Health Consultation

Centredale Manor Restoration Project Superfund Site:
Dioxins In Fish Tissue

North Providence, Providence County, Rhode Island

EPA Facility ID: RID981203755

Prepared by the
Rhode Island Department of Health

July 29, 2025

Prepared under a Cooperative Agreement with the
U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Agency for Toxic Substances and Disease Registry (ATSDR)

Office of Capacity Development and Applied Prevention Science
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. To prevent or mitigate exposures, a consultation may suggest specific actions, such as restricting the use of water, replacing water supplies, intensifying environmental sampling, restricting site access, or removing contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes, conducting biological indicators of exposure studies to assess exposure, and providing health education for health care providers and community members.

This report concludes the health consultation process for this site, unless additional information is obtained by ATSDR. If the new information, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued, the consultation may resume.

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List of Abbreviations

ALP	Allendale Pond
ATSDR	Agency for Toxic Substances and Disease Registry
BW	Body weight
CDC	Centers for Disease Control
CSF	Cancer slope factor
CTE	Central tendency exposure
ED	Exposure duration
EF	Exposure frequency
EHRAP	Environmental Health and Risk Assessment Program
ELCR	Excess lifetime cancer risk
FDA	Food and Drug Administration
g/day	Grams per day
GMP	Greystone Mill Pond
GVP	Georgiaville Pond
HQ	Hazard quotient
IR	Ingestion rate
LMP	Lyman Mill Pond
LMR	Lyman Mill Reach
LY	Lifetime
mg/kg/day	Milligrams per kilogram per day
MRL	Minimal risk level
ng	Nanograms
PCB	Polychlorinated biphenyl
RIDEM	Rhode Island Department of Environmental Management
RIDOH	Rhode Island Department of Health
RME	Reasonable maximum exposure
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TEF	Toxic equivalency factor
TEQ	Toxic equivalency quotient
µg/L	Micrograms per liter
USEPA	United States Environmental Protection Agency
WRWC	Woonasquatucket River Watershed Council

Summary

Introduction

The Centredale Manor Restoration Project Superfund Site (USEPA ID: RID981203755) will be referred to as "the Site." The Site is located in North Providence, Rhode Island, on the Woonasquatucket River. From the 1940s through the 1970s, the Atlantic Chemical Co./Metro-Atlantic Inc. and the New England Container Company Inc. operated chemical manufacturing and drum reconditioning businesses, respectively. The businesses were operated at a nine-acre area (the Source Area) immediately to the east of the Woonasquatucket River.[1] **The Source Area is the location of the chemical manufacturer/drum reconditioner and is where the chemical contamination comes from.** The Site encompasses the Source Area and downstream affected areas. Figure 1 shows the Source Area (OU1) in relation to the rest of the Site. A 1972 fire destroyed most of the structures at the Source Area. The Brook Village apartments and Centredale Manor apartments were constructed on the grounds of the former facilities. They were built after the fire and opened in 1977 and 1982, respectively. The apartment complexes still occupy what was once the Source Area.[2]

Chemicals were released directly into the soil and river because of chemical production and drum reconditioning at Atlantic Chemical Co./Metro-Atlantic Inc. and the New England Container Company Inc. Soil, river sediments, and fish samples collected from within the Site boundaries have elevated levels of several chemicals. Some of the elevated levels are for dioxins, furans, polychlorinated biphenyls (PCBs), including dioxin-like PCBs, which were used, generated, or released during on-site operations.[1]

In addition to the Source Area, the Site also includes some of the impacted areas downstream in the Woonasquatucket River and the associated floodplain soils (Figure 1). Fish samples were collected at three impacted areas downstream of the Source Area (Lyman Mill Reach, Allendale Pond, Lyman Mill Pond) and two upstream ponds (Greystone Mill Pond and Georgiaville Pond). Fish collected at upstream sampling sites were used to establish background conditions (current river conditions in the absence of contamination from the Source Area).

This health consultation was initiated in response to fish samples collected in 2019. The samples were collected as part of an investigation overseen by United States Environmental Protection Agency (USEPA). American eels, largemouth bass, and white suckers were tested for dioxins, furans, and PCBs at several locations along the Woonasquatucket River, including upstream background locations and in Allendale Pond and Lyman Mill Pond. The 2019 data were used by the

	Rhode Island Department of Health (RIDOH) to assess the health risks posed by consuming fish from the Woonasquatucket River. Reports from stakeholders indicate that the Woonasquatucket River is especially important for a community that uses the river for subsistence fishing.
Conclusions	1. Dioxins and dioxin-like PCBs in contaminated fish in Allendale and Lyman Mill Ponds could harm people's health when eaten for one year or more. 2. Increased risks of dioxin-related noncancer and cancer health effects could be expected among adults and children who eat 1 ounce (oz) or more of fish per 20 lbs body weight per week caught from Allendale and Lyman Mill Ponds for one year or more. This is due to the presence of dioxins, furans, and dioxin-like PCBs, particularly 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). 3. The health risks posed by dioxins in fish collected downstream of the Source Area likely outweigh the benefits of consuming fish. People should avoid eating fish from downstream of Centredale Manor. 4. The benefits of fish consumption relative to other protein sources likely outweigh the potential health risks posed by background levels of dioxins and related compounds in fish collected upstream of Centredale Manor. People may continue to eat fish caught upstream of Centredale Manor following state mercury guidelines. 5. RIDOH urges stakeholders not to eat fish, turtles, eels, or plants from the river downstream of the Johnston/Smithfield border. Do not swim or wade in the river downstream of the Johnston/Smithfield border. 6. Community members eating fish upstream of the Johnston/Smithfield border are encouraged to follow the state guidance regarding mercury contamination. 7. While eating fish caught downstream from Centredale Manor could increase cancer risks, an analysis of health outcomes indicates that local cancer rates are not statistically different from the rest of the state. While some cancer types have elevated rates compared to the state, the difference is not statistically significant.
Basis for Conclusions	In 2019, three different species of fish were sampled from five locations along the Woonasquatucket River: American eels (*Anguilla rostrata*, whole body), largemouth bass (*Micropterus salmoides*, skin-on fillet), and white sucker (*Catostomus commersoni*, whole body). These species have different feeding habits. All may be consumed by the public.[3] Two

upstream sampling locations (Georgiaville Pond, Greystone Mill Pond) provided background concentrations. Background concentrations are the levels of dioxins and PCBs in the Woonasquatucket River in areas that are not impacted by Centredale Manor. The background concentrations were compared with the Site locations downstream of the Source Area (Lyman Mill Reach, Allendale Pond, Lyman Mill Pond).

Dioxin and dioxin-like PCBs were detected in 100% of the 2019 fish tissue samples, both upstream and downstream of the Source Area. In fish tissue samples from the Site, dioxin concentrations were higher than those from the background locations. Concentrations from upstream fish tissue samples ranged from 1.1-3.0 ng TCDD equivalent/kg wet weight (kg ww) and 70-380 ng TCDD equivalent/kg ww at the Site collection sites.

RIDOH estimated potential exposure to contaminants in fish tissue for central tendency exposure (CTE) and reasonable maximum exposure (RME) scenarios for the subsistence fishing community living close to the Woonasquatucket River. The CTE and RME scenarios were based on the 2019 fish tissue data and estimated fish consumption rates. CTE represents an estimate of the average person's exposure to a given contaminant. In this case, the contaminants are dioxins and dioxin-like PCBs. RME is an estimate of the contaminant dose received by the most exposed people. Risks for different age groups (calculated based on body weight) make up different exposure scenarios for CTE and RME. For the RME scenarios, the amount of fish consumed per meal was based on fish consumption guidance from the Minnesota, Washington, and Oregon Health Departments. The amount of fish consumed in the CTE scenarios was set to half of the RME amount. For the RME scenario, we assumed three (3) fish meals per week. For the CTE scenario, we assumed one (1) fish meal per week.

Risks for noncancer health effects are assessed using hazard quotients (HQs). HQs greater than 1.0 indicate a need for further toxicological investigation. For each fish species found within the Site Area, HQs were greater than 1.0 under both consumption scenarios. Upstream of the Source Area, HQs were less than 1.0 for all fish species in the CTE consumption scenario. Further evaluation indicated that noncancer health risks from these exposures are much less likely than cancer. In addition, given the health benefits of fish consumption, an overall increase in noncancer health effects would only be anticipated at higher dioxin levels than were found in this health consultation.

Cancer risks were higher for Site sampling locations compared to upstream background sampling locations due to the higher concentrations of dioxin and dioxin-like PCBs. Cancer risks associated with

	consumption of fish from sampling locations upstream of the Source Area at Centredale Manor were within the range of 10^{-6} to 10^{-4}. RIDOH does not consider this a concern for increased cancer risks. For Site sampling locations, cancer risks from fish consumption range from 10^{-4} to 10^{-2}. Based on the 2019 fish tissue data and the exposure assumptions described above, consuming fish from the Site sampling locations would pose a concern for increased cancer risk.[4] These trends in concentration upstream/downstream of the Source Area are consistent with the 2005 Baseline Human Health Risk Assessment by USEPA.
Next Steps	• The remediation described by USEPA in their Draft Final Remedial Design Work Plan (dated September 2018) should be implemented as written. To protect the health of the community and the people working onsite, dust suppression should be emphasized during the remediation process. • Official messaging from RIDOH should continue to discourage eating fish and other wildlife from the Woonasquatucket River area, downstream from the Johnston/Smithfield border to prevent exposure to dioxins. • This is near the outfall of the Greystone Mill Pond. Upstream of the Johnston/Smithfield border, fish consumption should follow state mercury guidance. • After remediation is complete, USEPA is recommended to perform follow up testing of fish tissues for dioxins and dioxin-like PCBs to measure the success of the remediation methods. **Public Health Action Plan Activities** Actions to protect the public from exposure to dioxins and dioxin-like PCBs in fish from the Woonasquatucket River include: • Previous recommendations from USEPA have been implemented to avoid consumption of fish from the Woonasquatucket River downstream of the Johnston/Smithfield town line (complete). • Future communications (fact sheets) from RIDOH will reinforce this language until remediation is complete (pending). • RIDOH staff will be participating in meetings through the Woonasquatucket River Watershed Council and USEPA to educate stakeholders on the potential risks (pending).
For more Information	If you have concerns about your health, you should contact your local health care provider. Questions about this report or exposures associated with this site can be directed to the Environmental Health Risk Assessment Program (EHRAP) at zachary.shepard@health.ri.gov.

Objectives and Health Issues

The Rhode Island Department of Health (RIDOH) Environmental Health Risk Assessment Program (EHRAP) evaluated potential public health concerns related to contaminants in fish from the Woonasquatucket River near the Centredale Manor Restoration Project Superfund site. Chemicals of concern in fish tissue include dioxins, furans, and polychlorinated biphenyls (PCBs). This health consultation (HC) was written to determine whether the chemical levels in fish tissue posed a health hazard to nearby populations, specifically anyone using the river for subsistence fishing.

The objectives of this HC are to

1) determine whether contaminants detected in the Woonasquatucket River fish pose a public health hazard,
2) recommend appropriate actions to protect public health,
3) identify data gaps where additional sampling may be needed to better assess health risks, and
4) determine whether cancer rates were within the expected range for the area around Centredale Manor compared to the rest of the state.

This HC was initiated in response to a request for support from the U.S. Environmental Protection Agency (USEPA). In July 2021, USEPA requested an assessment and comparison of 2019 fish sampling event data and 2001 sampling data. The 2019 sampling data will serve as a baseline for any follow up sampling that might occur after remediation is complete. The data contained in this HC was provided by the USEPA and various public records.

Background

Site History

The Centredale Manor Restoration Project Superfund site (EPA ID: RID981203755), referred to as "the Site", is located along the Woonasquatucket River at 2072 Smith Street, North Providence, Rhode Island. It includes the location of the former Atlantic Chemical Co./Metro-Atlantic, Inc. and the New England Container Company (the Source Area). The Atlantic Chemical Co. was a chemical manufacturer. The New England Container Company, Inc. was a drum reconditioner (1940s-1970s). A fire destroyed most of the structures in 1972. The Brook Village apartments and Centredale Manor apartments were built on the Source Area and opened in 1977 and 1982, respectively. The apartment complexes still occupy the Source Area.[2]

The portions of the Site to be remediated are divided into 4 Operable Units: including the "Source Area" and three downstream locations where sediment accumulated (Allendale Pond, the Oxbow Area, and Lyman Mill Pond). During site cleanup, called remediation, a site may be divided into distinct areas, called Operable Units. The number of Operable Units depends on the complexity of the problems at the site. Operable Units allow site cleanup to happen in organized steps. In the past, chemicals were released directly into the soil and the river. Since then, elevated levels of dioxins, furans, and dioxin-like PCBs have been detected in soil, river sediments, groundwater, and fish tissue at the Site (see Exposure Pathway Analysis: Contaminants of Concern). These chemicals were used, generated, or released through on-site operations.[1] In 2012, USEPA proposed a plan to clean up the Site. In 2018, they finalized a settlement to initiate cleanup. Manton Pond and Dyerville Pond were included in the Site investigations and feasibility

study, but those areas were not recommended for remediation in the Record of Decision for the Site.

The USEPA cleanup at the Site has started and will progress in several stages along the Woonasquatucket River beginning with the Source Area and ending at Lyman Mill Pond.[5] Contaminated sediment and soil will be excavated and a cover of clean fill material will be placed.[5] Contaminated material will be disposed of at a confined disposal facility.[5] Contractors performing remediation wok will monitor and prevent offsite migration of excavated sediment and soil at every stage of the remediation process.[5] Long-term monitoring will be performed to ensure the success of the remediation.[5] USEPA and remediation contractors will monitor surface water, groundwater, sediment, and fish monitoring in the affected area.[5]

Nearby Demographics and River Use

To understand the socioeconomic status of the affected area, demographic data from 2020 were reviewed for U.S. census tracts (123, 121.02, 20, 124.01, 18, 19, 25) along the Woonasquatucket River south of Centredale Manor.[6] An estimated 37,812 people live within the seven census tracts. Of those, 50.9% are women and 49.1% are men.[7] About 26.7% of residents are children (<18 years old) and 44.0% of women are of childbearing age. Most of the nearby residents identify as White (51.8%), with 10.7% identifying as African American, 1.7% as Asian, and 30.5% as Hispanic or Latino. For people 25 years or older, 53.2% have a high school diploma or less, 22.1% have at least two years of college, and 24.8% have a bachelor's or higher degree. Working individuals (71.8%) had an income below $50,000/year, and the estimated median individual income was $36,702. There is a higher percentage of people living at or below the poverty line in this area compared to the national average (19.2% compared to 11.8% nationally).[7] Social factors (race, poverty, ethnicity) can worsen the impacts of an unhealthy environment.[8] There is also a large immigrant community, some of whom are believed to use the river for subsistence fishing.

As a Class B1 waterbody, the Woonasquatucket River does not serve as a drinking water source. It is used primarily for recreational activities and as a fish/wildlife habitat.[9,10] The river is also used for hydropower, aquaculture, navigation, and irrigation. The riverbank has heavy vegetation and surrounding fences in some areas. River access is available at several points. Additionally, the Woonasquatucket River Greenway bike path ends along the southern shore of Lyman Mill Pond (Figure 2),[11] potentially increasing the number of visitors to the area.

Previous Investigations

On May 13, 1996, USEPA staff collected fish from two locations on the Woonasquatucket River. Sunfish were captured at Valley Street near Lonigan Dam and American eels were captured at Smith Street in North Providence.[12] Smith Street intersects with the Woonasquatucket River just slightly upstream of Centredale Manor. Valley Street intersects much further downstream of Centredale Manor. Three sunfish composite samples, each consisting of 5 fish, were analyzed for metals, PCBs, organochlorine pesticides, and dioxins. Fillets of the fish, with the skin attached, were analyzed separately from the offal. Three American eels were composited and tested for the same chemicals. After this study, USEPA and RIDOH issued an advisory for the Woonasquatucket River. The advisory asserted that for the

entire Woonasquatucket River, fishing should be catch and release only.[13] This was in response to dioxin, PCB, and mercury concentrations in sunfish and eels.[13]

The results indicated that the most significant contaminants in the fish were dioxins and PCBs.[12] The USEPA's National Health and Environmental Effects Research Laboratory (NHEERL) reported the total dioxin content. The dioxin content of the sunfish and eel composites were 63.1 and 91.7 ng dioxin equivalents per kg wet weight (ww) of fish, respectively.[12] These results informed our decision to focus on dioxins and PCBs in the current analysis.

Soil and sediment samples were acquired in multiple sampling investigations between 1997 and 2018.[5,12] ATSDR's 1999 Centredale Manor Health Consultation analyzed contaminant concentrations in the soil from residential and recreational areas around the Oxbow Area and residential areas at Lyman Mill Pond.[12] See the Exposure Pathway Analysis section in this document for more details on the classification of the exposure pathways.

A 2001-2003 USEPA investigation was conducted as part of a Remedial Investigation for the Site. They analyzed the concentration of dioxins in fish at six areas near the Site.[1] American eel, largemouth bass, and white sucker were harvested from five locations on the Woonasquatucket River and at Assapumpset Pond.[1] Assapumpset Pond is located near the Site but is not affected by contaminant releases (see Figure 4).

The study showed there were higher dioxin concentrations in fish collected from Allendale Pond and Lyman Mill Pond compared to upstream Greystone Mill Pond and reference area Assapumpset Pond. Dioxin concentrations in fish from Allendale and Lyman Mill Ponds were also higher compared to Manton Pond and Dyerville Pond, which are further downstream than Lyman Mill Pond. USEPA found the concentrations of dioxin in fish from Allendale and Lyman Mill Ponds frequently approached or exceeded the FDA's "Do Not Consume" limit of 50 parts per trillion (ppt).[3] The fishing advisory and the guidance not to consume fish from the Woonasquatucket River were updated to be downstream of the Johnston/Smithfield town line.[3] The study was used to develop USEPA's 2005 baseline human health risk assessment for the Centredale Superfund Site.[1]

Community Health Concerns

In April and July 2022, EHRAP held community meetings to get input from local community groups and stakeholders about their concerns. Local community groups, such as the Woonasquatucket River Watershed Council (WRWC), organized cleaning campaigns and environmental education events to raise awareness about the Centredale Manor Superfund Site. Some community members expressed concerns regarding the socioeconomic status of the people living near the area and the potential exposure of nearby subsistence fishing populations that included young children. Stakeholders described activities around the river and ponds activities such as fishing, rafting, walking, biking, and bird watching.

Fishing near the Site in the Woonasquatucket River has been reported by stakeholders. Stakeholders also reported that people fishing near the Site often keep what they catch. This and the socioeconomic factors of the community in the area suggest that the area could be used by

subsistence anglers. The exact number of people subsistence fishing the area is unknown at this time.

Community members expressed concern about periodically low water levels at Lyman Mill Pond and the future tree removal at the Oxbow area. Their questions centered around the soil excavation remediation plans (e.g., draining the ponds to dry the sediment prior to removal), whether contaminated dust could blow onto private property, and whether contaminated dust inhalation would be investigated as an exposure route. In March/April 2022, several community members noticed that work conducted by contractors significantly lowered water levels at Lyman Mill Pond and exposed the sandbar. This low water level prompted questions about whether children could walk out onto the contaminated sediment and whether the sediment removal process would be conducted in a way that completely protects community health. Conversations with the engineering firm performing the remediation work determined that engineering controls are in place that eliminate these potential exposure pathways. Excavated sediment and soil were kept wet to prevent dust migration offsite.

Stakeholders were also concerned about contaminated soil and sediment moving and spreading due to flooding. Risks posed by sediment movement during flooding are discussed briefly in the 1999 Centredale Manor Health Consultation.[12] The 1999 health consultation ultimately dismissed the possibility of increased health risks from sediment and soil.[12] If contaminated soil and sediment mixed with flood water or if rainwater spread soil and sediment across a larger area, the concentration of contaminants would be less than what was reported in the 1999 health consultation.[14] This indicates that dioxins and PCBs in soil and sediment that are mobilized due to raining/flooding are not likely to increase risk compared to the current situation. Currently, there are no new data to assess the risk posed by contaminant migration during flooding.

Site Investigation

Fish Sampling Locations

In September and October of 2019, contractors sampled three different species of fish from five locations along the Woonasquatucket River (Figure 4): Georgiaville Pond (GVP), Greystone Mill Pond (GMP), Lyman Mill Reach (LMR), Allendale Pond (ALP), and Lyman Mill Pond (LMP). Lyman Mill Reach, Allendale Pond, and Lyman Mill Pond are considered part of the Site and are downstream from the source area (Figure 1). No samples from downstream of the Lyman Mill Pond were collected as a part of this study. The upstream Georgiaville Pond and Greystone Mill Pond locations provided background concentrations for comparison with the Site locations. The 2019 fish sampling locations corresponded to the locations used in the fish sampling conducted in 2001-2003.[3] Only one species (American eel) was collected at Lyman Mill Reach (Table 1).

Fish Species

In 2019, American eels (*Anguilla rostrata*, whole body), largemouth bass (*Micropterus salmoides*, skin-on fillet), and white sucker (*Catostomus commersoni*, whole body) were collected along the river. USEPA originally selected these species in 2001 because they were anticipated to be among the species most exposed to dioxins due to their feeding habits.[3] American eel and white sucker are bottom feeders, living in the sediment. Largemouth bass are the top predator in the ecosystem. These species were expected to have high concentrations of

dioxins, PCBs, and other bioaccumulative pollutants because they either consume organisms living in the sediment or consume other fish that do, leading to biomagnification.

Current Recommendations

Since 2003, USEPA, RIDOH, and WRWC have urged stakeholders not to eat fish, turtles, eels, or plants from the river and not to swim or wade in the river downstream from the Smithfield border.[3] These recommendations were directly related to the 2001 fish sampling results and USEPA's 2005 baseline human health risk assessment.[1] Although other contaminants of concern (e.g., dieldrin, benzo(a)pyrene) were included in the risk analysis, elevated concentrations of dioxins, specifically TCDD, contributed over 90% of the health risks for both the adult and child fish ingestion scenarios.[1]

ATSDR Evaluation Methodology

This section discusses ATSDR's methodology for evaluating the public health implications of eating fish with contaminants from the Woonasquatucket River. All calculations were performed using ATSDR's Public Health Assessment Site Tool (PHAST version 2.2.1.0, database rev 7.4.5). This process involves two separate evaluations, one for exposure and one for health effects.

The ATSDR exposure evaluation process has two steps: determine what hazards are at the Site (environmental data screen) and evaluate how people may contact these hazards (exposure pathway analysis). ATSDR identifies contaminants of concern by comparing site-specific concentrations to health-based comparison values (CVs). An ATSDR CV is a contaminant concentration at which adverse health effects are not expected.[15] The CVs are based on animal studies and human epidemiological studies. Adverse health effects include both cancer and noncancer outcomes. If a contaminant of concern is present at concentrations higher than the corresponding CV, then the contaminant is included in the exposure pathway analysis. Even if a contaminant concentration is higher than the CV, an adverse health effect may not occur.

During the exposure pathway analysis, five elements must all be present for an exposure to occur. This is known as a completed exposure pathway:

- Contaminant source (e.g., hazardous waste site)
- Environmental medium (e.g., fish); which the contaminant moves through
- Exposure point (e.g., fish tissue); where people contact a contaminated medium
- Exposure route (e.g., eating fish tissue); how people contact the contaminant
- Potentially exposed population (e.g., subsistence fishing population)

Even if all five elements are present, an adverse health effect may not occur. The chemical concentration, or the amount of contact a person has with the chemical, and the duration of exposure must both be high enough for possible harm to occur.[15] If data for one or more elements is unknown, then it is considered a potential exposure pathway. An eliminated exposure pathway is one that lacks one or more of these elements and poses no threat to the potentially exposed population in the past, present, or future.

If the initial evaluation indicated that an exposure may occur, then a more in-depth analysis is conducted to consider possible public health impacts. The ATSDR health effects evaluation has

three steps: identify site-specific exposure dose estimates, compare those exposure doses to health guidelines like ATSDR's minimal risk levels (MRLs) or USEPA's reference doses, and determine public health implications for contaminants that exceeded health guidelines. The evaluation determines whether a public health hazard exists, depending on the site-specific contaminant levels and estimated exposures in the community. It also calculates whether contact potentially contributes to cancer health risks.

Contact with a contaminant does not always result in harmful health effects. Some factors that influence whether contact results in adverse health effects include

- Dose (how much contaminant a person is exposed to)
- Duration (how long a person is exposed to a contaminant)
- Frequency (how often a person is exposed to a contaminant)
- Toxicity (what type of damage a contaminant can cause to a person)

Furthermore, different people or groups of people may respond differently to contaminant exposures. When exposed to the same concentration of a contaminant in the environment, children, the elderly, and people with pre-existing health conditions (i.e., sensitive subpopulations) may have larger responses and more severe health outcomes compared to members of the general population.

All these factors are considered when calculating an exposure dose. An exposure dose estimates the contaminant level that a person may come into contact with over time. When site-specific information was unavailable, several default assumptions were used for the ATSDR equation:

$$Estimated\ Exposure\ Dose = \frac{(C * IR * EF * ED)}{(BW * AT)}$$

C = Concentration of chemical in biota (e.g., mg dioxin equivalents/kg fish ww; Table 4)
IR = Ingestion rate (varies by age; see Table 5)
EF = Exposure frequency (365 d/y)
ED = Exposure duration (1 y for all age groups for noncancer endpoints; varies by age for cancer endpoints)
BW = Body weight (kg; varies by age; see Table 5)
AT = Averaging time (AT = ED × 365 days per year)

Dioxin equivalents are calculated when quantifying the concentration of dioxins, furans, and dioxin-like PCBs. These compounds form a group of chemicals that have a similar chemical structure and mechanism of toxicity. Toxicity equivalence factors are used to calculate a single dose value for the mixture of compounds in the sample. This value is presented as dioxin equivalents, which has the same toxicity as an equivalent amount of TCDD.

Exposure doses are calculated from exposure point concentrations (referred to as concentrations here).[15] The concentration used in the exposure dose calculation depends on the number of samples collected. For eight or more fish samples, the 95th upper confidence limit (95UCL) of the arithmetic mean was used as the exposure point concentration. This limit accounts for variability within the data. If there were fewer than eight fish samples, then the maximum

concentration of a contaminant was used as the exposure point concentration. By using upper-limit estimates of the concentration, ATSDR and USEPA are conservative (meaning more health-protective) in calculating exposure doses.

Site-specific doses are derived by estimating the amount of intake (e.g., from eating fish) divided by a person's body weight. The dose is reported as milligrams of chemicals per kilogram body weight per day (or mg/kg/day). The dose also differs when evaluating risks of noncancer compared to cancer health outcomes. To protect public health, ATSDR and USEPA assume a worst-case scenario (i.e., frequent fish consumption) to conservatively calculate noncancer exposure doses.

Estimated exposure doses were compared with ATSDR MRL. An MRL estimates the daily exposure to a contaminant below which noncancer health outcomes are unlikely to occur.[15] When the noncancer exposure dose is divided by a contaminant's MRL, the resulting hazard quotient (HQ) describes the risk of noncancer health effects:

$$HQ = \frac{D_{non-cancer}}{MRL}$$

Generally, an HQ less than 1.0 means that it is unlikely an exposed person would experience adverse noncancer health effects. An HQ equal to or greater than 1.0 means further toxicological evaluation is needed to determine if estimated doses approach or exceed doses that might cause harmful noncancer effects. Different MRLs may be developed for each contaminant based on length of exposure:

- Acute (<15 days)
- Intermediate (15-365 days)
- Chronic (>365 days)

The increased cancer risk from a lifetime (t=78 years) of exposure to a contaminant by ingestion or inhalation was calculated using a cancer slope factor (CSF).[15] When the cancer-specific exposure dose is multiplied by a contaminant's CSF, the result is an excess lifetime cancer risk (ELCR). The ELCR describes the risk of cancer health effects in excess of the "background" risk. That is, everyone has some baseline risk of developing cancer and the ELCR shows the increase in risk of cancer after exposure to a contaminant:

$$ELCR = D_{cancer} * CSF * \frac{ED}{LY}$$

ED = Exposure duration (varies by age)
LY = Lifetime (78 y)

The ELCR does not estimate the number of expected cancer cases in a community. Instead, the ELCR measures the probability that a group of similarly exposed people may develop cancer sometime in their lifetime following exposure to a particular contaminant. RIDOH and ATSDR use the following ranges to characterize cancer risk estimates:

1. An ELCR below $1.0x10^{-6}$ (one in one million) is "no concern for increased cancer risk."
2. An ELCR between $1.0x10^{-6}$ and $1.0x10^{-4}$ (one in ten thousand) is "possible concern for increased cancer risk" depending on the situation, and
3. An ELCR $\geq 1.0x10^{-4}$ (one in one thousand) is "a concern for increased cancer risk."[16]

Risks were calculated using ATSDR's standard age groups in the Public Health Assessment Site Tool.

Exposure Pathway Analysis

Contaminants of Concern

The chemical dataset for fish included 150 different contaminants from five separate analyses: dioxins and furans (USEPA 1613B), PCBs (USEPA SW1668C), pesticides (USEPA SW8081B), metals (USEPA SW6010C), and semi-volatile organic compounds (USEPA 8270D). Of the 150 contaminants, 77 individual analytes were detected at least once in the fish tissue samples (Table 2). In USEPA's 2005 health risk assessment, dioxins, furans, and dioxin-like PCBs were the only contaminants that USEPA considered to be associated with contamination from the Site.[1] Due to these previous results, EHRAP selected dioxins, furans, and dioxin-like PCBs as the primary chemicals of concern for this health assessment.[1]

Dioxins and Furans

Dioxins and furans include multiple individual chemical structures, known as congeners, which vary by the number and location of chlorine atoms. Environmental sources of dioxin include pulp and paper manufacturing; combusted fossil fuels; and incinerated municipal, medical, and hazardous wastes. Low levels of dioxin may occur from natural sources and are detected in food, water, and cigarette smoke.[17] Humans are most frequently exposed to dioxins from eating contaminated food, such as fish. As lipophilic chemicals, dioxins can build up in the liver and fat for many years before the body eliminates them. In the environment, dioxins concentrate in animals, soil, and sediment, and are typically only present in trace amounts in water.[17]

PCBs

PCBs are a group of man-made organic chemicals that were manufactured in the United States until the mid-1970s. As good insulators, PCBs were applied to a wide variety of products, including hydraulic fluids, fluorescent light fixtures, flame retardants, inks, adhesives, carbonless copy paper, paints, pesticide extenders, plasticizers, wire insulators, and electrical transformers. PCB manufacturing was stopped due to concerns about PCB persistence in the environment and toxicity to animals and humans. Humans are most frequently exposed to PCBs from contaminated food and soil, but inhalation of volatile PCBs is also a concern.[18] PCBs are lipophilic and can accumulate and persist in the human body for many years.[18]

PCBs have 209 congeners, with 10 possible locations for chlorine atoms. However, only 12 PCBs have similar toxicological mechanisms of action and health effects to dioxins (see previous section). As a result, these 12 congeners are examined separately in risk analyses. Adverse health outcomes associated with non-dioxin-like PCB exposures have included liver, reproductive, and developmental effects. There were also reports of damage to the thyroid, endocrine, and immune

systems.[18] Liver and biliary tract cancer have also been associated with PCB exposures in humans.[19]

Completed, Potential, and Eliminated Pathways at Centredale Manor
EHRAP considered reasonable exposure pathways at Centredale Manor and whether contaminants could have an adverse health effect on fish consumers from past, present, or future exposures.

Completed human exposure pathways for the Site were quantitatively evaluated:

- **On-site biota** – Ingestion of contaminated fish from Georgiaville Pond, Greystone Mill Pond, Lyman Mill Reach, Allendale Pond, and Lyman Mill Pond (Figure 4) for nearby subsistence fishing community is addressed in this health consultation (past, present, future).

Eliminated human exposure pathways for the Site were not evaluated:

- **On-site surface water** – Dioxins do not readily dissolve into water, so Woonasquatucket River surface water is not likely to be heavily contaminated with dioxins.
- **On-site sediment** – During excavation of sediment and soil, visitors and private property owners are unlikely to accidentally ingest or have dermal (skin) contact of contaminated Woonasquatucket River sediments by visitors or private property owners is unlikely due to the controls planned by USEPA during excavation of sediment and soil.
- **On-site and off-site surface soils** – Accidental ingestion or dermal contact of contaminated surface soils by private property owners (past, present, future) was addressed in the 1999 health consultation.

Health Effects Evaluation
Fish Consumption Exposure Pathway
Fish Tissue Results
Dioxin and dioxin-like compounds were detected in 100% of the 2019 fish tissue samples. Specimens collected from Site locations were substantially higher in dioxins than those collected from the reference areas upstream (Figure 5, Table 4). Upstream and downstream dioxin equivalent concentrations ranged from 1.1-3.1 and 70.5-380.7 ng dioxin equivalents/kg ww, respectively across three species (Table 4). White sucker had the highest concentration of dioxins with downstream dioxin equivalent concentrations at 239.5-380.7 ng dioxin equivalents/ kg ww (Table 4). Dioxin equivalent concentrations in white sucker tended to increase in samples collected further downstream of the Source Area. Data for American eel and largemouth bass do not show a marked increase in the dioxin concentrations for samples taken further downstream in the Woonasquatucket River.

Fish Consumption Scenarios
Two calculations, based on different fish consumption rates, were used to create two exposure scenarios: the central tendency exposure (CTE, an estimate of the average exposure to a contaminant) and reasonable maximum exposure (RME, an estimate of the highest reasonable exposure). CTE fish meal sizes were half of the fish meal sizes used for the RME scenario. RME values were calculated using guidance from various state health departments.[20–22] These departments recommend 1 oz fish for every 20 lbs body weight.[20–22] The recommended meal size

was 8 oz for an adult weighing 160-210 lbs.[20–22] The amount of fish per meal was scaled based on body weights in the ATSDR age group categories. The CTE and RME intake rates are presented in Table 5.

Fish meals per week were based on FDA recommendations and assumed to be one meal per week for the CTE scenario and three meals per week for the RME scenario. The scenarios used the United States average lifetime (78 years). Table 5 provides the precise values used for each age group. The calculations were performed by conservatively assuming that 100% of the fish meals would come from American eel, largemouth bass, or white sucker harvested from the Woonasquatucket River (Georgiaville Pond, Greystone Mill Pond, Lyman Mill Reach, Allendale Pond, and Lyman Mill Pond).

ATSDR's PHAST was used to calculate doses and noncancer/cancer health risks posed by dioxins and dioxin-like compounds detected in fish samples. Noncancer hazard quotients were calculated for each ATSDR age group category. Cancer risks were calculated for two age groups: child (birth to 21 years) and adult.

Health Risk Results

Chronic noncancer hazard quotient (HQ) and cancer risk results for the CTE and RME scenarios can be found in Figure 6-Figure 9. All results (chronic, intermediate, and acute exposure) have been provided for each fish species and consumption scenario in Table 7—Table 18. The HQs and cancer risks calculated for every age group increase for fish consumed downstream of the Centredale Manor Source Area (Figure 6—Figure 9, Table 7—Table 18). These results follow the same trends as the dioxin concentrations displayed in Figure 5. Release of pollutants from the Source Area, particularly TCDD, led to greater contamination of the fish tissues downstream (Figure 5).

For locations downstream from the Source Area, in both the chronic CTE and RME scenarios, HQs were greater than 1.0 for all three fish species (American eel, largemouth bass, and white sucker). For locations upstream from the Source Area, in the chronic CTE scenario, HQs were less than 1.0 except for American eels. The HQs for American eels and white sucker were slightly above 1 at upstream locations in the RME scenario (Figure 6, Figure 8, Table 7 — Table 18).

An HQ greater than 1.0 indicates that noncancer health risks should be evaluated against the study or studies that provided the MRL. ATSDR used a series of studies that examined the toxicity of TCDD in Rhesus monkeys to calculate the MRL. Monkeys were exposed to TCDD in their food for 3.5-4 years.[17] Estimated daily intakes for the monkeys in this study ranged 1.2×10^{-7} to 6.4×10^{-7} mg/kg/day.[17] At this dose, the monkeys experienced decreased rate of reproductive success, which is measured by the ability to become pregnant and produce a viable offspring.[23,24] Exposed groups were also more likely to socialize differently compared to control.[25,26] Changes in immune response have also been documented when exposed groups are challenged with phytohemagglutinin.[27] A lowest observable effect level of 1.2×10^{-7} mg/kg/day was established based on changes in socialization and immune response.[27]

The estimated RME doses in the three species collected from downstream locations range from approximately $4x10^{-8}$ mg/kg/day to $2x10^{-7}$ mg/kg/day. Average RME doses were $5x10^{-8}$ to $2x10^{-7}$ mg/kg/day. The average for all three species was around $1x10^{-7}$ mg/kg/day. At the three downstream sampling locations, the estimated RME doses from eating fish were within the range that showed adverse reproductive, social, and immune effects in monkeys. People who eat fish from the Site Area at the rate assumed in the RME scenario, or at a higher rate, could be at risk for similar health effects.

Long-term exposure to dioxins can also lead to soft tissue sarcoma and lymphoma.[28] As mentioned previously, the cancer risk value estimates the risk of cancer health effects compared to the background risk. Cancer risks for fish caught upstream of the Source Area and consumed under the CTE scenario assumptions range approximately $1x10^{-6}$ to $1x10^{-5}$ (Figure 7). Cancer risks increase downstream of the Source Area, ranging from $1x10^{-4}$ to $1x10^{-3}$ (Figure 7). These results indicate that people consuming fish from downstream areas have a higher risk compared to people who consume fish from upstream areas (Figure 7). Cancer risks are higher under the RME scenario because this scenario assumes more fish is consumed (Figure 8). Upstream of the Source Area, cancer risks range from $1x10^{-5}$ to $1x10^{-4}$ (Figure 8). Downstream of the Source Area, cancer risks range from approximately $1x10^{-3}$ to $1x10^{-2}$ (Figure 8).

When deciding whether an estimated cancer risk is a concern, it is appropriate to consider the nutritional benefits from eating fish. Given the nutritional benefits of fish, consuming American eel, largemouth bass, or white sucker from Georgiaville Pond and Greystone Mill Pond (upstream of the site) would pose little risk under the CTE and RME scenarios. The estimated cancer risks at these locations are at or below $1x10^{-5}$ for the CTE scenario or $1x10^{-4}$ for the RME scenario. These values mean that there is a risk for 1 extra cancer for every 100,000 or 10,000 people, in the CTE and RME scenarios, respectively. Cancer risks upstream of the Source Area are within the category of possible concern for increased health risks but given the health benefits from eating fish and the conservative assumptions used to estimate rates of fish consumption, eating fish from these upstream locations is not a health concern.

At downstream Site locations (Lyman Mill Reach, Allendale Pond, and Lyman Mill Pond), cancer risks for adults exceed $1x10^{-4}$ for all fish species under the CTE consumption scenario (Table 7—Table 10). Under the RME scenario for adults, cancer risk ranges from $1.3x10^{-3}$ to $2.9x10^{-2}$ for American eels, largemouth bass, and white sucker downstream of the Source Area. These cancer risk results are in the "concern for increased cancer risk" category. The cancer risk values indicate that fish downstream of Centredale Manor are too contaminated for consumption under both the CTE and RME scenarios. In general, the health risks from consuming those fish outweigh the health benefits (see the *Context for Health Risk Results* section for details on the benefits of fish consumption).

Historical Data for Dioxin/PCB Contamination of Fish Tissues in the Woonasquatucket River
The data provided by USEPA for this health consultation are from the most recent of several studies that have examined the dioxin levels in fish from the Woonasquatucket River. The results published by USEPA in 1999 and 2005 are briefly described in this section. Overall, the current health consultation has very similar results to the previous studies. All studies report similar

levels of dioxins in fish tissue and similar health risk results. Concentrations of dioxins in fish tissues have not changed significantly since the original 1999 health consultation.

The HQ and cancer risk values calculated here were in the same range as those calculated for the data presented in the original 1999 health consultation. The 1999 health consultation examined the concentration of dioxins, furans, and dioxin-like PCBs in sunfish and eels (Table 19).[12] Eels were collected upstream of Centredale Manor and sunfish were collected downstream.[12] The hazard quotients and cancer risks (Table 19) for American eels in the 1999 survey and those collected at Lyman Mill Reach for the current analysis (Table 13) were very similar. Largemouth bass at Lyman Mill Pond (Table 16) also had similar hazard quotients and cancer risks to the sunfish (Table 20). Hazard quotients and cancer risk estimates calculated for the fish species analyzed in the 1999 health consultation support the current analysis but are limited because of the small number of samples.

In the 1999 health consultation, the upstream HQs and cancer risks were similar to the downstream HQs and cancer risks (Table 19 and 20). This could be due to differences in the species sampled or the sampling locations. American eels are bottom feeders while sunfish live higher in the water column. These species also have different feeding habits. Differences in their habitats and feeding strategies could affect their dioxin uptake and subsequent cancer risk. The American eels analyzed in 1999 were collected from the Woonasquatucket River near Smith Street.[12] This location is only slightly upstream of Centredale Manor, and it is possible that contamination from Centredale Manor affected the measured concentrations in eels collected just upstream of the Site.[12] The PCB concentrations for the American eels collected in 1999 are about the same as the concentrations measured downstream (Lyman Mill Reach and Lyman Mill Pond) in the current health consultation.

The results of USEPA's 2005 Baseline Human Health Risk Assessment support the results found in the current health consultation. American eel, largemouth bass, and white sucker were sampled in both the current health consultation and in USEPA's 2005 assessment. In general, the trends established in the 2005 assessment are still true in the current analysis. Both analyses show that dioxin concentrations and risk posed by fish consumption increased downstream of Centredale Manor relative to upstream samples.[1] The 2005 assessment also evaluates fish samples taken from Assapumpset Pond, which releases into the Woonasquatucket River at Lymans Mill Pond (Figure 3). Assapumpset Pond is positioned so that it cannot be contaminated with water leaving the Source Area. Dioxin concentrations in samples collected from Assapumpset Pond were similar to dioxin concentrations in samples from Greystone Mill Pond, which is upstream of the Site. This shows that the background concentrations of dioxin in fish from an area unaffected by Centredale Manor are roughly the same as those upstream of the Site. In 2005, samples were also taken from further downstream than the samples analyzed in this health consultation (Figure 3). Largemouth bass and American eels were collected from Manton Pond and Dyerville Pond, respectively. Dioxin concentrations measured in these samples were lower than those measured at Lyman Mill Pond.[1] The 2005 assessment showed a small decrease in dioxin concentrations downstream of Lyman Mill Pond. The small sample size limits the ability to draw conclusions about the trend of dioxin concentrations downstream of the Source Area.

Context for Health Risk Results

The health risks presented here are calculated by making assumptions about consuming fish from the Woonasquatucket River. The first set of assumptions used to calculate the health risks are that 100% of the fish meals consumed are American eel, largemouth bass, or white sucker harvested from the Woonasquatucket River. The conclusions in this health consultation assume that all fish meals consist of these three species. If stakeholders are eating fish from other locations or purchased from stores, their risk of harmful effects is likely lower.

Our assumptions about fish consumption are very protective because it is unlikely that 100% of a person's fish meals are coming from one of these three species. Actual exposure to dioxins will depend on the species consumed and the frequency of fish meals. The species analyzed in this health consultation were selected because they were likely to have the highest concentrations of dioxins and PCBs. Bottom feeders, such as American eels and white sucker, have higher dioxin concentrations compared to species that live higher in the water column. Largemouth bass are top predators. They accumulate dioxins and PCBs in their tissue from eating other contaminated fish. It is unlikely that any of the fish, especially white sucker, are consumed with the frequency assumed in this health consultation. The other part of this assumption is that all the fish consumed are harvested from the Woonasquatucket River, which is unlikely. Grocery stores stocking fish and other freshwater and marine sources are readily available in Rhode Island.

The fish consumption rates (Table 5) are based on those recommended by various state governments[20–22] and the number of fish meals recommended by the FDA.[29] The consumption rates and fish meal frequencies assumed in this study overestimate the amount of fish consumed by the average stakeholder. The CTE and RME intake rates for the over 21 age group are within the range of the 50th-75th and >99th percentiles, respectively, of total finfish and shellfish consumption as measured by the USEPA.[30] The intake rates for children were based on the CTE and RME values for adults and scaled according to body weight (see *Fish Consumption Scenarios* for more details).

The assumptions mentioned previously ensure that the health risk values calculated here are adequately protective of most exposure scenarios. While these values accurately predict the risk posed to people with the most exposure, they likely overestimate the risk posed for people who consume fewer fish from the Woonasquatucket. Due to the estimated increased risk, messaging from the State should continue to discourage fishing from downstream of Centredale Manor, but health risks from dioxins should be minimal for people consuming fish from the river very infrequently. Upstream of Centredale Manor, health risks posed by dioxins are minimal, especially for largemouth bass. People should be able to fish for and consume largemouth bass at GVP and GMP, which are upstream from the Site. In these areas, fish consumption should be dictated by statewide fish consumption guidance based on mercury. Our guidance continues to be "people should not consume fish from the Woonasquatucket River downstream of the Johnston/Smithfield town line (Figure 11)." This is based on dioxin/PCB concentrations downstream of Centredale Manor. Upstream of the Johnston/Smithfield town line (Figure 11), people consuming fish from the Woonasquatucket River should follow statewide fish consumption guidance based on mercury. The Johnston/Smithfield border is near the Greystone Mill Pond (Figure 11), which is the furthest downstream location with data indicating that levels of dioxins in fish are safe to consume.

Fish contain protein, omega-3 fatty acids, vitamins, and minerals that are an essential part of a healthy diet.[22] This health consultation deals with the risks posed from fish contaminated with dioxins consumed from the Woonasquatucket River. Frequent fish meals sourced from the river should be avoided, but fish, in general, are still an excellent source of nutrients. Rhode Island has other areas that are safer to fish for freshwater and saltwater species.

Limitations

Fish Behavior and Dioxin Concentrations

Aquatic species accumulate dioxins differently, but concentrations can typically be predicted based on nearby sediment concentrations.[31,32] Dioxins will preferentially adhere to sediment and organic matter, such as fish, rather than remain freely dissolved in the water column.[33–35] Dioxin equivalent concentrations in American eel and white sucker were higher compared to the largemouth bass dioxin equivalent concentration (Figure 5). American eels and white sucker are generally bottom feeders (e.g., close to the sediment) while largemouth bass spend more time near the water surface but are top predators.[36–38] Increased time spent interacting with sediment and a position higher in the food chain leads to more dioxin uptake and accumulation in fish tissue.

Fish Tissue Type

Samples of American eel and white sucker were analyzed as whole body and largemouth bass as skin-on fillet. All types of fish caught from the Woonasquatucket River could be eaten whole or as a fillet. Cultural differences could change preparation styles and, therefore, alter the dioxin concentration and change the amount of exposure. Because dioxins and PCBs preferentially accumulate in the organs and fats, whole body concentrations potentially overestimate how much contaminant a person may eat compared to fillets only, and vice-versa.[39–41] When the species are compared, largemouth bass tends to have lower dioxin concentrations compared to American eel and white sucker. This could be due to sample preparation from fillets compared to whole body homogenates (an analysis where the entire fish is analyzed including muscle tissue, organs, skin, etc.). If the largemouth bass were prepared as a whole-body homogenate instead of a fillet, the concentration of dioxins would presumably have been higher.[1]

Fish Species in the Human Diet

While the fish species sampled (American eel, largemouth bass, white sucker) are eaten in the United States, other species may be caught as frequently. Other species, such as sunfish and yellow perch, are likely lower in contaminants and are often caught and consumed in Rhode Island. Sunfish and yellow perch are likely to be lower in PCB/dioxin contamination.[42] Sunfish analyzed in ATSDR's 1999 health consultation had dioxin concentrations of 63 ng dioxin equivalents per kg wet weight (ww) of fish.[12] This is similar to the concentration of dioxin in largemouth bass collected in Lyman Mill Pond (Figure 5). It is also lower than American eel and white sucker collected downstream of the Source Area (Figure 5). For future studies, nearby communities could provide detailed information about the species, sizes, and seasons when they fish, enabling a more complete health effects evaluation.

Risk-Benefit of Eating Contaminated Fish

In addition to environmental contaminants, fish also contain high-quality protein and omega-3 fatty acids, which have numerous long-term health benefits: decreased risk of stroke, decreased rates of coronary heart disease, and improved fetal neurodevelopment during pregnancy.[43,44] Some studies suggest that these fish lipids offset the adverse neurodevelopmental outcomes of methylmercury exposure.[45,46] Other studies have demonstrated that moderate fish consumption can outweigh contamination with dioxins and PCBs.[44,47,48] Fish is an excellent source of nutrients, including proteins, vitamins (A, D, and B_{12}), minerals and fatty acids.[48] Fish consumption lowers the risk of coronary heart disease.[48] 1-2 fish meals per week lower the risk of coronary heart disease by 20-30%.[44,48] There is also limited evidence supporting the effect of fish consumption in reducing the risk for stroke (12-30% reduction) and age-related maculopathy (36% reduction).[48] The benefits and risk depend on the levels of nutrients and contamination, respectively.[44,47,48] When balanced appropriately, the health risks posed by contaminants in fish can be similar to or less than the benefits from the nutrients in fish. The current study only quantifies the negative health impact of the contaminants found in fish. Calculating the benefits is outside the scope of this analysis. Given the substantial health impact associated with dioxin levels in fish downstream of Centredale Manor, the benefits are unlikely to outweigh the risks at any level of fish consumption. Upstream, the benefits likely outweigh the risks for fish consumers.

Human Behavior

The exposure scenarios presented in this health consultation are health-protective estimates of freshwater fish ingestion based on recommendations from the USEPA and FDA[30,49]. These estimates rely on consistent and predictable human behavior, but human activities are variable and exposures are unique to each individual person. Therefore, health-protective estimates were used for the calculation of the doses, HQs, and cancer risks.

Health Outcomes Data

Initial outreach indicated that members of the community were concerned that contaminants from Centredale Manor could be impacting the rate of cancer in the area around the site. In 2021, the Rhode Island Internal Cancer Investigation Team (ICIT) reviewed cancer rate data among residents of Providence County. The goal of this review was to determine whether cancer rates were within the expected range for the area around Centredale compared to the state. Cancer registry data can be useful for identifying cancer patterns and analyzing trends in cancer rates. It is difficult to prove a cause-and-effect relationship between environmental contamination and cancer rates using this data. In response to community concerns, we analyzed the cancer registry data to determine if rates in the area around Centredale Manor are different compared to what is expected. Limitations in the cancer registry data mean that we can determine if the cancer rate is elevated, but not the cause of differences between observed and expected cancer cases. ICIT focused on census tracts 20, 121.02, and 123 (2011-2018 data), which border the Centredale Manor Restoration Project Superfund site.[6] Cancer rates for the Census tracts of interest were calculated and compared to statewide rates.

Census tract-specific standardized incidence rates (SIRs) for leukemia and non-Hodgkin's lymphoma were examined. Leukemia and non-Hodgkin's lymphoma were examined because they are associated with dioxin exposures and we were interested in determining if there were a higher number of observed cases than expected.[17] These analyses cannot be used to find health

effects caused by Centredale Manor but were performed to answer the community's question about the prevalence of cancer in the area. SIRs can be used to determine if the observed number of cancer cases is different from the expected number of cancer cases. An SIR of 100% means that the observed number of cancer cases is equal to the expected number. A 95% confidence interval (CI) evaluates the magnitude and stability of the SIR estimate. When a 95% CI range does not include 100%, then the observed number of cancer cases is considered statistically different from the number of expected cancer cases.

Based on the SIR calculation, no statistically significant difference between the number of observed and expected cancer cases for the cancer types included in this analysis were found (Figure 10). For every cancer type, the confidence interval overlaps with 100%. Confidence intervals are large for this data set because of the small number of cancer cases in this area. Small case numbers tend to increase the range of confidence intervals. Figure 11 shows that the number of female leukemia cases are higher than expected in these census tracts. While the number of cases is higher than expected, the large confidence interval means that there was no statistically significant difference found between the number of observed and expected cases. This is likely because the number of female leukemia cases is small. The data presented in Figure 101 is limited because the long latency period for most cancers to appear means that there may not have been enough time for the cancer to develop. Another confounding factor is that environmental exposures leading to cancer may have occurred elsewhere. People moving to and from the area make it difficult to determine if cancer cases are being caused by environmental contaminants such as those found at Centredale Manor. People exposed to dioxins from eating fish from the downstream area may have moved away and thus their cancer would not be counted. Cancer rates can also vary from high to low because of the small number of diagnosed cancers in the region. In addition, the percentage of the population consuming fish from the Woonasquatucket River is likely relatively low, thus most people are not exposed to dioxins in fish. The wide range of risk factors affecting cancer rates means that it would be very difficult to identify an impact from eating dioxin-contaminated fish from the Woonasquatucket River. With these limitations in mind, we can say that cancer rates in the area are not outside of the expected range.

Conclusions

At the Centredale Manor Restoration Project Superfund Site, EHRAP evaluated environmental contaminant data in fish tissues. Specifically, they looked at exposure for nearby subsistence fishing communities. Consuming fish from the Woonasquatucket River downstream of the Johnston/Smithfield border puts nearby populations at risk of both cancer and noncancer health effects because of the presence of dioxins and dioxin-like PCBs in the fish tissue. Based on the samples and exposure scenarios evaluated, RIDOH and ATSDR came to the following conclusions:

1. Dioxins and dioxin-like PCBs in contaminated fish in Allendale and Lyman Mill Ponds could harm people's health when eaten for one year or more.
2. Increased risks of dioxin-related noncancer and cancer health effects could be expected among adults and children who eat 1 ounce (oz) or more of fish per 20 lbs body weight per week caught from Allendale and Lyman Mill Ponds for one year or more. This is due

to the presence of dioxins, furans, and dioxin-like PCBs, particularly 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD).

3. The health risks posed by dioxins in fish collected downstream of the Source Area likely outweigh the benefits of consuming fish. People should avoid eating fish from downstream of Centredale Manor.
4. The benefits of fish consumption relative to other protein sources likely outweigh the potential health risks posed by background levels of dioxins and related compounds in fish collected upstream of Centredale Manor. People may continue to eat fish caught upstream of Centredale Manor following state mercury guidelines.
5. RIDOH urges stakeholders not to eat fish, turtles, eels, or plants from the river downstream of the Johnston/Smithfield border. Do not swim or wade in the river downstream of the Johnston/Smithfield border.
6. Community members eating fish upstream of the Johnston/Smithfield border should follow the state guidance regarding mercury contamination.
7. While eating fish caught downstream from Centredale Manor could increase cancer risks, a analysis of health outcomes indicates that local cancer rates are not statistically different from the rest of the state. While some cancer types have elevated rates compared to the state, the difference is not statistically significant.

Recommendations

EHRAP provides the following recommendations to potentially reduce dioxin, furan, and dioxin-like PCB exposures:

- The remediation described by USEPA in their Draft Final Remedial Design Work Plan (dated September 2018) should be implemented as written. Dust suppression should be emphasized during the remediation process to protect the health of the community and the people working onsite.
- Official messaging from RIDOH and the Woonasquatucket River Watershed Council should continue to discourage eating fish and other wildlife from the Woonasquatucket River downstream from the Johnston/Smithfield border to prevent potential exposures to dioxins. Upstream of the Johnston/Smithfield border, fish consumption should follow the state's mercury guidance.
- After remediation is complete, follow up testing of fish tissues for dioxins should be performed to measure the success of the remediation methods.

Public Health Action Plan Activities

Actions taken to protect the public from exposure to PCBs as a result of consumption of fish from the Woonasquatucket River include:

- Previous recommendations from EPA have been to avoid consumption of fish from the Woonasquatucket River downstream of the Johnston/Smithfield town line (complete).
- Future communications (fact sheets) from RIDOH will reinforce this language until remediation is complete (pending).
- RIDOH staff will be participating in meetings through the Woonasquatucket River Watershed Council and USEPA to educate stakeholders on the potential risks (pending).

Report Preparation

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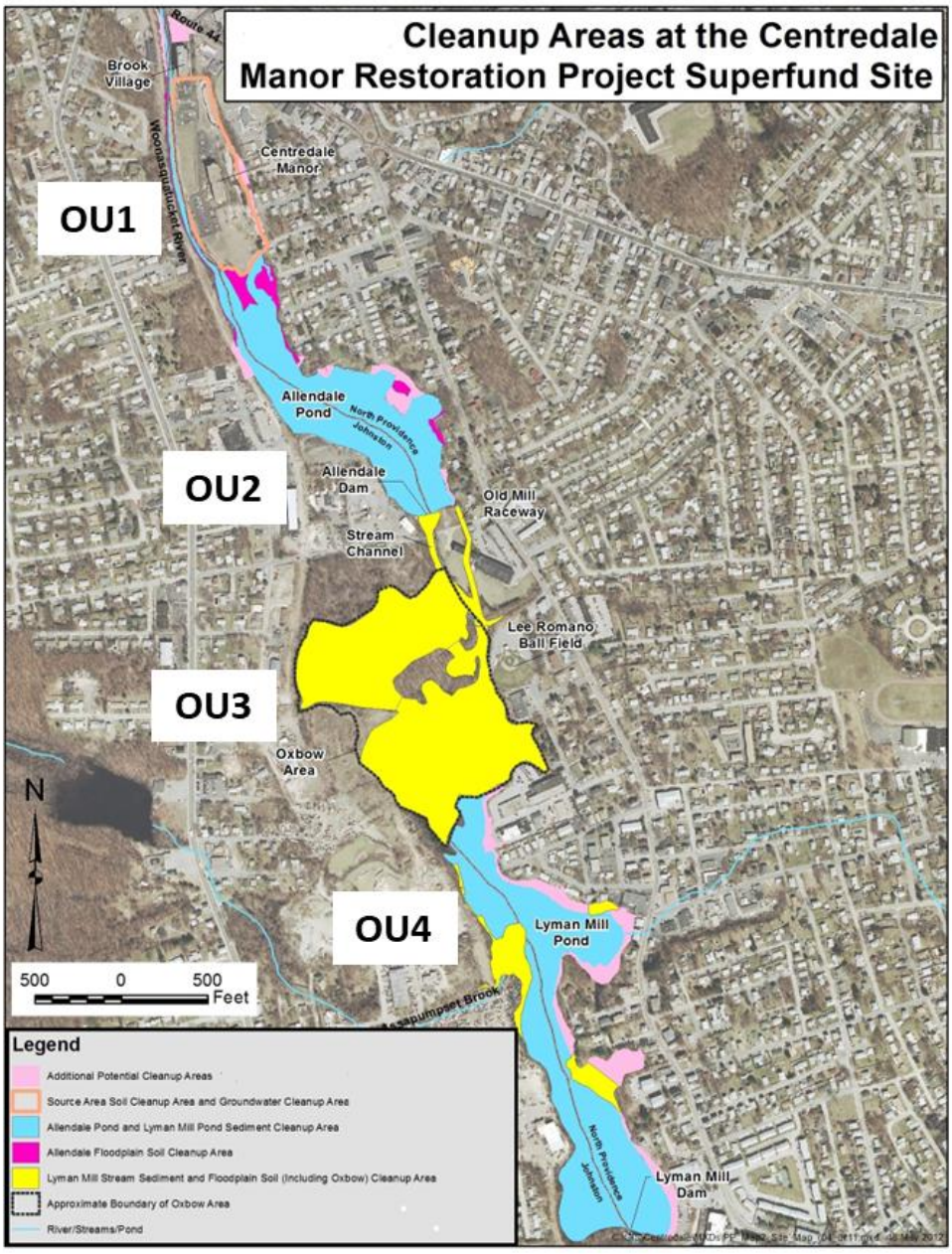
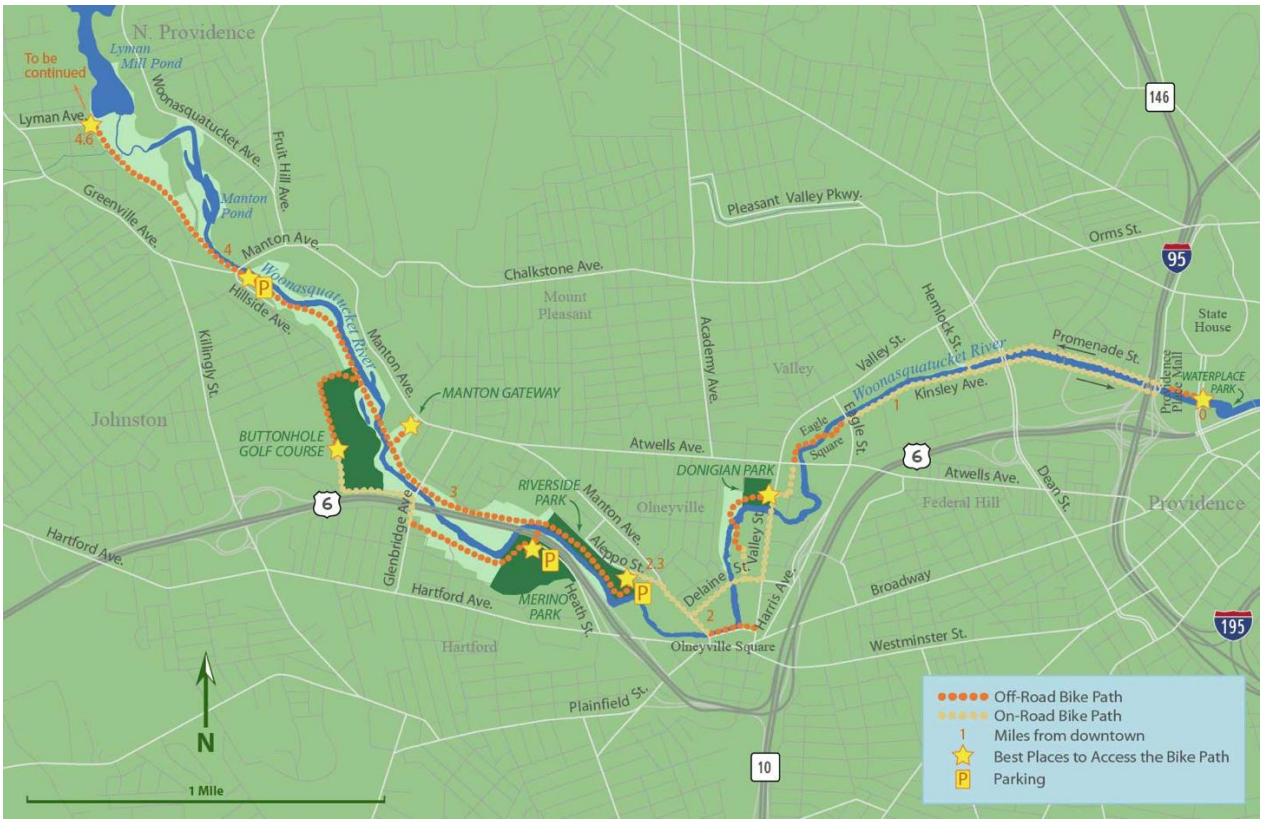
Figures



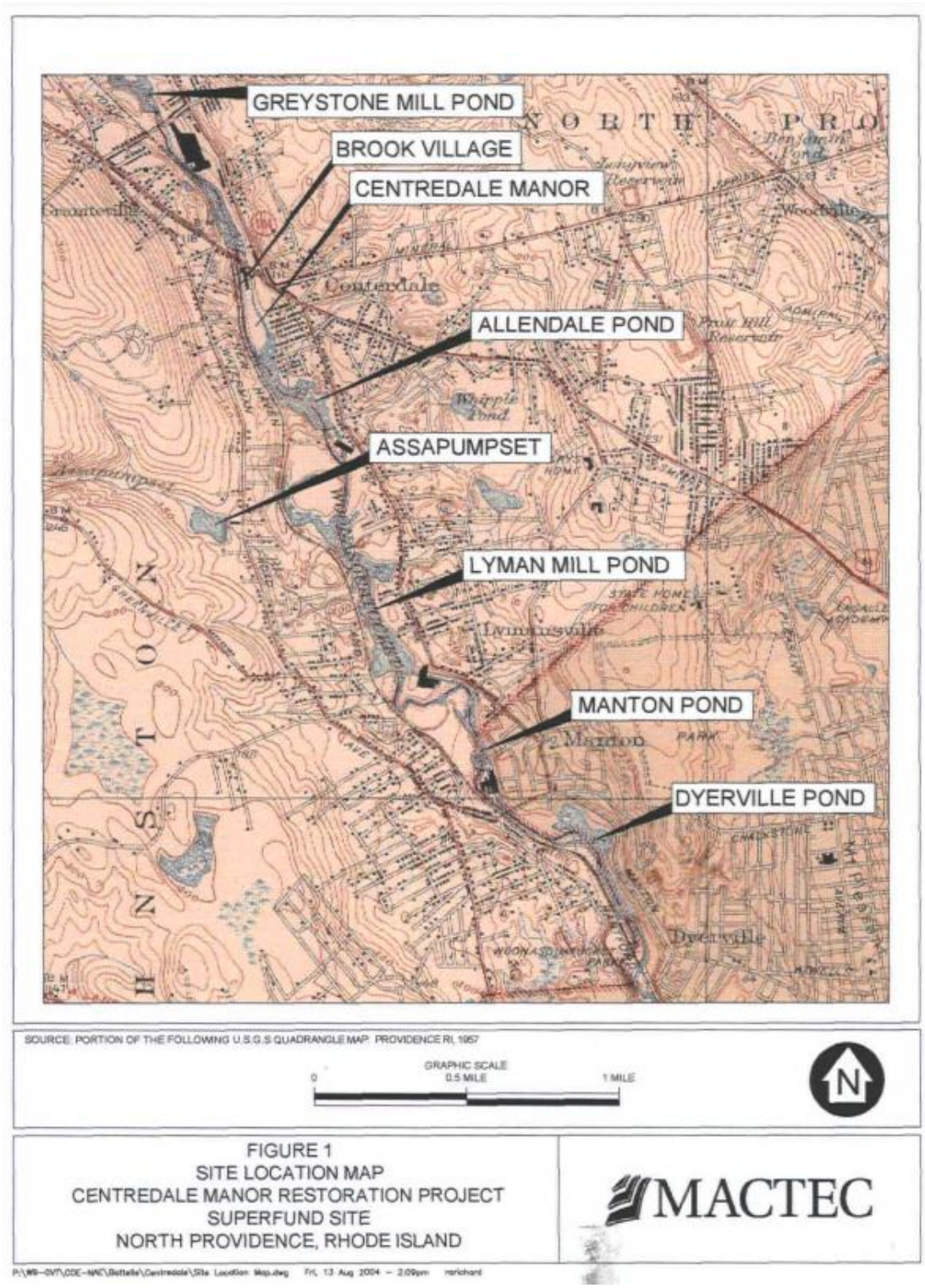
Source: USEPA, 2012

Figure 1: Map with the operational units for Centredale Manor Restoration Project Superfund Site. The Site is divided into four "Operable Units". These include the Source Area (OU1) and three downstream locations where sediment accumulated: Allendale Pond (OU2), the Oxbow Area (OU3), and Lyman Mill Pond (OU4). Together, these operable units make up the Site.



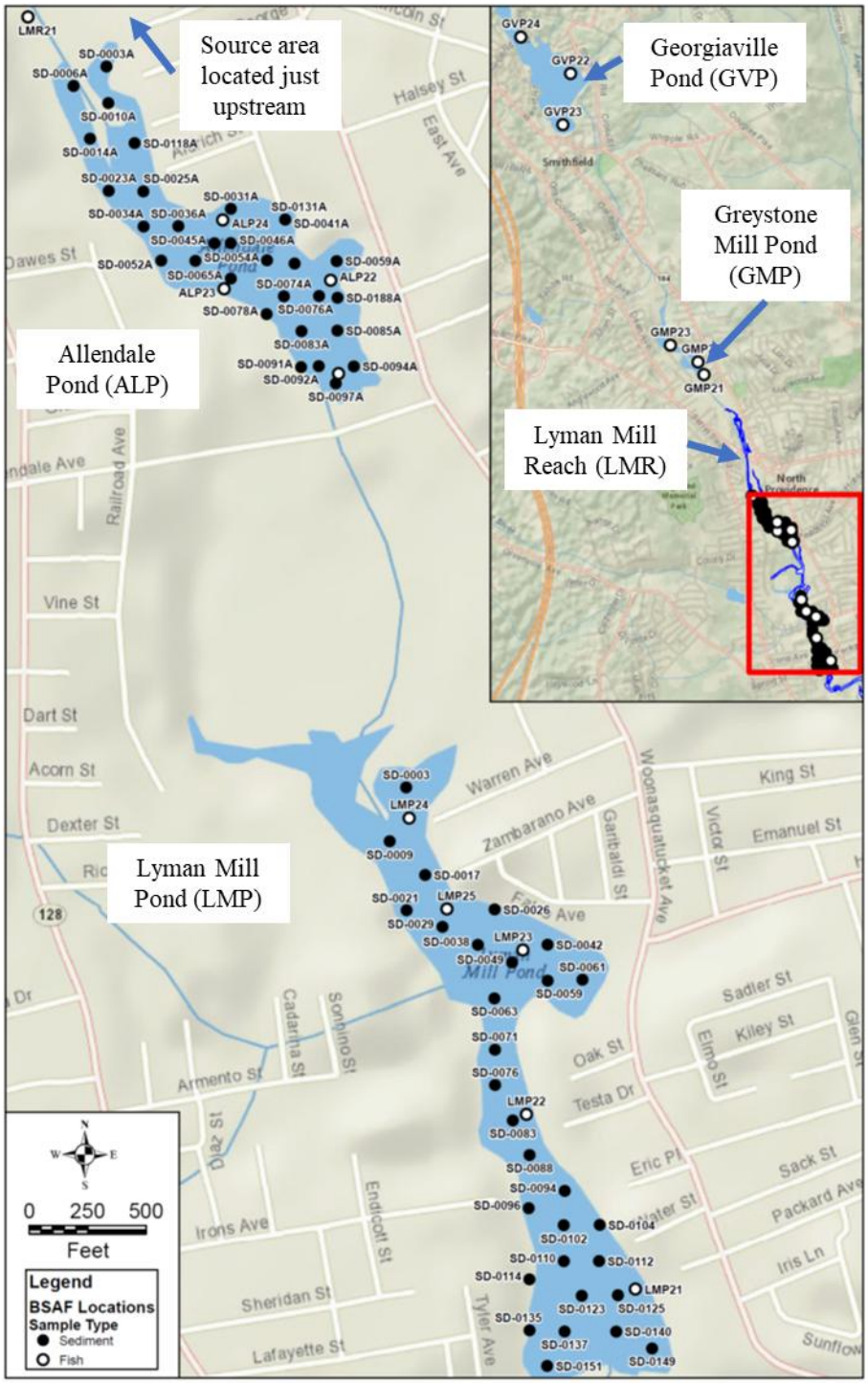
Source: [Woonasquatucket River Watershed Council](), 2023

Figure 2. Woonasquatucket River Greenway. This map shows a bike path that follows the Woonasquatucket River downstream of Centredale Manor, which can be easily accessed by members of the public. People have easy access to this area and could be fishing from any number of places.



Source: USEPA, 2005

Figure 3: Sampling locations from USEPA's 2005 Baseline Human Health Risk Assessment. This map shows the locations of Brook Village and Assapumpset, Manton, and Dyerville Ponds, which were not included in the most recent fish collection.



Source: USEPA, 2019

Figure 4. Fish sampling locations up- and downstream of the Centredale Manor Superfund Site. Source area indicated with yellow star on the inset map. Fish sampling locations are shown as white circles with black outlines. Black circles indicate sediment sampling locations.

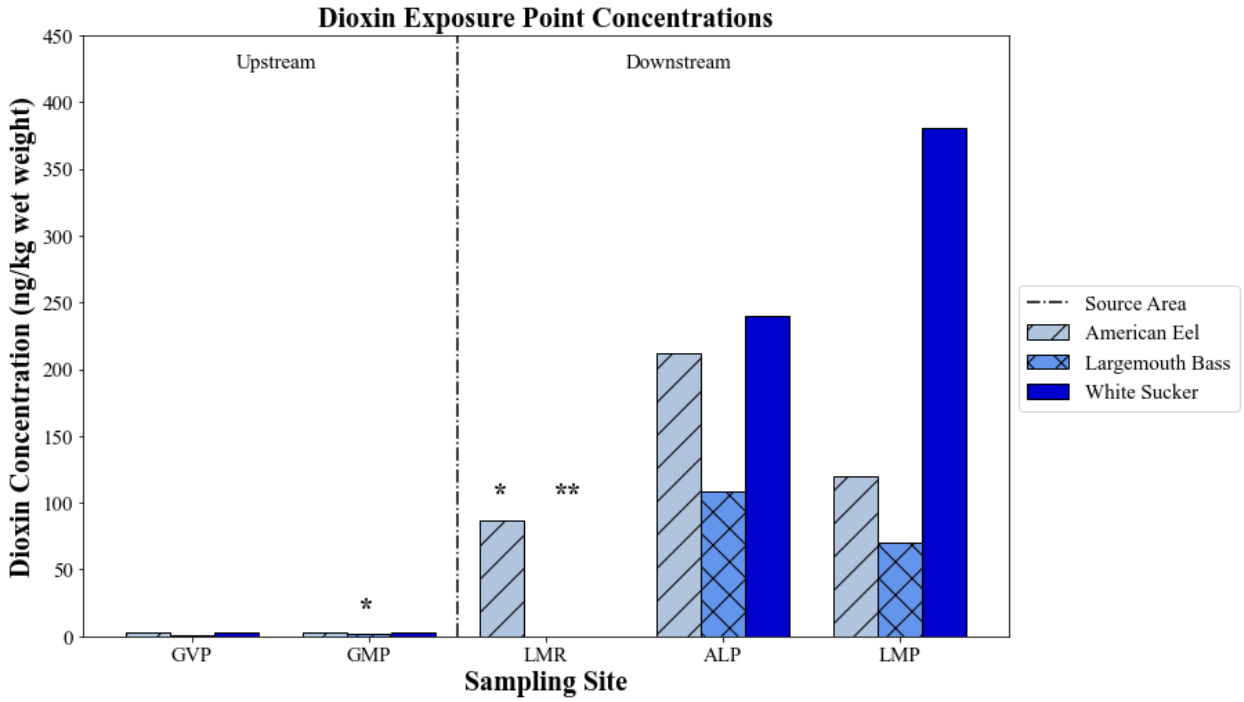


Figure 5: Dioxin concentrations in fish tissue. Concentrations are shown as toxicity equivalents for dioxins detected in American eels, largemouth bass, and white sucker at Georgiaville Pond (GVP), Greystone Mill Pond (GMP), Lyman Mill Reach (LMR), Allendale Pond (ALP), and Lyman Mill Pond (LMP). Data marked with an * are maximum values. All other concentrations are presented as the 95% upper confidence level (UCL) of the mean. No largemouth bass or white sucker were collected at LMR and are marked with **. Table 1 indicates the type of fish tissue sample (whole body or fillet) for each species.

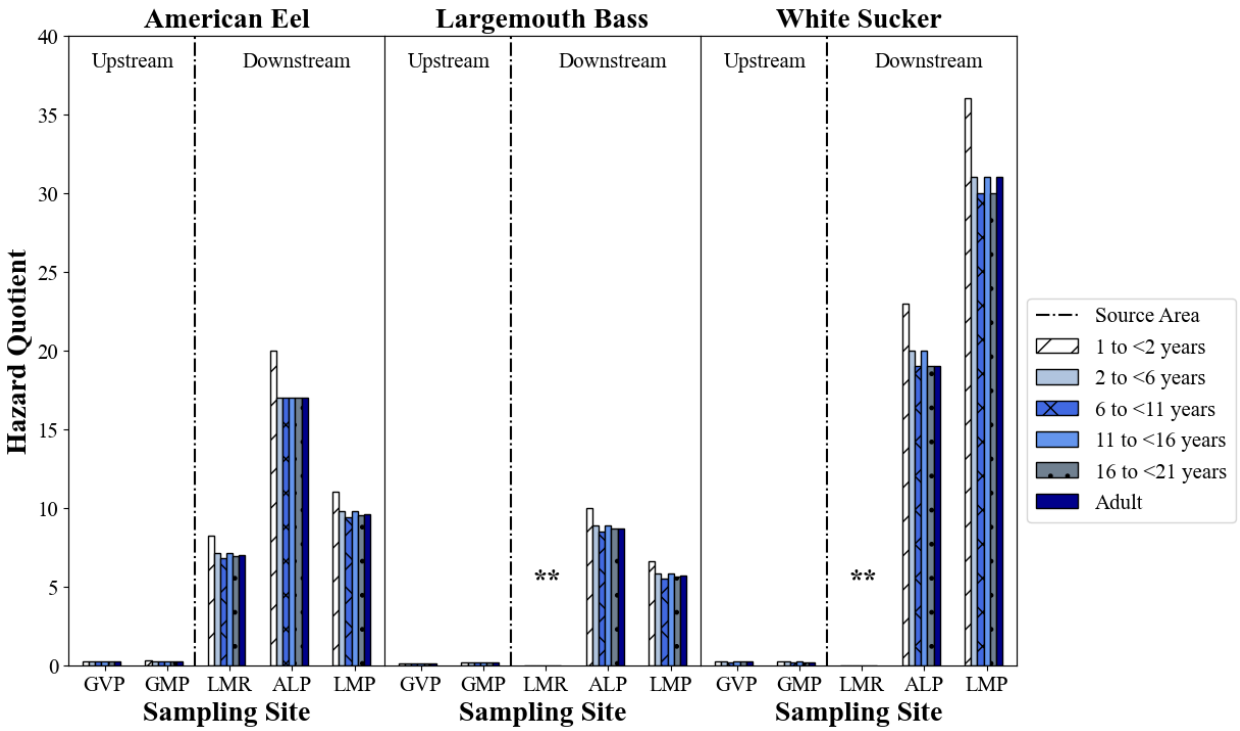


Figure 6: Dioxin noncancer hazard quotients for the chronic CTE scenario. Hazard quotients were calculated for each fish species: (A) American eel, (B) largemouth bass, and (C) white sucker for every ATSDR age category. No data is available for largemouth bass or white sucker at LMR (marked with **). A hazard quotient greater than 1.0 indicates increased risk for negative health effects. Table 7-Table 12 have more detailed information about the chronic CTE exposure scenario.

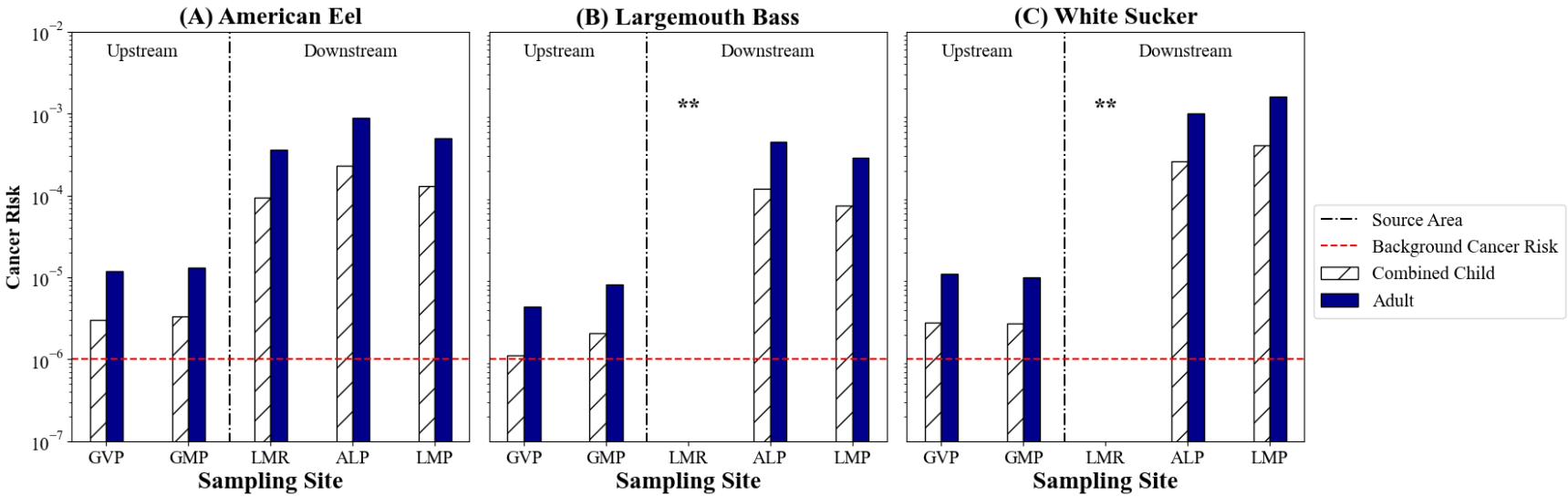


Figure 7: Dioxin cancer risks for the chronic CTE scenario. Cancer risks were calculated for three fish species: (A) American eel, (B) largemouth bass, and (C) white sucker for two ATSDR categories (adult and children birth to 21 years). No data are available for largemouth bass or white sucker at LMR (marked with **). Horizontal dashed red line indicates ATSDR's CREG of 1 extra case of cancer for every 1 million people exposed. Values greater than $1*10^{-6}$ indicate a risk of cancer greater than the baseline risk for screening carcinogens for further evaluation.

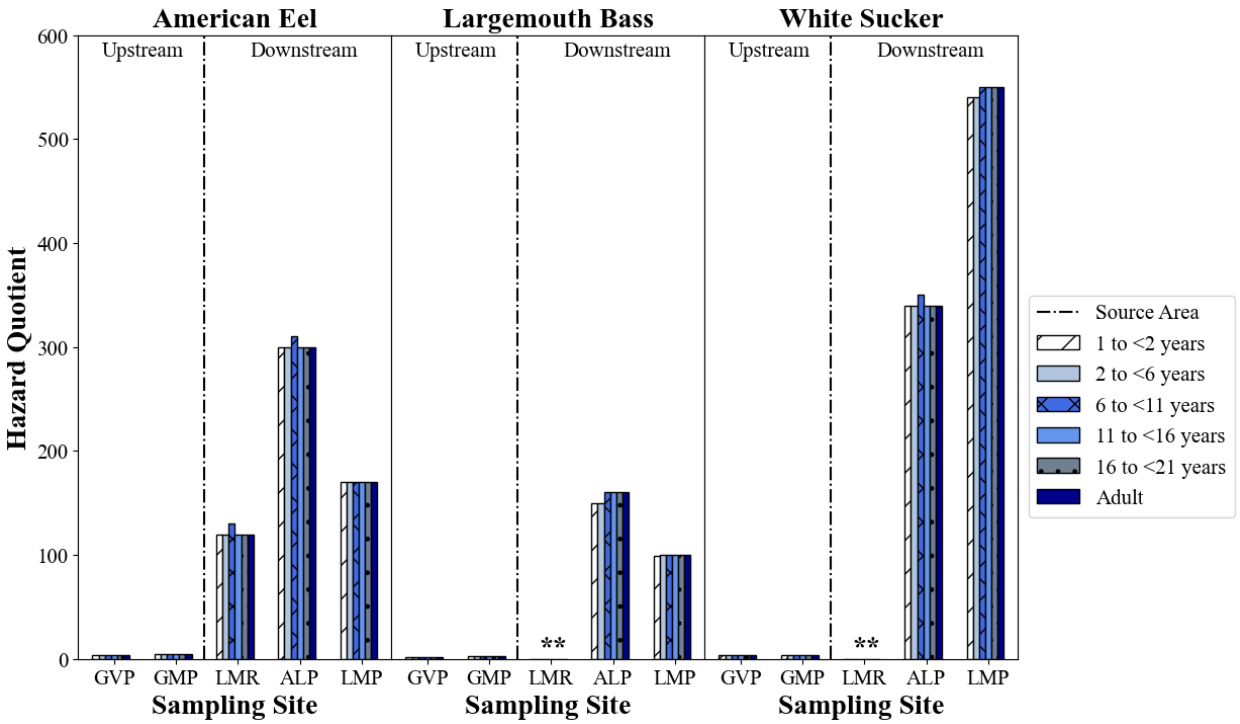


Figure 8: Dioxin noncancer hazard quotients for the chronic RME scenario. Hazard quotients were calculated for each fish species: (A) American eel, (B) largemouth bass, and (C) white sucker for every ATSDR age category. No data is available for largemouth bass or white sucker at LMR (marked with **). A hazard quotient greater than 1.0 indicates increased risk for negative health effects. Table 13Table 18 have more detailed information about the chronic CTE exposure scenario. Values greater than 1.0 indicate an increased risk of noncancer health effects.

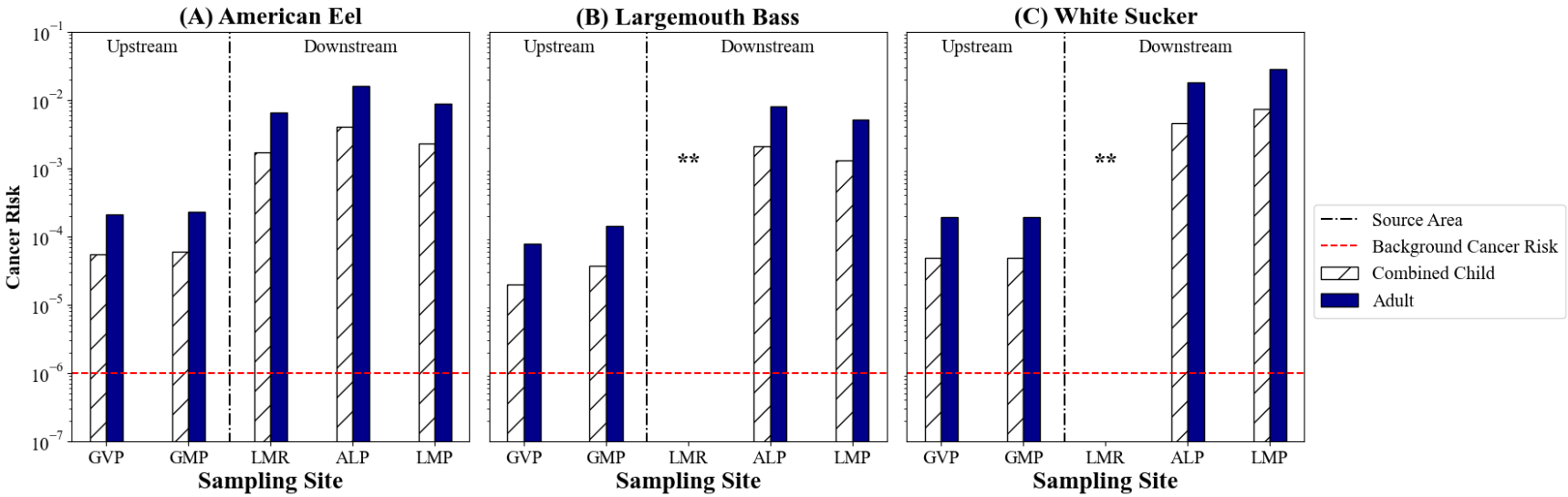


Figure 9: Dioxin cancer risks for the chronic RME scenario. Cancer risks were calculated for each fish species: (A) American eel, (B) largemouth bass, and (C) white sucker for two ATSDR categories (Birth to 21 years and adult). No data is available for largemouth bass or white sucker at LMR (marked with **). Horizontal dashed red line indicates the ATSDR background cancer risk screening value ($1*10^{-6}$). Values greater than $1*10^{-6}$ indicate a risk of cancer greater than the baseline risk.

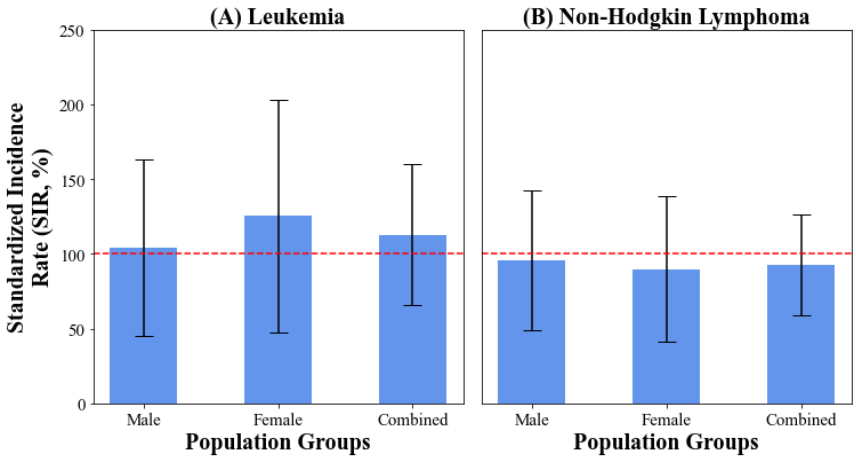
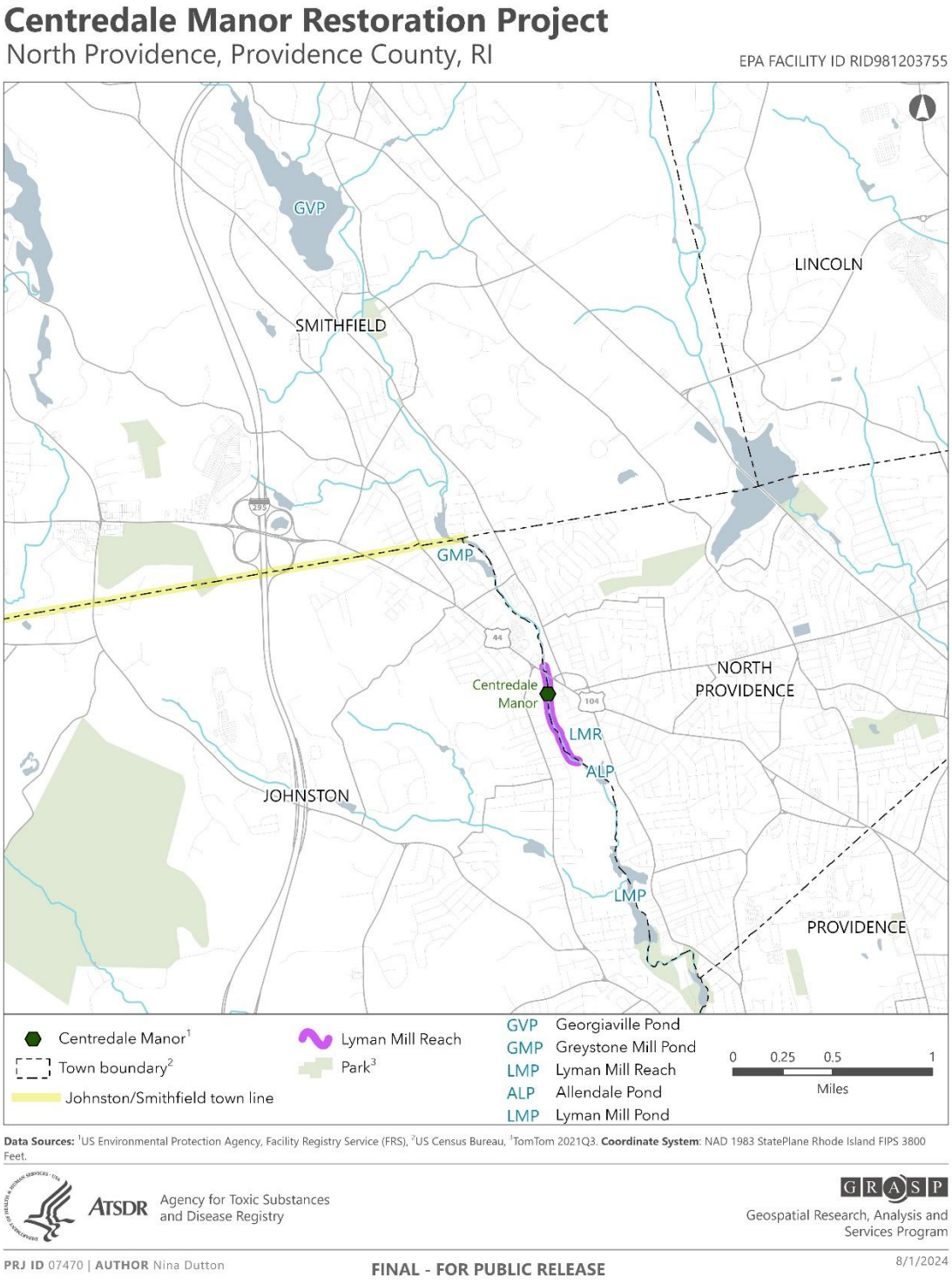


Figure 10: Standardized incidence rates (SIRs) for (A) leukemia and (B) non-Hodgkin lymphoma. The reference population for these calculations is the state. SIRs for male, female, and combined are presented using 2011-2018 cancer data for census tracts 123, 121.02, 20, 124.01, 18, 19, 25. The red dashed line represents an SIR of 100%, indicating that the number of expected cases exactly matches the number of observed cases. Error bars represent the 95% confidence interval. If the red line is within the error bars, the SIR is not statistically different than 100% and that differences are likely due to random chance.



Source: ATSDR GRASP, 2024

Figure 11: Map of sampling areas for the current study. This map shows the locations of the sampling areas for this health consultation: Georgiaville Pond (GVP); Greystone Mill Pond

(GMP); Lyman Mill Reach (LMR); Allendale Pond (ALP); Lyman Mill Pond (LMP). Also indicated here is the Johnston/Smithfield town line, which is used to indicate where fish from the Woonasquatucket River can be consumed.

Tables

Table 1. Number of fish tissue samples by location.

Sampling Location	Abbreviation	American Eel (Whole Body)	Largemouth Bass (Skin-On Fillet)	White Sucker (Whole Body)
Georgiaville Pond	GVP	12	10	10
Greystone Mill Pond	GMP	10	3	11
Lyman Mill Reach	LMR	3	NA	NA
Allendale Pond	ALP	10	10	10
Lyman Mill Pond	LMP	10	10	10
Total	-	45	33	41

American eel: *Anguilla rostrata*
Largemouth bass: *Micropterus salmoides*
White sucker: *Catostomus commersoni*
NA: Not Available
Site abbreviations: GVP – Georgiaville Pond; GMP – Greystone Mill Pond; LMR – Lyman Mill Reach; ALP – Allendale Pond; LMP – Lyman Mill Pond

Table 2. Toxic equivalency factors (TEF) for dioxins, furans, and dioxin-like PCBs.[50]

Dioxins	CAS Number	TEF
2,3,7,8-Tetrachlorodibenzo-p-dioxin (reference)	1746-01-6	1
1,2,3,7,8-Pentachlorodibenzo-p-dioxin	40321-76-4	1
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	39227-28-6	0.1
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	57653-85-7	0.1
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	19408-74-3	0.1
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	35822-46-9	0.01
Octachlorodibenzo-p-dioxin	3268-87-9	0.0003
Furans	**CAS Number**	**TEF**
1,2,3,7,8-Pentachlorodibenzofuran	57117-41-6	0.03
1,2,3,4,7,8-Hexachlorodibenzofuran	70648-26-9	0.1
1,2,3,6,7,8-Hexachlorodibenzofuran	57117-44-9	0.1
1,2,3,7,8,9-Hexachlorodibenzofuran	72918-21-9	0.1
1,2,3,4,6,7,8-Heptachlorodibenzofuran	67562-39-4	0.01
1,2,3,4,7,8,9-Heptachlorodibenzofuran	55673-89-7	0.01
2,3,7,8-Tetrachlorodibenzofuran	51207-31-9	0.1
2,3,4,7,8-Pentachlorodibenzofuran	57117-31-4	0.3
2,3,4,6,7,8-Hexachlorodibenzofuran	60851-34-5	0.1
Octachlorodibenzofuran	39001-02-0	0.0003
Dioxin-Like PCBs	**CAS Number**	**TEF**
2,3,3',4,4'-Pentachlorobiphenyl (PCB 105)	32598-14-4	0.00003
2,3,4,4',5-Pentachlorobiphenyl (PCB 114)	74472-37-0	0.00003
2,3',4,4',5-Pentachlorobiphenyl (PCB 118)	31508-00-6	0.00003
2,3',4,4',5'-Pentachlorobiphenyl (PCB 123)	65510-44-3	0.00003
3,3',4,4',5-Pentachlorobiphenyl (PCB 126)	57465-28-8	0.1
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB 169)	32774-16-6	0.03
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB 167)	52663-72-6	0.00003
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189)	39635-31-9	0.00003
3,3',4,4'-Tetrachlorobiphenyl (PCB 77)	32598-13-3	0.0001
3,4,4',5-Tetrachlorobiphenyl (PCB 81)	70362-50-4	0.0003

TEF – toxicity equivalence factors
CAS number – chemical abstracts service number
PCBs – polychlorinated biphenyls

Table 3. All detected analytes in fish from the Woonasquatucket River by chemical class in September and October 2019.

Class	Analyte	Class	Analyte
Dioxins and furans	1,2,3,4,6,7,8-Heptachlorodibenzofuran	Pesticides	Aldrin
Dioxins and furans	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	Pesticides	Chlordane
Dioxins and furans	1,2,3,4,7,8,9-Heptachlorodibenzofuran	Pesticides	cis-Chlordane
Dioxins and furans	1,2,3,4,7,8-Hexachlorodibenzofuran	Pesticides	Dieldrin
Dioxins and furans	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	Pesticides	Endosulfan I
Dioxins and furans	1,2,3,6,7,8-Hexachlorodibenzofuran	Pesticides	Endosulfan II
Dioxins and furans	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	Pesticides	Endosulfan sulfate
Dioxins and furans	1,2,3,7,8,9-Hexachlorodibenzofuran	Pesticides	Endrin
Dioxins and furans	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	Pesticides	Endrin aldehyde
Dioxins and furans	1,2,3,7,8-Pentachlorodibenzofuran	Pesticides	Endrin ketone
Dioxins and furans	1,2,3,7,8-Pentachlorodibenzo-p-dioxin	Pesticides	Heptachlor
Dioxins and furans	2,3,4,6,7,8-Hexachlorodibenzofuran	Pesticides	Heptachlor epoxide
Dioxins and furans	2,3,4,7,8-Pentachlorodibenzofuran	Pesticides	Methoxychlor
Dioxins and furans	2,3,7,8-Tetrachlorodibenzofuran	Pesticides	Toxaphene
Dioxins and furans	2,3,7,8-Tetrachlorodibenzo-p-dioxin	Pesticides	trans-Chlordane
Dioxins and furans	Octachlorodibenzofuran	Metals	Aluminum
Dioxins and furans	Octachlorodibenzo-p-dioxin	Metals	Barium
PCBs	2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB 189)	Metals	Calcium
PCBs	2,3,3’,4,4’-Pentachlorobiphenyl (PCB 105)	Metals	Chromium
PCBs	2,3’,4,4’,5,5’-Hexachlorobiphenyl (PCB 167)	Metals	Copper
PCBs	2,3,4,4’,5-Pentachlorobiphenyl (PCB 114)	Metals	Iron
PCBs	2,3’,4,4’,5’-Pentachlorobiphenyl (PCB 123)	Metals	Lead
PCBs	2,3',4,4',5-Pentachlorobiphenyl (PCB 118)	Metals	Magnesium
PCBs	3,3’,4,4’,5-Pentachlorobiphenyl (PCB 126)	Metals	Manganese
PCBs	3,3’,4,4’-Tetrachlorobiphenyl (PCB 77)	Metals	Mercury
PCBs	3,4,4’,5-Tetrachlorobiphenyl (PCB 81)	Metals	Methyl mercury
PCBs	Aroclor 1248	Metals	Nickel
PCBs	Aroclor 1254	Metals	Potassium
PCBs	Aroclor 1260	Metals	Selenium
PCBs	Aroclor 1268	Metals	Silver
PCBs	Coelution of PCB 156 and 157	Metals	Sodium
Pesticides	4,4'-DDD	Metals	Zinc
Pesticides	4,4'-DDE	PAHs	Benzo[a]pyrene
Pesticides	4,4'-DDT	PAHs	Fluoranthene
Pesticides	alpha-Benzenehexachloride	PAHs	Naphthalene
Pesticides	beta-Benzenehexachloride	PAHs	Phenanthrene
Pesticides	delta-Benzenehexachloride	Semivolatiles	4-Methylphenol
Pesticides	gamma-Benzenehexachloride	Semivolatiles	Acetophenone
		Semivolatiles	Benzaldehyde

PCBs – polychlorinated biphenyls
PAH – polycyclic aromatic hydrocarbons

Table 4. Contaminant concentrations by location and fish species in September and October 2019.

Fish Species	Sampling site	Location with respect to Centredale	Dioxin equivalent* concentration (ng/kg fish ww)	Concentration type
American eel	GVP	Upstream	2.81	95% UCL of the mean
American eel	GMP	Upstream	3.07	95% UCL of the mean
American eel	LMR	Downstream	86.72	Maximum
American eel	ALP	Downstream	212.01	95% UCL of the mean
American eel	LMP	Downstream	119.64	95% UCL of the mean
Largemouth bass	GVP	Upstream	1.06	95% UCL of the mean
Largemouth bass	GMP	Upstream	1.94	Maximum
Largemouth bass	LMR	Downstream	NA	NA
Largemouth bass	ALP	Downstream	108.41	95% UCL of the mean
Largemouth bass	LMP	Downstream	70.45	95% UCL of the mean
White sucker	GVP	Upstream	2.57	95% UCL of the mean
White sucker	GMP	Upstream	2.51	95% UCL of the mean
White sucker	LMR	Downstream	NA	NA
White sucker	ALP	Downstream	239.53	95% UCL of the mean
White sucker	LMP	Downstream	380.68	95% UCL of the mean

*Dioxin equivalents were calculated using the ATSDR calculator.
UCL-Upper confidence limit.
NA-Not applicable, American eel were the only species collected at Lyman Mill Reach.
Site abbreviations: GVP – Georgiaville Pond; GMP – Greystone Mill Pond; LMR – Lyman Mill Reach; ALP – Allendale Pond; LMP – Lyman Mill Pond
ng/kg ww – nanograms per kilogram wet weight

Table 5. Age-specific exposure dose variables for fish consumption.

Exposure group	Body weight categories (kg)	CTE intake rate (g/day)*	CTE intake rate (oz/meal)	CTE meals per week	RME intake rate (g/day)**	RME intake rate (oz/meal)	RME meals per week
1-2 years	11.4	3	0.6	1	15	1.3	3
2-6 years	17.4	4	1.0	1	23	1.9	3
6-11 years	31.8	7	1.8	1	43	3.5	3
11-16 years	56.8	13	3.1	1	76	6.3	3
16-21 years	71.6	16	3.9	1	96	7.9	3
Adult (>21 years)	80.0	18	4.4	1	107	8.8	3

*The CTE fish meal size is ½ the RME fish meal size.
**RME intake rate was determined based on fish consumption guidance from the Minnesota Department of Health, Washington Department of Health, and Oregon Health Authority.[20–22]
kg – kilograms
g/day – grams per day
CTE – central tendency exposure
RME – reasonable maximum exposure

Table 6. Health guidance values for contaminants of concern*.

Contaminant	Chronic (Lifetime) Reference Dose (mg/kg/d)	Cancer Slope Factor (mg/kg/d)
Total Dioxins	$4*10^{-10}$	$1.3*10^{5}$

*Health guidance values provided by ATSDR's PHAST v2.2.1.0.

mg/kg/day – milligrams per kilogram per day

Table 7: American eel doses and risk quotients for the central tendency exposure scenario at Georgiaville Pond, Greystone Mill Pond, and Lyman Mill Reach (2019 data).

Duration	Age Group (years)	GVP Dose (mg/kg/day)	GVP Hazard Quotient	GVP Cancer Risk	GMP Dose (mg/kg/day)	GMP Hazard Quotient	GMP Cancer Risk	LMR Dose (mg/kg/day)	LMR Hazard Quotient	LMR Cancer Risk	ED (years)
Chronic	1 to < 2	1.10E-10	0.26	-	1.20E-10	0.29	-	3.30E-09	8.2†	-	1
Chronic	2 to < 6	9.20E-11	0.23	-	1.00E-10	0.25	-	2.80E-09	7.1†	-	4
Chronic	6 to < 11	8.80E-11	0.22	-	9.70E-11	0.24	-	2.70E-09	6.8†	-	5
Chronic	11 to < 16	9.20E-11	0.23	-	1.00E-10	0.25	-	2.80E-09	7.1†	-	5
Chronic	16 to < 21	9.00E-11	0.22	-	9.80E-11	0.25	-	2.80E-09	6.9†	-	5
Chronic	Combined Child	-	-	3.00E-06‡	-	-	3.30E-06‡	-	-	9.40E-05‡	20
Chronic	Adult	9.00E-11	0.23	1.20E-05‡	9.90E-11	0.25	1.30E-05‡	2.80E-09	7.0†	3.60E-04‡	78
Intermediate	1 to < 2	1.10E-10	-	-	1.20E-10	-	-	3.30E-09	-	-	-
Intermediate	2 to < 6	9.20E-11	-	-	1.00E-10	-	-	2.80E-09	-	-	-
Intermediate	6 to < 11	8.80E-11	-	-	9.70E-11	-	-	2.70E-09	-	-	-
Intermediate	11 to < 16	9.20E-11	-	-	1.00E-10	-	-	2.80E-09	-	-	-
Intermediate	16 to < 21	9.00E-11	-	-	9.80E-11	-	-	2.80E-09	-	-	-
Intermediate	Adult	9.00E-11	-	1.20E-05‡	9.90E-11	-	1.30E-05‡	2.80E-09	-	3.60E-04‡	-
Acute	1 to < 2	7.40E-10	0.0037	-	8.10E-10	0.004	-	2.30E-08	0.11	-	-
Acute	2 to < 6	6.50E-10	0.0032	-	7.10E-10	0.0035	-	2.00E-08	0.10	-	-
Acute	6 to < 11	6.20E-10	0.0031	-	6.80E-10	0.0034	-	1.90E-08	0.095	-	-
Acute	11 to < 16	6.40E-10	0.0032	-	7.00E-10	0.0035	-	2.00E-08	0.099	-	-
Acute	16 to < 21	6.30E-10	0.0031	-	6.90E-10	0.0034	-	1.90E-08	0.097	-	-
Acute	Adult	6.30E-10	0.0032	1.20E-05‡	6.90E-10	0.0035	1.30E-05‡	2.00E-08	0.098	3.60E-04‡	-

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
mg/kg/day – milligram per kilogram per day
Site abbreviations: GVP – Georgiaville Pond; GMP – Greystone Mill Pond; LMR – Lyman Mill Reach
ED – exposure duration

Table 8: American eel doses and risk quotients for the central tendency exposure scenario at Allendale and Lyman Mill Pond (2019 data).

Duration	Age Group (years)	ALP Dose (mg/kg/day)	ALP Hazard Quotient	ALP Cancer Risk	LMP Dose (mg/kg/day)	LMP Hazard Quotient	LMP Cancer Risk	ED (years)
Chronic	1 to < 2	8.00E-09	20†	-	4.50E-09	11†	-	1
Chronic	2 to < 6	7.00E-09	17†	-	3.90E-09	9.8†	-	4
Chronic	6 to < 11	6.70E-09	17†	-	3.80E-09	9.4†	-	5
Chronic	11 to < 16	6.90E-09	17†	-	3.90E-09	9.8†	-	5
Chronic	16 to < 21	6.80E-09	17†	-	3.80E-09	9.5†	-	5
Chronic	Combined Child	-	-	2.30E-04‡	-	-	1.30E-04‡	20
Chronic	Adult	6.80E-09	17†	8.90E-04‡	3.80E-09	9.6†	5.00E-04‡	78
Intermediate	1 to < 2	8.00E-09	-	-	4.50E-09	-	-	-
Intermediate	2 to < 6	7.00E-09	-	-	3.90E-09	-	-	-
Intermediate	6 to < 11	6.70E-09	-	-	3.80E-09	-	-	-
Intermediate	11 to < 16	6.90E-09	-	-	3.90E-09	-	-	-
Intermediate	16 to < 21	6.80E-09	-	-	3.80E-09	-	-	-
Intermediate	Adult	6.80E-09	-	8.90E-04‡	3.80E-09	-	5.00E-04‡	-
Acute	1 to < 2	5.60E-08	0.28	-	3.10E-08	0.16	-	-
Acute	2 to < 6	4.90E-08	0.24	-	2.80E-08	0.14	-	-
Acute	6 to < 11	4.70E-08	0.23	-	2.60E-08	0.13	-	-
Acute	11 to < 16	4.90E-08	0.24	-	2.70E-08	0.14	-	-
Acute	16 to < 21	4.70E-08	0.24	-	2.70E-08	0.13	-	-
Acute	Adult	4.80E-08	0.24	8.90E-04‡	2.70E-08	0.13	5.00E-04‡	-

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
mg/kg/day – milligram per kilogram per day
Site abbreviations: ALP - Allendale Pond; LMP - Lyman Mill Pond
ED – exposure duration

Table 9: Largemouth bass doses and risk quotients for the central tendency exposure scenario Georgiaville Pond, Greystone Mill Pond, and Lyman Mill Reach (2019 data).

Duration	Age Group (years)	GVP Dose (mg/kg/day)	GVP Hazard Quotient	GVP Cancer Risk	GMP Dose (mg/kg/day)	GMP Hazard Quotient	GMP Cancer Risk	LMR Dose (mg/kg/day)	LMR Hazard Quotient	LMR Cancer Risk	ED (years)
Chronic	1 to < 2	4.00E-11	0.100	-	7.30E-11	0.18	-	-	-	-	1
Chronic	2 to < 6	3.50E-11	0.087	-	6.40E-11	0.16	-	-	-	-	4
Chronic	6 to < 11	3.30E-11	0.083	-	6.10E-11	0.15	-	-	-	-	5
Chronic	11 to < 16	3.50E-11	0.087	-	6.30E-11	0.16	-	-	-	-	5
Chronic	16 to < 21	3.40E-11	0.085	-	6.20E-11	0.15	-	-	-	-	5
Chronic	Combined Child	-	-	1.10E-06‡	-	-	2.10E-06‡	-	-	-	20
Chronic	Adult	3.40E-11	0.085	4.40E-06‡	6.20E-11	0.16	8.10E-06‡	-	-	-	78
Intermediate	1 to < 2	4.00E-11	-	-	7.30E-11	-	-	-	-	-	-
Intermediate	2 to < 6	3.50E-11	-	-	6.40E-11	-	-	-	-	-	-
Intermediate	6 to < 11	3.30E-11	-	-	6.10E-11	-	-	-	-	-	-
Intermediate	11 to < 16	3.50E-11	-	-	6.30E-11	-	-	-	-	-	-
Intermediate	16 to < 21	3.40E-11	-	-	6.20E-11	-	-	-	-	-	-
Intermediate	Adult	3.40E-11	-	4.40E-06‡	6.20E-11	-	8.10E-06‡	-	-	-	-
Acute	1 to < 2	2.80E-10	0.0014	-	5.10E-10	0.0026	-	-	-	-	-
Acute	2 to < 6	2.40E-10	0.0012	-	4.50E-10	0.0022	-	-	-	-	-
Acute	6 to < 11	2.30E-10	0.0012	-	4.30E-10	0.0021	-	-	-	-	-
Acute	11 to < 16	2.40E-10	0.0012	-	4.40E-10	0.0022	-	-	-	-	-
Acute	16 to < 21	2.40E-10	0.0012	-	4.30E-10	0.0022	-	-	-	-	-
Acute	Adult	2.40E-10	0.0012	4.40E-06‡	4.40E-10	0.0022	8.10E-06‡	-	-	-	-

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
mg/kg/day – milligram per kilogram per day
Site abbreviations: GVP – Georgiaville Pond; GMP – Greystone Mill Pond; LMR – Lyman Mill Reach
ED – exposure duration

Table 10: Largemouth bass doses and risk quotients for the central tendency exposure scenario Allendale and Lyman Mill Ponds (2019 data).

Duration	Age Group (years)	ALP Dose (mg/kg/day)	ALP Hazard Quotient	ALP Cancer Risk	LMP Dose (mg/kg/day)	LMP Hazard Quotient	LMP Cancer Risk	ED (years)
Chronic	1 to < 2	4.10E-09	10†	-	2.60E-09	6.6†	-	1
Chronic	2 to < 6	3.60E-09	8.9†	-	2.30E-09	5.8†	-	4
Chronic	6 to < 11	3.40E-09	8.5†	-	2.20E-09	5.5†	-	5
Chronic	11 to < 16	3.50E-09	8.9†	-	2.30E-09	5.8†	-	5
Chronic	16 to < 21	3.50E-09	8.7†	-	2.20E-09	5.6†	-	5
Chronic	Combined Child	-	-	1.20E-04‡	-	-	7.60E-05‡	20
Chronic	Adult	3.50E-09	8.7†	4.50E-04‡	2.30E-09	5.7†	2.90E-04‡	78
Intermediate	1 to < 2	4.10E-09	-	-	2.60E-09	-	-	-
Intermediate	2 to < 6	3.60E-09	-	-	2.30E-09	-	-	-
Intermediate	6 to < 11	3.40E-09	-	-	2.20E-09	-	-	-
Intermediate	11 to < 16	3.50E-09	-	-	2.30E-09	-	-	-
Intermediate	16 to < 21	3.50E-09	-	-	2.20E-09	-	-	-
Intermediate	Adult	3.50E-09	-	4.50E-04‡	2.30E-09	-	2.90E-04‡	-
Acute	1 to < 2	2.90E-08	0.14	-	1.90E-08	0.093	-	-
Acute	2 to < 6	2.50E-08	0.12	-	1.60E-08	0.081	-	-
Acute	6 to < 11	2.40E-08	0.12	-	1.60E-08	0.078	-	-
Acute	11 to < 16	2.50E-08	0.12	-	1.60E-08	0.081	-	-
Acute	16 to < 21	2.40E-08	0.12	-	1.60E-08	0.079	-	-
Acute	Adult	2.40E-08	0.12	4.50E-04‡	1.60E-08	0.079	2.90E-04‡	-

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
mg/kg/day – milligram per kilogram per day
Site abbreviations: ALP – Allendale Pond; LMP – Lyman Mill Pond
ED – exposure duration

Table 11: White sucker doses and risk quotients for the central tendency exposure scenario Georgiaville Pond, Greystone Mill Pond, and Lyman Mill Reach (2019 data).

Duration	Age Group (years)	GVP Dose (mg/kg/day)	GVP Hazard Quotient	GVP Cancer Risk	GMP Dose (mg/kg/day)	GMP Hazard Quotient	GMP Cancer Risk	LMR Dose (mg/kg/day)	LMR Hazard Quotient	LMR Cancer Risk	ED (years)
Chronic	1 to < 2	9.70E-11	0.24	-	9.40E-11	0.24	-	-	-	-	1
Chronic	2 to < 6	8.40E-11	0.21	-	8.20E-11	0.21	-	-	-	-	4
Chronic	6 to < 11	8.10E-11	0.20	-	7.90E-11	0.20	-	-	-	-	5
Chronic	11 to < 16	8.40E-11	0.21	-	8.20E-11	0.21	-	-	-	-	5
Chronic	16 to < 21	8.20E-11	0.21	-	8.00E-11	0.20	-	-	-	-	5
Chronic	Combined Child	-	-	2.80E-06‡	-	-	2.70E-06‡	-	-	-	20
Chronic	Adult	8.30E-11	0.21	1.10E-05‡	8.10E-11	0.20	1.00E-05‡	-	-	-	78
Intermediate	1 to < 2	9.70E-11	-	-	9.40E-11	-	-	-	-	-	-
Intermediate	2 to < 6	8.40E-11	-	-	8.20E-11	-	-	-	-	-	-
Intermediate	6 to < 11	8.10E-11	-	-	7.90E-11	-	-	-	-	-	-
Intermediate	11 to < 16	8.40E-11	-	-	8.20E-11	-	-	-	-	-	-
Intermediate	16 to < 21	8.20E-11	-	-	8.00E-11	-	-	-	-	-	-
Intermediate	Adult	8.30E-11	-	1.10E-05‡	8.10E-11	-	1.00E-05‡	-	-	-	-
Acute	1 to < 2	6.80E-10	0.0034	-	6.60E-10	0.0033	-	-	-	-	-
Acute	2 to < 6	5.90E-10	0.0030	-	5.80E-10	0.0029	-	-	-	-	-
Acute	6 to < 11	5.70E-10	0.0028	-	5.50E-10	0.0028	-	-	-	-	-
Acute	11 to < 16	5.90E-10	0.0029	-	5.70E-10	0.0029	-	-	-	-	-
Acute	16 to < 21	5.70E-10	0.0029	-	5.60E-10	0.0028	-	-	-	-	-
Acute	Adult	5.80E-10	0.0029	1.10E-05‡	5.60E-10	0.0028	1.00E-05‡	-	-	-	-

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
mg/kg/day – milligram per kilogram per day
Site abbreviations: GVP – Georgiaville Pond; GMP – Greystone Mill Pond; LMR – Lyman Mill Reach
ED – exposure duration

Table 12: White sucker doses and risk quotients for the central tendency exposure scenario Allendale and Lyman Mill Ponds (2019 data).

Duration	Age Group (years)	ALP Dose (mg/kg/day)	ALP Hazard Quotient	ALP Cancer Risk	LMP Dose (mg/kg/day)	LMP Hazard Quotient	LMP Cancer Risk	ED (years)
Chronic	1 to < 2	9.00E-09	23†	-	1.40E-08	36†	-	1
Chronic	2 to < 6	7.90E-09	20†	-	1.30E-08	31†	-	4
Chronic	6 to < 11	7.50E-09	19†	-	1.20E-08	30†	-	5
Chronic	11 to < 16	7.80E-09	20†	-	1.20E-08	31†	-	5
Chronic	16 to < 21	7.60E-09	19†	-	1.20E-08	30†	-	5
Chronic	Combined Child	-	-	2.60E-04‡	-	-	4.10E-04‡	20
Chronic	Adult	7.70E-09	19†	1.00E-03‡	1.20E-08	31†	1.60E-03‡	78
Intermediate	1 to < 2	9.00E-09	-	-	1.40E-08	-	-	-
Intermediate	2 to < 6	7.90E-09	-	-	1.30E-08	-	-	-
Intermediate	6 to < 11	7.50E-09	-	-	1.20E-08	-	-	-
Intermediate	11 to < 16	7.80E-09	-	-	1.20E-08	-	-	-
Intermediate	16 to < 21	7.60E-09	-	-	1.20E-08	-	-	-
Intermediate	Adult	7.70E-09	-	1.00E-03‡	1.20E-08	-	1.60E-03‡	-
Acute	1 to < 2	6.30E-08	0.32	-	1.00E-07	0.50	-	-
Acute	2 to < 6	5.50E-08	0.28	-	8.80E-08	0.44	-	-
Acute	6 to < 11	5.30E-08	0.26	-	8.40E-08	0.42	-	-
Acute	11 to < 16	5.50E-08	0.27	-	8.70E-08	0.44	-	-
Acute	16 to < 21	5.40E-08	0.27	-	8.50E-08	0.43	-	-
Acute	Adult	5.40E-08	0.27	1.00E-03‡	8.60E-08	0.43	1.60E-03‡	-

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
mg/kg/day – milligram per kilogram per day
Site abbreviations: ALP – Allendale Pond; LMP – Lyman Mill Pond
ED – exposure duration

Table 13: American eel doses and risk quotients for the reasonable maximum exposure scenario Georgiaville Pond, Greystone Mill Pond, and Lyman Mill Reach (2019 data).

Duration	Age Group (years)	GVP Dose (mg/kg/day)	GVP Hazard Quotient	GVP Cancer Risk	GMP Dose (mg/kg/day)	GMP Hazard Quotient	GMP Cancer Risk	LMR Dose (mg/kg/day)	LMR Hazard Quotient	LMR Cancer Risk	ED (years)
Chronic	1 to < 2	1.60E-09	4.0†	-	1.70E-09	4.3†	-	4.90E-08	120†	-	1
Chronic	2 to < 6	1.60E-09	4.0†	-	1.70E-09	4.4†	-	4.90E-08	120†	-	4
Chronic	6 to < 11	1.60E-09	4.1†	-	1.80E-09	4.5†	-	5.00E-08	130†	-	5
Chronic	11 to < 16	1.60E-09	4.0†	-	1.80E-09	4.4†	-	5.00E-08	120†	-	5
Chronic	16 to < 21	1.60E-09	4.0†	-	1.80E-09	4.4†	-	5.00E-08	120†	-	5
Chronic	Combined Child	-	-	5.40E-05‡	-	-	5.90E-05‡	-	-	1.70E-03‡	20
Chronic	Adult	1.60E-09	4.0†	2.10E-04‡	1.80E-09	4.4†	2.30E-04‡	5.00E-08	120†	6.50E-03‡	78
Intermediate	1 to < 2	1.60E-09	-	-	1.70E-09	-	-	4.90E-08	-	-	-
Intermediate	2 to < 6	1.60E-09	-	-	1.70E-09	-	-	4.90E-08	-	-	-
Intermediate	6 to < 11	1.60E-09	-	-	1.80E-09	-	-	5.00E-08	-	-	-
Intermediate	11 to < 16	1.60E-09	-	-	1.80E-09	-	-	5.00E-08	-	-	-
Intermediate	16 to < 21	1.60E-09	-	-	1.80E-09	-	-	5.00E-08	-	-	-
Intermediate	Adult	1.60E-09	-	2.10E-04‡	1.80E-09	-	2.30E-04‡	5.00E-08	-	6.50E-03‡	-
Acute	1 to < 2	3.70E-09	0.018	-	4.00E-09	0.020	-	1.10E-07	0.57	-	-
Acute	2 to < 6	3.70E-09	0.019	-	4.10E-09	0.020	-	1.10E-07	0.57	-	-
Acute	6 to < 11	3.80E-09	0.019	-	4.20E-09	0.021	-	1.20E-07	0.59	-	-
Acute	11 to < 16	3.80E-09	0.019	-	4.10E-09	0.021	-	1.20E-07	0.58	-	-
Acute	16 to < 21	3.80E-09	0.019	-	4.10E-09	0.021	-	1.20E-07	0.58	-	-
Acute	Adult	3.80E-09	0.019	2.10E-04‡	4.10E-09	0.021	2.30E-04‡	1.20E-07	0.58	6.50E-03‡	-

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
mg/kg/day – milligram per kilogram per day
Site abbreviations: GVP – Georgiaville Pond; GMP – Greystone Mill Pond; LMR – Lyman Mill Reach
ED – exposure duration

Table 14: American eel doses and risk quotients for the reasonable maximum exposure scenario Allendale and Lyman Mill Ponds (2019 data).

Duration	Age Group (years)	ALP Dose (mg/kg/day)	ALP Hazard Quotient	ALP Cancer Risk	LMP Dose (mg/kg/day)	LMP Hazard Quotient	LMP Cancer Risk	ED (years)
Chronic	1 to < 2	1.20E-07	300†	-	6.70E-08	170†	-	1
Chronic	2 to < 6	1.20E-07	300†	-	6.80E-08	170†	-	4
Chronic	6 to < 11	1.20E-07	310†	-	6.90E-08	170†	-	5
Chronic	11 to < 16	1.20E-07	300†	-	6.90E-08	170†	-	5
Chronic	16 to < 21	1.20E-07	300†	-	6.90E-08	170†	-	5
Chronic	Combined Child	-	-	4.10E-03‡	-	-	2.30E-03‡	20
Chronic	Adult	1.20E-07	300†	1.60E-02‡	6.90E-08	170†	8.90E-03‡	78
Intermediate	1 to < 2	1.20E-07	-	-	6.70E-08	-	-	-
Intermediate	2 to < 6	1.20E-07	-	-	6.80E-08	-	-	-
Intermediate	6 to < 11	1.20E-07	-	-	6.90E-08	-	-	-
Intermediate	11 to < 16	1.20E-07	-	-	6.90E-08	-	-	-
Intermediate	16 to < 21	1.20E-07	-	-	6.90E-08	-	-	-
Intermediate	Adult	1.20E-07	-	1.60E-02‡	6.90E-08	-	8.90E-03‡	-
Acute	1 to < 2	2.80E-07	1.4†	-	1.60E-07	0.79	-	-
Acute	2 to < 6	2.80E-07	1.4†	-	1.60E-07	0.79	-	-
Acute	6 to < 11	2.90E-07	1.4†	-	1.60E-07	0.81	-	-
Acute	11 to < 16	2.80E-07	1.4†	-	1.60E-07	0.80	-	-
Acute	16 to < 21	2.80E-07	1.4†	-	1.60E-07	0.80	-	-
Acute	Adult	2.80E-07	1.4†	1.60E-02‡	1.60E-07	0.80	8.90E-03‡	-

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
mg/kg/day – milligram per kilogram per day
Site abbreviations: ALP – Allendale Pond; LMP – Lyman Mill Pond
ED – exposure duration

Table 15: Largemouth bass doses and risk quotients for the reasonable maximum exposure scenario Georgiaville Pond, Greystone Mill Pond, and Lyman Mill Reach (2019 data).

Duration	Age Group (years)	GVP Dose (mg/kg/day)	GVP Hazard Quotient	GVP Cancer Risk	GMP Dose (mg/kg/day)	GMP Hazard Quotient	GMP Cancer Risk	LMR Dose (mg/kg/day)	LMR Hazard Quotient	LMR Cancer Risk	ED (years)
Chronic	1 to < 2	6.00E-10	1.5†	-	1.10E-09	2.7†	-	-	-	-	1
Chronic	2 to < 6	6.00E-10	1.5†	-	1.10E-09	2.7†	-	-	-	-	4
Chronic	6 to < 11	6.10E-10	1.5†	-	1.10E-09	2.8†	-	-	-	-	5
Chronic	11 to < 16	6.10E-10	1.5†	-	1.10E-09	2.8†	-	-	-	-	5
Chronic	16 to < 21	6.10E-10	1.5†	-	1.10E-09	2.8†	-	-	-	-	5
Chronic	Combined Child	-	-	2.00E-05‡	-	-	3.70E-05‡	-	-	-	20
Chronic	Adult	6.10E-10	1.5†	7.90E-05‡	1.10E-09	2.8†	1.40E-04‡	-	-	-	78
Intermediate	1 to < 2	6.00E-10	-	-	1.10E-09	-	-	-	-	-	-
Intermediate	2 to < 6	6.00E-10	-	-	1.10E-09	-	-	-	-	-	-
Intermediate	6 to < 11	6.10E-10	-	-	1.10E-09	-	-	-	-	-	-
Intermediate	11 to < 16	6.10E-10	-	-	1.10E-09	-	-	-	-	-	-
Intermediate	16 to < 21	6.10E-10	-	-	1.10E-09	-	-	-	-	-	-
Intermediate	Adult	6.10E-10	-	7.90E-05‡	1.10E-09	-	1.40E-04‡	-	-	-	-
Acute	1 to < 2	1.40E-09	0.007	-	2.60E-09	0.013	-	-	-	-	-
Acute	2 to < 6	1.40E-09	0.007	-	2.60E-09	0.013	-	-	-	-	-
Acute	6 to < 11	1.40E-09	0.0072	-	2.60E-09	0.013	-	-	-	-	-
Acute	11 to < 16	1.40E-09	0.0071	-	2.60E-09	0.013	-	-	-	-	-
Acute	16 to < 21	1.40E-09	0.0071	-	2.60E-09	0.013	-	-	-	-	-
Acute	Adult	1.40E-09	0.0071	7.90E-05‡	2.60E-09	0.013	1.40E-04‡	-	-	-	-

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
mg/kg/day – milligram per kilogram per day
Site abbreviations: GVP – Georgiaville Pond; GMP – Greystone Mill Pond; LMR – Lyman Mill Reach
ED – exposure duration

Table 16: Largemouth bass doses and risk quotients for the reasonable maximum exposure scenario Allendale and Lyman Mill Ponds (2019 data).

Duration	Age Group (years)	ALP Dose (mg/kg/day)	ALP Hazard Quotient	ALP Cancer Risk	LMP Dose (mg/kg/day)	LMP Hazard Quotient	LMP Cancer Risk	ED (years)
Chronic	1 to < 2	6.10E-08	150†	-	4.00E-08	99†	-	1
Chronic	2 to < 6	6.10E-08	150†	-	4.00E-08	100†	-	4
Chronic	6 to < 11	6.30E-08	160†	-	4.10E-08	100†	-	5
Chronic	11 to < 16	6.20E-08	160†	-	4.00E-08	100†	-	5
Chronic	16 to < 21	6.20E-08	160†	-	4.00E-08	100†	-	5
Chronic	Combined Child	-	-	2.10E-03‡	-	-	1.30E-03‡	20
Chronic	Adult	6.20E-08	160†	8.10E-03‡	4.00E-08	100†	5.20E-03‡	78
Intermediate	1 to < 2	6.10E-08	-	-	4.00E-08	-	-	-
Intermediate	2 to < 6	6.10E-08	-	-	4.00E-08	-	-	-
Intermediate	6 to < 11	6.30E-08	-	-	4.10E-08	-	-	-
Intermediate	11 to < 16	6.20E-08	-	-	4.00E-08	-	-	-
Intermediate	16 to < 21	6.20E-08	-	-	4.00E-08	-	-	-
Intermediate	Adult	6.20E-08	-	8.10E-03‡	4.00E-08	-	5.20E-03‡	-
Acute	1 to < 2	1.40E-07	0.71	-	9.30E-08	0.46	-	-
Acute	2 to < 6	1.40E-07	0.72	-	9.30E-08	0.47	-	-
Acute	6 to < 11	1.50E-07	0.73	-	9.50E-08	0.48	-	-
Acute	11 to < 16	1.50E-07	0.73	-	9.40E-08	0.47	-	-
Acute	16 to < 21	1.50E-07	0.73	-	9.40E-08	0.47	-	-
Acute	Adult	1.40E-07	0.72	8.10E-03‡	9.40E-08	0.47	5.20E-03‡	-

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
mg/kg/day – milligram per kilogram per day
Site abbreviations: ALP – Allendale Pond; LMP – Lyman Mill Pond
ED – exposure duration

Table 17: White sucker doses and risk quotients for the reasonable maximum exposure scenario Georgiaville Pond, Greystone Mill Pond, and Lyman Mill Reach (2019 data).

Duration	Age Group (years)	GVP Dose (mg/kg/day)	GVP Hazard Quotient	GVP Cancer Risk	GMP Dose (mg/kg/day)	GMP Hazard Quotient	GMP Cancer Risk	LMR Dose (mg/kg/day)	LMR Hazard Quotient	LMR Cancer Risk	ED (years)
Chronic	1 to < 2	1.40E-09	3.6†	-	1.40E-09	3.5†	-	-	-	-	1
Chronic	2 to < 6	1.50E-09	3.6†	-	1.40E-09	3.6†	-	-	-	-	4
Chronic	6 to < 11	1.50E-09	3.7†	-	1.50E-09	3.6†	-	-	-	-	5
Chronic	11 to < 16	1.50E-09	3.7†	-	1.40E-09	3.6†	-	-	-	-	5
Chronic	16 to < 21	1.50E-09	3.7†	-	1.40E-09	3.6†	-	-	-	-	5
Chronic	Combined Child	-	-	4.90E-05‡	-	-	4.80E-05‡	-	-	-	20
Chronic	Adult	1.50E-09	3.7†	1.90E-04‡	1.40E-09	3.6†	1.90E-04‡	-	-	-	78
Intermediate	1 to < 2	1.40E-09	-	-	1.40E-09	-	-	-	-	-	-
Intermediate	2 to < 6	1.50E-09	-	-	1.40E-09	-	-	-	-	-	-
Intermediate	6 to < 11	1.50E-09	-	-	1.50E-09	-	-	-	-	-	-
Intermediate	11 to < 16	1.50E-09	-	-	1.40E-09	-	-	-	-	-	-
Intermediate	16 to < 21	1.50E-09	-	-	1.40E-09	-	-	-	-	-	-
Intermediate	Adult	1.50E-09	-	1.90E-04‡	1.40E-09	-	1.90E-04‡	-	-	-	-
Acute	1 to < 2	3.40E-09	0.017	-	3.30E-09	0.017	-	-	-	-	-
Acute	2 to < 6	3.40E-09	0.017	-	3.30E-09	0.017	-	-	-	-	-
Acute	6 to < 11	3.50E-09	0.017	-	3.40E-09	0.017	-	-	-	-	-
Acute	11 to < 16	3.40E-09	0.017	-	3.40E-09	0.017	-	-	-	-	-
Acute	16 to < 21	3.40E-09	0.017	-	3.40E-09	0.017	-	-	-	-	-
Acute	Adult	3.40E-09	0.017	1.90E-04‡	3.40E-09	0.017	1.90E-04‡	-	-	-	-

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
mg/kg/day – milligram per kilogram per day
Site abbreviations: GVP – Georgiaville Pond; GMP – Greystone Mill Pond; LMR – Lyman Mill Reach
ED – exposure duration

Table 18: White sucker doses and risk quotients for the reasonable maximum exposure scenario Allendale and Lyman Mill Ponds (2019 data).

Duration	Age Group (years)	ALP Dose (mg/kg/day)	ALP Hazard Quotient	ALP Cancer Risk	LMP Dose (mg/kg/day)	LMP Hazard Quotient	LMP Cancer Risk	ED (years)
Chronic	1 to < 2	1.40E-07	340†	-	2.10E-07	540†	-	1
Chronic	2 to < 6	1.40E-07	340†	-	2.20E-07	540†	-	4
Chronic	6 to < 11	1.40E-07	350†	-	2.20E-07	550†	-	5
Chronic	11 to < 16	1.40E-07	340†	-	2.20E-07	550†	-	5
Chronic	16 to < 21	1.40E-07	340†	-	2.20E-07	550†	-	5
Chronic	Combined Child	-	-	4.60E-03‡	-	-	7.30E-03‡	20
Chronic	Adult	1.40E-07	340†	1.80E-02‡	2.20E-07	550†	2.80E-02‡	78
Intermediate	1 to < 2	1.40E-07	-	-	2.10E-07	-	-	-
Intermediate	2 to < 6	1.40E-07	-	-	2.20E-07	-	-	-
Intermediate	6 to < 11	1.40E-07	-	-	2.20E-07	-	-	-
Intermediate	11 to < 16	1.40E-07	-	-	2.20E-07	-	-	-
Intermediate	16 to < 21	1.40E-07	-	-	2.20E-07	-	-	-
Intermediate	Adult	1.40E-07	-	1.80E-02‡	2.20E-07	-	2.80E-02‡	-
Acute	1 to < 2	3.20E-07	1.6†	-	5.00E-07	2.5†	-	-
Acute	2 to < 6	3.20E-07	1.6†	-	5.00E-07	2.5†	-	-
Acute	6 to < 11	3.20E-07	1.6†	-	5.10E-07	2.6†	-	-
Acute	11 to < 16	3.20E-07	1.6†	-	5.10E-07	2.5†	-	-
Acute	16 to < 21	3.20E-07	1.6†	-	5.10E-07	2.6†	-	-
Acute	Adult	3.20E-07	1.6†	1.80E-02‡	5.10E-07	2.5†	2.80E-02‡	-

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.
‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.
mg/kg/day – milligram per kilogram per day
Site abbreviations: ALP – Allendale Pond; LMP – Lyman Mill Pond
ED – exposure duration

Table 19: Eel doses and risk quotients from the 1999 Woonasquatucket River Health Consultation.*

Duration	Age Group (years)	CTE Dose (mg/kg/day)	CTE Hazard Quotient	CTE Cancer Risk	RME Dose (mg/kg/day)	RME Hazard Quotient	RME Cancer Risk
Chronic	1 to < 2	3.40E-09	8.6†	-	5.20E-08	130†	-
Chronic	2 to < 6	3.00E-09	7.5†	-	5.20E-08	130†	-
Chronic	6 to < 11	2.90E-09	7.2†	-	5.30E-08	130†	-
Chronic	11 to < 16	3.00E-09	7.5†	-	5.30E-08	130†	-
Chronic	16 to < 21	2.90E-09	7.3†	-	5.30E-08	130†	-
Chronic	Combined Child	-	-	9.90E-05‡	-	-	1.80E-03‡
Chronic	Adult	2.90E-09	7.4†	3.80E-04‡	5.30E-08	130†	6.80E-03‡
Intermediate	1 to < 2	3.40E-09	-	-	5.20E-08	-	-
Intermediate	2 to < 6	3.00E-09	-	-	5.20E-08	-	-
Intermediate	6 to < 11	2.90E-09	-	-	5.30E-08	-	-
Intermediate	11 to < 16	3.00E-09	-	-	5.30E-08	-	-
Intermediate	16 to < 21	2.90E-09	-	-	5.30E-08	-	-
Intermediate	Adult	2.90E-09	-	3.80E-04‡	5.30E-08	-	6.80E-03‡
Acute	1 to < 2	2.40E-08	0.12	-	1.20E-07	0.6	-
Acute	2 to < 6	2.10E-08	0.11	-	1.20E-07	0.61	-
Acute	6 to < 11	2.00E-08	0.1	-	1.20E-07	0.62	-
Acute	11 to < 16	2.10E-08	0.1	-	1.20E-07	0.61	-
Acute	16 to < 21	2.00E-08	0.1	-	1.20E-07	0.61	-
Acute	Adult	2.10E-08	0.1	3.80E-04‡	1.20E-07	0.61	6.80E-03‡

*Values were calculated using the concentrations determined in the 1999 Health Consultation[12] and the current central tendency exposure (CTE) and reasonable maximum exposure (RME) intake assumptions in Table 5. Eels were collected upstream of Centredale Manor near Smith Street.

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

mg/kg/day – milligram per kilogram per day

Table 20: Sunfish doses and risk quotients from the 1999 Woonasquatucket River Health Consultation.

Duration	Age Group (years)	CTE Dose (mg/kg/day)	CTE Hazard Quotient	CTE Cancer Risk	RME Dose (mg/kg/day)	RME Hazard Quotient	RME Cancer Risk
Chronic	1 to < 2	2.40E-09	5.9†	-	3.60E-08	89†	-
Chronic	2 to < 6	2.10E-09	5.2†	-	3.60E-08	89†	-
Chronic	6 to < 11	2.00E-09	5†	-	3.70E-08	91†	-
Chronic	11 to < 16	2.10E-09	5.2†	-	3.60E-08	90†	-
Chronic	16 to < 21	2.00E-09	5†	-	3.60E-08	91†	-
Chronic	Combined Child	-	-	6.80E-05‡	-	-	1.20E-03‡
Chronic	Adult	1.80E-09	4.5†	2.30E-04‡	3.60E-08	90†	4.70E-03‡
Intermediate	1 to < 2	2.40E-09	-	-	3.60E-08	-	-
Intermediate	2 to < 6	2.10E-09	-	-	3.60E-08	-	-
Intermediate	6 to < 11	2.00E-09	-	-	3.70E-08	-	-
Intermediate	11 to < 16	2.10E-09	-	-	3.60E-08	-	-
Intermediate	16 to < 21	2.00E-09	-	-	3.60E-08	-	-
Intermediate	Adult	1.80E-09	-	2.30E-04‡	3.60E-08	-	4.70E-03‡
Acute	1 to < 2	1.70E-08	0.083	-	8.30E-08	0.42	-
Acute	2 to < 6	1.50E-08	0.073	-	8.30E-08	0.42	-
Acute	6 to < 11	1.40E-08	0.069	-	8.50E-08	0.43	-
Acute	11 to < 16	1.40E-08	0.072	-	8.40E-08	0.42	-
Acute	16 to < 21	1.40E-08	0.071	-	8.50E-08	0.42	-
Acute	Adult	1.30E-08	0.063	2.30E-04‡	8.40E-08	0.42	4.70E-03‡

*Values were calculated using the concentrations determined in the 1999 Health Consultation[12] and the current central tendency exposure (CTE) and reasonable maximum exposure (RME) intake assumptions in Table 5. Sunfish were collected downstream of Centredale Manor near Valley Street and Lonigan Dam.

† A shaded cell indicates the hazard quotient is greater than 1, which ATSDR evaluates further.

‡ A shaded cell indicates that the cancer risk exceeds one extra case in a million people similarly exposed, which ATSDR evaluates further.

mg/kg/day – milligram per kilogram per day

Appendix A. ATSDR Glossary of Terms

ATSDR is a federal public health agency with headquarters in Atlanta, Georgia. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency. In contrast, the USEPA develops and enforces environmental laws to protect the environment and human health.

This glossary defines words used by ATSDR in communications with the public, last reviewed on January 1, 2009. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-800-CDC-INFO (232-4636).

Absorption
The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute
Occurring over a short time [compare with chronic].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Background concentration or background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Cancer
Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Chronic
Occurring over a long time [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see route of exposure].

Dose
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Hazard
A source of potential harm from past, current, or future exposures.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

mg/kg
Milligram per kilogram.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Potentially responsible party (PRP)
A company, government, or person legally responsible for cleaning up the pollution at a hazardous waste site under Superfund. There may be more than one PRP for a particular site.

ppb
Parts per billion.

ppm
Parts per million.

Prevalence
The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action
A list of steps to protect public health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories
Public health hazard categories are statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five public health hazard categories are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
An USEPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Risk
The probability that something will cause injury or harm.

Risk reduction
Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Risk communication
The exchange of information to increase understanding of health risks.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Sample
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size
The number of units chosen from a population or an environment.

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Stakeholder
A person, group, or community who has an interest in activities at a hazardous waste site.

Substance
A chemical.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].