Till/Clay	? - ? 42 - 48	09/27/2011	14:21	1.8	0.3	NA	1.47	0.11	4	NA	27.47	NA	0.70878
MW-14	W-32A	Till/Clay	? - ? ? - 30.5	09/26/2011	10:14	4.6	0.5	8.01	NA	NA	NA	113	3.00	1530	0.70890
MW-15															
MW-16	W-44	Dolomite	526.6 - 516.6 158 - 168	09/26/2011	14:50	<0.8	0.3	12	1.74	0.16	7	282	20.23	1550	0.70878
MW-17	W-45A	Till/Sand Seam	637.1 - 632.1 55 - 60	09/26/2011	14:05	<0.8	0.3	64	2.32	0.13	3	393	20.23	473	0.70884
MW-18	W-45B	Dolomite	508.3 - 503.3 184 - 189	09/27/2011	8:08	<0.8	0.3	34.2	3.12 & 3.18	0.15 & 0.04	6 & 3	471	13.49	405	0.70932
MW-19	W-47B	Dolomite	522.2 - 516.7 143.5 - 149	09/27/2011	13:46	<0.8	0.3	20.5	3.82 & 3.87 & 3.89	0.04 & 0.08 & 0.05	3 & 3 & 3	589	23.73	2240	0.70878
MW-20	Dup for MW-03	Till		09/27/2011	11:30	NA	NA	56.7	6.77	0.02	3	526	NA	1070	NA
MW-21	Dup for MW-08	Dolomite		09/27/2011	10:03	NA	NA	56	2.63	0	3	560	NA	1470	NA
MW-22	Field Blank	-		09/27/2011	15:00	13	1.1	0.065	NA	NA	NA	14.4	NA	0.3	NA
R-02	Rinse for Monitoring Well	-		09/27/2011	14:20	13.5	1.2	ND	NA	NA	NA	14.5	NA	ND	NA
Hums															
MW-30	P-1A	till/sand	? - ? 7 - 17	11/28/2011	10:42	9.4	0.8	1.88	3.16	0.04	3	83.8	-0.75	251	0.71032
MW-31	P-1B	till/clay	? - ? 14 - 24	11/28/2011	10:28	8.8	0.8	0.355	3.01	0.15	4	709	3.75	674	0.70958
MW-32	P-2B	till/sand	? - ? 19.8 - 29.8	11/29/2011	10:15	8.6	0.8	0.299	NA	NA	NA	550	14.24	554	0.70978
MW-33															
MW-34	P-4BR	till/sand	? - ? 20 - 30	11/28/2011	15:44	10.7	0.9	1.62	NA	NA	NA	1640	3.25 & 2.00	802	0.70945
MW-35	MW-4D	till/sand & gravel	644.4 - 639 17.1 - 22.1	11/29/2011	10:36	6.9	0.7	1.61	NA	NA	NA	98.2	-1.00	494	0.70937 & 0.70935
MW-36	MW-6D	till/sand	621.2 - 616.2 42.1 - 47.1	11/28/2011	13:12	<0.8	0.3	6.02	NA	NA	NA	109	19.23	1090	0.70879
MW-37	P-3B	till/sand	? - ? 18.4 - 28.4	11/29/2011	10:41	9	0.8	0.288	2.47	0.09	4	496	-3.25	749	0.71009
MW-38	MW-8D	till/sand	643.4 - 638.4 18.7 - 23.7	11/29/2011	9:38	7.8	0.8	2.39	NA	NA	NA	161	16.23	1680	0.70895 & 0.70893
MW-39	MW-10S	till/sand	655.5 - 645.5 2.7 - 12.7	11/28/2011	12:10	7.8	0.7	0.345	NA	NA	NA	258	9.99 & 10.24	322	0.70961
MW-40	MW-10D	till/silt	638 - 633 20.5 - 25.5	11/28/2011	12:15	4.1	0.5	15.6	3.59	0.1	3	245	20.980	1020	0.70890
MW-41	MW-11D	till/sand	638.9 - 634.0 22.1 - 27.0	11/29/2011	11:11	<0.8	0.3	26.2	3.21	0.04	3	310	24.73	687	0.70918
MW-42	MW-13B	Dolomite	610.8 - 605.6 47.8 - 53	11/28/2011	14:03	6.5	0.7	5.82	2.82	0.1	4	157	22.23	708	0.70915
MW-43	MW-14S	till/sand	659.2 - 649.2 8.2 - 18.2	11/28/2011	14:00	11.5	0.9	2.44	NA	NA	NA	1480	8.24	1350	0.70952
MW-44	MW-16B	Dolomite	575.0 - 569.8 88.8 - 94.0	11/29/2011	12:23	8.3	0.7	10.7	3.65	0.06	3	129	24.48	403	0.70960
MW-45	MW-17B	Dolomite	605.7 - 600.5 59.1 - 64.3	11/28/2011	15:10	4.7	0.5	10.4	3.14	0.04	3	225	21.98	1150	0.70902
MW-46	Dup for MW-39	till/sand		11/28/2011	12:10	8.2	0.8	0.35	NA	NA	NA	262	9.99	327	0.70959
MW-47	Dup for MW-34	till		11/28/2011	15:44	10.3	0.9	1.71	NA	NA	NA	1540	2.00	615	0.70943
R-01	Rinse for Monitoring Well	-		11/29/2011	12:30	12.1	1.00	ND	NA	NA	NA	8	NA	1.4	NA
R-02	Rinse for Monitoring Well	-		11/29/2011	12:39	12.3	1.00	ND	NA	NA	NA	6.8	NA	0.7	NA

Table 10: Summary of Coal Ash Molybdenum Isotope Sample Data

Sample ID	Description (All cores were lined with a plastic membrane.)	Sample Date	Molybdenum Isotope (δ 98/95 Mo) (per mil)	2sd	n (# of repetitions on instrument)
CA-01	LH-06 (LHN-4) Taken from top of pile. Wet, Black	10/27/2011	1.65	0.06	5
CA-02	LH-06 (LHN-4) Taken from sides of pile. Wet, Black	10/27/2011	1.69 & 1.84	0.06 & 0.12	4 & 4
CA-03	LH-05 (LHN-3) Taken from 5' core at interval 20-25' depth. Saturated, Black; Note: Some non-ash soil landed on top of the ash core when driller shoveled. After it happened the consultant told driller not to let other material, i.e. soil, contaminate the core ash sample.	10/27/2011	1.73	0.07	3
CA-04	LH-05 (LHN-3) Taken from 5' core at interval 30-31' depth. Saturated, Black; Note: Some non-ash soil landed on top of the ash core when driller shoveled. Core contained some material from the 20-25' depth interval	10/27/2011	1.60	0.04	5
CA-05	LH-05 (LHN-3) Sample taken from top of ash pile. Saturated, Black	10/27/2011	1.51	0.06	4
CA-07	LH-06 (LHN-4) Taken from sides of pile. Wet, Black	10/27/2011	1.62	0.02	4
CA-09	LH-06 (LHN-4) Taken from sampling core after chunks removed from core and placed on pile. Wet, Black	10/27/2011	1.44	0.04	4
CA-10	Coal Ash Sample collected from bluff slide at a location near the NW corner of the old power plant frame structure. Top of pile. Wet, Black	11/04/2011	2.28	0.11	5
CA-11	Coal Ash Sample collected from bluff slide at a location near the NW corner of the old power plant frame structure. Sampled from beneath CA-10. Wet, Black	11/04/2011	2.3	0.06	3
CA-12	Coal Ash Sample collected from bluff slide at a location near the NW corner of the old power plant frame structure. Sampled from beneath CA-11. Wet, Black	11/04/2011	2.46	0.04	3
CA-13	Coal Ash Sample collected from bluff slide at a location near the NW corner of the old power plant frame structure. Bottom sample. Wet, Black	11/04/2011	2.53	0.08	3
W-01	Leach water from coal ash samples CA-01 thru CA-13 that were sitting in plastic ziplock bags in cooler. Water collected from bottom of cooler.	11/04/2011	acidified, filtered: 2.25 unacidified, filtered: 2.34	acidified, filtered: 0.07 unacidified, filtered: 0.11	acidified, filtered: 3 unacidified, filtered: 3

Figures





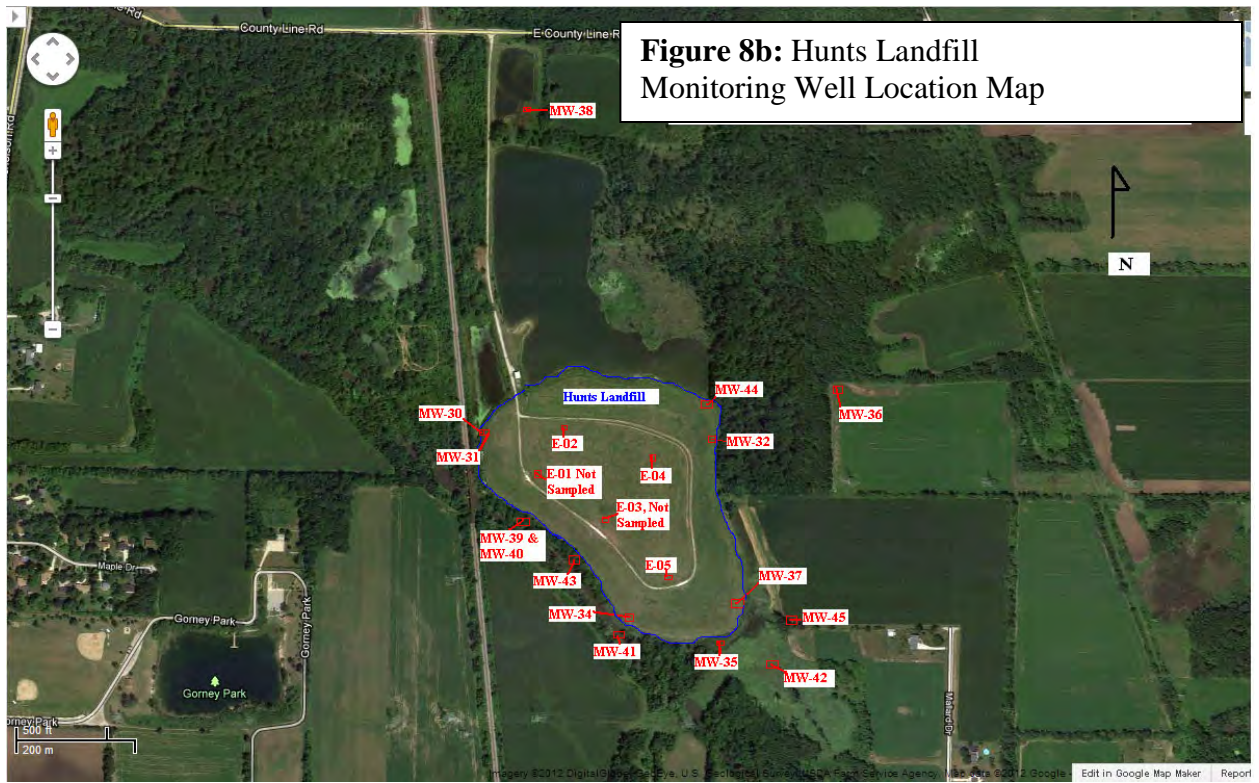
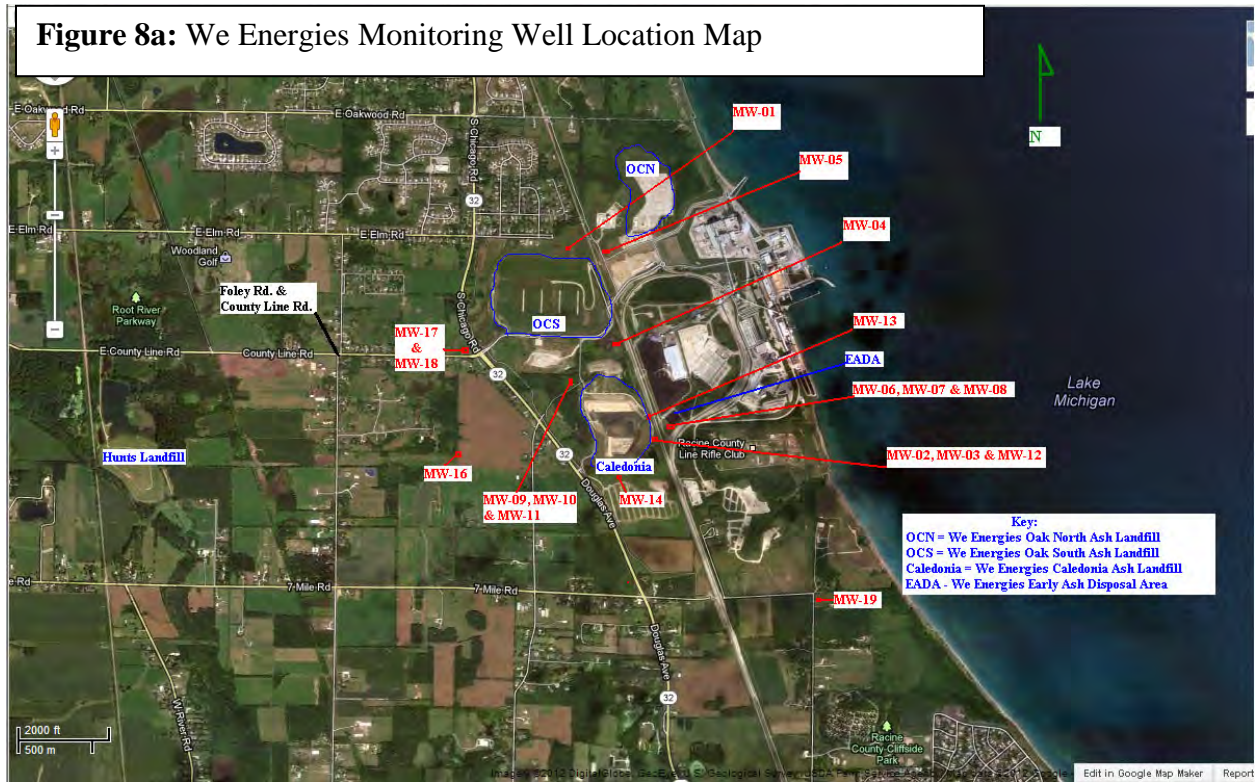


Figure 9a: Surface Water Map East of Foley Rd.

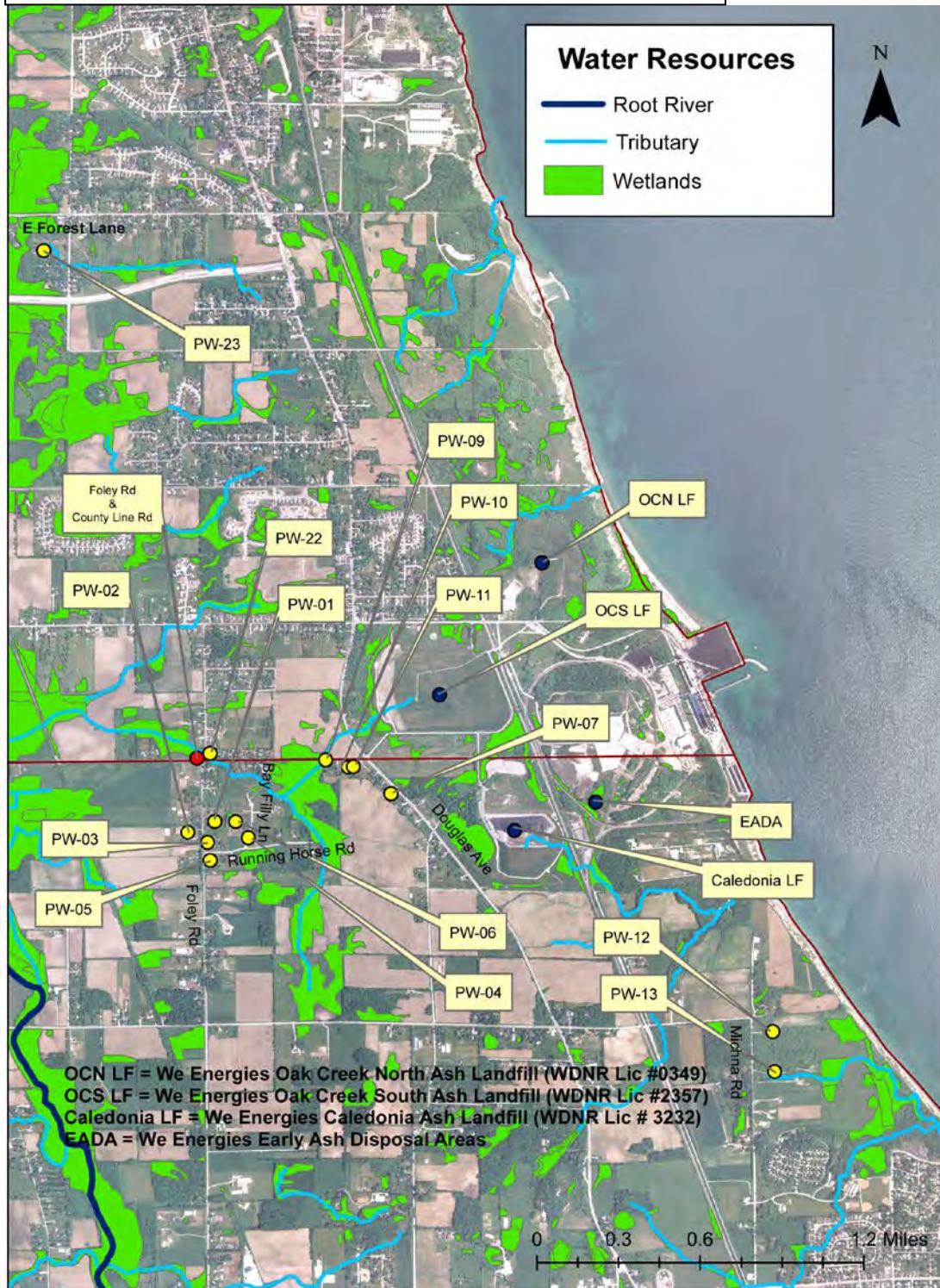


Figure 9b: Surface Water Map West of Foley Rd.

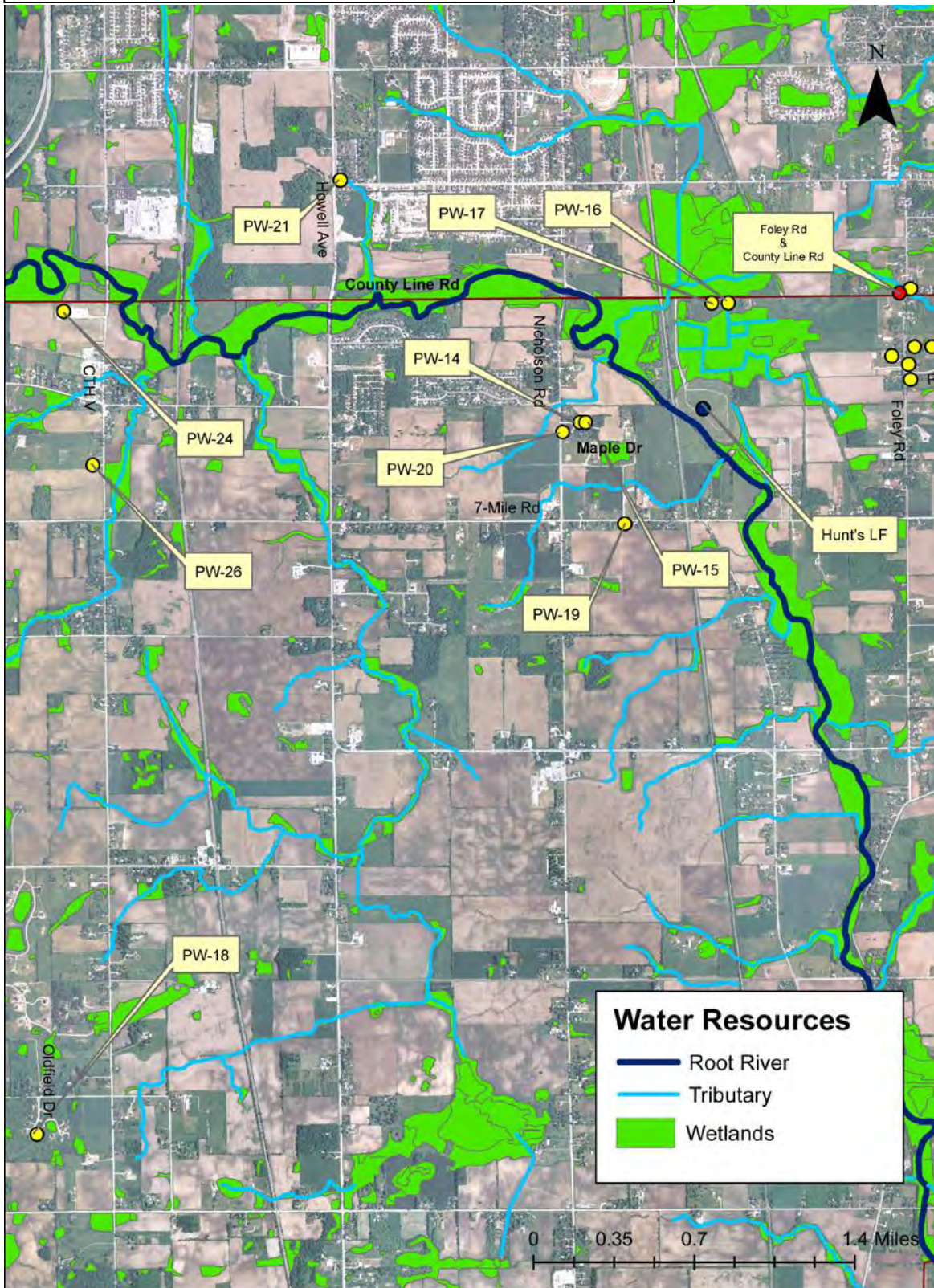


Figure 10a: Soil Map East of Foley Rd.

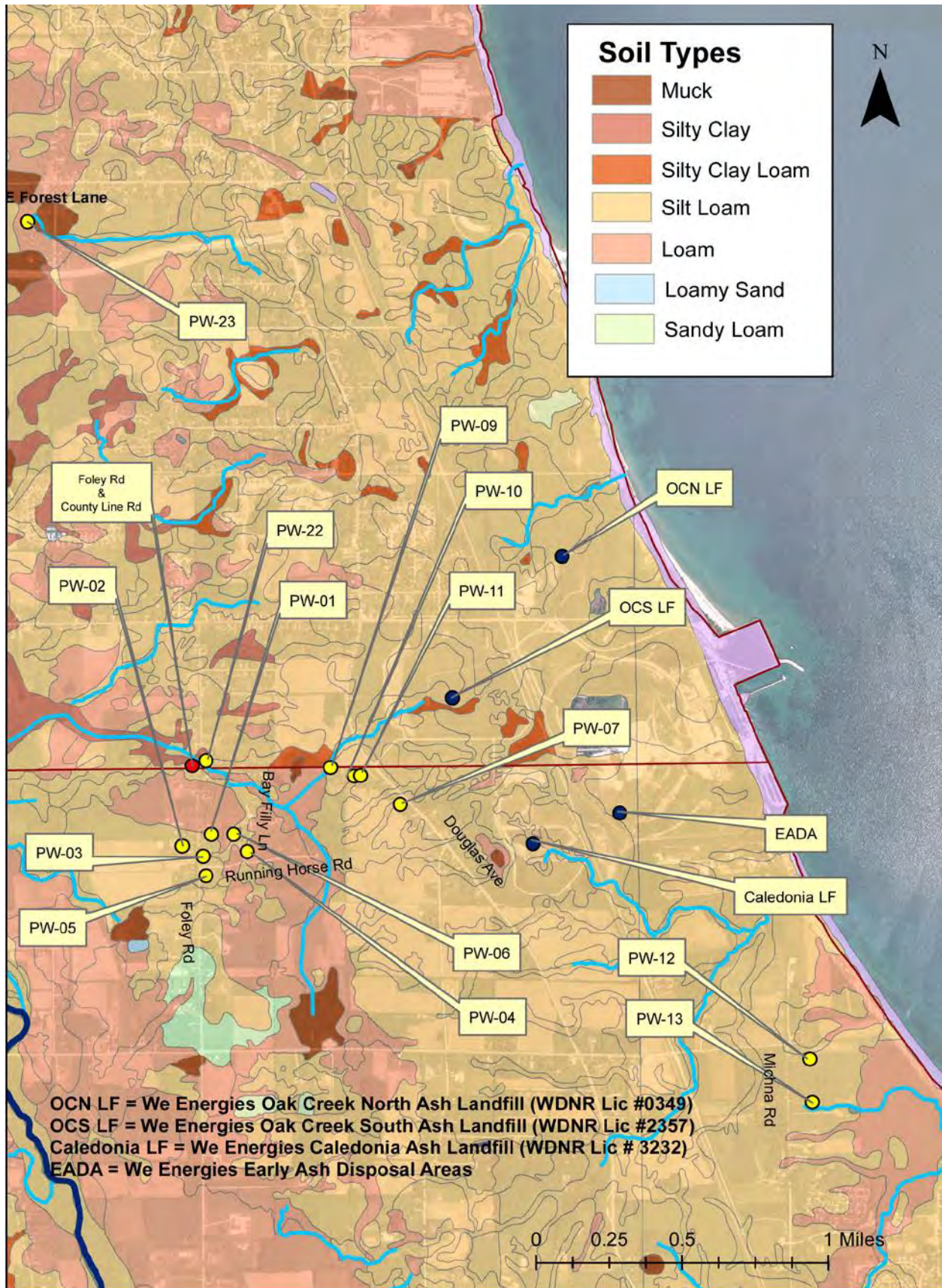


Figure 10b: Soil Map West of Foley Rd.

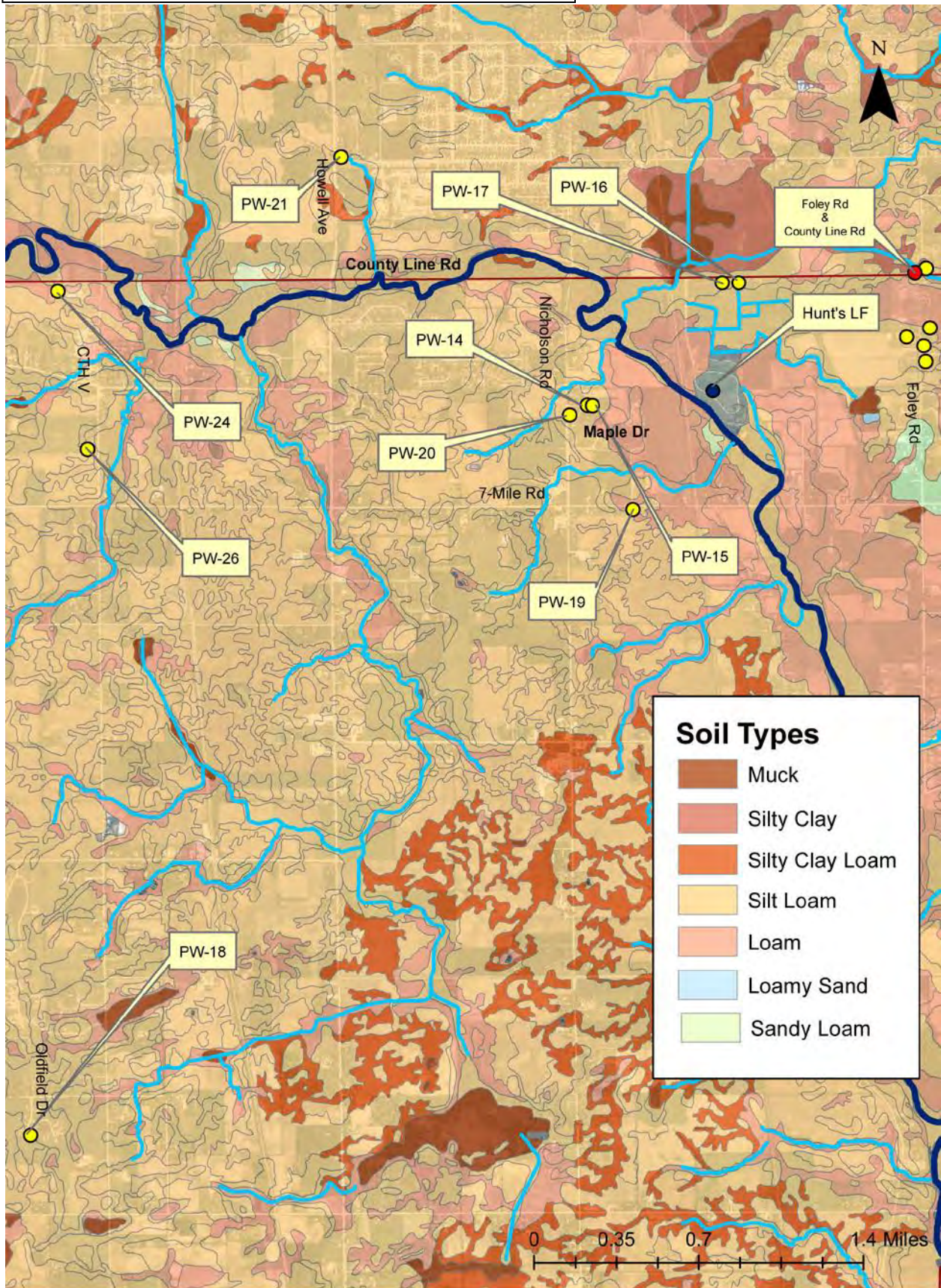
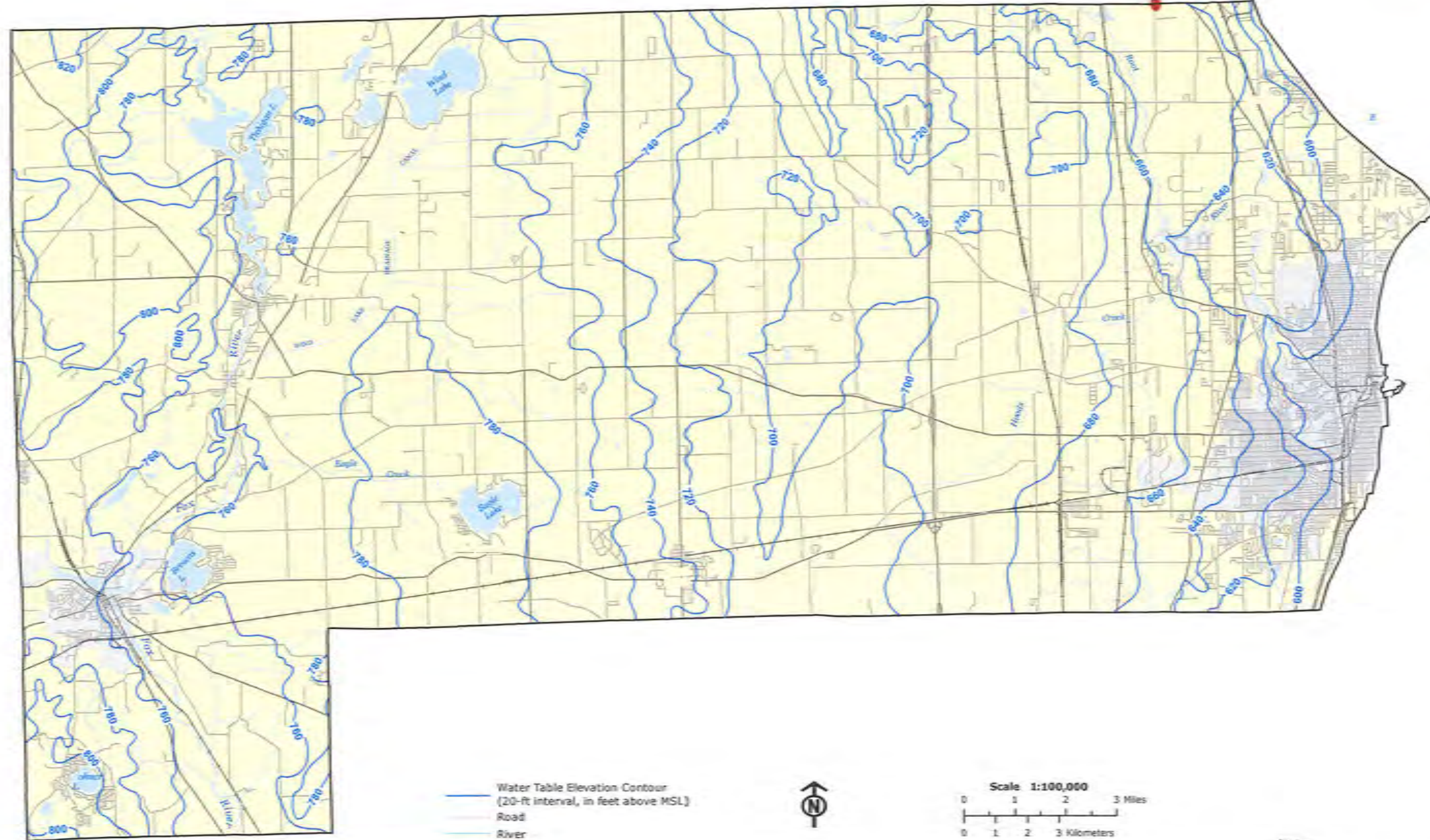


Figure 11: Groundwater Elevation Contour Map for Racine County

**Water Table Elevation
Racine County, Wisconsin**



FOLEY ROAD
AND
COUNTY LINE ROAD



Wisconsin Geological and Natural History Survey
3817 Mineral Point Road Madison, Wisconsin 53705-5100
TELEPHONE 608.262.1705 FAX 608.262.8086
<http://www.dnr.wisconsin.gov/gnhs>
James M. Robertson, Director and State Geologist

Notes
Geological data reprinted at 1:100,000-scale from Map 21, Generalized Water Table Elevation in the Southeastern Wisconsin Region, published in Groundwater Resources of Southeastern Wisconsin, Technical Report 37, Southeastern Wisconsin Regional Planning Commission and Wisconsin Geological and Natural History Survey, 2002.

Base map data from Wisconsin Department of Natural Resources 1:24000- and 1:100000-scale sources.

Figure 12: Generalized Water Table Map Elevation Map in the Southeastern Wisconsin Region

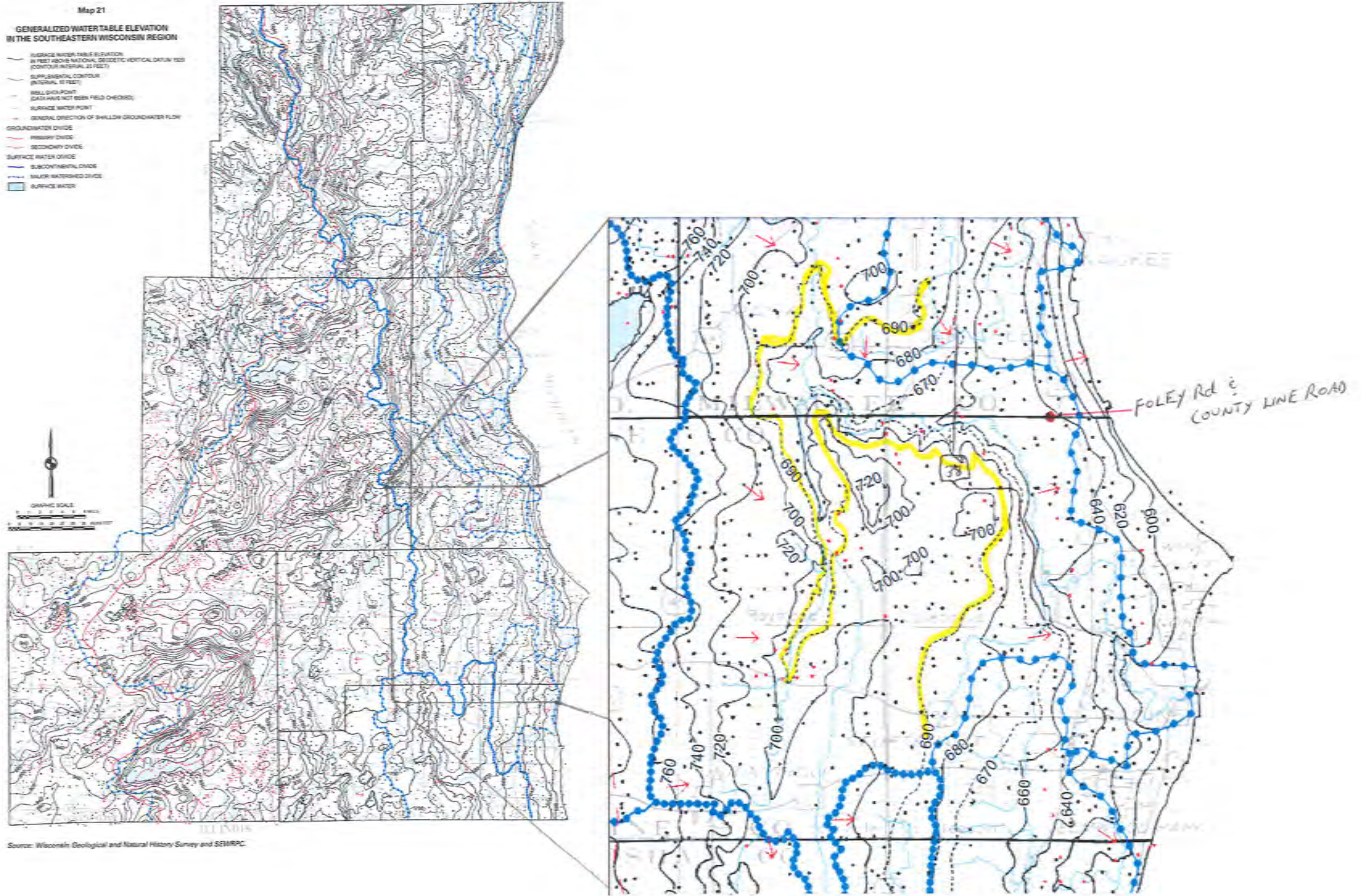
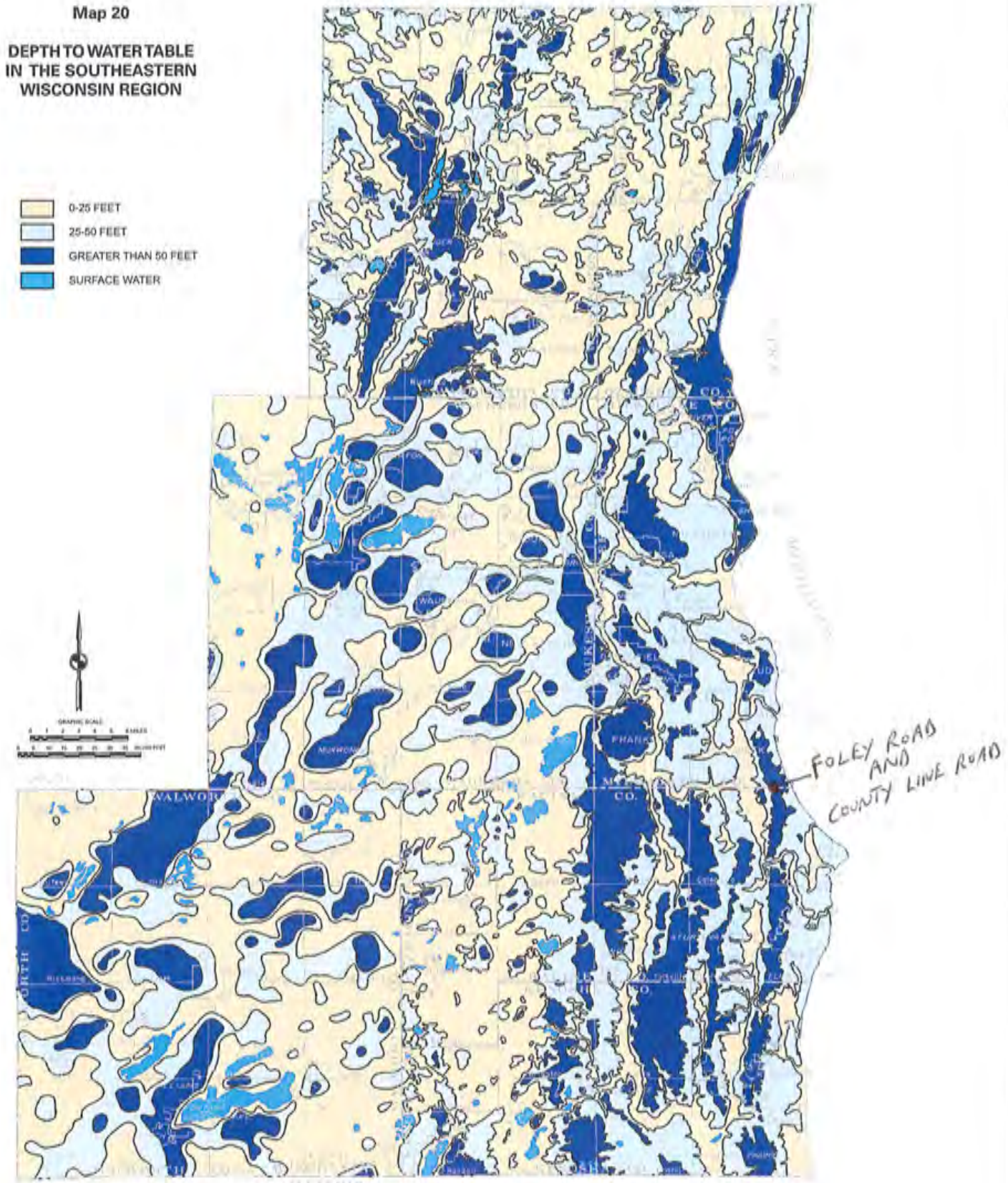


Figure 13: Depth to Water Table in Southeastern Wisconsin Region



Source: Wisconsin Geological and Natural History Survey and SEWRPC.

Figure 14: Approximate Extent of Major Pre-Glacial Bedrock Valleys in Southeastern Wisconsin

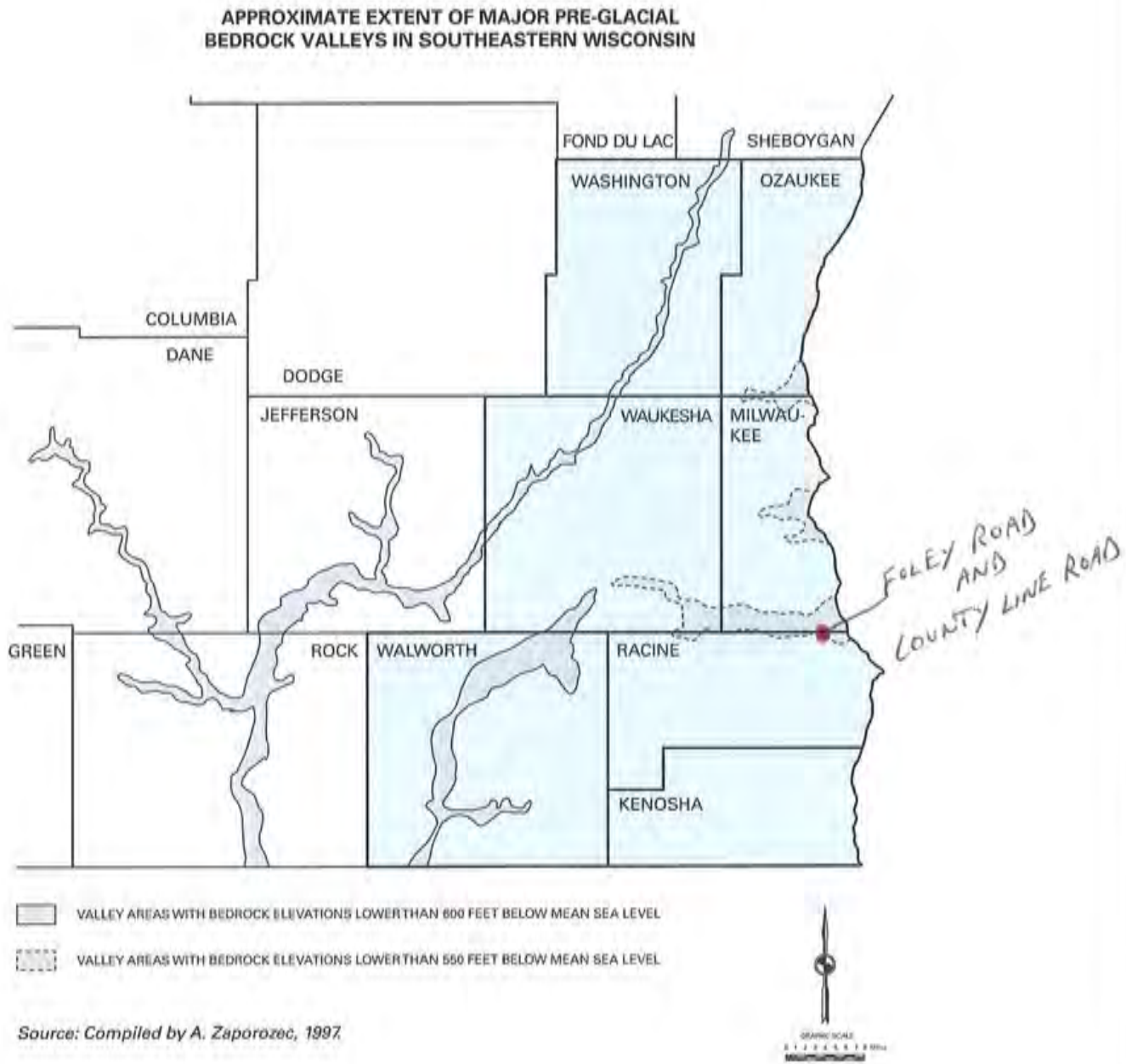
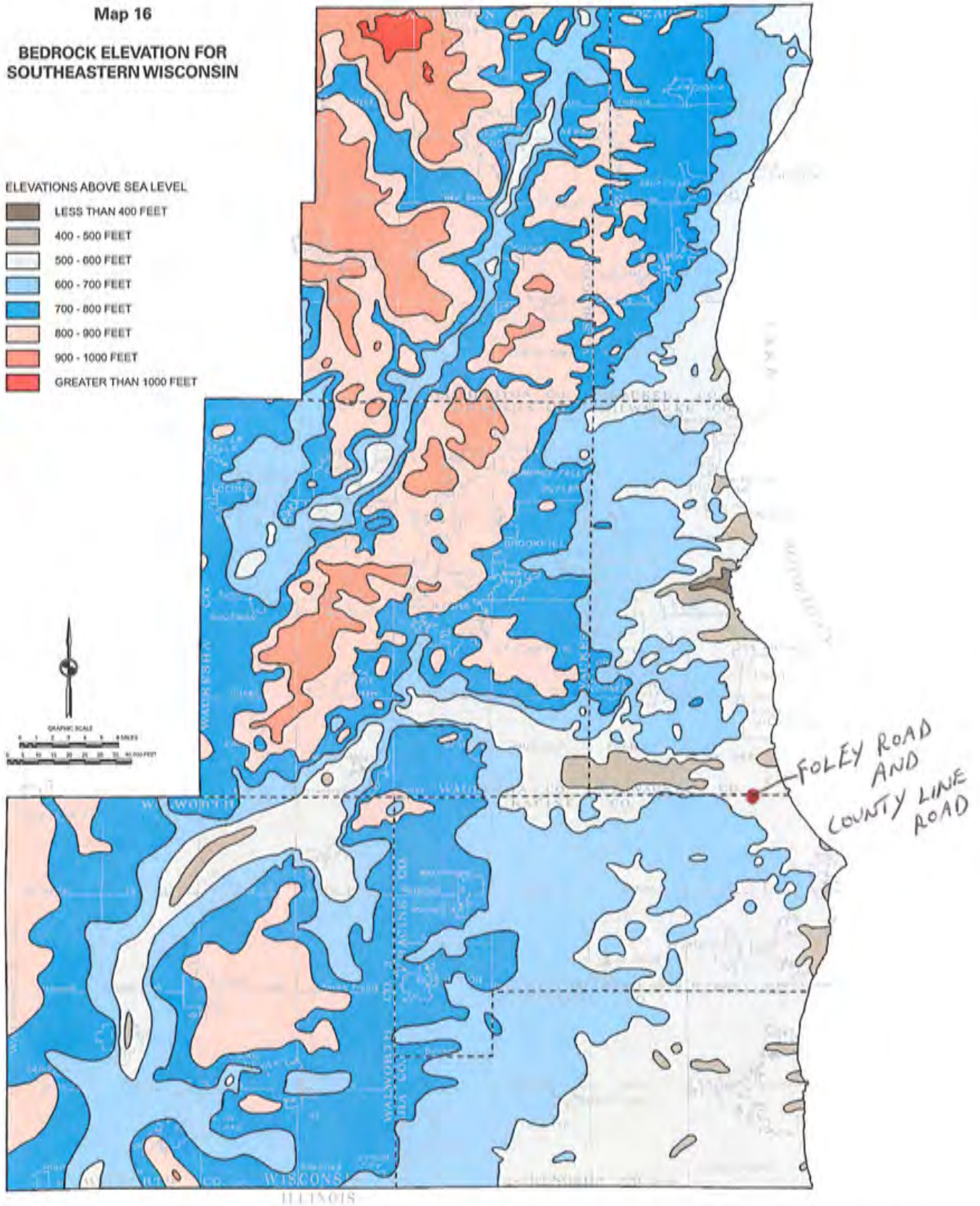


Figure 15: Bedrock Elevation Map for Southeastern Wisconsin.



Source: Wisconsin Geologic and Natural History Survey.

Figure 16: Generalized Depth to Bedrock Map for Southeastern Wisconsin

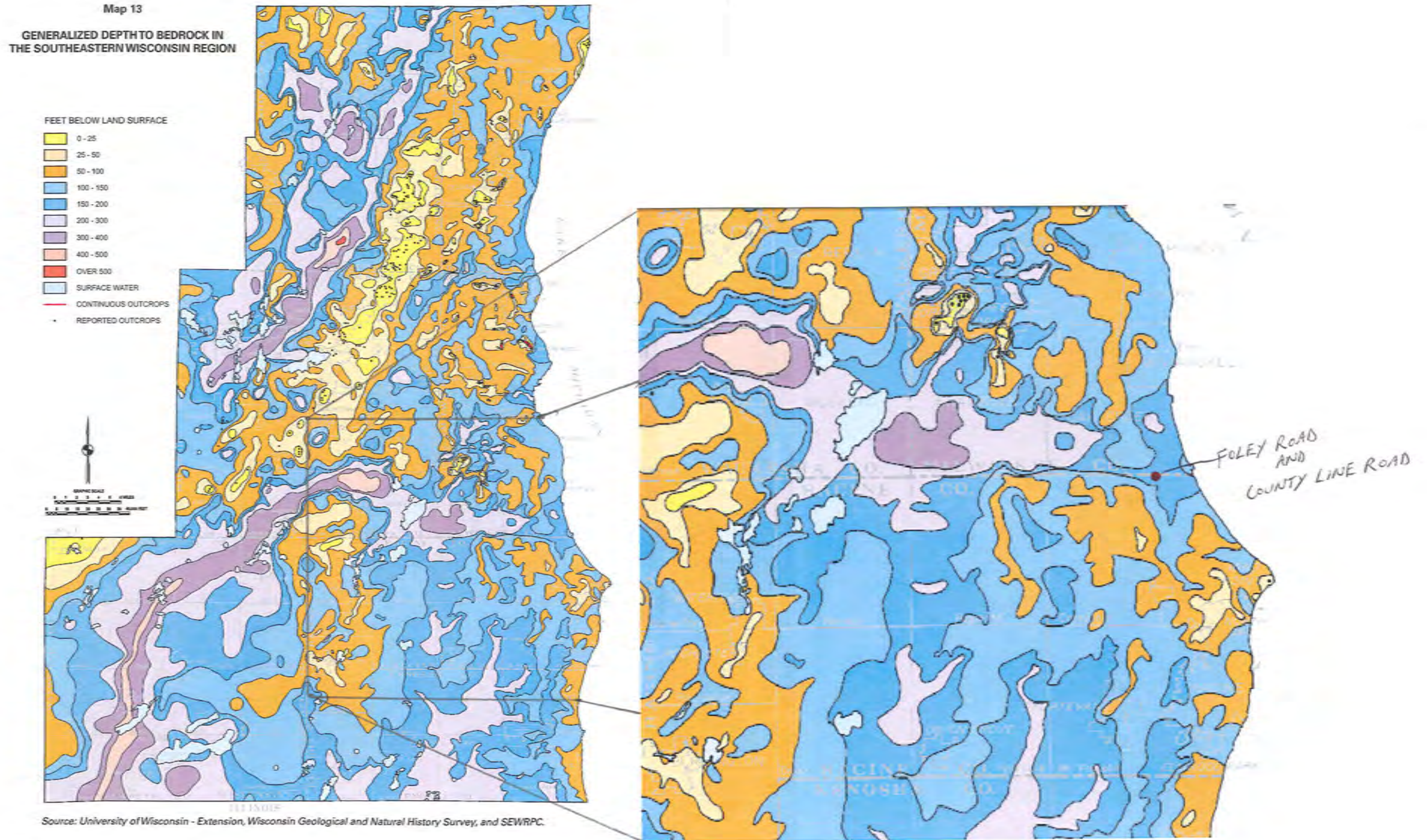
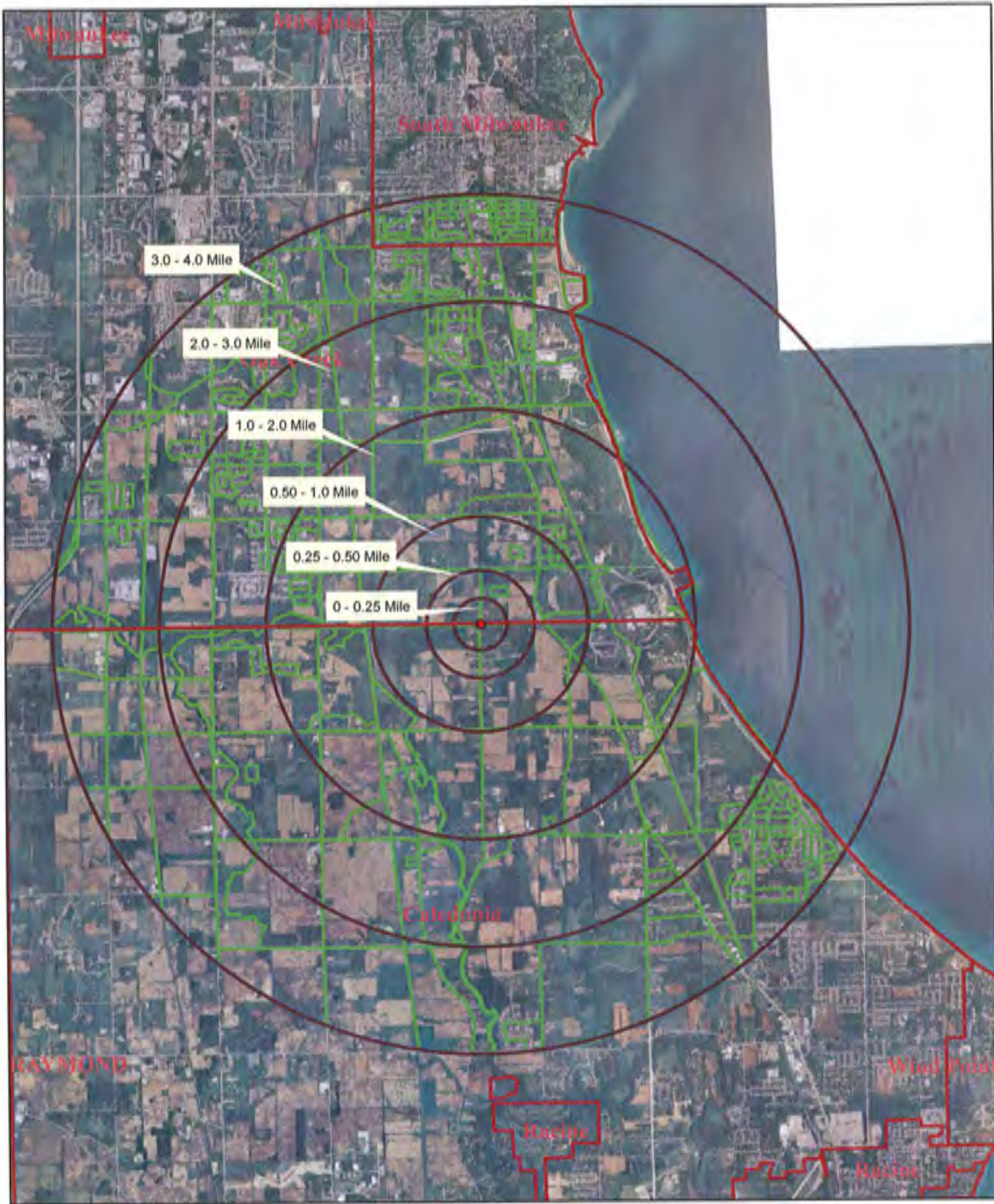


Figure 17: Population Radii Map

SW Corner of Foley & County Line Rd, Caledonia, WI



Radii(mi)	Population*
0 - 0.25	55
0.25 - 0.5	209
0.5 - 1.0	711
1.0 - 2.0	3,872
2.0 - 3.0	7,968
3.0 - 4.0	17,613
Total	30,428



Legend

- Source Point
- ▭ Municipal Boundaries
- ▭ Census Blocks



* Population counts based on 2000 U.S. Census data adjusted to 2008 estimated change.

Figure 18: Extended Map of the Area

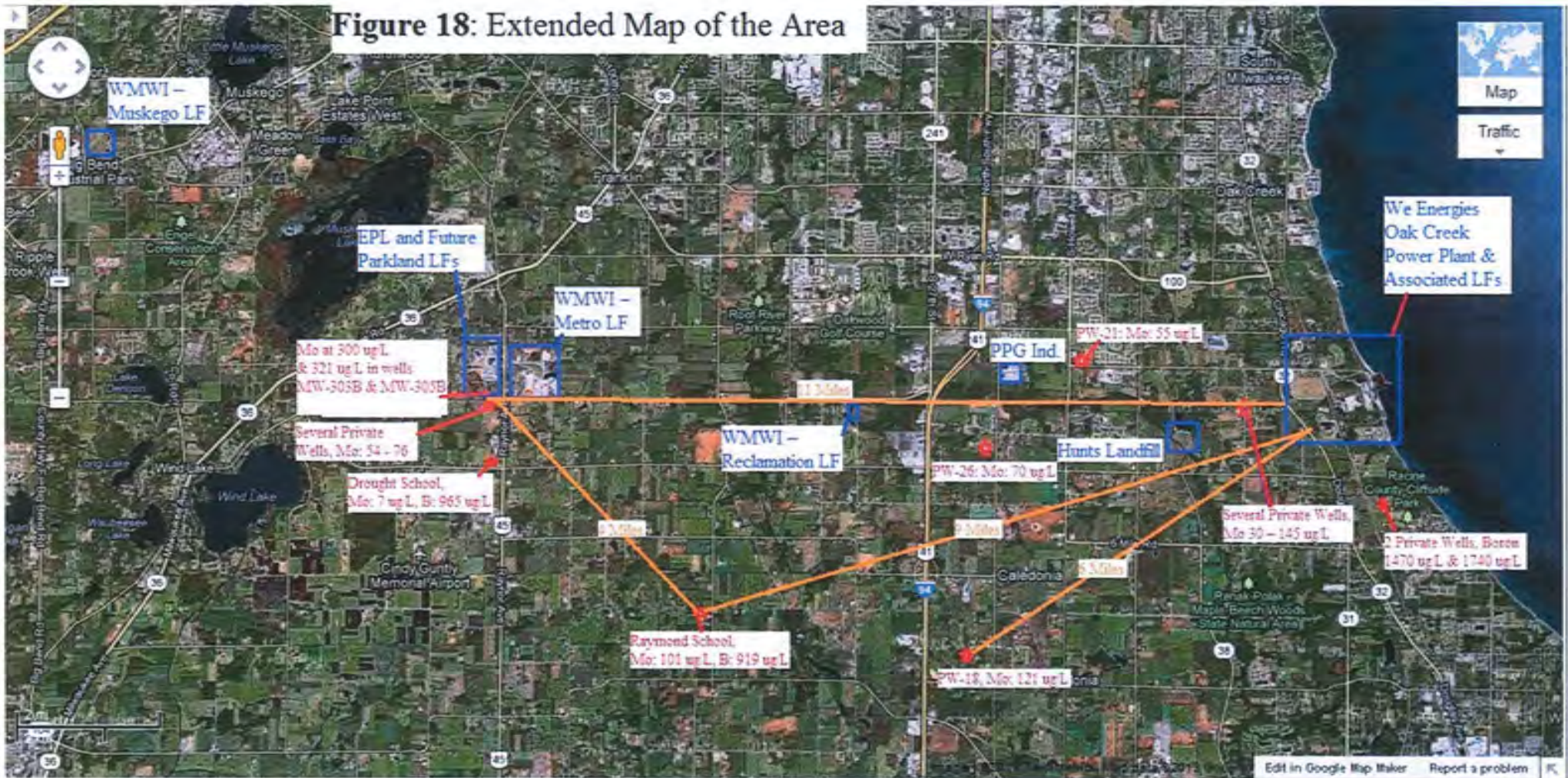
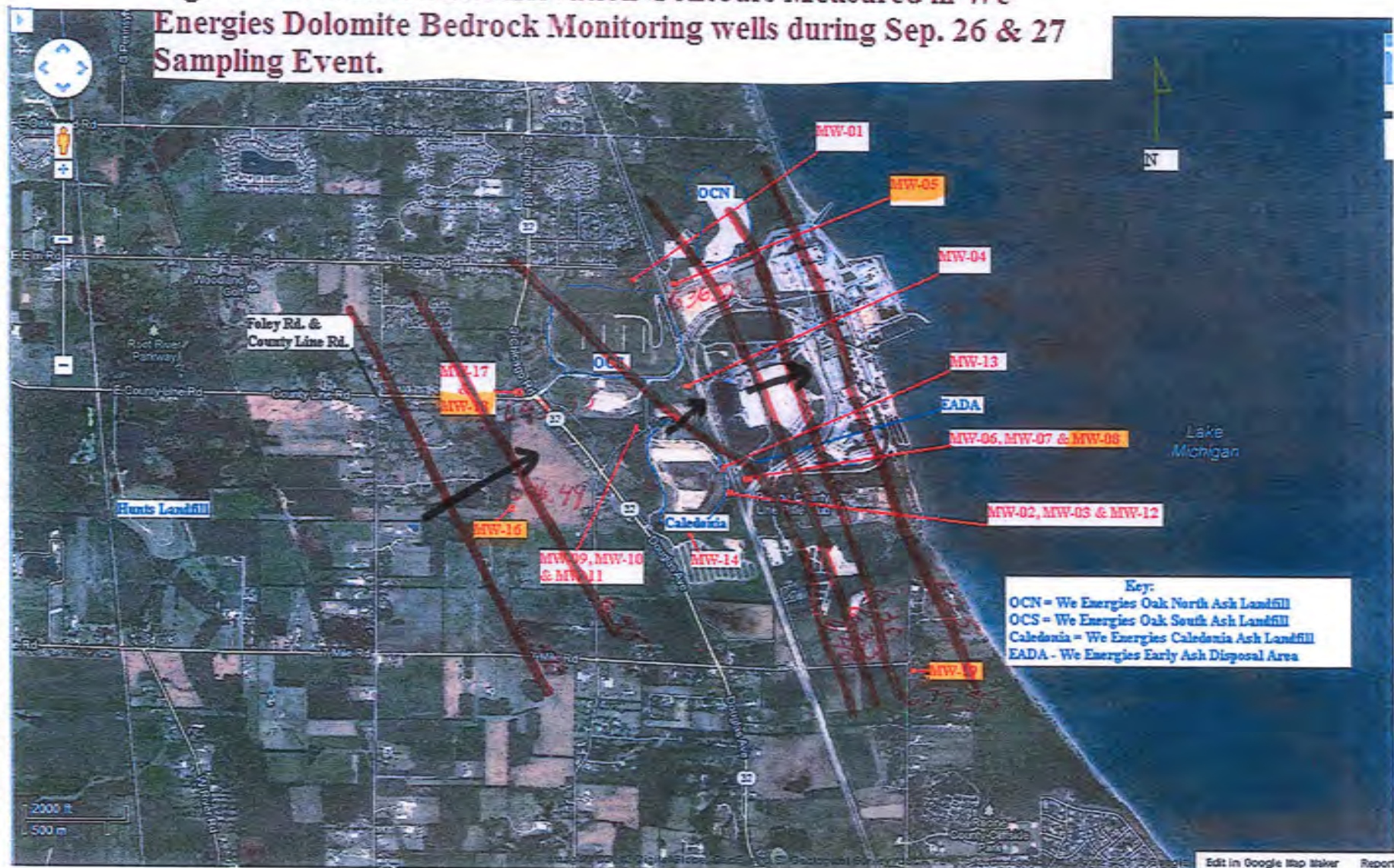


Figure 19: Groundwater Elevation Contours Measured in We Energies Dolomite Bedrock Monitoring wells during Sep. 26 & 27 Sampling Event.

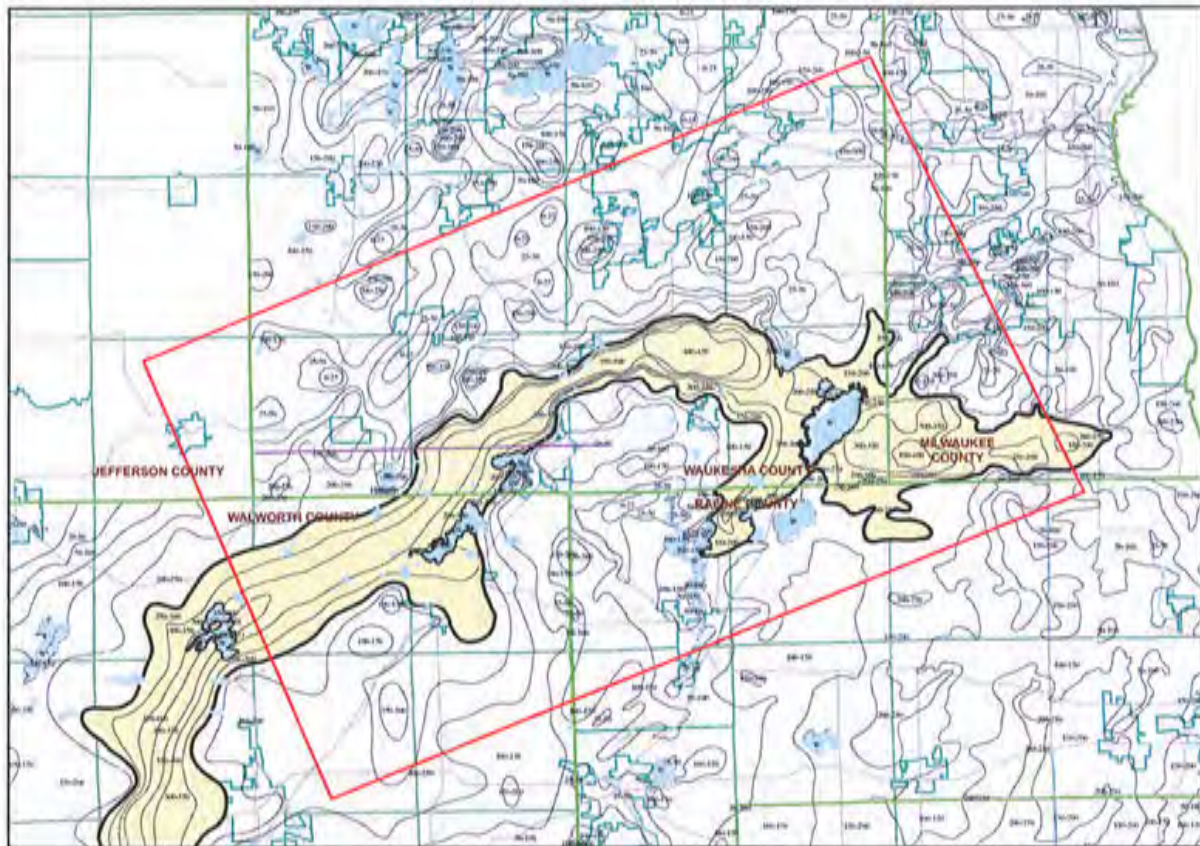


- BEDROCK MONITORING WELLS
- GROUNDWATER FLOW DIRECTION
- GROUNDWATER ELEVATION CONTOURS (5 FT INTERVALS, FT ABOVE MSL)

Figure 20: Location of Troy Bedrock Valley [Fig. 1 - Ref. (1)]

2

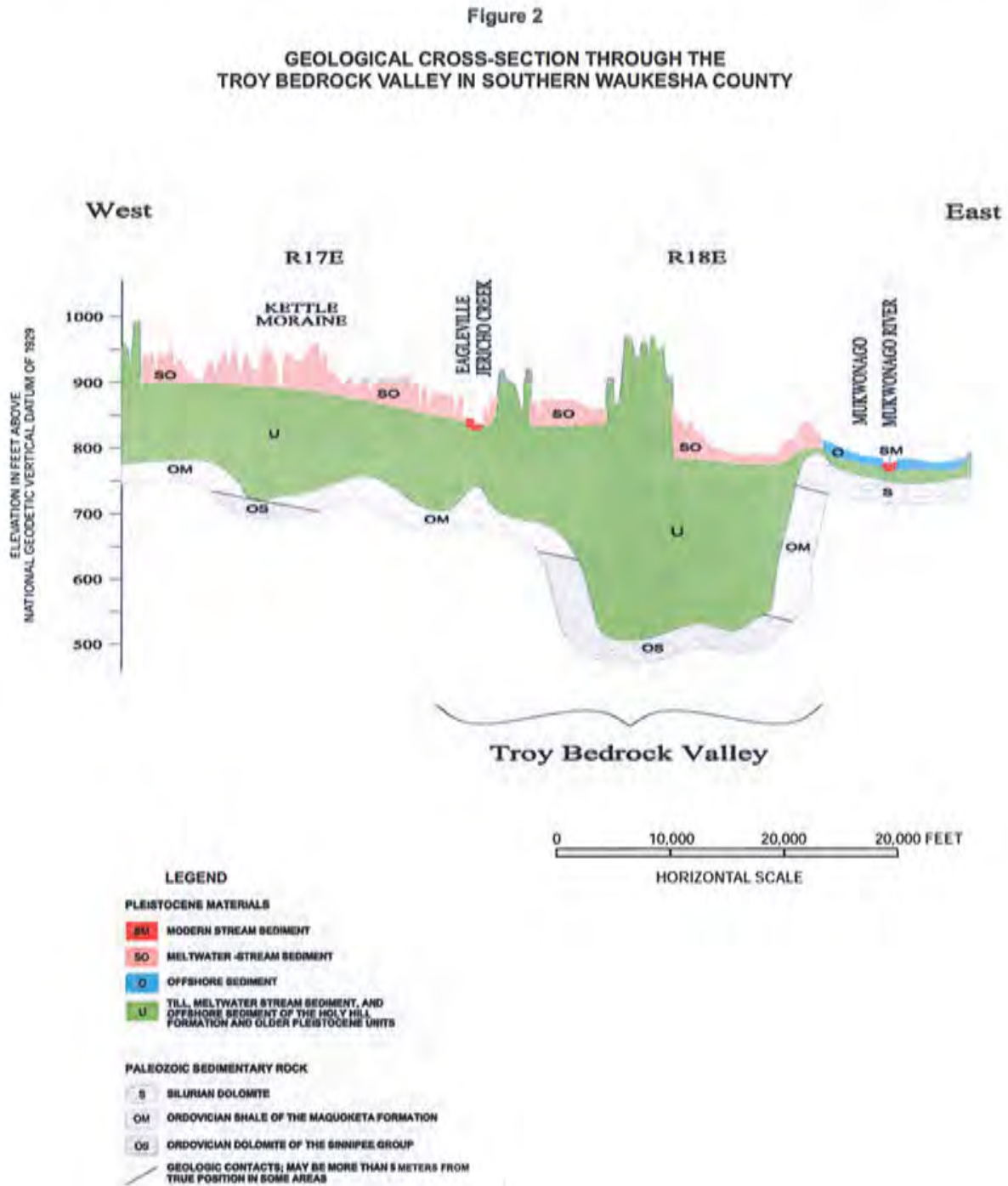
**Figure 1
LOCATION OF TROY BEDROCK VALLEY**



- LEGEND**
- DEPTH TO BEDROCK
 - TOWNSHIP LINES
 - COUNTY LINE
 - TROY BEDROCK VALLEY
 - MAJOR HIGHWAYS
 - MUNICIPAL BOUNDARY
 - APPROXIMATE MODEL NEAR FIELD
 - GEOLOGICAL CROSS-SECTION LOCATION (SEE FIGURE 2)

Source: Ruekert & Mielke, Inc.

Figure 21: Cross-Section through Troy Bedrock Valley [Fig. 2 - Ref. (1)]



Source: Clayton 2001.

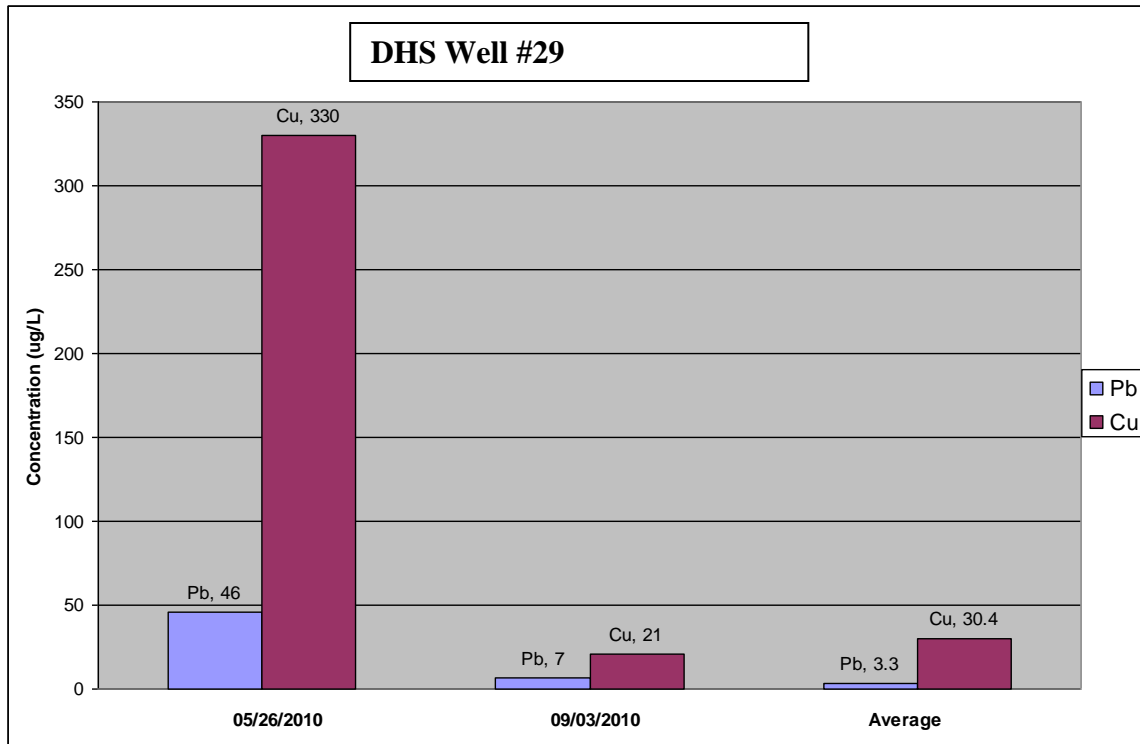
Appendix A:

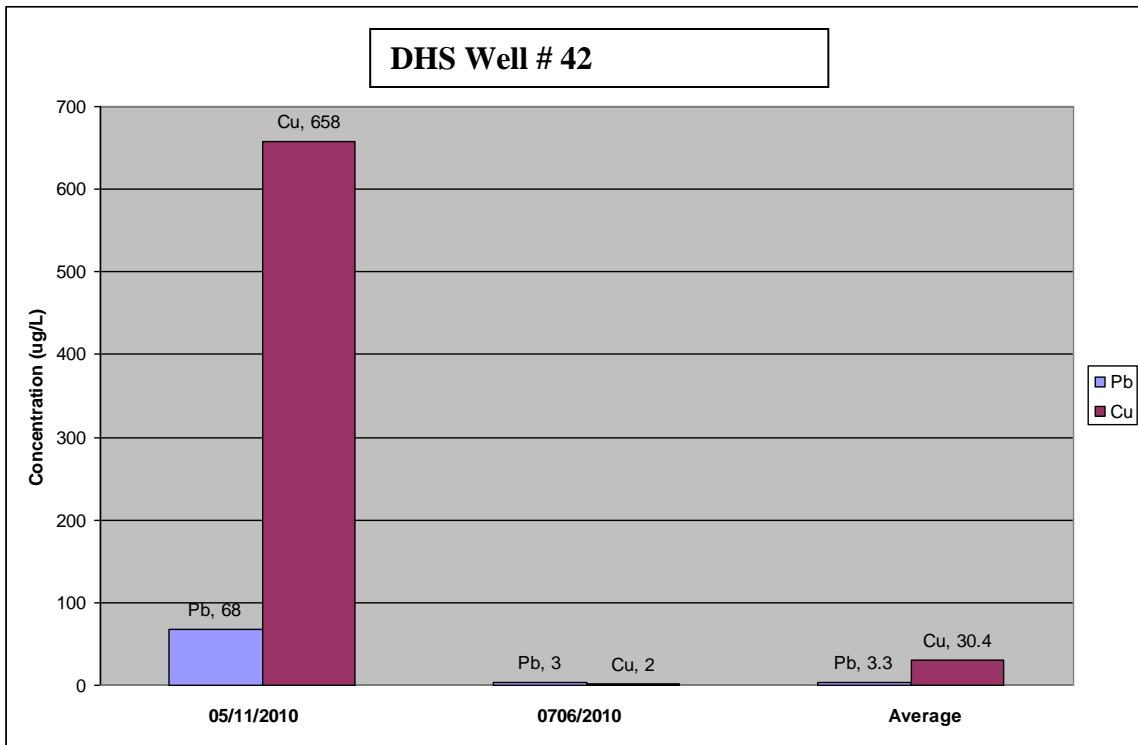
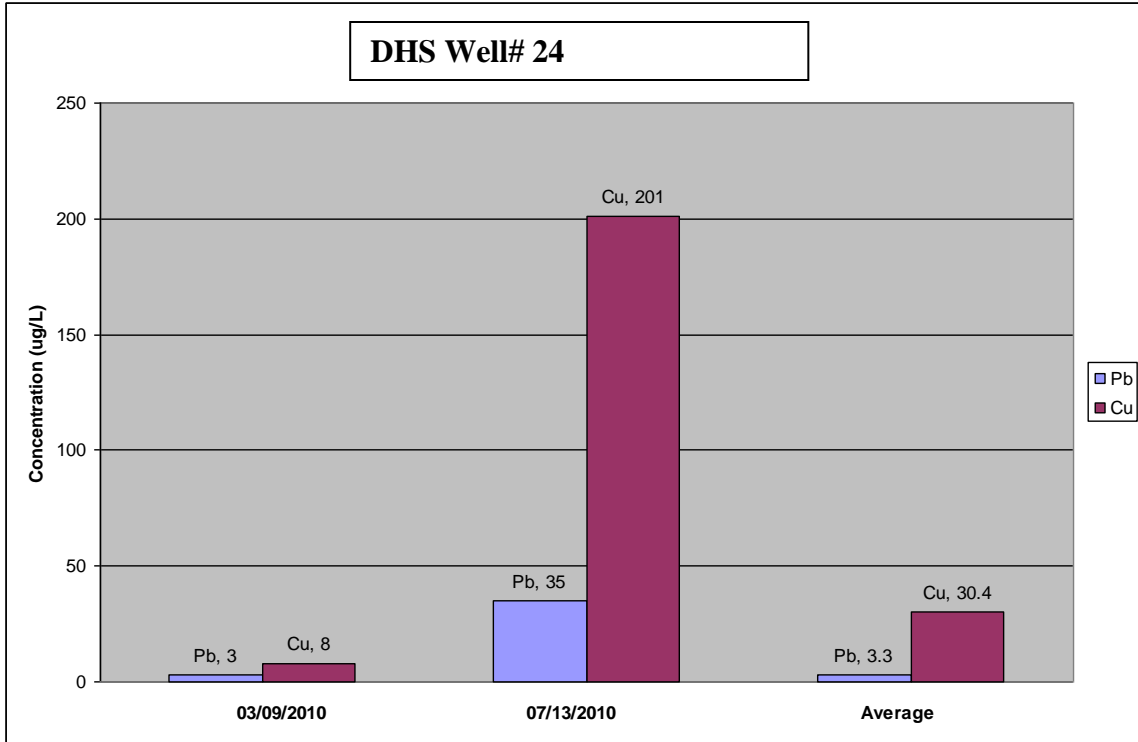
Comparison of lead and copper concentrations in private water supply well samples collected in 2010 that had a lead ES and MCL exceedance.

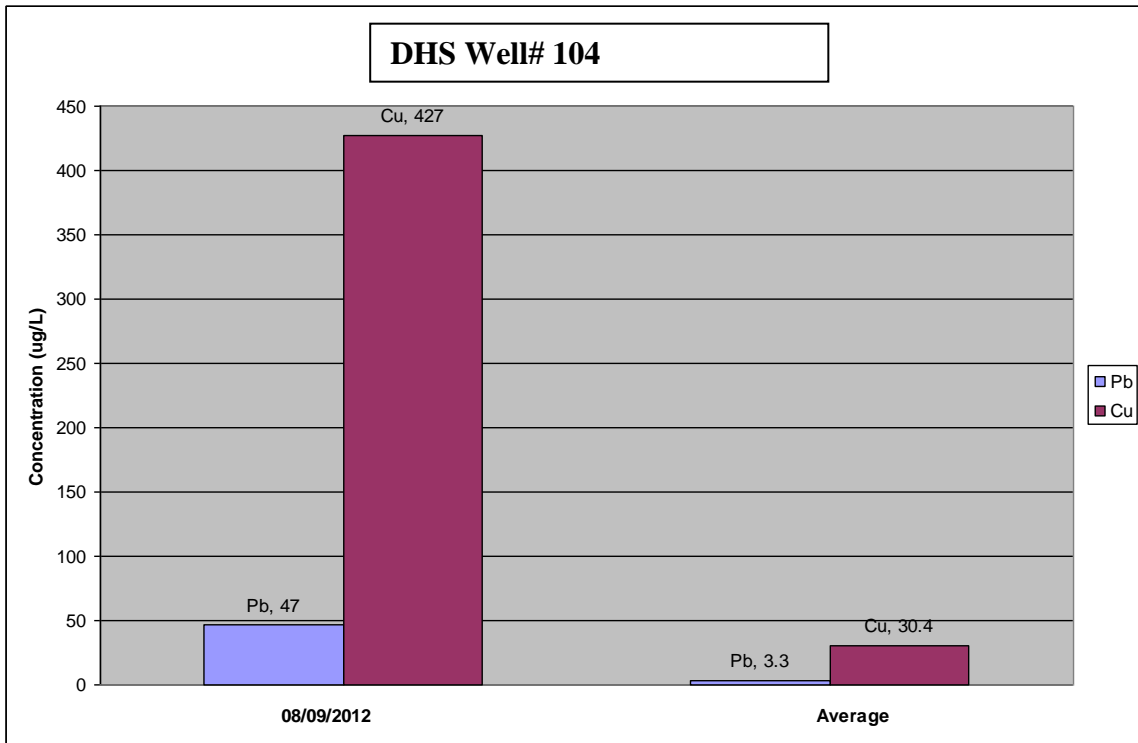
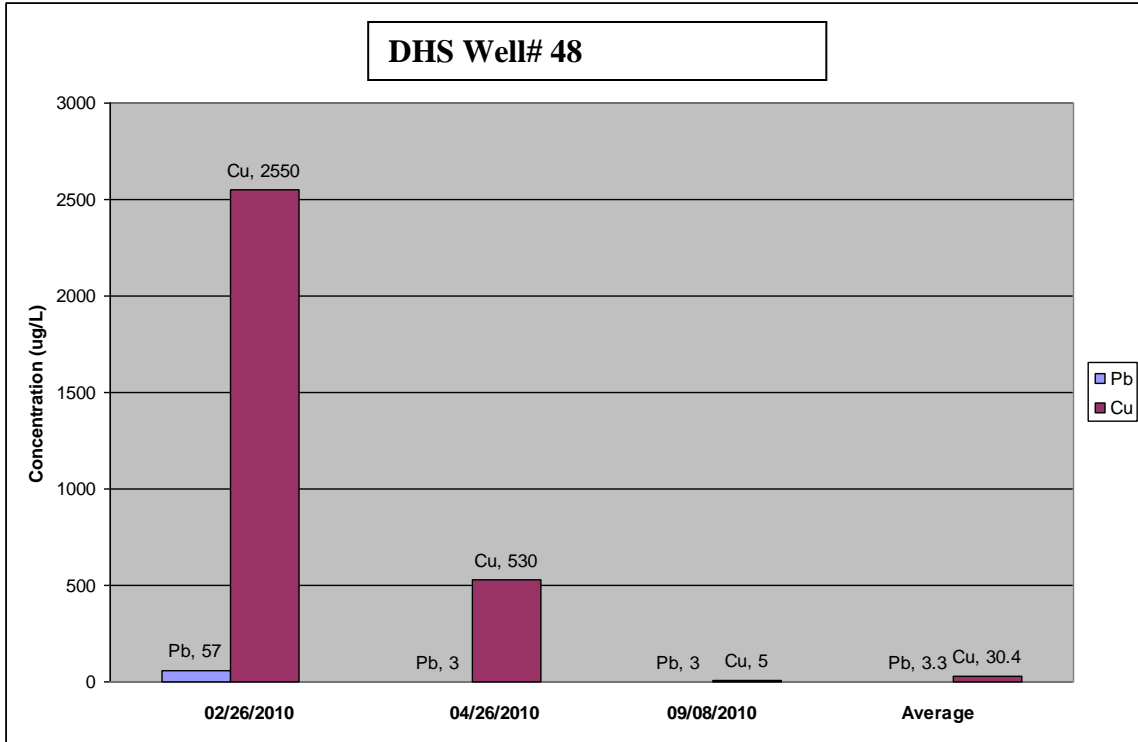
There were samples with elevated copper levels above the average copper concentration that did not have a lead ES exceedance; however, every sample that had a lead ES exceedance (>15 ug/L) also had an elevated copper level above the average copper concentration that was calculated for samples without a lead exceedance.

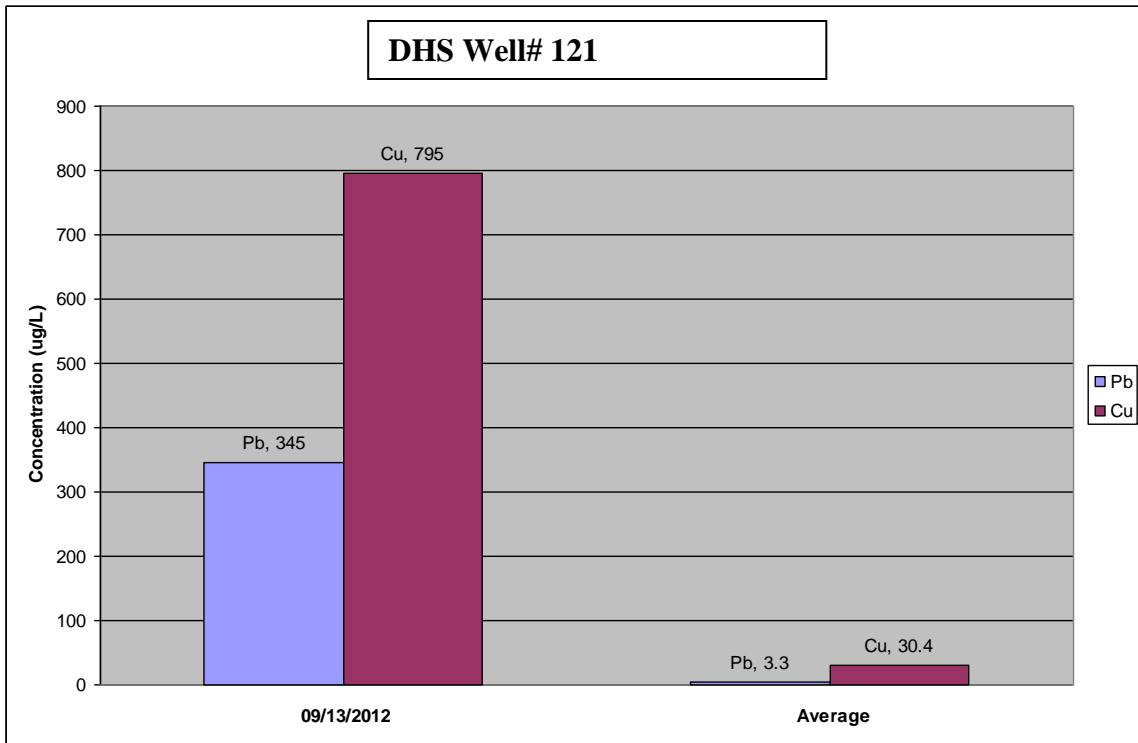
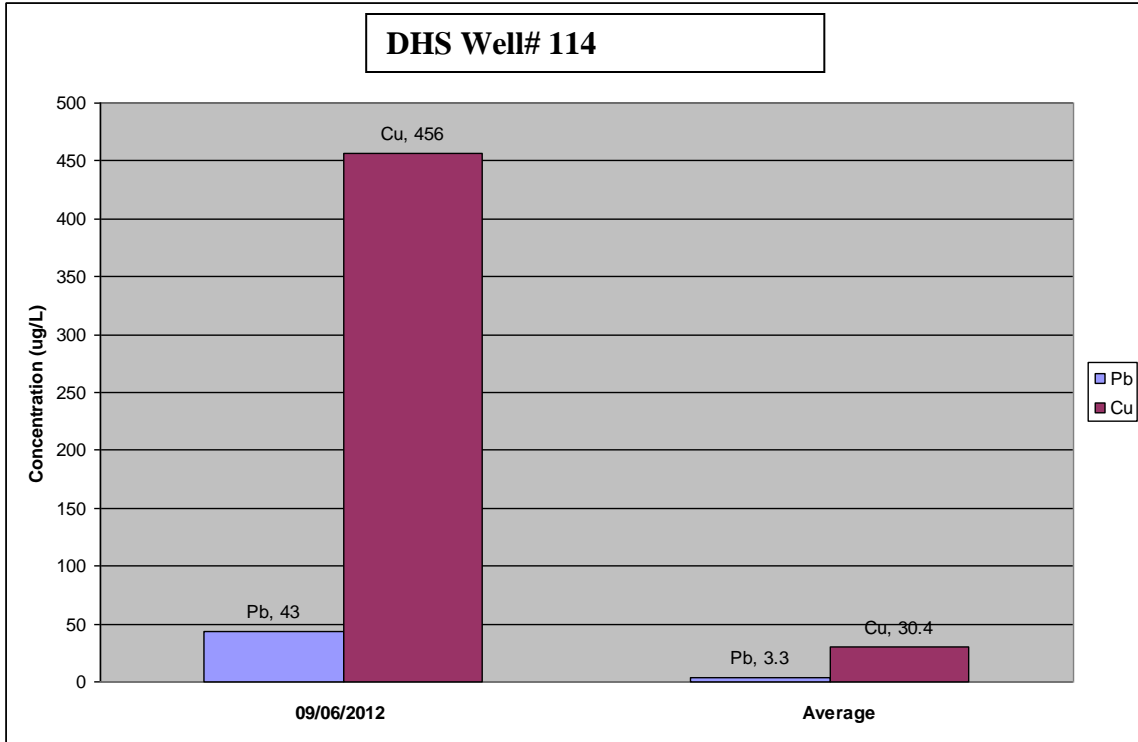
Note: In calculating the average concentrations, the Limit of Detection (LOD) was used as the concentration for samples that had No Detection. For lead the LOD was 3 ug/L and for copper the LOD was 2 ug/L. The averages were calculated by using the sample concentrations from every private well that was sampled in 2010 and that did not have a lead ES exceedance. This was done to compare the the copper concentrations in the samples with the lead exceedances to the average copper concentrations in the samples without the lead exceedances.

Wells that had a lead ES and MCL Exceedance in 2010 DHS Samples:









DHS Well# 122

