Public Health Assessment

Public Comment Release

Post-dredging contaminant levels in

RUDDIMAN POND AND CREEK (MAIN BRANCH)

MUSKEGON (MUSKEGON COUNTY), MICHIGAN

Prepared by the
Michigan Department of Community Health

AUGUST 20, 2014

COMMENT PERIOD ENDS: SEPTEMBER 23, 2014

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Division of Community Health Investigations
Atlanta, Georgia 30333

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR's Cooperative Agreement Partner has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR's Cooperative Agreement Partner will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i) (6) (H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them to ATSDR's Cooperative Agreement Partner. This revised document has now been released for a 45-day public comment period. Subsequent to the public comment period, ATSDR's Cooperative Agreement Partner will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR's Cooperative Agreement Partner which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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MUSKEGON (MUSKEGON COUNTY), MICHIGAN

Prepared by:

Michigan Department of Community Health
Bureau of Epidemiology
Division of Environmental Health
Toxicology and Response Section
Under Cooperative Agreement with the
Agency for Toxic Substances and Disease Registry

Foreword

The Michigan Department of Community Health (MDCH) conducted this evaluation under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR conducts public health activities (assessments/consultations, advisories, education) at sites of environmental contamination. The purpose of this document is to identify potentially harmful exposures and actions that would minimize those exposures. This is not a regulatory document and does not evaluate or confirm compliance with laws. This is a publicly available document that is provided to the appropriate regulatory agencies for their consideration.

The following steps are necessary to conduct public health assessments/consultations:

- Evaluating exposure: MDCH toxicologists begin by reviewing available information about environmental conditions at the site: how much contamination is present, where it is found on the site, and how people might be exposed to it. This process requires the measurement of chemicals in air, water, soil, or animals. Usually, MDCH does not collect its own environmental sampling data. We rely on information provided by the Michigan Department of Environmental Quality (MDEQ), U.S. Environmental Protection Agency (EPA), and other government agencies, businesses, and the general public.

- Evaluating health effects: If there is evidence that people are being exposed – or could be exposed – to hazardous substances, MDCH toxicologists then determine whether that exposure could be harmful to human health, using existing scientific information. The report focuses on public health – the health impact on the community as a whole.

- Developing recommendations: In its report, MDCH outlines conclusions regarding any potential health threat posed by a site, and offers recommendations for reducing or eliminating human exposure to contaminants. If there is an immediate health threat, MDCH will issue a public health advisory warning people of the danger, and will work with the appropriate agencies to resolve the problem.

- Soliciting community input: The evaluation process is interactive. MDCH solicits and considers information from various government agencies, parties responsible for the site, and the community. If you have any questions or comments about this report, we encourage you to contact us.

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www.michigan.gov/mdch-toxics

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Acronyms and Abbreviations

µg	microgram
AOC	Area of Concern
ATSDR	Agency for Toxic Substances and Disease Registry
AWRI	Robert B. Annis Water Resources Institute
BaP	benzo(a)pyrene
CDC	Centers for Disease Control and Prevention
EPA	U.S. Environmental Protection Agency
g	gram
kg	kilogram
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
MFCAP	Michigan Fish Consumption Advisory Program
MI	Michigan
MRL	Minimal Risk Level
NA	not available
NC	not calculated
ND	not detected
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PEC	probable effect concentration
ppm	parts per million
SPMD	semi-permeable membrane device
SVOCs	semi-volatile organic chemicals
U.S.	United States
UCL	95% Upper Confidence Limit on the mean
VOCs	volatile organic chemicals
yds^3	cubic yards

Summary

The Ruddiman watershed covers approximately 5.6 square miles in Muskegon County, Michigan, and includes a 21-acre pond and 2.3 miles of creeks. The three branches of Ruddiman Creek flow through residential areas. Ruddiman Pond and the Main Branch of the creek are located on the other side of the street from McGraft Park, a popular suburban park. Residents in the vicinity engage in recreational activities in Ruddiman Pond and Creek, including fishing and wading. Previous investigations found a variety of contaminants (metals, cyanide, semi-volatile organic compounds [SVOCs], volatile organic compounds [VOCs], and polychlorinated biphenyls [PCBs]) in Ruddiman Pond and in the Main Branch of Ruddiman Creek. Dredging of Ruddiman Pond and the Main Branch of the creek occurred from fall 2005 to spring 2006 and approximately 90,000 cubic yards of contaminated sediment was removed. Restoration, after dredging, included using clean sand and rock as fill and planting native species along the waterline. In this public health assessment, the Michigan Department of Community Health (MDCH) uses post-dredging data to assess whether remaining contaminants could harm people's health.

<u>MDCH's conclusions about Ruddiman Pond and the Main Branch of Ruddiman Creek:</u>

1. *MDCH concludes that contaminated sediments in Ruddiman Pond will not harm people's health.* Although levels of certain chemicals (lead and polycyclic aromatic hydrocarbons [PAHs]) were above the screening levels in some samples, people's exposure to these chemicals will be limited and is therefore not expected to cause health effects. The water depth of the pond ranged from 3.7 to 20.5 feet, which will reduce people's exposure to chemicals in the sediment, especially children.

<u>Next steps:</u> No additional steps are necessary.

2. *MDCH concludes that contaminated sediment in the Main Branch of Ruddiman Creek is not expected to harm people's health.* Although levels of PAHs, lead, and Aroclor 1254 (PCBs) are elevated in certain locations in the creek with low water depth, people are not expected to have enough exposure to these chemicals to cause health effects. Lead, benzo(a)pyrene, and Aroclor 1254 levels are not uniformly elevated throughout the creek.

<u>Next steps:</u> No additional steps are necessary.

3. *MDCH concludes that contact with oil and grease sheen on Ruddiman Pond or the Main Branch of the creek could cause temporary health effects, such as skin irritation.* Sheen from oil or grease may be on the water from urban runoff. Contact with the sheen could cause skin irritation or other temporary health effects.

<u>Next steps:</u> No additional steps are necessary.

4. *MDCH concludes that if people follow the Eat Safe Fish Guide, eating fish from Ruddiman Pond and the Main Branch of the creek will not harm their health.* Although levels of PCBs in the sediment have decreased, fish in Ruddiman Pond and the Main

Branch of the creek still have levels of polychlorinated biphenyls (PCBs) to prompt consumption guidelines. Along with the waterbody-specific guidelines, other fish from these waters are included in Michigan's Statewide Safe Fish Guidelines. See www.michigan.gov/eatsafefish for the most current guidelines and for more information.

Next steps: MDCH will continue to evaluate fish contaminant data provided by the Michigan Fish Contaminant Monitoring Program and issue fish consumption guidelines as necessary.

Purpose and Health Issues

After dredging Ruddiman Pond and the Main Branch of Ruddiman Creek, the U.S. Environmental Protection Agency (EPA) asked the Michigan Department of Community Health (MDCH) to evaluate the effectiveness of the remediation in protecting people's health. MDCH discussed health concerns in a previous health consultation completed in 2003 (ATSDR 2003), and identified contaminants in Ruddiman Pond and the Main Branch of Ruddiman Creek that may affect people's health. MDCH concluded that contaminants, primarily arsenic and lead, in the sediment of Ruddiman Pond would not harm people's health because of limited contact with those sediments. MDCH could not determine if contact with two contaminants, lead and PCBs, in sediments from the Main Branch of Ruddiman Creek would harm people's health because of the limited number of samples. The current health assessment uses post-dredging data to assess whether remaining contaminants could harm people's health.

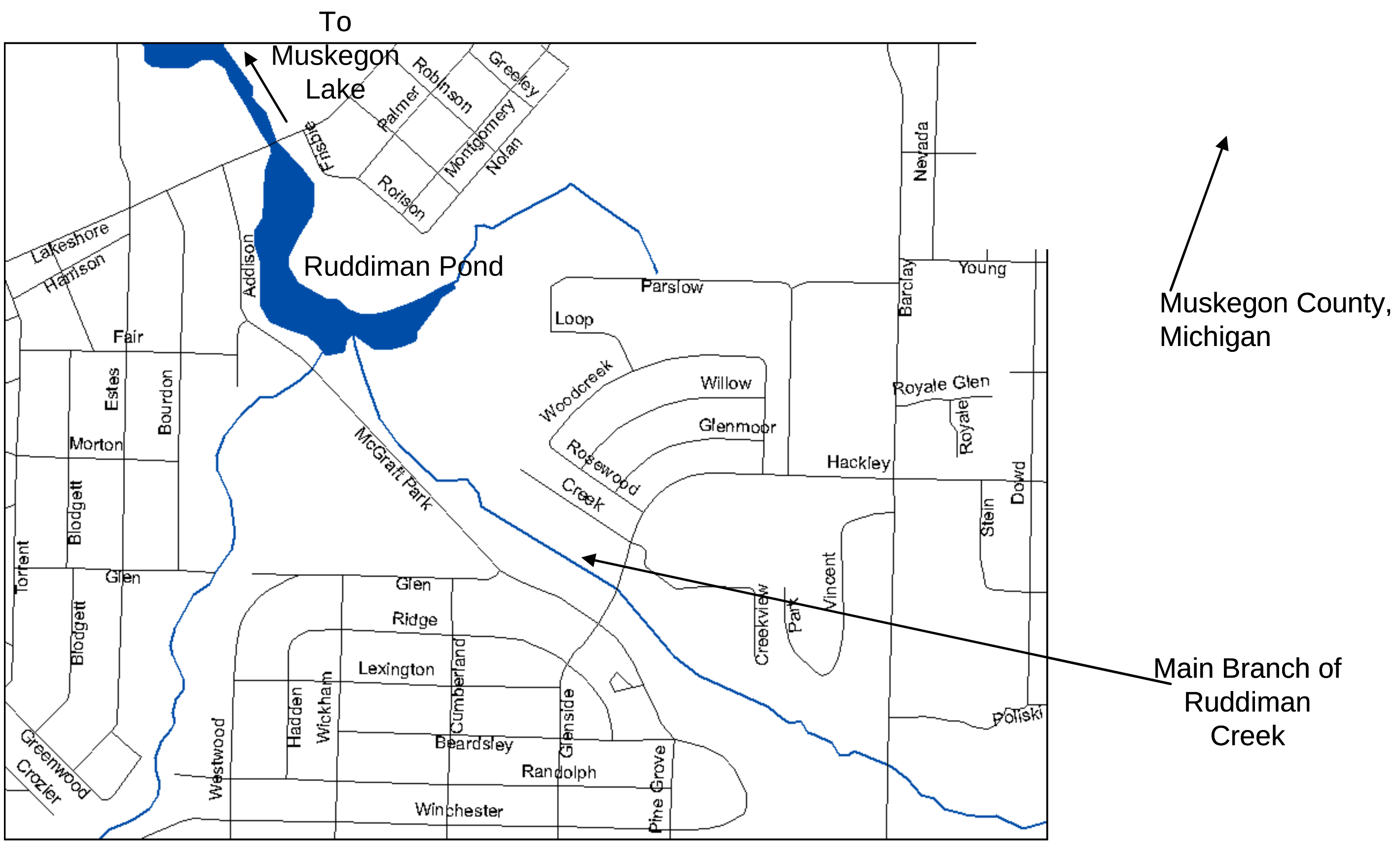
Background

The Ruddiman watershed covers approximately 5.6 square miles in Muskegon County, Michigan, and includes a 21-acre pond and 2.3 miles of creeks (Figure 1). The watershed consists of portions of the cities of Muskegon, Norton Shores, Muskegon Heights, and Roosevelt Park. Storm sewers from all four cities contribute to the creek. The three primary branches of the creek are the West, North, and Main Branches, which all flow through residential areas. The Main Branch of the creek is located less than one-quarter of a mile from the Glenside Elementary School (Muskegon Public Schools). It begins at a storm sewer outfall east of Barclay Road and flows through residential and wetland areas to the southeast portion of Ruddiman Pond (Earth Tech 2002).

The three branches of the creek flow into Ruddiman Pond, which is located next to McGraft Road and McGraft Park, a popular suburban park. Bordering the pond is Lakeshore Drive (north), Addison Street (west), McGraft Park Road (south), and residences and wetlands (east). Area residents, including children, take part in recreational activities in and around the pond and creek branches. The pond empties into Muskegon Lake, which has a connection to Lake Michigan via the Muskegon Channel.

MDCH previously noted that residents wade, canoe, and fish in Ruddiman Creek and Pond. Observed activities along the creek include digging for worms (for fish bait), bird watching, and building temporary structures (e.g. children's "forts"). The creek was identified as a popular place for children to play both after school and during the summer. McGraft Park visitors, such as those playing Frisbee golf, occasionally wade into the pond to retrieve lost items (Frisbees

Figure 1: Ruddiman Pond and the Main Branch of Ruddiman Creek located in Muskegon (Muskegon County), Michigan.



hats, or other play equipment). Ruddiman Pond is also a location for ice skating and fishing in the winter (ATSDR 2003).

The Phase I Environmental Site Assessment, completed by DLZ, Inc. in 1999, identified potential environmental concerns that were present in the watershed (Earth Tech 2002). The Phase II Site Investigation Report, completed by DLZ, Inc. in 2000, identified metals, cyanide, semi-volatile organic compounds (SVOCs), volatile organic compounds (VOCs), and PCBs in Ruddiman Pond and in the Main Branch of Ruddiman Creek (Earth Tech 2002).

At a request from the Michigan Department of Environmental Quality (MDEQ), the MDCH evaluated the human health risk associated with potential exposures to contaminated sediments in the Ruddiman Creek Watershed. MDCH concluded that people's health was not expected to be harmed (no apparent public health hazard) from the sediments in Ruddiman Pond, or the North and West Branches of Ruddiman Creek. MDCH was unable to determine whether people's health would be harmed (an indeterminate public health hazard) from the sediments in the Main Branch of Ruddiman Creek, in particular the area between Glenside Avenue and Barclay Road, because of limited characterization of the contamination. Two contaminants, PCBs and lead, in the sediments in this area were at levels of potential concern for children playing in and around the creek. MDCH recommended additional sediment sampling to further characterize the contamination in the Main Branch of the creek along with sampling and analysis of fish in the watershed (ATSDR 2003).

The former Surface Water Quality Division of the MDEQ contracted Earth Tech, Inc. (Earth Tech) to conduct a remedial investigation of Ruddiman Pond and Creek. Objectives included identifying the extent of contaminated sediments and estimating the volume of the contaminated sediments in Ruddiman Pond and the three primary branches of the creek. Approximately 78,000 cubic yards (yds^3) of sediment was calculated to have contaminant levels that exceeded Probable Effect Concentrations (PECs) (Earth Tech 2002). PECs are consensus-based sediment quality guidelines calculated from the mean (geometric) of three or more individual sediment quality guidelines. A PEC represents the level at which adverse effects for freshwater ecosystems, but not human health, are expected to occur (MacDonald et al. 2000). Additional information on the remedial investigation is in Appendix A.

Ruddiman Pond and the Main Branch of the creek were dredged from fall 2005 to spring 2006. Dredging of the pond took place as part of the EPA and MDEQ cleanup of the Muskegon Lake Area of Concern (AOC). Ruddiman Pond is connected to Muskegon Lake via a channel.

Approximately 90,000 yd^3 of contaminated sediment, which was 10,000 yd^3 over the goal, was removed (EPA 2009A). During the dredging, levels of cadmium, chromium, lead, benzo(a)pyrene, and PCBs were monitored in the remaining sediment to ensure the levels were below the dredging criteria. The pond and Main Branch of the creek were then restored, using clean sand and rock as fill and planting native plant species in locations along the waterline. In certain locations, sampling results were not available until after the stone and sand fill was added. More fill was added to locations with sediment that did not meet the dredging criteria (Earth Tech 2006). Additional information, including dredging criteria, on the remediation is in Appendix A.

Discussion

Environmental Sampling Data

Environmental samples were collected and analyzed for contaminants in sediment and surface water from Ruddiman Pond and Creek. Results were compared to screening levels. If maximum levels of the contaminant were above the screening levels, the 95% Upper Confidence Limit (UCL) of the mean was calculated. The UCL provides an upper estimate of the amount of chemical that people may be exposed to from wading in Ruddiman Pond or the Main Branch of Ruddiman Creek. Contaminants with UCLs above the screening level were evaluated further. Screening levels are described in Appendix B.

Fish were collected from neighboring Muskegon Lake for analysis.

Ruddiman Pond Sediment Sampling in 2008 and 2012

On November 3 through 5, 2008, surficial sediment samples were collected from Ruddiman Pond. The sediment collected went to a depth of approximately six inches below the sediment-water interface. Arsenic, cadmium, chromium, copper, lead, nickel, zinc, total mercury, and oil and grease, PCBs, and polycyclic aromatic hydrocarbons (PAHs) were measured in the samples (Battelle 2009). Table 1 presents the maximum levels and 95% UCL for the chemicals that were over the screening levels in Ruddiman Pond sediments. See Appendix B for a description of the screening levels. Appendix C presents the maximum values for all contaminants tested in sediments.

Table 1: Contaminants (in parts per million [ppm]) in Ruddiman Pond sediment without or over the screening levels, November 2008 (Battelle 2009).

Contaminant	Screening level (in ppm)[a]	Maximum value in pond sediments (in ppm)	95% Upper Confidence Limit (UCL) on the mean for pond sediments (in ppm)	Number of samples over the screening level/total number of samples
Oil & Grease	2,000	38,000	15,612	15/15
Benzo(a)pyrene	0.096	6.7	2.0	27/27
Benzo(b)fluoranthene	1.5	8.6	2.5	13/27
Benzo(e)pyrene	NA[b]	6.9	3.3	27[c]/27
Dibenz(a,h)anthracene	0.15	1.7	0.5	22/27
Indeno(1,2,3-cd)pyrene	1.5	8.2	2.5	13/27
Perylene	NA[b]	2.0	1.4	27[c]/27

a = See Appendix B for more information on the screening levels.
b = Not available (NA). No screening levels are available.
c = There are no screening levels for this chemical. This is the number of samples with the chemical detected.

All samples measured for benzo(a)pyrene were over the screening level of 0.096 ppm. Six were from areas with a water depth of 4.4 feet or less, 10 were from areas with a water depth of 4.6 to 9.5 feet, and 11 were from areas with a water depth of 10.7 to 20.5 feet.

Of the 13 samples over the benzo(b)fluoranthene screening level, one was from an area with a water depth of 4.4 feet. Four were from areas with water depths ranging from 4.6 to 9.5 feet and eight were from areas with water depths ranging from 10.7 to 20.5 feet.

For the samples over the dibenz(a,h)anthracene screening level, only three were from areas with a water depth of 4.4 feet or less. Eight were from areas with 4.6 to 9.5 feet and 11 were from areas with 10.7 to 20.5 feet.

Of the 13 samples over the indeno(1,2,3-cd)pyrene screening level, one was from an area with a water depth of 4.4 feet. Five were from areas with water depths ranging from 4.6 to 9.5 feet and seven samples over the screening level were from areas with water depths ranging from 10.7 to 20.5 feet.

Two of the PAHs tested have no screening levels: benzo(e)pyrene and perylene. Levels of benzo(e)pyrene ranged from 0.2 to 7.0 ppm and levels of perylene ranged from 0.1 to 2.0 ppm. They were detected in all samples regardless of water depth. Levels of oil and grease in sediment ranged from 2,100 to 32,000 ppm, thus all 21 samples tested were above the screening level regardless of water depth (Battelle 2009). The value of 2,000 ppm has been used in EPA and joint EPA and MDEQ reports to indicate sediments that are heavily polluted (Collier and Cieniawski 2003; EPA 2009B).

In the summer of 2012, sediment samples were taken by MDEQ and EPA from Ruddiman Pond (MDEQ 2014). Twelve grab sediment samples were analyzed for metals and PCBs (Appendix C). Three sediment samples were analyzed for PAHs

Lead was the only contaminant that exceeded its screening level. Six of 11 Ruddiman Pond sediment samples were above the lead screening level of 400 ppm. The maximum value was 960 ppm and the 95% UCL was 553 ppm. The 95% UCL for lead was higher in pond sediment collected in 2012 as compared to the 95% UCL calculated from the 2008 sediment samples (Appendix C). PCBs and PAHs were not detected over the screening levels in the Ruddiman Pond sediments collected in 2012. However, only four sediment samples were analyzed for PAHs.

Ruddiman Creek (Main Branch) Sediment Sampling in 2008 and 2012

Twenty-eight surficial sediment samples were collected from the Main Branch of Ruddiman Creek in November 2008. The sediment collected included sediment from approximately as deep as six inches below the sediment-water interface. Arsenic, cadmium, chromium, copper, lead, nickel, zinc, total mercury, and oil and grease, PCBs, and PAHs were measured in the samples (Battelle 2009). Table 2 presents the contaminants with maximum values over the screening levels or without screening levels.

Table 2: Contaminants (in parts per million [ppm]) in Main Branch of Ruddiman Creek sediment that are over or have no screening level, November 2008 (Battelle 2009).

Contaminant	Screening level (in ppm)[a]	Maximum value in main branch sediments (in ppm)	95% Upper Confidence Limit (UCL) on the mean for main branch sediments (in ppm)	Number of samples over the screening level/total number of samples
Oil & Grease	2,000	24,000	7.627	7/22
Lead	400	971	407	7/28
PCBs - Aroclor 1254	1.0	3.3	2.2	4/28
Benzo(a)anthracene	1.5	9.3	3.3	12/28
Benzo(a)pyrene	0.096	10.6	4.1	27/28
Benzo(b)fluoranthene	1.5	10.7	4.3	13/28
Benzo(e)pyrene	NA[b]	8.0	3.6	28[c]/28
Dibenz(a,h)anthracene	0.15	2.1	0.9	18/28
Indeno(1,2,3-cd)pyrene	1.5	9.4	4.1	13/28
Perylene	NA[b]	2.9	1.2	28[c/]28

a = See Appendix B for more information on the screening levels.
b = Not available. No screening levels are available.
c = There are no screening levels for this chemical. This is the number of samples with the chemical detected.

Five of the seven samples above the lead screening level and three of the four samples above the Aroclor 1254 screening level were within about 450 yards from the connection to Ruddiman Pond. The depth of the Main Branch in this area ranged from 1.5 to 3.8 feet. The other two samples above the lead screening level and the fourth sample above the Aroclor 1254 screening level were in areas of the creek with a water depth of 0.7 or 1.0 foot. The samples that were above the PAH screening levels (benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene) were throughout the Main Branch of Ruddiman Creek.

Two of the PAHs tested have no screening levels: benzo(e)pyrene and perylene. Levels of benzo(e)pyrene ranged from 0.07 to 8.0 ppm and levels of perylene ranged from 0.02 to 3.0 ppm (Battelle 2009). Oil and grease levels in the main branch sediments ranged from 180 to 24,000 ppm (Battelle 2009) and six of the 21 samples tested were above 2,000 ppm.

Eleven grab sediment samples were collected by MDEQ and EPA from the Main Branch of Ruddiman Creek in the summer of 2012 and analyzed for metals and PCBs (Appendix C) (MDEQ 2014). Three sediment samples were analyzed for PAHs.

Benzo(a)anthracene was detected over the screening level (1.5 ppm) in one sample (6.5 ppm), but was not detected in the other two samples. Many of the PAHs detected over the screening levels in the 2008 sampling were not detected in the 2012 samples. However, only three samples collected in 2012 were analyzed for PAHs. No metals or PCBs were found above their screening levels in the 11 sediment samples.

Ruddiman Pond and Creek (Main Branch) Surface water

Eleven surface water samples collected on November 6, 2008 were tested for PCBs (as congeners), 36 individual PAHs, and total organic carbon (Battelle 2009). PCBs were below the detection limit when measured as Aroclors and when measured as individual congeners. Levels of total PCBs were below 170 parts per trillion.[1] Although this water is not used for drinking water, all the PAH levels were well below drinking water screening levels[2].

On November 6, 2008, semi-permeable membrane devices (SPMDs) were deployed at nine locations. SPMDs can be used as a model for accumulation of contaminants in fish. The solution in the SPMD is similar to fish fat and will accumulate similar contaminants as fish or other animals (Chapman 2009). As the SPMD accumulates PCBs, fish in Ruddiman Pond or the Main Branch of Ruddiman Creek are expected to as well. Table C-7, in Appendix C, presents the maximum amount of contaminant per SPMD and the maximum amount calculated to be present in the water. While PCBs and some PAHs accumulated in the SPMDs, levels of these chemicals in surface water are expected to be low.

Fish from Muskegon Lake

Fish from Ruddiman Pond and Creek have not been collected and analyzed for contaminants after the dredging. However, fish from Muskegon Lake, which is connected to Ruddiman Pond, may migrate to Ruddiman Pond or vice versa. Fish in Muskegon Lake may also be an indication of conditions of fish in Ruddiman Pond. Dredging of the pond and creek took place as part of the cleanup of the Muskegon Lake AOC. Table 3 presents fish PCB levels in Muskegon Lake from fish data collected by the Robert B. Annis Water Resources Institute (AWRI) or used in the Michigan Fish Consumption Advisory Program[3] (MFCAP). AWRI collected fish in 2006. PCB levels were lower in the fish collected in 2006; however, the fish were smaller than the fish collected in 2001 and 2002. Smaller fish tend to be younger and leaner. Younger fish haven't had time to accumulate PCBs. PCBs are stored in the fat, so leaner fish have lower levels of PCBs than fish with more fat.

[1] The EPA's Regional Screening Level for PCBs (low risk) in drinking water is 170 parts per trillion.
[2] The MDEQ's Part 201 Residential Drinking Water Criteria.
[3] The Michigan Fish Contaminant Monitoring Program data includes fish collected from Bear Lake. Bear Lake is directly connected to Muskegon Lake and the datasets are combined for the Eat Safe Fish Guidelines.

Table 3: PCB levels (in parts per million [ppm]) in fish filets from Muskegon Lake, which is connected to Ruddiman Pond via the Muskegon Channel, used in the Michigan Fish Consumption Advisory Program (MFCAP) and from the Robert B. Annis Water Resources Institute (AWRI).

Fish	AWRI [a]			MFCAP[b]		
	Month/Year collected (number of samples)	PCBs (ppm)		Month/Year collected (number of samples)	PCBs (ppm)	
		Mean	Range		Mean	Range
Northern Pike	8 & 9/2006 (9)	0.03	0.01 to 0.06	6/2006 (10)	0.03	0.001 to 0.07
Walleye	6/2006 (10)	0.2	0.02 to 0.6	9/2002 & 5/2008 (17)	0.2	0.001 to 0.7
Largemouth Bass	7/2006 (11)	0.02	0.007 to 0.06	9/2001 (20[c])	0.3	0.05 to 0.4
Carp[d]	8/2006 (9)	0.4	0.1 to 1.4	9/2002 (10)	1.4	0.1 to 8.0

a = Data from Joe Bohr, MDEQ, (Personal communication)
b = Data includes fish from Bear Lake, a waterbody directly connected to Muskegon Lake.
c = Smallmouth bass are included in this dataset.
d = Carp collected from Ruddiman Pond were not included in this dataset. This information is used to set the Eat Safe Fish guidelines for carp in Ruddiman Pond.

Exposure Pathways Analysis

An exposure pathway contains five elements: (1) the contaminant source, (2) contamination of environmental media, (3) an exposure point, (4) a human exposure route, and (5) a receptor population. An exposure pathway is complete if there is a high probability or evidence that all five elements are present.

The contaminants present at Ruddiman Pond or Main Branch of the Creek are bound to sediments and, due to the water content and location, are not expected to be inhaled. As for the contaminants being inhaled without the sediments, volatilization of PCBs or PAHs is not expected to occur from sediments at temperatures typical in Michigan. People might eat fish from Ruddiman Pond or the Main Branch of the creek that accumulated elevated levels of PCBs. However, there are currently fish consumption guidelines on fish from Ruddiman Pond to limit people’s exposure to PCBs and mercury. Contaminants in surface water were not above screening levels, so accidentally drinking a gulp or two (incidental ingestion) of water would not be expected to be of health concern. Therefore, the only exposure routes that will be addressed are direct (dermal) contact and accidental ingestion of small amounts of sediment (incidental ingestion). Table 4 describes human exposure pathways to contaminants in the Ruddiman Pond and Creek (Main Branch) in Muskegon, Michigan.

Table 4: Exposure pathway for human exposure to contaminants in the Ruddiman Pond and Creek (Main Branch) in Muskegon (Muskegon County), Michigan.

Source	Environmental Medium	Exposure Point	Exposure Route	Exposed Population	Time Frame	Status
Inorganic and organic (PCBs and PAHs) contaminants in sediments in the pond	Pond sediments	Sediments in shallow areas of the pond	Dermal contact and incidental ingestion	Adults and children that wade or play in the water or along the shore	Past Present Future	Completed
Inorganic and organic (PCBs and PAHs) contaminants in sediments	Main Branch of the creek sediments	Sediments in shallow areas of the main branch	Dermal contact and incidental ingestion	Adults and children that wade or play in the water or along the bank of the main branch of the creek	Past Present Future	Completed
PCBs in the sediments or water	Fish (accumulation of PCBs from the sediments and water)	Fish	Ingestion	Adults and children that eat fish from the main branch of Ruddiman Creek and Pond	Past Present Future	Completed

Sediment Dermal Contact and Ingestion Exposure Pathway

Residents that use the Main Branch of Ruddiman Creek and the pond for activities could make direct (dermal) contact with sediments. However, adults and children are expected to have limited or no contact with sediments in the pond due to the depth, which is between 3.7 and 20.5 feet (Battelle 2009), and the vegetation along the edge growing up to the waterline.

The 95% UCL is an upper estimate of the chemical levels people wading in Ruddiman Pond are likely to encounter. The UCL was calculated[4] using pond sediment samples taken from areas with a 9.5 foot or less water depth. That water depth was selected based on children's and adult's average heights preventing them from touching the sediment, and included the possibility of water levels dropping. Using tables compiled from the Centers for Disease Control and Prevention (CDC) National Center for Health Statistics, the 50th percentile height for boys and girls at age 12 is approximately four feet eleven inches. Younger children would be shorter. Even at age 18, the 50th percentile for boys and girls heights are five feet nine inches and five feet four inches, respectively (CDC 2001).

Although the levels of benzo(a)pyrene and other PAHs present in many of the sediment samples from Ruddiman Pond and the Main Branch of Ruddiman Creek are over the screening levels, several conditions could reduce people's exposure. One is that PAHs, in general, absorb strongly on suspended particulates and biota (EPA 2003). This means that not all of the PAHs present in any sediment stuck to the skin will be absorbed, as it first would need to separate from the

[4] Both the mean and 95% UCL were calculated using the EPA's ProUCL 4.1. This software is available at: http://www.epa.gov/osp/hstl/tsc/software.htm.

sediment. Although levels of these PAHs are higher than the screening levels, the barriers of sample location (six inches under the sediment-water boundary for the 2008 samples) and factors that reduce the absorption of benzo(a)pyrene and other PAHs, would reduce the amount of chemicals that people would be exposed to.

The UCL for lead was below the screening level for lead in the pond sediment collected in 2008 (353 ppm), but above the screening level for the sediment collected in 2012 (553 ppm). A mean of 318 ppm and a UCL of 412 ppm results from combining lead levels from the 2008 and 2012 sediment samplings.[5] Although the combined UCL is slightly over the screening level, the mean is not. The UCL is expected to represent the largest amount of lead that people are exposed to while wading in the pond. Based on the exposure and the mean being under the screening level, people are not expected to be exposed to lead levels that would harm their health.

Several PAHs measured in pond sediment collected in 2008 had UCLs over the screening levels. The UCLs were: 2 ppm for benzo(a)pyrene, 2.5 ppm for benzo(b)fluoranthene, 0.5 ppm for dibenz(a,h)anthracene, and 2.5 ppm for indeno(1,2,3-cd)pyrene. These PAHs were not detected in the four sediment samples collected in 2012.

People might more easily encounter sediment present at the bottom of the Main Branch of Ruddiman Creek, which only has a depth of 0.5 to 3.6 feet (Battelle 2009). Five of the seven samples over the lead screening level (ranging from 413 to 971 ppm) were within 400 meters of the pond. All of the benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene levels from the samples taken in this area were over the screening levels (except for benzo(a)anthracene levels in one sample). The water depths ranged from 1.5 to 3.8 feet. Children younger than age 12 (average heights are less than 4.5 feet) are expected to have limited contact with sediments in this area due to the depth of the Main Branch of Ruddiman Creek.

The remaining two exceedences (546 and 971 ppm) of the lead screening level and all other exceedences of the PAH (for benzo[a]anthracene, benzo[a]pyrene, benzo[b]fluoranthene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene) screening levels were located throughout the rest of the Main Branch of the creek. The water depths for these sample locations ranges from 0.5 to 2.2 feet. Children would be able to walk easily in most of this stretch of the Main Branch of the creek. However, people’s contact with contaminants in sediments from this stretch of the Main Branch is limited by two factors. First, these contaminant levels were from sediment sampled up to six inches below the sediment-water boundary (for the 2008 samples). Second, people’s contact with the creek sediments is limited by Michigan weather. Due to snow, ice, and cold temperatures, contact with the sediments is not expected to occur for at least four months out of the year. The three summer months are when people are most expected to have contact with the sediments.

The lead exceedences in the Main Branch of Ruddiman Creek were in only seven of the sample locations and do not represent the lead levels in a majority of the sediment samples. The mean

[5] The 2008 pond samples from areas with a water depth of 9.5 feet or less were combined with all of the 2012 pond sediment samples.

lead value from the Main Branch of Ruddiman Creek is 211 ppm and the UCL is 407 ppm. The mean is below the screening level and the UCL is approximately equal to the screening level. The maximum level from the 2012 sediment sampling (320 ppm) was under the screening level of 400 ppm. Based on these lead values and taking into account other factors discussed in this section, lead present in sediments from the Main Branch of Ruddiman Creek is not expected to harm the health of children or adults.

Fish Ingestion Exposure Pathway

Fishing in Ruddiman Pond or the Main Branch of the creek would allow people to encounter PCBs and other contaminants present in the fish all year round. MDCH has fish consumption guidelines for carp and largemouth and smallmouth bass in Ruddiman Pond and Creek due to the presence of PCBs. These guidelines recommend that no one eat carp and that no one eat more than 6 MI Servings a year of largemouth or smallmouth bass from Ruddiman Pond or Creek. (A MI Serving is about six to eight ounces for adults and two to four ounces of fish for children.) Other fish species that might be caught from Ruddiman Pond or Creek are included in the Statewide Safe Fish Guidelines. Following the guidelines in the Eat Safe Fish Guide will reduce the amount of PCBs that people eat. See www.michigan.gov/eatsafefish for the most current guidelines and for more information.

Contaminants without Screening Levels

Benzo(e)pyrene and perylene are PAHs. Maximum levels of these two chemicals were below 10.0 ppm in the sediment. This maximum value are is between 1.5 and 1500 times below most of the screening levels for other PAHs. Due to the low amounts of these chemicals present, it is expected that exposure, if it occurs, will not harm people's health.

Although oil and grease levels in the sediments range from 180 to 32,000 ppm, no health effects are linked to specific levels of uncharacterized oil and grease. A value of 2,000 ppm has been used in EPA and joint EPA and MDEQ reports to indicate sediments that are heavily polluted (Collier and Cieniawski 2003; EPA 2009B). All 21 sediment samples from the pond were above 2,000 ppm and six of the 21 samples from the Main Branch were above 2,000 ppm (Battelle 2009). There have been several historic spills of oil into the Main Branch of Ruddiman Creek. Oil in the sediment may remain from historic spills that were not adequately cleaned up (T. Berdinski, MDEQ, personal communication). It is possible that this oil and grease is from individuals dumping items, such as motor oil, into the storm drains or from water (with oil) running off parking lots. People could develop a temporary skin irritation from contact with an oily sheen on the water. People may want to avoid contact with water that has an oily sheen or odor.

Toxicological Evaluation

As discussed in the Exposure Pathways Analysis section, people are not expected to come into contact with levels of lead that may result in health effects. For reference information on health effects of lead see Appendix D. This toxicological evaluation includes benzo(a)pyrene, other PAHs, PCB Aroclor 1254, and oil and grease.

Benzo(a)pyrene and other PAHs

All of the PAHs over the screening levels (benzo[a]anthracene, benzo[b]fluoranthene, dibenz[a,h]anthracene, indeno[1,2,3-cd]pyrene) are thought to act the same in people's bodies to cause health effects. This allows these chemicals to be evaluated using benzo(a)pyrene (BaP) equivalent factors, relating all of them to an equivalent amount of benzo(a)pyrene. After multiplying these factors with the measured levels in the sediment, they can be added together to obtain a total BaP equivalent amount. (Additional details are in Appendix D.) Because of this, the focus of the discussion below is on benzo(a)pyrene.

Although the levels of benzo(a)pyrene present in many of the sediment samples from Ruddiman Pond and the Main Branch of Ruddiman Creek are elevated, several conditions specific to PAHs, and benzo(a)pyrene in particular, could reduce people's exposure. First, not all benzo(a)pyrene present in the sediment adhering to the skin will be absorbed. Second, for benzo(a)pyrene to be bioavailable (available to absorb in people's skin), it first needs to desorb (be released) from the sediments. PAHs, in general, adsorb strongly on suspended particulates and biota (EPA 2003). In addition, as sediments age, less of the PAHs that are present are available (Leppanen and Kukkonen 2000; Schuler and Lydy 2001). Because of these factors, the dermal route is not expected to be a significant exposure route (EPA 2003). The main way that people will be exposed to benzo(a)pyrene and other PAHs is through accidental eating of sediment (incidental ingestion).

For the pond or creek sediment, children and adults may ingest up to 0.002 micrograms per kilogram-day (µg/kg-day) of a BaP equivalent amount.[6] This amount overestimates people's exposure to these PAHs. The maximum level for all PAHs with BaP equivalent factors were used (see the tables in Appendix C) and people were assumed to only ingest the sediment, no other soil for the summer (90 days). Even though these values overestimate people's exposure, the possible cancer risk is not elevated from this exposure.[7]

Benzo(e)pyrene and perylene are two PAHs detected that do not have screening levels. Maximum levels and 95% UCL for these two chemicals were below 10.0 ppm in the sediment. These values are between 1.5 and 1500 times below most of the screening levels for other PAHs. Due to the low amounts of these chemicals present, it is expected that exposure, if it occurs, will not harm people's health.

Aroclor 1254

Both the maximum level and the UCL for Aroclor 1254 in the Main Branch of Ruddiman Creek sediments, collected in 2008, were over the screening level. Although these values were elevated, people are not expected to be exposed to levels of chemicals that would cause health

[6] This amount assumes that all of the soil people ingest in a day is from the sediment. To calculate this amount, a 50 kilogram body weight was used for children, representing ages 6 to 16. Children were exposed for 90 days out of the year for 10 years. See Appendix D for further information.

[7] The EPA uses a cancer risk range of one extra case in 1,000,000 to one extra case in 10,000 exposed individuals. The MDEQ uses a cancer risk of one extra case in 100,000 exposed individuals. The possible cancer risk from this exposure, which is an overestimate of the possible exposure, is less than two extra cases in 100,000 exposed individuals.

effects. People may ingest up to 0.0003 µg/kg-day of Aroclor 1245.[6] This amount is about six times below the Agency for Toxic Substances and Disease Registry's (ATSDR) PCB chronic oral Minimal Risk Level (MRL) of 0.02 µg/kg-day. The MRL is an estimate of the daily human exposure to PCBs that is likely to be without appreciable risk of adverse health effects during a year or longer of exposure.

Oil and Grease

Although oil and grease levels in the sediments range from 180 to 32,000 ppm, no health effects are linked to specific levels of uncharacterized oil and grease. A value of 2,000 ppm has been used in EPA and joint EPA and MDEQ reports to indicate sediments that are heavily polluted (Collier and Cieniawski 2003; EPA 2009B). All 21 sediment samples from the pond were above 2,000 ppm and six of the 21 samples from the Main Branch were above 2,000 ppm (Battelle 2009).

There have been several historic spills of oil into the Main Branch of Ruddiman Creek. Oil in the sediment may remain from historic spills that were not adequately cleaned up (T. Berdinski, MDEQ, personal communication). It is possible that this oil and grease is from individuals dumping items, such as motor oil, into the storm drains or from water (with oil) running off parking lots. People could develop a temporary skin irritation from contact with an oily sheen on the water. People may want to avoid contact with water that has an oily sheen or odor.

<u>Children's Health Considerations</u>

Children could be at greater risk as compared to adults from certain kinds of exposure to hazardous substances. Children play outdoors and sometimes engage in hand-to-mouth behaviors that increase their exposure potential. This site may be an attractive location to play, especially during the summer months. Children may play in the area around the pond and may wade into shallow areas of the creek to retrieve lost items or for other recreational purposes. In most areas, they would not have contact with sediment in the pond due to depth and may not wade in areas of the creek deeper than knee height (a couple feet).

Children are shorter than adults; this means they breathe dust, soil, and vapors close to the ground. However, the depth of the pond would limit their exposure to sediment in the pond and deeper areas of the creek. A child's lower body weight and higher intake rate results in a greater dose of hazardous substance per unit of body weight. Because of this the Michigan's Eat Safe Fish Guidelines uses serving sizes smaller (about two to four ounces) than an adult's serving (about six to eight ounces). This recommendation prevent children from have too high of exposure levels. If toxic exposure levels are high enough during critical growth stages, the developing body systems of children can sustain permanent damage.

Certain contaminants of concern, such as lead, produce greater adverse effects in children as compared to adults. Although children have both increased absorption and increased susceptibility to these contaminants, at this site, children are not exposed to levels of lead that would cause health concerns.

Community Health Concerns

While members of the community have not shared specific health concerns, there have been anecdotal reports of community members questioning whether the EPA-directed cleanup actually improved conditions in the Ruddiman Pond and the Main Branch of Ruddiman Creek. Community members were concerned that the levels of remaining chemicals could harm their health. This health assessment provides an update to community members that may be using this area for recreational activities.

Conclusions

MDCH concludes that contaminated sediments in Ruddiman Pond will not harm people's health. Although levels of certain chemicals (lead and PAHs) were above the screening levels in some samples, people's exposure to these chemicals will be limited and is therefore not expected to cause health effects. The water depth of the pond ranged from 3.7 to 20.5 feet, which will reduce people's exposure to chemicals in the sediment, especially children.

MDCH concludes that contaminated sediment in the Main Branch of Ruddiman Creek is not expected to harm people's health. Although levels of PAHs, lead, and Aroclor 1254 (PCBs) are elevated in certain locations in the creek with low water depth, people are not expected to have enough exposure to these chemicals to cause health effects. Lead, benzo(a)pyrene, and Aroclor 1254 levels are not uniformly elevated throughout the creek.

MDCH concludes that contact with oil and grease sheen on Ruddiman Pond or the Main Branch of the creek could cause temporary health effects, such as skin irritation. Sheen from oil or grease may be on the water from urban runoff. Contact with the sheen could cause skin irritation or other temporary health effects.

MDCH concludes that if people follow the Eat Safe Fish Guide, eating fish from Ruddiman Pond and the Main Branch of the creek will not harm their health. Although levels of PCBs in the sediment have decreased, fish in Ruddiman Pond and the Main Branch of the creek still have levels of PCBs to prompt consumption guidelines. Along with the waterbody-specific guidelines, other fish from these waters are included in Michigan's Statewide Safe Fish Guidelines. See www.michigan.gov/eatsafefish for the most current guidelines and for more information.

Recommendations

Maintain notice at storm drains cautioning against dumping of items, such as oil and grease, that could contaminate the watershed.

Avoid contact with oil and grease sheen on the water.

Collect fish from Ruddiman Pond and/or the Main Branch of Ruddiman Creek for analysis of PCBs.

Public Health Action Plan

Storm drains in the area were labeled at one time, but the group that did so is unknown as is the current status of the labeling (funding may not be available).

The MDNR and MDEQ will collect fish from Ruddiman Pond. MDCH will update the fish consumption guidelines accordingly.

Report Preparation

This Public Health Assessment was prepared by the Michigan Department of Community Health under a cooperative agreement with the federal Agency for Toxic Substances and Disease Registry (ATSDR). It is in accordance with the approved agency methods, policies, procedures existing at the date of publication. Editorial review was completed by the cooperative agreement partner. ATSDR has reviewed this document and concurs with its findings based on the information presented. ATSDR's approval of this document has been captured in an electronic database, and the approving agency reviewers are listed below.

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Appendix A: Contaminant levels in Ruddiman Pond and the Main Branch of Ruddiman Creek during dredging and remediation.

This appendix describes the dredging, post-dredging sampling, and reconstruction of Ruddiman Pond and the Main Branch of Ruddiman Creek. This work was overseen by the EPA and the MDEQ because Ruddiman Pond is connected to the Muskegon Lake Area of Concern (AOC). The main branch had a depth ranging from one to seven feet and a width ranging from 10 to 60 feet. Both the width and depth increase during heavy rain events and spring thaw. Ruddiman Pond had an average depth of nine feet. The pond is approximately 2,200 feet long and has an average width of 142 feet. Mechanical dredging was done to remove certain areas of contaminated sediment from both Ruddiman Pond and the main branch of the creek (Earth Tech 2006).

Based on contaminant levels indicating that the sediments had elevated levels of volatile organic chemicals (VOCs), polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and metals, criteria were set identifying levels to be met during the remediation. These contaminants represented the range of contamination present in the sediments of Ruddiman Pond and Creek. Table A-1 presents the criteria that, if met, would trigger dredging in that location. Dredging would continue until contaminant levels were below the criteria.

Table A-1: Dredging criteria (in parts per million [ppm]) for sediment in Ruddiman Pond and the Main Branch of Ruddiman Creek (Earth Tech 2006).

Contaminant	Dredging level (in ppm)
Cadmium	10.0
Chromium	400
Lead	900
Polychlorinated biphenyls (PCBs)	1.00
Benzo(a)pyrene	16.0

Temporary structures (roads and a pier) were built to allow access for the dredging equipment. Additional structures were placed in the Main Branch of Ruddiman Creek to slow peak water velocity and sediment erosion. The pond and the main branch of the creek were divided into different areas for dredging. Table A-2 presents the dredging parameters for the Main Branch of Ruddiman Creek. Table A-3 presents guidelines for cover depth after dredging for both the Main Branch of Ruddiman Creek and Ruddiman Pond.

Table A-2: Dredging dimensions and total volume (in cubic yards [yds^3]) dredged in the Main Branch of Ruddiman Creek (Earth Tech 2006).

<table>
<tr><th>Area</th><th>Length (in feet)</th><th>Width (in feet)</th><th>Depth (in feet)</th><th>Volume dredged (in yds^3)[a]</th></tr>
<tr><td>I</td><td>70</td><td>15</td><td>3</td><td rowspan="4">6,792</td></tr>
<tr><td>H1</td><td>35</td><td>15</td><td>3</td></tr>
<tr><td>H2</td><td>215</td><td>15</td><td>7</td></tr>
<tr><td>G</td><td>210</td><td>170</td><td>7 to 11</td></tr>
<tr><td>F1</td><td>150</td><td>10</td><td>5</td><td rowspan="2">490</td></tr>
<tr><td>F2</td><td>150</td><td>10</td><td>7</td></tr>
<tr><td>E1</td><td>169</td><td>15</td><td>1</td><td rowspan="2">298.6</td></tr>
<tr><td>E2</td><td>50</td><td>15</td><td>1</td></tr>
<tr><td>C1</td><td>310</td><td>30</td><td>4</td><td rowspan="3">2,623</td></tr>
<tr><td>C2</td><td rowspan="2">480</td><td rowspan="2">30</td><td rowspan="2">1.5</td></tr>
<tr><td>C3</td></tr>
<tr><td>D1</td><td>175</td><td>20</td><td>1.5</td><td rowspan="3">1,485</td></tr>
<tr><td>D2</td><td>275</td><td>15</td><td>2</td></tr>
<tr><td>D3</td><td>275</td><td>15</td><td>6</td></tr>
<tr><td>B1</td><td>280</td><td>40</td><td>4</td><td rowspan="2">2,038</td></tr>
<tr><td>B2</td><td>280</td><td>10</td><td>6</td></tr>
</table>

a = total volume of contaminated sediments removed was 14,472 yd^3 (differences in this table and that total volume are due to agreed upon estimates between Earth Tech and Environmental Quality, Inc [Emergency and Rapid Response Services contractors to the regulatory agencies])

After dredging, Area G was covered with three feet of sand and then stone. Areas H and I were covered with sand and stone before receiving the results of the post-dredging sampling. Additional cover, several feet of sand and stone, was added to certain spots within areas H and I after receiving the results of the sampling (mean PCB concentrations were above site-specific cleanup criteria). After dredging, areas F1, F2, E1, and E2 were covered with sand and stone. Areas C1, C2, C3, D1, D2, and D3 were covered with a reduced amount of cover (six inches of sand and/or six inches of stone) due to the softness of the sediment. Six inches of sand was the only cover placed on Areas B1 and B2, due to the softness of the sediment.

Table A-3: Guidelines for sand and stone cover (in feet) added after dredging in Ruddiman Pond and the Main Branch of Ruddiman Creek (Earth Tech 2006).

Dredge Depth (feet)	Cover Sand Thickness (feet)	Cover Stone Thickness (feet)
1.0	0.5	0.5
1.5	1.0	0.5
2.0	1.5	0.5
3.0	2.5	0.5
>3.0	3.0	0.5

Ruddiman Pond was dredged between August 2005 and May 2006. The pond was divided into five areas for dredging. Table A-4 contains the dimensions for dredging, dredging depth, and total volume dredged in Ruddiman Pond.

Table A-4: Dredging dimensions and total volume (in cubic yards [yds^3]) dredged in Ruddiman Pond (Earth Tech 2006).

Area	Length (in feet)	Width (in feet)	Depth (in feet)	Volume dredged (in yds^3)
A1	124	88	4	75,398
A2	633	125	9 to 11	
A3	658	111	9 to 11	
A4	259	43	6	
A5	647	102	3 to 7	

All of the five areas in Ruddiman Pond were covered with six inches of sand and six inches of stone after dredging was completed. Certain areas of the pond were covered by an extra six inches of sand. As occurred during the creek dredging, samples were taken after the initial depth was dredged to confirm dredging criteria (Table A-1) were met for the dredging location.

Table A-5 contains the maximum level of contaminants in Ruddiman Pond and the Main Branch sediment after the initial dredge. Some of the locations where elevated levels of chemical were identified were dredged further; other locations had extra cover added, but no additional dredging.

Table A-5: Maximum levels of contaminants (in parts per million [ppm]) present in Ruddiman Pond and the Main Branch of Ruddiman Creek sediments collected during remediation activities, from October 2005 to May 2006 (Earth Tech 2006).

Contaminants measured after dredging	Maximum level in pond sediment in ppm	Maximum level in main branch sediment in ppm
Cadmium	26.0	26.87
Chromium	2,803	2,404
Lead	1,430	1,165
Benzo(a)pyrene	14.0	17.0
Polychlorinated biphenyls (PCBs)	4.60	8.20

After all of the dredging was complete, the entire area was restored by removing temporary structures that facilitated the dredging, grading the excavation areas, restoring creek flow, and planting vegetation or seeding in the disturbed areas. Additional information about these activities can be found at www.epaosc.org/RuddimanCreek.

Appendix B: Screening Levels.

Chemicals in the sediment were compared to the screening levels calculated using the EPA's Online Screening Levels Calculator (see below Table B-1 for more details). Larger amounts of sediment, compared to soil, are expected to stick to people's skin because the sediment is saturated with water. The screening levels were calculated for sediment exposure (increased adherence factor, reduced ingestion for adults, and a 90 day exposure). The risk for carcinogens was set at one in 100,000 to match the default value used by the Michigan Department of Environmental Quality. These values include dermal (skin) contact, ingestion (eating), and inhalation (breathing) of chemicals. If the screening levels could not be calculated, the ATSDR soil comparison value was used. ATSDR soil comparison values are conservative, non-site specific, and only account for ingestion of chemicals. They are based on health guidelines with uncertainty or safety factors applied to ensure that they are adequately protective of public health. If no ATSDR value was available, the MDEQ Residential Direct Contact Criteria were used. The generic Residential Direct Contact Criteria (RDCC) identifies a soil concentration that is protective against adverse health effects to adults and children due to long-term, daily ingestion of and dermal exposure to contaminated soil.

Table B-1: Screening levels in parts per million (ppm).

Analyte	Screening level (ppm)	Source
1-Methylnaphthalene	122	Site-specific RSLs[a]
2-Methylnaphthalene	200	ATSDR RMEG[b]
Acenaphthene	3,000	ATSDR RMEG
Acenaphthylene	1,600	MDEQ RDCC[c]
Anthracene	15,000	ATSDR RMEG
Arsenic	11	Site-specific RSLs
Barium	10,000	ATSDR RMEG
Benzo(a)anthracene	1.5	Site-specific RSLs
Benzo(a)pyrene	0.096	ATSDR CREG[d]
Benzo(b)fluoranthene	1.5	Site-specific RSLs
Benzo(e)pyrene	NA[e]	--
Benzo(g,h,i)perylene	2,500	MDEQ RDCC
Benzo(k)fluoranthene	15	Site-specific RSLs
Cadmium	25	ATSDR RMEG
Chromium	75,000	ATSDR RMEG
Chrysene	150	Site-specific RSLs
Copper	500	ATSDR EMEG[f]
Dibenz(a,h)anthracene	0.15	Site-specific RSLs
Fluoranthene	2,000	ATSDR RMEG
Fluorene	2,000	ATSDR RMEG
Indeno(1,2,3-cd)pyrene	1.5	Site-specific RSLs
Lead	400	Site-specific RSLs
Mercury	160	MDEQ RDCC
Naphthalene	1,000	ATSDR RMEG
Nickel	1,000	ATSDR RMEG
Oil & Grease	2,000	EPA[g]
PCBs - Aroclor 1016	3.5	ATSDR RMEG
PCBs - Aroclor 1221	2.3	Site-specific RSLs
PCBs - Aroclor 1232	2.3	Site-specific RSLs

Table B-1 continued		
Analyte	Screening level (ppm)	Source
PCBs - Aroclor 1242	2.3	Site-specific RSLs
PCBs - Aroclor 1248	2.3	Site-specific RSLs
PCBs - Aroclor 1254	1.0	ATSDR RMEG
PCBs - Aroclor 1260	2.3	Site-specific RSLs
PCBs - Aroclor 1262	NA	--
PCBs - Aroclor 1268	NA	--
Perylene	NA	--
Phenanthrene	1,600	MDEQ RDCC
Pyrene	1,500	ATSDR RMEG
Selenium	250	ATSDR RMEG
Silver	250	ATSDR RMEG
Zinc	15,000	ATSDR RMEG

a = The screening level was calculated using the EPA's site-specific Regional Screening Levels calculator (Site-specific RSLs).
b = The screening levels is the Agency for Toxic Substances and Disease Registry's Reference Dose Media Evaluation Guide (ATSDR RMEG).
c = The screening level is the Michigan Department of Environmental Quality Residential Direct Contact Criterion (MDEQ RDCC).
d = The screening levels is the Agency for Toxic Substances and Disease Registry's Cancer Risk Evaluation Guide (ATSDR CREG).
e = A screening levels is not available (NA).
f = The screening levels is the Agency for Toxic Substances and Disease Registry's Environmental Media Evaluation Guide (ATSDR EMEG).
g = The screening level is from the EPA (2009B). This is not a health-based screening level.

The EPA's Online Screening Levels Calculator can be accessed at: http://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search. A soil/sediment recreational use was selected and default values were used for the parameters not listed below.

- Adherence Factor (AF; in milligrams per centimeter squared): 2.7 for ages 0-2, 2.7 for ages 2-6, 0.3 for ages 6-16, and 0.3 for ages 16-30
- Body Weight (BW; in kilograms): 15 for ages 0-2, 15 for ages 2-6, 50 for ages 6-16, and 70 for ages 16-30
- Exposure Frequency (EF; in days per year): 90 for all ages
- Exposure Time (ET; in hours per event): 0.5 for ages 0-2, 1 for ages 2-6, 1 for ages 6-16, and 0.5 for ages 16-30
- Surface Area (SA; in centimeter squared per day):2670 for ages 0-2, 2670 for ages 2-6, 5800 for ages 6-16, and 5800 for ages 16-30
- Target Cancer Risk (unitless):1 x 10^{-5} for all ages

Appendix C: Maximum concentrations of contaminants from post-remediation sampling in 2008 and 2012.

The tables in this appendix contain the maximum levels for all contaminants tested in sediment and semipermeable membrane devices (SPMD) during the post-remediation sampling (both the 2008 and 2012) in Ruddiman Pond and the Main Branch of Ruddiman Creek (Battelle 2009).

For most of the following tables, the 95% upper confidence limit (UCL) of the mean was included[8] along with the maximum concentration. The UCL is a more conservative value to use than the mean, but it is an upper estimate of levels of chemicals people may encounter as they wade in the water. Not all pond sediment samples were used for this calculation, as not all areas of the pond would be accessible due to water depth. Fifteen to seventeen samples from areas where the water depth was 9.5 feet or less were used in this calculation. Based on tables compiled from the Centers for Disease Control and Prevention (CDC)'s National Center for Health Statistics, the 50th percentile height for boys and girls at age 12 is approximately four feet eleven inches. Younger children would be shorter. Even at age 18, the 50th percentile for boys and girls heights are five feet nine inches and five feet four inches, respectively (CDC 2001). Samples were included from areas with water depths of 9.5 feet or less to include areas that may be accessible during low water levels. All samples were included to calculate the UCL for the Main Branch of Ruddiman Creek sediment samples.

If maximum chemical levels were above the screening levels, the chemicals were evaluated in the Environmental Contamination section in the main body of this document. (See Appendix B for more information about the screening levels.)

2008: Sediment sampling

In November 2008, up to 27 surficial sediment samples were collected from Ruddiman Pond and up to 28 surficial sediment samples were collected from the Main Branch of Ruddiman Creek and analyzed for several chemicals (Battelle 2009). The sediment collected went to a depth of approximately six inches below the sediment-water interface. Table C-1 presents levels of eight metals and oil and grease, Table C-2 presents the levels of polychlorinated biphenyls (PCBs), and Table C-3 presents the levels of polycyclic aromatic hydrocarbons (PAHs) in the sediments.

[8] Both the mean and 95% UCL were calculated using the EPA's ProUCL 4.1. This software is available at: http://www.epa.gov/osp/hstl/tsc/software.htm.

Table C-1: Maximum values (in parts per million [ppm]) of metals and oil and grease in the sediments of the Ruddiman Pond and the Main Branch of the creek, November 2008 (Battelle 2009).

Contaminant	Screening level (in ppm)[a]	Maximum value in main branch sediments (in ppm)	95% UCL for main branch sediments (in ppm)	Maximum value in pond sediments (in ppm)	95% UCL for pond sediments (in ppm)
Oil & Grease	2,000	**24,000**	7,627	**38,000**	15,612
Arsenic	11	**12.5**	6.6	**16.1**	10.0
Cadmium	25	23.9	NC[b]	23.9	NC
Chromium	75,000	2,250	NC	1,480	NC
Copper	500	316	NC	259	NC
Lead	400	**971**	**407**	**1,410**	353
Mercury	160	0.26	NC	0.54	NC
Nickel	1,000	146	NC	100	NC
Zinc	15,000	1,200	NC	1,570	NC

Bold values are those exceeding the screening level.
a = See Appendix B for more information on the screening levels.
b = The 95% UCL was not calculated for these chemicals as the maximum level was not over the screening level.

Table C-2: Maximum values (in parts per million [ppm]) of polychlorinated biphenyls (PCBs) in the sediments of the Ruddiman Pond and the Main Branch of the creek, November 2008 (Battelle 2009).

Polychlorinated biphenyls (PCBs)[a]	Screening level (in ppm)[b]	Maximum value in main branch sediments (in ppm)	95% UCL for main branch sediments (in ppm)	Maximum value in pond sediments (in ppm)	95% UCL for pond sediments (in ppm)
PCBs - Aroclor 1254	1.0	**3.3**	**2.2**	**2.7**	0.7
PCBs - Aroclor 1260	1.7	1.4	NC[d]	ND[c]	NC

Bold values are those exceeding the screening level.
a = Aroclor 1016, 1221, 1232, 1242, 1248, 1260, 1262, and 1268 were not detected in the samples.
b = See Appendix B for more information on the screening levels.
c = PCBs, based on Aroclor 1260 standard, were not detected
d = The 95% UCL was not calculated for these chemicals as the maximum level was not over the screening level.

Table C-3: Maximum values (in parts per million [ppm]) of polycyclic aromatic hydrocarbon (PAHs) in the sediments of the Ruddiman Pond and the Main Branch of the creek, November 2008 (Battelle 2009).

Polycyclic aromatic hydrocarbon (PAHs)	Screening level (in ppm)[a]	Maximum value in main branch sediments (in ppm)	95% UCL for main branch sediments (in ppm)	Maximum value in pond sediments (in ppm)	95% UCL for pond sediments (in ppm)
1-Methylnaphthalene	122	0.4	NC[b]	0.4	NC
2-Methylnaphthalene	200	1.0	NC	0.8	NC

Table C-3 continued					
Polycyclic aromatic hydrocarbon (PAHs)	Screening level (in ppm)[a]	Maximum value in main branch sediments (in ppm)	95% UCL for main branch sediments (in ppm)	Maximum value in pond sediments (in ppm)	95% UCL for pond sediments (in ppm)
Acenaphthene	3,000	1.0	NC	0.3	NC
Acenaphthylene	1,600	0.1	NC	0.1	NC
Anthracene	15,000	2.6 (D)[c]	NC	0.6	NC
Benzo(a)anthracene	1.5	**9.3** (D)	**3.3**	**3.8**	1.3
Benzo(a)pyrene	0.15	**10.6** (D)	**4.1**	**6.7**	**2.0**
Benzo(b)fluoranthene	1.5	**10.7** (D)	**4.3**	**8.6** (D)	**2.5**
Benzo(e)pyrene	NA[d]	8.0 (D)	3.6	6.9 (D)	3.3
Benzo(g,h,i)perylene	2,500	8.1 (D)	NC	7.4 (D)	NC
Benzo(k)fluoranthene	15	10.9 (D)	NC	7.3	NC
C1-Chrysenes *	NA[d]	3.8	NC	3.7	NC
C1-Fluoranthenes/Pyrenes*	NA[d]	7.3	NC	5.4	NC
C1-Fluorenes*	NA[d]	0.6	NC	0.5	NC
C1-Naphthalenes*	NA[d]	0.9	NC	0.7	NC
C1-Phenanthrenes/Anthracenes*	NA[d]	5.3	NC	2.2	NC
C2-Chrysenes*	NA[d]	2.7	NC	4.5	NC
C2-Fluoranthenes/Pyrenes*	NA[d]	7.4	NC	4.3	NC
C2-Fluorenes*	NA[d]	1.8	NC	1.7	NC
C2-Naphthalenes*	NA[d]	1.4	NC	1.2	NC
C2-Phenanthrenes/Anthracenes*	NA[d]	3.6	NC	3.8	NC
C3-Chrysenes*	NA[d]	2.0	NC	3.5	NC
C3-Fluoranthenes/Pyrenes*	NA[d]	3.8	NC	4.0	NC
C3-Fluorenes*	NA[d]	3.3	NC	3.0	NC
C3-Naphthalenes*	NA[d]	1.6	NC	1.5	NC
C3-Phenanthrenes/Anthracenes*	NA[d]	6.1	NC	4.8	NC
C4-Chrysenes*	NA[d]	1.1	NC	1.6	NC
C4-Naphthalenes*	NA[d]	2.6	NC	1.9	NC
C4-Phenanthrenes/Anthracenes*	NA[d]	4.4	NC	3.1	NC
Chrysene	150	12.2 (D)	NC	9.2 (D)	NC
Dibenz(a,h)anthracene	0.15	**2.1** (D)	**0.9**	**1.7**	**0.5**
Fluoranthene	2,000	28.5 (D)	NC	18.0 (D)	NC
Fluorene	2,000	1.2	NC	0.5	NC
Indeno(1,2,3-cd)pyrene	1.5	**9.4** (D)	**4.1**	**8.2** (D)	**2.5**
Naphthalene	1,000	0.7	NC	0.5	NC
Perylene	NA[d]	2.9 (D)	1.2	2.0	1.4
Phenanthrene	1,600	17.2 (D)	NC	5.7	NC
Pyrene	1,500	22.9 (D)	NC	14.6 (D)	NC

Bold values are those exceeding the screening level
* = alkylated PAHs, used to determine ecological risk only
a = See Appendix B for more information on the screening levels.
b = The 95% UCL was not calculated (NC) for these chemicals as the maximum level was not over the screening level or there is no screening level.
c = The (D) indicates that the sample was diluted for analysis.
d = Screening levels were not available (NA) for this chemical.

2012: Sediment sampling

In the summer of 2012, the MDEQ and the EPA sampled sediment (grab samples collected with a petite ponar dredge) from the main branch of Ruddiman Creek and Ruddiman Pond. Sediment samples were tested for10 metals, PCBs, and PAHs (MDEQ 2014).

Eleven sediment samples from both the main branch and the pond were collected and analyzed for metals (see Table C-4). The 95% upper confidence limit (UCL) of the average was also calculated, using all of the samples.[9]

Table C-4: Maximum values (in parts per million [ppm]) of metals in the sediments of the Ruddiman Pond and the Main Branch of the creek, summer 2012 (MDEQ 2014).

Metals	Screening level (ppm)[a]	Maximum value in main branch sediments (in ppm)	95% UCL for main branch sediments (in ppm)	Maximum value in pond sediments (in ppm)	95% UCL for pond sediments (in ppm)
Arsenic	11	7.5	5.8	11	10.3
Barium	1,000	180	NC[b]	240	NC
Cadmium	25	12	NC	21	NC
Chromium	75,000	350	NC	790	NC
Copper	500	150	NC	180	NC
Lead	400	320	NC	**960**	**553**
Mercury	160	0.4	NC	0.96	NC
Selenium	250	2.3	NC	3.4	NC
Silver	250	10	NC	19	NC
Zinc	15,000	970	NC	1,300	NC

Bold values are those exceeding the screening level.
a = See Appendix B for more information on the screening levels.
b = The 95% UCL was not calculated (NC) for these chemicals as the maximum level was not over the screening level.

Eleven samples were analyzed for PCBs (Aroclor 1016, 1221, 1232, 1242, 1248, 1254, 1260, 1262, and 1268) in the main branch and 10 or 11 samples were analyzed in the pond. Table C-5 presents the maximum levels and 95% UCLs, when the maximum level was over the screening level, for PCBs in sediment.

[9] Both the mean and 95% UCL were calculated using the EPA's ProUCL 4.1. This software is available at: http://www.epa.gov/osp/hstl/tsc/software.htm.

Table C-5: Polychlorinated biphenyls (PCBs) measured (in parts per million [ppm]) in sediment samples from the main branch of the creek and Ruddiman Pond from the summer 2012 sampling (MDEQ 2014).

Polychlorinated biphenyls (PCBs)[a]	Screening level (in ppm)[b]	Maximum value in main branch sediments (in ppm)	95% UCL for main branch sediments (in ppm)	Maximum value in pond sediments (in ppm)	95% UCL for pond sediments (in ppm)
Aroclor 1254	1.0	**1.2**	0.8	0.99	NC[c]
Aroclor 1260	1.66	0.87	NC	0.84	NC

Bold values are those exceeding the screening level.
a = Aroclor 1016, 1221, 1232, 1242, 1248, 1262, and 1268 were not detected in the samples
b = See Appendix B for more information on the screening levels.
c = The 95% UCL was not calculated (NC) for these chemicals as the maximum level was not over the screening level.

Sediment samples (three from the Main Branch of Ruddiman Creek and four from Ruddiman Pond) were analyzed for polycyclic aromatic hydrocarbons (PAHs). There were not enough samples to calculate 95% UCLs, so Table C-6 only presents the maximum levels of PAHs in the sediment.

Table C-6: Polycyclic aromatic hydrocarbons (PAHs) measured (in parts per million [ppm]) in sediment samples from the main branch of the creek and Ruddiman Pond from the summer 2012 sampling (MDEQ 2014).

PAHs	Screening level (ppm)	Maximum value in main branch sediments (in ppm)	Maximum value in pond sediments (in ppm)
2-Methylnaphthalene	200	ND[a]	ND
Acenaphthene	3000	ND	ND
Acenaphthylene	1600	ND	ND
Anthracene	15000	ND	ND
Benzo(a)anthracene	1.5	**6.5**	ND
Benzo(a)pyrene	0.096	ND	ND
Benzo(b)fluoranthene	1.5	0.63	ND
Benzo(g,h,i)perylene	2500	ND	ND
Benzo(k)fluoranthene	15	ND	ND
Chrysene	150	9.0	ND
Dibenz(a,h)anthracene	0.15	ND	ND
Fluoranthene	2000	24	19
Fluorene	2000	ND	ND
Indeno(1,2,3-c,d)pyrene	1.5	ND	ND
Naphthalene	1000	ND	ND

Table C-6 continued			
PAHs	Screening level (ppm)	Maximum value in main branch sediments (in ppm)	Maximum value in pond sediments (in ppm)
Phenanthrene	1600	7.6	ND
Pyrene	1500	20	17

Bold values are those exceeding the screening level.
a = See Appendix B for more information on the screening levels.
b = This chemical was not detected (ND) in any samples.

2008: Semi-permeable membrane devices

Semi-permeable membrane devices (SPMDs) were deployed on November 6, 2008 at four locations in in Ruddiman Pond and five locations in the Main Branch of Ruddiman Creek. The SPMD canister was stationed one foot above the sediment in the water column. The SPMDs canisters contained five shelves with a semi-permeable, solution-filled ribbon on each shelf (Battelle 2009). The SMPD canisters were collected on December 4, 2008 (28 days of exposure) and the solution in the ribbons was analyzed for PCBs (a total of 120 congeners) and 36 PAHs (Battelle 2009).

SPMDs can act as models for the bioconcentration (more chemicals present in the animals than in the environment) that can occur in animals (Chapman 2009). The solution added to the ribbons is similar to highly purified fish fat. The solution will accumulate similar lipid contaminants that fish or other animal fatty tissue accumulates (Chapman 2009). Thus, fish in Ruddiman Pond or the Main Branch of Ruddiman Creek are expected to accumulate PCBs similar to that detected in the SPMDs. SPMDs also contain a compound that is used to determine the amount of contaminants that go back into the water rather than stay in the solution in the ribbon (USGS 2004).

Table C-7 presents the maximum amount of contaminant per SPMD and the maximum amount calculated to be present in the water. As almost none of the PAHs data was suitable for calculating concentrations, the maximum concentration of PAHs calculated were from a single SPMD. The concentration of PCBs in water were calculated for eight of the SPMDs. The maximum calculated concentration of PAHs or PCBs in water was for fluoranthene (0.1 ppb). This value is half of the EPA's Maximal Contaminant Level for benzo(a)pyrene. It is not expected that large amounts of these chemicals will be present in surface water and that people would ingest enough of these chemicals to harm their health.

Table C-7: Maximum and calculated concentrations of contaminants in semipermeable membrane devices (SPMD) in the Main Branch of Ruddiman Creek and Ruddiman Pond (Battelle 2009).

Contaminant	Maximum amount of contaminant in SPMD (in microgram [µg]/sample)	Calculated concentration of contaminant in water (in parts per billion [ppb]) [a]
1-Methylnaphthalene[b]	0.3	0.003
2-Methylnaphthalene[b]	0.5	0.009
Acenaphthene	0.4	0.002
Acenaphthylene	0.1	0.0007
Anthracene	0.4	0.003
Benz(a)anthracene	3.0	0.01
Benzo(a)pyrene	3.3	0.01
Benzo(b)fluoranthene	5.4	0.02
Benzo(e)pyrene	4.2	0.02
Benzo(g,h,i)perylene	2.8	0.02
Benzo(k)fluoranthene	4.6	0.02
C1-chrysenes[b]	2.1	0.009
C1-fluoranthenes/pyrenes[b]	5.5	0.02
C1-fluorenes[b]	0.6	0.003
C1-naphthalenes[b]	0.5	0.006
C1-phenanthrenes/anthracenes[b]	3.8	0.02
C2-chrysenes[b]	1.2	0.007
C2-fluorenes[b]	2.0	0.01
C2-naphthalenes[b]	0.6	0.005
C2-phenanthrenes/anthracenes[b]	4.7	0.02
C3-chrysenes[b]	0.9	0.006
C3-fluorenes[b]	4.0	0.02
C3-naphthalenes[b]	2.1	0.009
C3-phenanthrenes/anthracenes[b]	4.7	0.02
C4-chrysenes[b]	0.4	0.006
C4-naphthalenes[b]	3.8	0.01
C4-phenanthrenes/anthracenes[b]	2.0	0.01
Chrysene	10.5	0.04
Dibenzo(a,h)anthracene	0.6	0.002
Fluoranthene	25.8	0.1
Fluorene	0.4	0.002
Indeno(1,2,3-cd)pyrene	3.3	0.01
Naphthalene	0.4	0.01
Polychlorinated biphenyls (PCBs)	1.2	0.04[c]
Phenanthrene	6.3	0.04
Pyrene	19.8	0.07

a = This value is calculated from amount of contaminant in one SPMD.
b = alkylated PAHs, used to determine ecological risk only
c = This is the maximum concentration calculated for total PCBs (sum of 120 PCB congeners) from 8 SPMDs.

Additional reference:

U.S. Geological Survey (USGS). 2004. Semipermeable Membrane Devices (SPMD). http://www.cerc.usgs.gov/pubs/center/pdfDocs/SPMD.pdf.

Appendix D: Toxicological evaluation of lead, additional discussion of benzo(a)pyrene and PAH chemical-physical factors, and dose calculations.

Lead

Although sources of lead have been reduced, people still encounter lead in their daily lives. Older houses may still have paint containing lead. Children are often exposed to lead from ingesting paint chips or dust. Almost all (99%) of the publicly supplied drinking water has less than 5.0 micrograms per liter (μg/L) lead. Lead in food ranges from less than 0.0004 to 0.5234 μg/gram (g). People have an average dietary intake of 1.0 μg/kg/day (ATSDR 2007).

Children are more vulnerable to lead poisoning as compared to adults. Children absorb about 50% of ingested lead, while adults absorb between 6-80% of ingested lead depending on recent food consumption. Although lead can be absorbed through the skin, absorption of inorganic lead from dermal (skin) 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 μg/deciliter (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).

Benzo(a)pyrene and other PAHs

Little information is available on health effects due to contact with benzo(a)pyrene through the skin (dermal contact). Use of benzo(a)pyrene as a treatment for skin conditions resulted in worsening symptoms in people with preexisting skin conditions. People without preexisting skin conditions exposed to benzo(a)pyrene through the skin (dermally) have had wart-like growths develop. Animals dermally exposed to benzo(a)pyrene developed inflammation and increased thickness of the skin. Benzo(a)pyrene can cause contact hypersensitivity (a rash) and skin cancer in laboratory animals (ATSDR 1995).

Although the levels of benzo(a)pyrene present in many of the sediment samples from Ruddiman Pond and the Main Branch of Ruddiman Creek are elevated, several conditions specific to PAHs, and benzo(a)pyrene in particular, could reduce people's exposure. First, not all benzo(a)pyrene present in the sediment stuck to the skin will be absorbed. In an experiment measuring absorption, less benzo(a)pyrene was absorbed when it was applied in soil than without the soil (Moody et al. 2007). The amount of benzo(a)pyrene absorbed into and accumulated by humans or other organisms refers to the bioavailable fraction in the sediments. In an experiment measuring benzo(a)pyrene accumulation, less that 1% of the total contaminant amount was calculated as bioavailable (Schuler et al. 2002).

For benzo(a)pyrene to be bioavailable, it first needs to desorb (be released) from the sediments. Desorption of benzo(a)pyrene depends on the amount of lipid (fat) present in the organic carbon of the sediments (Kukkonen et al. 2003). PAHs, in general, absorb strongly on suspended particulates and biota (EPA 2003). In soil that had a higher amount of organic carbon, lower levels of the tested PAHs were bioavailable (Ounnas et al. 2009). In addition, as sediments age, less of the PAHs that are present are available (Leppanen and Kukkonen 2000; Schuler and Lydy 2001). Because of these factors, at ambient levels (average of 0.55 parts per trillion in water, which is lower than benzo(a)pyrene levels at the site), the dermal route is not expected to be a significant exposure route (EPA 2003).

As discussed above, the bioavailable amount of benzo(a)pyrene is the amount that people are able to absorb. However, methods used to measure the amount of benzo(a)pyrene present in the sediment may overestimate the amount that is bioavailable (Schuler and Lydy 2001). The overestimation of the amount of benzo(a)pyrene may be as high as 10 to 100 times the actual bioavailable amount (Vanderheijden and Jonker 2009). The chemicals used to extract benzo(a)pyrene from the sediments may extract several times more that the amount of benzo(a)pyrene that is actually bioavailable in the sediments (Schuler and Lydy 2001). The EPA test method is one such method that may overestimate the amount of benzo(a)pyrene that is bioavailable (Bandow et al. 2009).

For the benzo(a)pyrene analysis used on these sediment samples, dichloromethane was used to extract PAHs from the sediments (Battelle 2009). Schuler and Lydy (2001) determined that a 1:1 ratio of dichloromethane: acetone extracted nearly 100% of benzo(a)pyrene spiked into sediment aged from one to 120 days. Using the same spiked sediments, only 24.7 to 30.4% of the benzo(a)pyrene was calculate to be bioavailable, based on the amount isolated from worms living in the spiked sediments. This bioavailable fraction was about equal to the amount of benzo(a)pyrene extracted from the sediments with water (Schuler and Lydy 2001).

As discussed in the Exposure Pathways section, several PAHs have BaP equivalent factors. These PAHs and their factors are in Table D-1.

Table D-1: Polycyclic aromatic hydrocarbons (PAHs) and their benzo(a)pyrene (BaP) equivalent factors.

PAH	BaP equivalent factors
benzo(a)pyrene	1.0[a]
benz(a)anthracene	0.1[a]
benzo(b)fluoranthene	0.1[a]
benzo(k)fluoranthene	0.01[a]
chrysene	0.001[a]
dibenz(a,h)anthracene	1.0[a]
indeno(1,2,3-cd)pyrene	0.1[a]
anthracene	0.01[b]
benzo(g,h,i)perylene	0.01[b]
acenaphthene	0.001[b]
acenaphthylene	0.001[b]
fluoranthene	0.001[b]
fluorene	0.001[b]
phenanthrene	0.001[b]
pyrene	0.001[b]

a = From EPA (1993)
b = From ATSDR (1995)

Levels of the PAHs, measured in the sediment, are multiplied by each PAH's BaP equivalent factor. The resulting BaP equivalent values are added together, to result in a total BaP equivalent value. Table D-2 provides the total BaP equivalent concentrations in Ruddiman Pond and the Main Branch of Ruddiman Creek. Levels of benzo(a)pyrene contribute approximately 65% of total BaP equivalent value.

Table D-2: Levels of benzo(a)pyrene and benzo(a)pyrene (BaP) equivalent values (in parts per million [ppm]) in Ruddiman Pond and Main Branch of the creek sediments.

	Pond sediments (in ppm)		Main Branch sediments (in ppm)	
	2008 samples[a]	2012 samples	2008 samples	2012 samples
Benzo(a)pyrene	6.7[b]	ND[c]	10.6[b]	ND[c]
Total BaP equivalent value	10.6[d]	0.04[e]	15.9[d]	0.77[f]

a = Only pond sediment samples from areas with a water depth of 9.5 feet or less were included.
b = This is the maximum level for benzo(a)pyrene.
c = Benzo(a)pyrene was not detected in any samples.
d = This calculation included maximum levels for each PAH.
e = The total BaP equivalent value includes only maximum levels for fluoranthene and pyrene. Other PAHs were not detected.
f = The total BaP equivalent value includes only the maximum levels for benzo(a)anthracene, benzo(b)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene. Other PAHs were not detected.

Using the total BaP equivalent concentration, people may be exposed up to 0.002 µg/kg-day from the pond or creek sediment.[10] This is an overestimate of the exposure that people will have to PAHs as it uses the maximum concentration for each chemical (from multiple samples) and assumes that the total amount of soil ingested (200 milligrams [mg]/day for children and 50 mg/day for adults) is from the sediment for every day of the summer (90 days). Since the likely exposure is less than the calculated daily dose for PAHs, people's possible cancer risk from this exposure would not be elevated.[11]

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[10] For children, using a body weight of 50 kg, the amount ingested would be 0.002 µg/kg-day. Children between the ages of 6 and 16 were included because they are the ones most likely to be wading in the sediment. For adults, with a body weight of 80 kg, the BaP equivalent amount ingested would be up to 0.001 µg/kg-day.

[11] The possible cancer risk from the total BaP equivalent dose would be less than 2 extra cases of cancer in 100,000 exposed people.

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