STATE OF MICHIGAN
DEPARTMENT OF HEALTH AND HUMAN SERVICES
LANSING

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September 15, 2017

Cathryn Beer, MPA, CPA
Health Officer/Executive Officer

Lynne Madison, R.S.
Director, Environmental Health Division

Western Upper Peninsula Health Department
540 Depot Street
Hancock, MI 49930

Dear Ms. Beer and Ms. Madison:

The Western Upper Peninsula Health Department requested that the Michigan Department of Health and Human Services (MDHHS) evaluate recently collected data for the Lake Linden and Hubbell shoreline, which includes the former Hubbell beach. Since 2013, the Michigan Department of Environmental Quality (MDEQ) has been compiling previous data and collecting new data on chemical levels in Torch Lake soil, waste material, sediment, and water, including the Lake Linden and Hubbell shoreline areas. MDHHS evaluated all available data to determine if residents and visitors using these areas could be exposed to chemical levels that would put them at risk of developing health effects.

MDHHS concludes that contamination present at the Lake Linden Beach area could pose a potential health hazard, depending on people's behavior, the use of the area, and the water levels of Torch Lake. Certain chemicals are present at levels above health-based screening levels, but concentrations are not consistently high throughout the area. Because accidently eating soil or sediment with elevated chemical levels is the primary exposure of concern, people could greatly reduce the risk of harmful exposure by:

- avoiding the creek area (especially if lake levels are low),
- monitoring children when playing in the area (to limit or prevent digging), and
- removing soil and sediment from skin and belongings (to avoid bringing any soil or sediment home).

MDHHS concludes that the physical hazards present in the former Hubbell Beach area could harm people's health if used as a swimming beach. The data support the current designation of the former Hubbell Beach as a non-swimming beach.

MDHHS recommends that

- Signs be posted at the Lake Linden Beach and fact sheets be made available for beachgoers, informing them of contamination at the beach and ways of reducing their exposure,
- Washing stations be installed at the Lake Linden Beach,
- Clean sand be added to the Lake Linden Beach as needed,
- Access to the drainage creek area of the Lake Linden Beach be restricted,
- Continued monitoring of contamination be performed at the Lake Linden Beach,
- Existing signs at Hubbell Beach be maintained, and
- People refer to MDHHS fish consumption guidelines for Torch Lake if eating lake-caught fish.

The attached detailed evaluation provides additional supporting information explaining the basis for the above conclusions.

Please contact me (grayj@michigan.gov or 517-281-3483) if you have any questions.

Sincerely,

Jennifer Gray, Ph.D.
Toxicologist

Jacob Carrick, MS
Toxicologist

CC:
Kory Groetsch, Environmental Public Health Director, MDHHS
Christina Bush, Acting Manager, MDHHS Toxicology and Response Section
Amy Keranen, Senior Environmental Quality Analyst, MDEQ
Brian Kelly, On-Scene Coordinator, U.S. EPA

Public Health Evaluation of Potential Environmental Exposures at the Lake Linden Beach Area and Hubbell Shoreline, including the former Hubbell Beach Area along Torch Lake in Houghton County, Michigan

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Michigan Department of Health and Human Services
September 15, 2017

Background and Statement of Issues

This report addresses contamination in the Lake Linden and Hubbell shoreline areas along the western shore of Torch Lake in Houghton County, Michigan (Figure 1). Nearly a century of copper mining, smelting, milling, and metal reclamation activity has resulted in widespread contamination of soil and sediment. The disposal practices of those activities have left behind large amounts of stamp sand and slag mining waste, which now serve as the primary surface material in certain areas around Torch Lake (Weston 2016). In 1984, the area was established as the Torch Lake Superfund site, which included the Lake Linden and Hubbell Beaches. According to the MDEQ Remediation and Redevelopment Division (RRD) Superfund Section staff, the U.S. Environmental Protection Agency (USEPA) Superfund Branch Torch Lake site designation is solely for stamp sands and slag extending six inches below ground surface in certain locations. The Lake Linden area has since been delisted along with surface water that was originally part of the Superfund site. In addition to chemical contamination, some areas have physical hazards due to the presence of metal, glass, and ceramic-like debris in shallow water along the beach.

MDHHS has previously conducted several public health assessments (PHAs) for the Torch Lake Superfund site and surrounding areas, including discussions of municipal and residential drinking water (ATSDR 2013a), physical hazards (ATSDR 2013b), inhalation of airborne stamp sands (ATSDR 2014a), and chemical exposure associated with recreational use of beaches (ATSDR 2014b). The Lake Linden and Hubbell shoreline areas are specifically addressed in the PHAs for physical hazards (ATSDR 2013b) and recreational use of beaches (ATSDR 2014b). The purpose of this report is to provide an updated evaluation of chemical and physical hazards at the Lake Linden and Hubbell shoreline areas. The most recent data, collected during the MDEQ's investigation of all former mining wastes, are used to determine whether current use is appropriate for the two locations, and whether any recommendations are needed to ensure people can safely use these areas. The two areas of focus, the Lake Linden Beach area (LLBA) and the Hubbell shoreline, are defined below. In the current evaluation, "soil" refers to any surface or subsurface samples that were obtained above the water line, while "sediment" refers to samples taken in submerged areas. This categorization was based on sample groupings in the MDEQprovided data report (Weston 2016). Soil and sediment samples described in this evaluation may actually refer to stamp sands[1], or to other mining waste (at LLBA) or municipal waste (at the Hubbell shoreline).

Lake Linden Beach Area

Lake Linden, Michigan lies along the northwestern shore of Torch Lake. The Lake Linden Beach is part of the Lake Linden Village Park located near 1000 Hiltunen Street. The LLBA is defined as an approximately 4.5-acre section of the lake, including the surface water, sediment, and beach. Lake Linden Beach is bordered by a playground and campground to the north and east. Additional play areas are located west and southwest of the site. A paved walking trail extends west along the boundary between beach sand and vegetated ground, leading across the creek and out of the site area. Residential and commercial properties are located to the west, separated from the beach by recreational fields. The nearest homes are approximately 450 feet to the west. Large wastewater treatment ponds are located to the east. Recreational use of the site typically peaks in the summer months.

The primary chemicals of concern at the LLBA are arsenic, lead, and other metals in the soil and sediment. In 2007, the USEPA conducted an emergency removal of contaminated material from two areas along the shoreline, but did not remove contamination below the waterline (ATSDR 2014b).

For this evaluation, The LLBA was subdivided into two regions, LLBA1 and LLBA2 (Figure 2). LLBA1 consists of soil along the beach and approximately 4.5 acres of sediment and surface water extending from the beach. LLBA2 includes soil and sediment near a drainage creek that empties into Torch Lake from the west side of the beach. LLBA2 also includes the area that had the 2007 USEPA emergency removal.

Hubbell shoreline, including the former Hubbell Beach

In this evaluation, the Hubbell shoreline is defined as the former Hubbell Beach, the former slag dump to the north, and approximately 900 feet of shoreline to the south (Figure 3). The former Hubbell Beach is located in Hubbell, Michigan on the western shore of Torch Lake about 1.5 miles south of the LLBA, and bordered by residential and commercial properties to the southwest, west, and northwest. A former dump containing slag and other industrial and residential waste lies adjacent to the beach along the shoreline to the northeast. The dump has been capped by the USEPA with a vegetated cover, although the cover may not be intact across the entire area (ATSDR 2013b). The RRD Superfund Section considers the cap to be sufficient and effective in preventing exposures (C. Clark, MDEQ Upper Peninsula District Office,

[1] The U.S. Department of Agriculture, Natural Resources Conservation Service has identified the "soil" type of various locations in the area around Torch Lake to be stamp sand, sand-sized waste material from copper stamping mills. See the Web Soil Survey at https://websoilsurvey.nrcs.usda.gov/app/ for more information.

personal communication 2017). Hubbell Beach was closed in 2015 primarily due to physical hazards in the shoreline soils and sediments.

One of the primary concerns at the former Hubbell Beach is the physical hazard posed by municipal debris, slag, and other waste which washes up on the shore. Sharp metal, glass, and ceramic-like debris could cause injury to people using the beach. The other concern is the elevated concentrations of metals in the soil and sediment, primarily in the slag dump to the north and wooded area to the south of the former beach.

Discussion

Environmental Contamination

Soil and Sediment

In the summer of 2007, low water levels in Torch Lake revealed white, clay-like material along the shoreline of LLBA2 that was found to contain elevated levels of polychlorinated biphenyls (PCBs), antimony, arsenic, barium, copper, and lead. Beachgoers also reported observing blue water in holes dug on the beach. The USEPA Emergency Response Branch responded by removing contaminated material from an approximately 200 feet by 200 feet area near the creek (identified as LLBA2 in this letter) and from the shoreline approximately 500 feet to the southwest. The top 1.5 to 5 feet of soil were removed above the water line, then the area was capped with clean soil and the shoreline was lined with rocks (Tetra Tech, Inc. 2017). In 2008, MDEQ Superfund Section staff collected sediment and soil cores from the Lake Linden emergency removal areas, and analyzed samples in the field via X-ray fluorescence (XRF). A number of metals were detected at elevated levels, including arsenic and lead. XRF analysis in the field is quite variable, however, and the results were mainly useful for identifying areas in need of further laboratory sampling. XRF analysis was also performed along the Hubbell shoreline. In the PHA for recreational use of beaches in the Torch Lake area, MDHHS concluded that while people could encounter isolated areas of the beaches with elevated metal concentrations, the contamination was not consistently high across the whole area.

In 2013, the USEPA refined their description of the Torch Lake Superfund site to be limited to the top six inches of stamp sand and slag in certain areas of Houghton County, including any vegetative cover applied to address those areas. Any other waste that may be beneath the vegetative cover was not considered part of the Superfund site. In response, the MDEQ RRD determined in August 2013 that additional investigation and response actions were necessary. Additional actions were determined to be especially needed to address the presence of PCBs in Torch Lake soil, sediment, and water and the presence of abandoned containers and other unaddressed wastes, such as asbestos, in the industrial ruins (Weston 2016; C. Clark, MDEQ Upper Peninsula District Office, personal communication 2017).

In the summer of 2014, the MDEQ started characterizing mining wastes along the western shore of Torch Lake in the Lake Linden and Hubbell areas. The MDEQ identified historical sources of contaminants and compiled previous sampling data. Once existing data were identified, additional soil, surface water, groundwater, and sediment samples were collected. The MDEQ informed community members, local officials, and MDHHS staff of initial results in the spring and summer of 2015 and 2016.

The current MDHHS evaluation considers soil and sediment samples collected from depths of up to three feet below the soil or sediment surface (Weston 2016). Samples collected from intervals extending below three feet were not included in the analysis. Typically, people are only expected to be exposed to contamination at the ground surface (less than three inches below ground surface). Contamination at depth was considered since children may dig large holes in beach areas, which could result in exposure to subsurface contamination and redistribution of contamination on the surface. All available data within a particular site area were considered, including samples obtained in 2007, 2008, 2011, 2014, and 2015. Maximum chemical concentrations were compared to conservative site-specific USEPA Regional Screening Levels (RSLs) for recreational exposure to soil or sediment (Table A1 – A7). If concentrations exceeded site-specific screening levels, the median, mean, 95% upper confidence limit (UCL) of the mean, and maximum were compared to those RSLs. Chemicals for which the 95% UCL of the mean exceeded site-specific screening levels are further discussed in the Toxicological Evaluation section. The Toxicological Evaluation section also provides more information about health effects associated with lead exposure since there is currently no screening level available for lead.

Lake Linden Beach Area

Chemical levels in soil and sediment of the LLBA were widely varying. In certain areas, maximum arsenic, copper, and total PCB concentrations were greater than screening values. Lead was found at levels of up to 7,800 milligrams per kilogram (mg/kg) in sediment.

The maximum soil arsenic concentration in LLBA1 exceeded the screening value; however, the 95% UCL was below the screening value (Table 1). In soil of LLBA2, both the maximum arsenic concentration and 95% UCL were below the screening value. In LLBA1 and LLBA2, maximum lead concentrations of 110 mg/kg and 134 mg/kg, respectively, were detected in the soil. In general, LLBA1 and LLBA2 have similar levels of arsenic and lead in the soil.

Chemical levels tended to be higher in the sediment compared to chemical levels in the soil (Table 2). In sediment of LLBA1, maximum concentrations of arsenic, copper, and total PCBs exceeded screening values. There is uncertainty regarding the total PCB exceedance, since the maximum concentration was an estimated value and the exact congeners (individual PCB constituents) of the PCB mixture are unknown. In sediment of LLBA2, no chemicals exceeded

Table 1. Medians, means, 95% upper confidence limits (UCLs) of the mean, and maximum soil concentrations (in milligrams per kilogram [mg/kg]) of chemicals with maximum concentrations above site-specific screening levels in the Lake Linden Beach area and Hubbell shoreline. Concentrations greater than screening values are highlighted.

Soil					
	Screening level[a] (mg/kg)	Median (mg/kg)	Mean (mg/kg)	95% UCL (mg/kg)	Maximum (mg/kg)
Lake Linden Beach Area 1 (LLBA1)					
Arsenic	11.7	1.5	2.43	5.85	14
Lead	NA[b]	4	14.6	45	110
Lake Linden Beach Area 2 (LLBA2)					
Lead	NA[b]	13.3	36.96	NA[c]	134
Hubbell shoreline					
Arsenic	11.7	4.3	22.2	93.1	460
Lead	NA[b]	43	138.3	465.4	2100
Manganese	7290	215	682.3	2520	12000

[a] EPA site-specific Regional Screening Level (RSL).

[b] No screening value is available for lead.

[c] 95% UCL not calculated due to small sample size.

Table 2. Medians, means, 95% upper confidence limits (UCLs) of the mean, and maximum sediment concentrations (in milligrams per kilogram [mg/kg]) of chemicals with maximum concentrations above site-specific screening levels in the Lake Linden Beach area and Hubbell shoreline. Concentrations greater than screening or comparison values are highlighted.

Sediment					
	Screening level[a] (mg/kg)	Median (mg/kg)	Mean (mg/kg)	95% UCL (mg/kg)	Maximum (mg/kg)
Lake Linden Beach Area 1 (LLBA1)					
Arsenic	11.7	2.2	5.0	9.32	26
Lead	NA[b]	19	553.6	2122	7800
Copper	12,200	760	2839	5410	28000
Total PCBs	1.02[c]	0.5	0.576	0.794	1.65 J[d]
Lake Linden Beach Area 2 (LLBA2)					
Lead	NA[b]	23	194.2	612.2	1900
Hubbell shoreline					
Arsenic	11.7	21	24.9	31.7	40
Lead	NA[b]	170	158	338.3	520

[a] EPA site-specific Regional Screening Level (RSL).

[b] No screening value is available for lead.

[c] RSL for Aroclor 1254 (a common PCB mixture).

[d] J = Estimated result

screening values. In both areas, the 95% UCLs of all chemicals were below screening levels. Lead was found at levels as high as 7,800 mg/kg in LLBA1 and 1,900 mg/kg in LLBA2 (Weston 2016).

Although no chemicals exceeded screening values in LLBA2 at the depths considered in the current assessment (up to three feet), deeper sediment samples contained much higher concentrations. A sediment sample taken from a depth of up to 3.4 feet contained 55 mg/kg of arsenic. Lead concentrations as high as 44,000 mg/kg and 75,000 mg/kg were detected in samples taken from depths of up to four and 5.3 feet, respectively, within LLBA2 (Weston 2016).

Hubbell Shoreline

Soils in the Hubbell shoreline generally contained higher chemical levels than the LLBA, primarily due to samples collected outside of the former beach area (Table 1). In contrast to the LLBA, the average soil sample contained arsenic levels above the screening value and lead levels of 151 mg/kg. The median of arsenic and lead concentrations was low, however, indicating that concentrations were not consistently high across the sampling area. The northeastern edge of the slag pile and the wooded area south of the beach tended to have higher levels of contamination, while the former beach tended to have lower levels. Nevertheless, varying levels of contamination were observed throughout the entire Hubbell shoreline. The maximum arsenic concentration was found in the slag pile to the north, the maximum lead concentration was found on the former beach, and the maximum manganese concentration was found in the wooded area south of the beach.

Although maximum sediment concentrations were lower than those in the soil, sediment levels were more consistently elevated, as shown by similar averages and medians (Table 2). The highest arsenic and lead levels were found in sediment samples taken offshore of the slag pile. The single sediment sample taken near the former beach contained arsenic below the screening level and a lead concentration of 11 mg/kg (Weston 2016).

<u>Surface water</u>

A few surface water samples were collected from the LLBA area. Since water undergoes relatively thorough mixing, the most recent samples were expected to be most representative of current chemical levels in the lake water. Metals and other organics were most recently analyzed in 2011, while PCBs were most recently analyzed in 2015. Maximum concentrations of all chemicals were below screening values. Summary statistics were not calculated due to low sample size.

Chemicals in surface water can also accumulate in fish. MDHHS reviews chemical levels in Torch Lake fish (edible portions) for the purpose of developing fish consumption guidelines.

PCB and mercury data indicate that unlimited consumption of fish could result in people having elevated exposure to those chemicals (MDHHS 2016).

Physical Hazards

As detailed in the PHA for physical hazards (ATSDR 2013b), municipal debris, slag, and other waste from an adjacent dump has been observed on the shore and in shallow waters along the former Hubbell Beach (Figure 4, Figure 5). The waste material, which includes sharp glass, metal, and ceramic-like debris, poses a physical hazard to people using the beach. People walking along the shoreline or wading in the water could potentially be injured by stepping on the material. This type of debris has not been observed in the Lake Linden Beach Area.

Exposure Pathway Analysis

An exposure pathway describes the way in which people may be exposed to a contaminant. Five basic elements are required in order for an exposure pathway to be complete: (1) A source of contamination, (2) a medium through which the contaminant can move, (3) An exposure point, (4) a human route of exposure, and (5) the presence of human receptors at the exposure point. If one or more of the elements is missing, the exposure pathway is incomplete. If insufficient information is available to determine whether one of the elements is missing, it is considered to be a potential exposure pathway. This assessment addresses exposure to chemicals in soil, sediment, and surface water at the Lake Linden Beach area and Hubbell shoreline, and through ingestion of fish from Torch Lake (Table 3). Physical hazards are also considered.

Table 3. Exposure pathways between source contamination and people at the Lake Linden and former Hubbell Beach areas.

Source	Medium	Exposure Point	Exposure Route	Population	Time Frame	Pathway Status
Mining and industrial waste	Sediment, soil	Lake Linden and Hubbell shoreline areas	Dermal contact, Incidental ingestion, Inhalation	People who use the beaches	Past, Present, Future	Complete
	Surface water	Torch Lake	Dermal contact, Incidental ingestion, Inhalation	People who swim in Torch Lake	Past, Present, Future	Complete
	Surface water, sediment	Lake-caught fish	Ingestion	People who consume fish from Torch Lake	Past, Present, Future	Complete

Lake Linden Beach Area

Beachgoers could have extensive contact with soil, sediment, and surface water during recreational use of the LLBA. In general, the potential routes of exposure for contaminated soil, sediment, and surface water are dermal contact, incidental ingestion, and inhalation. Beach activities, such as swimming and sunbathing typically involve exposure of a large portion of the body to the environment, making dermal contact highly likely. Dermal exposure may be a concern for skin irritants, but absorption of chemicals, especially metals, into the body is generally limited through this route. People could also be exposed to contamination through incidental ingestion. For example, people might accidentally ingest small amounts of water while swimming. Based on levels of chemicals present, dermal contact and accidental ingestion of water is not a health concern; however, people should avoid drinking untreated surface water due to bacterial contamination.

People could also ingest soil or sediment if they do not wash their hands before eating, or if children engage in hand-to-mouth behavior while playing on the beach. Exposure via ingestion allows for greater absorption of chemicals, but would occur less frequently than dermal contact. Another potential route of exposure is inhalation of chemicals. Since the primary contaminants of concern are metals, inhalation of metals from the water would not occur. Contaminated soil or dried sediment, however, could become airborne, allowing for inhalation.

Exposure would typically occur for up to several hours at a time, during periodic visits to the beach. Exposure to isolated areas of contamination would be relatively brief, unless the contaminated material remained on the skin. If someone were to wade through contaminated sediment, the material would generally be washed away by the water. The duration of exposure could be longer than the time spent at the beach if contamination is tracked out of the area on a person's body or their belongings. Contaminated soil and sediment could adhere to skin, shoes, towels, clothes, or other items, allowing it to be transported back to the home. Sediment that is tracked back home on shoes or other items could dry, allowing it to more easily enter the air and pose an inhalation risk.

Certain activities could put children at greater risk of exposure to contamination at the LLBA. For example, children may dig large holes on the beach, allowing them to have contact with subsurface contamination and redistribute it on the surface. The area accessible for digging could increase as water levels fluctuate in Torch Lake. The unusual appearance of certain kinds of waste (e.g., unnaturally blue water, white waste material) could draw the interest of children. Hand-to-mouth behavior among children could increase the likelihood of exposure via ingestion. Children may be more likely to be exposed to contaminated sediment in LLBA2 since the creek may be an attractive play area for children. They may also pass through the creek on the way from the beach to the adjacent playgrounds. Sediment in LLBA2 may also become shoreline in years with low lake levels.

Hubbell Shoreline

Because the former Hubbell Beach is no longer designated as a public beach, recreational use of the site is expected to be limited. Signs posted at the beach discourage recreational use of the area, but there are no physical barriers preventing access. If people disregard the signs, and use the former beach or other parts of the Hubbell shoreline, they could be exposed to contamination through the same pathways as described for the LLBA, including dermal contact, incidental ingestion, and inhalation. The former Hubbell Beach features the additional hazard of sharp debris, which people could encounter while walking along the shoreline or wading in the water.

Fish

People may be exposed to PCBs and mercury via consumption of fish from Torch Lake. MDHHS has issued fish consumption guidelines specifically for Torch Lake. The guidelines are based on chemical concentrations measured in edible portions of fish collected from the lake. The guidelines recommend amounts of fish that can be eaten that will not result in people having an elevated exposure to PCBs and mercury. Current guidelines recommend that people eat no more than six servings per year or up to 12 servings of Torch Lake fish per month, depending on the species and size of fish (MDHHS 2016). MDHHS has also developed informational material in partnership with the Keweenaw Bay Indian Community, which has a long legacy of fishing in Torch Lake and other nearby waters. Signs have been posted in partnership with the municipalities around the lake and brochures have been distributed in the communities; however, consumption of Torch Lake fish by residents of Lake Linden and Hubbell could exceed the recommended rates if people are unaware of the MDHHS guidelines, or if they choose to ignore the advice. Information is not available on fish consumption rates among anglers and their families who fish in Torch Lake.

Toxicological Evaluation

Chemicals for which the 95% UCL of the mean exceeded site-specific screening levels were further evaluated. The only chemical meeting this criterion was arsenic. Chemical exposures were evaluated by calculating estimated exposure doses along with corresponding hazard quotient (HQs) and cancer risks.

Lead was also further evaluated. Since no screening level is available for lead, HQs and cancer risk estimates were unable to be calculated. Instead, toxicological evaluation was conducted using the Integrated Exposure Uptake Biokinetic (IEUBK) model.

<u>Arsenic</u>

Arsenic is a naturally occurring element present in soil and water. Background levels of arsenic in Michigan soils typically range from less than 0.3 to 22.8 mg/kg (MDEQ 2015a). In the region of the Upper Peninsula around Torch Lake, the mean arsenic concentration in soil is 1.4 mg/kg with 95% of samples falling below 3.4 mg/kg (Figure 6). Short-term exposure to high levels of arsenic can cause nausea, vomiting, diarrhea, cardiovascular effects, and neurological effects. Long-term oral exposure to low levels of arsenic can lead to numbness in the hands and feet, and dermal effects, such as development of warts and corns. The EPA, IARC, and U.S. Department of Health and Human Services (USDHHS) classify arsenic as a human carcinogen. Long-term exposure can increase the risk of skin, liver, bladder, and lung cancer (ATSDR 2007a). The chronic MRL for arsenic is derived from an epidemiological study of dermal effects among individuals exposed to high levels of arsenic in water (ATSDR 2007a). The study reported a no observed adverse effect level (NOAEL) of 0.0008 mg/kg/day. The NOAEL was divided by an uncertainty factor of three to account for human variability, yielding an MRL 0.0003 mg/kg/day.

For arsenic, estimated exposure doses were calculated based on exposure to the 95% UCL of the mean concentration, which serves as a conservative but realistic estimate of the exposure level. Calculations were based on a conservative chronic exposure scenario involving combined exposure through ingestion and dermal routes (Table A8). The resulting dose was compared to the ATSDR chronic Minimal Risk Level (MRL) and USEPA Cancer Slope Factor (CSF) in order to calculate HQs and cancer risk estimates. HQs are a ratio of the estimated dose to the health-protective MRL dose. MDHHS uses an HQ of one as a benchmark for identifying exposures that require further evaluation. Cancer risk estimates are the theoretical number of increased cancers that may occur in a population as a result of exposure to a specific level of site contamination. MDHHS uses a cancer risk of one additional cancer in an exposed population of 100,000 as a benchmark for identifying exposures that require further evaluation.

Soil and sediment in the LLBA1 and Hubbell shoreline were found to contain maximum arsenic concentrations above the screening value, but only in the Hubbell shoreline was the 95% UCL of the mean greater than the screening value. In the Hubbell shoreline, which includes the former

Hubbell Beach, the former slag dump to the north, and approximately 900 feet of shoreline to the south, HQs for some age-specific soil exposure scenarios slightly exceeded a value of one (Table A9). HQs ranged from 1.6 to 2.1 depending on the dose estimate and age group. Cancer risk also slightly exceeded one theoretical extra case of cancer in an exposed population of 100,000, ranging from 3.1 to 7.8 theoretical extra cases of cancer in an exposed population of 100,000.

Exposure to sediment resulted in lower HQs and cancer risks than for soil (Table A10). No HQs exceeded a value of one, and the maximum cancer risk was 2.6 theoretical extra cases of cancer in an exposed population of 100,000. Within the former Hubbell Beach itself, there were 11 available soil samples, with a 95% UCL of the mean equal to 5.3 mg/kg, and a single sediment sample of less than 5 mg/kg. Based on an exposure level of 5.3 mg/kg, the estimated doses and corresponding HQs and theoretical cancer risks were all below levels of concern (Table A11).

In summary, there is potential for elevated arsenic exposures within the Hubbell shoreline. Conservative exposure scenarios resulted in slight exceedances of the acceptable HQ and theoretical cancer risks for some age groups, indicating that there could be an increased risk of adverse health effects under worst case exposure conditions. Current site use minimizes the potential exposure to arsenic in the soil or sediment. Considering only the former Hubbell Beach itself, elevated exposure to arsenic is unlikely.

Lead

Although sources of lead have been reduced, lead still remains in the environment and people may encounter it in their daily lives. In Michigan, background levels of lead in topsoil typically range from 0.4 to 38.9 mg/kg, with an average of 12.1 mg/kg (MDEQ 2015a). In the western portion of the Upper Peninsula, approximately 95% of soil samples contain less than 55.5 mg/kg of lead (MDEQ 2015a). These values are based on data that the MDEQ assumes to represent naturally occurring background concentrations. Due to limited sampling around Torch Lake, actual background concentrations near the site area may differ. Lead-based paint in older homes is another potential source of background lead exposure. People may be exposed through inhalation of dust from the paint, or from ingestion of paint chips, as is common among children. Approximately 74% of homes in Houghton County, Michigan were built before 1979 (United States Census Bureau 2015), suggesting that a substantial portion of total lead exposure may occur in the home. Lead in food ranges from less than 0.4 to 523.4 µg/kg, while publicly supplied drinking water typically contains less than 5.0 micrograms per liter (µg/L) of lead. The average dietary intake of lead via ingestion of food and water is 1.0 microgram per kilogram per day (µg/kg/day) (ATSDR 2007).

Children are more vulnerable to lead poisoning than adults. Children typically absorb about 40-50% of an ingested dose of water-soluble lead, while adults absorb around 3-10%. Although lead can be absorbed through the skin, absorption of inorganic lead from dermal exposure appears to be less efficient than absorption from ingestion or inhalation. In studies measuring the amount of lead absorbed after dermal exposure, people's absorption ranged from less than or equal to 0.3% to possibly as high as 30% of the applied dose (ATSDR 2007).

After absorption by ingestion, inhalation, or dermal exposure, lead is distributed throughout the body by the blood. In both adults and children, the main target is the nervous system, but lead will affect every organ system. Large amounts of lead can cause anemia, kidney damage, colic, muscle weakness, and brain damage. Even at low blood lead levels, adverse effects may include delays or impairments in development. Maternal blood lead levels less than 20 micrograms per deciliter (μg/dL) can impact the developing fetus. Alterations in immune function or any cognitive defects that occur during childhood from lead exposure can be detected as an adult (ATSDR 2007). Although blood lead levels of 5 μg/dL or higher are considered elevated, health effects have occurred at lower blood lead levels. No blood lead levels have been identified without associated health effects. Because of this, it is best to prevent lead exposure (ACCLPP 2012).

Adults older than 60 years and postmenopausal women are vulnerable to specific effects of lead, which include cognitive deficiency, hypertension, and depressed glomerular filtration rate (kidney function). There is a significant association of an increase in systolic blood pressure with an increase of blood lead levels. Lead and lead compounds are reasonably anticipated to be carcinogens (ATSDR 2007).

Neither the Centers for Disease Control and Prevention's Agency for Toxic Substances and Disease Registry (ATSDR) nor the USEPA have derived toxicity endpoints (e.g. MRL, reference dose) for lead to be used in risk assessments. Both agencies have stated that no blood lead level has been found to be safe. Using pharmacokinetic data and an initial acceptable blood lead, the EPA developed a biokinetic model for evaluating lead exposure from multiple media in children (Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children version 1.1 Build 11). Lead levels in air, soil, house dust, diet, drinking water, and maternal blood are used to estimate geometric mean blood lead levels for a population of children and the probability that a child would be above a specified blood lead level[2]. The model results are compared to an EPA population health protection goal for young children exposed to lead at residential properties of 5% or lower risk of a child having a blood level greater than the CDC reference value of 5 μg/dL[3].

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[2] The modeling output includes the percent of children in a population that are above a specified blood lead level, but that value can be also be viewed as the probability (risk) that a certain child would be above the specified blood lead level.
[3] As stated on the EPA's Lead at Superfund Sites: Frequent Questions from Risk Assessors on the Integrated Exposure Uptake Biokinetic (IEUBK) Model webpage, found at http://www2.epa.gov/superfund/lead-superfundsites-frequent-questions-risk-assessors-integrated-exposure-uptake#mean.

The IEUBK model was run for this evaluation using either default or adjusted parameters for environmental media (Table A12). The 95% UCL of the mean for lead in soil or sediment was used to calculate an amount of lead ingested per day, which was included in the model as an alternate lead exposure.[4] Using those parameters, children ages 1 to 7 years old could have an increased risk of having a blood lead level greater than 5 µg/dL after consistently ingesting small amounts of soil or sediment from certain areas. The risk of having blood lead levels greater than 5 µg/dL is increased by:

- 18% when eating LLBA1 sediment,
- 7.7% when eating LLBA2 sediment,
- 6.2% when eating Hubbell shoreline sediment, and
- 6.8% when eating Hubbell shoreline soil.

This evaluation is expected to overestimate the exposure to soil and sediment at the Lake Linden Beach area and Hubbell shoreline for several reasons. One reason is that the 95% UCL of the mean was used as it represents an upper end exposure estimate. The second is that the amount of exposure to soil and sediment was included in the model in addition to an amount at home or other locations. However, this was used to provide a conservative evaluation, as there is no way to identify the amount of lead exposure that children may have at home or in other locations. And the third, specific to the Hubbell shoreline, some of the sampling was outside of the former beach and would not represent exposure at the former beach.

In summary, a conservative assessment indicates that elevated blood levels could occur in children who are exposed to lead levels in LLBA1, LLBA2, and parts of the Hubbell shoreline to the north and south of the beach.

Conclusions

MDHHS concludes that people could be exposed to elevated chemical levels from soil and sediment contamination at the LLBA.

Certain locations within the LLBA contain elevated concentrations of lead, arsenic, and other chemicals, which people could be exposed to during recreational use of the site. Chemical levels are quite variable. While it is unlikely that people would be exposed to consistently elevated concentrations, certain behaviors, such as recreational digging may expose children to elevated arsenic or lead levels. Children may be more vulnerable to chemical hazards present at the LLBA due to greater potential for exposure and greater sensitivity to chemicals. Contaminated soils or sediments could be moved around due to recreational digging, or other activities, or be revealed due to changing lake levels.

[4] The 95% UCL of the mean was multiplied by 50 mg (as 0.00005 kg). A sediment or soil ingestion of 50 mg is expected to be a conservative estimate of exposure during recreational activities as a full day's soil ingestion is 200 mg for children, according to the USEPA Exposure Factors Handbook 2011 Edition, found at https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=236252.

MDHHS concludes that physical hazards and contamination at the Hubbell shoreline pose a human health hazard.

> The former Hubbell Beach current designation as a non-swimming beach prevents potential exposure to physical hazards. If people disregard the signs posted at the former Hubbell Beach and use the beach for swimming and wading, they could encounter sharp debris which could cause injuries. In other parts of Hubbell shoreline, such as the shoreline to the north and south, elevated chemical concentrations could pose a hazard if people make extensive contact with soil and sediment.

MDHHS concludes that swimming in Torch Lake will not harm people's health.

> Accidental ingestion of small amounts of water is not expected to be harmful. Dermal exposure is also not expected to be harmful since chemical concentrations in the water are low. Furthermore, chemicals such as metals are not readily absorbed through the skin.

MDHHS concludes that unlimited consumption of Torch Lake fish with elevated levels of PCBs could be harmful to people's health.

> If people do not follow the MDHHS fish consumption guidelines for Torch Lake, they could be exposed to elevated levels of PCBs and mercury that could harm their health.

Recommendations

MDHHS recommends that, unless contamination is removed from the LLBA, signs be posted at the Lake Linden Beach area with information regarding site contamination and guidance for reducing exposure. Information could also be distributed through fact sheets. In addition, installation of washing stations would help enable people to adhere to the guidance.

MDHHS recommends that supplemental clean sand be added to the Lake Linden Beach in order to further separate beachgoers from any soil contamination.

MDHHS recommends that access to LLBA2 be discouraged or restricted through use of signs, fencing, or other measures.

MDHHS recommends continued monitoring at the LLBA to determine if potential redistribution of subsurface contamination occurs, in the event that the contamination is not removed.

MDHHS recommends that signs be maintained at the former Hubbell Beach area.

MDHHS recommends that people fishing in Torch Lake be directed towards the MDHHS fish consumption guidelines for Torch Lake[5].

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[5] http://www.michigan.gov/mdhhs/0,5885,7-339-71548_54783_54784_54785_58671-243753--,00.html

Public Health Action Plan

MDHHS will remain available to assist in health education and community outreach, including design of signs, fact sheets, or other materials.

MDHHS will remain available to provide input on sampling plans.

MDHHS will remain available to evaluate any new data that is collected, and to prepare Public Health Assessments or Health Consultations as appropriate.

MDHHS will continue to analyze chemical concentrations in fish from Torch Lake on a rotating basis, and will update fish consumption guidelines as needed

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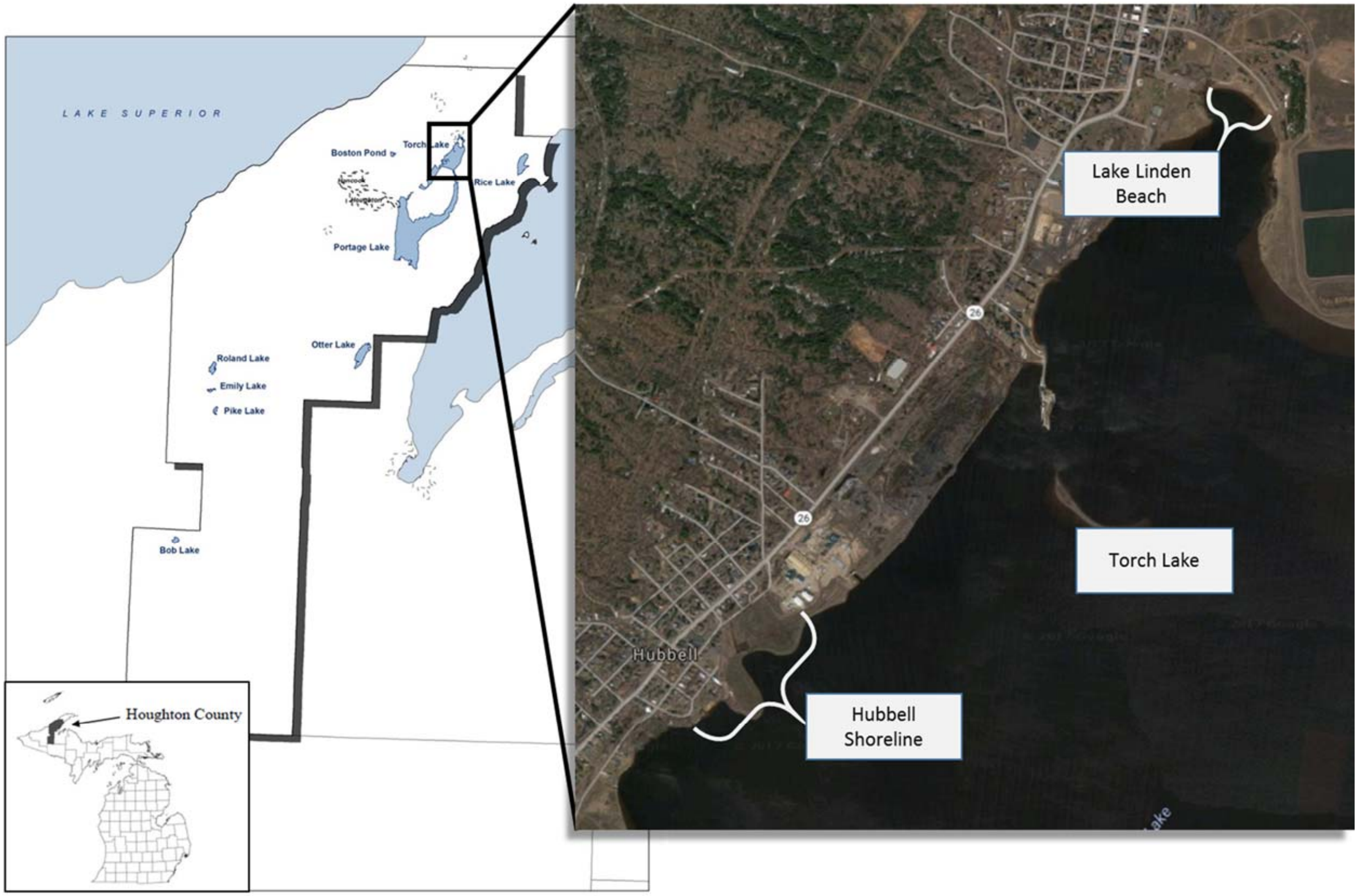

Figure 1. Map of Torch Lake, Lake Linden beach, and Hubbell shoreline in Houghton County, MI.

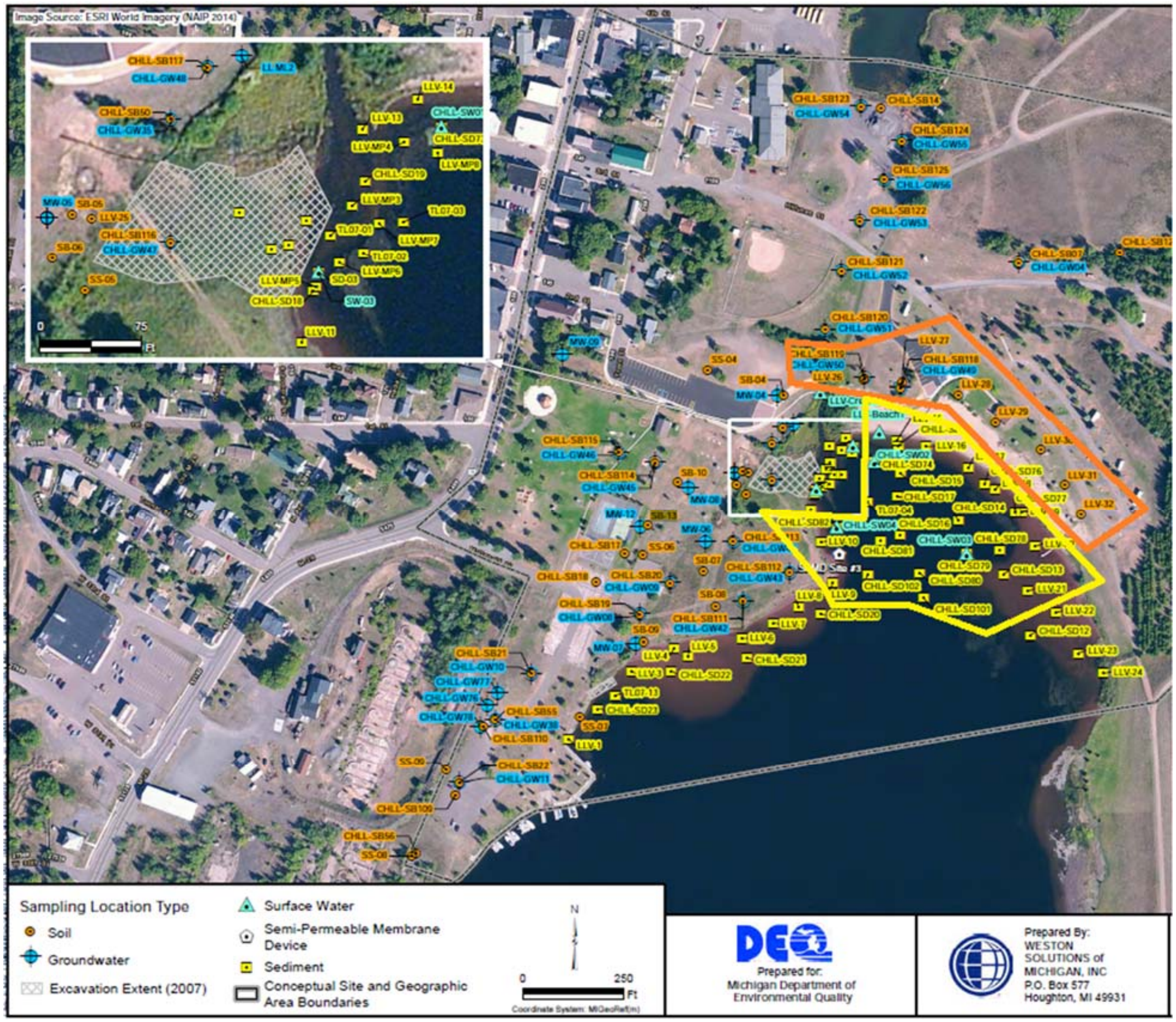

Figure 2. Site areas and sampling locations at the Lake Linden beach area. Lake Linden beach area 1 (LLBA1) is defined by the orange and yellow polygons which contain soil and sediment sampling locations, respectively. Surface water sampling locations are shown as turquoise markers. Lake Linden beach area 2 (LLBA2) is defined by the white square. (Figure adapted from Weston [2016]).

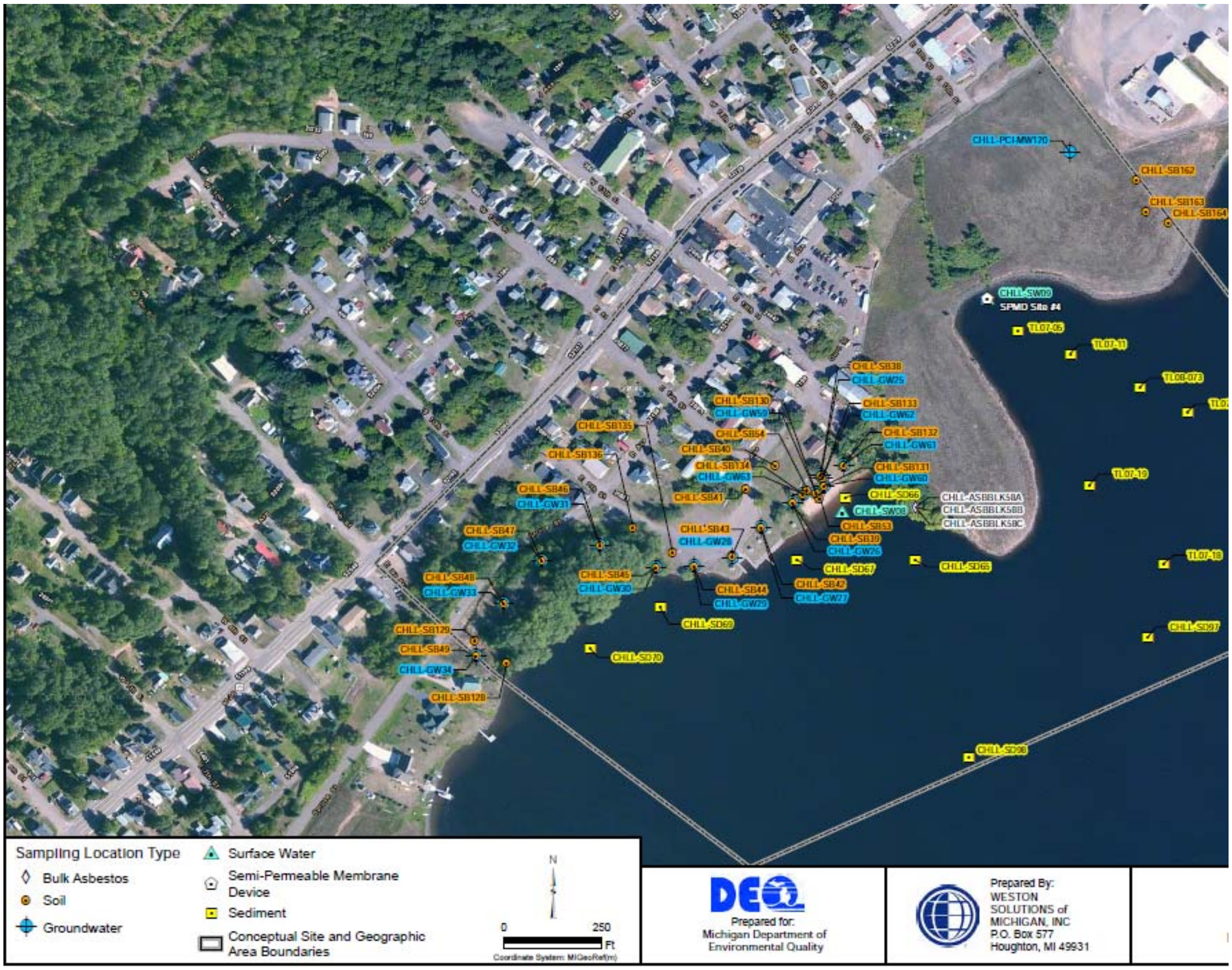

Figure 3. Hubbell shoreline with sampling locations for soil (orange) and sediment (yellow). (Figure from Weston [2016]).

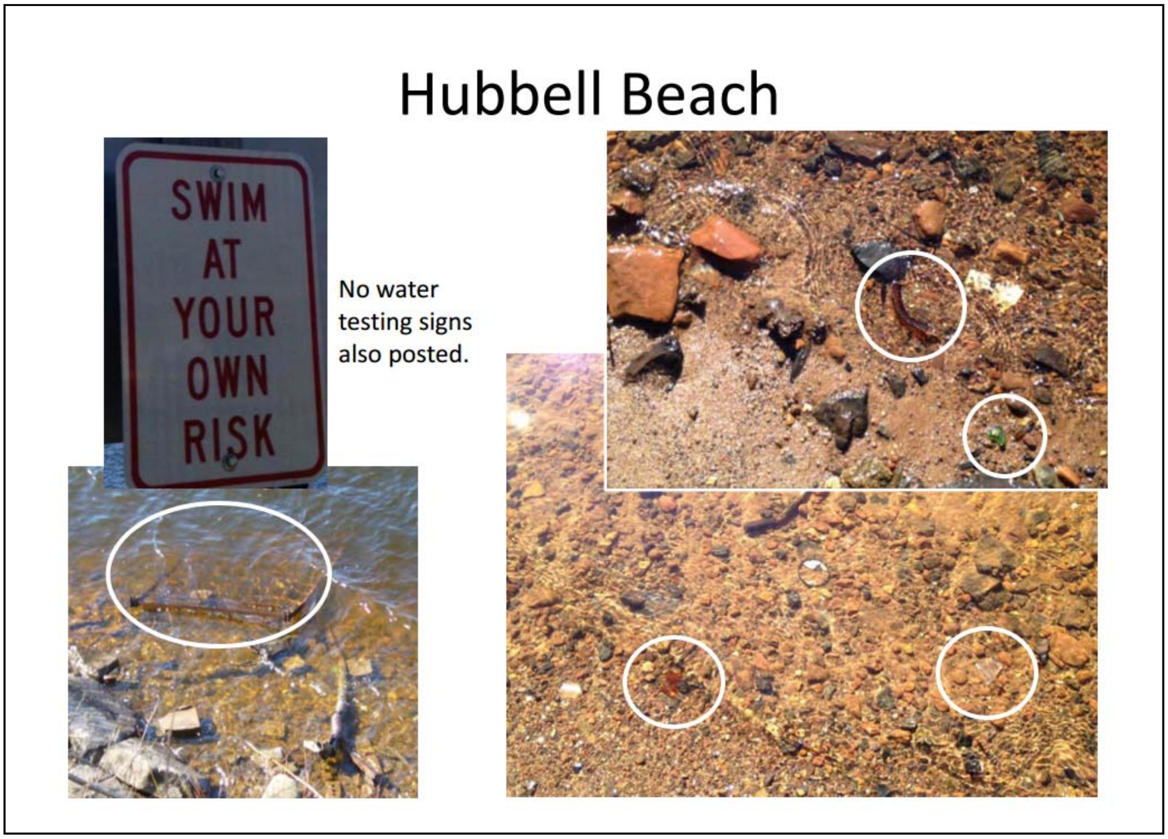

Figure 4. Glass and metal waste at the former Hubbell beach. Photo taken May 2013 by MDHHS staff and presented at a public meeting (http://www.michigan.gov/documents/mdch/Torch_lake_presentation_May_2013_5-15-2013_422403_7.pdf)

Figure 5. Metal and porcelain-like debris at the former Hubbell beach (Figure from MDEQ [2015b]).

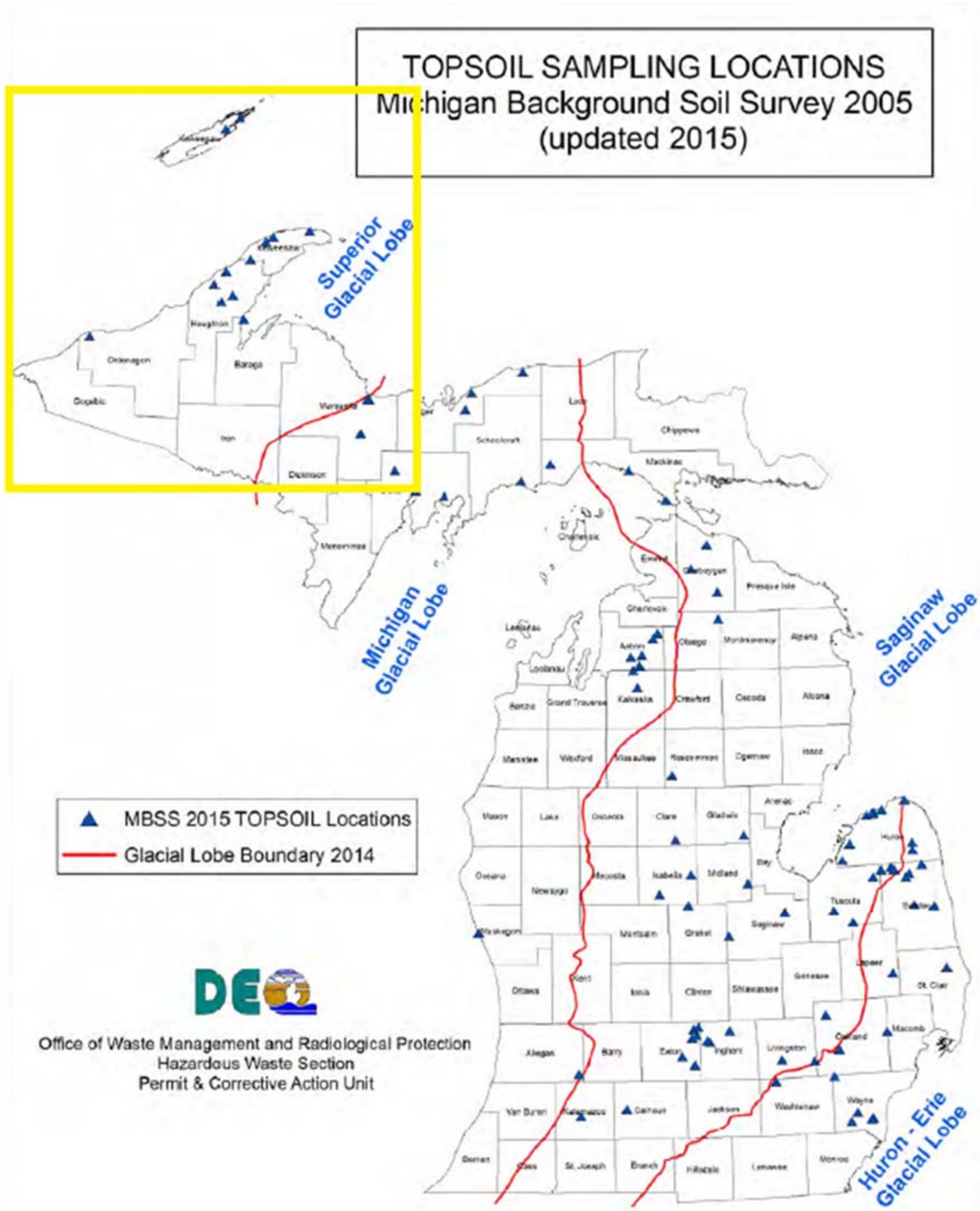

Figure 6. Michgan Background Soil Survey sampling locations for topsoil in the Superior Glacial Lobe (Figure from MDEQ [2015a]).

Appendix A

Table A1. Maximum soil concentrations from the Lake Linden Beach Area 1 (LLBA1) compared to site-specific Regional Screening Levels (RSLs). Lead and chemicals with maximum concentrations greater than the screening level are highlighted.

Chemical	Maximum (mg/kg)	RSL (mg/kg)
Antimony	2.3	122
Arsenic	14	11.7
Barium	120	60700
Copper	2000	12200
Lead	110	NA[a]
Aroclor-1262	<0.13 U	NA[a]
Total PCBs	0.057 J	1.02[b]

[a] Not applicable – RSL unavailable

[b] RSL for Aroclor 1254 (a common PCB mixture).

J = Estimated result

U = Analyte analyzed for but not detected above the reported sample reporting limit

Table A2. Maximum soil concentrations from the Lake Linden Beach Area 2 (LLBA2) compared to site-specific Regional Screening Levels (RSLs). Lead and chemicals with maximum concentrations greater than the screening level are highlighted.

Chemical	Maximum (mg/kg)	RSL (mg/kg)
Aluminum	9900	304000
Antimony	1.1 J	122
Arsenic	5	11.7
Barium	57.1 J	60700
Beryllium	1	608
Cadmium	1.2	126
Calcium	9940	NA[a]
Chromium[b]	22	456,000
Cobalt	13	91.2
Copper	989 J	12200
Iron	17000	213000
Lead	134	NA[a]
Magnesium	5190	NA[a]
Manganese	350	7290
Mercury	0.1	732
Nickel	31	6080
Potassium	<500 U	NA[a]
Selenium	<3.5 U	1520
Silver	2.5	1520
Sodium	249 J	NA[a]
Vanadium	33.2 J	1530
Zinc	60.5	91300
Cyanide	<0.5 U	172
Aroclor-1262	<0.23 U	NA[a]
Total PCBs	Non-Detect	1.02 [c]

[a] Not applicable – RSL unavailable.

[b] Trivalent chromium [Cr(III)] was not distinguished from hexavalent chromium [Cr(IV)] in chemical analyses. The RSL for Cr(III) is used here, since Cr(III) is the predominant species found in stamp sands, and Cr(IV) would not be expected to occur (Weston Solutions, 2016).

[c] RSL for Aroclor 1254 (a common PCB mixture).

J = Estimated result

U = Analyte analyzed for but not detected above the reported sample reporting limit

Table A3. Maximum soil concentrations from the Hubbell shoreline compared to site-specific Regional Screening Levels (RSLs). Lead and chemicals with maximum concentrations greater than the screening level are highlighted.

Chemical	Maximum (mg/kg)	RSL (mg/kg)
Aluminum	59000	304000
Antimony	8.6	122
Arsenic	460	11.7
Barium	640 J	60700
Beryllium	3.3	608
Cadmium	16	126
Chromium[b]	1200	456,000
Cobalt	24	91.2
Copper	12000	12200
Iron	110000 J	213000
Lead	2100	NA[a]
Lithium	18	608
Magnesium	19000	NA[a]
Manganese	12000	7290
Mercury	0.3	732
Nickel	33	6080
Selenium	4.1	1520
Silver	3.7	1520
Thallium	<5.0 U	NA[a]
Zinc	3100	91300
Cyanide	1.1	172
Benzo(a)anthracene	<0.25 U	11.1
Chrysene	0.3 J	1110
Fluoranthene	0.45	2170
Phenanthrene	0.28 J	NA[a]
Pyrene	0.37	1630
Toluene	<0.082 U	23900

[a] Not applicable – RSL unavailable.
[b] Trivalent chromium [Cr(III)] was not distinguished from hexavalent chromium [Cr(IV)] in chemical analyses. The RSL for Cr(III) is used here, since Cr(III) is the predominant species found in stamp sands, and Cr(IV) would not be expected to occur (Weston Solutions, 2016).
J = Estimated result
U = Analyte analyzed for but not detected above the reported sample reporting limit

Table A4. Maximum sediment concentrations from the Lake Linden Beach Area 1 (LLBA1) compared to site-specific Regional Screening Levels (RSLs). Lead and chemicals with maximum concentrations greater than the screening level are highlighted.

Chemical	Maximum (mg/kg)	RSL (mg/kg)
Aluminum	17000	304000
Antimony	15	122
Arsenic	26	11.7
Barium	12000	60700
Beryllium	<2 U	608
Cadmium	3.8	126
Chromium[b]	51	456,000
Cobalt	21	91.2
Copper	28000	12200
Iron	31000	213000
Lead	7800	NA[a]
Lithium	21	608
Magnesium	16000	NA[a]
Manganese	480	7290
Mercury	0.6	732
Nickel	53	6080
Selenium	5	1520
Silver	80	1520
Zinc	1000	91300
Total PCBs	1.65 J	1.02[c]
Fluoranthene	<1.1 U	2170
Pyrene	<1.1 U	1630
Diesel Range Organics (C10-C20)	75	NA[a]
Oil Range Organics (C20-C34)	420	NA[a]

[a] Not applicable – RSL unavailable.

[b] Trivalent chromium [Cr(III)] was not distinguished from hexavalent chromium [Cr(IV)] in chemical analyses. The RSL for Cr(III) is used here, since Cr(III) is the predominant species found in stamp sands, and Cr(IV) would not be expected to occur (Weston Solutions, 2016).

[c] RSL for Aroclor 1254 (a common PCB mixture).

J = Estimated result

U = Analyte analyzed for but not detected above the reported sample reporting limit

Table A5. Maximum sediment concentrations from the Lake Linden Beach Area 2 (LLBA2) compared to site-specific Regional Screening Levels (RSLs). Lead and chemicals with maximum concentrations greater than the screening level are highlighted.

Chemical	Maximum (mg/kg)	RSL (mg/kg)
Aluminum	7100	304000
Antimony	17	122
Arsenic	11	11.7
Barium	2700 J	60700
Beryllium	1	608
Cadmium	3.1	126
Calcium	1630	NA[a]
Chromium[b]	19	456,000
Cobalt	8.9	91.2
Copper	4400	12200
Iron	12000	213000
Lead	1900	NA[a]
Lithium	6.8	608
Magnesium	6000	NA[a]
Manganese	190	7290
Mercury	0.1	732
Nickel	27	6080
Selenium	<3.5 U	1520
Silver	13	1520
Sodium	313 J	NA[a]
Vanadium	18.4	1530
Zinc	290	91300
Total PCBs	0.72 J	1.02[c]
Acetophenone	<0.17 J	30400
Fluoranthene	1.2	2170

[a] Not applicable – RSL unavailable.

[b] Trivalent chromium [Cr(III)] was not distinguished from hexavalent chromium [Cr(IV)] in chemical analyses. The RSL for Cr(III) is used here, since Cr(III) is the predominant species found in stamp sands, and Cr(IV) would not be expected to occur (Weston Solutions, 2016).

[c] RSL for Aroclor 1254 (a common PCB mixture).

J = Estimated result

U = Analyte analyzed for but not detected above the reported sample reporting limit

Table A6. Maximum sediment concentrations from the Hubbell shoreline compared to site-specific Regional Screening Levels (RSLs). Lead and chemicals with maximum concentrations greater than the screening level are highlighted.

Chemical	Maximum (mg/kg)	RSL (mg/kg)
Aluminum	11000	304000
Arsenic	40	11.7
Barium	340	60700
Cadmium	11	126
Chromium[b]	500	456,000
Cobalt	14	91.2
Copper	3800	12200
Iron	23000	213000
Lead	520	NA[a]
Manganese	290	7290
Mercury	1.2	732
Nickel	34	6080
Selenium	<2.0 U	1520
Silver	6.1	1520
Zinc	430	91300
Aroclor-1254	<0.64 U	1.02
Total PCBs	0.29	1.02[c]

[a] Not applicable – RSL unavailable.

[b] Trivalent chromium [Cr(III)] was not distinguished from hexavalent chromium [Cr(IV)] in chemical analyses. The RSL for Cr(III) is used here, since Cr(III) is the predominant species found in stamp sands, and Cr(IV) would not be expected to occur (Weston Solutions, 2016).

[c] RSL for Aroclor 1254 (a common PCB mixture).

U = Analyte analyzed for but not detected above the reported sample reporting limit

Table A7. Maximum surface water concentrations from the Lake Linden Beach Area 1 (LLBA1) compared to site-specific Regional Screening Levels (RSLs). No chemicals exceeded the RSL.

Chemical	Maximum (µg/L)	RSL (µg/L)
Aluminum	22.6 J	241000
Antimony	<60 U	74.9
Arsenic	<10 U	12.9
Barium	44.1 J	28800
Beryllium	<5 U	59.1
Cadmium	<5 U	61.5
Calcium	17300	NA[a]
Chromium	<10 U	74,800[b]
Cobalt	<50 U	74.5
Copper	28.2	9630
Iron	110	168000
Lead	<10 U	NA[a]
Magnesium	2330 J	NA[a]
Manganese	11.5 J	2620
Mercury	<0.2 U	NA[a]
Nickel	1.8 J	4010
Potassium	<5000 U	NA[a]
Selenium	<35 U	1200
Silver	<10 U	706
Sodium	3610000	NA[a]
Thallium	<2 U[c]	2.41
Vanadium	<50 U	420
Zinc	<60 U	73700
Cyanide	20.7 J	144
Aroclor-1016	<0.10 U	17.7
Aroclor-1221	<0.10 U	0.258
Aroclor-1232	<0.10 U	0.258
Aroclor-1242	<0.10 U	10.8
Aroclor-1248	<0.10 U	10.8
Aroclor-1254	<0.10 U	5.07
Aroclor-1260	<0.10 U	10.8
Aroclor-1262	<0.10 U	NA[a]
Aroclor-1268	<0.10 U	NA[a]

[a] Not applicable – RSL unavailable.

[b] Trivalent chromium [Cr(III)] was not distinguished from hexavalent chromium [Cr(IV)] in chemical analyses. The RSL for Cr(III) is used here, since Cr(III) is the predominant species found in stamp sands, and Cr(IV) would not be expected to occur (Weston Solutions, 2016).

Table A7 continued

[c]2007 data. Two samples were also collected in 2011, and were determined to be below the reporting limit; however, the reporting limit for that analysis was higher (25 µg/L rather than 2 µg/L).

J = Estimated result

U = Analyte analyzed for but not detected above the reported sample reporting limit

Table A8. Exposure dose equations, exposure parameters, and exposure factors used in calculation of exposure doses.

Soil Ingestion Exposure Dose Equation

D = (C * IR * EF * CF) / BW

D = Exposure Dose (mg/kg-day), C = Contaminant Concentration (mg/kg), IR = Intake Rate (mg/day), EF = Exposure Factor (unitless), CF = Conversion Factor (10-6 kg/mg), BW = Body Weight (kg)

Soil Dermal Absorbed Dose Equation

DAD = (C * EF * CF * AF * ABSd * SA) / BW * ABSGI

DAD = Dermal Absorbed Dose (mg/kg-day), C = Contaminant Concentration (mg/kg), EF = Exposure Factor (unitless), CF = Conversion Factor (10^{-6} kg/mg),
AF = Adherence Factor to Skin (mg/cm^2-event), ABSd = Dermal Absorption Fraction to Skin (unitless), SA = Skin Surface Area Available for Contact (cm^2),
BW = Body Weight (kg), ABSGI = Gastrointestinal Absorption Factor (unitless)

Exposure Group	**Body Weight (kg)**	**Age-Specific Exposure Duration (years)**	**Intake Rate (mg/day)**		**Adherence Factor to Skin (mg/cm^2-event)**	**Combined Skin Surface Area (cm^2)**
			CTE	**RME**		
6 weeks to < 1 year	8.2	1	60	100	2.98	1,772
1 to < 2 years	11.4	1	100	200	2.98	2,299
1 to < 2 years (pica)	11.4	NA	5,000	NA	2.98	2,299
2 to < 6 years	17.4	4	100	200	2.98	2,592
2 to < 6 years (pica)	17.4	NA	5,000	NA	2.98	2,592

Table A8 continued

Exposure Group	Body Weight (kg)	Age-Specific Exposure Duration (years)	Intake Rate (mg/day)	Adherence Factor to Skin (mg/cm^2-event)	Combined Skin Surface Area (cm^2)	Combined Skin Surface Area (cm^2)
			CTE	RME		
6 to < 11 years	31.8	5	100	200	0.3	3,824
11 to < 16 years	56.8	5	100	200	0.3	5,454
16 to < 21 years	71.6	5	100	200	0.3	6,083
Adult	80	70	50	100	0.3	6,030

Exposure Factors

Duration	Days	Weeks	Years	Non-Cancer Exposure Factor	
Chronic	7	12	70	0.23	**EF cancer:** EF non-cancer x Age-Specific Exposure Duration (years)/78 years **EF dermal:** The dermal absorbed dose equation includes a 1 event/day EF parameter.

Table A9. Hazard quotients and cancer risk estimates for chronic combined dermal and ingestion exposure to the 95% upper confidence limit (UCL) of the mean **arsenic** concentration in **soil** of the **entire Hubbell shoreline**. Highlighted values exceed either a hazard quotient of one or a cancer risk of one theorticial extra case of cancer in a exposed population of 100,000 (1 X 10^{-5}).

Exposure Group	Site-Specific Scenario						
	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient		Cancer Risk		
	CTE[a]	RME[a]	CTE[a]	RME[a]	CTE[a]	RME[a]	ED (yrs)
Arsenic (EPC: 95.45 mg/kg; Chronic MRL: 0.0003 mg/kg/day; CSF: 1.5 $(mg/kg/day)^{-1}$) [b]							
6 weeks to < 1 year	0.00052	0.00059	1.7	2.0	6.1 X 10^{-5}	7.8 X 10^{-5}	0.88
1 to < 2 years	0.00051	0.00063	1.7	2.1			1
2 to < 6 years	0.00037	0.00044	1.2	1.5			4
6 to < 11 years	6.1 X 10^{-5}	0.00011	0.22	0.36			5
11 to < 16 years	4.2 X 10^{-5}	6.1 X 10^{-5}	0.14	0.22			5
16 to < 21 years	3.5 X 10^{-5}	5.4 X 10^{-5}	0.12	0.18			5
Total exposure duration for child cancer risk							21
Adult	2.3 X 10^{-5}	3.1 X 10^{-5}	0.077	0.10	3.1 X 10^{-5}	4.2 X 10^{-5}	70

[a] Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME) are two alternate methods of calculating exposure estimates. CTE is a measure of the mean or median exposure, while RME is a more conservative measure of exposure.

[b] EPC = Environmental Point Concentration; MRL = Minimal Risk Level; CSF = Cancer Slope Factor

Table A10. Hazard quotients and cancer risk estimates for chronic combined dermal and ingestion exposure to the 95% upper confidence limit (UCL) of the mean **arsenic** concentration in **sediment** of the **entire Hubbell shoreline**. Highlighted values exceed a cancer risk of one theorticial extra case of cancer in a exposed population of 100,000 (1 X 10^{-5}).

Exposure Group	Site-Specific Scenario						
	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient		Cancer Risk		
	CTE[a]	RME[a]	CTE[a]	RME[a]	CTE[a]	RME[a]	ED (yrs)
Arsenic (EPC: 31.7 mg/kg; Chronic MRL: 0.0003 mg/kg/day; CSF: 1.5 (mg/kg/day)$^{-1}$)[b]							
6 weeks to < 1 year	0.00017	0.00019	0.58	0.65	2.0 X 10^{-5}	2.6 X 10^{-5}	0.88
1 to < 2 years	0.00017	0.00021	0.57	0.69			1
2 to < 6 years	0.00012	0.00015	0.41	0.49			4
6 to < 11 years	2.2 X 10^{-5}	3.5 X 10^{-5}	0.072	0.12			5
11 to < 16 years	1.4 X 10^{-5}	2.2 X 10^{-5}	0.047	0.072			5
16 to < 21 years	1.2 X 10^{-5}	1.8 X 10^{-5}	0.039	0.059			5
Total exposure duration for child cancer risk							21
Adult	7.7 X 10^{-6}	1.0 X 10^{-5}	0.026	0.035	1.0 X 10^{-5}	1.4 X 10^{-5}	70

[a] Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME) are two alternate methods of calculating exposure estimates. CTE is a measure of the mean or median exposure, while RME is a more conservative measure of exposure.

[b] EPC = Environmental Point Concentration; MRL = Minimal Risk Level; CSF = Cancer Slope Factor

Table A11. Hazard quotients and cancer risk estimates for chronic combined dermal and ingestion exposure to the 95% upper confidence limit (UCL) of the mean **arsenic** concentration in **soil** of only the **former Hubbell beach**.

Exposure Group	Site-Specific Scenario						
	Chronic Dose (mg/kg/day)		Chronic Hazard Quotient		Cancer Risk		
	CTE[a]	RME[a]	CTE[a]	RME[a]	CTE[a]	RME[a]	ED (yrs)
Arsenic (EPC: 5.3 mg/kg; Chronic MRL: 0.0003 mg/kg/day; CSF: 1.5 $(mg/kg/day)^{-1}$)[b]							
6 weeks to < 1 year	2.9×10^{-5}	3.2×10^{-5}	0.096	0.11	3.4×10^{-6}	4.3×10^{-6}	0.88
1 to < 2 years	2.8×10^{-5}	3.5×10^{-5}	0.095	0.12			1
2 to < 6 years	2.0×10^{-5}	2.5×10^{-5}	0.068	0.082			4
6 to < 11 years	3.6×10^{-6}	5.9×10^{-6}	0.012	0.020			5
11 to < 16 years	2.3×10^{-6}	3.6×10^{-6}	0.0078	0.012			5
16 to < 21 years	2.0×10^{-6}	3.0×10^{-6}	0.0065	0.0099			5
Total exposure duration for child cancer risk							21
Adult	1.3×10^{-6}	1.7×10^{-6}	0.0043	0.0058	1.7×10^{-6}	2.3×10^{-6}	70

[a] Central Tendency Exposure (CTE) and Reasonable Maximum Exposure (RME) are two alternate methods of calculating exposure estimates. CTE is a measure of the mean or median exposure, while RME is a more conservative measure of exposure.

[b] EPC = Environmental Point Concentration; MRL = Minimal Risk Level; CSF = Cancer Slope Factor

Table A12. Inputs to the U.S. Environmental Protection Agency (USEPA) Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead in Children version 1.1 Build 11 used to evaluate lead levels in soil and sediment at the Lake Linden Beach areas and Hubbell shoreline.

Media	Default or updated values
Air lead level	Updated to 0.01 µg/m^3 based on urban air lead levels[a]
Water intake rates	Updated per USEPA Exposure Factors handbook: 2011 Edition[a] 0-1 years old - 0.32 liter/day (L/d) (age-adjusted from the values in Table 3-1) 1-2 years old - 0.271 L/d 2-3 years old - 0.317 L/d 3-4 years old - 0.327 L/d (3 to 6 years old in Table 3-1) 4-5 years old - 0.327 L/d (3 to 6 years old in Table 3-1) 5-6 years old - 0.327 L/d (3 to 6 years old in Table 3-1) 6-7 years old - 0.414 L/d (6 to 11 years old in Table 3-1)
Diet	Default
Maternal blood lead	Updated to 0.8 µg/dL to match the NHANES (2011-2012) geometric mean lead level for women[a]
Water lead level	Updated to 1 ppb per MDEQ draft technical support document for Part 201 Criteria[a]
Soil lead level	Updated to 190 ppm per MDEQ draft criteria for soil in residential locations[a]
"Alternate" lead exposure	Daily exposure to 50 mg of soil or sediment with 95% UCL of the mean[b]

a = MDEQ, Cleanup Criteria and Screening Levels Development and Application, draft June 2016Attachment P, Background Document, Criteria for Lead, http://www.michigan.gov/documents/deq/deq-rrd-chem-CleanupCriteriaTSD_527410_7.pdf
b = Central tendency for soil ingestion only in an indoor or outdoor setting for ages 1 to less than 21 years; U.S. EPA. Exposure Factors Handbook 2011 Edition (Final Report). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/052F, 2011.

The USEPA IEUBK model is available at https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals.

The recreational soil and sediment exposure was considered separately from a child's daily soil and dust ingestion for two reasons. One reason was that there is no way to determine the soil and dust lead levels in individual children's homes. The second reason was that recreational activities in beach areas often result in extensive soil contact through hand-to-mouth behavior while playing or inadvertent ingestion of soil or sediment while vigorously digging. This is expected to be and intended to be a conservative exposure scenario. In areas with older housing, lead paint dust could be in the house or mixed in with yard soil. Elevated exposure to lead in the home or in other locations would also increase the risk that a child may have an elevated blood lead level.

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