March 16, 2015

Comments on:
LCP Chemicals Site Proposed Plan
prepared by
Environmental Stewardship Concepts, LLC
on behalf of
Glynn Environmental Coalition

Questions for EPA:
Based on comments and questions from the community and detailed review of the Proposed Plan, Human Health Risk Assessment and Baseline Ecological Risk Assessment, and in consultation with the Glynn Environmental Coalition, ESC, LLC has not been able to successfully determine the correct answer to a number of questions. Therefore, we submit the following questions to EPA:

1) What sampling will be undertaken to determine the full extent of contamination in the Turtle River estuary system as a result of the LCP facility activities? This question is based on the data showing Aroclor 1268 congener profiles on Sapelo Island sediments, human tissues and in dolphins from the Turtle River.

2) How will EPA incorporate new methods for cleaning up contaminated sediments that have not been considered in the FS?

3) What corrections will EPA make to the Human Health Risk Assessment to account for the errors and omissions in human exposures and toxicity of contaminants, considering that site use is greater than estimated, fish consumption is greater than the value used and that dioxin contribution has not been included in the toxicity of site contaminants?

4) How does the Proposed Plan address the contamination of dolphins and other marine life that are not now included in the BERA or in another aspect of the RI/FS?

5) What additional sampling or analysis will EPA conduct in order to account for the omission of fate and transport of PCBs and other contaminants by *Spartina* grasses?

6) Will EPA require ecological risk evaluation of dolphins, based on all mammalian data, such as mink and other marine mammals and evaluate the toxicity to mink and river otter on the effects (toxicity) of PCBs as congeners?

7) The toxicity evaluations of the sediment have not adequately captured the anticipated toxicity, thus, how will EPA re-evaluate the sediment toxicity to account for this information?

8) Will EPA require measurement and assessment of dioxin in the site contaminants, EPA having included reference to the cleanup at Lake Onandoga that has both PCBs and dioxins, and obviously admits the occurrence of dioxins in this type of site.

9) Will EPA require alteration of the assessment of damage to the marsh to account for the factual errors present in the statements of damage to the marsh based on out-dated methods that are not used in working in salt marshes?

10) What provisions in the Record of Decision will EPA make for the consequences of rising sea-level and climate change on the remedy and the site?

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Introduction

Environmental Stewardship Concepts, LLC is submitting comments on the LCP Chemicals Site Proposed Plan on behalf of Glynn Environmental Coalition. We cover specific comments on the Proposed Plan report, as well as several areas of concern including institutional controls, fish consumption, site boundaries, new technologies, and a literature review of PCB toxicity.

Specific LCP Chemical Site OU1 Proposed Plan Comments

Several items in the LCP OU1 Proposed Plan raise concerns that threaten the goal of a cleanup that will protect human and environmental health.

- ≠ There needs to be more sediment removal, compared to capping and thin-cover placement, because sediment removal is a more effective and permanent cleanup option.
- ≠ A re-planting program of *Spartina* post-remediation should be one of the first monitoring efforts to help speed up ecosystem recovery.
- ≠ The evaluation of the way the LCP site is used by community members is inaccurate, specifically seen in the fish consumption rates used in the risk assessment that set the basis for achieving specific cleanup goals.
- ≠ Atlantic bottlenose dolphins are an essential part of the local ecosystem and are not included in the ecological risk assessment for the site.

- ≠ Thin-cover placement, or enhanced natural recovery, is not a sustainable recovery method.
- ≠ The Human Health Risk Assessment does not accurately assess human health risks because fish consumption values are wrong, and because dioxins and furans are not included in the exposure toxicity assessment.
- ≠ *Spartina* accumulates PCBs, but this fact is not considered in the estimates of PCB contamination or fate and transport.

These specific issues are each discussed further below.

Sediment Removal vs. Capping

Capping and thin-cover placement have been proposed as cleanup methods for large sections of the site. However, both of these methods cover up, rather than clean up, the contaminants of concern. Sediment removal is a viable option for the LCP site and should be implemented on a larger scale.

While the Proposed Plan claims that thin-cover placement is a well-studied method for site cleanup, there are not enough documented success stories of using thin-layer caps at contaminated sites to say that this remediation method is well-studied. Many of the examples of thin-layer capping for sediment remediation found in the LCP Feasibility Study are not salt marshes but bays, harbors or other large waterways like rivers (USEPA 2014). These are all environments with greater water depths and different hydrology than a typical salt water marsh. Thus, the thin-layer capping sediment remediation examples in the Proposed Plan are not very relevant to the LCP site.

Furthermore, thin-cover placement is not a sustainable recovery method. By nature, the layer of sediment will be thin, six inches or less, and will not be adequate to contain any contaminants in the marsh bed. A thin-cover layer is easily disturbed. For example, a storm surge could easily move the sediment around, as could scour from a passing boat. In addition, animals living in the marsh like crabs and worms will burrow into sediment and disturb the layer, causing bioturbation of the cap.

As larger storms and hurricanes occur more often due to climate change, there will be an increased chance that the contaminated sediments at this site will be disturbed and that neither thin-cover placement nor capping will be protective. Armoring of a wetland cap is not affective as the tidal flow will simply redirect, carrying sediment with it.

Salt Marsh Grasses

The RI, FS and Proposed Plan make two substantial and fundamental omissions with regard to *Spartina* grasses in the estuary and on the LCP site. The first omission is failure to take into account the fact that *Spartina* does take up contaminants, and the site of accumulation may be any and all parts of the plant, including the rhizome, roots, stalk or stem, and leaf. The failure to account for these processes of uptake and accumulation means that contaminants contained in the living medium are not accounted in the estimate of total contamination on site. The second consequence is that the fate and transport of contaminants left on site under the Fs options and in the

Proposed Plan do not include the movement of contaminants via *Spartina* in the marsh. Both of these components of fate and transport of PCBs are potentially significant pathways and compartments for contaminants. The RI and FS really need to be redrafted to include *Spartina*.

The cleanup process for the marshes of the LCP site will involve the removal of native marsh vegetation, which is essential for the health of the ecosystem. The Proposed Plan relies heavily on the assumption that marsh plants will re-grow on their own within two years. However, the Plan must include a re-planting program in order to speed up recovery of the ecosystem post-remediation. Native *Spartina* will attract native wildlife, which will in turn help the ecosystem return to a pre-remediation state. Replanting Spartina has been conducted for many decades and there is substantial expertise on the practice, in both the private and public sectors (U.S. Fish and Wildlife, NOAA and US Army Corps of Engineers.

Estuary Use by People

The Proposed Plan states that the estuary is rarely used for recreation because it is too difficult to navigate with a small boat, and therefore the impacts of cleanup on that area do not need to be considered. However, there are no data outside the Purvis Creek area to show that the waterways of the estuary are used infrequently. Community surveys must be completed before the Plan can conclude that community members are not using this area for fishing or recreation. The lack of information is not data in support of the negative. Personal observation by ESC, by GEC and accounts from community members contradict the statement of lack of use, which must be considered anecdotal and of questionable value.

Dolphins

Atlantic bottlenose dolphins, which inhabit the Turtle/Brunswick estuary and coastal waters, are apex predators in the southeast. Because they are at the top of the food chain, dolphins bioaccumulate more toxins in their bodies than the animals lower in the food chain. Studies have shown that concentrations of PCBs in Brunswick dolphins are ten times higher than the PCB concentrations in dolphins found in the Savannah area, and the resident dolphins of Brunswick have the highest reported PCBs levels of any marine mammal in the world (Balmer et al. 2011). Dolphins across multiple generations have already been harmed by PCBs, suffering from anemia, reduced hormone levels, and increased susceptibility to disease (Schwacke et al. 2012). Dolphins play an important role in the Brunswick ecosystem and should be a central consideration in the Proposed Plan.

Human Health and Ecological Risk Assessments

The Human Health Risk Assessment in the Proposed Plan does not adequately account for the risks to human health posed by the contaminants at the estuary site. According to the risk assessment, the two chemicals causing the most harm are mercury and Aroclor 1268. There is no consideration of dioxin as a toxic chemical at the site, despite the fact that dioxin is a known contaminant of the industrial process at LCP (chlor-alkali). The reductions necessary to meet fish/shellfish goals to eventually end

consumption advisories “are likely to be observed only after several years post remediation,” delaying the health-protective measures of this remediation.

The Proposed Plan defines a high quantity fish consumer as an adult who eats 40 fish meals per year for 30 years, and a recreational fish consumer as someone who eats 26 fish meals per year for 30 years. The difference between the two consumer categories is small and the fish consumption numbers should be increased based on detailed surveys of local fishermen. The data on local fish consumption in the Brunswick area could have been obtained via surveys, but was not. In fact, ATSDR has a better data set from a nearby community and ATSDR recommended using that data, which would have substantially increased the consumption rates used in the HHRA. The result would have been a conclusion to reduce site risks by more contaminant removal or treatment.

In the Ecological Risk Assessment, one of the sites used to compare the levels of chemicals in the sediment at LCP is only four miles from the LCP site at Troup Creek, and has shown to be contaminated with the same chemicals. Another reference site with a history of cleaner sediments should be used instead. Very little constructive comparison can be made when using an equally contaminated reference site.

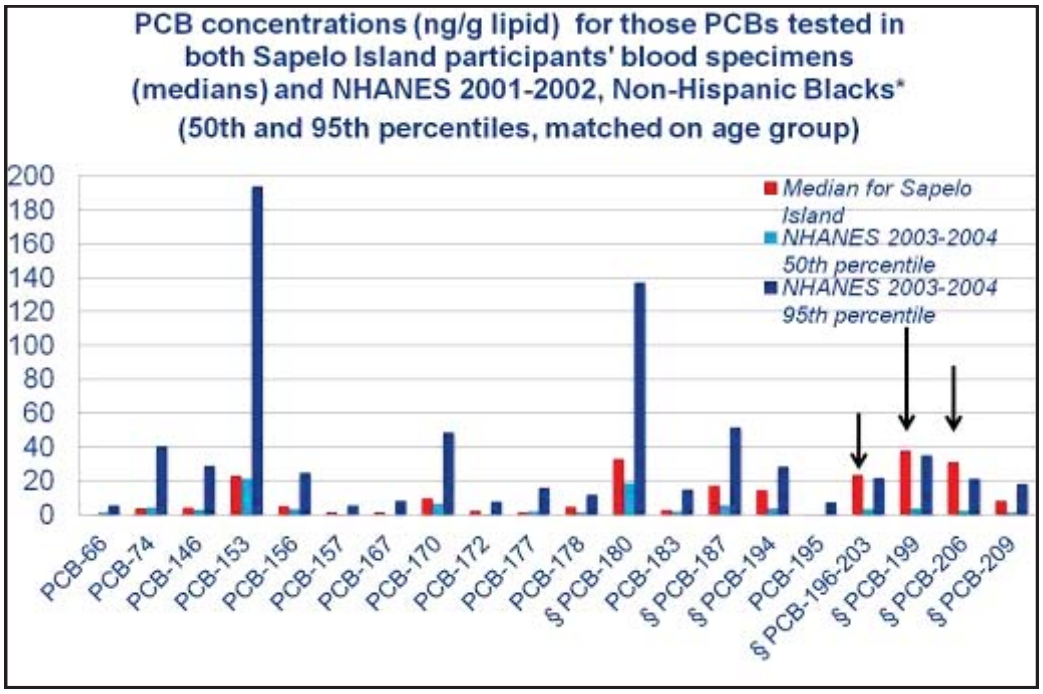
Additionally, not all of the individual stations, domains, and creeks meet the acceptable PRG risk ranges; they are only protective of the local ecosystem when creeks and/or domains are considered collectively. This averaging across spatial data dilutes the exposure possible at each area of contamination. Further, the proposed cleanup levels were determined to be adequate, despite areas “Where CULs may not be achieved and residual risks in some areas may occur” because they existed “in combination with a robust monitoring program”; a monitoring program should not be considered “robust” when monitoring only occurs every five years with an undefined set of “triggers” for additional actions.

Total Acreage of Cleanup
To clean up the marsh to a level protective of human and environmental health, 81 acres of marsh would need to be cleaned up. However, the chosen cleanup plan will only clean up 24 acres of marsh, leaving behind 57 acres with high levels of mercury and PCBs.

Sapelo Island
Sapelo Island is a state-protected barrier island north of Brunswick. The Agency for Toxic Substances and Disease Registry (ATSDR) recently conducted a study that showed that residents of Sapelo Island have dangerously high levels of PCBs in their bodies, based on their blood samples. Scientists conducting the study sampled nine residents, ages 21-74. All the residents stated that they ate two to three meals of locally-caught seafood per week, and had eaten locally-caught seafood for over five years.

When the results of the blood tests were compared to samples from non-Hispanic African Americans throughout the country, some of the PCB levels in blood of the

Sapelo Island residents were above the 95th percentile. In addition, when the Sapelo residents' samples were compared to the samples from local Atlantic bottlenose dolphins, scientists found that the human and dolphin samples contained similar environmental contaminants. This shows that contaminants from the LCP Chemicals Site have migrated into the waters and sediment surrounding Sapelo Island, into the local seafood, and finally, into the bodies of local residents who eat the local seafood.



The red bars are the median sample for the Sapelo Island residents. The three samples with the arrows above them point to Sapelo Island blood samples that were above the 95th percentile for PCB levels in blood (Backer and Mellard 2014).

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Institutional Controls at the Site

Institutional controls are a group of actions that seek to limit human activity to decrease exposure to a contaminated ecosystem. The EPA defines institutional controls as "…administrative and legal controls, that help minimize the potential for human exposure to contamination and/or protect the integrity of the remedy" (USEPA 2014a). Common examples of institutional controls (ICs) include fish consumption advisories, land use designations, and zoning restrictions. The EPA's Proposed Plan for the LCP Chemicals Superfund Site relies heavily on ICs in the form of fish consumption advisories and permit requirements. Currently, fish consumption advisories are in effect for Purvis Creek and the Turtle River, and a commercial fishing ban was issued for Purvis Creek. Permits are required for any in-water construction activities for Operable Unit 1 of the site (USEPA 2014b).

To estimate risk at the LCP Chemicals Superfund site, the EPA used Baseline Risk Assessments (BRAs) found in the Remedial Investigation/Feasibility Study. A Baseline Human Health Risk Assessment (BHHRA) and a Baseline Ecological Risk Assessment (BERA) were conducted for the site. The BHHRA provided the cancer and non-cancer risks associated with consuming fish and shellfish from the site, and the BERA provided the estimated likelihood of adverse ecological effects at the site. While the EPA clearly outlined how risk reduction was estimated in the BRAs, any risk reductions that result directly from the use of ICs are not made clear. Thus, based on the information given in the Proposed Plan and Feasibility Study, it is not possible to determine the actual risk reduction resulting from the use of ICs.

Issues with Institutional Controls

While ICs are meant to protect human health, they are simply a means of removing an exposure pathway by restricting human activity. The Proposed Plan for the LCP Chemicals site states that ICs will address residual risks posed by any un-remediated contaminants, and that ICs "help ensure the remedy's long-term structural integrity and effectiveness in reducing COC concentrations in fish/shellfish…" (USEPA 2014c 40). Yet ICs do nothing to reduce contamination; they simply keep people away from contaminated media at a site. Studies and government reports have found significant flaws in the philosophy and implementation of institutional controls, specifically with fish consumption advisories.

In 2005, the U.S. Government Accountability Office published a report titled "Improved Effectiveness of Controls at Sites Could Better Protect the Public." The study analyzed the implementation and effectiveness of institutional controls at Superfund and RCRA sites throughout the U.S. The researchers found that while the use of ICs has increased over time, there are numerous problems with both the implementation and the organization of ICs. One of the most obvious issues is one of timing and accountability. The GAO found that often documentation did not adequately address when the ICs should be implemented, how long implementation should last, or who would be responsible for enforcement. This led to ICs not being implemented until after cleanup processes were finished, posing significant risks to local residents. The GAO also found

issues with the process for implementation of ICs. Language in the IC documentation was often vague, and the EPA sometimes failed to identify the specific mechanism for each IC. The GAO pointed out that in creating ICs, the EPA needs to identify the parties responsible for enforcing the ICs, such as state governments or site owners (2005). Because of the faulty implementation and enforcement of ICs, ICs come across as recommendations, and are thus taken much less seriously.

Results of a recent study of people living on Sapelo Island, a barrier island 25 miles northeast of Brunswick, showed that residents have dangerously high levels of PCBs in their bodies due to the consumption of locally-caught seafood (Backer and Mellard 2014). The study, which was conducted by the Agency for Toxic Substances and Disease Registry, examined blood levels from adults who had lived on Sapelo Island for at least five years, and who consumed at least two meals of locally-caught seafood each week. The researchers found that 44% of the sampled residents were unaware of Georgia's fish consumption advisories. Out of the five residents who were asked if they changed their fish consumption habits after learning of the advisories, only two responded that they had. If this small sample size is representative of the population in and around Brunswick, then the majority of residents who practice subsistence fishing are continuing to consume the contaminated fish that the consumption advisories warn against. Many scientific studies on fish consumption advisories, such as the two studies mentioned below, provide similar results to the Sapelo Island study: fish consumption advisories are often ignored or simply interpreted as recommendations.

In a study on the effectiveness of fish consumption advisories, researchers found that fish consumption advisories are unlikely to be effective in reducing the exposure of infants and children to persistent organic pollutants that have long elimination rates in the human metabolic system (Binnington et al. 2014). Persistent organic pollutants like PCBs have long elimination half-lives, meaning that the human metabolic system takes longer to break down persistent pollutants like PCBs than non-persistent pollutants. For this study, scientists used a mechanistic model to estimate and compare prenatal, postnatal, and childhood exposure to PCB-153 under different scenarios of maternal guideline adherence to fish consumption advisories. The scientists assumed realistic time periods for advisory compliance for mothers (from one year to five years before birth), and found that temporarily eliminating or reducing maternal fish consumption for fish contaminated with persistent organic pollutants did very little to reduce the exposure of infants and children to PCBs (Binnington et al. 2014). This study shows that it is not just the contaminated fish that prove problematic; it is the environmental persistence of the contaminants inside the human body, which can take years to be eliminated.

In a 2008 study concerning public knowledge about fish consumption advisories, Burger and Gochfeld found that many subjects questioned in a general university population could not give any specific answers to questions regarding the existence of fish consumption advisories. Of the respondents, 62% could not give any specific information as to why fish consumption warnings exist. Over half of the respondents did not know which fish are high or low in contaminants, and 16% of the subjects could not provide an answer as to why eating fish can be healthy. The authors point out that

government agencies are often concerned that the public will be confused by advisory details, and that information on the nature of risks and benefits of fish consumption can be too complicated to convey. The authors believe that operating based upon that assumption is a mistake. They state that the lack of such information is a major part of ineffective communication. The study concluded that public agencies must provide more directed messages regarding the basis for making risk decisions (Burger and Gochfeld 2008).

The results of the Burger and Gochfeld study on public knowledge of fish consumption advisories were echoed by the Sapelo Island study, where residents continue to consume locally caught seafood even after learning of the risks posed by eating contaminated fish. The problem with relying on fish consumption advisories and other ICs for the LCP Chemicals site is two-fold. Half of the problem is that ICs do nothing to reduce contamination; they are simply a means of controlling human activity. The other part of the problem is that fish consumption advisories are, and will continue to be, an ineffective way to protect human and ecological health. Many residents are unaware of the fish consumption advisories, and many of those that are aware of the advisories choose to ignore the regulations and continue eating contaminated seafood. The LCP Chemicals Proposed Plan needs to be amended to rely on a more comprehensive removal of contaminants, not on institutional controls that attempt to keep humans away from their local waterways.

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Fish Consumption Advisories at the Site

At the LCP Chemicals Superfund Site, fish consumption advisories are in effect for Purvis Creek and the Turtle River, and a commercial fishing ban was issued for Purvis Creek. Permits are required for any in-water construction activities for Operable Unit 1 of the site (USEPA 2014a). However, the fish consumption advisories described in the Proposed Plan are insufficient for the protection of human health. The Proposed Plan relies on fish consumption information that is outdated and fails to gather appropriate data on local African-American residents' fishing habits and fish consumption rates. The fish consumption information for the local community, as outlined in the health risk assessment and carried forward in the Proposed Plan, must be fully revised in order to protect human health.

The Problems

The issues with fish consumption advisories are not unique to this site; government reports and scientific studies have found numerous problems with implementation and community adherence to fish consumption advisories. For example, a 2011 survey by the EPA found that fish advisories are not legally enforced in all states. The survey reported that 49 U.S. states and Native American tribes do not legally enforce advisories or bans, and only seven do. This same survey documented 17 out of 18 states that include consumption information for sport and subsistence fishers in their commercial fishing ban information (USEPA 2011). Other inconsistencies at the state level include differences in the ways sampling is conducted and differences in the number of contaminated fish required to affect an advisory. For example, four states in the survey required only one individual fish sample exceeding human health criteria to issue an advisory while others, such as Virginia, required between 11 to 20 fish. Additionally, some states require multiple years of sampling before an advisory can be issued, even after contaminant levels in fish tissue have exceeded state criteria (USEPA 2011).

At the LCP site, the fish consumption advisories proposed by the EPA do not protect human health, nor do they accurately reflect the demographic makeup of the local population. The advisories are based upon a 1999 study conducted by the Glynn County Health Department (GCHD), comparing 211 residents who may have been exposed to mercury through wild game and seafood consumption from the Turtle River (target group participants) to 105 residents who reported they had not consumed seafood or wild game from that area (comparison group participants). Overall, 101 target group participants identified themselves as either recreational, commercial, or subsistence fishers; 96% of these individuals reported themselves as recreational fishers, 3% identified themselves as commercial fishers, and only 1% identified themselves as subsistence fishers (USDHHS/ATSDR 2014). However, the African-American community is severely underrepresented in the target study group. African-Americans made up only 4% of the people surveyed, yet according the 2010 U.S. census, African-Americans make up 26% of the Glynn County population, and nearly 40% of the population within four miles of the LCP site (USDHHS/ATSDR 2014). Thus,

the ATSDR confirms that the GCHD study is not an accurate representation of commercial or subsistence fishers living in the area (2014).

Other shortcomings of the GCHD study include the possibility that participants purposely restricted their intake of fish following the dietary recall survey, leading to inaccurate urine mercury results (USDHHS/ATSDR 2014). Furthermore, in a study of fishers living along the nearby Savannah River, Burger et al. found that, on average, African-Americans eat more fish meals per month than whites, eat slightly larger portions of fish than whites, and therefore eat higher amounts overall of fish per month than whites (1999). The ATSDR states that it is reasonable to assume that African-Americans living in Brunswick have similar eating habits to those living along the Savannah River, and so the report explicitly states, “The results of the Brunswick fish study should not be applied to African-Americans in the Brunswick area [. . .]” (2014, pp.8).

Lastly, sensitive groups including children, women of childbearing age, and the elderly reside within a one-mile radius of the site. The ATSDR reports that based on a 2010 U.S. census, approximately 4,202 people live within a one mile radius of the LCP site; among these, nearly 451 are children aged 6 or younger, 519 are adults who are at least 65 years of age, and 827 are women of childbearing age (2014). Although 37% of target group participants were 60 or older, only 6% of participants were under the age of 10 years old (GCHD 1999).

In light of the major problems with the fish consumption advisories at the LCP site and the data that the advisories are based upon, it is essential to enforce stricter and more accurate fish consumption advisories. It will be many years until local fish and shellfish are clean enough for human consumption, and as such all advisories should be maximally protective of human health. Below we describe the ways in which new fish consumption advisories should be implemented.

The Solution

The fish consumption advisories in the LCP Chemicals Proposed Plan need to be based on data from a more accurate source. The data collected from local residents should accurately represent the population. This means that the data should reflect that African-Americans make up 26% of the Glynn County population (USDHHS/ATSDR 2014). This type of data collection could be done through an environmental justice analysis. An environmental justice analysis recognizes that some populations experience higher levels of risk than others. According to Executive Order 12898, an environmental justice analysis “directs federal agencies to identify and address disproportionately high adverse human health or environmental effects on minority and low-income populations that may result from their programs, policies, or activities” (USEPA 2014b, pp.1). An environmental justice analysis would account for the higher levels of risk experienced by residents who practice subsistence fishing, and therefore help to create guidance for more protective fish consumption advisories.

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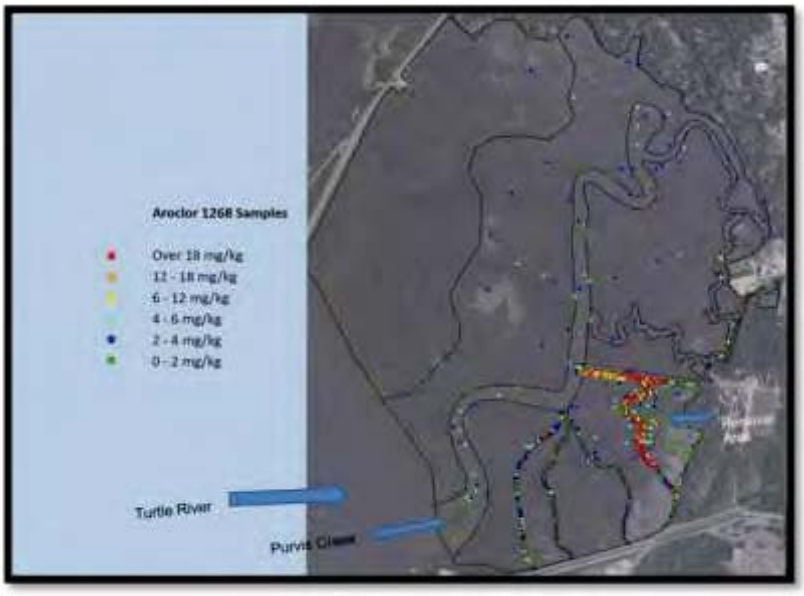
Site Boundaries at the Site

Site boundaries are established by the EPA as part of the Superfund process once the area of contamination has been determined. Boundaries delineate the area within which cleanup processes will occur and contamination will be contained. EPA further divides cleanup processes into operable units (OUs), which are "each of a number of separate activities undertaken as part of a Superfund site cleanup" (EPA 2013). The LCP Chemicals Superfund site is divided into three operable units (OUs) in order to address the differing types of contamination at the site. Following an EPA revision in 2005, Operable Unit 1 represents the marsh, Operable Unit 2 represents groundwater, and Operable Unit 3 represents dry-land soils (USDHHS/ATSDR 2014). The U.S. DHHS/ATSDR report (2014) states, "Other OUs may be examined when data are available for review" (pp.3). Sufficient data are available to question the currently designated site boundaries, conduct additional sampling, and add additional OUs.

The Problems

There are a number of problems with EPA's currently designated LCP Chemical's site boundaries. First, the boundaries are inaccurate. The EPA failed to include available data on the continued migration of Aroclor 1268 in its analysis of site boundaries. According to EPA's *Clarifying the Definition of 'Site' Under the National Priorities List*, "a 'site' is best defined as that portion of a facility that includes the location of a release (or releases) of hazardous substances and wherever hazardous substances *have come to be located* [emphasis added]." The document also advises that "the extent of contamination (site extent) may not be precisely determined at the time a site is listed on the NPL. In fact, the extent of the site may change significantly as the cleanup process progresses" (EPA 1996, pp.1). Recent scientific studies have discovered the presence of Aroclor 1268 outside of EPA-defined site boundaries, making the current delineation erroneous (Wirth et al. 2014; Balmer et al. 2011; Backer and Mellard 2014).



Source: EPA, LCP Chemicals Proposed Plan Public Meeting 2014

Secondly, sampling at the Brunswick LCP site is insufficient given the documented migration of contaminated media to Sapelo Island. Sediment and tissue sampling in the Turtle River must be conducted to determine the extent of contamination as well as the potential migration pathways to populations, such as residents of Sapelo Island, in order to accurately assess impacts of the contamination. As displayed

in the figure, previous sampling efforts for Aroclor 1268 and other contaminants have focused little on Turtle River as a potential migration pathway.

Additionally, Turtle River and Sapelo Island must be added as operable units. Backer and Mellard (2014) noted that there is evidence to suggest that Aroclor 1268 appears to be widespread around the Brunswick area and that residents of Sapelo Island have been exposed to the specific PCBs found at the LCP site; residents' median levels for highly chlorinated congeners of PCBs are equal to or greater than the 95th percentile NHANES study for Non-Hispanic Blacks. Another recent study documented similar PCB congener profiles for sediments and fish between the locations of Sapelo Island National Estuarine Research Reserve and Brunswick (Wirth et al. 2014). These congener profiles were also consistent with the Aroclor 1268 signature noted in residents of Sapelo Island in the former study.

Lastly, there are boundary discrepancies among various documents pertaining to the LCP site. Tables 1 and 2 include differing acreage estimates for the area of contamination. Table 1 refers to Operable Unit 1 acreage estimates only, while Table 2 refers to site-wide estimates. Once site boundaries have been updated to include additional areas of contamination, one consistent estimate is warranted.

Table 1: OU1 acreage estimates

Source	Acreage Marsh (OU1)	Acreage Land (OU1)	Acreage Tidal Creeks (OU1)	Link
EPA Brunswick LCP OU1 PP	670+			http://www.epa.gov/region04/foiapgs/readingroom/lcp_chemicals_site/superfund-proposed-plan-nov-2014.pdf
EPA Brunswick LCP OU1 Draft FS	≈662		98	http://www.epa.gov/region04/foiapgs/readingroom/lcp_chemicals_site/draft-feasibility-study-report-june-2-2014.pdf

Table 2: Site-wide acreage estimates

Source	Acreage Marsh (site-wide)	Acreage Land (site-wide)	Acreage Tidal Creeks (site-wide)	Link
Honeywell Fact Sheet	681	120		http://www.lcpbrunswickcleanup.com/documents/fact%20sheet.pdf
EPA LCP Chemicals Georgia webpage	"550-acre site"			http://www.epa.gov/region4/superfund/sites/npl/georgia/lcpchemga.html#location

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Modern Construction Methods for Salt Marsh Remediation

In the Proposed Plan, EPA states that the type of construction required for removal or treatment of contaminated sediments in the LCP salt marsh would cause "widespread physical damage to habitat and species" (USEPA 2014a, pp. 25). The EPA goes on to state that construction would also impact hydrology, "possibly in ways which are not readily anticipated or predictable" (USEPA 2014a, pp. 25). This line of thought leads the EPA to conclude that 48 acres is the largest possible removal action that would be sufficiently protective of the environment. These statements about salt marsh construction are not accurate. Construction in salt marshes is widely practiced and not nearly as environmentally detrimental as stated in the Proposed Plan. There are modern, accepted methods for construction in salt marshes that pose minimal disturbance risks to the surrounding ecosystems.

It is only later in the document (Section 7.6 Implementability) that EPA, by its own admission, states: "There are technologies and techniques available to meet the challenges associated with working in soft sediments in tidally influenced marsh areas. These include employing low-ground-pressure earthmoving equipment, telescoping conveyor belts for cap placement, shallow draft barges for water-based sediment removal and sediment capping, and hydraulic equipment to place thin-cover material." It is obvious there are technologies to attain effective remediation without irreparable damage to the marsh. There are also new technologies that should be considered before moving into the remedial design.

Use of Alternative Technologies

The Proposed Plan relies on sediment removal, capping, and thin-cover placement for contaminant remediation at the site. Modern remediation methods exist that would work best to remediate a salt marsh without stressing the marsh beyond its ability to recover. EPA needs to consider using new remediation technologies that are more efficient and more environmentally sound than the ones recommended in the LCP Proposed Plan. Below we outline several alternative technologies that could be applied at the LCP site.

In Situ Technologies

PCB remediation is an expensive process and removal of the contaminated soil or sediment, whether by excavation or dredging, contributes a large part of that cost. These processes also risk disturbing and dispersing PCBs. In situ remediation technologies are designed to clean up PCBs without removal from the environment. Most in situ technologies remain difficult to implement on a large scale and are typically suited to low concentrations of contamination; however, several emerging technologies may be viable alternatives to traditional practices.

Bioremediation

Bioremediation is a process through which microbial degradation of PCBs is facilitated through creating a favorable environment for the process; this can be done through controlling the physical, chemical, and microbial aspects of the environment (EPA,

2012). This process generally begins with instigating anaerobic dechlorination, or the removing of chlorine atoms by anaerobic bacteria; this results in lightly chlorinated PCBs that are both less toxic and degrade more readily into inert molecules through the secondary process of aerobic biodegradation (Gomes, Dias-Ferreira, and Ribeiro 2013). Bioremediation may be of particular use in combination with active containment technologies such as reactive capping or phytoremediation.

There are many examples of bioremediation used in the remediation industry. One such example of note is the South Carolina company BioTech Restorations[1]. BioTech specializes in the bioremediation of chlorinated contaminants including PCBs through application of a proprietary protein "factor" which stimulates the indigenous microbial population and enhances its ability to degrade PCBs. While previously demonstrated in soils, dredged sediment could also be treated in this manner. Some of BioTech's successful remediation projects include the cleanup of the former New England Log Homes factory site in Great Barrington, Massachusetts and the Hercules Chemical Plant in Brunswick, Georgia.

Phytoremediation

Phytoremediation is an increasingly popular technology that employs specific plants to sequester, extract, and degrade contaminants in situ. Phytoremediation of PCBs works through three main pathways: i) uptake by the roots (sequestration), ii) degradation through plant enzymes, and iii) improving natural bioremediation through root activity in the soils (Gomes et al., 2013). While PCBs are partially retained in plant biomass, phytoremediation provides a noninvasive means of removing/degrading the contaminants. PCB contaminated plant matter may also be converted into biofuels during which the remaining concentrations would be destroyed. Phytoremediation can be implemented using a variety of plants; canarygrass and switchgrass were found to be particularly effective on soil (Chekol et al., 2004), while eelgrass was effective in aquatic sediment (Huesemann et al. 2009). Phytoremedation is also a good candidate for use in conjunction with bioremediation due to the root and rhizomatic boosts to biological activity.

There are several exampes of phytoremediation in the field. In 2015, the Iowa Superfund Research Program will finish a full scale study of employing phytoremediation to remove PCBs from soil and groundwater at a confined disposal facility in East Chicago. A similar test is being conducted on a PCB contamined wastewater pond in Altavista, Virginia. Several engineering and remediation firms use phytoremediationto remove PCBs including Edenspace, TRC Companies, and EADHA enterprises.

In Situ Sediment Ozonator

[1] Disclaimer: Environmental Stewardship Concepts, LLC worked with BioTech Restorations on the first draft of the QAPP for the Housatonic River cleanup. ESC completed the project in May 2014 and is no longer under contract to BioTech Restorations.

In situ Sediment Ozonation (ISO) is a new technology developed by the University of Utah in cooperation with the National Oceanic and Atmospheric Administration (NOAA). ISO uses a floating rig equipped with ozone reactors and conveyors to remediate without dredging. Ozone has been shown to react with PCBs by forming more biodegradeable products, as well as boosting biological activity in sediment or soil (Gomes, Dias-Ferreira, and Ribeiro 2013). ISO enhances this process using pressure-assisted ozonation which injects sediment with ozone and rapidly cycled pressure changes to increase the efficacy of the ozone (Hong 2008). The final report on the technology suggests that the materials to build ISO rigs are readily available in current dredging technology, and that contaminated sediment could be treated for as little as fifty dollars a cubic yard. This technology also naturally enhances biological activity and would be a logical choice to increase remediation efficiency of more passive technologies, such as bioremediation or phytoremediation.

Ex Situ Technologies

In many cases, the most practical means to treat a contaminated area is to remove the target media with dredging or excavation. The materials can then be transported and treated ex situ, or off-site. Treating contaminations ex situ allows for the use of more intensive treatment technologies that would be unsafe or impractical in situ. While incineration remains the most common ex situ technology, several emerging technologies are showing promise.

BioGenesis℠

BioGenesis Enterprises' proprietary BioGenesis℠ Soil/Sediment Washing Technology is one of the most well documented alternatives to incineration. BioGenesis℠ is a sequence of eight processing steps that treat contaminated sediment sufficiently to allow the post-treatment media to be used as high-end topsoil or construction grade products (BioGenesis 2009). BioGenesis℠ is designed to accommodate large volumes of contaminated sediment through the construction of a facility in a location where sediment can be directly delivered by barge or hydraulic pipe.

BioGenesis℠ has conducted several bench-scale studys and a recently completed full-scale demonstration of the technology in the New York/New Jersey Harbor which handled materials from the Raritan, Passaic, and Arthur Kill. According to the final report, the full-scale test facility was capable of remediating 250,000 cubic yards of sediment per year at a cost of $51-59 per cubic yard (2009). While initial costs of construction of these facilities is higher than other technologies, repeated demonstrations have provided enough data to conclude that BioGenesis℠ is an environmentally and economically sound alternative.

Mobile UV Decontamination

Researchers at the University of Calgary have developed a mobile PCB remediation unit that builds upon a study showing ultraviolet light's capability of effectively degrading PCBs in transformer oil, as well as soils and sediment (Kong, Achari, and Langford 2013). The project, backed by SAIT Polytechnic and IPAC Services Corp., is a 15 meter long mobile unit that combines UV and visible light technologies to degrade PCBs

as much as 94%, at a fraction of the cost of inicineration while remaining on site (Unviersity of Calgary 2013). This technology is well suited for operation in areas where soil or sediment could be removed and processed nearby. The unit is currently designed to handle smaller contaminations but the project group plans to expand the technology to address the needs of larger remediation projects.

nZVI Dechlorination

Zero-valent iron nanoparticles (nZVI) is primarily an ex situ treatment based on zero-valent iron (ZVI), a technology which has been used to clean up aquifers contaminated with a variety of chemicals. Where PCBs are concerned, ZVI works through dechlorination into less toxic and more biodegradeable constituents (Gomes, Dias-Ferreira, and Ribeiro 2013). ZVI has been tested in the sediment of both the Housatonic River and New Bedford Harbor in Massachusetts; however mixed results have prevented ZVI from mainstream implementation. nZVI improves upon ZVI through a reformulation using nanoparticles which exhibits superior reactivity and more consistent removal of PCBs in groundwater and soil (Mikszewski 2004). While nZVI can be used in situ, due to limited research on the effects of nanoparticles on the environment, most commercial and academic uses are conducted off-site. However, NASA currently licenses an associated technology, emulsified zero-valent iron (eZVI), and has demonstrated successfully removing a variety of contaminants both in situ and ex situ (Parrish 2013).

Removal Technologies

When in situ treatment is not possible, removal of the contamination, whether it be industrial waste, soils, or sediment is required before ex situ remediation is possible. Where PCBs are concerned, the most common, and often most concentrated contaminations are found in river sediment in and around industrial areas. Heavy dredging equipment is often required to remove and transport the sediment, the use of which can be expensive economically and environmentally. However, advances in removal technologies can reduce these costs through more precise and focused application.

Environmental Dredging

Environmental dredges are designed with the understanding that dredging can re-suspend and disperse contaminants beyond the original site. Most environmental dredging uses hydraulic cutter dredges, which break up and then pump sediment and water through pipes to a desired location. The Bean technical Excavation Corporation's (Bean TEC) *Bonacavor* builds upon that standard using a hybrid model: mechanical excavation and hydraulic transport. This hybrid model allows more precise control of dredging which reduces unnecessary dredge area or depth and sediment disturbance. The *Bonacavor* also features an advanced onboard GPS and Crane Monitoring System (CMS) that provides precise control of the crane while dredging, as well as a Slurry Processing Unit (SLU) that increases solid concentration during dredging resulting in less water intake (Lally and Ikalainen). Smaller hydraulic cutter dredges have also been developed by companies such as Ellicott and Great Lakes Dredging (Randall, Drake,

and Ii 2010). These dredges have smaller footprints and are able to facilitate removal at less cost and disturbance to the environment.

Activated Metal Treatment and Green PCB Removal

Technologies that allow PCBs to be removed without removing the contaminated media may offer alternatives to dredging in the future. NASA has also licensed two technologies that are designed to absorb PCBs from the environment for removal. The Activated Metal Treatment System (AMTS) is a solvent solution that can be applied to surfaces to remove PCBs from paints, caulk, or sealants (Parrish 2013). AMTS has been extremely successful during in situ remediation of industrial facilities where PCBs were used widely as paints and sealants on storage tanks, buildings, and other structures. The product allows extraction of PCBs without removal of the structures, whereupon the contaminants can be treated safely ex situ. While AMTS is primarily used for structure remediation, Bio Blend ® Technologies, a company currently licensing AMTS, is testing the technology in a variety of applications including in situ extraction of PCBs from soils and sediment (Parrish 2013).

Specific to sediment and soil contamination, NASA is also developing GPRSS, or Green PCB Removal From Sediment Systems, which is a system that uses a redeployable polymer blanket with “resevoir spikes.” The spikes are treated with AMTS, which removes PCBs from sediment (Parrish 2013). The blanket is inserted into the target area, wherein the AMTS breaks down and absorbs PCBs; the blanket system can then be removed and decontaminated before reuse. While still in preliminary testing, GPRSS appears to be a promising technology for removal of PCBs without dredging.

Containment Technologies

Monitored natural recovery (MNR), a process by which PCBs are monitored and left to degrade naturally in the environment, is a remediation method employed in areas where removal of a contaminant is impractical or impossible. As natural degradation of PCBs is a slow process, the contaminant is often contained or capped to keep it from dispersing in the wider environment (Gomes, Dias-Ferreira, and Ribeiro 2013). This method has highly variable success, in large part due to the slow rate of natural PCB biodegradation. Advances in containment technology are increasingly implementing in situ treatments, such as bioremediation, to increase the outcome of the treatment.

Reactive Capping

While traditional capping passively contains a pollutant, reactive capping is an emerging technology that caps the designated area with additives that can absorb and immobilize, increase degradation, or reduce the bioavailability of PCBs; additives used in this process include Activated carbon, biochar, and metals such as zero-valent iron coated palladium (Gomes, Dias-Ferreira, and Ribeiro 2013). CETCO®, a minerals technologies company, markets the *Reactive Core Mat (RCM)*, a cap which can be tailored to meet the specific needs of a remediation project by augmenting the additives included in the product.

Aquablok® and Aquagate® are two complimentary reactive containment technologies from Aquablok Ltd that can be used to form a “funnel and gate” system in sediment. Aquablock® acts as a low permeability barrier to contain wastes while Aquagate® allows specific treatment materials for bioremediation or phytoremediation to interact with contaminated sediment, thus improving the remediation outcome.

Conclusions

Advances in PCB remediation and removal technologies provide viable alternatives to sediment removal, capping, and thin-cover placement. General conclusions include:

- ≠ Many viable technologies exist for in situ and ex situ treatment.
- ≠ Dredging and removal technology has improved as well and can be more economically and envrionmentally sustainable.
- ≠ As circumstances differ dramatically from one project site to another, each option should be assessed independently when determing appropriate remediation technologies.

The EPA needs to institute an evaluation of possible alternative technologies. This could mean re-opening the Feasibility Study.

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PCB Literature Review

Introduction

In reviewing PCBs in the scientific literature, the current review, now more than ever before, indicates the high level of toxicity and irreversible effects of PCBs on human health and the environment.

Polychlorinated biphenyls (PCBs) are industrial chemicals that were manufactured under the trade name Aroclor for use in transformers, electrical equipment, motor oils, plastics, paint, and numerous other applications. Although banned thirty-five years ago, these contaminants are still widely detected in humans and the environment.

PCBs primarily accumulate in soils and sediment as a result of spills, leaking toxic landfills, or contamination from products containing the chemicals. While PCBs do pollute the air via volatization and dispersion, the contaminants are most problematic in soils and sediments where they adhere to organics and are very slow to degrade. The primary route of exposure for humans and wildlife is through the ingestion of contaminated dietary items. PCBs are highly lipophilic and dissolve in fatty tissues and bioaccumulate over an organism's lifespan. This property is important to both human and ecological toxicology because bioaccumulation leads to biomagnification, the process by which persistent toxins increase in concentration upward through the food chain (Faroon et al., 2003). As a result, the highest concentrations of PCBs are often observed in top predators with long life-spans and high fat deposits such as dolphins, whales, and humans.

In the United States, PCBs are regulated by several different agencies and regulatory frameworks. The Environmental Protection Agency (EPA) requires drinking water to have a maximum contaminant level (MCL) of 0.5 parts per billion (EPA, 1996); fish consumption advisory numbers are also maintained in contaminated waters. States are increasingly being urged by EPA to develop PCB total maximum daily loads (TMDLs)-goals for reducing PCB concentrations in affected waterways. Disposal and remediation of PCBs is regulated under the Toxic Substances Control Act (TSCA) (EPA 2005). Finally, the Federal Drug and Food Administration (FDA) publishes tolerances for PCB concentrations and residues in foods such as milk, eggs, and poultry and enforces bans on the use of the compound in product packaging.

Brief Review of Human and Ecological Toxicology

PCBs are a broad category of compounds consisting of 209 individual congeners differentiated by the position and number of chlorine atoms that make up the molecule (Lauby-Secretan et al. 2013). Part of the complexity of studying PCB toxicity is recognizing that the chemical, physiological, and ecological effects of these distinct congeners can vary. PCBs are classified as endocrine disrupters because of their ability to mimic hormones and activate, deactivate, and even damage receptors that modulate

and control cellular and body systems (Lauby-Secretan et al. 2013). The specific receptors affected varies based on the congener or mixture of congeners involved and these multiple mechanisms of action result in a wide range of possible human and environmental effects. The following section provides an overview of toxicological effects of PCBs with the understanding that these general conclusions do not apply to all congeners.

Carcinogenic Effects
Increasingly the consensus points towards a strong link between cancer in humans and wildlife exposed to PCBs. In 2013 the International Agency for Research on Cancer (IARC) upgraded PCBs from “probable carcinogen to humans” to “carcinogenic to humans”. This decision was made based on 70 epidemiological studies which showed elevated risks of melanoma in both individuals with occupational exposure and the general public; increased risks of breast cancer and non-Hodgkin’s lymphoma were also noted (Lauby-Secretan et al. 2013). This report aligns and strengthens the position of EPA's 1996 report which concluded that PCBs are likely carcinogenic with evidence of increased risk of thyroid, liver, and gastrointestinal cancer from PCB exposure(EPA 1996)(EPA 1996)(EPA 1996)(EPA 1996)(EPA 1996)(EPA 1996)(EPA 1996)(EPA 1996)(EPA 1996)(EPA 1996)(EPA 1996)(EPA 1996)(EPA, 1996)(EPA, 1996).

Non-Carcinogenic Effects
PCBS have been shown to affect most of the major body systems including the respiratory, cardiovascular, gastrointestinal, renal, endocrine, and musculoskeletal (Faroon & Olson, 2000). PCBs can also affect the reproductive system; studies on rats have documented decreased litter sizes and body weight, as well as reduced sperm count and conception rates (Faroon et al. 2003). In both humans and rats, neurological and developmental deficits have been observed in children with high *in-utero* exposure (EPA, 1996). Children exposed to PCBs at an early age have been reported to exhibit weaker reflexes, reduced memory, and a higher likelihood of attention deficit issues (Faroon et al, 2003). PCBs have also been linked to immunological effects that range from a weakening of the immune system to increases in inflammatory disorders such as tonsillitis and bronchitis (Faroon et al, 2003).

The toxicology of PCBs continues to be an area of extensive international research and each year brings numerous new studies on the contaminant.

2013-2015 Literature Search

The current literature search is an update of one conducted in August-September 2014 (Appendix B) that covered PCBs in the literature from 2013-2014 and one conducted in August-September 2013 (Appendix C) that covered PCBs in the literature from 2002 to 2013. The most recent review of the literature published in 2014 and 2015 on PCB toxicology returned over 100 relevant publications. These publications are listed in

Appendix A for the reader's convenience. While it is not within the scope of this memo to address them all, a few key studies are discussed in brief below.

Carcinogenic Effects

As stated above, IARC's 2013 classification of PCBs as carcinogenic is significant and several recent studies support this classification. Dong et al. (2014) found some PCBs are both cytotoxic and genotoxic in liver cells and increased DNA and chromosome breaks were observed in cells exposed to this congener. Ruder, Hein, Hopf, & Waters (2014) examined a cohort of 24,865 workers exposed to PCBs at manufacturing plants in the U.S. and found elevated overall mortality and an increased risk of melanoma and stomach, prostate, and nervous system cancers. Similar studies conducted by Li et al., (2013) and Onozuka, Hirata, and Furue (2014) examined workplace exposure cohorts and found decreased net survival rates primarily caused by increased cancer rates. PCB exposure was also linked to chemoresistance of liver cancer, resulting in a poorer prognosis in patients with the disease (An et al., 2014).

Non-carcinogenic Effects

Several new studies have addressed the link between PCBs and neurological effects. Gaum et al. (2014) studied individuals with work-related exposure to PCBs and found a significant relationship between PCB burden and increased depression and psychosomatic symptoms. Wigestrand, Stenberg, Walaas, Fonnum, & Andersson (2013) found PCBs can inhibit uptake of dopamine in the same manner as cocaine; the researchers suggest this mechanism is a likely factor in PCB neurotoxicity and behavioral effects such as depression.

The effects of PCBs on human development have been well-documented but several new studies provide an international scope to the literature. A 2014 study of toddlers in Japan found a relationship between prenatal exposure of PCB congeners in cord blood and decreased IQ (Tatsuta et al., 2014). This is significant because prenatal exposure continues to be a significant exposure pathway in the U.S.; Nanes et al. (2014) surveyed 43 human placentas from several U.S. locations and found PCBs in all specimens. Dallaire et al. (2014) studied a cohort of Inuit children and found a correlation between concentrations of PCB 153 in blood and lower weight, shorter height, and smaller head circumference across a range of ages and suggest PCBs are disrupting thyroid function. Decreased motor coordination was also positively correlated with PCB exposure; a study of 97 Dutch infant-mother pairs found high PCB 107 and 187 blood concentrations were associated with decreased motor coordination (Berghuis, Soechitram, Hitzert, Sauer, & Bos, 2013).

Finally, a 2014 paper corroborates previous epidemiological studies that suggested a link between exposure to PCBs and auditory impairment in children and adults; data surveyed from 1999-2004 indicated a positive relationship between serum PCB levels and hearing impairment in U.S. adults (Min, Kim, & Min, 2014).

Environmental and Ecological Effects

PCBs are potent contaminants in the environment as well; many of the same effects seen in humans have been documented in wildlife. However, international bans and cleanup efforts have resulted in a reduction of PCB levels in soils and sediments in some cases. Everaert et al. (2014) report two to threefold reduction in PCB concentrations between 1991 and 2010 in an open water ecosystem near Belgium; no significant decrease was observed in an industrial estuary receiving no remediation. As Bruckman et al. (2013) indicate in their survey of PCB soil depositions in Germany, PCB congeners have long half-lives and can be retained in sediment for decades unless the PCBs are cleaned up.

Remediation of PCB contamination has been shown to be effective in many cases. A 2013 study by Ficko, Luttmer, Zeeb & Reimer compared PCB concentrations in vegetation and field mice on an abandoned Air Force station before and after PCB remediation work was conducted; the study found vegetation concentrations were four times lower while concentrations in deer mice were three times lower.

Several new studies add to the well-established ecotoxicological profile of PCBs. A 2013 study of six arctic birds found that migration and opportunistic feeding increased PCB burden equivalent to one full increase in trophic level (Baert, Janssen, Borgå, & De Laender, 2013). Evidence of these effects on migratory birds reinforces the international scope of PCB contamination. Persson & Magnusson (2014) surveyed 101 wild mink and found that PCBs alter the size and shape of mink reproductive organs, likely leading to reproductive effects. Similarly, Carpenter et al. (2014) found high PCB concentrations in Illinois river otters and concluded the species is at risk of PCB toxicity.

Marine mammals such as whales and dolphins have been shown to retain high PCB concentrations decades after the PCB ban. Dorneles et al. (2013) found high accumulation of PCBs in false killer whales and rough-toothed dolphins off the coast of Brazil. Similarly, a survey of beluga whales found moderate levels of PCB exposure and confirmed the contaminant can disrupt vitamin profiles in the large mammals (Deforges et al., 2013). As Kubo et al. (2014) report in their study of Steller sea lions, marine mammals are also at risk of PCB exposure through maternal-to-fetal transfer.

Summary

As investigations into all aspects of PCBs continue around the globe, new information continues to reveal several trends:

- ≠ PCBs are toxic at lower levels than previously believed
- ≠ PCBs cause a wider range of toxic effects on wildlife and humans, including cancer
- ≠ Remediating PCB contamination is effective in reducing the PCB burdens

PCB contamination is a local, regional and global problem- the PCBs in one locality will contaminate the living and non-living environment, contribute to the regional PCB burden, and add to the global PCB burden for generations to come.

Appendix A
Literature Search and References –2014-2015 Publications on Toxicology of Polychlorinated Biphenyls

The following is a reference list of materials resulting from a literature search conducted in January 2015 on the toxicology of Polychlorinated Biphenyls (PCBs), individual PCB congeners, and frequently associated compounds. This reference list is an update and addition to prior literature searches conducted on the toxicology of PCBs, which are listed below in Appendices B and C. Included in the search are references pertaining to the effects of PCBs on both human health and the environment, including persistence, fate and transport, and specific effects on ecological systems and organisms.

A number of studies focused specifically on early exposure to PCBs and effects on development in both humans and animals. In human health, Casas et al. (2015) studied prenatal exposure to PCB-153 and *p,p'*-DDE in order to evaluate the relationships between organochlorine compounds and birth outcomes. These authors observed an inverse linear exposure-response relationship between prenatal exposure to PCB-153 and birthweight, even at low levels of exposure. The association was modified by maternal smoking and ethnicity; the most susceptible subgroup was girls with mothers who smoked while pregnant. Elnar et al. (2015) conducted a study on juvenile male mice and found that lactational exposure to low levels of the six indicator non-dioxin-like (NDL) PCBs led to over expression of genes involved in the repair and response to DNA damage as well as repression of neuronal activity. The level used in the study was lower than the guidance level for human consumption of contaminated fish. Lastly, Poon et al. (2015) investigated the effects of a PCB mixture composed of Aroclors 1242, 1248, 1254, and 1260 on developmentally-exposed rats and observed that they were more susceptible to audiogenic seizures when exposed to loud noise as adults; female rats were also more susceptible than males.

The literature search was conducted through the Virginia Commonwealth University Library System using the VCU multi-database search tool as well as the specific database Science Direct. All of the following materials are peer-reviewed journal articles.

ESC, LLC makes no claims about the research in these citations in terms of validity and does not necessarily agree with the conclusions within. We note that readers need to confirm that authors of scientific papers are free of conflicts of interest, financial or

otherwise. We advise readers to determine if the authors receive funding from the industries or companies that may be affected by the results of their research.

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Appendix B
Literature Search and References –2013-2014 Publications on Toxicology of Polychlorinated Biphenyls

The following is a reference list of materials resulting from a literature search conducted in late August 2014 on the toxicology of Polychlorinated Biphenyls (PCBs), its congeners, and frequently associated compounds. The reference list includes primarily publications from 2013-2014 but a few key reports from agencies such as EPA and WHO have been included for background information. Toxicology is loosely defined as those materials documenting the effects of PCBs on both ecological systems as well as human health. While toxicological reports were the primary focus of this search, some related materials describing environmental prevalence, fate, and transport are also included.

This literature search was conducted via the Virginia Commonwealth University Library system using the VCU multi-database search tool, as well as specific databases such as BIOSIS and Science Direct. The majority of these materials are peer reviewed journal articles; however, government/NPO reports and white papers are included where appropriate and relevant.

ESC, LLC makes no claims about the research in these citations in terms of validity and does not necessarily agree with the conclusions within. We note that readers need to confirm that authors of scientific papers are free of conflicts of interest, financial or otherwise. We advise readers to determine if the authors receive funding from the industries or companies that may be affected by the results of their research.

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Appendix C
Literature Review on Toxicology of Polychlorinated Biphenyls (PCBs), 2002-2013

The following is a bibliographic listing of articles resulting from an extensive literature search, conducted during the period August-September 2013, on recent research regarding Polychlorinated Biphenyls (PCBs) during the period 2002 to present (2013). Research was narrowly defined as professional (peer-reviewed) journal articles relating to the toxicological effects on living organisms, which included human health effects, other aquatic and land animals, plants, microorganisms, etc. This literature search was conducted via the Virginia Commonwealth University Library system, specifically utilizing the BIOSIS reference database which includes abstracts of literature in biological and biomedical areas of specialty. The literature search also includes documents available in Environmental Stewardship Concepts, LLC's in-house resource files.

ESC, LLC makes no claims about the research in these citations and does not make any blanket claims as to their veracity, nor necessarily agree with the conclusions. We note that readers need to confirm that authors of scientific papers are free of conflicts of interest, financial or otherwise. We advise readers to determine if the authors receive funding from the industries or companies that may be affected by the results of their research.

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Relationship between persistent organic pollutants (POPs) and ranging patterns in common bottlenose dolphins (*Tursiops truncatus*) from coastal Georgia, USA

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ABSTRACT

Bottlenose dolphins (*Tursiops truncatus*) are apex predators in coastal southeastern U.S. waters; as such they are indicators of persistent organic pollutants (POPs) in coastal ecosystems. POP concentrations measured in a dolphin's blubber are influenced by a number of factors, including the animal's sex and ranging pattern in relation to POP point sources. This study examined POP concentrations measured in bottlenose dolphin blubber samples (n = 102) from the Georgia, USA coast in relation to individual ranging patterns and specifically, distance of sightings from a polychlorinated biphenyl (PCB) point source near Brunswick, Georgia. Dolphin ranging patterns were determined based upon 5 years of photo-identification data from two field sites approximately 40 km apart: (1) the Brunswick field site, which included the Turtle/Brunswick River Estuary (TBRE), and (2) the Sapelo field site, which included the Sapelo Island National Estuarine Research Reserve (SINERR). Dolphins were categorized into one of three ranging patterns from photo-identification data. Individuals with sighting histories exclusively within one of the defined field sites were considered to have either Brunswick or Sapelo ranging patterns. Individuals sighted in both field sites were classified as having a Mixed ranging pattern. Brunswick males had the highest concentrations of PCBs reported for any marine mammal. The pattern of PCB congeners was consistent with Aroclor 1268, a highly chlorinated PCB mixture associated with a Superfund site in Brunswick. PCB levels in Sapelo males were lower than in Brunswick males, but comparable to the highest levels measured in other dolphin populations along the southeastern U.S. Female dolphins had higher Aroclor 1268 proportions than males, suggesting that the highly chlorinated congeners associated with Aroclor 1268 may not be offloaded through parturition and lactation, as easily as less halogenated POPs. Individuals sighted farther from the Superfund point source had lower Aroclor 1268 proportions.

1. Introduction

Bottlenose dolphins (*Tursiops truncatus*) are top-level predators and long-lived residents of bays, estuaries, and tidal marshes along the southeastern United States (reviewed in Shane et al., 1986; Wells and Scott, 1999). Lipophilic persistent organic pollutants (POPs), which are biomagnified in organisms at higher trophic levels, are stored in their lipid-rich blubber, making the bottlenose dolphin a sensitive indicator for POPs in coastal ecosystems (Kucklick et al., in review).

Contamination of the Turtle/Brunswick River Estuary (TBRE) in southern coastal Georgia (Fig. 1) by the highly chlorinated (>5 chlorines) polychlorinated biphenyls (PCBs) mixture Aroclor 1268 has been well documented (Kannan et al., 1997, 1998; Maruya and Lee, 1998; Maruya et al., 2001). The primary PCB congeners found in the TBRE are those that comprise Aroclor 1268, a highly chlorinated (>5 chlorines) mixture of PCBs. This mixture was used extensively at a chlor-alkali plant that operated in the TBRE from 1955 to 1994. The site, referred to as LCP Chemicals, was designated a National Priority List (i.e. Superfund) site in 1996 due to extensive environmental

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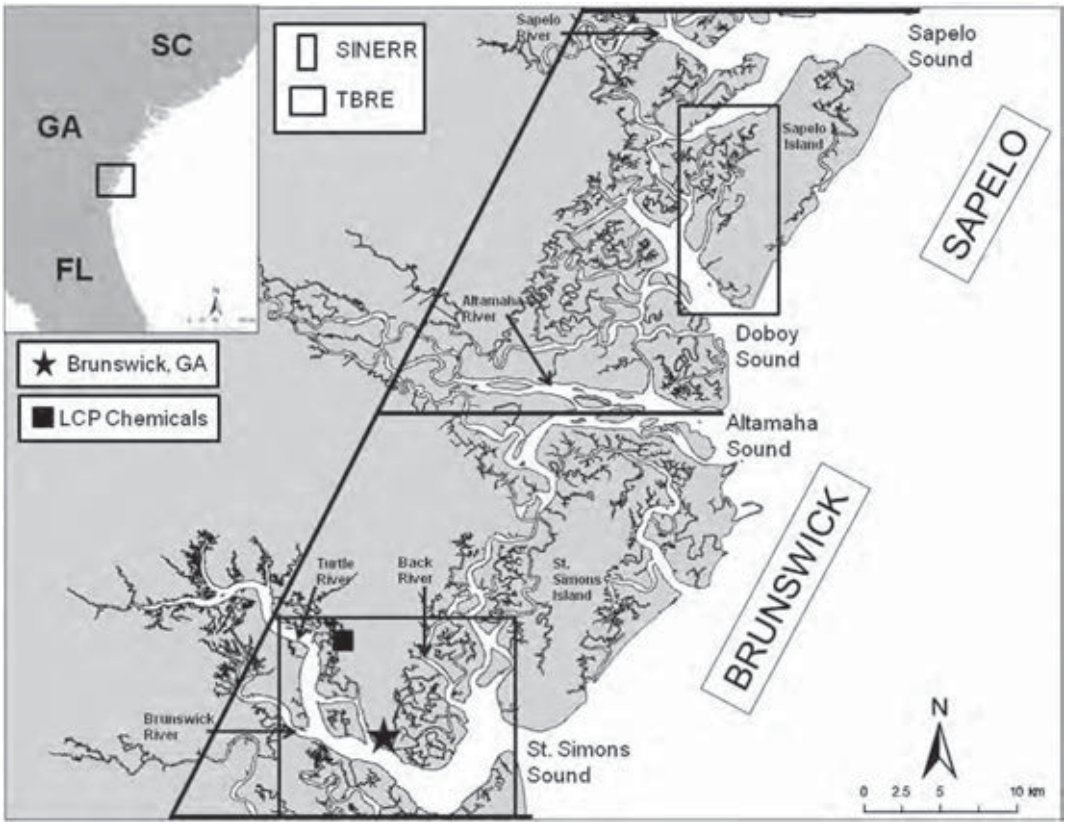

Fig. 1. Brunswick and Sapelo field sites located in the southern Georgia study area (SGA). The Sapelo Island National Estuarine Research Reserve (SINERR) is the area within the rectangular box located within the Sapelo field site. The Turtle/Brunswick River Estuary (TBRE), is the area within the square box located in the Brunswick field site. The brackets define the SGA boundaries including the division between the Brunswick and Sapelo field sites and 15 km upriver of the major tributaries.

contamination from mercury, lead, PCBs, dioxin, and other organic compounds (EPA, 2007; Kannan et al., 1997). Understanding the long-term impacts of these contaminants requires knowledge of the extent to which they contaminate the adjacent environment and food web.

Kannan et al. (1997) measured PCB levels in sediments within the TBRE and determined that sediments sampled from the LCP Chemicals site had PCB concentrations 50 times higher than those measured 500 m from the site. Fish species, including spotted sea trout (*Cynoscion nebulosus)* and striped mullet (*Mugil cephalus)*, sampled in the TBRE had PCB concentrations that were three times higher than PCB levels measured in fish from the Skidaway River, approximately 100 km north of the TBRE (Maruya and Lee, 1998). High concentrations of PCBs, specifically those with the Aroclor 1268 congener pattern, were also reported from a pilot study which sampled bottlenose dolphins in the TBRE (Pulster et al., 2009). Pulster et al. (2009) compared PCB levels from blubber of live dolphins sampled via remote biopsy in St. Simons Sound and the adjacent Back River in the TBRE with blubber samples from stranded dolphins collected approximately 90 km to the north, near Savannah, Georgia. Even with a small sample size of only four male TBRE dolphins, the study was able to discern a congener pattern indicative of an Aroclor 1268 source and similar to the congener profile documented in prey fish from the area (Pulster et al., 2009, 2005). In addition, Rosel (unpublished NOAA data) reported that mitochondrial DNA control region sequences and microsatellite markers from dolphins remotely biopsied in the TBRE were significantly different from those of dolphins sampled in Savannah, Georgia, and Charleston, South Carolina. Thus, it has been hypothesized that the dolphins in the TBRE and surrounding waters may be long-term residents to this region (Pulster et al., 2009). However, to date, this hypothesis has not been tested and no previous data have been published on ranging patterns of dolphins along this region of the Georgia coast.

This study builds on the previous research of Pulster et al. (2009) by expanding the sampling of dolphins within and outside of the TBRE to examine the relationship between measured POP concentrations and individual dolphin ranging patterns. Biopsy sampling was extended 40 km northeast of the TBRE to the waters in and around the Sapelo Island National Estuarine Research Reserve (SINERR) (Fig. 1). The SINERR is a federal- and state-managed protected area and is the focus of long-term ecological research projects such as water quality monitoring, primary productivity assessment, and fisheries sampling (e.g. Dresser and Kneib, 2007; Hanson and Synder, 1979; Owen and White, 2005). The area surrounding Sapelo Island, including the SINERR, is relatively undeveloped and was chosen with the intent that dolphins in this area could potentially act as a reference group for comparison with dolphins inhabiting the more contaminated TBRE. However, nothing was known about the ranging patterns of bottlenose dolphins within and between the TBRE and SINERR regions. Thus, if dolphins in the SINERR region were found to have elevated POP levels, it would be unclear whether such findings were due to contaminant transport or movement of dolphins between the two regions.

Photo-identification of dorsal fins has proven to be a very effective method of identifying individual dolphins and determining their ranging patterns (e.g. Irvine et al., 1981; Scott et al., 1990; Wells and Scott, 1990). Photo-identification surveys were initiated within the TBRE and SINERR regions to document the presence of individual dolphins and their potential movement between the sites. The goals of this study were to characterize the POP, and specifically PCB, exposure of dolphins in the TBRE and SINERR regions and examine patterns of

PCB congeners in relation to individual dolphin ranging patterns based upon photo-identification sighting histories.

2. Materials and methods

2.1. Study area

The southern Georgia photo-identification survey area (SGA) included the estuarine waters from Sapelo Sound south to St. Simons Sound, representing approximately 60 km of north–south estuarine shoreline (Fig. 1). The survey area's eastern boundaries were defined as the mouths of Sapelo, Doboy, Altamaha, and St. Simons Sounds. The western boundaries were defined as 15 km upriver of the Sapelo, Altamaha, and Turtle rivers. The SGA was divided into two field sites based upon the location of major sounds within each site. The Brunswick field site included the TBRE and all estuarine waters from St. Simons Sound north to and including Altamaha Sound. The Sapelo field site excluded Altamaha Sound and covered all estuarine waters north to, and including Sapelo Sound.

2.2. Biopsy sample collection

Biopsy samples from individual bottlenose dolphins were collected during both remote biopsy sampling surveys and a capture-release health assessment. Remote biopsy sampling was conducted in the Brunswick field site in August 2006 and March 2007 and in the Sapelo field site during August 2007, March 2008, and August 2008 utilizing standard techniques demonstrated to be safe and effective in numerous studies of small cetaceans (Kiszka et al., 2010; Sellas et al., 2005; Wells and Scott, 1990). The remote biopsy samples were obtained using a 0.3 m long carbon fiber dart with a 25 mm stainless steel cutterhead, which was propelled by a 0.22 blank charge from a modified 0.22 caliber rifle. The rifle was equipped with a holosight (Bushnell Corporation, Overland Park, KS) to improve sampling accuracy and a digital video camera and/or digital still camera to identify the dorsal fin of the sampled individual and to document the animal's reactions post-sampling. Dolphins were sampled within a range of 2–6 m from the vessel. Sampling location was typically along the animal's flank, approximately 10 cm below and 10 cm behind the caudal insertion of the dorsal fin. The sample collected from the biopsy cutterhead included a superficial layer of epidermis in addition to a full thickness section of blubber approximately 10 mm in diameter and 0.5–1.0 g in weight. Once a sample was obtained, the epidermis was removed from the blubber using latex gloves and sterile instruments. The blubber samples were placed in Teflon jars and frozen in a liquid N_2 dry shipper to be analyzed for persistent organic pollutant (POP) concentrations. Only full thickness blubber samples were utilized to determine POP concentrations in this study. The epidermis, which was stored in 20% DMSO/saturated NaCl, was used to identify the sex of the sampled individual using molecular methods (Rosel, 2003).

In addition to the remote biopsy samples, surgical biopsy wedges were collected during a health assessment of bottlenose dolphins in August 2009 (Schwacke et al., in review). Dolphins were captured through encirclement with a seine net and brought aboard a specially designed veterinary examination and sampling vessel. Biopsy wedge samples were collected by a veterinarian at a site 10 cm below and 10 cm behind the caudal insertion of the dorsal fin. A chlorohexiderm and ethanol scrub was used to sterilize the sampling region and lidocaine hydrochloride with epinephrine was administered as a local anesthetic. Sterilized instruments that were hexane and acetone washed as well as autoclaved were used to surgically remove the biopsy wedge sample. For POP analysis, a 0.7–1.0 g, full-depth, subsection of the biopsy wedge sample was placed into a 15 ml Teflon jar and frozen in a liquid N_2 dry shipper on the sample processing vessel. Following sampling, the dolphins were radio-tagged and released at the capture site. At the lab, the sample was stored frozen at −80 °C until analysis. Epidermal samples were also collected and utilized to identify sex as described above.

2.3. Biopsy sample analysis

Blubber samples were analyzed for POPs as described previously (Litz et al., 2007). Briefly, approximately 1 g of blubber was minced, dried with sodium sulfate and extracted by pressurized fluid extraction using dichloromethane. Samples were cleaned up by size exclusion chromatography and aluminum solid phase extraction prior to analysis by gas chromatography mass spectrometry. Lipid content was calculated gravimetrically from a weighed portion of the PFE extract. POP concentrations were determined using a gas chromatograph-mass spectrometer (GC/MS; Agilent 6890/5973, Palo Alto, CA).

A five to seven point calibration curve of compounds was determined from National Institute of Standards and Technology (NIST) Standard Reference Material (SRM) solutions and utilized to quantify all analytes and calibrants. Samples were extracted, cleaned, and analyzed by GC/MS in lots of 30–40 with a minimum of one blank and 1–3 aliquots of NIST SRM 1945 Organics in Whale Blubber (Kucklick et al., 2010). POP concentrations identified within each aliquot of SRM 1945 were within 7.5% ± 3.5% (mean ± standard deviation) of the certified values. The limit of detection (LOD) for each analyte was defined as the greater of (a) the mass of the analyte in the lowest detectable calibration solution divided by the sample mass, or (b) the average mass of the analyte detected in blanks plus three times the standard deviation. The limits of detection ranged from 0.089 ng/g wet mass to 16.9 ng/g wet mass for all measured analytes.

2.4. Photo-identification

The photographic records for this study were from three efforts of varying duration and scope, totaling 238 surveys from 2004 to 2009 (Table 1). All efforts were included in this analysis to establish the broadest record possible for each individual dolphin's sighting history.

Dorsal fin images were obtained from remote biopsy sampling surveys conducted in 1–2 week sessions in the TBRE during December 2004, August 2006, and March 2007 and in and around the SINERR during August 2007, March 2008 and August 2008 (Table 1). Contaminant results of biopsy samples from the December 2004 TBRE surveys were previously reported (Pulster et al., 2009) and are not included in this analysis. However, photographic images obtained during the 2004 surveys were included for analysis of individual sighting histories.

Abundance surveys utilizing photo-identification of individuals' dorsal fins were conducted during every season for 2008 and 2009 in both the Brunswick and Sapelo field sites. During this effort, a 6–7 m, center console vessel with three observers surveyed both field sites to obtain photographs of every individual dolphin's dorsal fin. Mark-recapture analyses were then performed to determine seasonal abundance (methods reviewed in Balmer et al., 2008) in both the Brunswick and Sapelo field sites.

Radio-tracking was used to identify ranging patterns during summer/fall 2009, following the capture–release health assessment. The two goals of the health assessment were to (1) perform detailed health examinations of bottlenose dolphins from the Brunswick and Sapelo field sites including collection of a surgical wedge biopsy sample for contaminant analysis and (2) attach radio transmitters on bottlenose dolphins to determine short-term ranging patterns. Balmer et al. (2008) have previously described the methodology for radio transmitter attachment and follow-up tracking. Briefly, bottlenose dolphins in both the Brunswick and Sapelo field sites were temporarily captured and restrained utilizing practices similar to those implemented by the Chicago Zoological Society's Sarasota Dolphin Research

Table 1
Photographic records and biopsy sampled obtained from 2004 to 2009 for all survey effort in the southern Georgia study area (SGA).

Date	Field site	Survey type	# of individuals sighted	# of remote biopsy samples obtained	# of surgical biopsy samples obtained
14–17 Dec. 2004	Brunswick	Remote biopsy	11		
21–30 Aug. 2006	Brunswick	Remote biopsy	130	13	
12–23 Mar. 2007	Brunswick	Remote biopsy	114	19	
20–31 Aug. 2007	Sapelo	Remote biopsy	169	20	
04–16 Feb. 2008	Brunswick and Sapelo	Abundance	146		
17–27 Mar. 2008	Sapelo	Remote biopsy	77	10	
01–11 Apr. 2008	Brunswick and Sapelo	Abundance	146		
29 Jul.–9 Aug. 2008	Brunswick and Sapelo	Abundance	222		
18–28 Aug. 2008	Sapelo	Remote biopsy	106	14	
06–16 Oct. 2008	Brunswick and Sapelo	Abundance	100		
29 Jan.–9 Feb. 2009	Brunswick and Sapelo	Abundance	131		
31 Mar.–11 Apr. 2009	Brunswick and Sapelo	Abundance	159		
06–16 Jul. 2009	Brunswick and Sapelo	Abundance	196		
03–14 Aug. 2009	Brunswick and Sapelo	Health assessment	26		26
15 Aug.–9 Oct. 2009	Brunswick and Sapelo	Radio tracking	224		
13–24 Oct. 2009	Brunswick and Sapelo	Abundance	179		
25 Oct.–20 Nov. 2009	Brunswick and Sapelo	Radio tracking	69		

Program (Wells et al., 2004). Radio transmitters were deployed on 28 dolphins (14 male, 14 female) and subsequently tracked by vessel for over 100 days with GPS positions recorded for the visual locations of all tagged individuals.

For all three survey efforts, dorsal fin images were graded on both distinctiveness of the dorsal fin, and photographic quality, following the methods of Urian et al. (1999). A catalog of all fins was created with each individual receiving a unique number based on its distinctive markings. Currently, the SGA photo-identification catalog consists of 646 individual bottlenose dolphins. The photo-identification records from the remote biopsy, abundance, and radio-tracking surveys were used to analyze individuals' sighting histories and classify each biopsy sampled individual into one of three ranging patterns. In this study, a ranging pattern is defined as the photo-identification sighting history for an individual dolphin within the SGA region. If all photo-identification sightings of a biopsy sampled individual were in either the defined Brunswick or Sapelo field site, they were identified as having a "Brunswick" or "Sapelo" ranging pattern, respectively. Biopsy sampled individuals that were sighted in both field sites were identified as having a "Mixed" ranging pattern.

2.5. Data analysis

Blubber samples in this study were analyzed for PCB congeners (IUPAC PCB numbers 18, 28 + 31, 44, 49, 52, 56, 66, 70, 74, 87, 92, 95, 99, 101, 105, 110, 118, 119, 128, 130, 137, 138, 146, 149, 153 + 132, 151, 154, 156, 157, 158, 163, 170, 172, 174, 176, 177, 178, 180, 183, 185, 187, 189, 194, 195, 197, 199, 200, 201, 202, 203 + 196, 206, 207, 208, and 209), polybrominated diphenyl ether (PBDE) congeners (47, 99, 100, 153, and 154), dichlorodiphenyl-dichloroethanes (DDTs) (2,4′-DDD DDE, and DDT; and 4,4′-DDD, DDE, and DDT), chlordanes (CHLs) (*cis*- and *trans*-chlordane and nonachlor, oxychlordane and heptachlor epoxide), hexachlorobenzene (HCB), dieldrin, and mirex. Σ PCBs was defined as the sum of the 54 PCB congeners. Σ Aroclor 1268 was defined as the sum of the following congeners identified by Maruya and Lee (1998) as indicative of Aroclor 1268 (174, 180, 183, 187, 194, 196, 199, 200, 201, 202, 206, 207, 208, and 209). Aroclor 1268 proportion was calculated as Σ Aroclor 1268/Σ PCBs. To control for lipid content variability between individuals and sampling seasons, POP concentrations for all samples were calculated on a lipid-weight basis and log transformed to meet the assumptions of normality.

Because mothers transfer much of their accumulated lipophilic contaminant loads to their offspring during each pregnancy and associated lactation period (Aguilar et al., 1999; Wells et al., 2005; Yordy et al., 2010), all biopsied individuals were separated based upon sex. Each sampled individual was classified into its respective ranging pattern (Brunswick, Sapelo, or Mixed) based upon its photo-identification sighting history from all survey efforts. If a sampled individual had a non-distinctive fin or had not been sighted pre- or post-biopsy sampling (i.e. its ranging pattern could not be identified), it was excluded from these analyses. The proportion of Aroclor 1268 congeners was arcsine transformed to meet the assumption of normality. A two-way analysis of variance (ANOVA) including sex (male, female) and ranging pattern (Brunswick, Sapelo, Mixed) as factors was performed. When the F-statistic was significant for ranging pattern, pairwise comparisons were made using Tukey's Honestly Significant Difference (HSD) test.

The location of the LCP Chemicals site (31.189440 N, 81.508330 W) (EPA, 2002), the likely point source for Aroclor 1268 contamination, was used as a reference point and photo-identification sighting histories for each biopsy sampled individual were utilized to calculate the distance of each sighting from this point. Distance for each photo-identification sighting was calculated as the closest on-water distance between the sighting and the reference point using the "Measure" tool in ArcMap 9.2 (ESRI, Redlands, CA). For each individual dolphin, the mean distance to point source was determined from that dolphin's entire sighting history. Linear regression analysis was performed to examine any relationships between the proportions of Aroclor 1268 congeners, and mean sighting distance from point source. A test for homogeneity of slopes was used to determine interactions between sex and distance from point source.

3. Results

A total of 105 blubber samples were collected via remote biopsy from dolphins in the Brunswick and Sapelo field sites. Of these, 29 remote biopsy samples were excluded because individuals had non-distinctive fins or were not sighted pre- or post-sampling. In addition, 26 samples were collected via surgical biopsy during the capture–release health assessment bringing the total number of samples utilized in this study to 102. Sampled individuals, which were sighted a mean number of 14 ± 12 (± standard deviation) times, were separated by sex and grouped into one of three ranging patterns; Brunswick (♀ = 10, ♂ = 24), Mixed (♀ = 4, ♂ = 18), and Sapelo (♀ = 14, ♂ = 32).

Male dolphins had significantly higher mean concentrations for all POP classes than did females (Table 2). Mean percent lipid was significantly higher in female dolphins than male dolphins ($P = 0.0022$). Σ PCB and Σ Aroclor 1268 differed significantly across all ranging patterns. There were no significant differences in mean

Table 2
Geometric mean persistent organic pollutant (POP) contaminant values and 95% confidence intervals in (μg/g) lipid weight mass from Brunswick, Mixed, and Sapelo bottlenose dolphins sampled in the SGA. Significant P-values are indicated in bold. *Note*: For each POP class, statistical differences were determined utilizing a two-way ANOVA with sex and ranging pattern as factors. When the F-statistic was significant for ranging pattern, pairwise comparisons for ranging patterns within each sex were made using Tukey's Honestly Significant Difference (HSD) test. Homogeneous groups are indicated by capital (male) or lower case (female) letter subscripts.

	POP class	Lipid (%)	Σ PCB	Σ Aroclor 1268	Aroclor 1268 proportion	Σ PBDE	Σ DDT	Σ CHL	HCB	Dieldrin	Mirex
Males	*Brunswick*	25.12	509.56^{A}	407.78^{A}	0.77^{A}	3.85	36.77	6.30	0.04	0.16	2.65
	(n=24)	(13.17–37.07)	(369.04–703.59)	(290.30–572.78)	(0.74–0.80)	(2.79–5.32)	(21.93–61.65)	(4.31–9.22)	(0.03–0.06)	(0.06–0.39)	(1.86–3.78)
	Mixed	27.90	253.57^{B}	170.71^{B}	0.68^{B}	5.12	28.55	5.75	0.05	0.32	2.17
	(n=18)	(17.02–38.77)	(177.89–361.45)	(119.14–244.61)	(0.65–0.71)	(3.78–6.95)	(16.87–48.32)	(3.68–9.01)	(0.04–0.07)	(0.19–0.55)	(1.53–3.08)
	Sapelo	23.57	115.73^{C}	69.10^{C}	0.60^{C}	2.48	20.49	3.83	0.04	0.15	1.69
	(n=32)	(14.39–32.74)	(91.66–146.13)	(54.97–86.86)	(0.58–0.62)	(1.95–3.17)	(14.03–29.93)	(2.76–5.34)	(0.03–0.04)	(0.11–0.21)	(1.30–2.20)
Females	*Brunswick*	32.80	116.47^{a}	94.87^{a}	0.85^{a}	0.63	15.68	0.63	0.02	0.16	0.45
	(n=10)	(12.71–52.90)	(78.14–173.60)	(64.41–139.72)	(0.79–0.84)	(0.22–1.82)	(2.79–88.10)	(0.24–1.63)	(0.01–0.04)	(0.03–0.72)	(0.27–0.76)
	Mixed	28.61	45.94^{a}	35.15^{a}	0.78^{a}	0.38	1.59	0.49	0.01	0.22	0.46
	(n=4)	(17.18–40.03)	(20.75–101.72)	(19.43–63.60)	(0.55–1.00)	(0.05–2.57)	(0.23–10.99)	(0.08–3.05)	(0.00–0.03)	(0.04–1.30)	(0.12–1.74)
	Sapelo	36.44	48.27^{a}	30.60^{a}	0.63^{b}	1.27	10.03	1.31	0.03	0.09	0.77
	(n=14)	(19.04–53.84)	(27.25–85.50)	(17.72–52.86)	(0.59–0.67)	(0.63–2.55)	(3.98–25.32)	(0.37–4.74)	(0.02–0.04)	(0.03–0.26)	(0.42–1.41)
P-value (ranging pattern):		P=0.8960	**P<0.0001**	**P<0.0001**	**P<0.0001**	P=0.7237	P=0.0674	P=0.7384	P=0.3640	P=0.8094	P=0.8948
P-value (sex):		P=0.0022	P<0.0001	P<0.0001	P<0.0001	P<0.0001	P=0.0006	P<0.0001	P<0.0001	P=0.0132	P<0.0001

percent lipid and all other POP classes, across male ranging patterns. The highest Σ PCB concentrations in male dolphins were 2870 μg/g (Brunswick), 756 μg/g (Mixed), and 333 μg/g (Sapelo). Brunswick males had significantly higher mean Σ PCB and Σ Aroclor 1268 concentrations than did Sapelo males (P<0.0001 and P<0.0001, respectively). Mean Σ PCB and Σ Aroclor 1268 concentrations for Mixed males were significantly lower than Brunswick males (P=0.0036 and P=0.0024, respectively) and significantly higher than Sapelo males (P=0.0028 and P=0.0090, respectively). The highest Σ PCB concentrations measured in female dolphins were 339 μg/g (Brunswick), 154 μg/g (Mixed), and 279 μg/g (Sapelo). There were no significant differences in mean percent lipid, Σ PCB, Σ Aroclor 1268, and all other POP classes between females across ranging patterns. However, the low sample size (n=4) for Mixed females limits interpretation of contaminant data associated with this ranging pattern in comparison to the other female ranging patterns.

Aroclor 1268 proportion in male dolphins differed significantly between all three ranging patterns (P<0.0001 for all pairwise comparisons), with Brunswick males having the highest proportion followed by Mixed, and Sapelo males (Table 2). Brunswick and Mixed females had a significantly higher proportion of Aroclor 1268 (P<0.0001 and P=0.0009, respectively) than did Sapelo females. Aroclor 1268 proportion did not differ significantly between Brunswick and Mixed females (P=0.9288).

Linear regression analysis was performed to identify relationships between Aroclor 1268 proportion and mean sighting distance from the point source for each biopsy sampled individual (Fig. 2). For both male and female dolphins, there was a negative relationship between the proportion of Aroclor 1268 congeners and mean sighting distance from the point source (males: $R^2=0.6842$, P<0.0001; females: $R^2=0.7137$, P<0.0001). The slopes of the regression lines did not differ between males and females (P=0.4020).

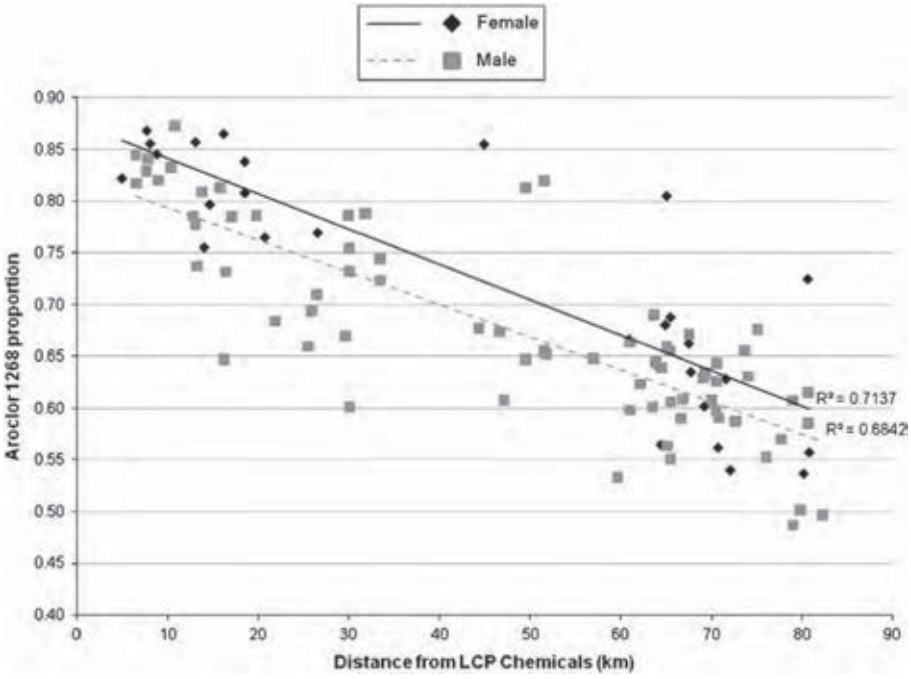

Fig. 2. Relationship between the proportions of Aroclor 1268 congeners found in the blubber of each biopsy sampled individual and its calculated mean sighting distance from LCP Chemicals.

4. Discussion

This study confirms that dolphins utilizing the TBRE are exposed to extraordinarily high levels of PCBs. The maximum PCB concentration measured in a Brunswick male was over 1.5 times greater than the maximum PCB level measured in transient, male Pacific killer whales (*Orcincus orca*), which were previously reported to have the highest PCB levels of any cetacean (Krahn et al., 2007; Ross et al., 2000). Biomagnification of contaminant concentrations has been extensively documented in marine mammal species (reviewed in Houde et al., 2005). Transient killer whales, at the top of the northeastern Pacific marine food web, primarily feed on other marine mammal species (Ford et al., 1998), therefore high contaminant levels would be expected in these individuals through biomagnification. Bottlenose dolphins along the southeastern U.S. are also considered top-level, marine predators (reviewed in Wells et al., 2005). However, bottlenose dolphin prey is primarily based on lower trophic levels such as pinfish (*Lagodon rhomboides*), mullet (*Mugil* spp.), and a variety of soniferous fish species (Barros and Odell, 1990; Barros and Wells, 1998; Berens McCabe et al., 2010; Gannon and Waples, 2004). Thus, based solely on trophic level differences, it would be expected that bottlenose dolphin contaminant concentrations should typically be lower than those of transient killer whales. The higher levels of PCBs measured in Brunswick male dolphins compared to male transient killer whales is related to the proximity of this population to a major PCB point source and the exposure to these contaminants within their localized environment due to their ranging patterns.

Σ PCB concentrations measured in male dolphins that were only sighted in the Sapelo field site were lower than in Brunswick males, but were comparable to those measured for male bottlenose dolphins in northern Biscayne Bay, Florida (Litz et al., 2007). These males were previously reported to have the highest PCB concentrations for bottlenose dolphins in the southeastern U.S. The Sapelo Island National Estuarine Research Reserve (SINERR) has been identified in numerous studies as a "pristine" reference site based upon the minimal amount of urbanization in the region (e.g. Alberts et al., 1990; Chalmers et al., 1985; Plumley et al., 1980). The elevated levels of PCBs and high Aroclor 1268 proportion in Sapelo male dolphins suggest otherwise. Although there are limited industrial influences surrounding the SINERR, dolphins that have been sighted exclusively in this region have elevated PCB levels associated with a point source located 40 km southwest of their observed ranging pattern. Future research is necessary to identify the pathways leading to Aroclor 1268 contamination in Sapelo dolphins, such as determining contaminant levels and movement patterns of key bottlenose dolphin prey fish species. Contaminated prey or sediments are the most likely routes leading to dolphin exposure as the Aroclor 1268 mixture is extremely hydrophobic (mean log $K_{ow} = 7.9$ L/kg) (Maruya and Lee, 1998) and water transport is unlikely.

For each ranging pattern within the southern Georgia survey area (SGA), female dolphins had significantly lower mean Σ PCB and Σ Aroclor 1268 concentrations, but significantly higher proportions of Aroclor 1268 than males. Female cetaceans, upon reaching sexually maturity, offload the majority of their contaminants to their first born offspring, primarily through lactation (reviewed in Aguilar et al., 1999). For example, PCB concentrations measured in adult female bottlenose dolphins from Sarasota are much lower than those of juvenile females from the same community (Wells et al., 2005; Yordy et al., 2010). Yordy et al. (2010) identified significant changes in POP profiles of female bottlenose dolphins at sexual maturity, where the smallest, least lipophilic contaminants were offloaded through lactation to their first offspring. The predominant Aroclor 1268 congeners are highly chlorinated and therefore may not partition to the milk during lactation, making them resistant to offloading (Kannan et al., 1997, 1998; Yordy et al., 2010). Thus, the proportion of Aroclor 1268 in female dolphins would be expected to be higher than in males, as females offload the less lipophilic contaminants and retain the most lipophilic contaminants. The results of this study suggest that SGA female bottlenose dolphins either continue to be exposed to PCBs, or are not offloading contaminants at the same rate as dolphins in other regions, or some combination of these two processes.

Schwacke et al. (2002) suggested that risk of reproductive failure, such as neonate mortality, would be highest for primiparous female bottlenose dolphins, but that following a successful birth and lactation, the risk of reproductive failure would be reduced with a lower contaminant load. The high PCB levels in SGA females, maintained over the course of a reproductive lifetime, may also maintain the high risk for reproductive failure, even for subsequent reproductive events. Photo-identification data from the 2008 survey effort identified six neonates within the SGA, only one of which survived until the following year (B. Balmer, unpublished data), yielding an annual neonate survival rate of 0.167. For comparison, Speakman et al. (2010) calculated an annual neonatal survival rate of 0.754 (95% CI = 0.647–0.878) for bottlenose dolphins in the Charleston Estuarine Stock. In Sarasota Bay, Florida, the average annual overall neonatal survival is approximately 80%, with about 50% of first-born calves surviving the first year (Wells and Scott, 1990; Wells et al., 2005). Although our SGA estimate is only for a single year, and survival rates often vary greatly across years, these results suggest that dolphin reproductive potential in the SGA may be limited in comparison to other estuarine areas. Knowledge of life history parameters from stranding data is necessary to improve the accuracy of neonatal survivorship estimates. However, collection of high quality stranded carcasses in the SGA has been hampered by geographic remoteness, high tidal flux, and other logistical constraints in the region. Enhanced stranding response, stranding reporting and continuation of photo-identification surveys in the SGA are all needed in order for survival estimates to be calculated and compared with other dolphin populations.

The PCB congeners that comprise Aroclor 1268 have been identified as a point source pollutant from the LCP Chemicals Superfund site (Kannan et al., 1997; Kucklick et al., in review; Maruya and Lee, 1998; Pulster and Maruya, 2008). There was a significant negative relationship between the proportion of Aroclor 1268 congeners and mean sighting distance from the LCP Superfund site, indicating that the exposure of a SGA dolphin is directly associated to its proximity to this site. Although PCBs are ubiquitous contaminants and there is potentially some background exposure resultant from long-range environmental transport, the high levels and proportion of Aroclor 1268 congeners indicate that PCB exposure of the sampled dolphins was predominantly from this single point source. Other studies along the southeastern U.S. have reported elevated levels of highly chlorinated PCB congeners in bottlenose dolphins (Hansen et al., 2004; Houde et al., 2006; Kucklick et al., in review; Watanabe et al., 2000). Watanabe et al. (2000) determined that over 60% of the PCB profile measured in liver samples from stranded bottlenose dolphins consisted of six (hexa) and seven (hepta) chlorobiphenyls. Similarly, in blood plasma samples from bottlenose dolphins obtained during capture-release health assessments, the predominant PCB homolog groups measured were those that contained between five (penta) and seven (hepta) chlorines (Yordy et al., 2010). However, the specific PCB profile of the highly chlorinated congeners associated with Aroclor 1268 have only been identified along the southern coast of Georgia (Kucklick et al., in review). Although our study has identified SGA dolphins with localized ranging patterns exclusively within the Brunswick and Sapelo field sites, future research is necessary to determine if other groups of dolphins are entering the SGA as well as prey species' movements into and out of the region.

Kucklick et al. (in review) utilized POP concentrations measured in bottlenose dolphins at 14 locations along the southeastern U.S. and Gulf of Mexico coasts, to identify geographic differences in POPs. The

contaminant levels measured in the Brunswick and Sapelo field sites for this study were two of the locations included in this analysis. Kucklick et al. (in review) confirmed the results of this study, which identified that Brunswick dolphins had the highest Σ PCB concentrations measured along the southeastern U.S. and Gulf of Mexico coasts. Σ PBDE concentrations in SGA dolphins were comparable to dolphins sampled in Charleston, SC, and Mississippi Sound, and higher than dolphins sampled in all other sampling locations. Mirex concentrations in SGA dolphins were comparable to dolphins sampled in Sarasota Bay, FL, Tampa Bay, FL, and Mississippi Sound, and higher than all other sampling locations. Σ DDT, Σ CHL, HCB, and dieldrin concentrations were intermediate in SGA dolphins, in comparison to all other sampling locations. The geographic differences in POP concentrations provide an additional tool to identify bottlenose dolphin stock delineations.

NOAA has defined five coastal and nine estuarine North Western Atlantic (NWA) bottlenose dolphin stocks, based upon photo-identification, telemetry, and genetic studies at multiple locations along the southeastern U.S. coast (reviewed in Waring et al., 2009). Numerous NWA bottlenose dolphin stocks overlap with each other and the precise delineations of these stocks, and movements of individuals between these stocks, are currently not well understood. On a broad-scale, Hansen et al. (2004) identified differences in POP concentrations between individual dolphins biopsy sampled in multiple states along the southeastern U.S. Similarly, Litz et al. (2007) identified significant differences in PCB exposure of different bottlenose dolphin communities in the localized estuary of Biscayne Bay, Florida. The results of this study suggest that the elevated POP levels and patterns may provide insight into Georgia bottlenose dolphin population structure. The two NOAA defined stocks in this region are the South Carolina/Georgia Coastal Stock (SCGCS) and the Southern Georgia Estuarine Stock (SGES) (Waring et al., 2009). The SCGCS includes all of the coastal waters of South Carolina and Georgia out to 25 m in depth. The SGES includes all of the estuarine waters from Altamaha Sound south to the Cumberland Sound (Georgia/Florida border). The spatial extent, ranging patterns, and overlap between these two stocks are not well understood. Dolphins that live in the estuarine waters to the north of the SGES, including Sapelo Island and the SINERR, are not classified into any stock at this time. The results from the photo-identification data and measured contaminant concentrations from this study suggest that Brunswick and Sapelo bottlenose dolphins may be part of separate estuarine stocks; SGES and a previously undefined stock beginning at the Altamaha Sound and extending northward, respectively. Recent studies determining seasonal abundance estimates, as well as ranging and movement patterns of bottlenose dolphins within the Brunswick and Sapelo field sites will augment this study and enhance these proposed changes in current SGA stock delineations.

The results of this study suggest that POP, and specifically Aroclor 1268, contamination extends farther outside of the TBRE than previously documented. Elevated levels of POPs, such as PCBs, have been identified as potential stressors to marine mammals (reviewed in Houde et al., 2005). Numerous studies have linked high tissue levels of PCBs to deleterious effects on reproduction and immune function (Aguilar and Borrell, 1998; DeLong et al., 1973; Helle et al., 1976; Martineau et al., 1987). However, identifying POPs as a causative factor of reproductive failure and immune suppression has proven difficult due to the logistical, political, and ethical constraints involved with marine mammals (reviewed in Schwacke et al., 2002). SGA bottlenose dolphins have extremely high levels of PCBs, specifically the highly chlorinated congeners associated with Aroclor 1268, which have been suggested to be resistant to offloading. Individual dolphins within the SGA have relatively localized distribution patterns facilitating routine follow up monitoring. Thus, the bottlenose dolphins within the SGA provide a unique opportunity to identify possible deleterious effects associated with chronic PCB exposure.

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Polychlorinated Biphenyls (PCBs) in Georgia Coastal Environments and Populations September 3, 2014

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Health Studies Branch, National Center for Environmental Health

Eastern Branch, Agency for Toxic Substances and Disease Registry

Outline

- **PCBs in Coastal Georgia Environments**
  - LCP Chemicals
  - Fish advisory areas
  - Seafood
- **PCBs in Coastal Populations**
  - Sapelo Island
    - Study description
    - Study findings
- **Next Steps**

PCBs in Coastal Georgia

- **Soil at the LCP Chemicals Superfund Site in Brunswick, GA**
- **Fishing advisory areas**
  - Brunswick
  - Near Sapelo Island
- **Distribution**
  - Total PCBs
  - PCB congener 206
- **Seafood samples from coastal Georgia**
  - Brunswick
  - Sapelo Island

PCBs at LCP Chemicals Superfund Site

- **Aroclors detected in soils at LCP**
  - 1016
  - 1221
  - 1248
  - 1254
  - 1260
  - 1268
- **Target EPA Action Level for total PCBs at LCP**
  - 25 ppm

Frequency of Aroclors Detected in Soils at LCP

Frequency of detection for various Aroclors in soil.			
Substance	# Detections	# Samples	Frequency
Aroclor 1016	2	891	0.2
Aroclor 1221	1	902	0.1
Aroclor 1232	0	902	0.0
Aroclor 1242	0	902	0.0
Aroclor 1248	2	902	0.2
Aroclor 1254	81	902	9.0
Aroclor 1260	37	902	4.1
Aroclor 1268	171	852	20.1

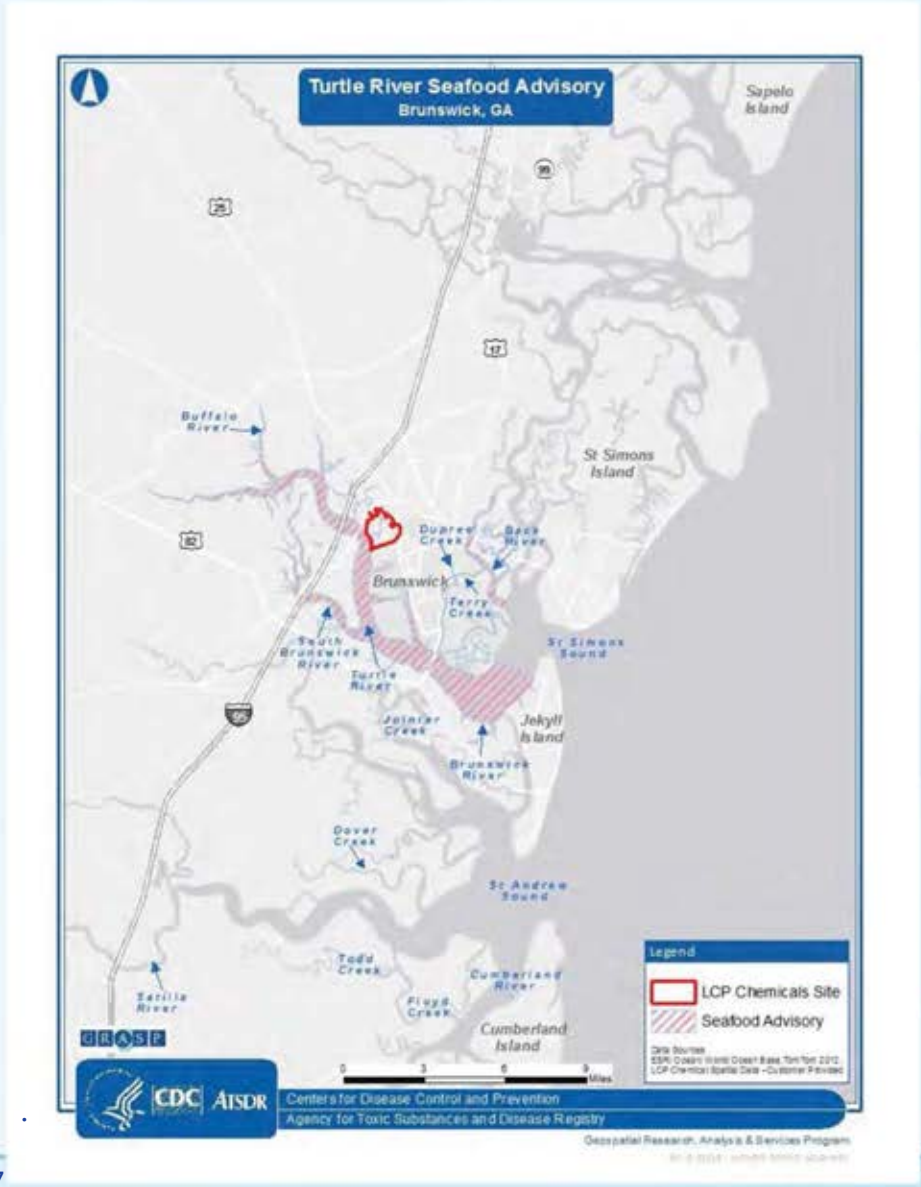
Aroclor 1268 concentration generally much higher than 1254 and 1260 concentrations

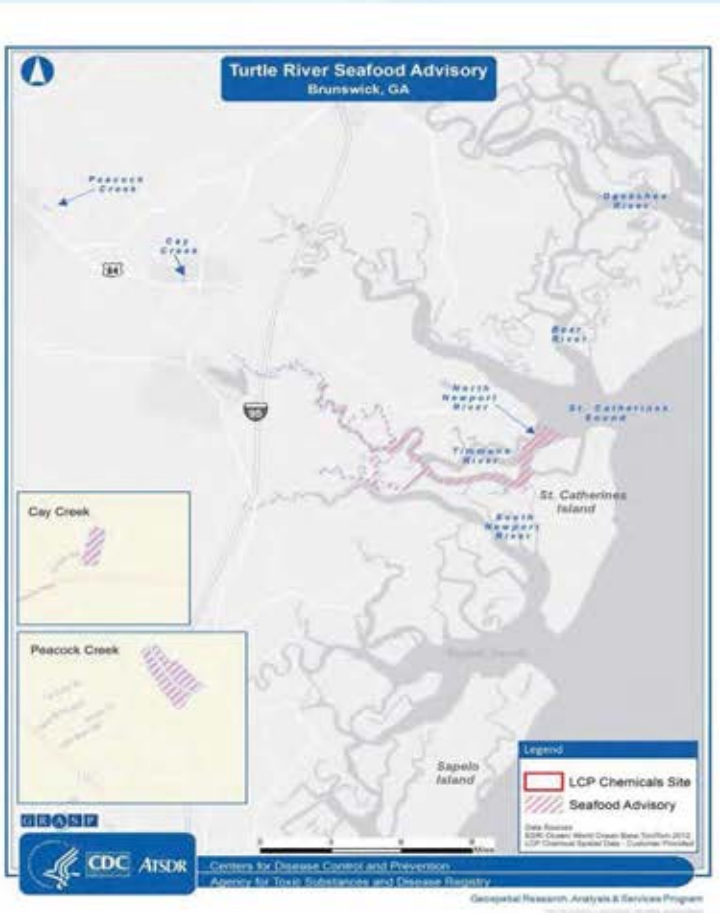
Source: ATSDR Public Health Assessment for the LCP Chemicals Superfund Site, 2014

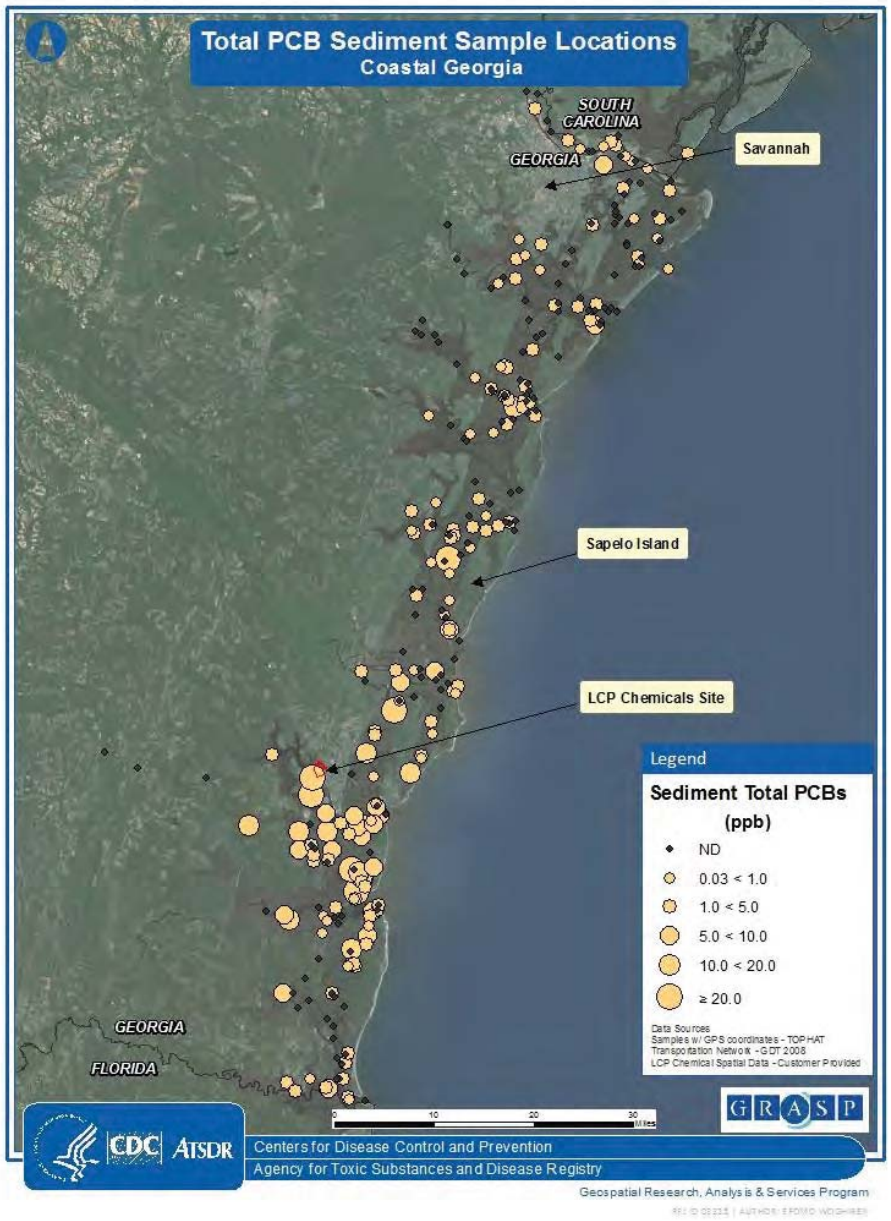
Aroclors 1268, 1260, and 1254 Congeners

Aroclor 1268	Aroclor 1260	Aroclor 1254
206 (>50%)	180	101
209	153	138
208	138	119
199	149	52
196	170	153
202	101	149
187	194	106
194		44
180+193		
201		

Coastal Georgia Fishing Advisory Areas

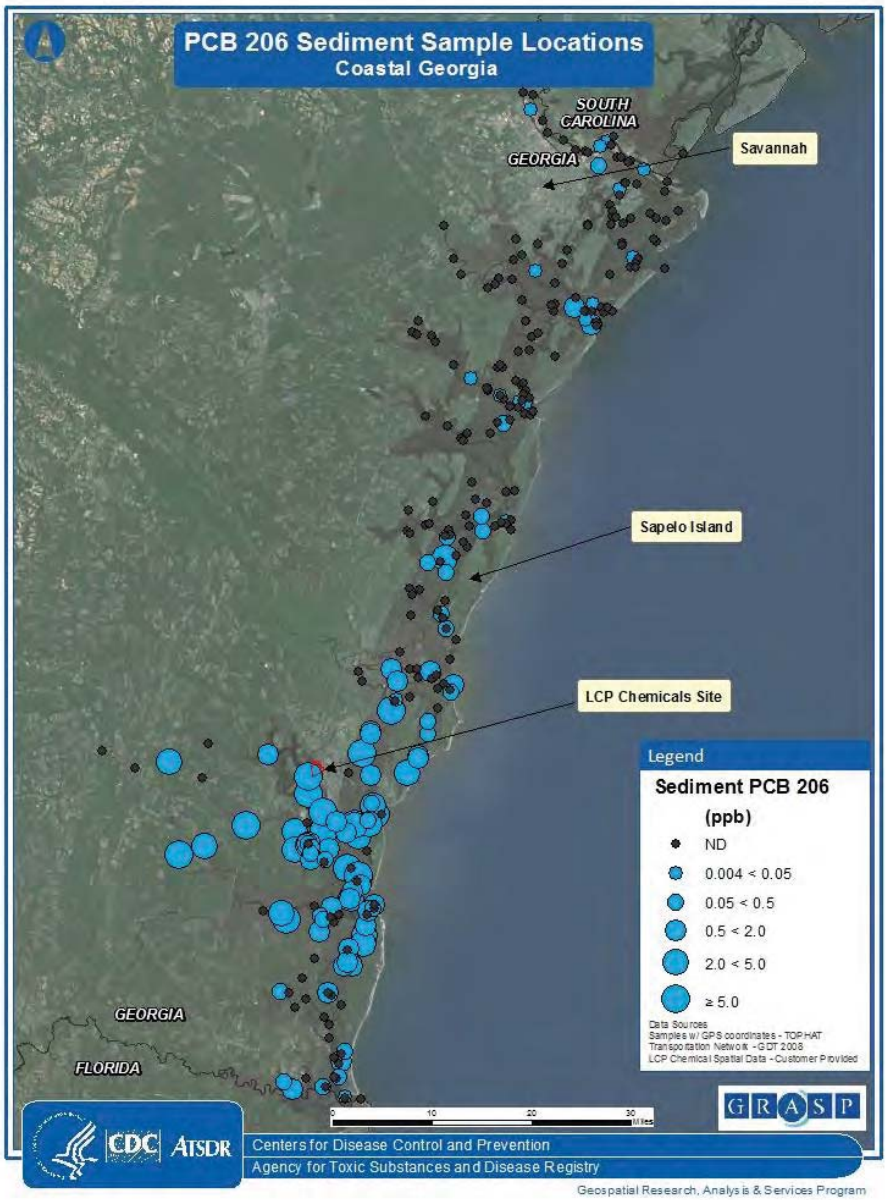




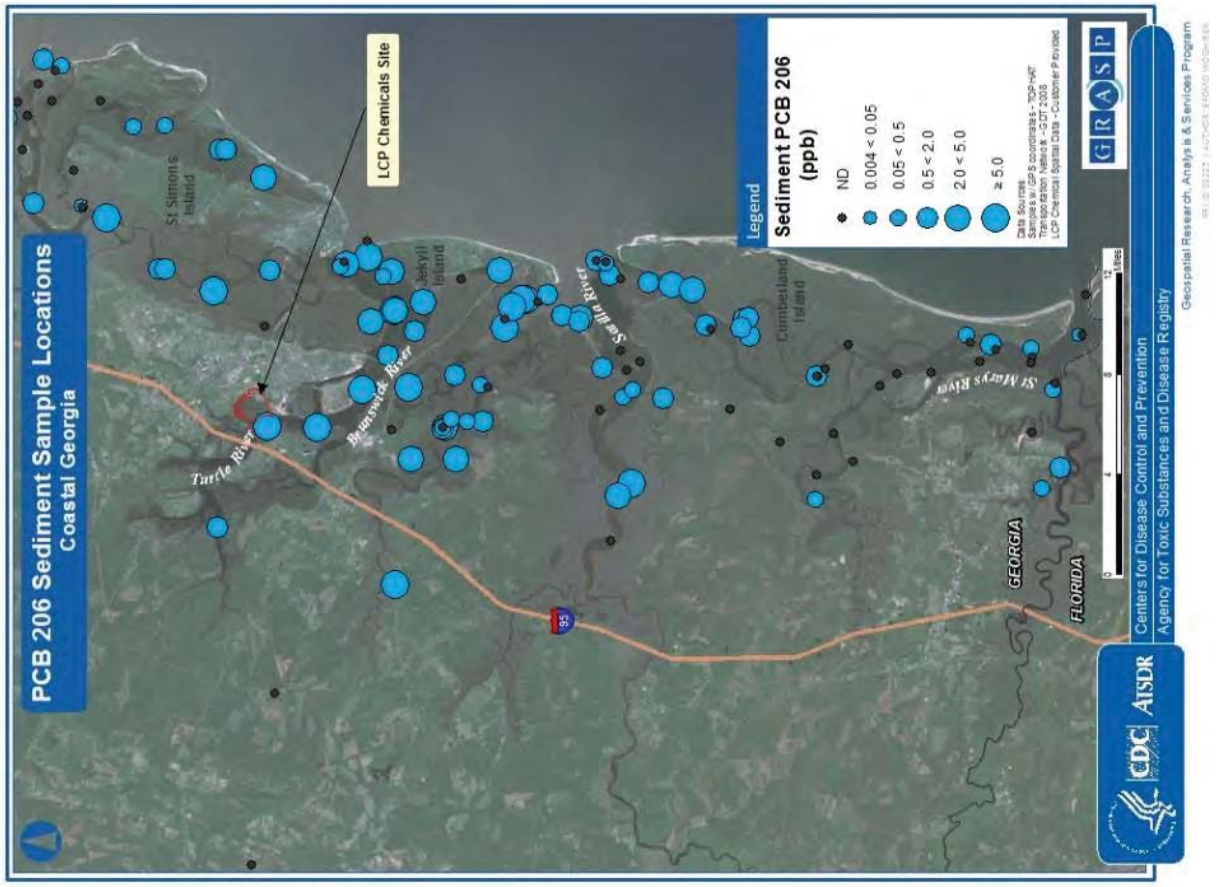


Source for all PCB sediment maps.
EPA's National Coastal Database

http://www.epa.gov/emap2/nca/html/data/index.html

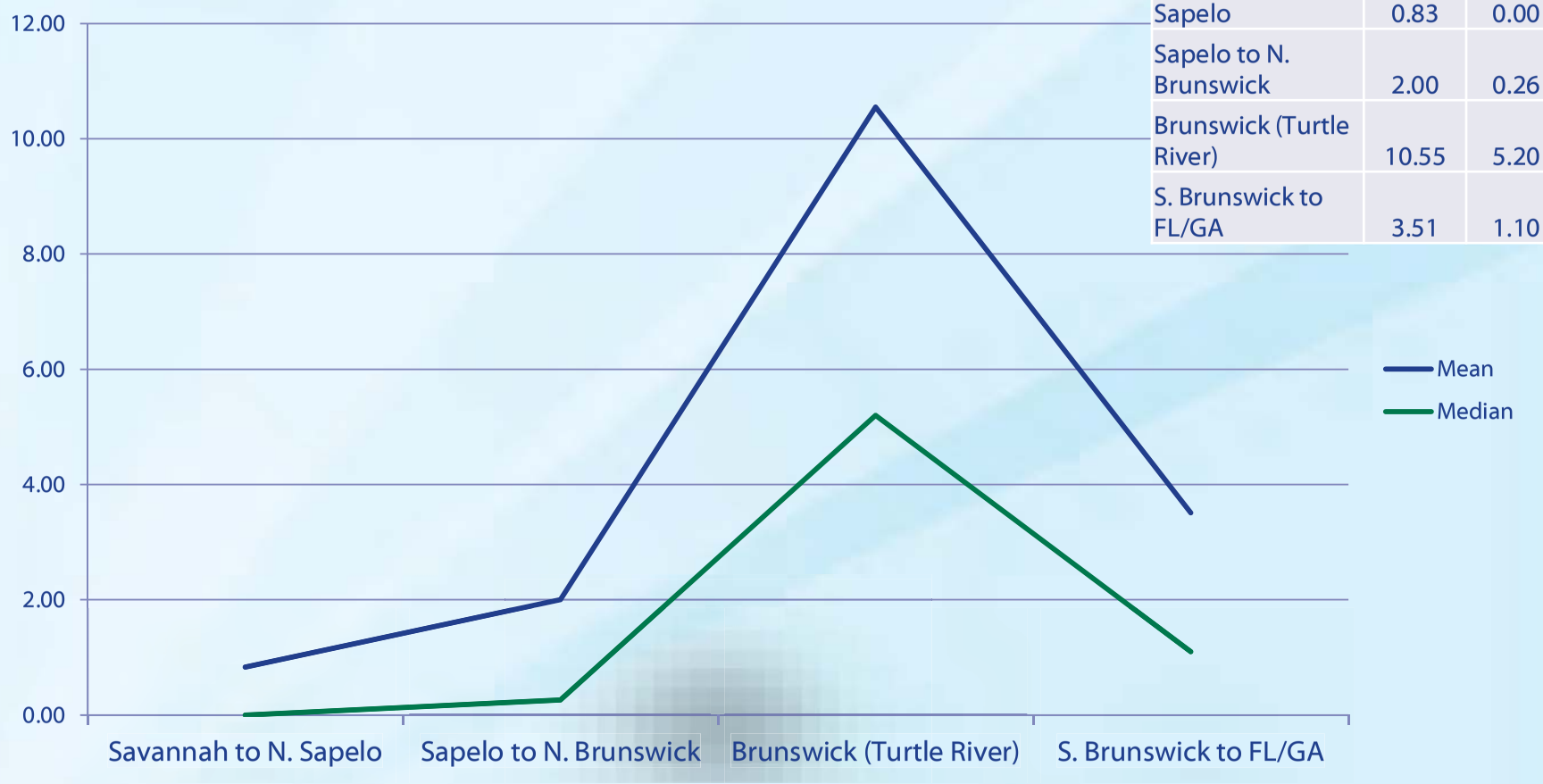


PCB 206
most abundant
congener in
Aroclor 1268


PCB 206 Sediment Sample Locations
Coastal Georgia
LCP Chemicals Site
St Simons Island
Jekyll Island
Brunswick River
Turtle River
Satilla River
Cumberland Island
St Marys River
GEORGIA
FLORIDA
Legend
Sediment PCB 206 (ppb)
ND
0.004 < 0.05
0.05 < 0.5
0.5 < 2.0
2.0 < 5.0
≥ 5.0
Data Sources
Samples w/ GPS coordinates - TOP HAT
Transportation Network - GDT 2008
LCP Chemical Spatial Data - Customer Provided
GRASP
Centers for Disease Control and Prevention
Agency for Toxic Substances and Disease Registry
Geospatial Research, Analysis & Services Program

Total PCB Sediment Levels in ppb

Location	Mean	Median
Savannah to N. Sapelo	0.83	0.00
Sapelo to N. Brunswick	2.00	0.26
Brunswick (Turtle River)	10.55	5.20
S. Brunswick to FL/GA	3.51	1.10



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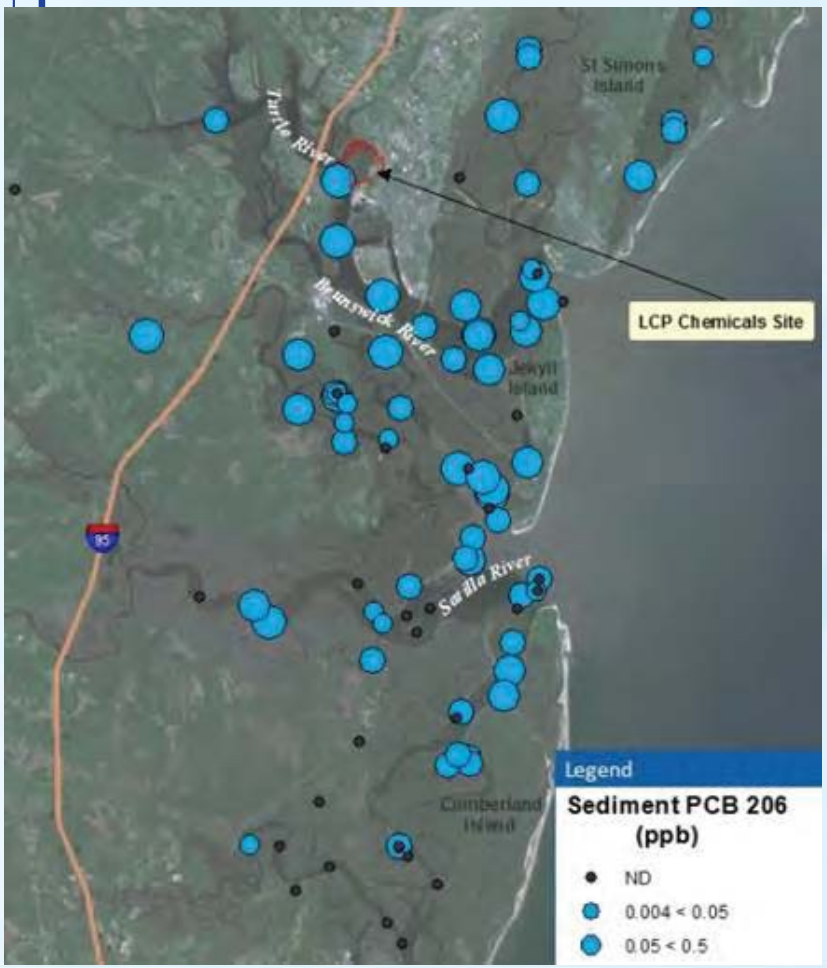
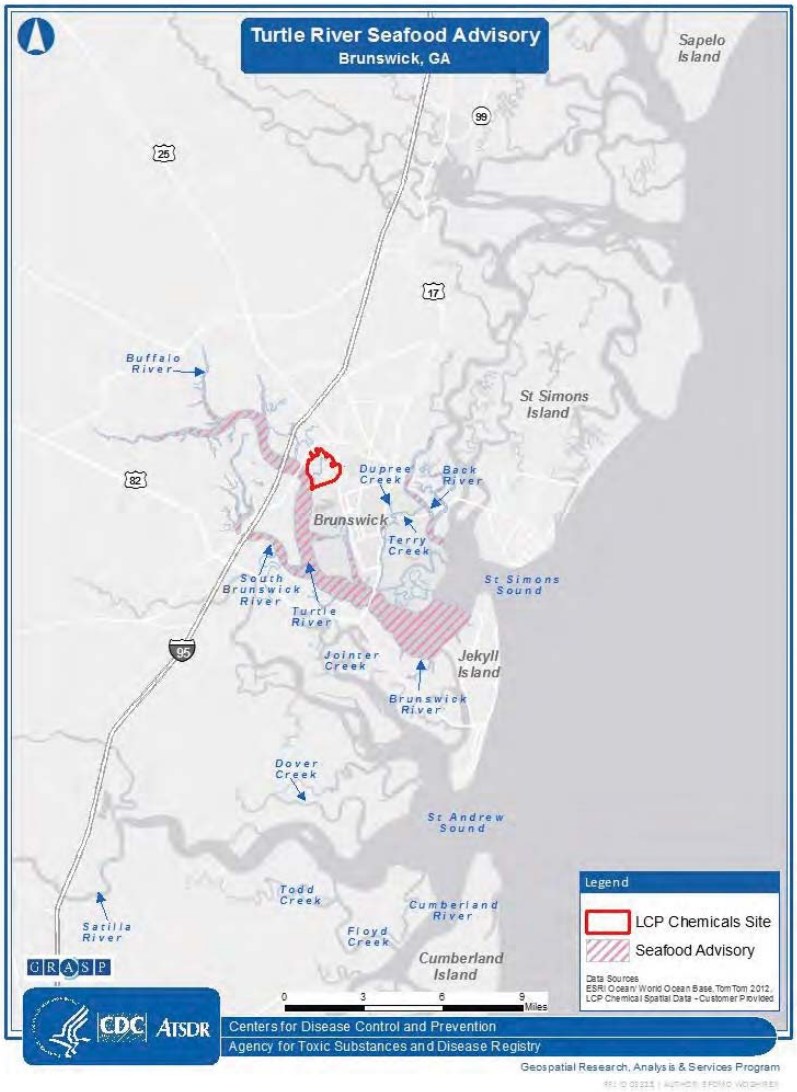
Turtle River Fish Advisory





Burnett Creek and Altamaha Canal

Recent Seafood Samples from the Turtle River system

Location and Date	Aroclor 1268 concentrations in mg/kg-wet weight (ppm-ww)				
	Red Drum	Mullet	Sea Trout	Blue Crab	Shrimp
Altamaha Canal* 2011	0.02	0.25	0.08	0.015	0.015
Burnett Creek 2012** Blackdrum 0.113 S. Kingfish 0.2 (Whiting)	0.035	NA	0.39	NA	NA

* Skin-on fillets; Source: ATSDR PHA for the LCP Chemicals Superfund Site, 2014

** Composite samples, skin-on fillets, except red drum (single sample): Source: ATSDR/GA DPH Health Consultation, Burnett Creek Fish Tissue, Brunswick Wood Preserving, Brunswick, GA

PCBs in Fish from the Turtle River System, 2002-2012

Location and Date	PCB concentrations in mg/kg-wet weight (ppm-ww)				
	Red Drum	Mullet	Sea Trout	Blue Crab	Shrimp
Altamaha Canal, 2011 (Aroclor 1268 only)	0.02	0.25	0.08	0.015	0.015
Burnett Creek, 2012 (Aroclor 1268 only)	0.035	NA	0.39	NA	NA
Lower Turtle River south of the site, 2002	0.11	0.36	NA	0.1	0.1
Upper Turtle River (north of LCP), 2002	0.25	1.4	NA	0.16	0.1
Middle Turtle River (adjacent to LCP), 2002	0.14	2.6	NA	0.02	0.23

Source: ATSDR Public Health Assessment for the LCP Chemicals Superfund Site, 2014

Comparison of Brunswick and Sapelo Island Seafood

Date and Location	Total PCB concentrations mg/kg-wet weight (ppm-ww)					
	Red Drum	Diff	Mullet	Diff	Sea Trout	Diff
2010 Sapelo Island*	0.007		0.004		0.0095	
2011 Altamaha Canal (Brunswick)	0.02	3	0.25	63	0.08	8
2012 Burnett Creek (Brunswick)	0.035	5	NA	NA	0.39	41
2002 Turtle River (Brunswick)	0.16	23	2.5	625	NA	NA

* Sapelo Island fish data collected by NCEH as part of their investigation at Sapelo Island

Environmental Contaminants in Coastal Populations

- **Purposes**
  - Conduct pilot studies
  - Compare results in people with what is known about dolphins
- **Method**
  - Targeted 3 coastal communities with offshore resident dolphins
    - Sapelo Island, Georgia; Biscayne Bay, Florida; Charleston Harbor, South Carolina
  - Inclusion criteria:
    - Have resided in the community for at least 5 years
    - Consume at least two meals of locally-caught seafood each week
  - Recruited 9 study participants in each community to:
    - Complete questionnaire unique to each community
    - Provide blood samples and seafood for analysis
      - PCBs, PFOAs, PBDEs, heavy metals, and chlorinated pesticides

Sapelo Island Study Results

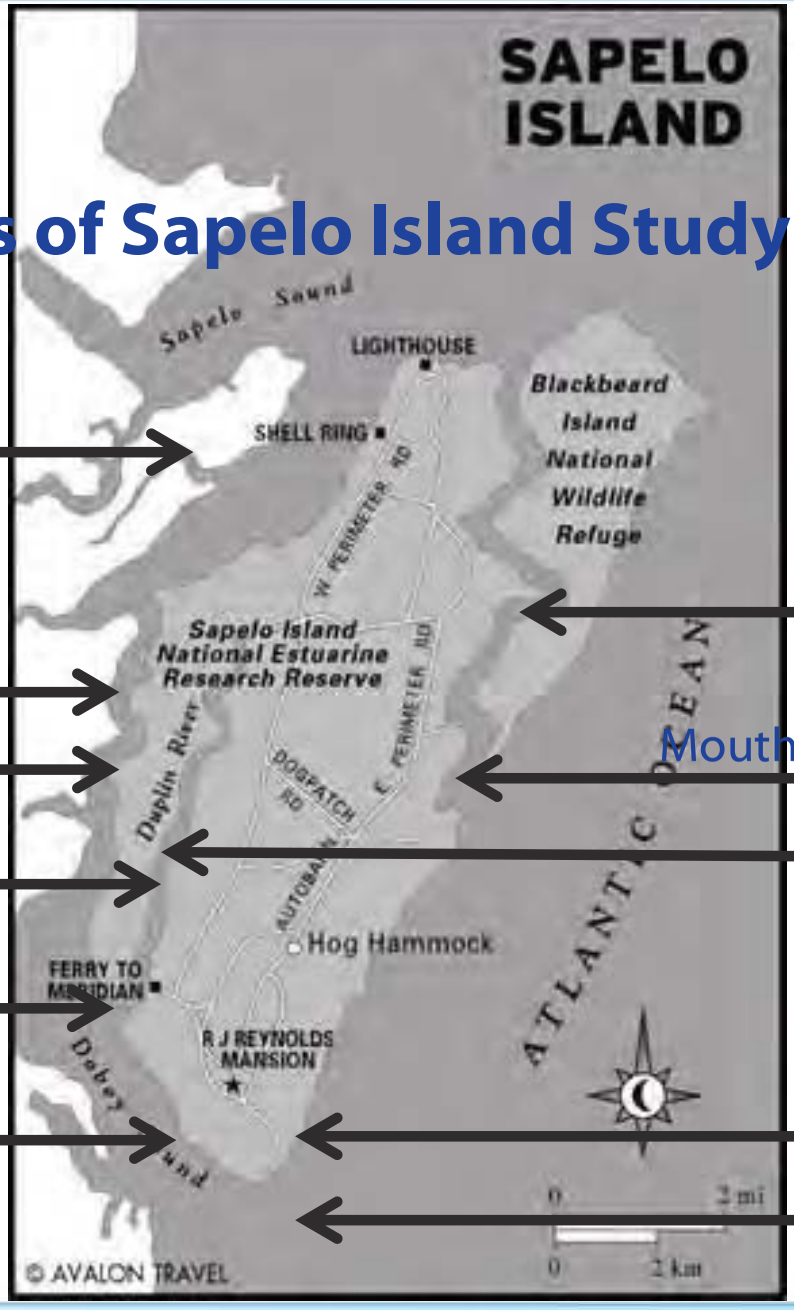
- **The discussion will be limited to our findings regarding PCBs**

Demographics of Sapelo Island Study Participants

Characteristic	Median (range)
Age (years)	51 (21-74)

Characteristic	Number (percent)
Race	
Black	6 (67 %)
White	3 (33 %)
Sex	
Female	1(11%)
Male	8 (89 %)
Residence	
On Sapelo Island	8 (89 %)
On mainland across estuary	1 (11%)

Fishing Areas of Sapelo Island Study Participants



Mud River (2)

Little Moses Hammock (1)

Lumber Landing (3)

Community Landing (3)

Marsh Landing (4)

Lighthouse (3)

Raccoon Bluff (2)

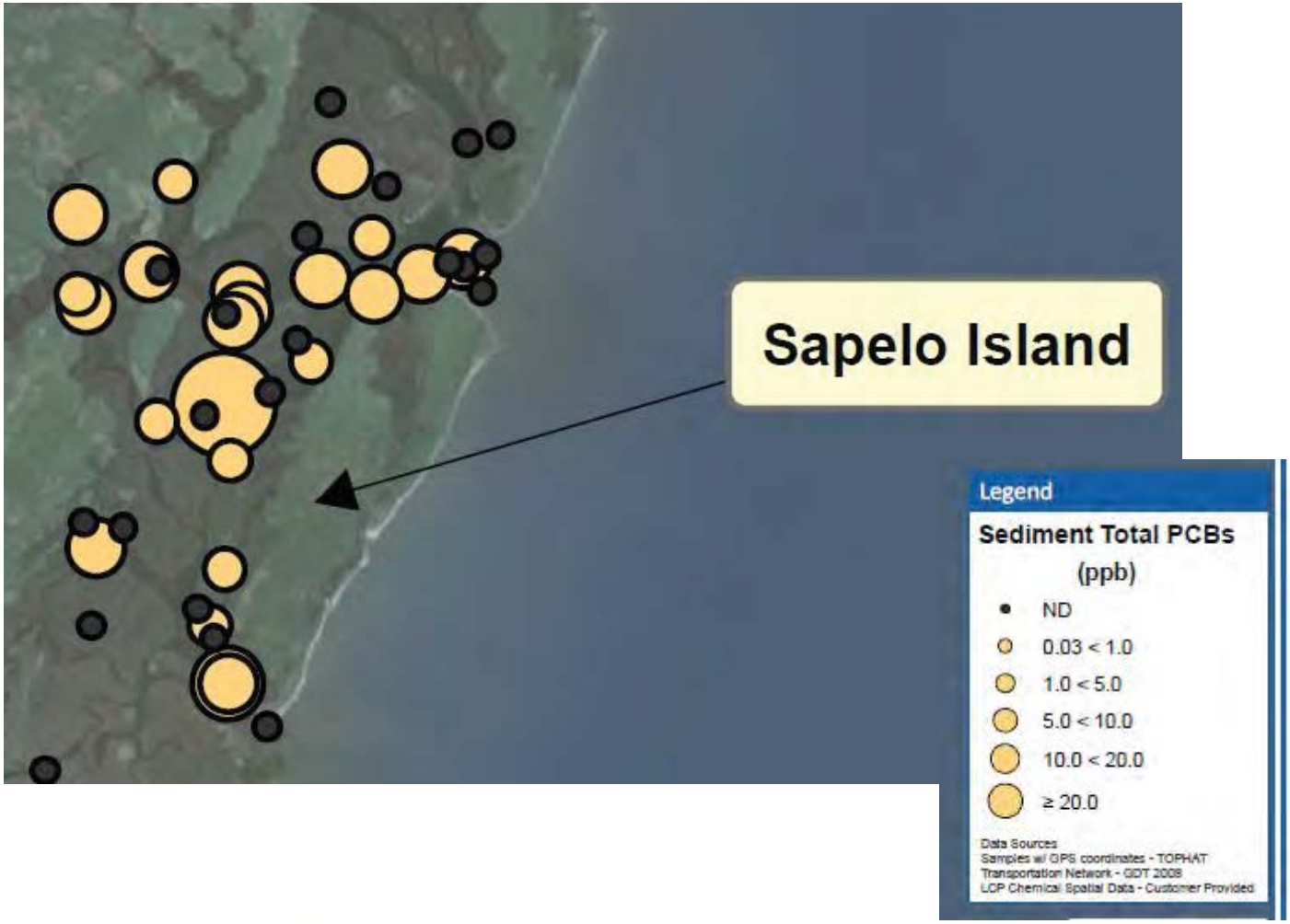
Mouth of Blackbeard Creek (1)

Duplin River (2)

Nanny Goat Beach (2)

Southeastern Coast (2)

Sapelo Island
Total PCBs in Sediment



Local Seafood Consumption by Sapelo Island Study Participants

Characteristic	Number
Eats 2-3 meals of locally-caught seafood/week	9 (100 %)
Has eaten locally-caught seafood for > 5 years	9 (100 %)
Eats seafood meals of: 6 oz 9 oz	 5 (56 %) 4 (44 %)
Eats seafood meals of*: Filet with skin removed Filet with skin on Whole fish (gutted) Whole fish (not gutted) Fish eggs * Responses not mutually exclusive	 1 (11 %) 3 (33 %) 5 (56 %) 1 (11 %) 4 (44 %)

Species of Fish Eaten by Sapelo Island Study Participants

Species	Number of People
Red drum	1 (11 %)
Catfish	1 (11 %)
Shark	1 (11 %)
Brim/spot	2 (22 %)
Flounder	2 (22 %)
Sheepshead	3 (33 %)
Croaker	6 (67%)
Mullet	6 (67 %)
Spotted sea trout	7 (78 %)
Spot-tailed bass/red fish	9 (100 %)
Whiting	9 (100 %)

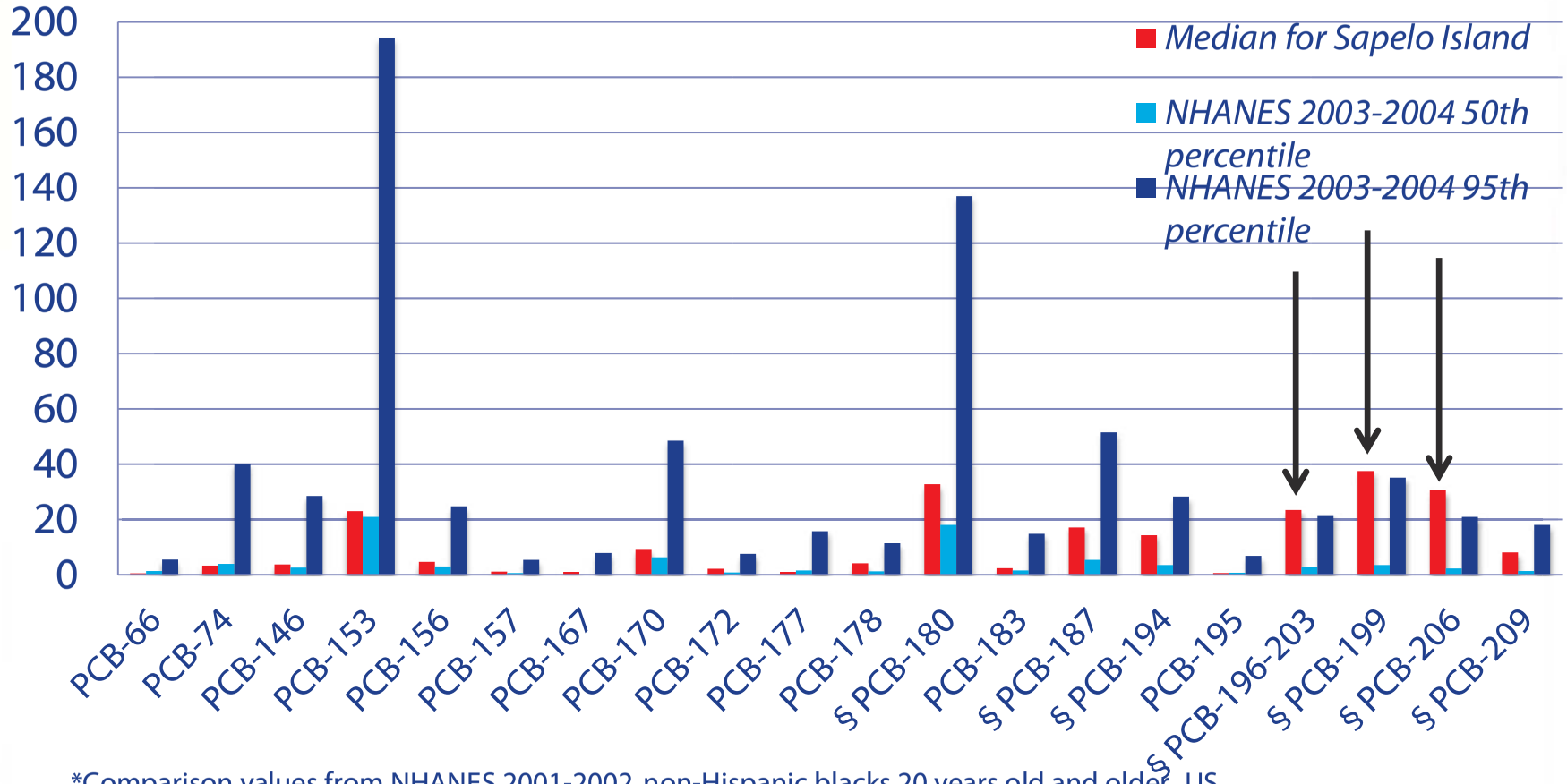
Local Meat Consumption by Sapelo Island Study Participants

Animal	Number
Venison	1 (11 %)
Duck	1 (11 %)
Raccoon	2 (22 %)

Knowledge of Fish Advisories in Sapelo Island Study Participants

Characteristic	Number of People
Aware of Georgia fish advisories?	
Yes	5 (56%)
No	4 (44 %)
Since you became aware of the advisories, did you change your habits of catching or eating seafood? (N = 5)	
Yes	2 (40 %)
No	3 (60 %)

PCB concentrations (ng/g lipid) for those PCBs tested in both Sapelo Island participants' blood specimens (medians) and NHANES 2001-2002, Non-Hispanic Blacks* (50th and 95th percentiles, matched on age group)



*Comparison values from NHANES 2001-2002, non-Hispanic blacks 20 years old and older. US Department of Health and Human Services. 2005. Third National Report on Human Exposure to Environmental Chemicals. July.

Study Limitations

- **The pilot study sample size was small (n =9).**
- **We analyzed legacy chemicals**
  - They accumulate in tissues over time
  - Cannot determine when exposure occurred
- **However, we did find that human and dolphin specimens contain qualitatively similar environmental contaminants (dolphin data not shown).**

Conclusions

- Aroclor 1268 appears to be widespread around Brunswick, GA.
- Based on sediment and fish samples, contamination from LCP Chemicals Superfund Sites may have migrated along the Georgia coast.
- The current fishing advisory for the Turtle River system may not adequately cover other contaminated rivers and creeks around Brunswick, GA.
- Residents of Sapelo Island have been exposed to specific PCB also found at the LCP site.

Now that we know more about the extent of PCB contamination along the Georgia coast, what should we do next?

- More fish sampling?
- More sediment sampling?
- Extend the fish advisory area?

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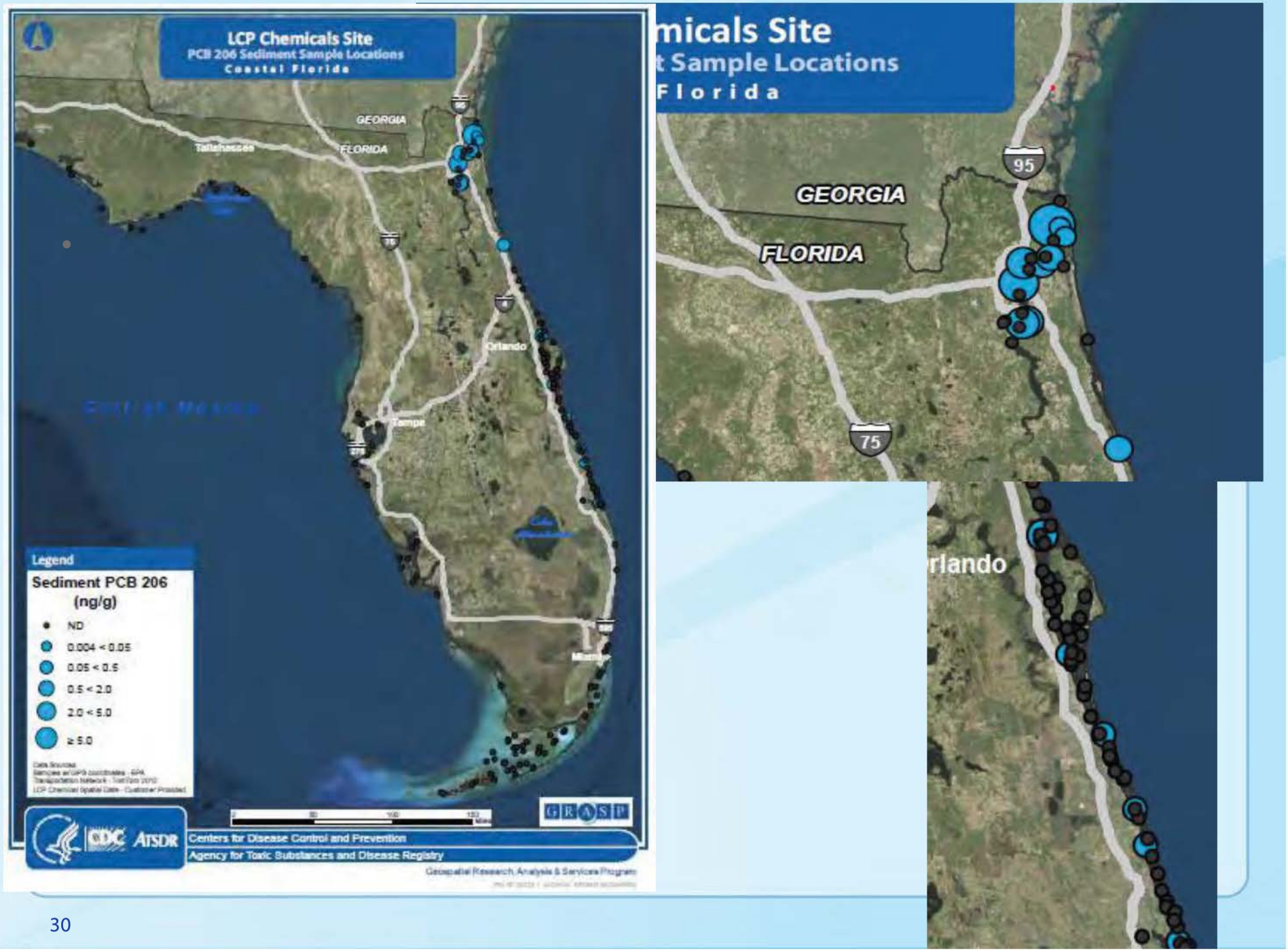
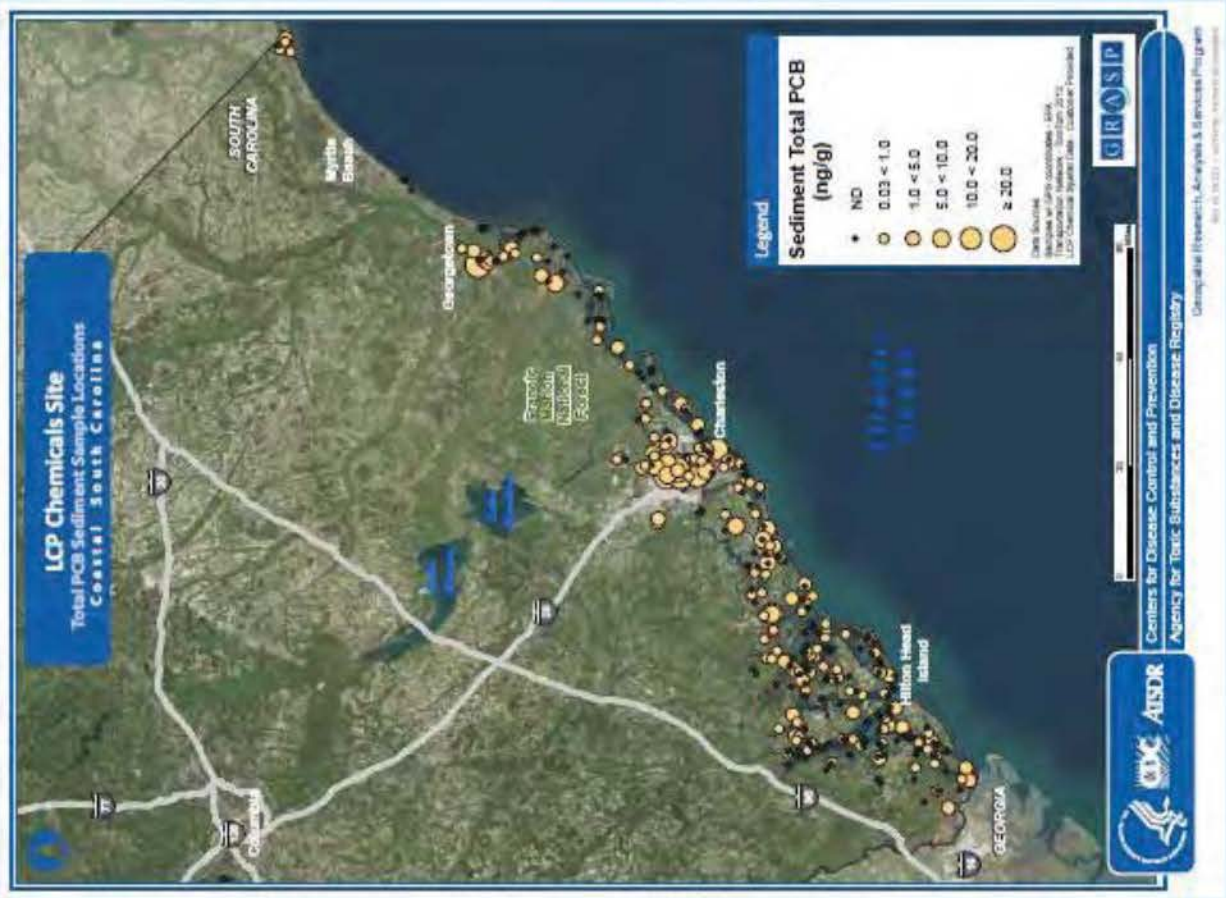
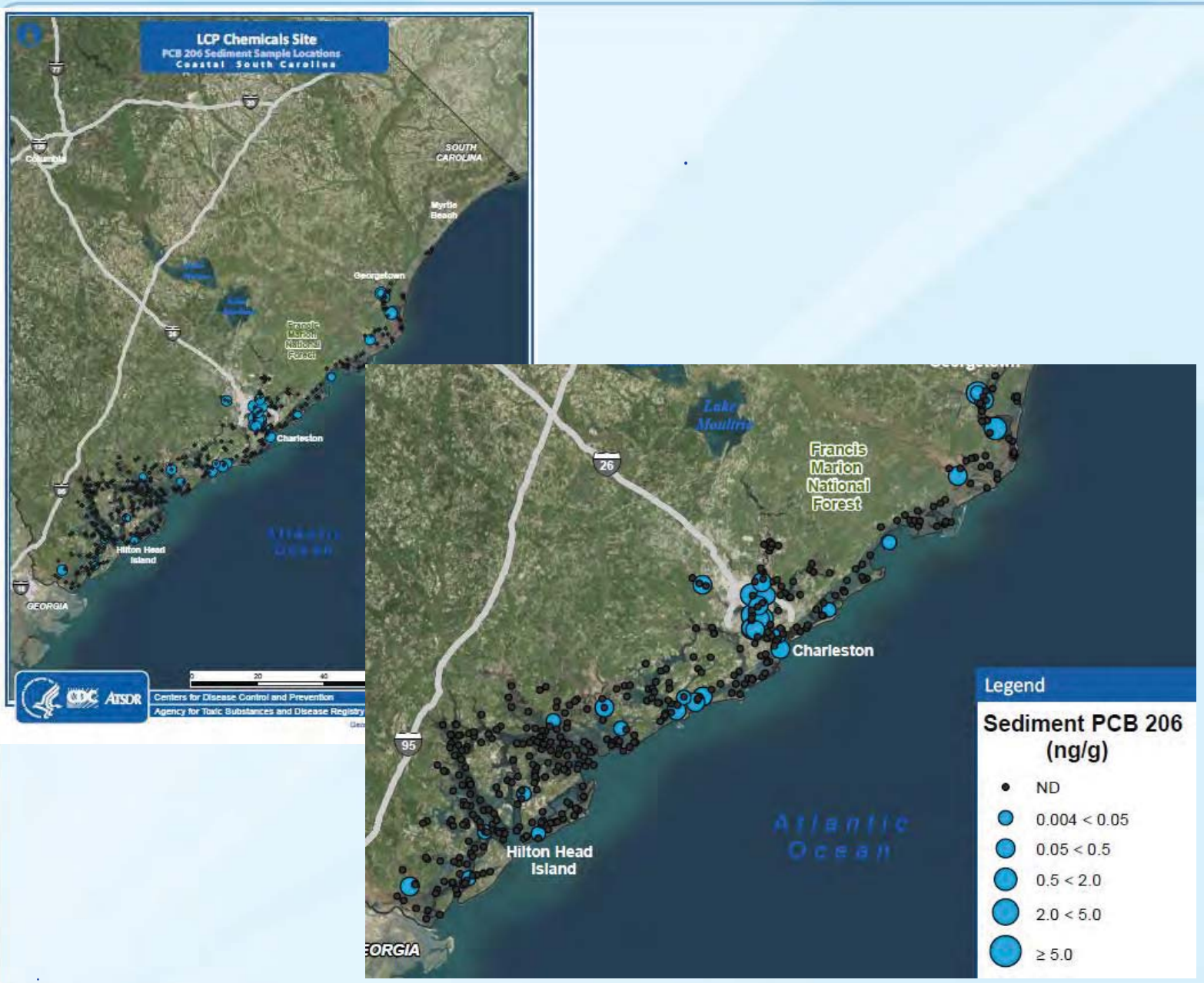
Extra Slides

(to be used to answer questions)

- **PCBs along Florida and South Carolina Coast**




LCP Chemicals Site
Total PCB Sediment Sample Locations
Coastal South Carolina
Legend
Sediment Total PCB (ng/g)
ND
0.03 < 1.0
1.0 < 5.0
5.0 < 10.0
10.0 < 20.0
≥ 20.0
SOUTH CAROLINA
Myrtle Beach
Georgetown
Charleston
Hilton Head Island
GEORGIA
Columbia
GRASP
ATSDR
Centers for Disease Control and Prevention
Agency for Toxic Substances and Disease Registry




LCP Chemicals Site
PCB 206 Sediment Sample Locations
Coastal Georgia and Florida
LCP Chemicals Site
Legend
Sediment PCB 206 (ng/g)
ND
0.004 < 0.05
0.05 < 0.5
0.5 < 2.0
2.0 < 5.0
≥ 5.0
Brunswick
Fernandina Beach
Jacksonville
St Johns
GEORGIA
FLORIDA
ATLANTIC OCEAN
Centers for Disease Control and Prevention
Agency for Toxic Substances and Disease Registry
Geospatial Research, Analysis & Services Program

Aroclor 1268
PCB Congener Non-Cancer Toxicity

PCB-180[a]	BMI	Highest BMI with intermediate exposures (quartile 2)
PCB-187[a]	HDL cholesterol levels	Lowest levels with intermediate exposures (quartile 2)
PCB 196–203	Diabetes incidence	Highest risk in groups with intermediate exposures (quartile 2)
PCB-196	Endometriosis	Decreased risk in groups with intermediate exposures (quartile 3)

Source: Vandenberg LN, Colborn L, Hayes TB et al. 2012. Hormones and endocrine-disrupting chemicals: Low-dose effects and nonmonotonic dose responses. Endocrine Reviews 33(3);378-455.

United States Government Accountability Office

GAO

Report to Congressional Requesters

January 2005

HAZARDOUS WASTE SITES

Improved Effectiveness of Controls at Sites Could Better Protect the Public

GAO-05-163

January 2005

GAO Accountability·Integrity·Reliability

Highlights

Highlights of GAO-05-163, a report to congressional requesters

HAZARDOUS WASTE SITES

Improved Effectiveness of Controls at Sites Could Better Protect the Public

Why GAO Did This Study

The Environmental Protection Agency's (EPA) Superfund and Resource Conservation and Recovery Act (RCRA) programs were established to clean up hazardous waste sites. Because some sites cannot be cleaned up to allow unrestricted use, institutional controls—legal or administrative restrictions on land or resource use to protect against exposure to the residual contamination—are placed on them. GAO was asked to review the extent to which (1) institutional controls are used at Superfund and RCRA sites and (2) EPA ensures that these controls are implemented, monitored, and enforced. GAO also reviewed EPA's challenges in implementing control tracking systems. To address these issues, GAO examined the use, implementation, monitoring, and enforcement of controls at a sample of 268 sites.

What GAO Recommends

To ensure the long-term effectiveness of institutional controls, GAO recommends that EPA (1) clarify its guidance on when controls should be used; (2) demonstrate that, in selecting controls, sufficient consideration was given to all key factors; (3) ensure that the frequency and scope of monitoring efforts are sufficient to maintain the effectiveness of controls; and (4) ensure that the information on controls reported in new tracking systems accurately reflects actual conditions. EPA generally agreed with GAO's recommendations.

www.gao.gov/cgi-bin/getrpt?GAO-05-163.

To view the full product, including the scope and methodology, click on the link above. For more information, contact John Stephenson at (202) 512-3841 or stephensonj@gao.gov.

What GAO Found

Institutional controls were applied at most of the Superfund and RCRA sites GAO examined where waste was left in place after cleanup, but documentation of remedy decisions often did not discuss key factors called for in EPA's guidance. For example, while documents usually discussed the controls' objectives, in many cases, they did not adequately address when the controls should be implemented, how long they would be needed, or who would be responsible for monitoring or enforcing them. According to EPA, the documents' incomplete discussion of the key factors suggests that site managers may not have given them adequate consideration. Relying on institutional controls as a major component of a site's remedy without carefully considering all of the key factors—particularly whether they can be implemented in a reliable and enforceable manner—could jeopardize the effectiveness of the remedy.

EPA faces challenges in ensuring that institutional controls are adequately implemented, monitored, and enforced. Institutional controls at the Superfund sites GAO reviewed, for example, were often not implemented before the cleanup was completed, as EPA requires. EPA officials indicated that this may have occurred because, over time, site managers may have inadvertently overlooked the need to implement the controls. EPA's monitoring of Superfund sites where cleanup has been completed but residual contamination remains often does not include verification that institutional controls are in place. Moreover, the RCRA corrective action program does not include a requirement to monitor sites after cleanups have been completed. In addition, EPA may have difficulties ensuring that the terms of institutional controls can be enforced at some Superfund and RCRA sites: that is, some controls are informational in nature and do not legally limit or restrict use of the property, and, in some cases, state laws may limit the options available to enforce institutional controls.

To improve its ability to ensure the long-term effectiveness of institutional controls, EPA has recently begun implementing institutional control tracking systems for its Superfund and RCRA corrective action programs. The agency, however, faces significant obstacles in implementing such systems. The institutional control tracking systems being implemented track only minimal information on the institutional controls. Moreover, as currently configured, the systems do not include information on long-term monitoring or enforcement of the controls. In addition, the tracking systems include data essentially derived from file reviews, which may or may not reflect institutional controls as actually implemented. While EPA has plans to improve the data quality for the Superfund tracking system—ensuring that the data accurately reflects institutional controls as implemented and adding information on monitoring and enforcement—the first step, data verification, could take 5 years to complete. Regarding the RCRA tracking system, the agency has no current plans to verify the accuracy of the data or expand on the data being tracked.

Contents

Abbreviations

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
EPA	Environmental Protection Agency
GPRA	Government Performance and Results Act of 1993
ICTS	Institutional Controls Tracking System
NPL	National Priorities List
RCRA	Resource Conservation and Recovery Act
ROD	record of decision

United States Government Accountability Office#
Washington, D.C. 20548

January 28, 2005

The Honorable James M. Jeffords#
Ranking Minority Member#
Committee on Environment and Public Works#
United States Senate

The Honorable Barbara Boxer#
Ranking Minority Member#
Subcommittee on Superfund, Toxics, Risk and Waste Management#
Committee on Environment and Public Works#
United States Senate

The Honorable Lincoln D. Chafee #
United States Senate

The Environmental Protection Agency (EPA) estimates that one in four Americans lives within 4 miles of a hazardous waste site. To protect the public's health, the Congress passed the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, which established the Superfund program to clean up the most seriously contaminated of these sites. In addition, in 1984, the Congress amended the Resource Conservation and Recovery Act (RCRA) to add a corrective action program to clean up contamination at facilities that treat, store, and dispose of hazardous waste.[1] Since the inception of these two programs, EPA has overseen the cleanup of over 5,000 hazardous waste sites across the country. At many of these sites, however, EPA has selected cleanup remedies that leave at least some waste in place because the agency believes it is impossible, impractical, or too costly to clean up the contaminated property so that it can be used without restriction. Cleanups at such sites often rely on institutional controls—legal or administrative restrictions on the use of land or water at the site—to limit the public's exposure to residual contamination. As of December 2004, about 1,600 hazardous waste sites were being cleaned up by the Superfund program and another 3,800 facilities were being cleaned up by the RCRA corrective action program.

[1]The Congress enacted RCRA in 1976 to establish a framework for managing hazardous waste from its generation to final disposal.

States play a significant role in the cleanup of hazardous waste sites under both the Superfund and RCRA programs. Within the Superfund program, states may enter into agreements with EPA to perform certain program actions, such as initial site assessments, and EPA also consults with states throughout the cleanup process. Under the RCRA program, EPA has authorized 40 states and Guam to implement and enforce their own hazardous waste regulations in lieu of federal regulations and to carry out corrective action activities. However, regardless of whether a particular state is authorized, either the state or EPA may assume the lead on working with a facility to implement corrective action. In addition, at certain Superfund and RCRA sites, state and local government entities may be responsible for monitoring the status of institutional controls and enforcing their terms.

The cleanup process for the Superfund and RCRA programs is similar in many ways. For both programs, the process begins with a preliminary investigation to determine the extent of the contamination at a site. In this initial phase, under Superfund, EPA places the most seriously contaminated sites on its National Priorities List (NPL).[2] In both programs, cleanup officials typically analyze a range of alternatives before selecting a remedy to address a site's contamination. In the Superfund program, the remedy is described in a record of decision (ROD); in the RCRA program, it is usually described in a "statement of basis." Once the remedy is selected, remedy implementation under both programs typically involves a number of phases, including remedy design, construction, operation and maintenance, and completion. Under Superfund, when EPA, in consultation with the relevant state, determines that no further remedial activities at a site are appropriate, EPA deletes the site from the NPL. When remedial measures are completed for a RCRA facility, the corrective action process for that facility is terminated.

[2]In this report, we use the term "Superfund program" to refer to long-term remedial actions carried out at sites on the NPL. EPA also carries out removal actions under Superfund, which are generally shorter term cleanups designed to address more immediate threats to health and the environment.

Institutional controls can be a critical component of the cleanup process and may be used to ensure short-term protection of human health and the environment during the cleanup process itself as well as long-term protection once the site is deleted from the NPL or corrective action is terminated. EPA defines institutional controls as "non-engineered instruments such as administrative and/or legal controls that minimize the potential for human exposure to contamination by limiting land or resource use." In September 2000 and December 2002, EPA issued guidance setting out, among other things, the key factors to be considered when evaluating and selecting institutional controls at Superfund and RCRA sites and responsibilities for implementing, monitoring, and enforcing institutional controls at these sites.[3] Under this guidance, EPA generally—although not always—requires that institutional controls be put in place at Superfund and RCRA sites where total cleanup is not practical or feasible. If deemed necessary, these controls may be combined with engineering controls—such as capping or fencing—to limit exposure to residual site contamination. For example, the remedy selected for a hazardous waste landfill may include engineering controls, such as placing a protective layer, or "cap" made of clay or synthetic materials, over the contamination. At such sites, EPA may also add institutional controls to prohibit any digging that might breach this protective layer and expose site contaminants.

Concerned that institutional controls may not be effectively protecting human health and the environment, you asked us to review (1) the extent to which institutional controls are used at sites addressed by EPA's Superfund and RCRA corrective action programs; (2) the extent to which EPA ensures that institutional controls at these sites are implemented, monitored, and enforced; and (3) EPA's challenges in implementing systems to track these controls. To address these issues, we examined EPA's use, implementation, monitoring, and enforcement of institutional controls at a nonprobability sample of nonfederal sites where (1) the cleanup process was completed in earlier periods, for historical perspective; (2) the cleanup process had ended more recently; and (3) the remedy had only recently been selected, for insight into the likely future use of these controls. (Results from nonprobability samples cannot be used to make inferences about a population, because in a nonprobability sample

[3]The December 2002 guidance was issued in draft form for public comment. It had not been finalized as of September 2004 because, according to an EPA official, the agency received and must respond to a large number of comments on the draft document.

some elements of the population being studied have no chance or an unknown chance of being selected as part of the sample.) Our review focused on institutional controls that remain in place after site deletion or termination to determine whether these controls are effective in the long run. Although both the Superfund and RCRA programs address federal and nonfederal sites, our review did not address federal sites because federal agencies are generally responsible for cleaning up their own sites and EPA involvement is limited. We also focused our reviews of RCRA facilities on those whose cleanup was led by EPA.

To gain a broader view of past use of institutional controls, we reviewed files for all 20 Superfund sites deleted from the NPL during fiscal years 1991 through 1993; in addition, in the two EPA regions[4] with the most corrective actions, we reviewed files for all 40 RCRA facilities at which, according to EPA's database, a preliminary investigation was conducted and corrective action was terminated before fiscal year 2001. Regarding sites where the cleanup was recently completed, we examined documentation related to institutional controls at all 53 Superfund sites deleted from the NPL during fiscal years 2001 through 2003 and at all 31 RCRA facilities where corrective action was terminated during the same period. For those sites whose documentation indicated the use, or potential use, of institutional controls, we conducted follow-up interviews with EPA or state officials knowledgeable about the site to obtain detailed information and additional documentation and to determine what institutional controls were actually in place.

To gain a sense of the projected use of institutional controls in the future, we examined all 112 Superfund RODs finalized during fiscal years 2001 through 2003, and statements of basis for all 23 RCRA corrective action facilities that reached the remedy decision stage during that period. For our review, we examined only the principal remedy decision documents for the sites in our universe, rather than all remedy decision documents. We also interviewed RCRA program managers from a sample of 6 states to understand the extent to which those states implement, monitor, and enforce institutional controls. In addition, we visited 5 Superfund sites with residual contamination and institutional controls remaining in place after the site was deleted from the NPL. To identify the challenges of implementing a system to track institutional controls, we interviewed EPA and state officials. A more detailed description of our scope and

[4]Region III in Philadelphia and Region V in Chicago.

methodology is presented in appendix I. We conducted our work from October 2003 to January 2005 in accordance with generally accepted government auditing standards, including an assessment of data reliability and internal controls.

Results in Brief

Institutional controls were used at most of the Superfund and RCRA sites we examined where cleanup was completed and waste was left in place. In reviewing selected Superfund and RCRA sites in three different time periods or stages of cleanup for comparison, we found an increase in the use of institutional controls over time. We found that one-half of the Superfund sites we reviewed where cleanup was completed during fiscal years 1991 through 1993 and three-quarters of the RCRA facilities we reviewed where cleanup was completed before fiscal year 2001 with residual waste remaining did not have institutional controls in place. In contrast, we found that institutional controls were in place at almost all (28 of 32) of the Superfund sites and all 4 RCRA sites we reviewed that were cleaned up during fiscal years 2001 through 2003 and had waste remaining. EPA's guidance states that it generally requires that institutional controls be placed on sites that cannot accommodate unrestricted use and unlimited exposure; however, because the agency's guidance does not specify when controls are necessary, it is unclear whether any of the sites we reviewed that had residual waste but no institutional controls were inconsistent with this guidance. When considering remedy decisions issued during fiscal years 2001 through 2003 for sites that have not yet been cleaned up, we found that 93 of the 112 Superfund and 15 of the 23 RCRA remedy decision documents we reviewed called for some type of institutional control. However, while EPA's guidance advises that four key factors be taken into account in selecting controls for a site, 69 of the 108 remedy decision documents we examined did not demonstrate that all of these factors were sufficiently considered to ensure that planned controls will be adequately implemented, monitored, and enforced. In this regard, the documents generally discussed two of these factors—the objective and mechanisms of the institutional controls—but the language was often vague. In many cases, the documents did not adequately address the two remaining factors—the timing or duration of implementation and the party responsible for monitoring and enforcing the controls. According to EPA, discussion in the ROD may be intentionally vague because key decisions on issues such as who may implement the remedy and institutional controls have not yet been made. Relying on institutional controls as a major component of a selected remedy without carefully considering all of the applicable factors—including whether they can be implemented in a

reliable and enforceable manner—could jeopardize the effectiveness of the site remedy.

EPA faces challenges in ensuring that institutional controls are adequately implemented, monitored, and enforced. Although EPA has taken a number of steps to improve the management of institutional controls in recent years, we found that controls at the Superfund sites we reviewed were often not implemented before site deletion, as EPA requires. In some cases, institutional controls were implemented after site deletion while, in other cases, controls were not implemented at all. An EPA program official believed that these deviations from EPA's guidance may have occurred because, during the sometimes lengthy period between the completion of the cleanup and site deletion, site managers may have inadvertently overlooked the need to implement the institutional controls. Moreover, in terms of monitoring, while EPA reviews Superfund sites where contamination was left in place every 5 years to ensure that the remedy is still protective, EPA officials acknowledged that such site reviews may be too infrequent to ensure the continued effectiveness of the institutional controls. For example, at 1 Superfund site we examined, an institutional control prohibiting any use of groundwater without prior written approval from EPA had been violated for at least a year before it was discovered during an EPA 5-year review. In addition, while parties other than EPA, such as state or local governments or site owners, are sometimes required to monitor a Superfund site more frequently than every 5 years, this monitoring does not always include a review of the site's compliance with institutional controls or verifying that the controls are still in place—and sometimes is not performed at all. In contrast to the Superfund program, the RCRA corrective action program does not include any general requirement to monitor institutional controls at terminated corrective action sites. Some states monitor institutional controls at RCRA sites independent of any EPA requirement; however, because not all states are required to or, in fact, do monitor institutional controls at RCRA sites, EPA has no assurance that such controls remain protective. Finally, EPA acknowledges that it may have difficulties ensuring that the terms of institutional controls can be enforced at some Superfund and RCRA sites for two reasons. First, some institutional control mechanisms selected for sites—such as deed notices and advisories to the public—are informational in nature and do not legally limit or restrict use of the property. Second, local and state laws may limit the options available to enforce institutional controls. For example, some states' laws do not allow enforceable institutional controls, such as covenants, to be placed on a property.

EPA faces significant obstacles in implementing institutional control tracking systems for its Superfund and RCRA corrective action programs. The agency recently began implementing such systems to improve its ability to ensure the long-term effectiveness of institutional controls. Such controls are often key components of selected cleanup remedies that need to be implemented, monitored, enforced, and kept in place as long as the danger of exposure to residual contamination remains. Because residual contamination can remain at a site long after EPA involvement is completed and an entity other than EPA assumes responsibility for long-term monitoring and enforcement of the controls, effective oversight requires that EPA be able to readily identify which sites have institutional controls in place and whether the controls are being monitored and enforced. However, historically, EPA has had no system in place to allow the agency to make these determinations. Although EPA recently has begun implementing such systems, they currently track only minimal information on the institutional controls—as currently configured, they do not include information on long-term monitoring or enforcement of the controls. In addition, initial reports of tracking system data show that there may be potential problems with the systems' implementation. For example, because RCRA program officials asked EPA regions and states to identify and report on only those facilities with institutional controls, the program has no way of determining the extent to which the data are complete. In addition, the tracking systems include data essentially derived from remedy decision documents, which reflect plans for the use of institutional controls, rather than the actual presence of these controls.

To help EPA site managers and other decision makers better understand when institutional controls are or are not necessary at sites where contamination remains in place after cleanup, we are recommending that EPA clarify its institutional controls guidance. Furthermore, to better ensure the long-term protectiveness of institutional controls, we recommend that EPA ensure that adequate consideration is given to the controls' objectives; the types of controls to be used; the timing of their implementation and their duration; and the party who will be responsible for implementing, monitoring, and enforcing them. We also are recommending that EPA take steps to ensure that the frequency and scope of monitoring at deleted Superfund sites and closed RCRA facilities where contamination has been left in place are sufficient to maintain the protectiveness of any institutional controls at these sites. In addition, we recommend that EPA ensure that the information on institutional controls reported in the Superfund and RCRA corrective action tracking systems

accurately reflects whether controls have actually been implemented at the site, rather than what is called for in site remedy decision documents.

Background

Land use and institutional controls are usually linked, and should be considered together during the investigation phase of cleanup, according to EPA guidance. As a site moves through the early stages of the cleanup process, site managers should develop assumptions about reasonably anticipated future land uses and consider whether institutional controls will be needed to maintain these uses over time. EPA guidance states that, if remediation leaves waste in place that would not permit "unrestricted use" of the site and "unlimited exposure" to residual contamination, use of institutional controls should be considered to ensure protection against unacceptable exposure to the contamination left in place. Even sites that are appropriate for residential use after the cleanup process is complete may require institutional controls if they do not allow for unlimited use and unrestricted exposure. For example, residential properties may be located over a contaminated groundwater plume where the properties are not the source of contamination. In such a situation, well drilling restrictions put in place to limit the use of groundwater may serve as appropriate institutional controls.

EPA recognizes four types of institutional controls—governmental controls, proprietary controls, enforcement and permit tools with institutional control components, and informational devices:

- Governmental controls use the regulatory authority of a government entity to impose restrictions. Generally, EPA must depend on state or local governments to establish these controls. Examples of governmental controls include zoning restrictions, local ordinances, and groundwater use restrictions.

- Proprietary controls involve legal instruments placed in the chain of title of the site or property, such as easements and covenants.

- Enforcement and permit tools with institutional control components are issued or negotiated to compel the site owner to limit certain site activities. These controls, which can be enforced by EPA under Superfund and RCRA legislation, include administrative orders and consent decrees.

- Informational devices warn the public of risks associated with using contaminated property. Examples of informational devices are deed notices, state registries of hazardous waste sites, and health advisories.

Approximately 3,800 RCRA facilities have corrective action under way or will require corrective action. EPA refers to these facilities as its "corrective action workload." Under the Government Performance and Results Act of 1993 (GPRA), which requires agencies to assess progress toward achieving the results expected from their major functions, EPA developed short-term goals for 1,714 of these facilities, referred to as the "GPRA baseline." According to EPA's GPRA goals, by 2005, EPA and the states will verify and document that 95 percent of the baseline facilities have "current human exposures under control" and 70 percent have "migration of contaminated groundwater under control."

According to EPA, over the last 10 years, the agency has focused increased attention on understanding and overcoming the complexities and challenges associated with using institutional controls. In recent years, this experience has led EPA to improve its approach to these controls. For example, the agency has hosted numerous meetings and workshops to identify institutional control issues and develop solutions; developed and administered national training programs for federal, state, tribal, and local agencies; developed a national strategy to help ensure that controls are successfully implemented; and established a national management advisory group to work on high-priority policy issues. Furthermore, in addition to issuing guidance in 2000 on evaluating and selecting institutional controls, the agency is currently developing four additional guidance documents covering specific implementation, monitoring, and enforcement issues. These improvements have been targeted at the full life-cycle of institutional controls from identification, evaluation, and selection to implementation, monitoring, and enforcement.

EPA Relied on Controls at Most Sites with Residual Contamination, but Planning of Controls May Not Ensure Protection of the Public

In reviewing selected Superfund and RCRA sites in three different time periods or stages of cleanup, we found an apparent increase in the use of institutional controls over time. Two of the 4 older Superfund sites and 6 of the 8 older RCRA facilities we reviewed where cleanup was completed but residual contamination remained had no institutional controls in place.[5] In contrast, of the 32 Superfund and 4 RCRA sites we reviewed where cleanup was completed during fiscal years 2001 through 2003 but residual contamination remained,[6] 28 and 4, respectively, had one or more institutional controls in place. However, because EPA's guidance is vague and does not specify in which cases controls are necessary, it is unclear whether any of the sites we reviewed were inconsistent with the agency's policy. When considering recent remedy decisions in both programs, we found that, of the 112 Superfund and 23 RCRA remedy decision document sets we reviewed that were issued during fiscal years 2001 through 2003, most documents called for some type of institutional control to prevent or limit exposure to residual contamination. Moreover, although EPA guidance directs staff to include four specific factors in documenting the institutional controls to be implemented at a site, the documents we reviewed frequently included no more than two of these factors, and the language was often vague.

Use of Institutional Controls at Superfund Sites and RCRA Facilities Appears to Be Increasing over Time

In reviewing selected Superfund and RCRA sites in three different time periods or stages of cleanup, we found an apparent increase in the use of institutional controls over time. The proportion of Superfund sites with institutional controls in place increased from 10 percent for those deleted during fiscal years 1991 through 1993 to 53 percent for those deleted during fiscal years 2001 through 2003. The proportion of RCRA facilities with institutional controls in place increased from 5 percent for those sites we examined where corrective action was terminated prior to fiscal year 2001 to 13 percent for those sites where corrective action was terminated during fiscal years 2001 through 2003. Moreover, 83 percent of the Superfund and 65 percent of the RCRA remedy decision documents finalized during fiscal

[5]Sites we reviewed for historical perspective included Superfund sites deleted from the NPL during fiscal years 1991 through 1993 and RCRA facilities from two regions where corrective action was terminated prior to fiscal year 2001. See appendix I for more information about the specific facilities included in our review.

[6]These sites include Superfund sites that were deleted from the NPL and RCRA facilities where corrective action was terminated within the given time period.

years 2001 through 2003 indicated the need for some sort of institutional controls, an increase over the proportion of completed sites with controls. (See tables 1 and 2.)

Table 1: Frequency of Use of or Requirements for Institutional Controls at Superfund Sites

Time periods or stages of cleanup	Percentage of sites with controls
Requirements for controls in 112 Superfund remedy decision documents, fiscal years 2001-2003	83%
Controls in place at 53 Superfund deleted sites, fiscal years 2001-2003	53
Controls in place at 20 Superfund deleted sites, fiscal years 1991-1993	10

Source: GAO analysis of EPA data.

Table 2: Frequency of Use of or Requirements for Institutional Controls at RCRA Facilities

Time periods or stages of cleanup	Percentage of sites with controls
Requirements for controls in 23 RCRA remedy decision documents, fiscal years 2001-2003	65%
Controls in place at 31 RCRA terminated facilities, fiscal years 2001-2003	13
Controls in place at 40 RCRA terminated facilities from 2 regions, corrective action terminated prior to fiscal year 2001	5

Source: GAO analysis of EPA data.

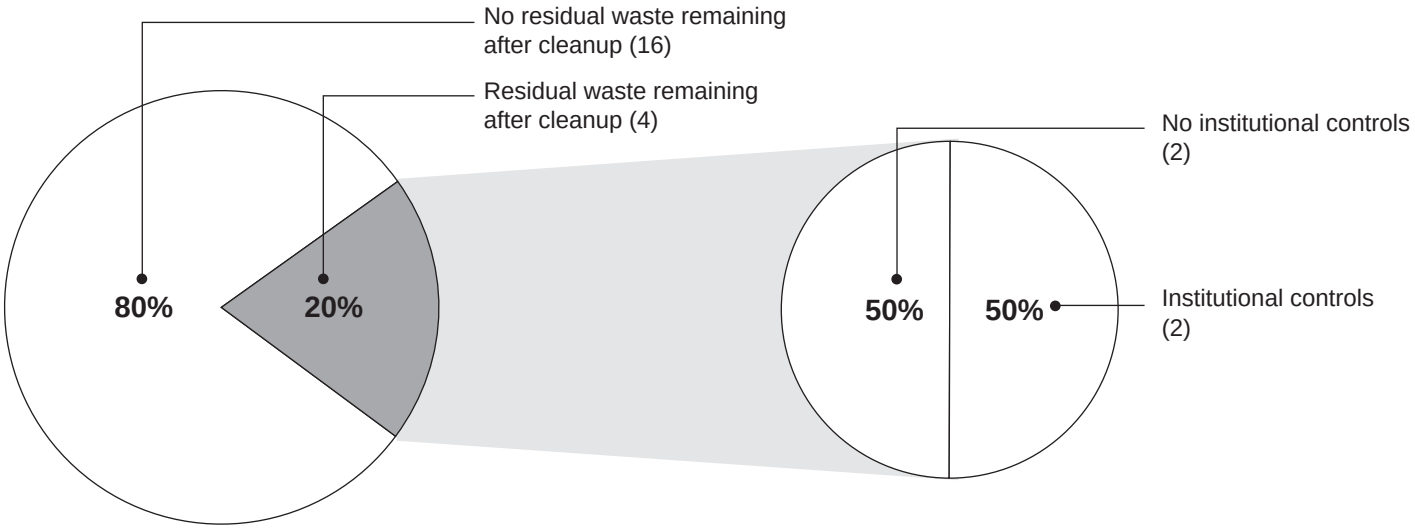
While EPA recognizes that the use of institutional controls is becoming increasingly common, the agency points out that this should not be interpreted to mean that sites are being less thoroughly cleaned up. The EPA project manager for 1 Superfund site deleted with residual contamination and no institutional controls told us that if the site were being remediated today, EPA might consider institutional controls to restrict groundwater use. In addition, EPA is now considering institutional controls for a site that was cleaned up to a level allowing for unrestricted use and unlimited exposure at the time of remediation. The levels of acceptable lead contamination have decreased since completion of this

remedy, so the levels of contamination at the site may now exceed the new standards.

Earlier Completed Sites

Four of the 12 older Superfund and RCRA sites we reviewed where residual contamination remained had institutional controls in place.[7] Waste was left in place after cleanup at 4 of the 20 Superfund sites that were deleted during fiscal years 1991 through 1993; as figure 1 shows, one-half of these sites had institutional controls in place.

Figure 1: Presence of Residual Waste and Institutional Controls at 20 Superfund Sites Deleted during Fiscal Years 1991-1993

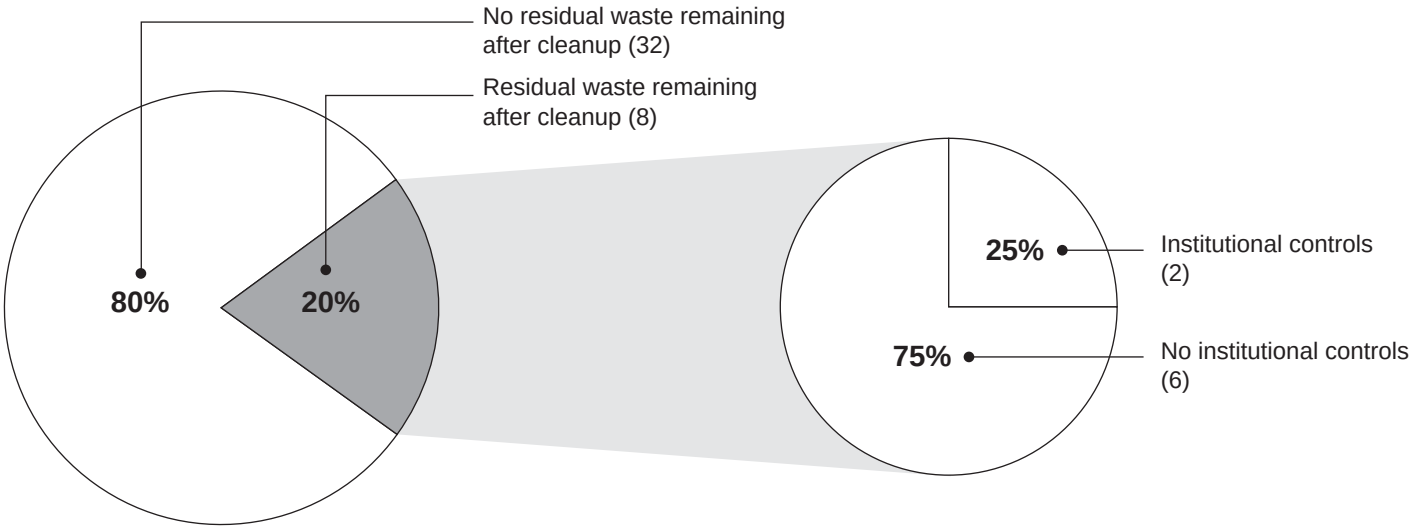


Source: GAO analysis of EPA data.

[7]These sites include Superfund sites deleted from the NPL during fiscal years 1991 through 1993 and RCRA facilities from two regions where corrective action was terminated prior to fiscal year 2001. RCRA facilities reviewed, those where corrective action was terminated both prior to fiscal year 2001 and during fiscal years 2001 through 2003, included those coded in the RCRAInfo database to indicate the termination of corrective action. However, EPA regions differed in their use of this code since it related to facilities with or without institutional controls, and EPA staff raised concerns about whether the code was used consistently over time within some regions. See appendix I for more information about the specific facilities included in our review.

Similarly, of the 40 RCRA facilities we reviewed where corrective action was terminated before fiscal year 2001, 8 had residual waste after cleanup; institutional controls appeared to be in place at 2 of these facilities (see fig. 2).

Figure 2: Presence of Residual Waste and Institutional Controls at 40 RCRA Facilities in Two Regions Where Corrective Action Was Terminated before Fiscal Year 2001



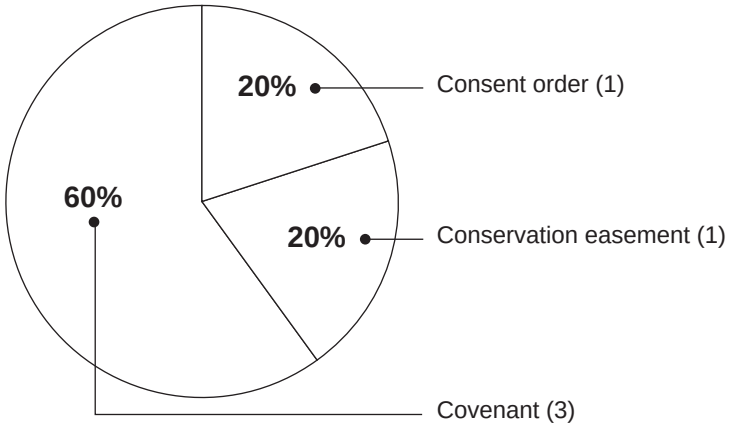
Source: GAO analysis of EPA data.

The most common type of institutional control in place at these older Superfund and RCRA sites was a covenant; there was also a consent order and a conservation easement, as shown in figure 3.[8] A covenant, as used in the institutional controls context, is a promise by a landowner to use or refrain from using the property in a certain manner. A consent order contains elements of both an administrative order (an order issued and enforced by EPA or states directly restricting the use of property) and a consent decree (in this context, a court order that implements the settlement of an enforcement case, which may restrict the use of the land

[8]In some cases where the types of controls were not clear, we categorized them on the basis of our evaluation of documents.

by the settling party, such as prohibiting well drilling).[9] A conservation easement, allowed by statutes adopted by some states, is established to preserve and protect property and natural resources. EPA guidance encourages the use of multiple controls—referred to as "layering"—stating that it is more effective than using only one institutional control.[10] Controls were layered at only 1 of these 4 older sites.

Figure 3: Proportions of Types of Institutional Controls at 4 Superfund and RCRA Sites Cleaned Up before Fiscal Year 2001



Source: GAO analysis of EPA data.

Note: In some cases, our attorneys made determinations based on evaluations of documents in order to categorize institutional controls.

Recently Completed Sites

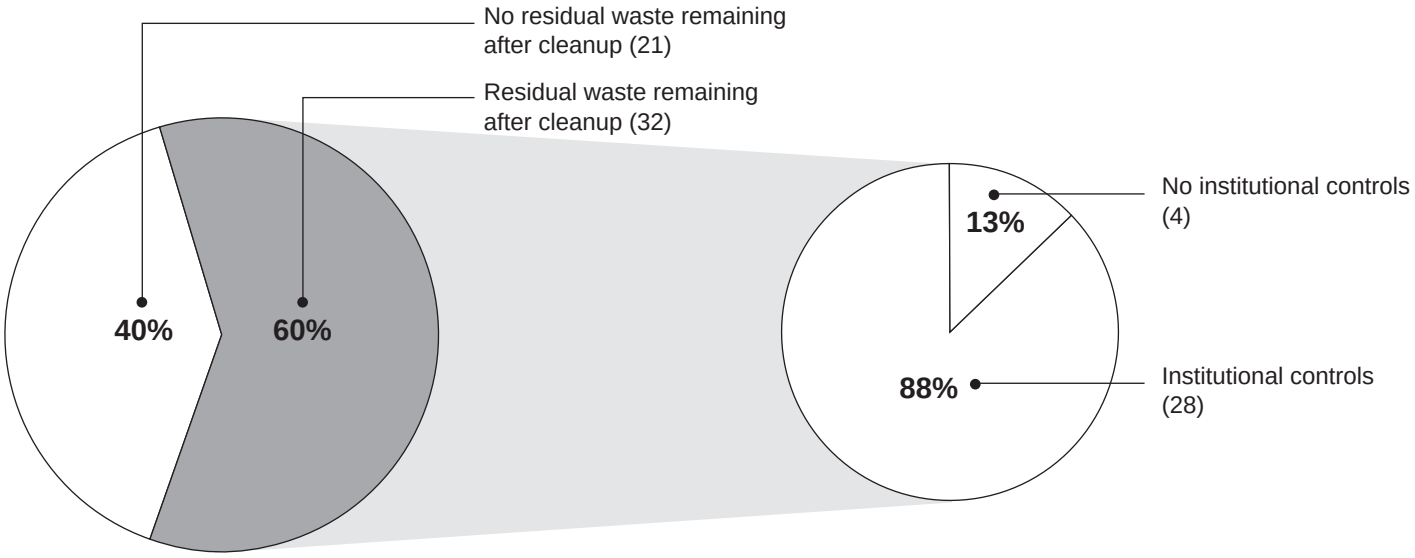
In contrast to sites where cleanup was completed in earlier years, 32 of the 36 Superfund and RCRA sites we reviewed where residual contamination remained after cleanup had one or more institutional controls in place. At

[9]Consent decrees have attributes both of contracts and judicial decrees. While they are arrived at by negotiations between the parties, they are motivated by threatened or pending litigation and must be approved by the court.

[10]EPA, *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups* (EPA 540-F-00-005, September 2000). This fact sheet is intended to provide an overview of the types of institutional controls that are commonly available and discusses key factors to consider when evaluating and selecting institutional controls in Superfund and RCRA corrective action cleanups.

most of the 53 Superfund sites deleted from the NPL during fiscal years 2001 through 2003, institutional controls were implemented if waste was left in place (see fig. 4). Furthermore, future controls were being considered at 2 of the sites where institutional controls were not originally planned.

Figure 4: Presence of Residual Waste and Institutional Controls at 53 Superfund Sites Deleted during Fiscal Years 2001-2003

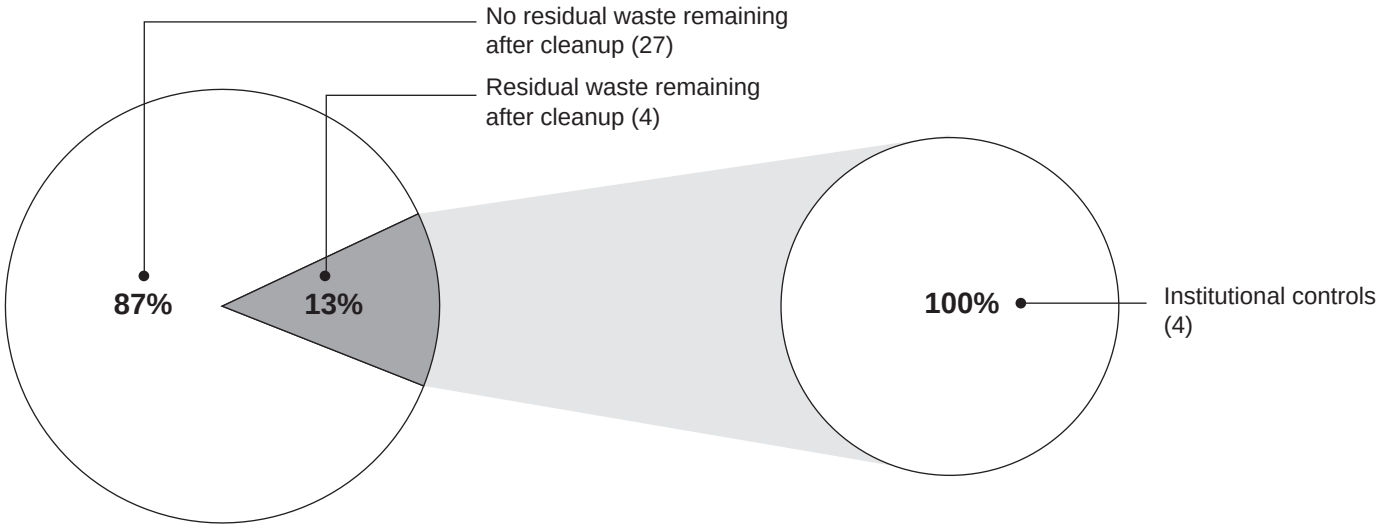


Source: GAO analysis of EPA data.

Note: Percentages presented in this figure do not add up due to rounding.

Of the 31 RCRA facilities we reviewed where corrective action was terminated during fiscal years 2001 through 2003, most corrective actions did not result in waste being left in place and, therefore, the facilities likely did not require institutional controls. As figure 5 shows, only 4 facilities had waste remaining, and all of these had institutional controls in place.

Figure 5: Presence of Residual Waste and Institutional Controls at 31 RCRA Facilities Where Corrective Action Was Terminated during Fiscal Years 2001-2003

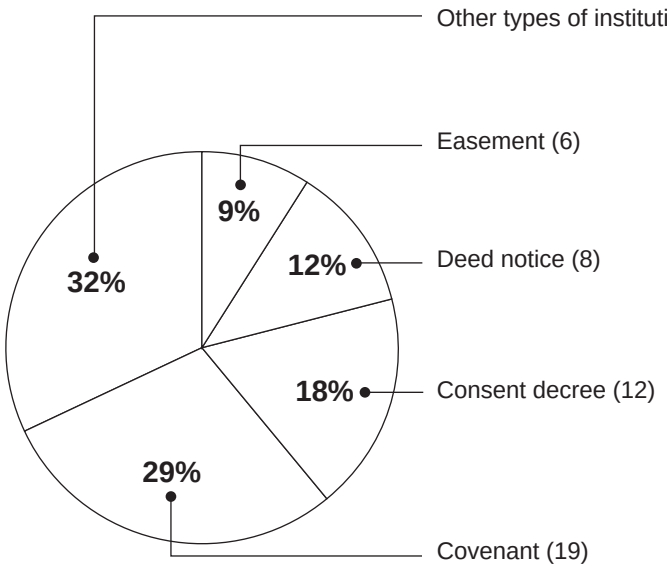


Source: GAO analysis of EPA data.

The most common types of institutional controls in place at these Superfund and RCRA sites were covenants and consent decrees, followed by deed notices and easements (see fig. 6).[11] Deed notices are informational documents filed in public land records, and these notices alert anyone searching the records to important information about the property. Easements are property rights conveyed by landowners to other parties, giving them rights with regard to the owner's land. Of the 28 Superfund sites with institutional controls, 17 included multiple controls, or layering, as encouraged by EPA guidance. One of the 4 RCRA facilities had multiple institutional controls. In total, there were 66 controls in place at the 32 sites.

[11]In addition, there were a number of other types of institutional controls on the sites we reviewed. Some of the sites had governmental controls, including zoning restrictions (ordinances exercised by local governments to specify land use for certain areas) and groundwater management zones. Some were listed on state registries, which are established by state legislatures and include information about properties, such as a list of hazardous waste sites in the state. There were also miscellaneous institutional controls on some sites, including an intergovernmental/corporate cooperative agreement, a tribal ordinance, and groundwater use restrictions.

Figure 6: Proportions of Types of Institutional Controls at 28 Superfund Sites and 4 RCRA Facilities Where Cleanup Was Completed during Fiscal Years 2001-2003



Source: GAO analysis of EPA data.

Note: In some cases, our attorneys made determinations based on evaluations of documents in order to categorize institutional controls. Some documents included aspects of more than one type of institutional control.

[a]"Other types of institutional controls" includes ordinances, groundwater use restrictions, consent orders, state registries, administrative orders, zoning, a conservation easement, and a state use restriction.

For both recently completed and older sites we reviewed, 6 of 36 Superfund sites and 6 of 12 RCRA sites with waste remaining did not have institutional controls in place.[12] EPA site managers told us that the potentially responsible parties or property owners of several sites we reviewed had agreed to file a proprietary or informational control, such as a covenant or deed notice, to limit the use of the contaminated land or water.[13] However, following our request for documents, EPA staff discovered that the controls had not been implemented. EPA is now working to implement institutional controls for some of these sites to ensure the protection of human health and the environment. Finally, at several sites we reviewed where contamination was left in place, the remedy decision documents did not call for institutional controls. Some of these sites were delegated to states for monitoring and possible future action. For example, in one case, groundwater contamination was contained as long as wells at a nearby plant continued to operate—the wells, which pump approximately 10 million gallons a day, provide protection by capturing contaminants from a former landfill on site before they migrate into the off-site groundwater. EPA asked the state to assume responsibility for monitoring the continued operation of the wells and to conduct an examination of groundwater contamination if well operation ceased.

Finally, deleting Superfund sites and terminating corrective action at RCRA facilities where waste remains without implementing institutional controls may be contrary to EPA guidance. Guidance issued in 2000 states that an institutional control is generally required if the site cannot accommodate unrestricted use and unlimited exposure. However, the guidance does not specify under what circumstances controls are necessary. Instead, it uses language like "generally required" and "likely appropriate." Four of the sites deleted during fiscal years 2001 to 2003, after the guidance was issued, had residual contamination but no institutional controls in place. However, because EPA's guidance is vague and does not specify in which cases controls are necessary, it is unclear whether any of the sites we reviewed

[12]One additional site was cleaned up to levels that allowed for unrestricted use and unlimited exposure at the time of remediation; however, the levels of lead contamination that are considered acceptable have decreased since completion of the remedy, so the levels of contamination at the site may now exceed the new standards.

[13]To ensure, as much as possible, that those responsible for the contamination at a site clean up or pay for the cleanup, EPA's Superfund program identifies the companies or people responsible for the contamination and enters into negotiations with them. EPA refers to these companies or people as "potentially responsible parties."

were inconsistent with the agency's policy. EPA's institutional controls project manager believed that some of these deviations from EPA's guidance may have occurred because, during the period between the completion of the cleanup and site deletion, site managers may have inadvertently overlooked the need to implement the institutional controls.

Recent Remedy Decisions

In reviewing files for 135 Superfund and RCRA remedy decisions that were issued during fiscal years 2001 through 2003, we found that most of the documents we reviewed called for some type of institutional control to prevent or limit exposure to residual contamination.[14] As previously mentioned, we reviewed the principal remedy decision documents issued during this time period; however, other remedy decision documents may also include information about institutional controls. Of the 112 Superfund remedy decisions, 85 called for institutional controls. In 8 additional cases, remedy decision documents called for institutional controls under certain circumstances but not others. For example, one Superfund remedy decision document outlined the need for institutional controls if excavated contaminated soil were to be disposed of on-site, rather than at another facility. Finally, some of the Superfund documents we examined were interim remedy decision documents; while some of those documents did not call for institutional controls, future documents may include provisions for such controls if waste is left on-site after remedy construction is completed. Of the 23 RCRA remedy decisions issued between fiscal years 2001 and 2003, 15 called for institutional controls.[15]

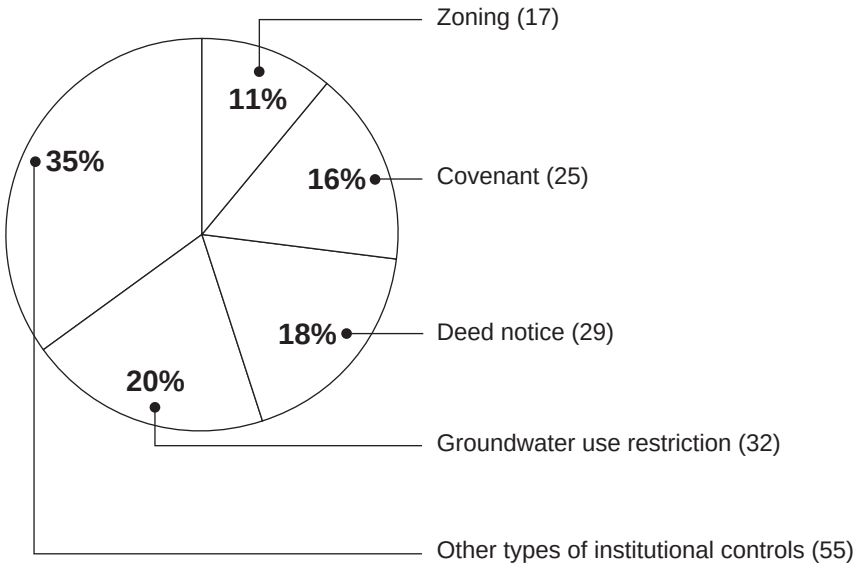
Many remedy decision documents did not identify the specific institutional control mechanism, or type of control, to be used. Of the 93 sets of Superfund remedy decision documents we examined that called for institutional controls under all or certain circumstances, 81 discussed the mechanism to some degree. Almost all of the 15 sets of RCRA remedy decision documents we examined that called for institutional controls discussed the mechanism to a certain extent. However, in both sets of documents, these discussions were often vague, gave a list of options, or

[14]Because sites with recent remedy decisions are still undergoing cleanup, we could not determine which sites had residual contamination, or which sites would have institutional controls. Therefore, we do not provide figures showing these groupings, as we do in the figures for completed sites.

[15]For 3 of the facilities, the documentation provided indicated the presence of or called for institutional controls, but did not indicate whether these controls were required by remedy decision documents.

discussed mechanisms for one planned control but not another (e.g., a document only specified an institutional control mechanism for restricting the use of groundwater and did not specify a control for contaminated soil). For those documents that discussed specific institutional controls—including those that listed options rather than a selected control or controls—deed notices and groundwater use restrictions, followed by covenants and zoning, were most commonly mentioned, as shown in figure 7. Twelve of the documents were vague in describing a mechanism, and, in 13 cases, the documents did not mention a mechanism at all.

Figure 7: Proportions of Types of Institutional Controls Mentioned in 81 Sets of Superfund and 14 Sets of RCRA Remedy Decision Documents Issued during Fiscal Years 2001-2003



Source: GAO analysis of EPA data.

Note: In some cases, we made determinations based on EPA language in remedy decision documents in order to determine the type of planned institutional control. Some controls mentioned in remedy decision documents appeared to include aspects of more than one type of institutional control.

Remedy Decision Documents Often Do Not Demonstrate Sufficient Planning of Controls to Determine the Adequacy of Public and Environmental Protection

Thorough planning is critical to ensuring that institutional controls are implemented, monitored, and enforced properly. EPA guidance specifies that staff should evaluate institutional controls in the same level of detail as other remedy components. Furthermore, it advises staff to make several determinations regarding a number of key factors (see table 3) and to describe them in the remedy decision documents.

Table 3: Provisions in EPA s Guidance Relating to Determinations on Institutional Controls

Factor	Guidance provisions	Sample language
Objective	Managers should clearly state what will be accomplished through the use of institutional controls where contamination remains on the site.	General: Protect human health and the environment. Specific: Restrict the use of groundwater as a drinking water source until the Maximum Contaminant Levels are met.
Mechanism	Managers should determine the specific types of institutional controls that can be used to meet the various remedial objectives.	EPA will work with the local jurisdiction to develop ordinances to restrict well drilling or prohibit groundwater access until cleanup goals are met.
Timing	Managers should investigate when the institutional control needs to be implemented and how long it needs to remain in place.	General: A deed notice may be required in the short term, and a formal petition for a zoning change may be necessary in the long term. Specific: The institutional control should be filed before the Remedial Action is final.
Responsibility	Managers should discuss and document any agreement with the proper entities on exactly who will be responsible for implementing, monitoring, and enforcing the control or outline potential parties.	Work with the state to determine whether it is willing and able to hold an enforceable easement to ensure appropriate land use; in addition, determine whether the local government is willing to change and enforce the applicable zoning requirements.

Source: EPA guidance, September 2000.

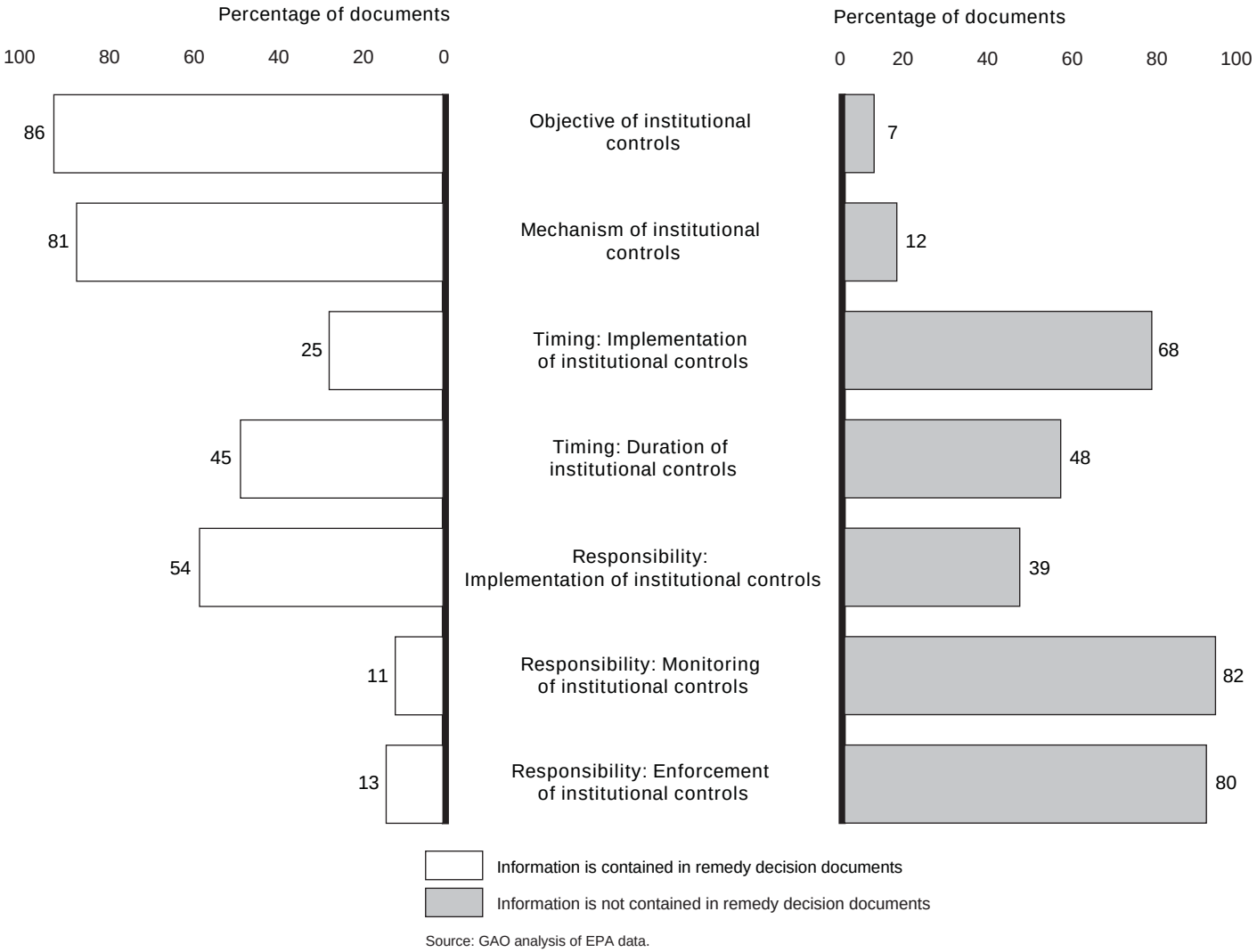
As EPA's draft guidance on institutional controls[16] points out, without specific information on the institutional controls—such as their objectives; the mechanisms (or kinds of controls) envisioned; the timing of their

[16]EPA draft guidance, *Institutional Controls: A Guide to Implementing, Monitoring, and Enforcing Institutional Controls at Superfund, Brownfields, Federal Facility, UST and RCRA Corrective Action Cleanups* (December 2002). This is the second in a series of guidance documents on the use of institutional controls. According to an EPA official, although the draft was issued in December 2002, it had not yet been finalized as of December 2004 due to the large number of comments that EPA received.

implementation and duration; and who will be responsible for implementing, monitoring, and enforcing them—the site manager and site attorney may be unable to interpret the intent of the remedy selection document. For example, managers currently responsible for some sites we reviewed were not involved with the remedial investigation or preparation of the ROD for the sites and, therefore, may not fully understand what types of controls were envisioned when the document was written. In addition, without specific information on the proposed institutional controls for a site, the public may not fully understand the restrictions on site use necessary to prevent exposure to residual contamination. Vague language may also result in creating unintended rights and/or obligations.

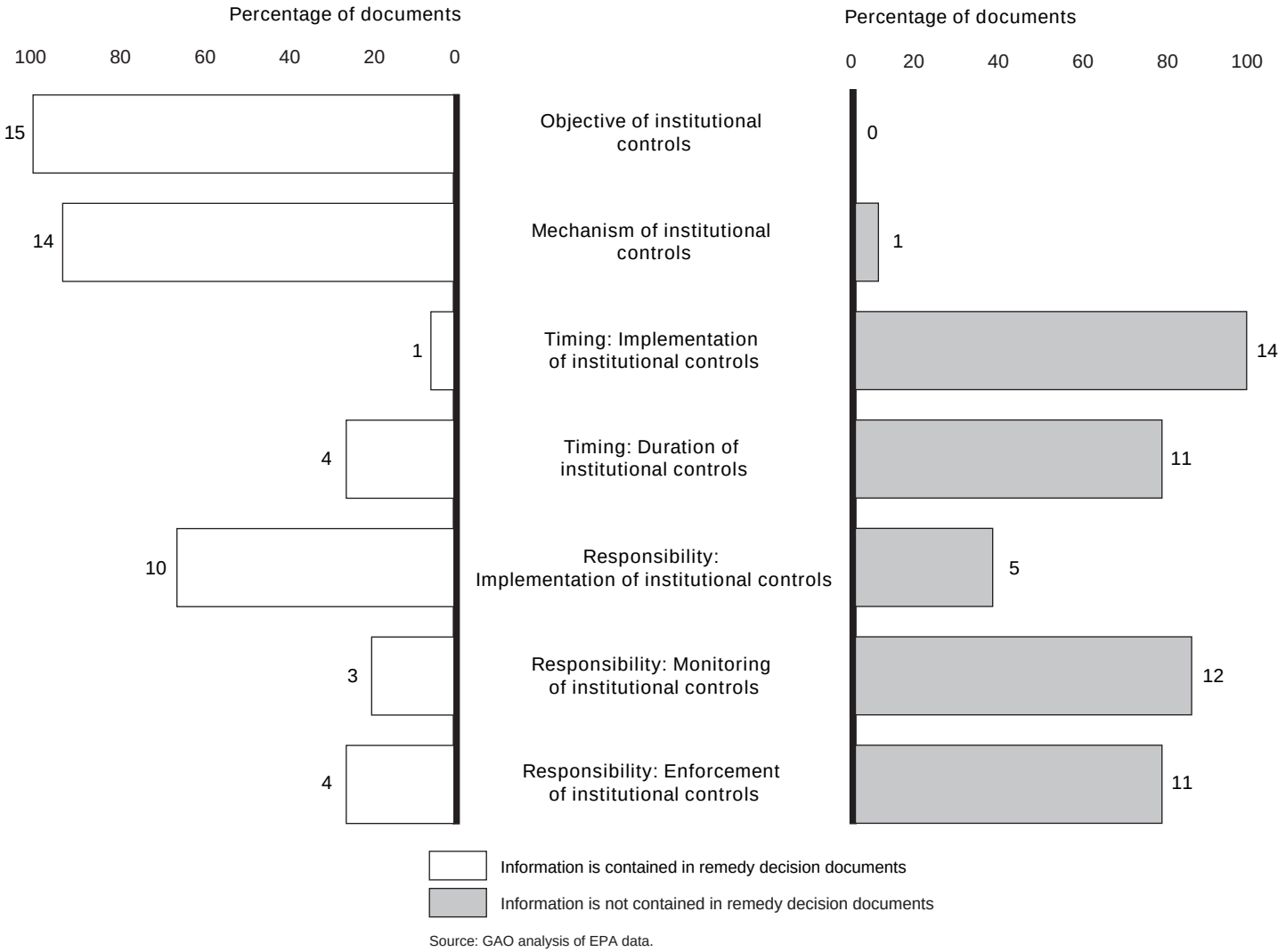
As shown in figures 8 and 9, the remedy decision documents we examined generally discussed the objective of the institutional controls.

Figure 8: Discussion of Key Elements Relating to Institutional Controls in 93 Sets of Superfund Remedy Decision Documents Issued during Fiscal Years 2001-2003



Source: GAO analysis of EPA data.

Figure 9: Discussion of Key Elements Relating to Institutional Controls in 15 Sets of RCRA Remedy Decision Documents Issued during Fiscal Years 2001-2003



Source: GAO analysis of EPA data.

Eighty-six of the 93 sets of Superfund documents we reviewed that addressed institutional controls (whether under all or certain conditions), and all of the document sets for the 15 RCRA sites, discussed the objective, at least in general terms. For both programs, however, the level of detail in the discussion of the objective varied greatly. For example, one Superfund ROD called for "the use of institutional controls to help prevent human exposure to any residual contaminants at the site following the completion

of remedy construction," which is a general purpose of institutional controls rather than a specific objective. Other decision documents included more detailed discussions of objectives; for example, one document discusses institutional controls "for future development that would prevent inappropriate disturbance of remediated mine sites and potential remobilization of contaminants" and "to prevent the use of new drinking water wells where contaminated aquifers exist."

Of the 93 sets of Superfund documents and 15 sets of RCRA documents we examined, 81 and 14, respectively, discussed the mechanism to be used, at least generally. However, the specific mechanism for each institutional control was identified in only 35 of the sets of Superfund documents and in 5 of the sets of RCRA documents.[17] Most discussions were vague, gave a list of options, or discussed mechanisms for one planned control but not another. For example, 24 documents mentioned "deed restrictions" without detailing how the deed would be restricted. EPA guidance points out that the term "deed restriction" is not a traditional property law term, but rather a shorthand way of referring to types of institutional controls. Furthermore, it states that site managers should avoid the generality of "deed restriction" and instead be specific about the types of controls under consideration. Other remedy decision documents were incomplete, suggesting mechanisms for one medium, such as soil, but not another, such as groundwater. In 30 of the Superfund cases and 4 of the RCRA cases, the remedy decision documents gave several options for control mechanisms rather than identifying those that were most appropriate. In contrast, some documents do include a detailed discussion of the institutional control mechanism. For example, one document suggested implementing and monitoring deed notices to ensure that land use is consistent with the cleanup levels selected for the site. If the land is used for residential purposes, additional institutional controls, such as a restrictive covenant, may be needed to limit access to soils. Because some institutional controls—such as informational devices—cannot be enforced, or may not transfer if the property is sold, careful consideration of the institutional control mechanism is generally necessary.

EPA guidance points out that since parties other than EPA often implement institutional controls, site managers should consider the time required to put a control in place. However, as shown in figures 8 and 9, less than one-third of the Superfund remedy decision documents and only 1 of the RCRA

[17]In addition, 13 sets of Superfund documents referred to existing institutional controls.

documents we examined specified the timing of institutional control implementation. Twenty-five Superfund documents and 1 RCRA document specified when the institutional controls should be implemented—for example, "before the RA [Remedial Action] is final"—although some of the documents were vague or only indicated timing for one out of several controls. Moreover, for 14 of the Superfund sites, the institutional controls referred to in remedy decision documents had already been implemented. Documents for 45 Superfund and 4 RCRA sites specified how long the institutional controls should remain in place—which was, in most cases, until the contamination was no longer present or cleanup levels were achieved. However, some of the documents indicated the duration of only one of several planned controls.

In the remedy decision documents we examined, many of the Superfund and RCRA documents did not discuss any of the parties responsible for implementing, monitoring, and enforcing institutional controls. To the extent that responsibility was addressed, most of the discussion centered only on the implementing party, rather than those responsible for monitoring and enforcing institutional controls. Only 11 Superfund and 3 RCRA document sets discussed parties responsible for monitoring institutional controls, and only 13 Superfund and 4 RCRA document sets discussed parties responsible for enforcing institutional controls (see figs. 8 and 9). According to the EPA draft guidance issued in December 2002, early cooperation and coordination between federal, state, and local governments in the selection, implementation, and monitoring of institutional controls is critical to their implementation, long-term reliability, durability, and effectiveness. Where EPA is implementing a remedy, states often play a major role in implementing and enforcing institutional controls. In addition, under the RCRA program, the state typically imposes and oversees the remedial action. Some governmental controls may be established under state jurisdiction. Furthermore, a local government may be the only entity that has the legal authority to implement, monitor, and enforce certain types of institutional controls, such as zoning changes. EPA guidance states that while EPA and the states take the lead on response activities, local governments have an important role to play in the implementation, long-term monitoring, and enforcement of institutional controls. Without the cooperation of these other parties, the successful implementation of institutional controls may not be ensured.

In many cases, remedy documents we examined contained no evidence that planning of institutional controls included consideration of all aspects of the four key elements in the remedy selection process. In total, 34 of the

93 sets of Superfund and 5 of the 15 sets of RCRA remedy decision documents discussed all four elements, at least in part. For example, the documents may have discussed the duration of the institutional controls but not when they will be implemented, or the documents may have discussed who will implement only one of the controls required. EPA's institutional controls project manager stated that discussion in the ROD may be intentionally vague because key decisions on such issues as who may implement the remedy and institutional controls have not yet been made. He also speculated that site managers may not have given adequate consideration to all relevant aspects of institutional controls at the remedy decision stage. Without careful consideration of all four factors, an institutional control put in place at a site may not provide long-term protection of human health and the environment. Furthermore, EPA's 2002 draft guidance recommends planning of the full institutional control life cycle early in the remedy stage—including implementation, monitoring, reporting, enforcement, modification, and termination—to ensure the long-term durability, reliability, and effectiveness of institutional controls. The guidance states that, critically evaluating and thoroughly planning for the entire life cycle early in the remedy selection process could have eliminated many of the problems identified to date. In addition, according to the EPA guidance, calculating the full life-cycle cost is an essential part of the institutional control planning process. This estimate is important to compare the cost-effectiveness of institutional controls with that of other remedy elements and to ensure that parties responsible for implementing, monitoring, and enforcing institutional controls understand their financial liability for these activities. Relying on institutional controls as a major component of a selected remedy without carefully considering all of the applicable factors—including whether they can be implemented in a reliable and enforceable manner—could jeopardize the effectiveness of the entire site remedy.

EPA Faces Challenges in Implementing, Monitoring, and Enforcing Institutional Controls

At the Superfund sites we reviewed, institutional controls often were not implemented before site deletion, as EPA requires. Moreover, efforts to monitor institutional controls after they are implemented may also be insufficient. Finally, EPA may have difficulties ensuring that the terms of certain types of institutional controls in place at some Superfund and RCRA sites can be enforced, and state laws may limit EPA's ability to implement and enforce needed controls.

Institutional Controls Were Often Not Implemented before the End of the Cleanup Process

Institutional controls were often not implemented before site deletion, as required, at the Superfund sites we reviewed. Under EPA guidance, a site may not generally be deleted from the NPL until all appropriate response actions, including institutional controls, have been implemented. Timely implementation of institutional controls is important because, until the controls are in place at a site, there is a greater potential for the public to become exposed to any residual contamination. At 32 of the 53 Superfund sites deleted during fiscal years 2001 through 2003, institutional controls were likely appropriate, according to EPA guidance, because waste remained in place at these sites above levels that allowed for unrestricted use and unlimited exposure. Our discussions with cleanup officials and our review of supporting documentation, however, indicate that all institutional controls were implemented before site deletion at only 24 of these 32 sites. In the case of 4 of the remaining 8 sites, even though EPA site managers believed certain of the institutional controls had been implemented at the site, our subsequent requests for documentation revealed that these controls had not been implemented. At 2 of these sites, there were no institutional controls in place at all. In another 2 cases, institutional controls were implemented, but only after deletion of the site. In 2 other cases, remedy decision documents did not call for institutional controls, but because EPA guidance does not specify in which cases controls are necessary, it is unclear whether these 2 sites were inconsistent with this guidance. Furthermore, institutional controls were implemented before site deletion at only 2 of the 4 Superfund sites deleted during fiscal years 1991 through 1993 that had residual contamination above levels that would allow for unrestricted use of the site. The 2 other sites were deleted without institutional controls, even though the site manager for 1 of these sites believed there were institutional controls in place. EPA's institutional controls project manager believed that sites with residual contamination may have been deleted without institutional controls at least in part because site managers lost track of the need to implement the institutional controls between the time that active remediation of the site ended and the site's deletion.

Implementation of institutional controls at the RCRA facilities we examined generally occurred by the time the corrective action was terminated. RCRA program guidance does not address the timing of implementation of institutional controls relative to termination of corrective actions. Rather, owners and operators of RCRA facilities that treated, stored, or disposed of hazardous waste must submit documentation indicating the location and dimensions of a closed hazardous waste facility before its closure. Facility closure in the RCRA

program occurs after all RCRA-related activities at a site, including corrective action, end and after the facility undergoes a closure process. Among the 6 state RCRA corrective action programs we reviewed, state officials for 3 of the programs stated that if institutional controls are required, they must be in place before the RCRA corrective action is terminated. Of the 4 RCRA facilities where corrective action was terminated during fiscal years 2001 through 2003 that likely required institutional controls, only 2 had all controls in place by the time the corrective action was terminated. At 1 of the remaining facilities, the sole institutional control was implemented about 1 year after the corrective action was terminated; at the last facility, at least one of several controls was implemented after the corrective action was terminated.

Monitoring of Institutional Controls May Be Insufficient to Ensure Their Protectiveness

Monitoring of institutional controls at Superfund sites after they have been implemented may be inadequate to ensure their continued protectiveness. At sites where contamination is left in place above levels that allow for unlimited use of the site and unrestricted exposure to site contaminants, CERCLA requires reviews once every 5 years of the continued protectiveness of the remedy, including any institutional controls in place. According to EPA's guidance, these 5-year reviews usually consist of community involvement and notification, document review, data review and analysis, site inspection, interviews, and a determination of remedy protectiveness. As a part of these reviews, EPA's guidance calls for a determination of whether institutional controls successfully prevent exposure to site contaminants and a specific check on whether they are still in place. EPA officials acknowledged, however, that reviews that only occur every 5 years may be too infrequent to ensure the continued protectiveness of the institutional controls. At some of the sites we examined, 5-year reviews uncovered institutional control violations that could have been discovered and stopped earlier with more frequent monitoring. For example, an institutional control at 1 Superfund site we examined prohibited any use of groundwater without prior written approval from EPA. When EPA conducted its 5-year review in April 2003, agency officials discovered that over 25 million gallons of groundwater from the site had been pumped for use as drinking water during 2002. Moreover, the agency official who conducted the 5-year review did not know how long groundwater had been pumped without EPA's approval. While many Superfund sites are no longer active, sites that are being reused may be especially vulnerable to activities occurring on-site that may violate an institutional control during the time period between 5-year reviews. At 1 Superfund site we visited, for example, the institutional control for the site

requires monitoring for worker safety precautions during digging on the site. At the time of our site visit, however, active digging was occurring at the site about which the EPA official charged with supervising the site was not aware (see fig. 10). The EPA official had not visited the site since the previous 5-year review, which had occurred 4 years earlier.

Figure 10: Digging Under Way at a Deleted Superfund Site without the EPA Site Manager s Knowledge

Source: GAO.

Five-year reviews, even when they do eventually occur, may not ensure that institutional controls are in place. EPA's guidance on conducting 5-year reviews instructs officials conducting the review to verify that (1) institutional controls are successful in preventing exposure to site contaminants and (2) institutional controls are in place. We interviewed officials at the 32 Superfund sites deleted during fiscal years 2001 through 2003 and the 4 Superfund sites deleted during fiscal years 1991 through 1993 with residual contamination. Most of these officials stated that, during 5-year reviews, they confirmed that the site remedy—including

institutional controls—continued to protect the public from exposure to site contaminants. However, while they usually confirmed the protectiveness of the remedy, 8 did not also verify that site institutional controls were in place. For example, EPA site managers in charge of 3 sites told us they generally did not check whether institutional controls were in place during 5-year reviews. Managers of 4 other sites stated that they generally verified that institutional controls were in place during 5-year reviews; our subsequent requests for documentation, however, revealed that the institutional controls these site managers believed to be in place were never actually implemented. One additional site manager was unsure whether the 5-year review process even included a check on the continued presence of institutional controls. A determination that institutional controls successfully prevent exposure to contaminants at a site is meaningless if the controls that are supposed to be at the site are, in fact, not in place, or their presence is unknown. Unless EPA verifies that institutional controls remain in place during its 5-year reviews, the agency cannot ensure the continued protectiveness of site remedies.

Monitoring of Superfund sites by parties other than EPA may occur more often than every 5 years, but this monitoring may not significantly contribute to ensuring the protectiveness of institutional controls at sites. Thirty-two Superfund sites were deleted during fiscal years 2001 through 2003 with contamination left in place. At 26 of these sites, parties responsible for contamination, site owners, or state or local government entities were responsible for conducting some form of site monitoring in addition to the 5-year reviews. In principle, this additional monitoring could help to ensure that site institutional controls remain protective. Often, however, this monitoring is unrelated to the institutional controls on the site. At fewer than half of these 26 sites, for example, do the additional monitoring activities specifically include a review of the sites' compliance with institutional controls; at the other sites, monitoring either focused on analyzing site groundwater or on other activities. Moreover, at none of the 26 sites did monitoring include a specific check on whether site institutional controls were in place, as 5-year reviews do. In fact, at 4 of these sites, monitoring that checked whether institutional controls were in place would have found that controls that had supposedly been implemented were not. In addition, some parties responsible for site monitoring sometimes do not meet their monitoring requirements. In 4 cases, site managers indicated that monitoring parties had either not performed the required monitoring or they were unable to provide documentation of this monitoring. In 1 case, for example, an official in a town with a Superfund site refused to perform monitoring of the site, even

though there was significant evidence of trespassing at the site, according to the responsible EPA site manager.

In contrast with the Superfund program, the RCRA corrective action program does not include any national requirement to review facilities with residual contamination that have been closed.[18] As a result, EPA has no way of knowing whether institutional controls implemented at such facilities remain in place, or whether they remain protective of human health and the environment. At least some states, however, conduct their own monitoring of closed RCRA corrective action facilities, including determining whether institutional controls remain in place and have not been violated. This practice may be in recognition of the necessity to track the status of RCRA facilities that have waste in place after the corrective action process is terminated and they are closed. Officials that we interviewed in 4 of 6 states reported some form of postclosure monitoring of RCRA corrective action facilities in their states; an official in 1 additional state stated that her agency is working to implement such monitoring. Two of these states specifically require that facility owners self-certify the continued presence of institutional controls. One state program, for example, requires facility owners to submit a form every 2 years certifying that facility institutional controls are still in place. In addition, this state's officials conduct inspections of the closed sites every 5 years, during which they verify the self-certifications and ensure that institutional controls remain in place. As of 2001, according to a 50-state survey that an independent research group prepared using funding from EPA, 17 states had established schedules for auditing sites where institutional controls have been implemented, including 7 states that review such sites at least annually.[19]

Ability to Enforce Institutional Controls Depends on the Nature of the Control Selected and State Laws

In addition to potentially inadequate monitoring, EPA may have difficulties enforcing the terms of certain institutional controls currently in place, or planned, for some Superfund and RCRA sites. Some institutional controls selected for sites are purely informational and do not limit or restrict use of the property. Informational institutional controls, according to EPA's guidance, include deed notices, state hazardous waste registries, and

[18]Facility closure in the RCRA corrective action program occurs after all RCRA-related activities at a site, including corrective action, end and after the facility undergoes a closure process.

[19]Environmental Law Institute, *An Analysis of State Superfund Programs: 50-State Study, 2001 Update*, (Washington, D.C.: 2002).

advisories to the public. For example, while a deed notice—which is required by the RCRA corrective action program for certain closed facilities—alerts anyone searching land records to the continuing presence of contamination at the site, such a notice does not provide a legal basis for regulators to prevent a property owner from disturbing or exposing that contamination. Seven of the 32 Superfund sites deleted during fiscal years 2001 through 2003 with waste remaining had some form of informational institutional control in place. Furthermore, EPA recognizes that another mechanism used often at sites to impose institutional controls, a consent decree, is not by itself binding on subsequent property owners or occupants. We found consent decrees in place at 12 of the 32 Superfund sites with residual contamination deleted during fiscal years 2001 through 2003. The use of multiple institutional controls at the same site could alleviate concerns about the use of nonenforceable mechanisms, as long as one of the additional controls is enforceable. In some cases, however, informational, nonenforceable institutional controls were the only controls in place at sites. This was the case at 1 of the Superfund and 2 of the RCRA corrective action sites that we examined that had reached the end of the cleanup process. Moreover, among the sets of remedy decision documents finalized during fiscal years 2001 through 2003 that we examined, 56 of 112 Superfund and 6 of 23 RCRA corrective action sets of documents specified at least one institutional control mechanism; among these, 6 of the Superfund and 3 of the RCRA sets of documents specified only an informational device as the sites' institutional control.

State property laws, which traditionally disfavor restrictions attached to deeds and other land use restraints in order to encourage the free transferability of property, can hinder EPA's ability to implement and enforce institutional controls. EPA's guidance warns that state property laws should be researched to ensure that certain types of institutional control mechanisms can be enforced. For example, one state only allows use restrictions attached to a deed to be enforced for 21 years from the recording of the deed. As an EPA official charged with managing a site with such restrictions in this state recognized, the issue of following up on this site after 21 years presents a planning problem for EPA. In several cases, EPA or state officials stated that property owners had to agree before certain proprietary controls, including covenants, could be put in place. Therefore, EPA officials are forced to negotiate aspects of the institutional control with the property owner. This process has the potential to compromise or dilute the enforceability of the proprietary control that is ultimately negotiated. Because RCRA generally does not authorize EPA to acquire any interests in property, many proprietary controls require that

third parties such as states be willing to be involved. RCRA officials must thus rely on states, localities, or sometimes even adjacent property owners to hold an easement over a facility property. At least one EPA regional official we interviewed was aware of a state that refuses to serve as a third party in such cases, limiting EPA's ability to put in place such institutional controls.

States have legislative options available to help ensure that institutional controls can be enforced. Certain states have enacted statutes that provide the state with the legal authority to restrict land use at contaminated properties. Colorado, for example, passed legislation in 2001 that allows the state's Department of Public Health and Environment to hold and enforce environmental covenants. Colorado's agreements are binding upon current and future owners of the property, thus allowing the state to enforce these agreements should they be violated. These covenants had been used at 11 state sites, including 1 RCRA corrective action facility, as of August 2004. In addition, several states have adopted statutes providing for conservation easements, which override certain common law barriers to enforcement. A recent effort by the National Conference of Commissioners on Uniform State Laws sought a way to allow states to implement enforceable institutional controls.[20] In 2003, this group finalized a Uniform Environmental Covenants Act that is available for state legislative adoption. According to the group, this legislation provides clear rules for state agencies to create, enforce, and modify a valid real estate document—an environmental covenant—to restrict the use of contaminated real estate. The act creates this new type of institutional control and, according to the group, ensures that it can be enforced. Several states have shown interest in adopting the legislation, according to the chairman of the group that drafted it.

Institutional controls help to ensure the protectiveness of remedies at Superfund and RCRA sites where waste remains in place after cleanup. If institutional controls are not properly functioning or cease to apply to the site, the administrative and legal barriers between the residual contamination and potential human exposure to site contaminants disappear. Because of the potential danger of losing these barriers, EPA has

[20]The National Conference of Commissioners on Uniform State Laws comprises more than 300 lawyers, judges, and law professors, appointed by the states as well as the District of Columbia, Puerto Rico, and the U.S. Virgin Islands to draft proposals for uniform and model laws on subjects where uniformity is desirable and practicable, and to work toward their enactment in legislatures.

recognized the importance of monitoring whether institutional controls are still in place and whether they continue to prevent exposure to residual contamination during its 5-year reviews. Current efforts to monitor institutional controls, however, may not occur with sufficient frequency to identify problems in a timely manner and may not always include checks on controls.

EPA Faces Significant Obstacles in Implementing Systems to Better Track Institutional Controls

Institutional controls are often key components of selected cleanup remedies and, as such, need to be monitored, enforced, and kept in place as long as the danger of exposure to residual contamination remains. Residual contamination can remain at a site long after EPA's involvement is completed, and an entity other than EPA may assume responsibility for long-term monitoring and enforcement of the controls. However, historically, EPA had no system in place to readily identify which sites had institutional controls in place or whether the controls were being monitored and enforced. To improve its ability to ensure the long-term effectiveness of these controls, EPA has recently begun implementing tracking systems for its Superfund and RCRA corrective action programs. These systems currently track only minimal information on the institutional controls—as currently configured, they do not include information on long-term monitoring or enforcement of the controls. In addition, initial reports of tracking system data show that there are potential problems in implementing the systems.

Tracking Systems Can Help Ensure the Long-term Effectiveness of Institutional Controls

Regulators must track institutional controls at hazardous waste sites in order to ensure that they remain effective over the long term. Such controls are often intended to remain in place long after cleanup work has been completed to ensure that a site's future use is compatible with the level of cleanup at the site and to limit exposure to residual contamination. EPA maintains that an institutional control tracking system should include information about the selection and implementation of the controls as well as their monitoring, reporting, enforcement, modification, and termination.

According to EPA, several unique characteristics of institutional controls make tracking them particularly challenging. First, the life-span of institutional controls may begin as early as site discovery and can continue for as long as residual contamination remains above levels that would allow for unrestricted use or unlimited exposure. Therefore, institutional controls may remain necessary at a site indefinitely. Second, the long-term

effectiveness of institutional controls depends on diligent monitoring, reporting, and enforcement. Third, institutional controls are often implemented, monitored, and enforced by an entity other than the one responsible for designing, performing, and/or approving the remedy. As a result, an entity other than EPA may be responsible for ensuring that one of the remedy's critical components—the institutional control—is both effective and reliable in the long term.

Historically, EPA has had no way to (1) readily identify which hazardous waste sites relied on institutional controls to protect the public from residual contamination or (2) monitor how the controls were working over the long term. According to EPA's institutional controls project manager, the need for institutional control tracking systems has been discussed since at least the early 1990s, and environmental groups have long advocated the development of such systems. While several existing EPA information systems track basic information on hazardous waste sites, such as cleanup status and selected remedies, these systems were not designed to capture information on institutional controls at the level of detail necessary to allow for effective tracking and monitoring of the use of these controls. As previously discussed, our analysis of EPA's use of institutional controls at Superfund and RCRA sites showed that the agency has generally not ensured that institutional controls are adequately implemented, monitored, and enforced. In some cases, for example, we found that controls had not been implemented on a timely basis, and, in at least 4 cases, controls that agency staff thought were in place had never been implemented. An effective institutional control tracking system may alert EPA management to such situations.

EPA Is Making Progress in Developing Tracking Systems

EPA has recently begun implementing institutional control tracking systems for the Superfund and RCRA corrective action programs. The Institutional Controls Tracking System (ICTS) was designed with the capability to track controls used in a variety of hazardous waste cleanup programs. However, at least initially, ICTS will only include data for Superfund "construction complete" sites.[21] For RCRA corrective action sites, EPA is utilizing its existing RCRA information database to identify sites where institutional controls have been established. In both instances,

[21]EPA defines a "construction complete" site as a site where physical construction of all cleanup actions is complete, all immediate threats have been addressed, and all long-term threats are under control.

the EPA tracking systems include only limited, basic information. EPA has not yet decided the extent to which ICTS may be expanded in the future to include more detailed information. The RCRA program currently has no plans to track more detailed information regarding institutional controls at its facilities.

EPA began developing ICTS in 2001. According to EPA, ICTS is a state-of-the-art tracking system that is Web-based, is scalable, and will serve as the cornerstone for future programmatic and trend evaluations. The system is built around a cross-program, cross-agency, consensus-based institutional control data registry developed by the agency.

The ICTS draft project management plan notes that EPA envisioned an integrated tracking system that would be developed collaboratively using a work group approach that relied on existing data sources for its information. The primary sources of the data to be entered in ICTS include RODs and any amendments; explanations of significant differences; notices of intent to delete; and actual institutional control instruments, such as consent decrees, easements, ordinances, and advisories. The objectives of ICTS are to

- make institutional controls more effective by creating links across all levels of government through a tracking network;
- improve EPA program management responsibilities;
- establish relationships with coregulators (other federal agencies, along with state and local regulatory agencies);
- improve information exchange with individuals interested in the productive use of a site after cleanup; and
- improve existing processes allowing for notification to excavators of areas that are restricted or need protection prior to digging.

EPA designed ICTS to be implemented in three separate phases, or "tiers," of data collection activities. The initial data gathering effort was focused on collecting Tier 1 data for all sites on the Superfund construction complete list, which includes all deleted sites. Data collected during Tier 1 can be used by EPA management to generate reports with basic status information about institutional controls at sites. Tier 1 data consist of information on

- the site name;
- whether site decision documents report the presence of residual contamination at the site above a level that prohibits unlimited use and unrestricted exposure, and if present, whether the documents call for controls;
- the objectives of the institutional control;
- the specific control instruments, including the administrative or legal mechanism that establishes a specific set of use restrictions;
- any person and/or organization that may be directly or indirectly involved with institutional controls at the site; and
- the source of the information that is entered into the data entry form.

The initial version of ICTS was designed to provide some baseline information on institutional controls and a step toward a more comprehensive system. EPA envisions that Tier 2 would (1) identify which institutional controls are in place to prevent use of which media (e.g., soil or groundwater); (2) identify parties responsible for implementing, monitoring, and enforcing the controls; and (3) provide for attaching the latest inspection report. Tier 3 information would include detailed site location information, such as the actual boundaries of the institutional controls. According to the draft ICTS quality assurance project plan, EPA plans to make information from ICTS accessible to EPA and other federal agencies, state and local governments, tribes, and industry groups. Some information may also be made available to the public via the Internet about site-specific institutional controls near and within local communities. Initially, only data for those Superfund sites where construction of remedies has been completed will be entered into ICTS. Although no decision has been made to date, future data collection efforts may include additional sites in EPA's other cleanup programs (RCRA and Underground Storage Tanks). According to ICTS plans, the tracking system also has the flexibility to include data for sites in other programs, such as Brownfields and State Voluntary Cleanup Programs.

Between April and July 2004, EPA regions entered data into ICTS for most of the 899 Superfund construction complete sites, including data on about 280 sites that had been deleted from the NPL. Reports on these data indicate that 154 of the deleted sites had residual contamination;

institutional controls were reported for 106 of these sites. Site decision documents did not report institutional controls for the other 48 sites, or about one-third of the deleted sites with residual contamination. EPA's institutional controls project manager cautioned, however, that the data reported may be inaccurate and need to be verified. The official was concerned, for example, that (1) the standard for what constitutes residual contamination was not consistently applied across all regions, (2) some data may have come from interim decision documents rather than final documents, and (3) some staff entering data into ICTS may have confused whether institutional controls were implemented or only planned. In addition, the EPA official stated that the EPA regions were asked to enter the data into ICTS in 8 weeks, using the best available information and/or their best professional judgment. Because of the expedited data entry, additional research into the status of institutional controls at the site-specific level and significant data quality assurance efforts are necessary to ensure the accuracy of the data.

Upon completing the ICTS Tier 1 data entry, EPA plans to assess the data to evaluate the current status of institutional controls at all construction complete sites for data gaps and site-specific control issues. According to the ICTS strategy, once the agency has determined where data gaps and site-specific institutional control problems may exist, the agency will prioritize the work to address these issues on the basis of a variety of factors, including resources and the number of sites with potential issues. EPA's goal is to identify and review institutional control problems at all construction complete sites over approximately the next 5 years, relying on a combination of special evaluations and scheduled 5-year reviews, focusing on deleted sites as the highest priority. The sites identified as priorities will likely be addressed through a special evaluation, unless a routine 5-year review is scheduled within 12 months of problem identification. Priority evaluations will focus on whether institutional controls were required and properly implemented for all media not cleaned up to levels that allow for unlimited use and unrestricted exposure. EPA does not yet know the scope of these priority evaluations, but expects that these evaluations will be conducted over the next 2 years, resources permitting. After 2 years, the remaining sites will be evaluated in conjunction with or as a component of the normal 5-year review process.

To track institutional controls at RCRA corrective action sites, EPA modified RCRAInfo—the agency's database of information on individual RCRA sites—to identify sites where institutional controls have been established as part of, or to augment, an interim or final corrective action.

Details to be entered into RCRAInfo for pertinent sites include the type of institutional controls (governmental control, proprietary control, enforcement or permit tool, or informational device); the scheduled and actual dates that the controls were fully implemented and effective; and the responsible agency (state or EPA). While EPA currently has no plans to track more detailed information regarding institutional controls at its facilities, the RCRA database requires identifying a location where additional information concerning the specific control can be accessed (e.g., responsible agency contact information). In April 2004, EPA officials asked the regions and/or states to enter the requested information into RCRAInfo by September 30, 2004, for the 1,714 GPRA baseline facilities, and by the end of fiscal year 2005 for the remainder of the 3,800 RCRA facilities in the corrective action workload universe.

Analysis of the RCRA institutional control tracking system information showed that, by November 22, 2004, only 4 EPA regions, and 7 states in those regions, had identified a total of 87 facilities where institutional controls had been established. Moreover, according to the head of EPA's RCRA corrective action program, because the agency asked the regions and states to identify and report on only those facilities with institutional controls, rather than asking for reports on all sites indicating whether or not controls were established, the agency does not know the extent to which the data reported by this minority of regions and states are complete. Additionally, the official stated that the agency does not know whether the institutional controls that were reported were actually verified to be in place and operating as intended. In December 2004, the RCRA corrective action program official reminded officials in all 10 EPA regions of the importance of entering these data. Unlike the Superfund ICTS, the agency has no plans to verify that the institutional control information reported for RCRA corrective action facilities accurately reflects actual conditions.

EPA Systems Used to Track Institutional Controls May Not Include Important Information

Information on institutional controls in the new Superfund and RCRA tracking systems was primarily derived from reviews of decision documents contained in the individual site files. As such, these data reflect the planned use of institutional controls, which may or may not reflect the controls as actually implemented. As previously noted, our review of the use of institutional controls at Superfund sites disclosed four cases where the planned controls had never been implemented. These cases illustrate the need for EPA to determine not only whether institutional controls were required at a site but also whether they were implemented. While EPA

currently plans to review the actual use of controls at all Superfund sites with residual waste, such reviews may take up to 5 years to complete. The RCRA program, on the other hand, has no current plans to determine whether (1) institutional controls have been required in all appropriate situations or (2) all required controls were actually implemented.

Information necessary to determine whether institutional controls are being monitored and enforced is not currently included in either the Superfund or RCRA tracking systems. As previously noted, monitoring of institutional controls at Superfund sites after they have been implemented may be inadequate to ensure their continued protectiveness. Failure to monitor or enforce institutional controls can lead to compromising the protectiveness of remedies put into place and, consequently, potential exposure of the public to residual hazardous waste. While EPA plans to include information on monitoring and enforcing institutional controls at Superfund sites in the Tier 2 data for ICTS, EPA's institutional controls project manager stated that it is uncertain whether ICTS will ever be expanded to include Tiers 2 or 3 data. Further, there is no plan to include such information in the RCRA tracking system, since EPA regulations do not require any review of terminated RCRA corrective action sites. Currently both tracking systems only identify where an interested party may go to obtain more information on a particular site.

As previously noted, the objectives of ICTS include improving information exchange with individuals interested in the productive use of a site after cleanup, and the existing processes allowing for notification to excavators of areas that are restricted or need protection prior to digging. EPA acknowledges that there is an immediate need for disseminating readily available information about institutional controls at contaminated sites. This need will only increase in the future as sites' remediation advances and as more contaminated land and water resources are identified for potential reuse. Without knowledge of the controls at a site, excavators might unknowingly contact or otherwise disturb residual contaminated media. At this time, to obtain information about possible institutional controls at the site of interest, excavators would need to search many different databases and sources of information before operations could begin. While information on institutional controls at RCRA corrective action sites is planned to be available to the public by April 2005 and this capability is planned for ICTS in the future, EPA has not yet determined what information on institutional controls at Superfund sites will be made available to the public. Additionally, EPA currently has no assurance that

the institutional control information on RCRA sites that will be made available to the public accurately reflects actual conditions.

The Superfund ICTS and RCRA tracking systems, together, currently cover a universe of more than 2,600 hazardous waste sites. Expanding the existing tracking system information to reflect the institutional controls as actually implemented and to include long-term monitoring and enforcement information will likely be a resource-intensive task. Nevertheless, without such additional data, EPA has no assurance that the institutional controls actually implemented are continuing to provide the level of protectiveness intended. In this regard, EPA currently has established a task force that will decide what will be done with regard to any expansion of the institutional control tracking systems.

Conclusions

Many of the sites that have been cleaned up under EPA's Superfund and RCRA corrective action programs rely on institutional controls to ensure that the public is not exposed to sites' residual contamination, and it is likely that a growing number of sites remediated in the future will rely on such controls. However, the long-term effectiveness of these institutional controls depends on EPA resolving several issues. First, EPA's guidance does not specify under what circumstances a site with residual contamination should have institutional controls. Rather, the guidance states that an institutional control is "generally required," or "likely appropriate," if the site cannot accommodate unrestricted use and unlimited exposure. In addition, EPA has identified four factors in its guidance that should be considered during the remedy decision stage—the objective of the institutional control; the mechanism, or type of control, used to achieve that objective; the timing of the implementation of the control and its duration; and the party who will bear the responsibility for implementing, monitoring, and enforcing the institutional controls. Adequately addressing these factors is intended to help ensure that the control will effectively protect human health. But without documentation that these four factors are considered at the remedy decision stage, there is no assurance that sufficient thought has gone into designing the institutional controls and ensuring that they can be successfully implemented, monitored, and enforced. Once the controls are implemented, monitoring is necessary to determine their continued effectiveness and to check that they remain in place. Current efforts to monitor institutional controls, however, may not occur with sufficient frequency to identify problems in a timely manner and may not always include checks on controls. Finally, EPA's current efforts to begin tracking

institutional controls could be a positive step toward achieving successful implementation, monitoring, and enforcement of institutional controls at Superfund and RCRA sites. As presently configured, however, these tracking systems may not significantly contribute to improving the long-term effectiveness of institutional controls. Although EPA has recognized many of these problems and is developing draft guidance documents that may address many of them, until these documents are finalized, the extent to which they will resolve the problems we have identified is unclear.

Recommendations for Executive Action

In order to ensure the long-term effectiveness of institutional controls, we recommend that the Administrator, EPA:

- clarify agency guidance on institutional controls to help EPA site managers and other decision makers understand in what cases institutional controls are or are not necessary at sites where contamination remains in place after cleanup;
- ensure that, in selecting institutional controls, adequate consideration is given to their objectives; the specific control mechanisms to be used; the timing of implementation and duration; and the parties responsible for implementing, monitoring, and enforcing them;
- ensure that the frequency and scope of monitoring at deleted Superfund sites and closed RCRA facilities where contamination has been left in place are sufficient to maintain the protectiveness of any institutional controls at these sites; and
- ensure that the information on institutional controls reported in the Superfund and RCRA corrective action tracking systems accurately reflects actual conditions and not just what is called for in site decision documents.

Agency Comments and Our Evaluation

We provided EPA with a draft of this report for its review and comment. EPA agreed with the findings and recommendations in the report and provided information on the agency's plans and activities to address them. Regarding our recommendation that EPA clarify in its guidance when controls are needed, EPA stated that the agency will continue to develop cross-program guidance to clarify the role of institutional controls in cleanups and has a number of such guidance documents in draft form,

under development, or planned. Regarding our recommendation that EPA demonstrate sufficient consideration of all key factors in selecting controls, EPA stated that the agency agrees that sufficient consideration of all key factors should be completed at remedy selection, but does not agree that this information should be included in the remedy decision document. However, our report does not suggest that the information should be included in the remedy decision document, but should be included in some cleanup-related documentation. Regarding our recommendation that EPA ensure that the frequency and scope of monitoring efforts are sufficient to maintain the effectiveness of the controls, EPA noted that it is revising guidance to address this issue. For example, according to EPA, the agency's draft implementation, monitoring, and enforcement guidance will require periodic evaluation and certification from a responsible entity at the site stating that the controls both are in place and remain effective, and the draft implementation and assurance plan guidance will include specific roles and responsibilities for monitoring efforts. Finally, regarding our recommendation that EPA ensure that the information on controls reported in new tracking systems accurately reflects actual conditions, EPA stated that, among other actions, regions are currently undertaking a quality assurance effort to ensure that the information in the system reflects actual conditions. EPA's completion of its ongoing and planned activities should, if implemented successfully, effectively address the concerns we raised in this report.

In addition to comments directly relating to our recommendations, EPA also offered a number of general comments on the draft report. EPA pointed out that a "missing institutional control" does not, by itself, necessarily represent an unacceptable human exposure or environmental risk or suggest a breach of remedy. We agree that the mere presence of residual contamination at a site does not necessarily indicate the need for institutional controls, and we acknowledge that EPA generally—although not always—requires that institutional controls be put in place at sites where total cleanup is not practical or feasible. We believe, however, that in cases where EPA's selected remedy for a particular site includes institutional controls as an integral component of the remedy, the agency has determined that such controls are necessary and, as such, the controls should be effectively implemented, monitored, and enforced. In addition, EPA noted that an evaluation of a small universe of sites may overestimate the number of sites with potential institutional control problems. However, we are not making any population estimates, but are describing only the results for those specific cases we reviewed. This report specifically acknowledges that the results from the nonprobability samples for our

analysis cannot be used to make inferences about a population because some elements of the populations being studied have no chance or an unknown chance of being selected as part of the sample(s). Finally, EPA commented that an increased use of institutional controls does not mean that the agency advocates less treatment; we do not believe that this report implies that this is the case. The full text of EPA's comments is included in appendix II.

As agreed with your offices, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the date of this letter. At that time, we will send copies of this report to the appropriate congressional committees; the Administrator, EPA; and other interested parties. We will also make copies available to others upon request. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staff have any questions, please call me at (202) 512-3841. Key contributors to this report are listed in appendix III.

John B. Stephenson#
Director, Natural Resources#
and Environment

Objectives, Scope, and Methodology

The primary objective of this review was to examine the long-term effectiveness of institutional controls at nonfederal sites in the Environmental Protection Agency's (EPA) hazardous waste cleanup programs. Specifically, we reviewed (1) the extent to which institutional controls are used at sites addressed by EPA's Superfund and Resource Conservation and Recovery Act (RCRA) corrective action programs; (2) the extent to which EPA ensures that institutional controls at these sites are implemented, monitored, and enforced; and (3) EPA's challenges in implementing systems to track these controls. Although both the Superfund and RCRA programs address federal and nonfederal sites, our review did not address federal sites because federal agencies are generally responsible for cleaning up their own sites and EPA involvement is limited. Furthermore, our review focused on institutional controls that remain in place after site deletion or termination to determine whether these controls are effective in the long run. We also focused our review of RCRA facilities on those whose cleanup was led by EPA.

To examine the extent of the planned use of institutional controls, we examined all 112 Superfund records of decision (ROD)—involving 101 Superfund sites—finalized during fiscal years 2001 through 2003, and statements of basis or other final decision documents for all 23 RCRA corrective action facilities that reached the remedy decision stage during that period. In this regard, we examined only the principal remedy decision documents for the sites in our universe, rather than all remedy decision documents. Institutional controls may be called for in a number of EPA documents. In the Superfund program, at least two types of documents, in addition to RODs, may sometimes include information about institutional controls at the site—ROD amendments and explanations of significant differences. In the RCRA program, a variety of documents may include information about institutional controls, including permits, permit modifications, statements of basis, and other documents. Because of the number of potential sources of information regarding the planned use of institutional controls, we asked regional officials responsible for the sites to provide us with documentation relevant to the remedy decision at the site. In most cases, regional officials provided us with either a statement of basis, a final decision document, or both. Because we did not look at all remedy decision documents for these sites, we may not have captured all institutional controls at the sites we examined.

To address the extent of institutional control use at Superfund sites and RCRA corrective action facilities, we examined EPA's use of institutional controls at a nonprobability sample of nonfederal sites and facilities where

(1) the cleanup process was completed in earlier periods, for historical perspective; (2) cleanup had recently ended; and (3) the remedy had only recently been selected, for insight into the future use of these controls.[1] To gain a broader view of past use of institutional controls, we reviewed files for all 20 Superfund sites deleted from the National Priorities List (NPL) during fiscal years 1991 through 1993; in addition, in the two EPA regions with the most such facilities—Region III in Philadelphia and Region V in Chicago—we reviewed files for all 40 RCRA facilities at which, according to EPA's database, a preliminary investigation was conducted and corrective action was terminated before fiscal year 2001. Regarding sites where the cleanup was recently completed, we examined site documentation for all 53 Superfund sites deleted from the NPL during fiscal years 2001 through 2003 and at all 31 RCRA facilities where corrective action was terminated during the same period. With the exception of the historical RCRA facilities we examined in two regions, for those deleted sites or terminated facilities whose documentation indicated the use, or potential use, of institutional controls, we conducted follow-up interviews with EPA or state officials knowledgeable about the site to obtain detailed information and additional documentation and to determine what institutional controls were actually in place.

To identify the universe of Superfund sites deleted from the NPL during fiscal years 1991 through 1993 and 2001 through 2003, as well as those sites where a remedy decision was reached during fiscal years 2001 through 2003, we obtained data from EPA's Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS)—a computerized inventory of potential hazardous waste sites that contains national site assessment, removal, remedial, enforcement, and financial information for over 44,000 sites. CERCLIS is a relational database system that uses client-server architecture (i.e., each computer or process on the network is either a client or server), installed on separate local area networks at EPA headquarters and all 10 regional Superfund program offices, and is used by more than 1,900 EPA staff. A September 30, 2002, report issued by EPA's Inspector General found that over 40 percent of CERCLIS data they reviewed were inaccurate or not adequately supported. The Inspector General's review focused on site actions, which it defined as activities that have taken place at a site—such as site inspections,

[1]Results from nonprobability samples cannot be used to make inferences about a population because in a nonprobability sample, some elements of the population being studied have no chance or an unknown chance of being selected as part of the sample.

removals, studies, potentially responsible parties searches, RODs, and remedial actions. As a result of its review, the Inspector General concluded that CERCLIS could not be relied upon to provide error-free data to system users.

For our review, we verified CERCLIS data related to the NPL sites in our universe, but we did not verify detailed site action data for all sites in CERCLIS. To address the reliability of CERCLIS data, we met with the Inspector General's staff to discuss the nature of the errors disclosed in their report. According to the Inspector General's staff, the reliability of CERCLIS data was more of a concern at the action level rather than the site level. They indicated that confirming the data with EPA regions would decrease concerns about data reliability. As a result, we confirmed all relevant CERCLIS data fields for all 53 NPL sites deleted during fiscal years 2001 through 2003 and all 23 NPL sites deleted during fiscal years 1991 through 1993; in addition, we verified information regarding all 232 remedy decisions, including 117 RODs, finalized during fiscal years 2001 through 2003. We verified all relevant CERCLIS data fields with staff in the relevant region, as appropriate, including confirming that sites were nonfederal and had been deleted or had a remedy decision during the time frames of interest. Regional staff found no errors with any of the deleted NPL sites in our universe. Regional staff identified errors regarding 2 of the 232 remedy decisions in our universe, including a change to information regarding 1 ROD, and added 1 remedy decision document to our universe, resulting in a 1 percent error rate. We corrected the CERCLIS site-level data that we used for our analysis to reflect regions' changes. In addition, we obtained remedy documentation, *Federal Register* notices of deletion, and other documents from regional staff that corroborated the accuracy of our data. We also conducted interviews with officials knowledgeable about deleted sites where it appeared there were institutional controls or where it was unclear. As a result of these interviews and further analysis, we amended the number of records of decision finalized during fiscal years 2001 through 2003 to 112 and the relevant number of sites deleted during fiscal years 1991 through 1993 to 20. After taking these additional steps, we determined that the CERCLIS data we used were sufficiently reliable for the purposes of this report.

In addition, we visited 5 Superfund sites that had been deleted from the NPL. For the site visits, we went to EPA Region III, headquartered in Philadelphia, which had (1) the most Superfund sites deleted during fiscal years 1991 through 1993 and fiscal years 2001 through 2003 and (2) the most RCRA facilities reaching corrective action termination during the

latter time period. Over the course of 5 days in July 2004, we visited the 5 sites that had institutional controls in place in EPA Region III. We conducted a physical inspection of each site to verify compliance with the terms of the institutional controls in place, accompanied by either the EPA site manager or a representative of the responsible party, or both. We also visited the relevant county recorder's office to verify that relevant institutional controls for each site had been recorded and to assess the process for accessing these documents. We also met with local officials responsible for informal monitoring of 1 site. In addition, we met with state officials to learn about a statewide system of groundwater management zones, an institutional control in place at 2 of the sites we visited.

To identify the universe of RCRA facilities that reached the corrective action termination or remedy decision stage throughout the life of the program, and specifically during fiscal years 2001 through 2003, we obtained data from the RCRAInfo system—the EPA Office of Solid Waste's national, mission-critical, major application consisting of data entry, data management, and data reporting functions used to support the implementation and oversight of the RCRA Subtitle C Hazardous Waste Program as administered by EPA and State/Tribal partners. RCRAInfo is a relational database management system (Oracle) that is centralized and Web-enabled, stored on a central Unix server at EPA's Research Triangle Park, North Carolina, facility. Access to RCRAInfo is restricted to authorized EPA Headquarters, EPA Regional, and State staff with RCRA program oversight or implementation responsibilities. During our review, we also spoke with officials in each of the 10 EPA regions regarding their use of the code in the RCRAInfo system used to indicate the termination of corrective action. Specifically, we asked them whether a site coded in this way could include an institutional control, as had been indicated by an official in EPA headquarters early in our review. Officials in 6 EPA regions indicated that regional policy dictated that a site coded in this manner should not include institutional controls, while officials in the other 4 regions stated that it could. In addition, officials in 5 of the regions expressed doubts or uncertainty about whether use of the code had been consistent over time, whether personnel within their region used the code consistently, or whether states in the region interpreted the code in a uniform manner. While EPA's Inspector General has not examined the reliability of the RCRAInfo database, at least one previous report about its predecessor system—the Resource Conservation and Recovery Information System—raised additional significant questions about data reliability.

For our review, we verified the data obtained from RCRAInfo with knowledgeable staff in each EPA region. We asked regional officials to verify that (1) the facilities in our universe belonged there and (2) there were no facilities that should be present in our universe but were not. Verifying the facilities in our universe entailed verifying information about each facility, such as whether it was a federal or nonfederal facility, whether corrective action activities at the facility were led by the state or by EPA, and whether the site had reached the relevant milestone within the prescribed time frame. As a result, we checked all relevant RCRAInfo data fields for the 30 EPA-led RCRA facilities where corrective action was terminated during fiscal years 2001 through 2003 and 21 EPA-led RCRA facilities where a remedy decision was finalized during that period, according to data provided by RCRA officials in EPA headquarters. We verified all relevant RCRAInfo data fields with staff in the relevant region, as appropriate, including confirming that facilities were nonfederal and had had corrective action terminated or had a remedy decision during the time frames of interest. From our universe of RCRA facilities where corrective action was terminated, regional officials deleted 1 facility, added 3 more, and edited the data for 1 additional facility, for a total of 32 facilities. Subsequent follow-up work and interviews with site managers brought the relevant universe of RCRA facilities to 31. Similarly, from our universe of RCRA facilities where a remedy decision was finalized, regional officials deleted 1 facility, added 3 more, and edited the data for 1 additional facility, for a total of 23 facilities. We corrected the RCRAInfo data for facilities in our universe to reflect regions' changes. In addition, we obtained documentation of remedy selection and corrective action termination from regional staff that corroborated the accuracy of our data. We also conducted interviews with knowledgeable site officials at terminated facilities where it appeared there were institutional controls or where it was unclear. After taking these additional steps, we determined that the RCRAInfo data we used were sufficiently reliable for the purposes of this report.

To learn the extent to which EPA ensures that institutional controls at Superfund sites and RCRA corrective action facilities are implemented, monitored, and enforced, we interviewed EPA or state officials knowledgeable about particular sites. To identify sites of interest, we examined documentation related to all 20 Superfund sites deleted from the NPL during fiscal years 1991 through 1993, as well as all 53 Superfund sites deleted from the NPL and all 31 RCRA facilities where corrective action was terminated during fiscal years 2001 through 2003. For those deleted sites or terminated facilities among these whose documentation indicated

the use, or potential use, of institutional controls, we conducted follow-up interviews with EPA or state officials knowledgeable about the site to obtain detailed information and documentation regarding the implementation, monitoring, and enforcement of any institutional controls in place.

To understand the extent to which states implement, monitor, and enforce institutional controls in the RCRA corrective action program, we interviewed RCRA program managers in the 2 states with the most corrective action remedy decisions and terminations at state-led facilities during fiscal years 2001 through 2003—Colorado and New Jersey. We also interviewed officials in 4 additional states that were selected at random from the 37 states that, in addition to Colorado, were authorized by EPA to conduct RCRA corrective action activities as of March 2002—California, Nevada, South Dakota, and Texas.[2] In addition, we reviewed *An Analysis of State Superfund Programs: 50-State Study, 2001 Update*, a 2002 report by the Environmental Law Institute, an independent environmental research organization, and interviewed the report's main author. To inform their study, the Environmental Law Institute collected documents from states, requested program information from them, and conducted telephone interviews to clarify responses and reconcile any discrepancies. While a few states declined to participate, the study achieved a 92 percent response rate. As a result of our review, we determined that this study was sufficiently methodologically sound for the purposes of our review.

To identify the challenges of developing a system to track institutional controls, we interviewed the EPA officials in charge of developing tracking systems for the Superfund and RCRA corrective action programs. We also analyzed documentation related to these efforts and initial data drawn from these systems. In addition, we discussed systems to track institutional controls with officials we interviewed in 6 states, including how the states tracked institutional controls, if at all, and whether the states had any concerns about such national tracking systems.

In addition, we collected information about the Superfund program's Institutional Controls Tracking System (ICTS) to inform a data reliability review of this new database. ICTS is an Oracle database accessed through a

[2]Officials we contacted for the state of Idaho, originally selected in our random sample, declined to be interviewed. Therefore, we interviewed officials in South Dakota, the next state on our list of randomly selected states, instead of Idaho.

user interface consisting of HTML Web pages with JavaScript. The current version of ICTS was designed to provide some baseline information on institutional controls but was planned as a step toward a more comprehensive system. The current ICTS has been used to gather baseline information on institutional controls at approximately 900 EPA Superfund construction completion sites. Officials in all 10 EPA regions were asked to populate the system in 8 weeks using the best available information and/or their best professional judgment. Because of the expedited data entry, EPA plans additional research into the status of institutional controls at the site-specific level and significant data quality assurance activities. In light of the uncertain quality of the data, in this report we present data from ICTS with appropriate caveats.

We conducted our work from October 2003 to January 2005 in accordance with generally accepted government auditing standards, including an assessment of the data reliability and internal controls.

Comments from the Environmental Protection Agency

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JAN 7 2005

Mr. John B. Stephenson
Director
Natural Resources and Environment
Government Accountability Office
Washington, D.C. 20548

Dear Mr. Stephenson:

Thank you for the opportunity to review and comment on the January 2005 Draft Report titled "Hazardous Waste Sites: Improved Effectiveness of Controls at Sites Could Better Protect the Public." The U.S. Environmental Protection Agency (EPA) appreciates GAO's efforts to recognize the challenges that EPA faces when implementing institutional controls (ICs). General comments and comments specific to the GAO recommendations are enclosed. Generally, EPA agrees with the recommendations and has undertaken a number of activities over the past four years to improve implementation and monitoring of appropriate ICs. These activities are summarized below.

EPA and other government agencies have used ICs at cleanup sites for nearly two decades. Over the last ten years, we have focused increased attention on understanding and overcoming the complexities and challenges associated with the use of ICs, many of which are highlighted in the Draft Report. As a result, we have made significant improvements in our approach to ICs in recent years, targeted at the full life-cycle of ICs from identification, evaluation, and selection to implementation, monitoring, and enforcement. By making these changes and more clearly defining EPA's policies and practices, we are confident that the reliability and durability of ICs at sites that have been recently cleaned up has greatly improved. We acknowledge, however, that there are sites addressed earlier in the Superfund and RCRA programs that have not benefitted from our increased understanding of ICs.

We recently undertook a comprehensive effort, beginning with the Superfund program, to improve our practices and to apply them to both old and new sites. In 2004, the Office of Superfund Remediation and Technology Innovation, the Federal Facilities Restoration and Reuse Office, and the Office of Site Remediation Enforcement, developed a comprehensive IC strategy for the Superfund program. The "EPA Strategy to Ensure Institutional Control Implementation at Superfund Sites," issued October 7, 2004 (National Superfund IC Strategy; OSWER document 9355.0-106) is focused on addressing potential IC problems at the Superfund sites that have reached the "Construction Complete" stage of the cleanup. The National Superfund IC Strategy calls for the Agency to evaluate close to 900 Construction Complete sites and determine whether

the ICs are appropriate and effective and, if not, to take the appropriate corrective measures. The baseline information on these Superfund sites is maintained in the recently developed IC Tracking System (ICTS). This state-of-the-art tracking system will serve as the cornerstone for future programmatic and trend evaluations.

For the Superfund program, we also developed a network of Regional experts on ICs to resolve emerging issues quickly and consistently across the country. Each Region in EPA has designated both a Regional IC Program Coordinator and Legal Coordinator (IC Coordinators), as well as at least one person to represent the Region on the Superfund Management Advisory Group for Institutional Controls. The IC Coordinators resolve key implementation issues on a day-to-day basis, and the Management Advisory Group provides direction on emerging national policy issues and monitors Regional implementation of the National Superfund IC Strategy.

The "Framework to Establish National Consistency for Prioritizing Institutional Controls Workload" was developed to help with implementation of the National Superfund IC Strategy. It establishes criteria and requirements for expedited reviews, to be completed by October 2005, and longer term evaluations, to be completed by October 2009. Most of the expedited reviews are of sites deleted from the National Priorities List; consistent with the GAO findings, EPA believes these sites may be the ones warranting more immediate attention. Each Region conducted a critical analysis of its site portfolio to develop Region-specific workplans for all construction complete sites and is currently implementing them, consistent with the National IC Strategy. To date, we have identified over 200 sites from our working universe of Superfund sites, as needing no additional IC evaluation or corrective measures.

EPA's comprehensive approach under its cleanup programs includes development of numerous products to help accurately define and improve the status of ICs. For example, we have developed the following IC guidance documents to address key implementation issues: (1) *Identifying, Evaluating and Selecting ICs for Superfund, Federal Facility and RCRA Cleanups (September 2000; OSWER 9355.0-74 FS-P)*); (2) *Implementing, Monitoring and Enforcing ICs at Superfund, Federal Facility, RCRA, Brownfields and UST Cleanups (draft final; February 2003); (3) ICs and Communities at Superfund, Federal Facility, RCRA, Brownfields and UST Cleanups (draft)*; and (4) *ICs and Five-Year Reviews Guidance Supplement (draft)*. In addition, we have developed and delivered several types of IC training courses nationally.

Currently, EPA is addressing some of the more challenging implementation issues with respect to ICs, including: revising the Superfund Five-Year Review process; improving our understanding and use of title searches; developing guidance to assist with site-specific issues that will arise when determining the appropriate corrective measures; and creating model language and documents to improve reliability and enforceability of ICs in the future. In addition, EPA is piloting some innovative projects that we hope will have transferrable "lessons learned" for ICs. Examples include: collaborating with States and DOE on IC data exchange and tracking; monitoring the successes and shortcomings of a "One-Call" approach for identifying

ICs, which links IC information to utility line information when individuals call before digging on property; and relying on private entities for long-term stewardship responsibilities.

EPA has recognized that there are areas for improvement in how it and the states have selected, implemented, monitored, and enforced ICs at contaminated properties. While the National IC Strategy is focused on Superfund sites, our training efforts and guidance documents are directed at multiple cleanup programs – designed to assist our RCRA and Superfund practitioners. Under the RCRA program, we are working closely with authorized states to ensure effective institutional controls are imposed, where needed, and are applying the lessons learned in the other cleanup programs. We have also recently revised the RCRA Info data system so that it can track imposition and implementation of ICs at RCRA facilities. EPA has also worked with the National Conference of Commissioners on Uniform State Laws in developing the Uniform Environmental Covenants Act. The Agency supports the goals of the Uniform Environmental Covenants Act in seeking to promote greater uniformity in the implementation of institutional controls.

EPA is confident that our efforts will result in vast improvements to the implementation and reliability of ICs at cleanup sites. It is essential to ensure that ICs selected for a particular purpose in fact serve that purpose and remain a reliable and integral part of the remedy. As in-place management of hazardous wastes increases at sites across the Nation, the need for reliable institutional controls and vigilance in administering them increases as well. A "missing IC," as defined in the Draft Report, does not by itself necessarily represent an unacceptable human exposure or environmental risk or suggest a breach of remedy. For example, a landfill cap will still protect humans and the environment, even if no institutional controls exist to prevent digging, as long as no digging occurs and it remains intact. Conversely, a landfill cap with an institutional control preventing digging will not protect human health and the environment if digging has taken place contrary to the restriction.

EPA appreciates the efforts that GAO expended conducting this review. Thank you for the opportunity to provide comments on the Draft Report, and EPA looks forward to working collaboratively with GAO to continue to protect the public.

Sincerely,

Thomas P. Dunne
Acting Assistant Administrator
Office of Solid Waste
and Emergency Response

Thomas V. Skinner
Acting Assistant Administrator
Office of Enforcement and
Compliance Assurance

Enclosure

Enclosure
EPA Comments on GAO Recommendations

I. General Comments

1. The absence of ICs should not be interpreted to necessarily mean remedies are not protective.

One key aspect not considered in the Draft Report, but extremely germane to the findings, is the effect of ICs on the overall protectiveness of remedies. EPA agrees it is essential to ensure that ICs selected for a particular purpose in fact serve that purpose and remain a reliable and integral part of the remedy. As more sites mature into the long-term operation and maintenance phase, the need for reliable institutional controls and vigilance in administering them increases as well. However, a "missing IC," as defined in the Draft Report, does not by itself necessarily represent an unacceptable human exposure or environmental risk, or suggest a breach of remedy. For example, a landfill cap will still protect humans and the environment, even if no institutional controls exist to prevent digging, as long as no digging occurs and it remains intact. Conversely, a landfill cap with an institutional control preventing digging will not protect human health and the environment if digging has taken place contrary to the restriction. Whether a remedy continues to protect human health and the environment is not dependent on the mere presence or absence of an institutional control.

The Superfund Program conducts detailed remedy evaluations no less often than every five (5) years at sites that cannot support unlimited use and unrestricted exposure. This statutory threshold for site remedy reviews is also the policy threshold for determining whether a site requires ICs. The effect of using the same threshold for remedy reviews and ICs is that virtually all sites with ICs receive periodic reviews. The explicit purpose of the "Five-Year Review" is to critically evaluate the remedy to ensure it remains protective. During fiscal years 2003 and 2004 alone, the Superfund Program conducted over 400 Five-Year Reviews at NPL sites. Another 250 NPL sites are scheduled for evaluation in fiscal year 2005. The combined result is that almost the entire Superfund portfolio of construction completion sites will have relatively recent evaluations of whether the remedy remains protective. An analysis of Five-Year Reviews to date indicates that very few remedies have been deemed to not be protective. Further, of the very few sites with issues regarding protectiveness, the vast majority were related to an engineered remedy, rather than ICs. The important message is that the absence of an IC should not be interpreted to mean that a particular remedy results in unacceptable human exposure or environmental risk.

2. Evaluation of a small universe of sites may overestimate the number of sites with potential IC problems.

The second general comment involves the relatively small number of Superfund sites evaluated during the period 1991-1993 and the impact of this small universe on inferences drawn from the Draft Report. Specifically, there were four deleted Superfund sites with residual

contamination evaluated for the period 1991-1993. The Draft Report accurately states that two of the four, or 50%, of the deleted sites evaluated lack ICs. However, use of this statistic to estimate the number of older deleted sites would significantly overestimate the true number of deleted sites with residual contamination and no ICs in place for the Superfund Program. The Superfund Program conducted an evaluation of 890 Construction Complete sites in 2004, 280 of which are deleted. This research indicates that a significantly smaller percentage of deleted sites lack ICs. The Draft Report states that "results from nonprobability samples cannot be used to make inferences about a population;" however, a more direct statement – that the use of this statistic in any other context would be misleading – is likely appropriate. The aggregated average of the universe of sites evaluated in the Draft Report indicates that approximately 17% of the deleted sites may have IC issues. This statistic is much closer to EPA's internal analysis of the deleted sites with potential IC issues and is likely a much better measure of deleted sites with potential IC issues.

3. An increased use of ICs does not mean EPA advocates less treatment.

The final general comment involves the potential for misinterpreting the finding of an increased use of ICs. An increased use of ICs should not be interpreted to mean that less treatment is occurring at Superfund cleanups or under other cleanup programs. The Superfund Program continues to clean up sites consistent with the statutory preference for treatment and permanent remedies. The RCRA program takes a similar approach. The data in this Draft Report were not evaluated for, nor do they support, any inference that an increased use of ICs results in a reduction in treatment.

II. Responses to Draft Report Recommendations

1) Clarify Guidance on When Controls Should be Used

EPA concurs with GAO's recommendation to continue to develop cross-program guidance to clarify the role of ICs in EPA lead cleanups. The specific guidance documents developed or under development include:

a) *Identifying, Evaluating and Selecting ICs for Superfund, Federal Facility and RCRA Cleanups*
b) *Implementing, Monitoring and Enforcing ICs at Superfund, Federal Facility, RCRA, Brownfields and UST Cleanups**
c) *ICs and Communities at Superfund, Federal Facility, RCRA, Brownfields and UST Cleanups**
d) *ICs and Five-Year Reviews Guidance Supplement***
e) *IC Implementation and Assurance Plans***
f) *Regional Best Practices for ICs****

* currently draft final
** currently draft
*** planned draft 05

The combination of these six guidance documents will add significant detail and guidance on the use of ICs.

2) Demonstrate that, in Selecting Controls, Sufficient Consideration Was Given to All Key Factors

EPA concurs with GAO's recommendation that sufficient consideration of all key factors should be completed at remedy selection, but we do not necessarily agree that this information should be included in the remedy decision document. The Checklist for Implementing ICs contained in the September 2000 EPA guidance on identifying, evaluating, and selecting ICs, states explicitly that key criteria should be considered during the remedy selection phase, however, the guidance does not recommend the analysis to be documented in the remedy decision. This was a considered policy decision to allow EPA to present an "enforcement neutral" remedy description.

For example, it is not always clear at the remedy decision stage whether the remedy will be EPA lead versus private party lead, and whether the remedy will be completed under a judicial Consent Decree or Administrative Order. These different leads and enforcement approaches have significantly different enforcement and monitoring responsibilities. Also, flexibility at the remedy decision phase allows for the emergence of new IC tools. For example, many States are actively considering passing legislation like the Uniform Environmental Covenants Act as a new IC tool, and remedy flexibility will allow for these situations. EPA guidance encourages an appropriate evaluation at the Remedial Investigation/Feasibility Study phase and new guidance will recommend additional detail at the remedy design phase. The scope of the GAO review included only principal decision documents rather than all supporting documents. The evaluation of key factors may have occurred in the RI/FS and/or other remedy decision documents. The list of the sites evaluated in the GAO Draft Report was not provided, so EPA was unable to determine whether sufficient consideration was given to all key factors in other documents for the sites evaluated.

In the case of RCRA cleanups, EPA notes that in many cases facilities at the remedy selection phase will be subject to ongoing regulation – for example, under a RCRA permit or interim status standards – and under the control of a viable operator. In such cases, the RCRA permit or security requirements may well provide adequate institutional controls, enforceable by EPA or the authorized states. On the other hand, the situation may be very different if property transfer or redevelopment is contemplated. Therefore, EPA is convinced that flexible approaches are needed in assuring that RCRA facilities have acceptable engineering and institutional controls during and after remedy completion.

3) Ensure That the Frequency And Scope Of Monitoring Efforts Are Sufficient to Maintain the Effectiveness Of Controls

EPA concurs with GAO's recommendation. As noted in the Draft Report, one of the key challenges is that monitoring is often completed by parties other than EPA and often there is little leverage to compel these other parties to action. In response to this concern, EPA's draft Revised

Operation and Maintenance (O&M) checklist identifies additional IC specific O&M requirements; the draft Implementation, Monitoring and Enforcement guidance will require periodic evaluation and certification from a responsible entity at the site that the ICs are both in place and that they remain effective; the draft guidance supplement on ICs and Five-Year Reviews will include criteria on evaluating the effectiveness of ICs; and the IC Implementation and Assurance Plan guidance will include specific roles and responsibilities for monitoring efforts.

4) Ensure That The Information On Controls Reported In New Tracking Systems Accurately Reflects Actual Conditions

EPA concurs with GAO's recommendation regarding IC tracking. EPA has undertaken a concerted effort to gather accurate information on the status and effectiveness of ICs throughout their life-cycle. The Superfund program has added almost 900 sites to its tracking system and regions are currently undertaking a significant quality assurance effort to ensure that the information in the system reflects actual conditions. Over the next year, expedited reviews will be conducted at approximately 80 high priority Superfund sites and reviews will be conducted at the remaining Superfund IC sites over the next five years. Further, the Superfund Program is currently considering enhancing ICTS to include tracking implementation, monitoring, and enforcement responsibilities as well as other IC issues.

GAO Contacts and Staff Acknowledgments

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ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Public Health Assessment for

LCP CHEMICALS SUPERFUND SITE
and Adjacent Areas
BRUNSWICK, GEORGIA

EPA FACILITY ID: GAD099303182

APRIL 16, 2014

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i) (6) (H) for their information and review. The revised document was released for a 90-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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Use of trade names is for identification only and does not constitute endorsement by the Public Health Service or the U.S. Department of Health and Human Services.

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PUBLIC HEALTH ASSESSMENT

LCP CHEMICALS SUPERFUND SITE
and Adjacent Areas
BRUNSWICK, GEORGIA

EPA FACILITY ID: GAD099303182

Prepared by:

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
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Atlanta, Georgia 30333

Table of Contents

Summary

Introduction

The Agency for Toxic Substances and Disease Registry (ATSDR) in Atlanta, Georgia has evaluated environmental data from the LCP Chemicals Superfund Site in Brunswick, Georgia. The LCP Chemicals Superfund Site (LCP Chemicals Site) is located on Ross Road and occupies approximately 813 acres immediately northwest of the city of Brunswick. Tidal marshland covers more than 670 acres of the property. Former manufacturing operations at the LCP Chemicals Site are located on about 133 acres of dry land (upland), east of the marsh.

The current LCP Chemicals Site has been associated with industrial-related activities since at least 1919 (EPS 2007a). An oil refinery, a paint manufacturing company, a power plant, and a chlor-alkali plant have all operated at this site over the years. During various manufacturing activities by several companies, site soils in the dry-land portion of the site, groundwater beneath the site, and the tidal marsh adjacent to the site became contaminated with waste products from these operations (EPA 2011).

In September 2010, ATSDR released this public health assessment as a draft for public comment. The 2010 public health assessment focused on the evaluation of contaminants in soil in the 133 acres of dry-land area because this area is being redeveloped and could be used for either commercial or residential purposes. We received comments on the 2010 report, which are presented in Appendix F.

In addition, EPA collected environmental data since 2010, in part based on recommendations in the 2010 report. New data are available for soils, sediment, and pond water from the dry-land area and for sediment and seafood samples from a portion of the Altamaha Canal, just south of the site.

This final Public Health Assessment for the LCP Site presents the findings, conclusions, and recommendations that were part of the 2010 report as well as new findings, conclusions, and recommendations based on new environmental data.

ATSDR has conducted numerous activities at the site since it was added in 1996 to the National Priorities List of hazardous waste sites. These activities include the following:

- The 2010 public release of this public health assessment focused on the dry-land area. This public release made numerous recommendations to other agencies to collect additional environmental data, which now are part of this final release of the same report.

≠ A 2005 health consultation for the Arco neighborhood, which evaluated soil samples from the former Arco neighborhood adjacent to the LCP Site.

≠ A 1999 report about the consumption of seafood and wild game contaminated with mercury to evaluate self-reported symptoms and illnesses for persons who ate locally caught seafood. The report also assesses person's exposure to mercury and provided information that was used to develop recommendations for a seafood consumption advisory.

≠ A series of health consultations from 1994 to 1996 that evaluated the risk of harmful effects from consuming locally caught seafood from the Turtle River System contaminated with hazardous waste from the LCP site. These evaluations were used to develop the initial fish consumption advisory.

Throughout ATSDR's activities at the LCP site, we worked closely with federal, state, and local officials and most importantly with the community to assess the impact that the LCP site may have had on the residents of Brunswick and Glynn County. ATSDR has strived to serve the public by using the best science, take responsive public health actions, and provide trusted health information to prevent people from coming into contact with harmful toxic substances.

Overall Conclusion

ATSDR divided the 133 acres into half-acre grids to determine whether a grid would be a concern for future residential or commercial development. Some of these grids were found to contain harmful soil levels of mercury, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, lead, and dioxins should certain portions of the site be developed.

If the LCP Chemicals Site becomes residential, 66 half-acre grids have at least one chemical in soil that could harm the health of children and adults. If the site becomes commercial or industrial, 9 half-acre grids have at least one chemical in soil that could harm the health of workers (see figures below). Some uncertainty exists in this overall conclusion because uncertainty exists in the amount of chemical exposure that will occur after the site is developed and some dry-land areas were inadequately sampled.

This figure shows the 66 half-acre grids that are a health concern if the LCP Chemicals Site becomes residential.

This figure shows the 9 half-acre grids that are a health concern if the LCP Chemicals Site becomes commercial or industrial.

Conclusions 1-5

Conclusions 1-5 were presented in the September 2010 release of this report for public comment. The basis for these conclusions is environmental soil samples collected by the U.S. Environmental Protection Agency (EPA) predominantly in the 1990s, although a few samples were collected in the early 2000s. These conclusions focus on soil contamination in the dry-land area of the LCP site. During the 1990s, EPA also removed much of the contaminated soils from the site.

Conclusion 1 PCBs in Dry-land Area+

If certain dry-land areas of the LCP Chemicals Site become residential, polychlorinated biphenyls (PCBs) in soil at 41 half-acre grids on the site could harm the health of children and adult.

If certain dry-land areas of the LCP Chemicals Site become commercial or industrial, PCBs in soil in six half-acre grids on the site pose a health risk for commercial and industrial workers.

Basis for Decision (Conclusion 1)

Children and adults who come in contact with high PCBs in soil might experience harmful effects to the immune, dermal, nervous, developmental, and reproductive systems (ATSDR 2000). Specific health effects include

- ≠ Small changes in immune function as evidenced by a weakened response to an antigenic challenge,
- ≠ Mild damage to fingernails and toenails,
- ≠ Inflamed oil-producing glands associated with the eyes
- ≠ Gum recession,
- ≠ Learning and performance problems,
- ≠ Problems with attention and impulse control,
- ≠ Fewer male births,
- ≠ Lower birth weight,
- ≠ Longer menstrual cycles in women,
- ≠ An increase in cardiovascular disease in women,
- ≠ An increase in deaths from Parkinson disease in women,
- ≠ An increase in deaths from dementia in women, and
- ≠ An increase in diabetes in women.

Children and especially preschool children, with their nervous systems still developing, may be a particularly susceptible group if they come in contact with high PCBs levels in soil in some areas.

Commercial and industrial workers also are at risk of harmful effects if they have contact with soil in six half-acre grids of the site with the highest PCB

levels. Their estimated exposure to PCBs could cause the same health effects as listed previously.

Daily contact with PCBs in soil over many years poses a high cancer risk for children and adults should the site become residential. PCBs in soil pose a moderate cancer risk for workers if the site becomes commercial or industrial. Such exposure could put residents and workers at increased risk for several cancers, including cancers of the liver, thyroid, biliary tract, intestines and skin.

Some uncertainty exists when deciding if harmful effects might be expected because very little health information is available on the most common type of PCBs found in LCP soils. Therefore, ATSDR relied upon health information from other types of PCBs. Uncertainty also exists in estimating how much PCBs people will contact once the site is developed and from using results from soil samples that were collected 15 years ago. These soil samples may not represent current or future conditions at the site. In addition, some dry-land areas were insufficiently sampled.

Six half-acre grids on the site exceed the U.S. Environmental Protection Agency's (EPA) 1994 clean-up level for PCBs of 25 parts per million (ppm) while 41 grids have average PCB concentrations greater than 1 ppm. In the text of this report, see Table 4 for a list of grids that are a concern because of residual PCB contamination and see Figure 34 for their location.

Conclusion 2 Mercury in Dry-Land Area

If certain dry-land areas of the LCP Chemicals Site become residential, mercury in soil in 10 half-acre grids on the site could harm the health of children and the developing fetus if women are pregnant.

If certain dry-land areas of the LCP Chemicals Site become commercial or industrial, mercury in soil in four half-acre grids on the site could harm the health of the developing fetus if a female worker is pregnant. One of these half-acre grids also could harm the health of women who are not pregnant and the health of men.

Basis for Decision (Conclusion 2)

For women who live in the 10 half-acre grids on the site with high mercury concentrations in soil, the estimated intake of mercury from soil approaches or exceeds levels that cause harmful neurological effects to the fetus during pregnancy. Children born to these women might experience neurological effects involving language, attention and memory, and to a lesser extent visual/spatial and motor functions. The estimated exposure levels in preschool children who live in these areas also approach or exceed levels that could harm their health. They are at risk of the same neurological effects.

Mercury in soil in four half-acre grids on the site also poses a risk for commercial and industrial workers if the site is developed. Pregnant workers who have contact with mercury in soil in these areas are at risk of exposing their developing fetus to mercury levels that might cause harmful effects after birth. Some children born to women exposed to these levels might experience neurological effects involving language, attention and memory, and to a lesser extent visual/spatial and motor functions.

Male and female workers who have prolonged contact with soil from the one half-acre grid with the highest remaining mercury contamination also are at risk of harmful effects. Their estimated exposure level might result in damage to their neurological system, such as diminished sensitivity to pain, diminished touch, decreased fine motor performance, impaired vision, and impaired hearing.

Some uncertainty exists concerning the risk of harmful effects from mercury in soil. The chemical form of mercury in soil at the LCP Chemicals Site has not been well-established, although scientific studies from marsh sediment show that almost half the mercury is organic mercury. Therefore, ATSDR assumed that most of the mercury in soil at the LCP Chemicals Site was organic mercury. There's some uncertainty about whether the organic mercury bound to soil would cause harmful effects. In addition, uncertainty exists in the mercury concentrations in surface soil following development of the site and uncertainty exists from using the results from soil samples that were collected 15 years ago. These soil samples may not represent current or future conditions at the site.

Ten half-acre grids exceed EPA's 1994 clean-up level of 20 ppm mercury in soil. See Table 29 for a list of the 10 grids that are a concern because of residual mercury contamination and see Figure 37 for their location.

Conclusion 3 Lead in Dry-land Area

If certain dry-land areas of the LCP Chemicals Site become residential, lead in soil in 28 half-acre grids on the site could harm the health of children.

Basis for Decision (Conclusion 3)

If the site becomes residential, exposure to lead in soil at these 28 half-acre grids could increase children's blood lead levels and result in the following harmful effects:

≠ Small decreases in IQ,
≠ An increase in attention deficit hyperactivity disorder,
≠ Reduced attention span,
≠ Lack of concentration,
≠ Decreased fine muscle skills,
≠ Withdrawn behavior,

≠ Decreased height,
≠ Small delays in puberty, and
≠ Small changes in kidney function.

Some uncertainty exists in this conclusion because uncertainty exists in estimating children's exposure to lead in soil if the site becomes residential. Uncertainty also exists from using the results of soil samples that were collected 15 years ago. These soil samples may not represent current or future conditions at the site.

See Table 31 for a list of the 28 half-acre grids that are a concern because of residual lead contamination and see Figure 40 for their location.

Conclusion 4 PAH in Dry-land Area

If certain dry-land areas of the LCP Chemicals Site become residential, polycyclic aromatic hydrocarbons (PAHs) in soil in six half-acre grids on the site could harm the health of children and adults.

If certain dry-land areas of the LCP Chemicals Site become commercial or industrial, PAHs in soil in two half-acre grids on the site could harm the health of workers.

Basis for Decision (Conclusion 4)

Daily contact with PAHs in residential soil over many years poses a moderate risk of certain cancers for children and adults. Similarly, workers also have a moderate risk of certain cancers should some areas become commercial or industrial. Such exposure could put residents and workers at increased risk for lung and skin cancers.

Some uncertainty exists in these conclusions because uncertainty exists in estimating how much PAHs people will contact once the site is developed. Uncertainty also exists from using the results from soil samples that were collected 15 years ago. These soil samples may not represent current or future conditions at the site.

See Table 35 for the list of half-acre grids that are a concern because of residual PAH contamination and see Figure 41 for their location.

Conclusion 5 Mixtures of PCB, Mercury, and Lead in Dry-Land Area

If certain dry-land areas of the LCP Chemicals Site become residential, contact with soil containing a mixture of PCBs, mercury, and lead (or a combination of these) could harm the health of children.

Basis for Decision (Conclusion 5)

Studies have shown that children exposed to low levels of PCBs, mercury, and lead showed impaired learning of a performance task, resulting in problems with attention and impulse control.

Three grids have elevated levels of PCBs, lead, and mercury; eight grids have elevated levels of PCB and lead; and, five grids have elevated levels of PCBs and mercury. See Figure 42 for the location of these grids.

Conclusions 6–12

Conclusions 6–12 are based on new environmental samples collected by EPA after 2010. Many of these samples were collected in response to recommendations from ATSDR in the December 2010 public release version of this report. The new environmental samples consist of soil samples from the dry-land area with a focus on the former drive-in theater and the pond in the northwest corner of the site. EPA also collected sediment and seafood samples from the Altamaha Canal just south of the LCP Site.

Conclusion 6 Dioxin in Dry-land Area

In 2011, EPA collected soil samples from eight, dry-land areas and measured dioxin levels. These dry-land area varied in size and thus consisted of varying numbers of half-acre plots. One sampling area consisting of 30 half-acre plots contained dioxins in soil that could harm the health of children and adults should this area become residential.

Basis for Decision (Conclusion 6)

Daily contact with dioxins in soil in this one area over many years poses a high risk of cancer for children and adults. Human studies have shown that dioxin can cause liver cancer and might be associated with cancers of the lung, colon, prostrate, breast, blood, and lymphatic system. Rodent studies have confirmed that dioxin can cause cancer at multiple sites, including the liver, lung, mouth, and thyroid.

In addition, preschool male children who have daily contact with these soils could be at risk of reproductive effects once they reach adulthood. As adults, they might experience problems with (1) decreased number of sperm, (2) decreased number of motile sperm, and (3) fewer male offspring

The location of this 30 half-acre area contaminated with dioxin is shown in Figure 43 and is labeled as sampling area 8.

Conclusion 7 Former Theater

In 2010, EPA collected soil samples from the former theater area in the northeast section of the site. Glynn County plans to build a detention center in this area so ATSDR evaluated the risk for adult workers and inmates who might come in contact with chemicals in soil. Mercury, lead, and PCBs in soil from the former drive-in theater area is not expected to harm people's health.

Basis for Decision (Conclusion 7)	The mercury and lead levels in soil in the former theater area were either below ATSDR's screening levels or the levels were at or near background levels in soils. Therefore, harmful effects from mercury and lead in soil are not likely. The exposure of prison inmates and adult workers to PCBs in soil would be at levels far below ATSDR's health guideline for PCBs. Therefore, PCBs in soil are not likely to cause harmful, non-cancerous effects. The risk of cancer from daily exposure to PCBs in soil is insignificant.
Conclusion 8 On-site Pond	In 2010, EPA collected surface water and sediment samples from the on-site pond in the northwest corner of the dry-land area. The levels of PCBs, mercury, PAHs, and lead in surface water and sediment from the on-site pond are not expected to harm people's health.
Basis for Decision (Conclusion 8)	Levels of PCBs, mercury, PAHs and lead in the on-site pond were either below ATSDR's comparison values or at background levels. In addition, the pond does not serve as a source of drinking water nor does the pond support fish.
Conclusion 9 Sampling Sufficiency for Dry-land Area	Some dry-land areas do not have adequate sampling data; therefore, it is difficult to draw conclusions about whether these unsampled soils could harm people's health. Most of the insufficiently sampled areas are in the southeastern portion of the site (including the cell building area) and in the western dry-land area closest to the marsh. For other areas that have been sufficiently sampled, we are able to draw conclusions about potential health impacts.
Basis for Decision (Conclusion 9)	One reason for the limited sampling in some areas is that EPA decided that some environmental data were unusable because of data quality issues. In addition, some areas were not sampled because LCP Chemicals did not perform industrial activities on certain portions of the site. However, numerous industries occupied the site before LCP's chlor-alkali facility, and those industries could have disposed of waste throughout the property. Approximately half of the grids are considered sufficiently sampled for making a health conclusion for the chemicals PCBs, mercury, and lead. That means that half of the grids require additional sampling in order to be sure that those areas are not contaminated. See Figures 22 through 25 for the dry-land areas considered to have adequate sampling data.

Conclusion 10 Altamaha Canal

In 2011, EPA collected sediment samples from a portion of the Altamaha Canal that exists south of the LCP Site. ATSDR evaluated the risk of harmful effects from exposure to PCBs, mercury, PAHs, and dioxins in sediment along the Altamaha Canal. Adults and children who visit or play along the canal would not be exposed to contaminants in sediment at levels that could cause harmful, non-cancerous effects. It is unlikely that contact with these chemicals in sediment could cause cancer.

Basis for Decision (Conclusion 10)

These chemicals are not a health concern in Altamaha Canal sediment because:

≠ The concentration of lead in sediment from the canal is at or near background lead levels in soils and is unlikely to cause harmful health effects from direct contact,

≠ The concentration of mercury is below ATSDR's comparison value; therefore, mercury in sediment is unlikely to cause harmful health effects from direct contact,

≠ The estimated exposure to dioxins and PCBs for adults and children who visit or play along the canal is well below ATSDR's and EPA's health guidelines. Therefore, harmful non-cancerous effects are not likely. The estimated exposure to PCBs, PAHs, and dioxins for adults and children who visit or play along the canal results in insignificant cancer risks.

Conclusion 11 Mercury in Seafood from Altamaha Canal

In 2011, EPA collected fish and shellfish samples from the canal. ATSDR estimated exposure to mercury from eating various fish and shellfish from the Altamaha Canal and reached the following conclusions about adults and children with typical and high fish consumption:

≠ Mercury levels in mullet and shrimp from the Altamaha Canal is not expected to harm people's health.

≠ Mercury levels in blue crab, red drum, and sea trout is not expected to harm the health of typical fish consumers but could harm the health of high fish consumers.

Basis for Decision (Conclusion 11)

Depending upon age and race, high fish consumers eat about 2 to 7 ounces of fish and shellfish daily. Typical fish consumers eat about a half to 2 ounces of fish daily. These daily fish consumption rates do not necessarily mean that people eat fish every day. Their fish consumption averages out to the rates previously described. For example, someone with a daily fish consumption rate of 2 ounces might eat one 14 ounce fish meal a week or two 7 ounces fish meals a week. This frequency and amount of fish consumption averages out to two ounces of fish eaten daily.

≠ Typical and high fish consumers of mullet and shrimp from the Altamaha Canal have estimated exposures to mercury that are well below levels that cause harmful effects. Typical fish consumers of blue crab, red drum, and sea trout from the Altamaha Canal have estimated exposures to mercury that are well below levels that cause harmful effects.

≠ High fish consumers of blue crab, red drum, and sea trout from the Altamaha Canal have estimated exposures to mercury that approach levels that can cause harmful effects in young children and in children born to pregnant women who are high consumers. These children might experience neurological effects involving language, attention and memory, and to a lesser extent visual/spatial and motor functions.

Some uncertainty exists in the conclusions for sea trout and red drum because only one fish of each species was collected from the Altamaha Canal.

Conclusion 12 PCBs in Seafood from Altamaha Canal

Fish and shellfish from the Altamaha Canal were also found to contain PCBs. ATSDR estimated exposure to PCBs from eating various fish and shellfish from the Altamaha Canal and reached the following conclusions about adults and children with typical and high fish consumption:

≠ PCB levels in red drum, blue crab, and shrimp is not expected to cause harmful, non-cancerous effects.

≠ PCB levels in sea trout is not expected to harm the health of typical fish consumers, but could harm the health of high fish consumers.

≠ PCB levels in mullet could harm the health of typical and high fish consumers.

The results of the fish and shellfish sampling from the Altamaha Canal support the current fish advisory for the Turtle River system issued by the Georgia Department of Natural Resources (GDNR). The Altamaha Canal is tidally connected to the lower Turtle River through several waterways and GDNR has fish and shellfish consumption advice specifically for the lower Turtle River. See Table 46 for more information about the state's fish and shellfish consumption recommendations for the lower Turtle River.

Basis for Decision (Conclusion 12)

The basis for this decision are:

≠ Typical and high fish consumers of red drum, blue crab, and shrimp have estimated exposures to PCBs that are well below levels that can cause harmful, non-cancerous effects. Typical fish consumers of sea trout have estimated exposures to PCBs are well below levels that can cause harmful, non-cancerous effects.

≠ High fish consumers of sea trout and typical and high fish consumers of mullet have estimated exposure to PCBs that approach levels that can cause harmful, non-cancerous effects.

High consumers of sea trout and typical and high consumers of mullet might experience the following harmful effects to the immune, dermal, nervous, developmental, and reproductive systems. Specific health effects include:

- ≠ Small changes in immune function as evidenced by a weakened response to an antigenic challenge,
- ≠ Mild damage to fingernails and toenails,
- ≠ Inflamed oil-producing glands associated with the eyes
- ≠ Gum recession,
- ≠ Learning and performance problems,
- ≠ Problems with attention and impulse control,
- ≠ Fewer male births,
- ≠ Lower birth weight,
- ≠ Longer menstrual cycles in women,
- ≠ An increase in cardiovascular disease in women,
- ≠ An increase in deaths from Parkinson disease in women,
- ≠ An increase in deaths from dementia in women, and
- ≠ An increase in diabetes in women (ATSDR 2000).

Children and especially preschool children, with their nervous systems still developing, may be a particularly susceptible group.

Children and adults who frequently eat mullet from the Altamaha Canal for many years also have a high increased risk for several cancers, including cancers of the liver, thyroid, biliary tract, intestines and skin.

Next Steps

ATSDR recommends

1. Restricting some LCP Chemicals Site areas from residential development unless further steps are taken to prevent contact with PCB, mercury, lead, PAH, and dioxin contamination that remains in soil on the property.

2. Restricting some LCP Chemicals Site areas from commercial or industrial use unless further steps are taken to prevent contact with PCB, mercury, and PAH contamination that remains in soil on the property.

3. Additional soil sampling in and around the former cell building's footprint because of residual soil contamination if future plans include development of this area.

4. Additional sampling in areas where sampling data are limited. In general, the western portion of the site has been sampled more than the eastern portion. Particular attention should be given to the former cell building area should the land use change and to future enclosed structures built above the caustic brine pool area.

5. Continued monitoring of fish and shellfish in the Turtle River and in the marsh near the LCP Chemicals Site. The Georgia DNR continues to monitor seafood in the area and to maintain the fishing advisory for the Turtle River System.

6. Continuation of the GDNR's fish advisory for the Turtle River System. The major components of this advisory are provided in Tables 43-46 of this health assessment. GDNR's recommendations for the lower Turtle River (see Table 46) apply for fish obtained from the Altamaha Canal.

   The 2013 GDNR fish advisories for rivers, lakes, and estuaries in Georgia, including the Turtle River system, can be found at this website: http://www.gaepd.org/Documents/fish_guide.html. To view their brochure, click on "Guidelines for Eating Fish from Georgia's Waters, 2013".

   In addition, GDNR has a brochure, 'A woman's guide for eating fish and seafood from coastal Georgia'. This brochure is available at http://health.state.ga.us/pdfs/environmental/chemhazard/fish%20consumption/wfcg_coastal.pdf.

For More Information

ATSDR's Public Health Assessment for the LCP Chemicals Superfund Site is available at this internet address: http://www.atsdr.cdc.gov/sites/lcp/.

For more information about ATSDR's work at the LCP Chemicals Superfund Site, you should contact ATSDR at 1-800-CDC-INFO (1-800-232-4636) and ask to be transferred to Dr. David Mellard or you can dial Dr. Mellard direct at 770-488-0727.

I. PURPOSE AND PUBLIC HEALTH ISSUES

The purpose of this document is to describe ATSDR's public health assessment activities at the LCP Chemicals Superfund Site (aka LCP Chemicals Site) and to provide the Agency's opinion about the public health significance of exposure to chemicals at the site. A public health assessment (PHA) is a document prepared after an evaluation of pertinent environmental data, community concerns, and, when appropriate, health outcome data, to determine whether people have been, are being, or will be exposed to hazardous substances; and, if so, whether those exposures are harmful. If the exposure is harmful, ATSDR will recommend actions to prevent or reduce those exposures.

The LCP Chemicals Site was placed on the U.S. Environmental Protection Agency's (EPA's) National Priorities List (NPL) in June 1996. In the 1990s, ATSDR prepared several health consultations (HC) for the site, most of which focused on potential health impacts from eating local fish and seafood. However, the community remained concerned because ATSDR had not prepared a PHA for the LCP Chemicals Site. A local environmental group, the Glynn Environmental Coalition, requested that ATSDR conduct a PHA for the LCP Chemicals Site. ATSDR reviewed its activities at the site and in 2004 agreed that a PHA was warranted. Staff members from ATSDR were assigned and conducted additional site visits to learn about community concerns. During these initial meetings, residents expressed concern about whether site-related contaminants might have migrated into the nearby Arco neighborhood, and whether these potential exposures could result in adverse health effects. ATSDR worked with EPA, Honeywell, [one of the parties responsible for the contamination], and the Glynn Environmental Coalition to create a neighborhood soil sampling plan. These efforts resulted in another HC focused specifically on neighborhood soil issues; this HC was released in 2005.

Since that time, ATSDR staff has worked to understand the extensive environmental data that exist for the LCP Chemicals Site. Because the LCP Chemical property is scheduled for redevelopment, ATSDR focused on potential exposures to future populations once the site is redeveloped.

ATSDR prepared this PHA using available data. At the time of publication of this document, a full evaluation of the nature and extent of groundwater contamination (defined by EPA as Operable Unit 2) had not been completed. Therefore, ATSDR will focus this PHA on the dry-land soils region of the LCP Chemicals Site, with some information about the pond and marsh areas that also are part of the site, and the off-site Altamaha Canal area. EPA documents refer to the dry-land areas as upland soils; EPA's investigations of these areas are part of Operable Unit 3.

The public comment version of this document was released in September 2010. ATSDR received comments on the document from the general public and other third party entities. ATSDR's responses to the comments are in Appendix F of this document. ATSDR has added to this document an evaluation of new environmental data received since the public comment release in September 2010. The evaluation of new data is discussed separately.

II. BACKGROUND

II.A. Site Description

The LCP Chemicals Site is located on Ross Road in Brunswick, Glynn County, Georgia. It occupies approximately 813 acres immediately northwest of the city of Brunswick. The site is bordered by a county land disposal facility and a pistol firing range on the north, Ross Road on the east, the Turtle River and associated marshes on the west, and Georgia-Pacific Cellulose to the south. (See Figure A1 in Appendix A). Tidal marshland comprises more than 670 acres of the property. Former manufacturing operations at the LCP Chemicals Site were located on approximately 133 acres of dry-land area, east of the marsh (EPS 2007a).

II.B. Site History

The current LCP Chemicals Site has been associated with industrial-related activities since at least 1919 (EPS 2007a). An oil refinery, a paint manufacturing company, a power plant, and a chlor-alkali plant have all operated at this site over the years. During various manufacturing activities by several companies, site soils, groundwater, and the tidal marsh became contaminated. The contamination resulted from past manufacturing operations at the site (EPA 2011).

Past industrial operators and activities include:

≠ ARCO Petroleum (1919–1935), a successor of the Atlantic Refining Company, operated the site as a petroleum refinery that refined crude oil into fuel and oils. At one time, over 100 process and storage tanks were present on site. ARCO may have released petroleum products and wastes onto the ground.

≠ Georgia Power (1937–1950s) purchased portions of the site at various times between 1937 and 1950. The property purchased by Georgia Power included two parcels of land, two 750 kilowatt (kW) electric generators, and an additional 4.0 megawatts of electric generation capacity. Georgia Power may have released polychlorinated biphenyls (PCBs) onto the ground.

≠ The Dixie Paint and Varnish Company (later known as the Dixie O'Brien Corporation) (1941-1955) operated a paint and varnish manufacturing facility on a portion of the site south of the Georgia Power parcel. The Dixie Paint and Varnish Company is reported to have generated lead- and mercury-containing wastes at the site. These wastes may have been released by the O'Brien Paint Company operations at the site from 1942 to 1955.

≠ Allied Chemical and Dye Corporation (aka, AlliedSignal; Honeywell) (1950s–1979) acquired most of the land constituting what is now known as the LCP Chemicals Site. Allied Chemical operated a chlor-alkali facility at the site, principally for the production of chlorine gas, hydrogen gas, and caustic solution. The plant operated using the mercury cell process, which involves passing a concentrated brine solution between a stationary graphite or metal anode and a flowing mercury cathode to produce chlorine gas, sodium hydroxide (caustic) solution, and hydrogen gas, as a by-product. Sodium hypochlorite (bleach) was also produced in a secondary reaction.

Allied Chemical may have released mercury, mercury-containing wastes, and other chemicals onto the ground.

≠ LCP Chemicals (1979–1994) purchased the property and chlor-alkali plant in 1979. The chlor-alkali process continued with modification following the purchase. Part of the modification included the production of hydrochloric acid by reacting chlorine and hydrogen. LCP Chemicals is reported to have released mercury, mercury-containing wastes, and other chemicals onto the ground at the site before ceasing operations in 1994.

Upon the plant's closing in February 1994, the State of Georgia asked EPA to take immediate action at the site to address the threat of releases of chlorine gas and the flow of contamination into the adjacent saltwater tidal marsh containing endangered species. In 1994, EPA issued a Unilateral Administrative Order for Removal (UAO) which directed cleanup operations at the site. The LCP Chemicals Site was proposed for listing on the National Priorities List (NPL) in October 1995. The site was finalized on the NPL in June 1996 (EPA 2002).

The LCP Chemicals Site is currently divided into operable units to address the different contaminated media at the site. Operable Unit 1 (OU1) previously represented the marsh and dry-land soils and OU2 represented groundwater. In 2005, EPA redefined the operable units as follows: OU1 represents the marsh, OU2 represents groundwater, and OU3 represents the dry-land (upland) soils. OU3, dry-land soils, is the focus of this public health assessment ATSDR also reviewed data from the on-site pond, the marsh, the Altamaha Canal and other off-site areas. Other OUs may be examined when the data are available for review.

II.C. Summary of Removal Response Actions

Between 1994 and 1997, a removal action was performed on the dry-land portion of the Site. The removal action included the excavation of contaminated soils and industrial process waste from 26 discrete areas. A total of approximately 167,000 cubic yards of soil, sediment, and waste was removed during these actions. The removal areas contained material contaminated with constituents including petroleum hydrocarbons (volatile and semi-volatile organic compounds), mercury, alkaline sludge, polychlorinated biphenyls (PCBs), and lead. Between 1998 and 1999, the removal response action was extended to approximately 13 acres within the marsh and 2,650 linear feet of tidal channels (EPA 2011).

During the removal response action, the petroleum process buildings and the mercury cell buildings were among the structures dismantled onsite. The mercury cell buildings were demolished to the slab at grade and the area capped and fenced.

As stated above, the LCP Chemicals Site is comprised of 3 operable units: OU1 represents the marsh, OU2 represents groundwater, and OU3 represents the dry-land soils. The cleanup/removal activities for each operable unit are summarized below.

II.C.1. Marsh (OU1)

A large dispersion of mercury and polychlorinated biphenyls (PCBs) occurred throughout the marshlands as a result of the chemical manufacturing processes undertaken at the site between

1955 and 1979. EPA estimates that more than 380,000 pounds of mercury were "lost" in the area during this period. In addition to mercury and PCBs, lead, other metals, and volatile organic compounds contaminated the marshlands area, a 1-mile portion of the Turtle River, and the entirety of Purvis Creek (EPA 2011).

Mercury and PCBs were detected in aquatic life at levels sufficient to produce a ban on commercial fishing in these areas and a seafood consumption advisory for parts of the river and all of the creek. In 1992, the Georgia Environmental Protection Division (GEPD) issued a seafood consumption advisory for fish, crabs, oysters and other seafood harvested in the Turtle River estuary after mercury and PCBs were found in seafood samples. The seafood consumption advisory remains in effect at the time of the publication of this document and is available at this State of Georgia website: http://www.gaepd.org/Documents/fish_guide.html (GDNR 2012).

Between 1998 and 1999, a removal response action was conducted on approximately 13 acres within the marsh and 2,650 linear feet of tidal marshes. Removal activities included the excavation and off-site disposal of contaminated sediment and waste materials as a part of EPA's Remedial Investigation/Feasibility Study (RI/FS), additional ecological (biota and sediment) sampling was conducted.

II.C.2. Groundwater (OU2)

Groundwater monitoring has occurred periodically at the site since 2001. Leakage of mercury contamination was discovered beneath a sandstone layer. As a result, horizontal wells were installed in 2002 (approximately 75 feet below ground surface). In addition, a caustic brine pool which has a high pH was discovered beneath the site. A phytoremediation project was approved by EPA during November 2003. The purpose was to locally suppress the groundwater table to prevent seepage of groundwater to the marsh and staining of marsh sediments from occurring (EPA 2009). The phytoremediation project is reported to have failed because all of the poplars and many of the pine trees died (GDNR 2010).

EPA negotiated an Administrative Order of Consent (AOC) with Honeywell on April 18, 2007. According to the AOC, the caustic brine pool (CBP) will be extracted to meet the following removal action objectives: 1) reduce the pH of the CBP to less than 10.5, and 2) reduce the density of the CBP. The removal action began on September 25, 2007.

As of 2012, a total of 138 monitoring wells and 12 horizontal wells are on the site (EPS 2012). In 2012, Honeywell tested the feasibility of using CO_2 sparging to remediate the subsurface CBP. The results of the test show that CO_2 sparging is an effective technology for full-scale implementation at the site, and should be conducted over a multiple-year, sequential effort (Mutch Associates 2013). The results of the sparging effort were not available at the time of publication of this document.

II.C.3. Upland Soils (OU3)

A removal response action was performed on the dry-land (upland) portion of the LCP Chemicals Site from 1994 to 1997. The removal action included the excavation of contaminated soils and industrial process waste from 26 geographical areas on the site. A total of

approximately 167,000 cubic yards of soil and waste was removed during these actions. The removal areas contained material contaminated with constituents including petroleum hydrocarbons (volatile and semi-volatile organic compounds), mercury, alkaline sludges, polychlorinated biphenyls (PCBs), and lead. (EPA 2009)

During the removal response action, the petroleum process buildings and the former mercury cell buildings were among the structures dismantled. The mercury cell buildings were demolished to slab and the area capped and fenced.

II.D. Site Features

A dominant physical feature of the site is the approximately 670 acres of tidal marsh located in the western areas of the site. The salt marsh is characterized by a flat, heavily vegetated surface dissected by numerous channels and larger creeks under tidal influence from nearby Turtle River. The dry-land area to the east of the marshland is characterized by gently sloping terrain ranging from approximately 5 feet above mean sea level along the marsh/dry-land border to an elevation of approximately 15 feet along Ross Road. This area of the site is roughly divided in half by the east-west entrance road (EPS, 2007a) (See Figure A2 in Appendix A). Other notable features include an onsite pond and a former drive-in theater in the northern portion of the site (See Figure A3 in Appendix A).

The locations of the site's past industrial operations and staging areas are depicted in Figure A4 in Appendix A. A total of 26 discrete removal areas were delineated on the site. Operations related to the chlor-alkali process were primarily located in the areas south of the entrance road and the area of the boiler house, along with smaller isolated waste disposal areas dispersed over the northern half of the site. Refinery operations were present over most of the dry-land areas (EPA 2009).

II.E. Site Visit

Staff members from ATSDR visited the LCP Chemicals Site on several occasions to conduct activities as part of the PHA process. Beginning in September 2004, ATSDR conducted a public availability session to speak with the community to gather community concerns and to assess site conditions. ATSDR conducted additional visits in October 2006, March 2007, and July 2009. ATSDR also met with state, local, or Honeywell representatives on numerous other occasions from 2004 until present.

During our March 2007 visit, staff members from ATSDR, Honeywell, EPA, and the Glynn County Health Department toured the site by land and car. At the time of the visit, all industrial operations at the site had ceased. Many of the industrial buildings and structures had been removed from the site. An office building and a guard house stood at the entrance of the site. The footprint of several demolished buildings could be observed only by the above ground concrete pads.

The LCP Chemicals Site is currently surrounded by barbed-wired fencing on all sides except for the back of the site which faces Purvis Creek and the Turtle River. Purvis Creek is accessible from the Turtle River. Vehicle entry to the site is controlled by a guard at the main gate. During

site operations, residences were located just outside the fence on the southeastern boundary of the site. Recently, a portion of the Arco neighborhood southeast of the site was torn down. Currently, the closest residential areas are approximately 300 yards north of the site and about 600 yards southeast of the site.

There are no full-time production workers at the facility. However, there are full-time and/or part-time employees who work in the administration and security buildings. Remedial workers occasionally access the site to conduct site-related remedial activities.

II.F. Demographics

Demographic information characterizes the populations potentially affected by the site and the current population trends. Identifying the presence of potentially sensitive populations, such as young children (aged 6 and under), the elderly (aged 65 and older), and women of childbearing age (ages 15 to 44), is particularly important because these sub-groups could be more sensitive to environmental exposures than the general population.

According to the 2010 U.S. census, approximately 4,202 people live within a 1-mile radius of the site. Of this total population, approximately 451 are children aged 6 and younger, 519 are adults aged 65 and older, and 827 are women of childbearing age. See Figure A5 in Appendix A for more detailed demographic information.

II.G. Past ATSDR Health Evaluations

At various times throughout the history of this site, ATSDR has evaluated potential risks for humans near the LCP Chemicals Site, including the Arco neighborhood. A summary of ATSDR's past activities and reports is included below to highlight the progression of events and activities at the site. Full reports may be obtained by contacting any of the contacts listed at the end of this report, by calling ATSDR's toll-free hotline at 1-800-CDCINFO, or by visiting ATSDR's website for the LCP Chemicals Site at this URL: http://www.atsdr.cdc.gov/sites/lcp/.

II.G.1. Health Consultation, Arco Neighborhood 2004 Soil Samples – June 2005

ATSDR prepared a report in June 2005 titled, Health Consultation, Arco Neighborhood 2004 Soil Samples, LCP Chemicals Site (ATSDR 2005a). This health consultation (HC) evaluated the public health significance of certain chemicals in soil in the Arco neighborhood. The HC was prepared in response to residents' concern about soil contamination in their neighborhood because of past industrial activities related to the LCP Chemicals Site. EPA collected soil samples from residential yards and measured for mercury, lead, arsenic, polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs), which included Aroclor 1268.

ATSDR concluded that:

≠ The concentration of lead at all but one of the properties in the Arco neighborhood is not a public health hazard. The lead contamination at one property in the Arco neighborhood was a public health hazard for children aged 6 and younger who might frequently play there.

≠ The levels of other chemicals (arsenic, mercury, PAHs, and PCBs) in soil from the Arco neighborhood are not a public health hazard.

II.G.2. Final Report, Consumption of Seafood and Wild Game Contaminated with Mercury – July 1999

In July 1999, the Glynn County Health Department (GCHD), in cooperation with ATSDR, conducted a study that evaluated the potential health effects associated with consuming seafood and wild game from the Turtle River and its tributaries (GCHD 1999). The study was in response to concerns regarding the consumption of mercury-contaminated seafood and wild game from these areas. The GCHD conducted a community-based study which compared 211 residents who may have been exposed to mercury by consuming seafood and wild game from the waters of the Turtle River (target group) to 105 residents who reported that they had not consumed seafood and wild game from those areas (comparison group).

The objectives of the study were: 1) to compare the prevalence of self-reported symptoms and illnesses between target and comparison group participants; 2) to determine seafood and wild game consumption levels among study participants and to assess the accuracy of the self-reported consumption levels; 3) to provide a basis for developing sound recommendations for seafood consumption advisories to the community; and 4) to assess individuals for evidence of mercury exposure using biological evidence (24-hour urine mercury test).

GCDH concluded that:

- ≠ Participants in the target group reported a statistically higher number of symptoms compared with participants in the comparison group. The symptoms were lightheadedness, difficulty concentrating, trouble remembering, problems retaining reading/conversations, irritability, and sleep changes.
- ≠ Respondents generally underestimated their amount of seafood consumption as reported in the questionnaire when compared to the amount they reported actually consuming as measured by the two-week dietary diary.
- ≠ Seafood comprised a smaller proportion of protein in study participants' diets than anticipated.
- ≠ The current seafood consumption guidelines are protective for the general public because individuals are not consuming more seafood per meal than values used in calculating the consumption guidelines.
- ≠ The majority of study participants do not fish in the restricted area; the few that do, however, state that they are aware of the advisory.
- ≠ All study participants had urine mercury concentrations levels below the reference level of 20 µg mercury/g creatinine.
- ≠ There is evidence that the target group consumed seafood from the restricted area, without evidence of high mercury burden.

Additionally, the GCDH recommended continued public education about the hazards of consuming contaminated seafood and continued monitoring of mercury levels in seafood and wild game.

One of the study objectives was to assess mercury exposure in recreational, commercial, and subsistence fishers. Of the 101 (65%) target group participants who self-reported which type of fisher they were:

- 97 (96%) classified themselves as recreational fishers,
- 3 (3%) identified as commercial, and
- 1 (1%) identified as subsistence fisher.

Therefore, the study results reflect characteristics of recreational fishers and do not necessarily apply to commercial or subsistence fishers.

In addition, urine mercury results might have been influenced by prior knowledge of the risks associated with mercury in fish. Participants might have reduced their fish intake following the dietary recall survey as they realized that they might be consuming too much mercury-contaminated fish. A more appropriate test of mercury exposure would have been hair mercury levels because it is a better indicator of long-term methylmercury exposure than urinary mercury levels. A more appropriate reference level to determine whether excessive urinary mercury levels were present would have been 2 micrograms per gram creatinine (µg/g) instead of 20 µg/g.

And finally, it should be noted that African-Americans made up only 4% (9 out of 211) of the people who participated in the study. African-Americans make up 26% of the population of Glynn County and nearly 40% of the population within four miles of the LCP Chemicals Site. Therefore, African-Americans are underrepresented in the Brunswick fish study.

A study of fishers along the Savannah River showed that African-Americans

- Eat more fish meals per month than whites (average, 5.4 vs. 2.9),
- Eat slightly larger portions than whites (average, 13.7 oz. vs. 13.1), and
- Eat higher amounts of fish per month than whites (average, 75 ounces vs. 41 ounces).

It is reasonable to assume that the fish-eating habits of African-Americans in Brunswick, Georgia, are similar to African-Americans along the Savannah River. Therefore, African-Americans who fish along the Turtle River are likely to have higher exposure to mercury from eating fish than whites. The results of the Brunswick fish study should not be applied to African-Americans in the Brunswick area for those reasons.

II.G.3. Health Consultation, LCP Chemical – October 1996

ATSDR prepared a HC in October 1996 to evaluate post-removal conditions at the LCP Chemicals Site. The HC was prepared in response to concerns about conditions after on-site removal and containment actions had been completed, and whether contaminant levels in seafood were a public health hazard. [ATSDR had previously identified the site as a public health hazard in August 1994 because the uncontrolled release of mercury into the environment posed an imminent threat to human health (ATSDR 1994)]. From 1994 to 1996, extensive seafood sampling took place and several studies were in progress, including the Emory University Former LCP Workers Health Study and the Brunswick Area Fish Consumption Study. However, at the time of the release of the 1994 health consultation, ATSDR did not have sufficient information to determine whether exposures to contaminants were occurring at levels that could be a health concern.

Therefore, ATSDR concluded in 1996 that:

- ≠ The LCP Chemicals Site is an indeterminate public health hazard because there is insufficient exposure information to support any other public health classification. However, this classification may change when additional pending data are evaluated. (e.g., results from the seafood consumption survey).
- ≠ The food chain in the LCP marsh, the Turtle River, and Purvis Creek and its tributaries is contaminated with mercury and PCBs because of past disposal practices.
- ≠ On-site removal and containment have stopped the movement of contaminants into the marsh.
- ≠ Marsh sediments are contaminated because of past disposal practices due to migration from the LCP Chemical Site.
- ≠ The nature and extent of groundwater contamination in the shallow aquifer is unknown. The water that people use for drinking is not contaminated.
- ≠ On-site surface and subsurface soils are contaminated but do not pose a health threat to people off-site because they have no contact with on-site soils.
- ≠ Off-site soils are not contaminated from past disposal practices.
- ≠ Several data gaps are yet to be filled (e.g., fish consumption and health studies).

II.G.4. Health Consultation, LCP Chemical – August 1994

In 1994, ATSDR prepared its first HC for the LCP Chemicals Site that evaluated the public health implications of exposure to mercury and PCB-contaminated seafood along areas of Purvis Creek and the Turtle River. Seafood samples collected in 1991, 1992 and 1993, revealed the presence of elevated levels of mercury and PCBs.

After evaluating the data, ATSDR concluded in 1994 that:

- ≠ Residents who have consumed fish and shellfish from Purvis Creek and other restricted fishing areas nearby may have been exposed to unsafe levels of PCB and mercury prior to the fish advisory.
- ≠ Exposures to contaminated fish may be ongoing due to noncompliance or lack of awareness of the existing fishing advisory.
- ≠ Fish and shellfish may continue to bioaccumulate mercury and PCBs until the source of contamination is removed.
- ≠ There is no evidence of residents being exposed to on-site or off-site surface water and sediment contamination.
- ≠ Since off-site private wells are upgradient from the site, it is unlikely that offsite wells are contaminated.

III. EVALUATION OF EXPOSURE PATHWAYS

To determine whether nearby residents or on-site workers could be exposed to contaminants on the site, ATSDR will now describe the environmental and human components that could result in exposure to remaining contaminants on the site or to contaminants that have migrated off site.

III.A. What is an exposure pathway?

ATSDR's PHAs are driven by exposure to, or contact with, environmental contaminants. Contaminants released into the environment have the potential to cause harmful health effects. Nevertheless, a release does not always result in exposure. People can only be exposed to a contaminant if they come in contact with that contaminant—if they breathe, eat, drink, or come into skin contact with a substance containing the contaminant. If no one comes in contact with a contaminant, then no exposure occurs, and thus no health effects could occur. Often the general public does not have access to the source area of contamination or areas where contaminants are moving through the environment. This lack of access to these areas becomes important in determining whether people could come in contact with the contaminants.

> An exposure pathway has five elements: (1) a source of contamination, (2) an environmental media, (3) a point of exposure, (4) a route of human exposure, and (5) a receptor population.
>
> The source is the place where the chemical was released. The environmental media (such as groundwater, soil, surface water, or air) transport the contaminants. The point of exposure is the place where people come into contact with the contaminated media. The route of exposure (for example, ingestion, inhalation, or dermal contact) is the way the contaminant enters the body. The people actually exposed are the receptor population.

The route of a contaminant's movement is the *pathway*. ATSDR identifies and evaluates exposure pathways by considering how people might come in contact with a contaminant. An exposure pathway could involve air, surface water, groundwater, soil, dust, or even plants and animals. Exposure can occur by breathing (inhaling), eating (ingesting), drinking (ingesting), or by skin (dermal) contact with a substance containing the chemical contaminant. ATSDR identifies an exposure pathway as completed or potential, or in some cases eliminates the pathway from further evaluation.

III.A.1. Completed Exposure Pathways

Completed exposure pathways exist for a past, current, or future exposure if contaminant sources can be linked to a human receptor population. All five elements of the exposure pathway must be present. In other words, people have contact or are likely to come in contact with site-related contamination at a particular exposure point via an identified exposure route. As stated above, a release of a chemical into the environment does not always result in human exposure. For an exposure to occur, a completed exposure pathway must exist. Completed exposure pathways require further evaluation to determine whether exposures are sufficient in magnitude, duration, and frequency to result in adverse health effects.

IIIA.2. Potential Exposure Pathways

Potential exposure pathways indicate that exposure to a contaminant could have occurred in the past, could be occurring currently, or could occur in the future. It exists when one or more of the elements are missing or uncertain, but available information indicates possible human exposure.

A potential exposure pathway is one which ATSDR cannot rule out, even though not all of the five elements are identifiable.

III.A.3. Eliminated Exposure Pathway

An eliminated exposure pathway exists when one or more of the elements are missing. Exposure pathways can be ruled out if the site characteristics make past, current, and future human exposures extremely unlikely. If people do not have access to contaminated areas, the pathway is eliminated from further evaluation. Also, an exposure pathway is eliminated if site monitoring reveals that media in accessible areas are not contaminated.

Site-specific characteristics are used to determine whether completed, potential, or eliminated exposure pathways exist at a site. The completed, potential, and eliminated exposure pathways for the LCP Chemicals Site are listed in the Table 1. Each of the identified exposure pathways is explained further in the following section.

III.B. Exposure Pathways at the LCP Chemicals Site

This section identifies and discusses completed and potential exposure pathways associated with past, present and future use of the LCP Chemicals Site.

III.B.1. Completed Exposure Pathways

III.B.1.a. On-site Soils

Pre- and post-remedial soil sampling data confirm the presence of contaminants in on-site soils. However, access to the site property is restricted and there are no on-site workers or residents (except for limited security staff and occasionally remedial workers). Thus, current exposure to contaminants in on-site soil is limited to the occasional trespasser who might access the site by breaching security measures or by arriving onsite via the river. The trespasser is assumed to engage in general recreational activities such as walking, hiking, riding a bike, or riding an all-terrain vehicle (ATV). The trespasser may be exposed to soil by accidentally swallowing it (ingestion), inhaling it (inhalation), and touching it (dermal contact). The typical trespasser is assumed to be an older child (7 through 18 years of age) or an adult (19 years and older). However, because trespassing events would occur infrequently, if at all, ATSDR concluded that trespassers are not likely to be exposed to high enough levels of contaminants in soil to cause adverse health effects.

When industrial activities were taking place on the site, workers were likely exposed to contaminants in soil as they performed their job-related duties or otherwise accessed outdoor areas (e.g., outdoor lunches, traveling to and from other buildings, etc.). The frequency, duration, and magnitude of exposure would vary depending on the type of job performed and the area in which it was performed. The typical worker exposure scenario includes incidental swallowing of and dermal contact with soil.

Table 1. Completed and Potential Exposure Pathways Identified at the LCP Chemicals Site, Brunswick, GA (All OUs)							
Exposure Pathway	***Exposure Pathway Elements***					***Time Frame***	***Comments***
	Sources of Contamination	***Fate and Transport***	***Point of Exposure***	***Exposed Population***	***Route of Exposure***		
Completed Exposure Pathways							
On-site Soil							
Surface and subsurface soils on the facility property	Wastes from previous industrial operations at the site	Improper disposal or spillage onto ground	On-site property	Former facility workers, remedial workers, future residents/property owners	Ingestion Dermal Inhalation	Past Present Future	Currently, the facility is not operational. Most of the property is fenced and access is restricted. Therefore, contact with on-site soil is limited except to the occasional trespasser. However, the site may be developed in the future for any use (residential, commercial, etc.).
Seafood							
Seafood from nearby rivers and waterways	Wastes from previous industrial operations at the site	Surface water runoff, waste seeps into the Turtle River; uptake and bioaccumulation of contaminants in aquatic organisms	Entire Turtle River system	People eating contaminated seafood from affected areas	Ingestion	Past	Seafood consumption advisories have been issued for the Turtle River system. This advisory should reduce people's exposure to contaminated seafood. Therefore, consumption of contaminated seafood prior to the issuance of the advisory was a past, completed exposure pathway.

Table 1. Completed and Potential Exposure Pathways Identified at the LCP Chemicals Site, Brunswick, GA (All OUs)

Exposure Pathway	*Exposure Pathway Elements*					*Time Frame*	*Comments*
	Sources of Contamination	*Fate and Transport*	*Point of Exposure*	*Exposed Population*	*Route of Exposure*		
Potential Exposure Pathways							
Groundwater							
Private groundwater wells	Wastes from previous industrial operations at the site	Migration of contaminated groundwater into areas with private wells, municipal supply wells	Residential tap water; other potable water taps	People with nearby private wells and others not connected to public water supply	Ingestion Dermal Inhalation	Past Future	The extent to which private wells are used in the area is uncertain. The groundwater investigation is completed; only groundwater monitoring and treatment (CBP) are ongoing. This pathway remains a potential future pathway in case the plume migrates to areas with private wells. Groundwater is not evaluated in this document.
Off-site Soil							
Off-site Soil	Wastes from previous industrial operations at the site	Surface water runoff ; air deposition; off-site dumping	Residential yards and public places near the site or off-site dumping areas	People in nearby neighborhoods, communities, schools	Ingestion Dermal Inhalation	Past Current Future	Residents report the existence of off-site dumping areas. Also, the nearby Arco neighborhood was previously sampled and did not contain unsafe levels of contaminants, except for lead. These potential off-site areas should be revisited if planned for re-development.
Surface water and Sediment							
Surface water and Sediment	Wastes from previous industrial operations at the site	Surface water runoff; marsh seeps	Turtle River estuaries and tributaries; Altamaha Canal	People recreating in or near the Turtle River or the Altamaha Canal	Ingestion Dermal Inhalation	Past Current Future	Sediment in the marsh was found to contain elevated levels of contaminants. Therefore, contact with sediment or surface water is a potential exposure pathway.

Table 1. Completed and Potential Exposure Pathways Identified at the LCP Chemicals Site, Brunswick, GA (All OUs)							
Exposure Pathway	***Exposure Pathway Elements***					***Time Frame***	***Comments***
	Sources of Contamination	***Fate and Transport***	***Point of Exposure***	***Exposed Population***	***Route of Exposure***		
Soil Gas							
Indoor Air	Wastes from previous industrial operations at the site	Migration of subsurface waste vapors into indoor air	Enclosed structures over contaminated soil or groundwater	People living or working in homes or buildings built over contaminated subsurfaces (e.g., caustic brine pool)	Inhalation	Future	The potential for migration of vapors into indoor structures should be examined if the site is re-developed. Mercury vapors are of particular concern for this potential pathway.

ATSDR's evaluation included residential development as a future use because residential development was considered in EPA's assessment of the property (e.g., EPA's draft Human Health Risk Assessment considers a future on-site resident in the exposure assessment) and because residential use has not been ruled out. Although Honeywell claims in some reports that the site is intended to remain industrial, they acknowledge the potential for some mixed land use of the property and/or the possibility that some portion of the site might be used as residential property in the future. Therefore, ATSDR believes it prudent to evaluate all possible future scenarios to be protective of public health.

In the future, the site property can be developed for any use, including commercial, industrial, or residential use. While the property is zoned for industrial use, land use can change with time; therefore, ATSDR will assume that the intended future land use is mixed-use residential, commercial, or industrial. The exposures in these settings would occur by incidental swallowing, dermal contact, and inhalation of contaminants from contaminated soil. It should be noted that EPA's risk assessment for the LCP Chemicals Site also includes a residential exposure scenario.

III.B.1.b. Fish and Shellfish

Site-related wastes have entered nearby marshes and aquatic areas. These wastes are present in the water column and/or are attached to bottom sediment or particles in the water. PCBs and other contaminants are taken up into the bodies of small organisms and fish in water. They are also taken up by other animals, including humans that eat these aquatic animals as food. Previous data have shown that some species of fish from the Turtle River contain elevated levels of mercury, PCBs, and other contaminants. The GCHD has determined that the levels of these contaminants in some fish are high enough to cause health problems (see discussion above in *Past ATSDR Health Evaluations* section). The GDNR currently monitors contaminant levels in fish and shellfish from the Turtle River system and has issued fish consumption guidelines (*Guidelines for Eating Fish from Georgia Waters*) designed to protect consumers from experiencing health problems associated with eating contaminated fish from the Turtle River system. These guidelines are available on the internet at http://www.georgiawildlife.com/node/705.

A local environmental group, the GEC, published a "Seafood Consumption Advisory for Turtle River" which sets out in plain language the recommended limits on the consumption of fish and seafood from the Turtle River system (see Appendix D.) Along with the GDNR's fish advisory, these public health actions are believed to have reduced the amount of contaminated fish and seafood from the Turtle River system eaten by residents, although it is possible that some contaminated fish are still eaten by people who are not aware of the advisory or who disregard it.

Although the biota pathway is completed, ATSDR will not re-evaluate the data in this document because the agency has released two health consultations on the topic. In addition, the GCHD and the GDNR have already done extensive work evaluating fish and seafood in the Turtle River and have issued consumption advisories for residents to follow. However, in 2011, EPA collected fish and shellfish samples from the Altamaha

Canal. Neither ATSDR nor any other agency had evaluated these data. ATSDR did evaluate in this document the fish and shellfish data for samples collected from the Altamaha Canal in 2011.

III.C. Potential Exposure Pathways

III.C.1. Groundwater

The drinking water supply for the area is composed of private wells and the Brunswick municipal wells. The municipal wells draw water from the Upper Floridan Aquifer while the private wells are drilled at a wide range of depths. Within a 4-mile radius of the site, the municipal system serves approximately 28,000 residents and private wells serve approximately 5,000 residents (EPS 2007a).

A 1995 well inventory report indicated that private wells in the vicinity had not been impacted by site-related contaminants because they are located upgradient of the site (EPS 2007a). More recent sampling efforts have found no site-related contaminants in private or municipal wells. According to local officials, to date, no private or municipal wells in the area have been impacted by site-related contaminants (EPS 2007a). However, given that contaminants in groundwater move over time, it might be possible in the future that contaminants from the site can migrate to previously uncontaminated wells. Although highly unlikely, future developers/residents may drill new wells into the contaminated groundwater. If this happens, future workers/residents would be exposed via ingestion, inhalation, and dermal contact with contaminated water.

III.C.2. Off-Site Soil

The off-site areas are comprised of the current and former Arco community located southeast of the site and the off-site areas along New Jesup Hwy/Newcastle Street that were former tank farms. Portions of the Arco community are currently owned by Georgia-Pacific Cellulose, while other parts of the Arco community remain industrial and residential. The areas formerly occupying the off-site tanks along New Jesup Hwy/Newcastle Street Road have been transitioned to other commercial or industrial uses. One of the former off-site tanks is currently covered by US Highway 341/25 and was not accessible for sampling.

III.C.3. Surface Water & Sediments

Sediment sampling data from the 1990s confirm the presence of contaminants in surface water and sediments near the LCP Chemicals Site. Sediments that contain some contaminants can also release the chemicals into the surrounding water. Impacts to the Turtle River surface water and river sediment have been documented through laboratory testing. Wastes containing contaminants seeped into the marsh at several locations (EPS 2007b). To date, actions have been taken to address the release of contaminants from the site to the surface water pathway.

People who recreated (swim, wade, boat, canoe, etc.) in the Turtle River near the site or downstream of the site in the past could have been exposed to contaminants in surface water and sediment. Exposure would have occurred by swallowing small amounts of water or sediment, or by absorbing some of the chemicals in the water or sediments through bare skin.

III.C.4. Soil Gas

Some of the contaminants currently remaining beneath the ground surface of the site have the potential to evaporate into the air spaces between soil grains ("soil gas") and gradually work their way to the surface. Mercury, in particular, has the potential to evaporate into the air and be carried long distances. If mercury or volatile organic compounds (VOCs) volatilize between soil grains and enter an enclosed structure, these contaminants can accumulate in the air of the structure and be breathed in (inhaled) by humans. This potential pathway is not a current pathway because most on-site buildings have been removed. However, this pathway should be evaluated if the site is re-developed for either residential or commercial uses.

IV. ENVIRONMENTAL CONTAMINATION

An important component of the exposure assessment process is the evaluation of environmental contamination using available environmental sampling data collected on or near the site. Environmental data indicate the levels of chemicals in water, soil, air or the food chain (biota). ATSDR relies on environmental data collected from EPA, Honeywell, other governmental agencies, or other third party sources. ATSDR determines whether the available data for a site accurately and sufficiently reflect past, current, and future exposure conditions, and requests additional data to fill critical data gaps, if necessary.

After evaluating site conditions and determining that people could have been, are being, or could be exposed in the future (i.e., via a past, current, or future exposure pathway) to site-related contaminants, ATSDR must then consider whether chemicals were/are present at levels that might affect people's health. The health effects evaluation consists of two pieces: 1) a screening analysis and 2) based on the results of the screening analysis (and community concerns), a more in-depth analysis to determine possible health implications of site-specific exposures (detailed in Section V).

IV.A. The Screening Analysis – How ATSDR Selects Chemicals to Evaluate

During the screening analysis, ATSDR sorts through the environmental data in a consistent manner to identify substances within completed and potential exposure pathways that may need to be evaluated more closely. ATSDR selects the chemicals for further evaluation by comparing them to health-based *comparison values*.

These are developed by ATSDR and other governmental agencies from available scientific literature related to exposure and health effects. Comparison values are derived for each of the different media and reflect an estimated contaminant concentration that is *not likely* to cause adverse health effects for a given chemical, assuming a standard daily contact rate (e.g., an amount of water or soil consumed or an amount of air breathed) and body weight.

What are comparison values?

Comparison values are chemical concentrations in soil, water, or air that are set well below levels known or anticipated to result in adverse health effects. ATSDR and other governmental agencies develop these values to make consistent decisions about what substance concentrations might require a closer look.

Comparison values are not thresholds of toxicity and therefore should not be used to predict adverse health effects. Although concentrations at or below the relevant comparison value may reasonably be considered safe, it does not automatically follow that any environmental concentration that exceeds a comparison value would be expected to produce adverse health effects. Additional toxicological evaluation is needed to determine if harmful effects might be expected when a comparison value is exceeded.

ATSDR has developed comparison values for substances in drinking water, soil, and air. ATSDR's comparison values include environmental media evaluation guides (EMEGs), reference dose media evaluation guides (RMEGs), and cancer risk evaluation guides (CREGs). Comparison values are developed in a uniform way using health guidelines and standard default exposure assumptions that protect children and adults. ATSDR uses comparison values as a screening tool to compare to the contaminant levels found at the site. This screening process is a way to select contaminants that require further evaluation at the site. When no comparison value is available, the contaminant is generally retained for further evaluation. Other factors that become important in deciding which chemicals to evaluate further include the frequency of detection and a chemical's inherent toxicity.

Analytical data that characterize the post-removal conditions of the site were evaluated by ATSDR. The screening analysis revealed the presence of many chemicals, but most were eliminated because they were below applicable comparison values.

On the basis of the initial screening analysis, site history, and results from previous published assessments of soil (the dry-land soil portion) at the site, ATSDR selected Aroclors (PCBs), polycyclic aromatic hydrocarbons (PAHs), lead, mercury, and dioxins for further evaluation.

IV.B. The Exposure Analysis – How ATSDR Evaluated the Environmental Data

Although completed pathways for past exposure to site contaminants were identified for onsite and offsite receptors, this document focuses on risks to future populations from exposure to soil after the LCP Chemicals Site is redeveloped. Therefore, ATSDR focused the health evaluation on the chemicals left in the soil after clean-up activities (post-removal action) was completed. Most of these clean-up activities were completed in the mid-1990s. The residual contaminants in soil represent current contaminant levels and

pose the greatest likelihood for future exposure and therefore, the greatest potential risk for future populations when the site is redeveloped.

ATSDR made the following assumptions when evaluating the post-removal environmental data.

IV.B.1. Subdivided the Property into Half-acre Exposure Units

Most often, an average chemical concentration is used as a single quantitative measure to determine the risks posed by a particular chemical for a contaminated area. Because the site is so large, ATSDR divided the site into smaller geographic (or exposure) units, which we believe will more accurately reflect whether a particular exposure area contains elevated concentrations of contaminants if the site becomes residential, commercial, or industrial.

ATSDR defined the exposure units as 1/2 acre parcels, or 150 x 150 foot lots. This area is about half the size of the American football field. In the absence of a defined redevelopment plan for the site, ATSDR concluded that each future home or commercial lot would occupy approximately this much space, particularly in a mixed-use community. ATSDR believes that this subdivision produces reasonably sized parcels with which to evaluate risks to potential future residential and commercial populations.

In order to evaluate these ½ acre exposure areas, ATSDR randomly overlaid ½ acre-sized grids onto a map of the site. This produced a series of equal-sized parcels, but with varying amounts of environmental sampling data for each lot. Potential health risks for each parcel were assessed separately. Where possible, ATSDR calculated the concentration of contaminants in each parcel to determine if the level was high enough to cause adverse health effects. In some cases, if the parcel contained too few samples to derive a health conclusion, ATSDR recommended additional sampling for that grid.

ATSDR's exposure unit approach is different than the approach chosen by EPA. Rather than dividing the site into ½ acre parcels, EPA divided the site into 4 large exposure units called quadrants. Each quadrant is roughly equal in size and is based on the location of B-Street and the north-south fence line located by the former guard house on B-Street (See Figure A13 in Appendix A). EPA Quadrant 1 and Quadrant 2 are in the eastern parcel of the site; EPA Quadrant 3 and Quadrant 4 (including the salt dock area) comprise the western parcel of the site. EPA's quadrants range from approximately 20 to 50 acres in size. The quadrants used by EPA are considerably larger than the ½ parcels used by ATSDR. Therefore, it is possible for ATSDR and EPA to reach different conclusions regarding assessing exposure and making health determinations.

IV.B.2. Evaluated Contaminants to Depth of 0-5 and 0-2 Feet

The process for determining which soil samples to include in our evaluation was driven by the groundwater field investigations and our assumptions regarding potential soil exposures of future populations. Previous investigative documents reveal that the depth to groundwater in the area is approximately 5 feet. Also, because the site is slated for

redevelopment, we assumed that various earth-moving activities will occur during the redevelopment process. These earth-moving activities increase the probability that soil that is currently subsurface (and therefore not accessible for human contact) will become surface soil (and vice versa) as it is being moved around. Therefore, ATSDR assumed that a person may be exposed to any soil above the water table (5 ft.). Where the soil sample was collected at less than 5 ft., ATSDR included that sample result in the evaluation. Where the soil sample was collected at 6 ft. or greater, ATSDR eliminated that sample from further consideration. This process was conducted to account for the uncertainty in identifying surface versus subsurface soil. The EPA used a similar evaluation method in their human health risk assessment for the site, although their focus was the top 1 or 2 foot of soil (EPS 2007b).

In addition to estimating descriptive statistics for contamination at the 0-5 ft. depth, ATSDR also determined descriptive statistics for contamination at 0-2 ft. depth as well. The reasons for looking at this depth are that contaminant concentrations might be different in the top few feet, and the possibility that construction activity might be limited to a more shallow depth than 0-5 ft.

IV.C. Previous Sampling – Dry-land Soils

Site dry-land soils were investigated as part of a removal response action and during four phases of a remedial investigation. Removal action sampling was performed on the dry-land soil portion of the site from 1994 to 1997. Remedial investigation sampling was conducted from 1995 to 2004.

IV.C.1. Removal Action

The objective of the removal response action was to mitigate conditions deemed by the EPA to pose an imminent and substantial threat to human life, health or the environment. The dry-land removal response activities included the following components: (i) characterization of the dry-land area of the site; (ii) delineation of removal areas; (iii) removal and off-site disposal of impacted materials; (iv) post-excavation confirmational sampling to verify compliance with the removal action goals; (v) containment and treatment of contaminated water; (vi) permanent abandonment of water-supply wells; (vii) backfilling and grading of removal areas; and (viii) closure of the site sewer system. Decommissioning and removal activities at the Cell Building Area began immediately following the chlor-alkali plant closure in February 1994. The onsite mercury cell buildings were demolished and the area was capped and fenced. Other dry-land removal activities commenced in July 1994 and were completed in June 1997 (Geosyntec 1996, 1997, 1998).

Surface and subsurface soil samples were collected during the removal action using the following methods: 1) hand augering, 2) test trenching, 3) direct push drilling, 4) hollow stem auger drilling, and 5) mud rotary drilling. Lateral and vertical dimensions of each excavation grid were surveyed during the removal action.

Characterization and delineation sampling was performed concurrently with waste removal activities. Analytical results were compared to EPA removal criteria to determine areas requiring cleanup from those areas that did not. Contaminated soil was excavated and disposed off-site. The depth of excavation at the dry-land portion of the site ranged from less than 1 ft. (0.3 m) to approximately 13 ft. (4 m).

The removal response action also included a confirmational (post-excavation) sampling program. Confirmational soil samples were collected to verify attainment of the following removal target action goals identified by EPA (Geosyntec, June 1998). EPA target action levels for the LCP Chemicals Site are shown in Table 2.

Table 2. EPA Target Action Levels used between 1994 and 1997 at the LCP Chemicals Site

Contaminant	*Cleanup Goal*
Total Mercury	20 ppm*
Total Lead	500 ppm**
Total PCBs	25 ppm
Total carcinogenic PAHs	50 ppm

* ppm = parts per million

**When removal actions were taking place between 1994 and 1997, the total lead target action level was 500 ppm. Since that time, the EPA has set 400 ppm as the target action level for lead.

One composite sample was generally collected from the subgrade of each grid excavated to verify that the vertical extent of excavation was sufficient to meet site clean-up goals. The number of points in a subgrade composite sample depended on the size of the excavation grid, and varied from two to five points. An excavation grid comprised an area of approximately 2,500 ft^2-- nominally 50 ft. by 50 ft. To verify the horizontal limit of excavation, a three-point vertical composite sample was collected approximately every 100 linear ft. (30 m) around the perimeter sidewall of the excavations. If confirmational sampling results did not meet cleanup goals, additional excavation and re-sampling was conducted in the corresponding subgrade or sidewall. However, in some deep excavation areas where ground water infiltration and possible unstable slopes were a concern, grids were backfilled before confirmational samples were analyzed. The decision to backfill was based on visual examination of the subgrade and analytical results from nearby excavation grids. Once the confirmational sampling showed that the cleanup goal had been met, the area was backfilled with clean fill from off-site sources to restore the natural grade and promote positive drainage.

Confirmational samples were collected from the dry-land area of the site. Removal performance goals were not met at numerous sampling locations, prompting additional soil excavations. These sampling locations were removed during the additional soil excavations. Final confirmational samples represent the current (i.e., post-removal) conditions of the dry-land soils at the site. ATSDR noted that no samples were collected from the onsite pond; some samples were collected from the on-site theater.

Soil samples that were excavated during the removal action can be used to define past exposures. Soil samples that were not excavated, along with confirmational samples, represent existing conditions at the site, and were used to define present and future exposures.

IV.C.2. Exclusion of Sampling Data Collected during Removal Action

ATSDR was informed by EPA that data generated by Transglobal Environmental Geochemistry (TEG), which analyzed soil and water samples between April 1995 and June 1996, had data quality problems (EPA 2010a). TEG was the onsite laboratory used at the LCP Chemicals site during the removal action. The TEG data produced from approximately April 1995 to June 1996 has been deemed to be of poor quality because of quality control issues with the on-site laboratory. EPA has informed ATSDR that they did not include the TEG data in their baseline Human Health Risk Assessment for the site. However, EPA will use the TEG data in their Remedial Investigation.

Because of the concerns regarding the TEG data quality, ATSDR decided not to include TEG data in this evaluation. ATSDR recommends additional sampling in areas where sampling data are limited due to the exclusion of the TEG data. For example, the following highly contaminated areas were identified by ATSDR as having limited (confirmational) sampling data once the TEG data were removed:

- The scrap yard,
- The former facility disposal area,
- The cell parts area,
- The north and south dredge spoils area, and
- The outfall pond.

These areas are located between the former cell building and the marsh (see Figure 1). With the removal of the TEG data, it is uncertain whether these areas met EPA's target action levels.

IV.C.3. Remedial Investigation

Four separate soil sampling programs were conducted as part of the remedial investigation for dry-land soils.

IV.C.3.a. Phase I investigation

The purpose of the Phase I investigation was to assess the degree of preferential vertical distribution of chemical contaminants in the upper 2 ft. of soil. A set of 9 test trenches were located at two different areas of the site – one in the eastern portion in an area that had little industrial activity; the second in the southern portion in an area suspected to be more heavily contaminated. Each test trench was excavated approximately 5 ft. long and 2 ft. deep; samples were collected from each test trench at typical discrete depths of 0 ft., 0.5 ft., 1.25 ft. and 2.0 ft.

IV.C.3.b. Phase II investigation

The Phase II investigation was focused on verifying removal action characterization previously performed on the eastern portion of the site. Nine random sampling points were identified and collected. Each sampling point consisted of a square with an approximate side length of 25 ft. from which 2 five-point composite samples were collected. The samples were collected from depth ranges of 0 to 1 ft. and 2 to 3 ft.

IV.C.3.c. Phase III investigation

The Phase III investigation was focused on off-site tank farm sampling to characterize surface and subsurface soils at the locations of former refinery tanks east of Ross Road. Fourteen sample points at 3 former tank locations were identified and sampled. Sample points were located in the approximate center and corners or the former tank enclosures. Grab samples were collected from each sample point at typical depth increments of 0 to 1 ft. and 2 to 3 ft.

IV.C.3.d. Phase IV investigation

Soil sampling was conducted in a portion of the nearby ARCO neighborhood in 1995 and 2004. The portion of the ARCO community was southeast of the LCP property and consisted of residential homes. In 1995, the EPA collected two composite samples from the front and back yards of 5 residences in the ARCO community. Each composite sample was comprised of a 5-point sample of the upper 3 inches of soil. ATSDR evaluated the analytical results from the ARCO neighborhood sampling and determined that no contaminants were found at levels that would represent a public health threat [ATSDR 2005].

In 2004, a second sampling event was performed in this portion of the ARCO neighborhood and surrounding areas. City blocks were divided into quadrants to create 36 sampling grids. Samples were collected from each grid as 5-point composites. Composite sampling was conducted from a 0 to 3 inch and 0 to 12 inch depth. Samples for the two depth increments were collected immediately adjacent to each other.

IV.D. Contaminants of Potential Concern

As discussed above, ATSDR selected PCBs, PAHs, lead, and mercury as contaminants of potential concern because of their noted predominance at the site and because of the concerns raised by community members. Therefore, the focus of the health discussion will be on these contaminants. The section below discusses the distribution of these contaminants in and around the LCP Chemicals Site. The discussion will reference specific locations on the LCP property; therefore, the use of the Figure A4 in Appendix A (site map) may be helpful to identify the areas being discussed.

IV.D.1. Polychlorinated biphenyls (PCBs)

IV.D.1.a. What are PCBs?

Polychlorinated biphenyls (PCBs) are mixtures of up to 209 individual chlorinated compounds (known as congeners). There are no known natural sources of PCBs, yet they are found all over the world. With few exceptions, PCBs were manufactured as a mixture of various PCB congeners (EPA 2008b). In general, commercial mixtures with higher percentages of chlorine contained higher proportions of the more heavily chlorinated congeners, but all congeners could be expected to be present at some level in all mixtures (EPA 2008b). While PCBs were manufactured and sold under many names, the most common trade name was the Aroclor series. There are several types of Aroclors and each has a distinguishing suffix number, which usually indicates the degree of chlorination. The numbering standard for the different Aroclors is as follows: The first two digits generally refer to the number of carbon atoms in the phenyl rings (for PCBs this is 12), the second two numbers indicate the percentage of chlorine by mass in the mixture. For example, the name Aroclor 1254 means that the mixture contains approximately 54% chlorine by weight (EPA 2008b). The exception is Aroclor 1016, which has 12 carbons and 42% chlorine by weight. Once in the environment, PCBs do not readily break down and may remain for very long periods of time.

IV.D.1.b. Combined PCB congeners (except Aroclor1016)

For the purposes of this health assessment, ATSDR added all Aroclors (except Aroclor 1016) to arrive at a "total PCB" concentration for a given sample. The Aroclors detected at the site include Aroclor 1016, Aroclor 1221, Aroclor 1248, Aroclor 1254, Aroclor 1260, and Aroclor 1268. Aroclors 1232, 1242, and 1262 were not detected at the site. Aroclor 1016 has its own cancer toxicity values; therefore, it was not included in the Total PCB concentration. Table 3 lists the frequency with which the various Aroclors were detected in soil at the site.

EPA recommends that Aroclors be summed to give "total PCBs" when evaluating cancer (EPA 2009b). The derived cancer slope factor, therefore, applies to total PCBs. ATSDR used the same summing method when assessing non-cancer risk.

Table 3. Frequency of detection for various Aroclors in soil.

Substance	*# Detections*	*# Samples*	*Frequency*
Aroclor 1016	2	891	0.2
Aroclor 1221	1	902	0.1
Aroclor 1232	0	902	0.0
Aroclor 1242	0	902	0.0
Aroclor 1248	2	902	0.2
Aroclor 1254	81	902	9.0
Aroclor 1260	37	902	4.1
Aroclor 1262	0	0	0.0
Aroclor 1268	171	852	20.1

IV.D.1.c. Residual PCB Levels in Soil

Prior to clean-up (removal) actions, elevated concentrations of PCBs were detected in the former facility disposal area, the outfall pond and canal, the anode loading area, the north and south dredge spoils area, the scrap yard, northwest field, the material staging area, the south rail yard, and portions of the marsh, including tidal channels. After clean-up (removal) actions, residual PCB contamination exists in the some of the same areas.

Figure 1 shows the location of each sample collected and tested for PCBs that represents PCB levels in soil following clean-up activities. The figure also depicts where residual PCB concentrations are higher in some areas than in others by using a color scheme. Generally, the western portion of the site contains the most samples; the southwestern portion of the site contains the most residual PCB contamination. The eastern portion of the site contains fewer samples and less residual contamination.

The distribution of total PCBs remaining in soil is shown in Figure 1. Generally, residual PCB concentrations are highest in the north and south dredge spoils area, the scrap yard, the material staging and retort area, and the cell building area.

The exposure units for the site are defined as ½ acre-sized parcels. Figure 2 shows the overlay of the ½ acre grids to reflect residual PCB contamination and distribution at the site. Average PCB concentrations were calculated for each ½ acre grid. Non-detects were assumed to be zero because of irregularities in reporting laboratory detection limits.

0-5 Ft Depth

For the 0 to 5 foot soil depth, six grids have average total PCB levels that exceed EPA's 1994 LCP target action level of 25 parts per million (ppm); 35 grids have average total PCB levels between 1 and 24 ppm (see Table 4). Fifty-five grids have average total PCB concentrations less than 1 ppm, but not including non-detects. The maximum PCB concentration from a single sample remaining at the site is 826 ppm (Grid #93) and is located in the northwest corner of the former cell building area. The highest average PCB concentration for any grid (Grid #93) is 139 ppm.

0-2 Ft Depth

Soil samples with a depth of 0-2 ft. showed similar results as the 0-5 ft. depth. In the 0-2 ft. samples, 6 grids have average total PCB levels that exceed EPA's LCP target action level of 25 ppm; 35 grids have average total PCB levels between 1 and 24 ppm. The highest average PCB concentration for any grid is 240 ppm; however, more uncertainty exists in the average concentration because fewer soil samples are available from the 0-2 ft. depth.

Table 4. Average Total PCB concentration in soil by grid number, all depths								
ATSDR Grid #	*Average Total PCB in ppm*	*Maximum Total PCB in ppm*	*# Soil Samples*		*ATSDR Grid #*	*Average Total PCB in ppm*	*Maximum Total PCB in ppm*	*# Soil Samples*
93	138.6	826	6		75	2.6	23	17
58	122.0	122	1		94	2.4	16.8	22
114	53.0	53	1		38	2.4	4.9	2
53	42.3	167	7		70	2.3	9	9
90	40.9	350	13		92	2.2	11	8
60	34.0	34	1		39	2.1	2.1	1
89	20.6	240	13		42	1.9	10	12
111	15.8	37	3		8	1.6	3	2
37	11.9	28.5	4		69	1.5	28.3	21
128	10.5	19	2		154	1.4	4.3	6
55	9.0	27	3		112	1.4	7.3	8
76	7.3	53	10		74	1.4	10.9	8
10	7.0	13	2		152	1.4	2.7	2
91	6.2	24	6		153	1.4	2.7	2
56	5.6	11	3		71	1.3	7.5	9
155	5.6	10	2		77	1.3	3.3	7
110	4.0	22	12		133	1.3	8.8	17
95	3.5	16	12		197	1.1	3.5	6
59	3.3	12	6		17	1.1	9.5	12
73	2.6	4.3	4		134	1.0	12	12
118	2.6	10	4					

Figure 1. Sampling Locations Showing Residual PCB Levels in Soil, 0-5 ft.

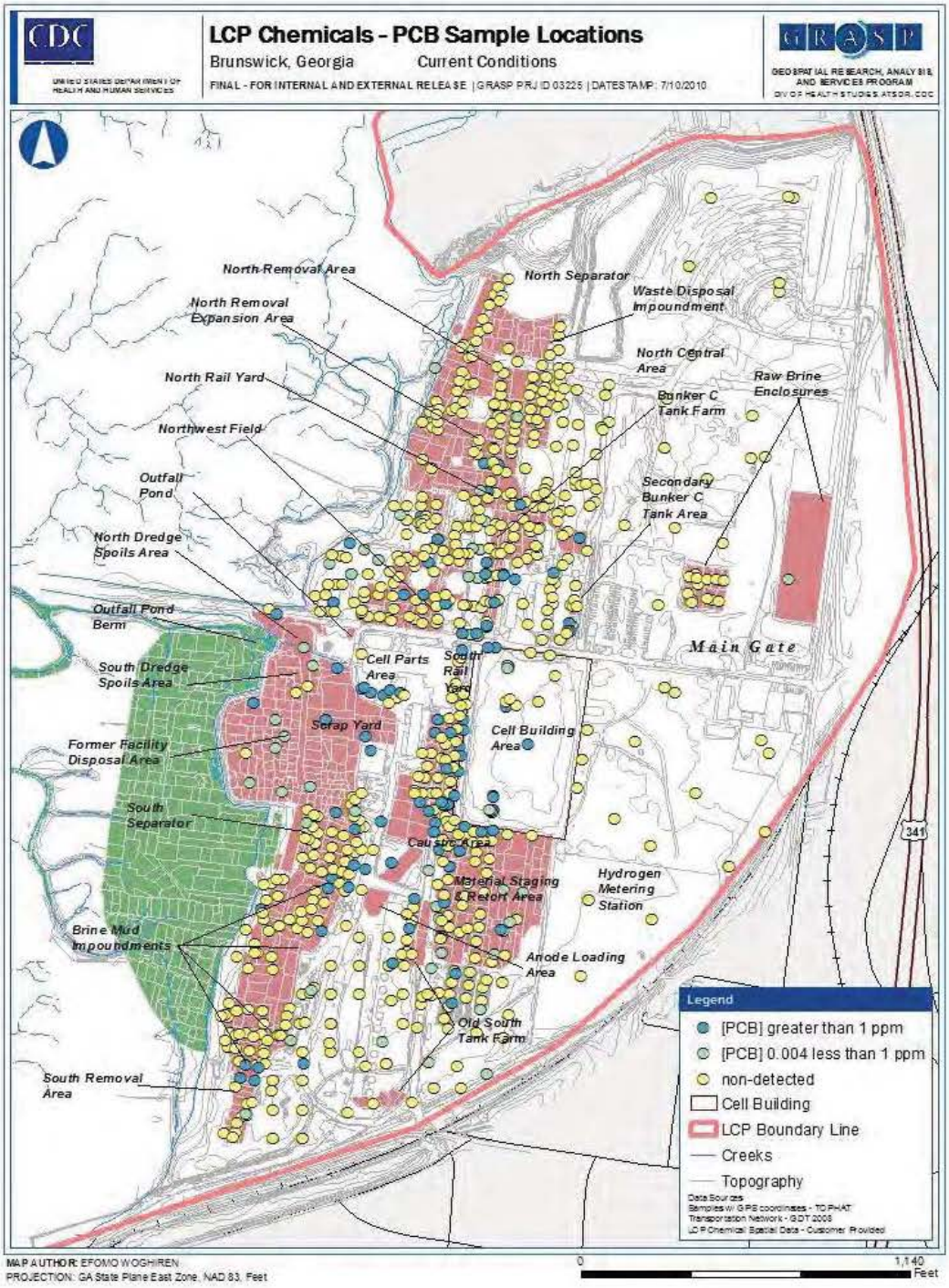
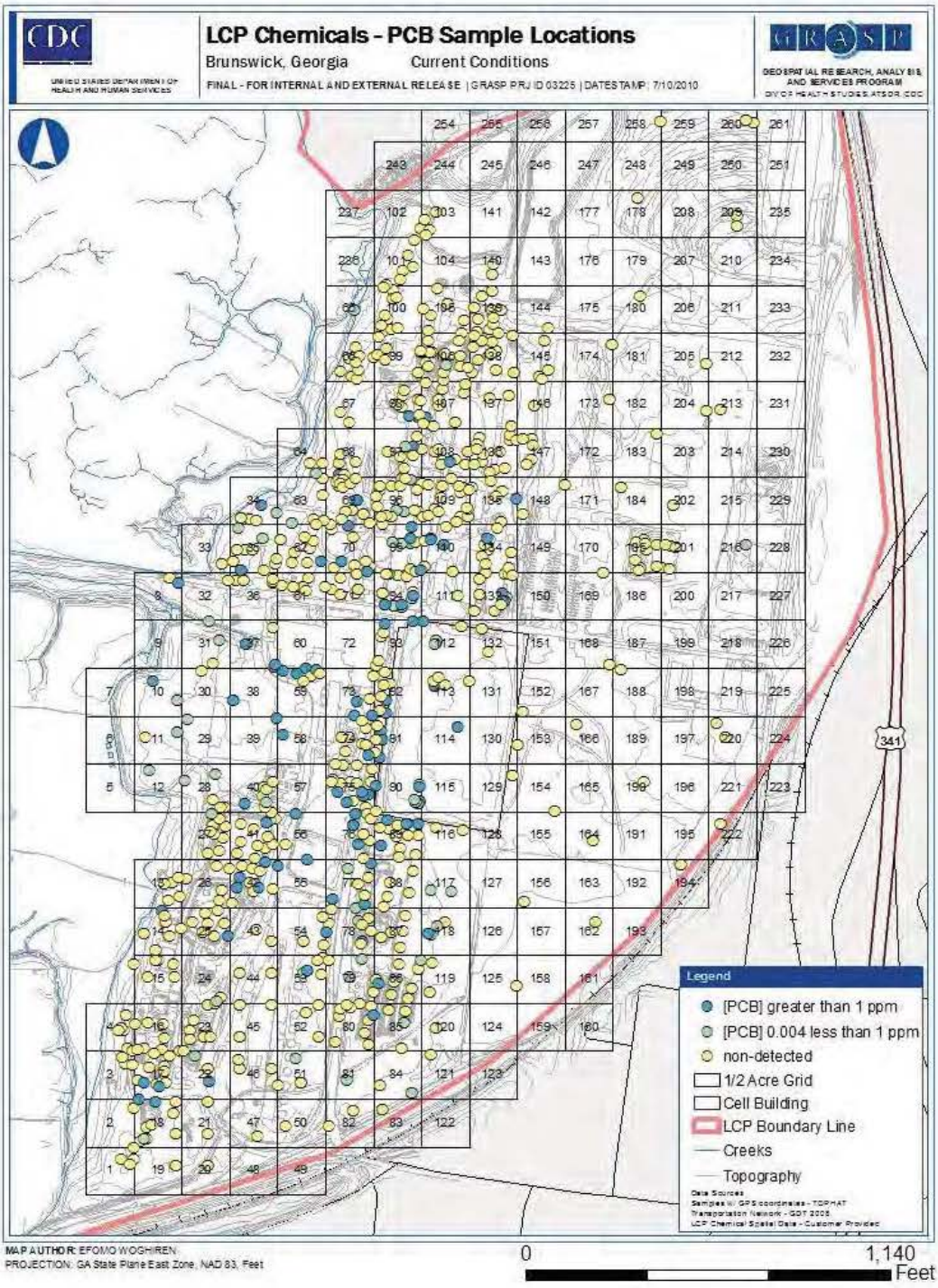


Figure 2. Exposure Units: ½ Acre Grids
PCB Samples and Residual Levels, 0-5 ft.



IV.D.2. Mercury

Prior to removal actions, mercury and mercury-contaminated alkaline sludges were detected in the cell building area, the mercury retort area, the caustic tanks area, the bleach mud at the north removal area, the lime softening mud at the waste disposal impoundment, the brine mud impoundments, the former facility disposal area, and portions of the marsh, including tidal channels. After EPA's clean-up actions, residual mercury still exists in some of the same areas. Figure 3 shows the location of each sample collected and tested for mercury that represents current mercury levels. The figure also depicts where residual mercury concentrations are higher in some areas than in others by using a color scheme. Generally, the western portion of the site contains more samples and more residual mercury contamination.

IV.D.2.a. The Chemistry of Mercury in Soil

Chlor-alkali plants such as LCP use mercury as electrodes in the electrolysis process that liberates dichlorine from a brine solution (Rule *et al*. 1998). The original form of mercury that is discharged into the environment in many cases is elemental mercury (Renneberg and Dudas 2001). Over time, the mercury-containing waste in soil may undergo chemical transformations into new forms. Elemental mercury is likely to be transformed into divalent mercury salts, such as mercuric chloride, mercuric hydroxide, mercuric sulfide, and to organic mercury. In soil, most of the mercuric salts become bound to the organic matter in soil, by reacting with sulfur- and oxygen-containing areas in aromatic and aliphatic chemicals. Some mercuric salts also can be bound to soil minerals, while a small portion can remain as elemental mercury or dissolved mercury (Schuster 1991, Stevenson 1994, Renneberg and Dudas 2001).

When the soil is co-contaminated with industrial hydrocarbons, some of the mercuric salts can react with sulfur- and oxygen-containing areas of these hydrocarbons, much like it does with organic matter in soil (CCME 1997, Renneberg and Dudas 2001). Renneberg and Dudas have analyzed soil that was contaminated with mercury several decades ago. They found 62% to 85% of the mercury in the soil samples was associated with organic matter. Several soil samples, however, showed small amounts of mercury bound to hydrocarbons (i.e., less than 5%), although one sample showed almost 30%. The percentage of mercury bound to minerals ranged from 5% to 10% for some samples and 20% to 30% in other samples. One soil sample showed that elemental mercury made up 30% of the remaining mercury in soil. The authors were not able to identify the specific chemical form of mercury in each sample (Renneberg and Dudas 2001).

In 2003, EPA collected 10 sediment samples from the nearby marsh and performed laboratory tests to determine which form of mercury was present. The organic mercury typically was 45% with individual marsh sediment samples ranging from 3% to 86% organic mercury. The other major components consisted of mercury in a mineral lattice, mercuric chloride, or elemental mercury. The mineral or elemental component typically was 41% with individual marsh sediment samples ranging from 0% to 72% (EPA 2010). These results are consistent with the previously cited studies. It is important to remember

that these are marsh sediment samples and may or may not accurately represent the speciation of mercury in soils.

These results show that a large proportion of mercury in soil at the LCP Chemicals Site is likely to be organic mercury and this mercury is now bound to the organic humic content of soil. However, other forms, such as inorganic mercuric salts, and possibly elemental mercury, might also be present.

IV.D.2.b. Residual Mercury Levels in Soil

The distribution of mercury remaining in soil is shown in Figure 3. Residual mercury concentrations are highest in the footprint of the cell building area and in the areas immediately north and south of the cell building area. Soils beneath the footprint of the cell building area are poorly characterized and were not a significant part of the removal effort. It is likely that significant mercury contamination remains in these soils.

The exposure units for the site are defined as ½ acre-sized parcels. Figure 4 contains the overlay of the ½ acre grids to show residual mercury contamination and distribution at the site. Average mercury concentrations were calculated for each ½ acre grid.

0-5 Ft Depth

In the 0-5 ft. depth, 10 grids have average mercury levels that exceed EPA's LCP target action level of 20 ppm (see Table 5). Approximately 114 grids have average total mercury levels between 0.5 ppm and 19 ppm. Approximately 49 grids have average mercury concentrations less than 0.5 ppm, or levels which are considered background for mercury. The maximum mercury concentration at the site from a single soil sample is 10,400 ppm and is located in the footprint of the cell building area (Grid #113). The highest average mercury concentration for any grid (Grid #113) is 1,470 ppm and is also located in the former cell building area.

Table 5 (0-5 ft. Depth). Grids with average mercury levels in soil above EPA's LCP target action level of 20 ppm

Grid #	*Average Concentration*	*Maximum Concentration*	*Minimum Concentration*	*# Samples*
113	1470	10400	2	13
93	296	3510	0.32	12
112	271	3700	0.55	17
90	184.4	840	0.30	26
60	85	85	85	1
128	81	150	12	2
114	41	260	1.8	8
118	29.8	86	0.03	6
53	23.5	82.0	0.29	5
55	23.4	23.4	23.4	1

0-2 ft. Depth

In the 0-2 ft. samples, 5 grids have average mercury levels that exceed EPA's LCP target action level of 20 ppm (see Table 6). Approximately 103 grids have average total mercury levels between 0.5 ppm and 19 ppm. The remaining 42 grids have average mercury concentrations less than 0.5 ppm, or levels which are considered background for mercury. The maximum mercury concentration at the site from a single soil sample is 280 ppm for grid #90. The maximum average mercury concentration for any grid is 250 ppm, also in grid #90. Many of the grids in the 0-2 ft. depth contained only a single to a few samples. More uncertainty exists in these average concentrations because so few samples are available.

Table 6 (0-2 ft. Depth). Grids with average mercury levels in soil above EPA's LCP target action level of 20 ppm

Grid #	*Average Concentration*	*Maximum Concentration*	*Minimum Concentration*	*# Samples*
90	250	280	220	2
89	142	142	142	1
60	85	85	85	1
53	27.7	82	0.00	3
55	23.4	23.4	23.4	1

Figure 3. Sampling Locations Showing Current Mercury Levels in Soil (0 -5 ft.)

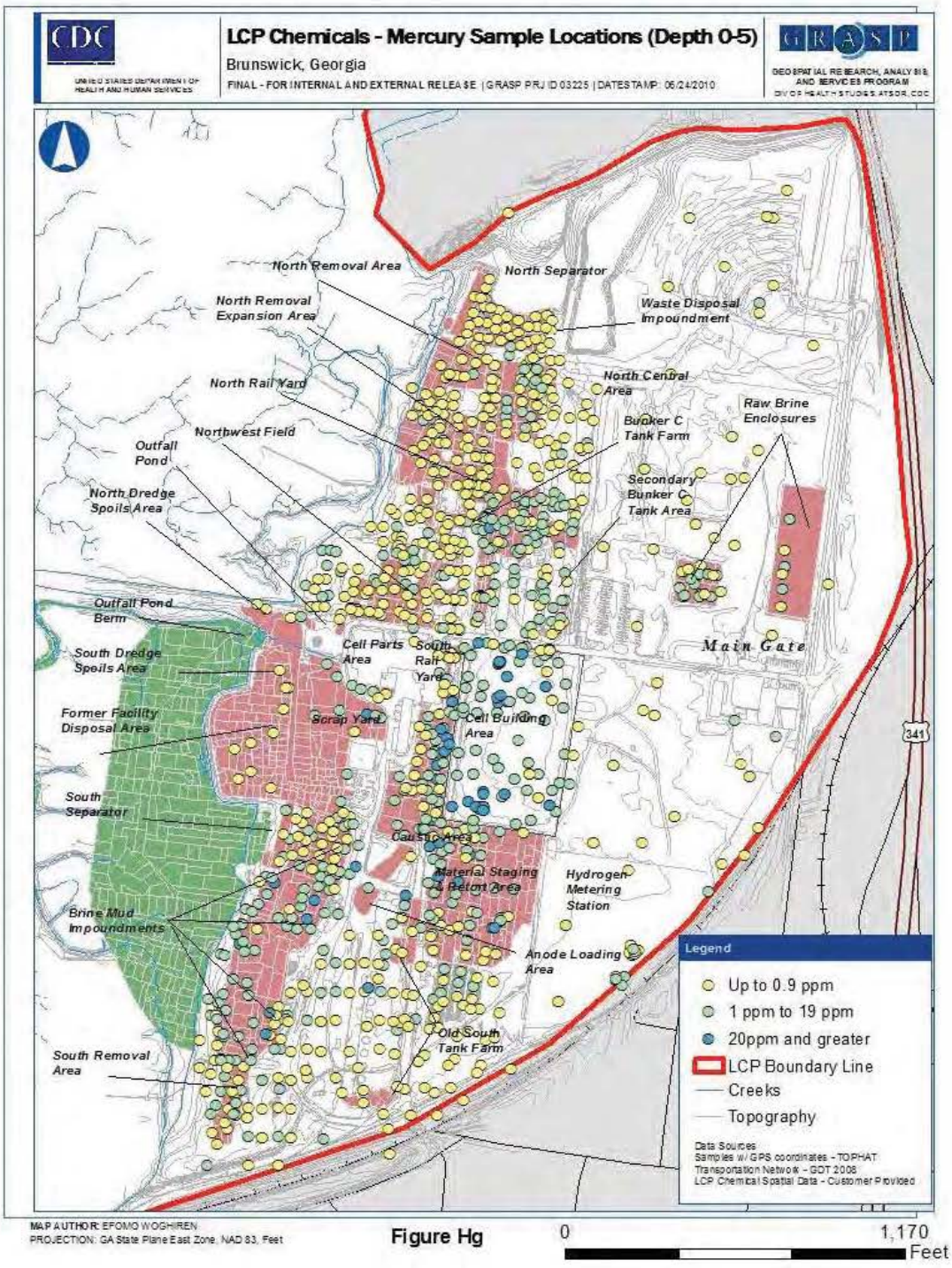
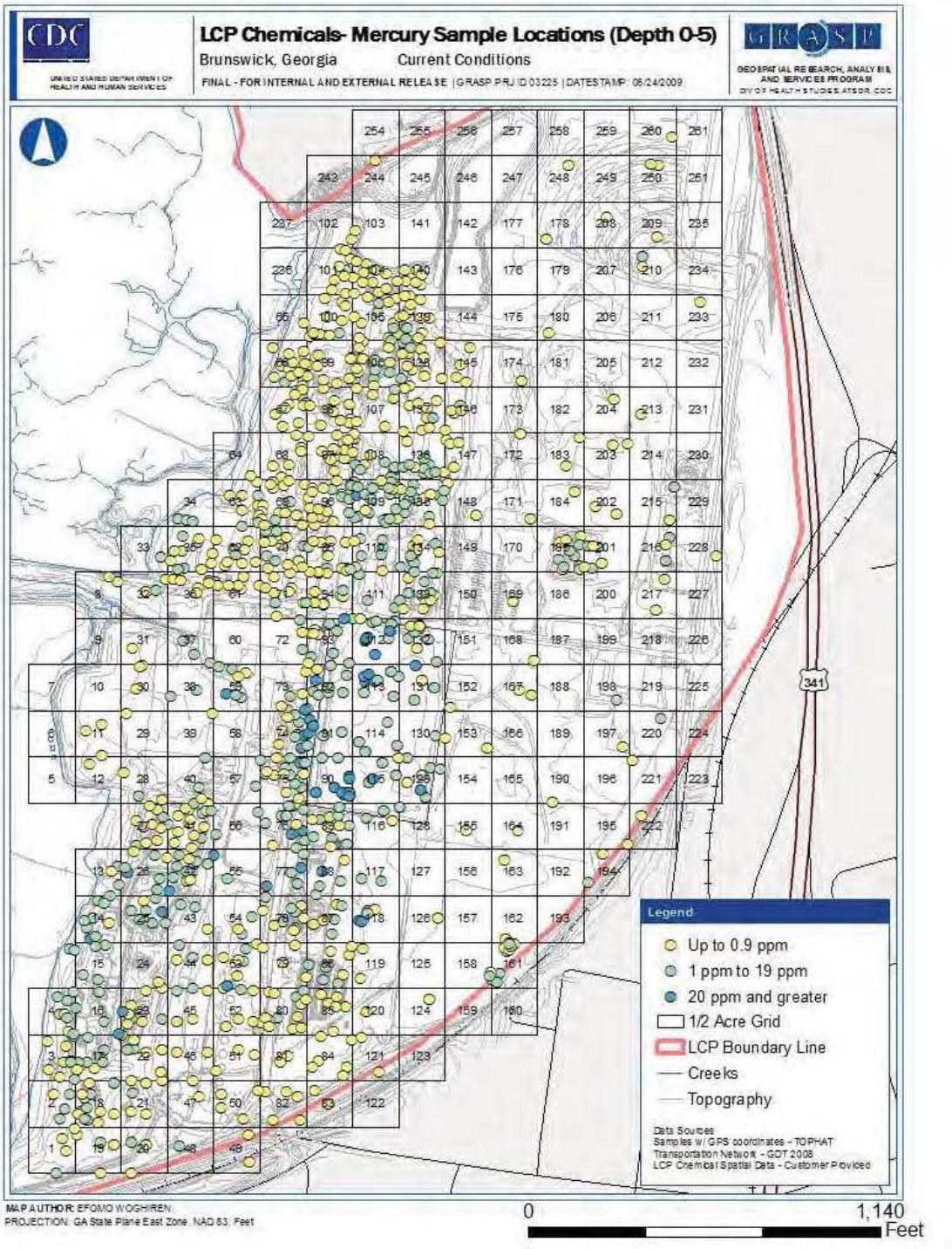


Figure 4. Exposure Units: ½ Acre Grids
Mercury Sampling Locations and Residual Levels, 0-5 ft.



IV.D.3. Polycyclic Aromatic Hydrocarbons (PAHs)

Prior to clean-up actions, PAHs were detected in the north and south removal areas, the north and south separators, and the bunker "C" tank area. Figure 5 shows the location of each sample collected and tested for PAHs. The figure also depicts where residual PAH concentrations are higher in some areas than in others by using a color scheme. Generally, the western portion of the site contains more samples and more residual PAH contamination.

IV.D.3.a. What are PAHs?

Polycyclic aromatic hydrocarbons (PAHs) are a group of over 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances like tobacco or charbroiled meat. PAHs may occur naturally or be manufactured. Many products contain PAHs including creosote wood preservatives, roofing tar, certain medicines, dyes, and pesticides. PAHs enter the atmosphere from vehicle exhaust, emissions from residential and industrial furnaces, tobacco smoke, volcanoes, and forest fires (ATSDR 1996b). The PAHs at the LCP Chemicals Site are residues from the distillation of crude oil.

IV.D.3.b. How are Carcinogenic PAHs Evaluated?

PAHs are composed of carcinogenic and non-carcinogenic PAHs. To evaluate the risk of cancer, an approach is used from the California Environmental Protection Agency (Cal EPA) that converts the total PAH concentration in a sample to a total carcinogenic PAH concentration (CalEPA 2005). On the basis of benzo(a)pyrene toxicity, this approach uses potency factors specific for each carcinogenic PAH to change the concentration of that PAH to a benzo(a)pyrene equivalent concentration. Thus, the benzo(a)pyrene equivalent concentration of various individual carcinogenic PAHs in a soil sample are summed to give the total carcinogenic PAHs (cPAH) for that sample. Therefore, in this document benzo(a)pyrene equivalents will be referred to as cPAHs.

More information about this approach can be found at these websites:

- ≠ http://oehha.ca.gov/air/hot_spots/pdf/May2005Hotspots.pdf
- ≠ http://cfpub.epa.gov/ncea/iris_drafts/recordisplay.cfm?deid=194584
- ≠ http://www.health.state.mn.us/divs/eh/risk/guidance/pahmemo.html

IV.D.3.c. Current cPAH Levels in Soil

The exposure units for the site are defined as ½ acre-sized parcels. Figure 6 contains the overlay of the ½ acre grids to show residual carcinogenic PAH (cPAH) contamination and distribution at the site. Average cPAH concentrations were calculated for each ½ acre grid. The highest average cPAH in any grid was 29 ppm. No grids had average cPAH levels that exceeded EPA's LCP target action level of 50 ppm in soil at either the 0-5 or 0-2 ft. depths. The highest cPAH concentration for any grid (#93) is 59 ppm in the 0-5 ft. depth.

Figure 5. Sampling Locations and Current cPAH Levels in Soil, 0-5 ft.

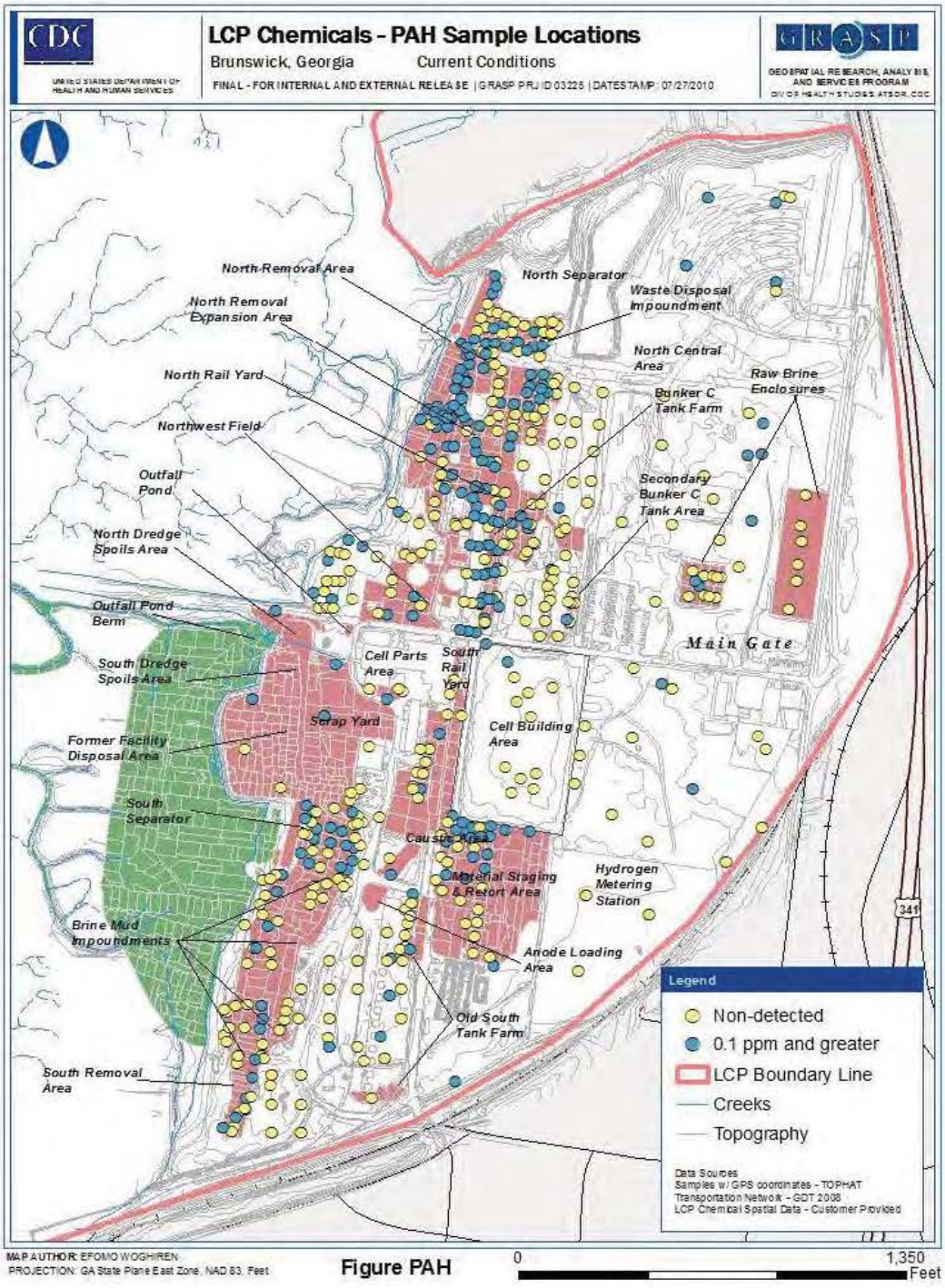
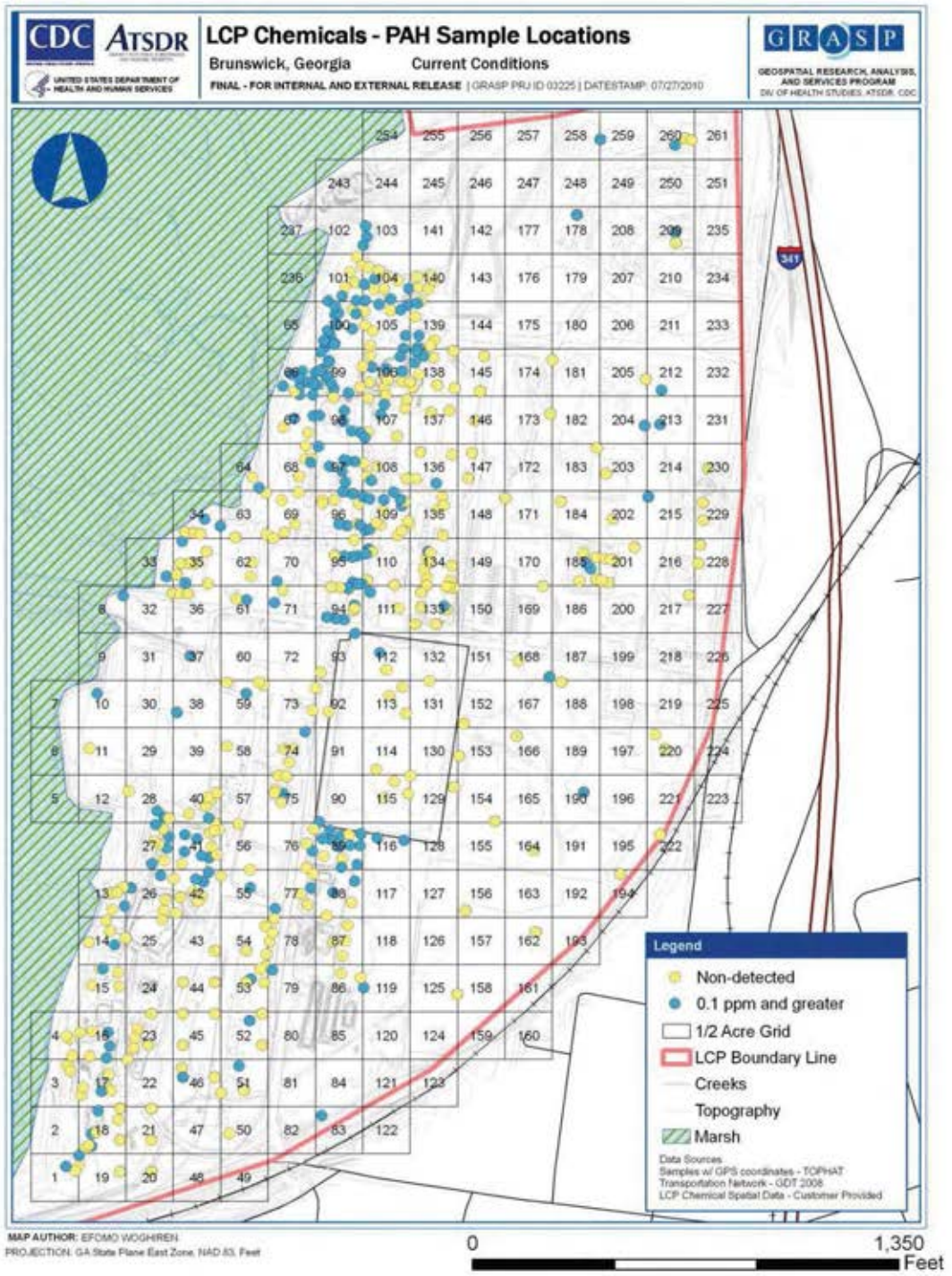


Figure 6. Exposure Units: ½ Acre Grids
cPAH Sampling Locations and Residual Levels in Soil, 0-5 ft.



IV.D.4. Lead

Prior to EPA's clean-up actions, lead was detected in the north removal expansion area, the north central area, the north rail yard, and the old south tank farm. After removal actions, residual lead still exists in some areas. Figure 7 shows the location of each sample collected and tested for lead that represents current lead levels in soil. The figure also depicts where residual lead concentrations are higher in some areas than in others by using a color scheme. Generally, more samples were collected from the western portion of the site. Residual lead levels appear to be evenly dispersed throughout the site.

IV.D.4.a. Current Lead Levels in Soil

The exposure units for the site are defined as ½ acre-sized parcels. Figure 8 contains the overlay of the ½ acre grids to show lead contamination and distribution at the site. Average lead concentrations were calculated for each ½ acre grid.

0-5 Ft Depth

Using samples with any depth between 0 and 5 foot, six grids have average lead levels that exceed EPA's 1994 LCP target action level for this site of 500 ppm (see Table 7); 21 grids have average lead levels between 154 and 499 ppm. (See more discussion in section "*V.F.3.b. Estimating children's lead dose from soil lead levels"* about how 154 ppm was derived). The maximum lead concentration at the site from a single soil sample is 4,430 ppm (Grid #136) and is located slightly northeast of the Bunker C Tank Farm. The highest average lead concentration for any grid (Grid #136) is 745 ppm.

Table 7 (0-5 ft. Depth). Grids with average lead levels in soil above EPA's 1994 site-specific target action level of 500 ppm

Grid #	*Average Concentration*	*Maximum Concentration*	*Minimum Concentration*	*# Samples*
136	745	4,430	52	18
48	728	820	635	2
103	692	1,580	14	6
26	660	3,680	6	7
93	590	3,040	46	6
59	513	1,040	66	6

0-2 Ft Depth

Using samples with any depth between 0 and 2 foot, five grids have average lead levels that exceed EPA's 1994 target action level for this site of 500 ppm (see Table 8); 36 grids have average lead levels between 154 and 499 ppm. (See more discussion in section "*V.F.3.b. Estimating children's lead dose from soil lead levels"* about how 154 ppm was derived). When comparing the 0-2 ft. averages with the 0-5 ft. averages, the maximum lead concentration at the site from a single soil sample is still 4,430 ppm (Grid #136). The highest average lead concentration for any grid (Grid #103) is 1,111 ppm compared to 745 for the 0-5 ft. samples. It is also worth noting that the number of samples per grid decreases, as expected, in the 0-2 ft. depth range.

Table 8 (0-2 ft. Depth). Grids with average lead levels in soil above EPA's 1994 LCP target action level of 500 ppm

Grid #	*Average Concentration*	*Maximum Concentration*	*Minimum Concentration*	*# Samples*
136	745	4,430	52	18
48	728	820	635	2
103	1111	1,580	832	3
26	638	638	638	1
59	513	1,040	66	6

Figure 7. Sampling Locations Showing Current Lead Levels in Soil, 0-5 ft

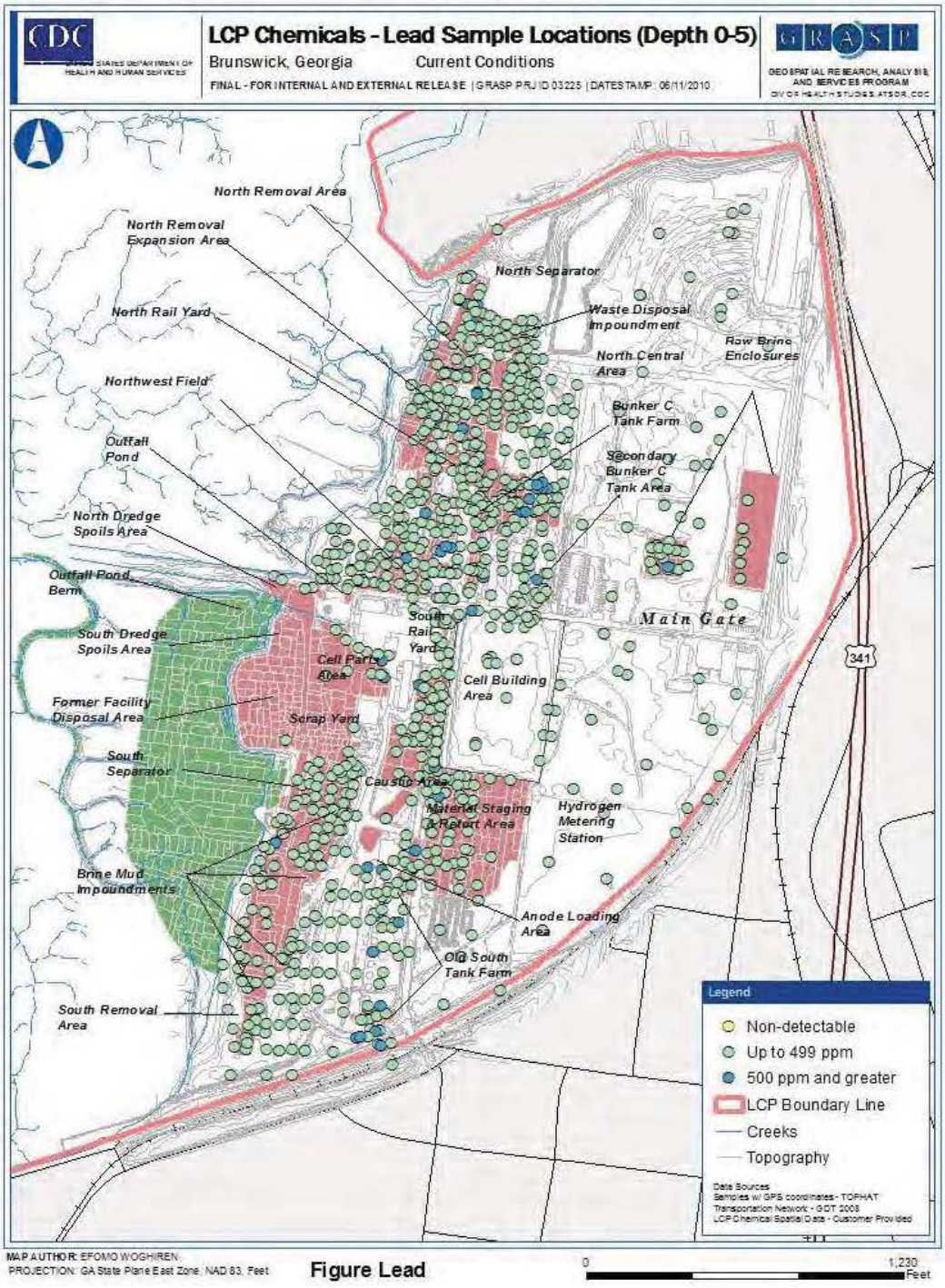
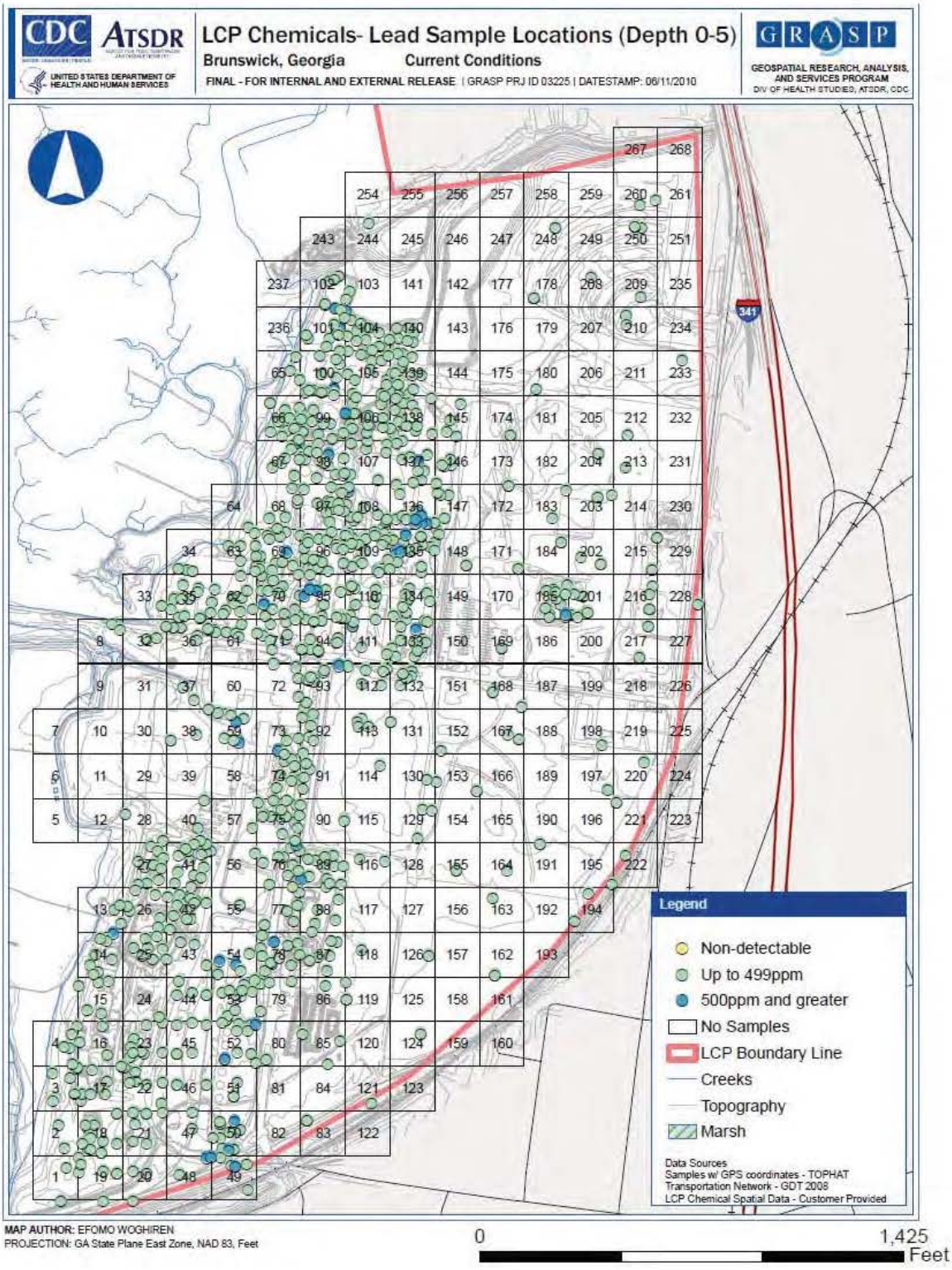


Figure 8. Exposure Units: ½ Acre Grids Lead Sampling Locations and Residual Levels, 0-5 ft.



IV.E. Potential Off-site Disposal Areas

During our assessment of the off-site areas surrounding the LCP Chemicals Site, ATSDR was informed of the existence of four potential historically contaminated areas. These off-site locations are alleged to have been the disposal grounds for various industries in the past. ATSDR has not confirmed, and is not suggesting, that these alleged disposal areas are associated with the LCP Chemicals Site. However, in some instances, historical photos suggest that these off-site locations may be linked to past industrial enterprises, including industries at the (former) LCP Chemicals property. Using historical aerial photos, this link is indicated by the presence of worn paths/roads extending from the LCP industrial facility to a potentially contaminated area.

Because it was raised by the community as a concern, and because some evidence exists to suggest a plausible connection to past industrial activities, ATSDR examined four potential disposal areas. We determined whether environmental samples had been collected in a given area and, when possible, evaluated the results. Below is a list of these potentially contaminated disposal areas:

IV.E.1. Former Tank Areas

Historical photos show the presence of three off-site tanks approximately one-quarter mile from the LCP Chemical property, east of Newcastle Street. The use or content of these former tanks is not known. In the presented historical photo, Figure A6 in Appendix A, the tanks appear as large white circles inside a square enclosure at the rightmost edge of the page. A present-day image of this area shows that the northernmost tank coincides with an area located between Knight Street and Ross Road extension (Former Tank Area 1); the middle tank lies at the western end of Cedar Street and Newcastle (Former Tank Area 2); and the southernmost tank lies at the corner of Cedar and Whitlock Streets (Former Tank Area 3).

EPA conducted limited soil sampling at each of the identified former tank locations (See Figures A7 through A11 in Appendix A).

ATSDR visited each location in July 2009 and made the following observations:

IV.E.1.a. Former Tank Area 1

Former tank area 1 is overgrown in some areas, including thick vegetation covering several mounds of soil currently located on the site. The site also contains piles of rock. Earthmoving equipment (e.g., bulldozers, dump trucks, etc.) was stored on the property. A mobile trailer which appeared to be the office for a car maintenance shop was located on the property. Many vehicles in various stages of disrepair were near the office trailer. A well pump was found on the property and is apparently used to wash trucks.

Limited sampling of the area conducted by EPA revealed the presence of up to 88 ppm of lead and 0.1 ppm of mercury in soil. These levels are not a health concern because they are below ATSDR's comparison values.

IV.E.1.b. Former Tank Area 2

Former tank area 2 contains an abandoned industrial building. The site was posted against trespassing or dumping, so we walked only the public access road along the perimeter of the site. A repair shop appeared to be located approximately 100 yards east of the site.

Ten soil samples were collected from former tank area 2. While the highest lead level was 3,155 ppm, the average lead level from all the samples was 347 ppm. This average lead level is not a health concern for a commercial area but would be a concern for a residential area.

IV.E.1.c. Former Tank Area 3

Former tank area 3 is currently occupied by a business and is fenced; therefore, we could not observe current conditions at the location. Samples collected from former tank area 3 contained lead up to 232 ppm in soil. PCBs were not detected in any of the soil samples. The level of lead detected is not a health concern for a commercial location.

IV.E.2. Clairmont Lane

The Clairmont Lane area is a residential street that intersects Habersham Street and is surrounded by a densely wooded area. Previous community interest arose regarding this area when it was selected by the Glynn County Board of Education for the location of a new elementary school (GEC, undated). The GDNR, Environmental Protection Division, performed environmental sampling at the site to determine if the site was contaminated by historical waste dumping (GDNR 2004a). A total of 35 investigative soils borings were taken across the site in December 2003. Each boring was taken to a depth of 16 feet below existing grade, and sample composites were taken at one foot intervals (GDNR 2004b).

Clinker material, a type of waste product believed to be associated with past industrial activities at the LCP property, and the surrounding soils were analyzed to determine the chemical composition of the clinker for proper disposal, and whether the clinker had caused the immediate surrounding soils to become contaminated (GDNR 2004b). Detectable but low levels of metals were found in the soil. Carbon disulfide was detected in the clinker material at a concentration which exceeded the regulatory level for the chemical. Calcite, a naturally occurring carbonate mineral, was also found in the clinker material. Analytical results found no substances above regulatory limits in the soil samples tested; carbon disulfide was detected above detection limits in the clinker material itself (GDNR 2004b).

In January 2004, approximately 8.8 tons of clinker material were removed from the Clairmont Lane site (GDNR 2004b). Despite the cleanup in 2004, ATSDR staff members observed what appeared to be an area of waste material (i.e. clinker) near the backyard of a home on Clairmont Lane during our visit in July 2009. The material was a black deposit

that had been removed from an area that contained loose clinker rocks. The material was near shrubbery and covered by pine needles, but was easily accessible by walking along the edge of the back yard.

IV.F. Residual Contamination in the Marsh

The marsh near the LCP Chemicals Site contains residual concentrations of PCBs, mercury and dioxins in sediment.

IV.F.1. Residual PCB Levels in the Marsh

Approximately 1,400 sediment samples were collected from the marsh, the Turtle River, off-site areas, and the salt dock area and were tested for PCBs. Total PCB concentrations ranged from non-detect to 570 ppm. The distribution of total PCBs remaining in these areas is shown in Figure 9. Generally, more PCB samples were collected in the marsh areas near the facility; therefore, these areas are more characterized. Samples were also collected from the salt dock area located southwest of the site, along the Turtle River (See Figure 9). Approximately 252 samples had concentrations above 10 ppm total PCBs; approximately 477 samples had concentrations between 1 and 9.9 ppm. The remaining 737 samples had total PCB concentrations less than 1 ppm, including some non-detects.

IV.F.2. Residual Mercury Levels in the Marsh

Approximately 1,500 sediment samples were collected from the marsh, the Turtle River, off-site areas, and the salt dock area and were tested for mercury. Mercury concentrations ranged from non-detect to 450 ppm. The distribution of mercury remaining in these areas is shown in Figure 10. Approximately 110 samples had concentrations above 20 ppm; approximately 693 samples had concentrations between 1 and 19 ppm. The remaining 727 samples had mercury concentrations less than 1 ppm, including some non-detects.

IV.F.3. Residual Dioxin Levels in the Marsh

Dioxins, or chlorinated dibenzo-*p*-dioxins (CDDs), are a class of structurally similar chlorinated hydrocarbons. The basic structure is comprised of two benzene rings joined via two oxygen bridges at adjacent carbons on each of the benzene rings. Dioxins is a term used interchangeably with 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCCD or TCDD). TCDD is the most toxic form of the numerous dioxin compounds. Dioxins are not intentionally produced and have no known use. They are the by-products of various industrial processes (i.e., bleaching paper pulp, and chemical and pesticide manufacture) and combustion activities (i.e., burning household trash, forest fires, and waste incineration) (ATSDR 2006).

Not all dioxins have the same toxicity or ability to cause illness and adverse health effects. The most toxic chemical in the group is 2,3,7,8-TCDD. It is the chemical to which other dioxins are compared. The levels of other dioxins measured in the environment are converted to a TCDD-equivalent concentration on the basis of how toxic they are compared to 2,3,7,8-TCDD. These converted dioxin levels are then added

together to determine the total equivalent (TEQ) concentration of the dioxins in a sample (ATSDR 2006). Hereafter, TCDD equivalents will be referred to as dioxins.

A total of 45 samples were tested for dioxins. Of the 45 samples tested, 6 were surface water samples and 1 was a groundwater sample. Two sediment samples were collected to determine background concentrations. The 36 remaining samples were sediment samples collected from the marsh and from selected off-site locations. Figure 11 shows the sample locations and concentration of dioxins at the site using a color scheme.

Dioxin concentrations in sediment ranged from non-detect to 0.003 ppm. ATSDR's current comparison value for dioxin is 35 parts per trillion (ppt), or 0.000035 ppm. Nine samples exceeded had dioxin levels that exceeded 35 ppt. No samples for dioxins were collected from the dry-land area during this round of sampling. Samples from the dry-land area were collected in 2011 and are discussed in Section IV.G. of this document.

Figure 9. Sampling Locations Showing Residual PCB Levels in Sediment
in the Marsh and Off-Site Locations

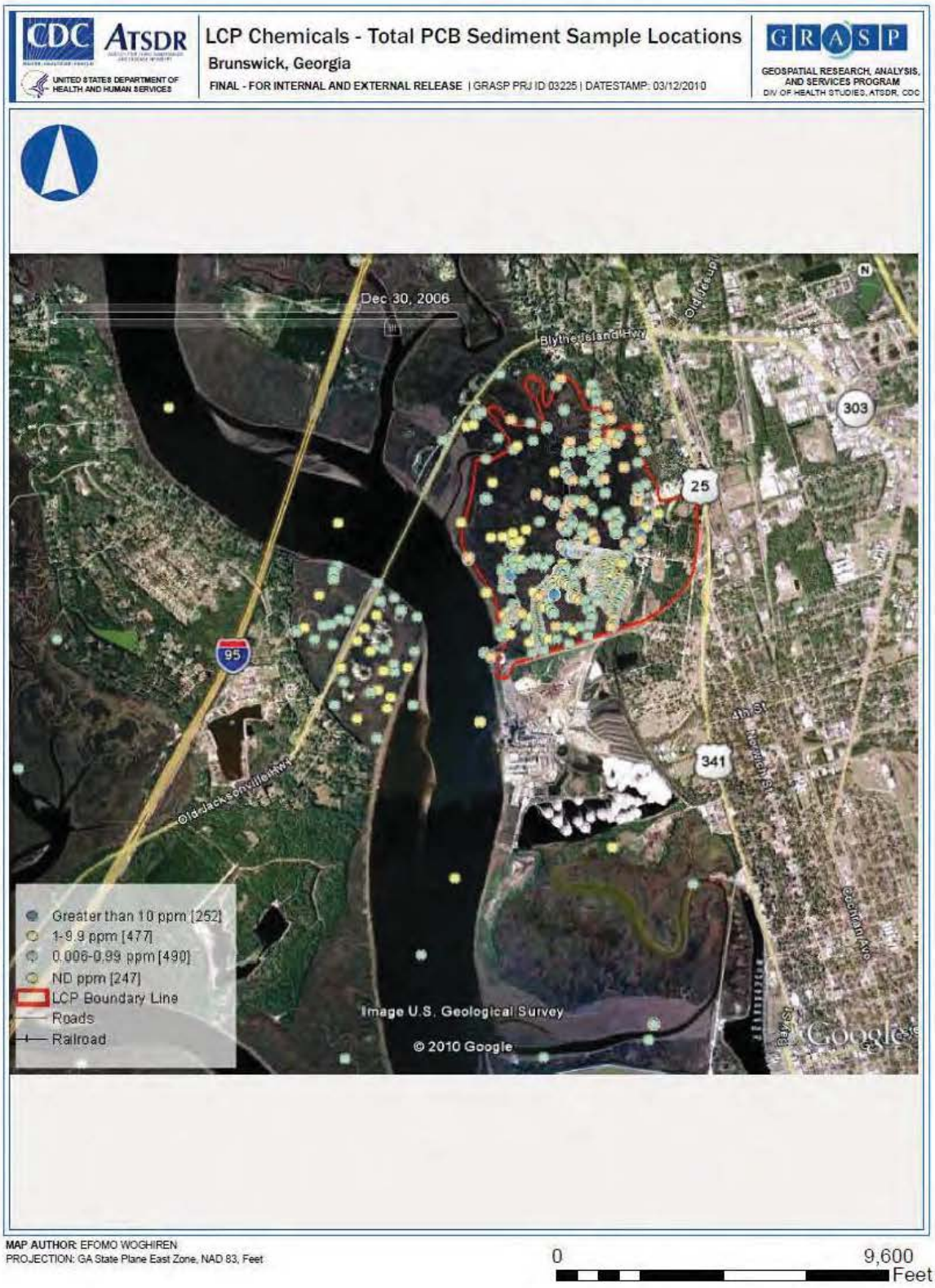


Figure 10. Sampling Locations Showing Residual Mercury Levels in Sediment in the Marsh and Off-site Locations

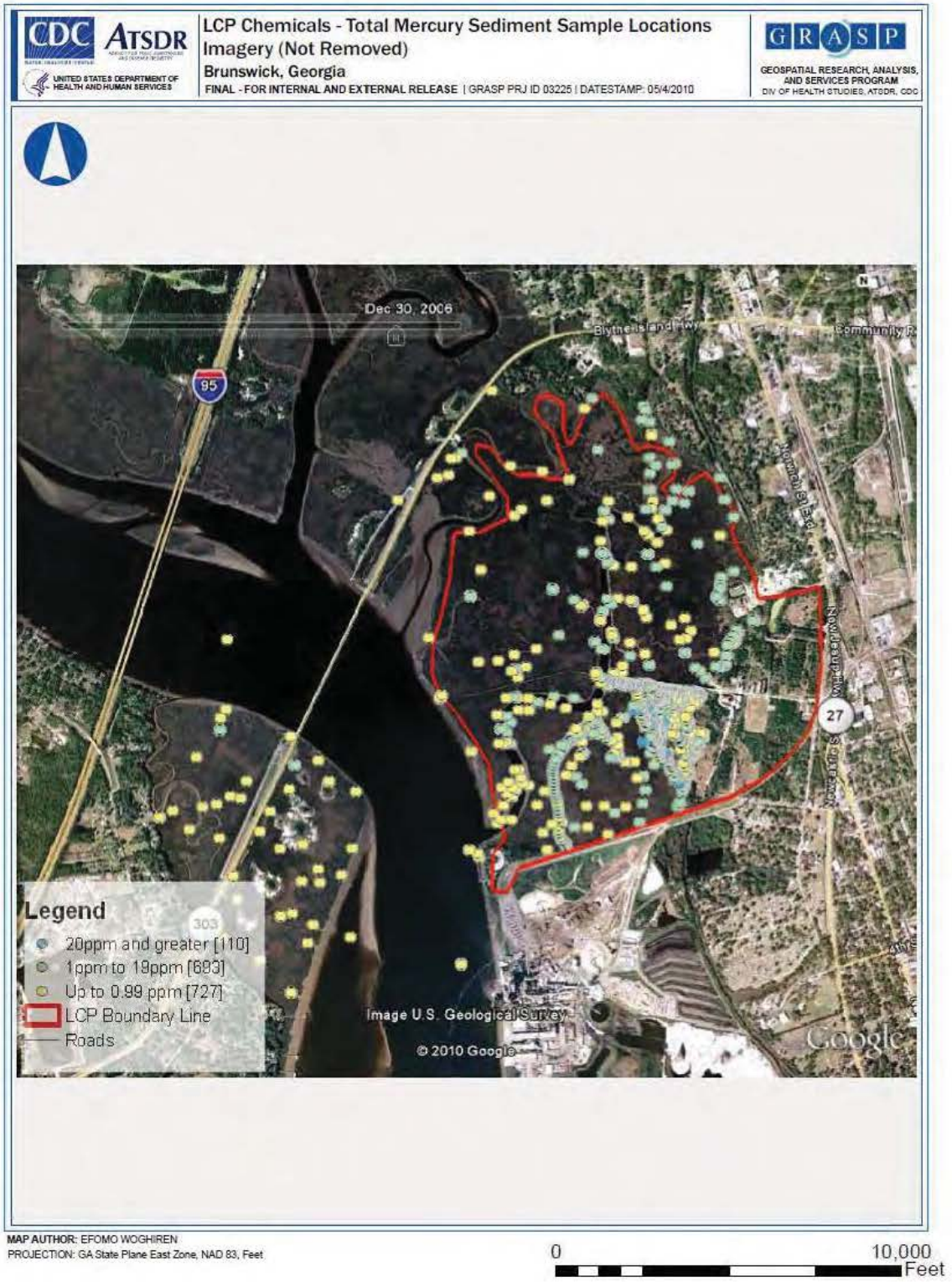
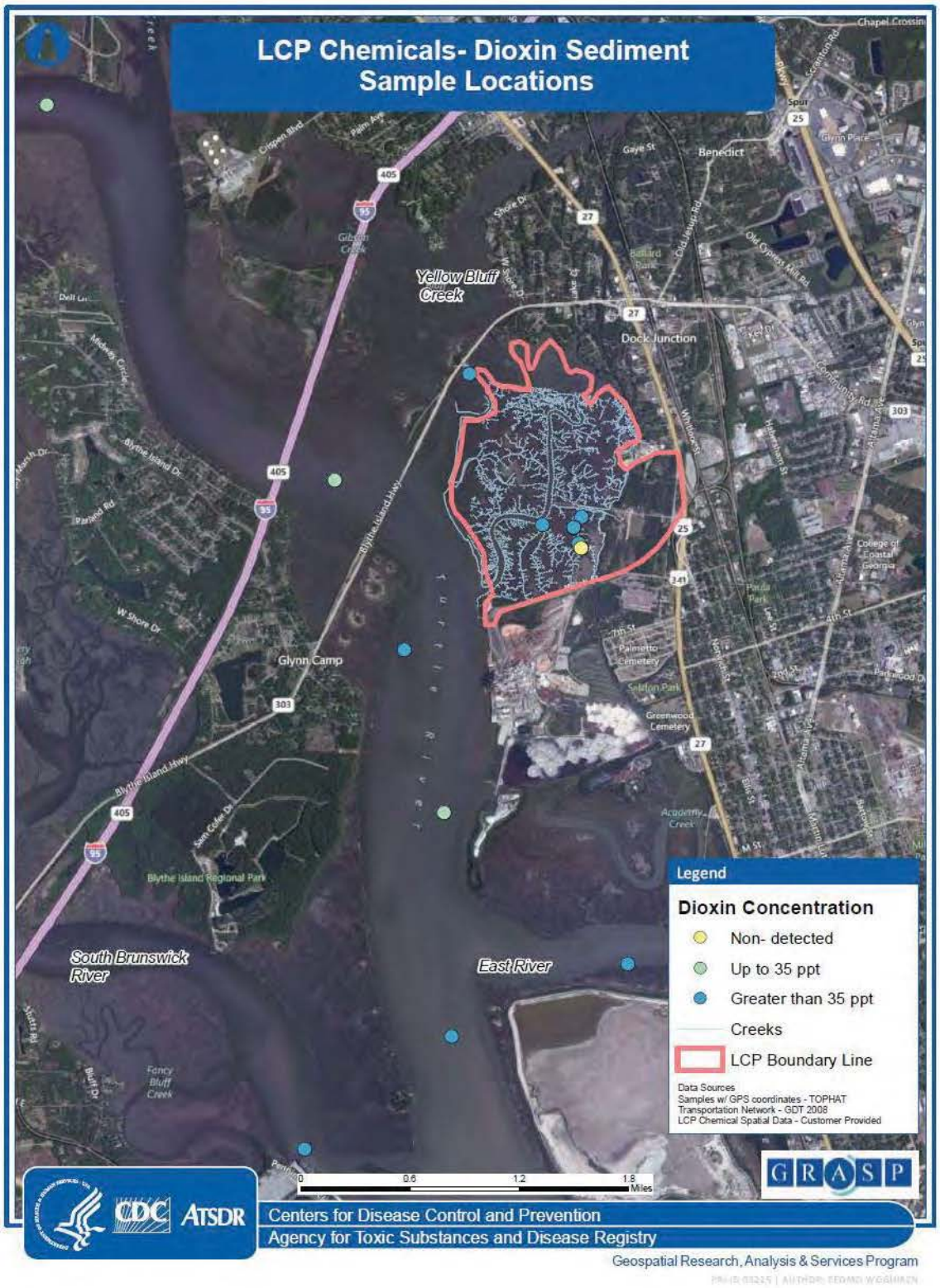


Figure 11. Sampling Locations Showing Residual Dioxin Levels in Sediment in the Marsh and Off-site Locations



IV.G. New Data Collected Since the Public Release of the LCP PHA in 2010

This section presents the results of environmental samples collected in 2010 and 2011. These data were not part of the data evaluated during the previous public release of this document in fall 2010. Some of the new environmental sampling was conducted in response to recommendations by ATSDR in the public release document. The new sampling was focused in the following areas: 1) the dry-land area (dioxins), 2) the on-site former theater area, 3) the on-site pond, and 4) the Altamaha Canal.

IV.G.1. The Dry-land Area (Operable Unit 3)

In April 2011, Honeywell, with the concurrence of EPA and the Georgia Environmental Protection Division (GEPD), sampled soil from the dry-land area for dioxins. The purpose of the sampling was to determine the concentrations of dioxin in the dry-land area (also referred to by EPA as the upland soil area) of the site. The dry-land area also includes the former theater area and on-site pond, which are discussed separately below. The sampling protocol used Incremental Sampling Methodology (ISM), which is a structured composite sampling method that uses "sampling units" as a way to determine contaminant concentrations in a specified geographical area.

Honeywell divided the site into 4 separate quadrants, which is consistent with the sampling design used in EPA's upland soils Human Health Risk Assessment for the site. Each quadrant identified by EPA contained from 1 to 3 sampling units. The size of the sampling units varied. ATSDR renumbered the sampling units in each quadrant from left to right, top to bottom, for easy referencing (see Figure 12 in Appendix E). Appendix E discusses in detail the use of EPA's quadrants and ATSDR's numbering method.

The new data for the dry-land area included sampling results for dioxins only. The dioxin data were converted to TCDD-equivalent concentrations based on how toxic the congeners are compared to 2,3,7,8-TCDD. These converted dioxin/furan concentrations are then added together to determine the total equivalent (TEQ) TCDD concentration in a sample. Hereafter, TCDD equivalents will be referred to as dioxins.

Table 9 below contains the sampling results for total dioxins for the dry-land area. Two dioxin concentrations were reported for most sampling areas; three dioxin concentrations were reported for sampling area 4. For purposes of this assessment, the highest dioxin value was selected to determine health risks.

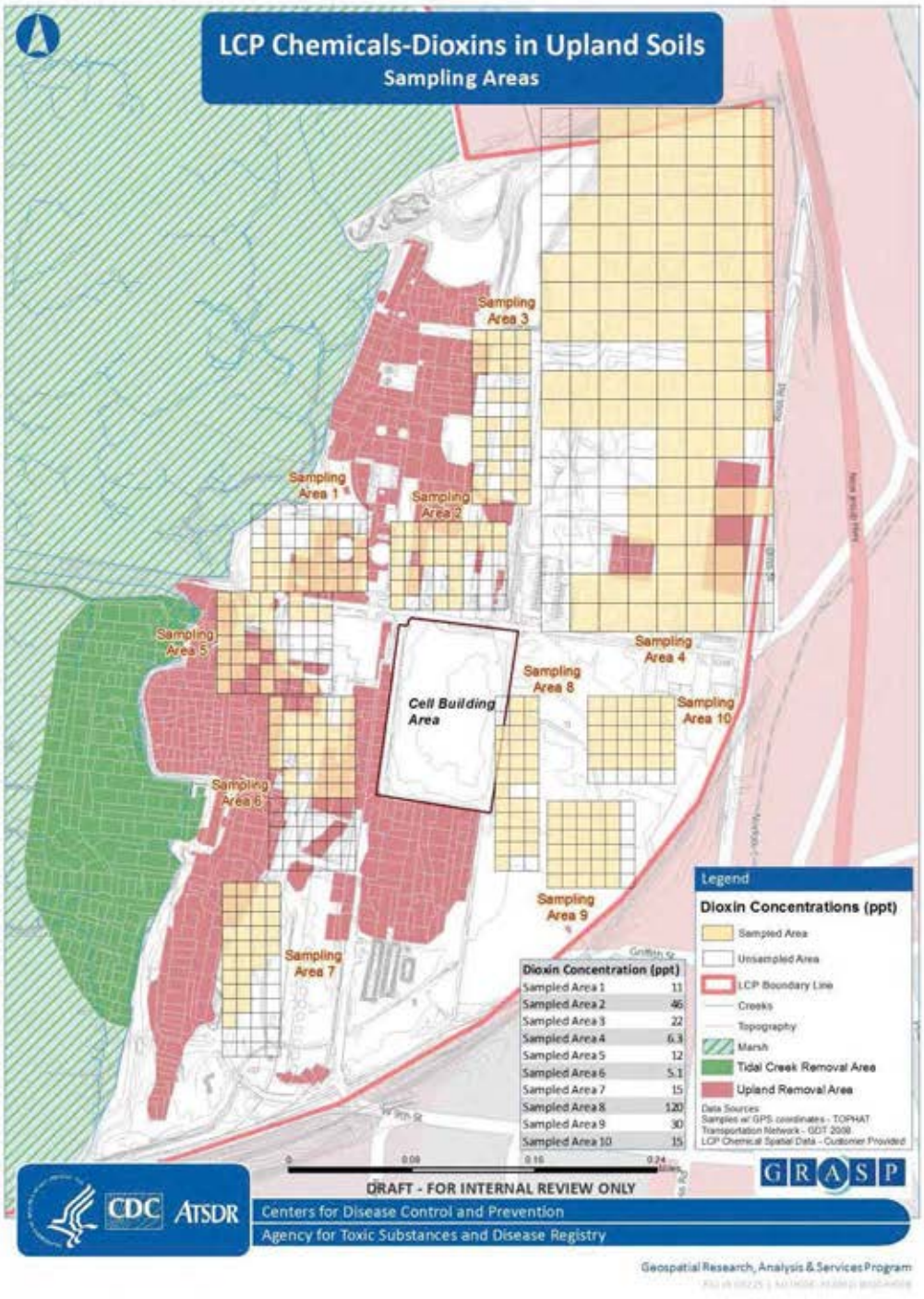
Figure 13 shows the location of the sampled dry-land areas and the dioxin concentration for each sampled area. In some cases, no samples were taken from a smaller block within the larger sampling unit. Where this occurred, ATSDR deleted the smaller block from the sampling unit to show that no sample was taken. The areas not sampled appear as a blank block on the map in Figure 13.

Table 9. List of Sampling Areas and Dioxin Levels in Soil for the Dry-Land Area (See Figure 13)				
Sampled Area	***Dioxin Conc. (ppt)***		***Sampled Area***	***Dioxin Conc. (ppt)***
4	6.2		**2**	**38**
4	5.5		**2**	**46**
4	6.3		3	14
10	13		3	22
10	15		5	12
8	**81**		5	8
8	**120**		6	5.1
9	30		6	1.2
9	30		7	15
1	9.3		7	14
1	11			

Four samples exceed ATSDR's current comparison value of 35 parts per trillion (ppt) for dioxins in soil. The four samples are from two sampling areas – sampling area 8 and sampling area 2 (See Figure 13). Seventeen samples have dioxins concentrations below the comparison value of 35 ppt.

The distribution of dioxins in the dry-land area is shown in Figure 13. Sampling areas 2 and 8 contain the highest concentrations of dioxins. Sampling area 2 is located north of the former cell building area and sampling area 8 is located immediately east of the former cell building area.

Figure 13. Sampling Locations Showing Concentration of Dioxins
for Dry-Land Area (2011)



In some cases, no samples were taken from a smaller section within the larger sampling area. Where this occurred, ATSDR deleted the smaller block from the sampling area to show that no sample was taken. The areas not sampled appear as a blank block on the map.

IV.G.1.a. Former Theater Area

In December 2010, Honeywell sampled the soil at five locations along an arc in the middle of the theater area. Soil samples were collected at two depths: 0 to 1 ft. (surface soil) and 2 to 3 ft. (subsurface soil). Figures 14 through 17 show soil sample locations and sampling results for PCBs, mercury, cPAHs and lead from the December 2010 sampling event.

The soil sampling results from the December 2010 sampling event are summarized in Table 10.

Table 10. Recent Sampling Results, December 2010, for Soil in the Theater Area (ppm)

Contaminant	*Comparison Value (ppm)*	*Concentration Range in Surface Soil (ppm) (0-1 f.t depth)*		*Concentration Range in Subsurface Soil (ppm) (2-3 ft. depth)*	
		Min	*Max*	*Min*	*Max*
PCBs	0.35	0.005	0.13	ND	0.01
Mercury	5*	0.04	0.20	0.01	0.03
cPAHs	0.096	0.003	**0.14**	ND	0.02
Lead	None	8	63	4	43

*indicates comparison value for methylmercury

As shown in the table, only cPAHs in surface soil exceeded its comparison value. None of the other sampling results that had a comparison value exceeded their applicable soil comparison value. Lead does not have a comparison value. The level of PAH exceed the comparison value and therefore will be evaluated further in the public health implications section of this report.

Figure 14. Sampling Locations Showing Concentration of PCBs in Soil
In Theater Area, 2010

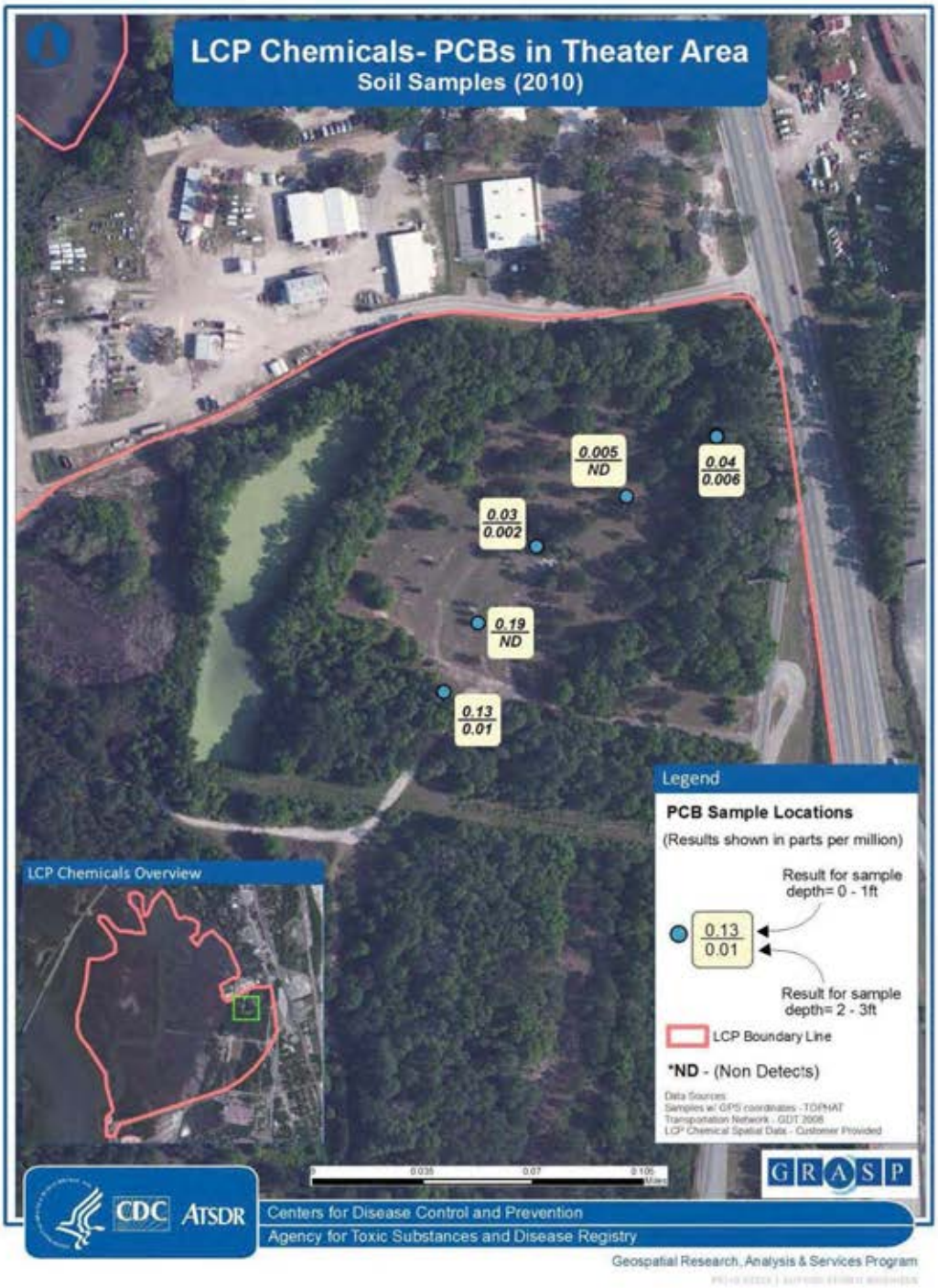


Figure 15. Sampling Locations Showing Concentration of Mercury in Soil
In Theater Area, 2010

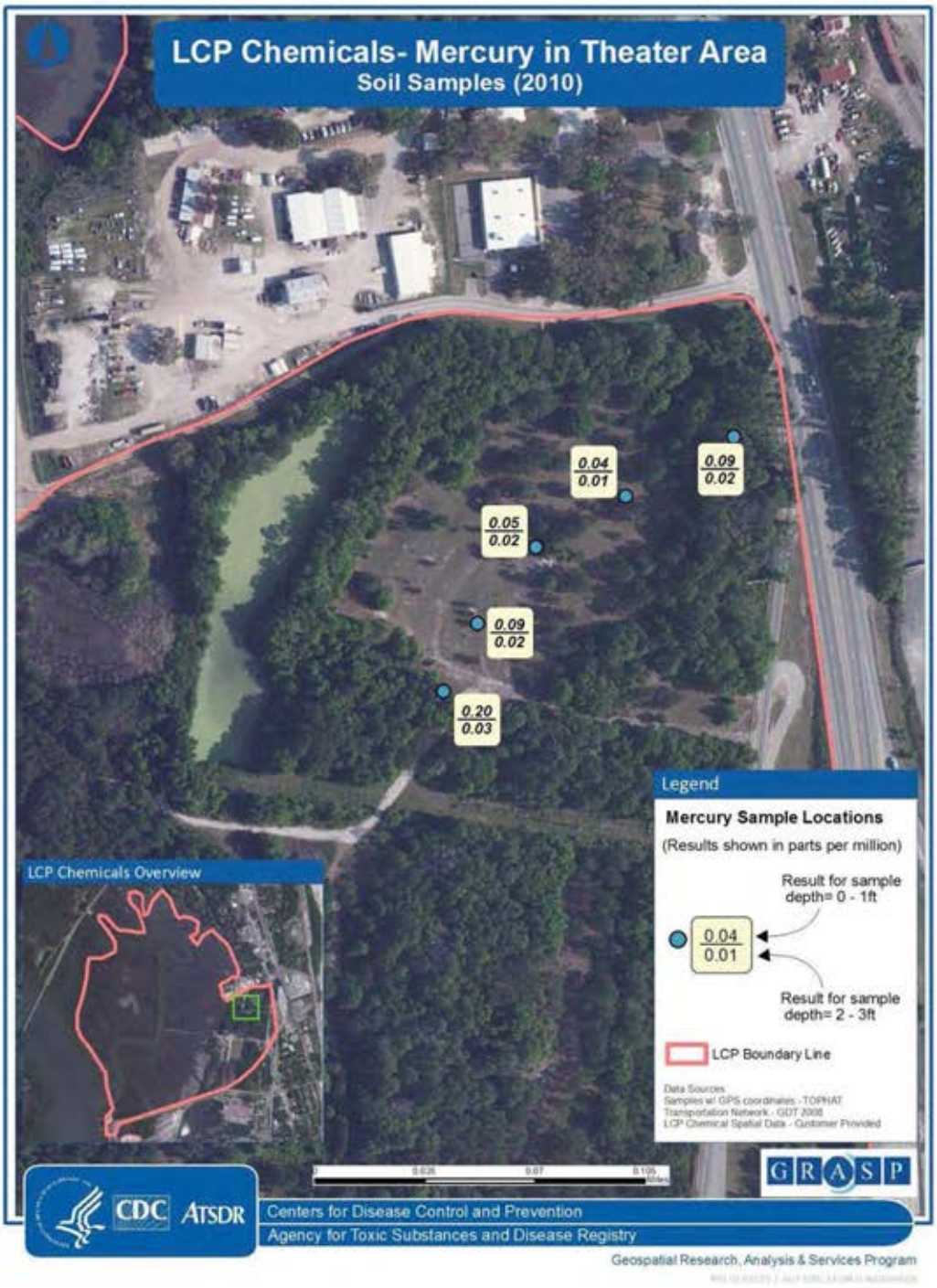


Figure 16. Sampling Locations Showing Concentration of cPAHs in Soil
In Theater Area, 2010

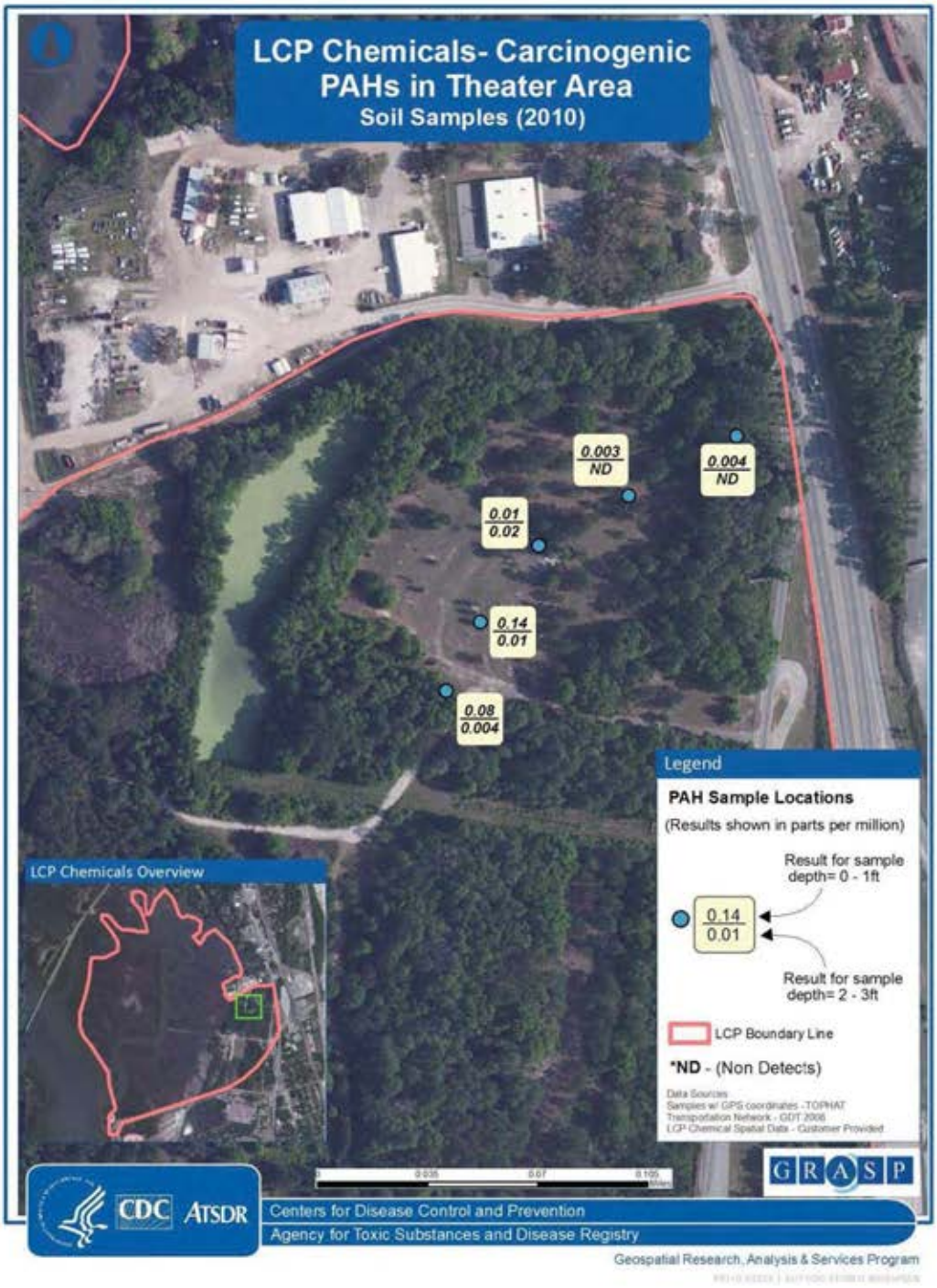
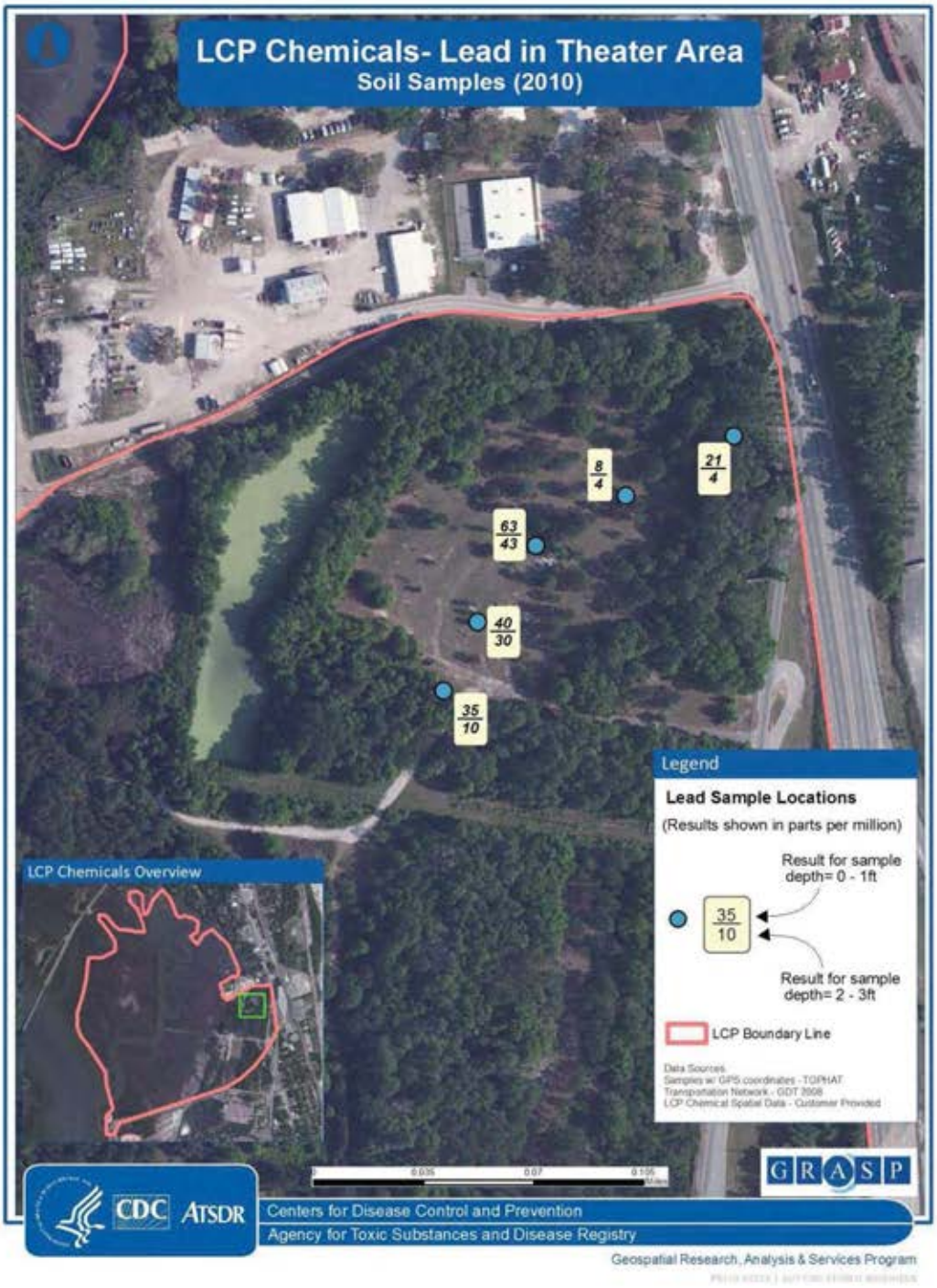


Figure 17. Sampling Locations Showing Concentration of Lead in Soil
In Theater Area, 2010



IV.G.1.b. The On-site Pond

During three different sampling events between 1989 and 2008, a total of 4 surface water and 3 sediment samples were collected from the freshwater pond located in the theater area. The three sampling events are summarized below:

- ≠ One surface water sample was collected in 1989;
- ≠ One surface water and one sediment sample were collected in 2007; and
- ≠ Two surface water and two sediment samples were collected in 2008.

In December 2010, Honeywell collected surface water and sediment samples from three locations in the on-site pond. The three locations were selected to be evenly spaced along the longitudinal axis of the pond near the former drive-in theater. One surface water sample and one sediment sample (0 to 1/2 ft.) were collected from each location. Fish collection was attempted but no fish were caught in the on-site pond.

The location of the surface water and sediment samples and the analytical results are illustrated in Figures 18 through 21 and summarized in Tables 11 and 12.

Table 11. Recent Sampling Results, December 2010, for Surface Water in On-site Pond (ppm)

	Contaminant	***Comparison Value***	***Min Conc.***	***Max Conc.***
Surface Water	PCBs	0.000018	ND	ND
	Mercury	None	0.000002	0.000002
	cPAHs	0.0000048	ND	ND
	Lead	0.015*	0.0002	0.0002

Table 12. Recent Sampling Results, December 2010, for Sediment in On-site Pond (ppm)

	Contaminant	***Comparison Value***	***Min Conc.***	***Max Conc.***
Sediment	PCBs	0.35	0.01	0.14
	Mercury	None	0.03	0.1
	cPAHs	0.096	0.004	0.01
	Lead	None	3	4

*indicates the MCL action level

None of the surface water or sediment concentrations exceeds their applicable comparison value. (Surface water concentrations were compared to drinking water comparison values for conservatism.) Therefore, PCBs and cPAHs in the pond's surface water and sediment will not be evaluated further. The concentrations of mercury (0.004 to 0.01 ppm vs. a background of 0.12 ppm) and lead (3 to 4 ppm vs. a background of 17 ppm) are well below background soil levels (ATSDR 1992); therefore, mercury and lead in sediment will not be evaluated further. Because pond water does not serve as a drinking water source and because the mercury levels are very low, mercury in pond water is not a health concern.

Figure 18. Sampling Locations Showing Concentration of PCBs in Surface Water and Sediment in On-site Pond, 2010

Figure 19. Sampling Locations Showing Concentration of Mercury in Surface Water and Sediment in On-site Pond, 2010

Figure 20. Sampling Locations Showing Concentration of cPAHs in Surface Water and Sediment in On-site Pond, 2010

Figure 21. Sampling Locations Showing Concentration of Lead in Surface Water and Sediment in On-site Pond, 2010

IV.G.2. Adequacy of the sampling in the dry-land area

ATSDR evaluated the adequacy of sampling in the dry-land area of the site. The goal of our evaluation was to determine if the collection of soil samples was adequate for making public health decisions. Our public health decision-making considers all available or proposed uses for the site - residential, commercial and industrial uses.

ATSDR now understands that approximately 32 acres of the dry-land area have been purchased by Glynn County to build a detention center (The Florida Times-Union, 2012) According to the report, a 610-bed detention center will be built on the grounds of the former theater area, which also includes the on-site pond. Using publicly available files, ATSDR was able to approximate the location of the 32 acre detention center facility on the site. The (approximate) prison boundaries are shown in Figures 22 through 25. The area of the detention center will not be evaluated for sampling adequacy because the future land use has already been determined.

Figures 22 through 25 illustrate the areas of the site ATSDR considers to have enough samples to draw health conclusion and which areas do not. Grids shaded in blue are considered to have enough samples to draw a health conclusion. Grids that are not shaded are considered to be under-sampled (i.e., not enough samples taken to make a health conclusion). Generally, ATSDR considered a grid with 3 or more samples to have an adequate amount of samples to make a health call. There are separate sampling adequacy figures for the contaminants of concern - PCBs, cPAHs, mercury and lead.

IV.G.2.a. Dioxin

Generally, the dioxin sampling appears to be adequate to evaluate surface soil (top 3 inches) for the site. However, we do not have adequate sampling from soil below 3 inches. Soils below 3 inches are important because we expect soil at all depths to be moved during future on-site construction activities. Because no samples were collected at depth, it is not possible to evaluate whether dioxin contamination might exist below the surface. The lack of depth samples seems inconsistent with all the other sample designs for the LCP Chemicals Site. For example, recent soil samples collected from the theater area consisted of sample depths 0 to 1 ft. and 2 to 3 ft.

IV.G.2.b. PCBs, Mercury, cPAHs and Lead

Approximately half of the grids are considered sufficiently sampled for making a health conclusion for the chemicals PCBs, mercury, and lead. That means that half of the grids require additional sampling in order to have an adequate amount of samples to make a health determination. For cPAHs, approximately one-third of the grids are sufficiently sampled for ATSDR to make a health conclusion. Most of the insufficiently sampled areas (excluding the area of the proposed detention center) for each chemical of concern is in the southeastern portion of the site. Another area frequently identified as not having

adequate sampling is the western dry-land area closest to the marsh. A possible reason for this is that the TEG data were deemed unusable because of data quality issues.

One reason certain areas may not have been sampled is that LCP Chemicals did not perform industrial activities on that portion of the site. However, LCP Chemicals may have disposed industrial waste anywhere on the property. In addition, numerous other industries existed at this location before LCP Chemicals and those industries may have disposed of waste throughout the property.

Figure 22. Adequacy of Sampling for PCBs in the Dry-land Area

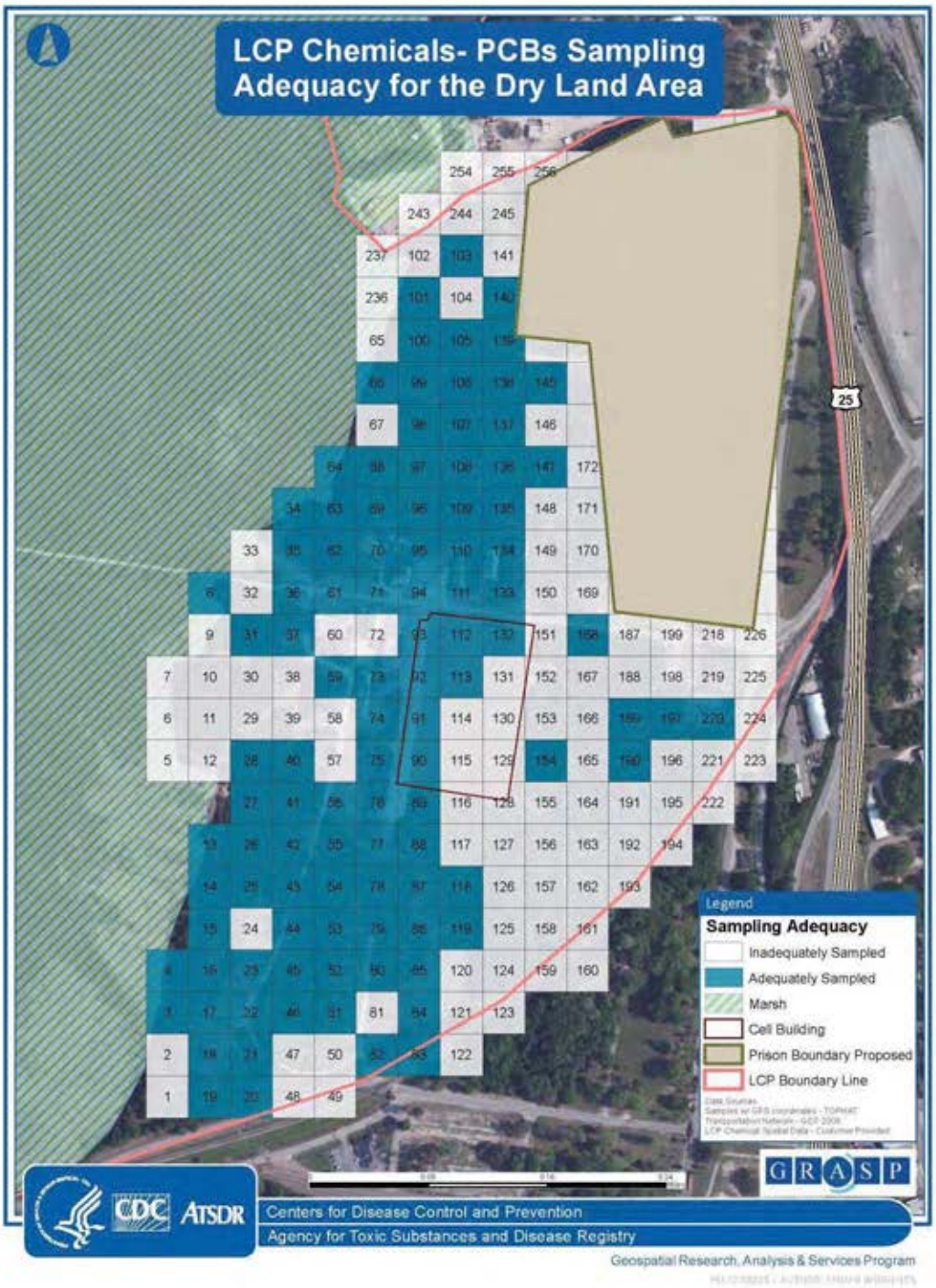


Figure 23. Adequacy of Sampling for Mercury in the Dry-land Area

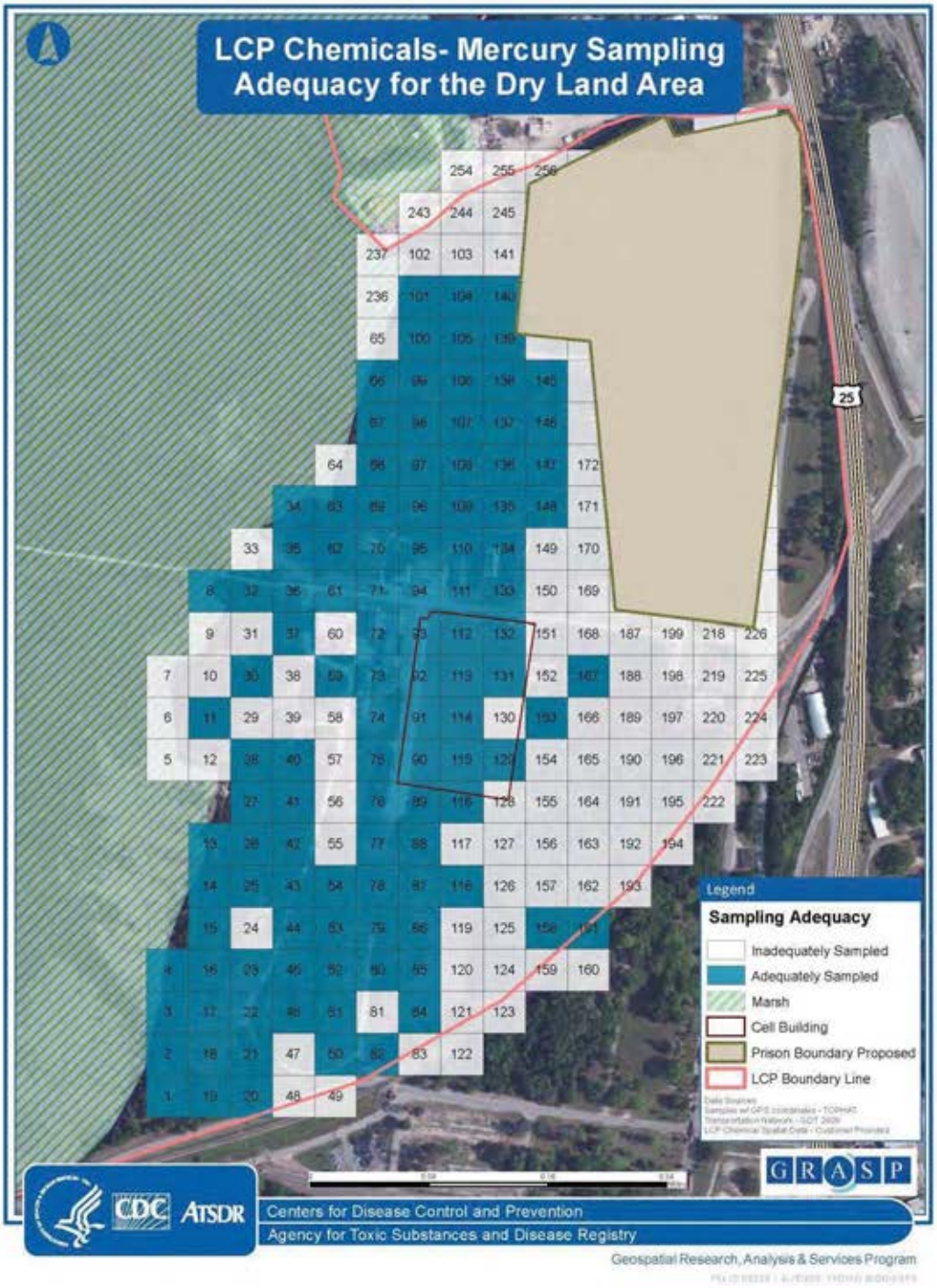


Figure 24. Adequacy of Sampling for PAHs in the Dry-land Area

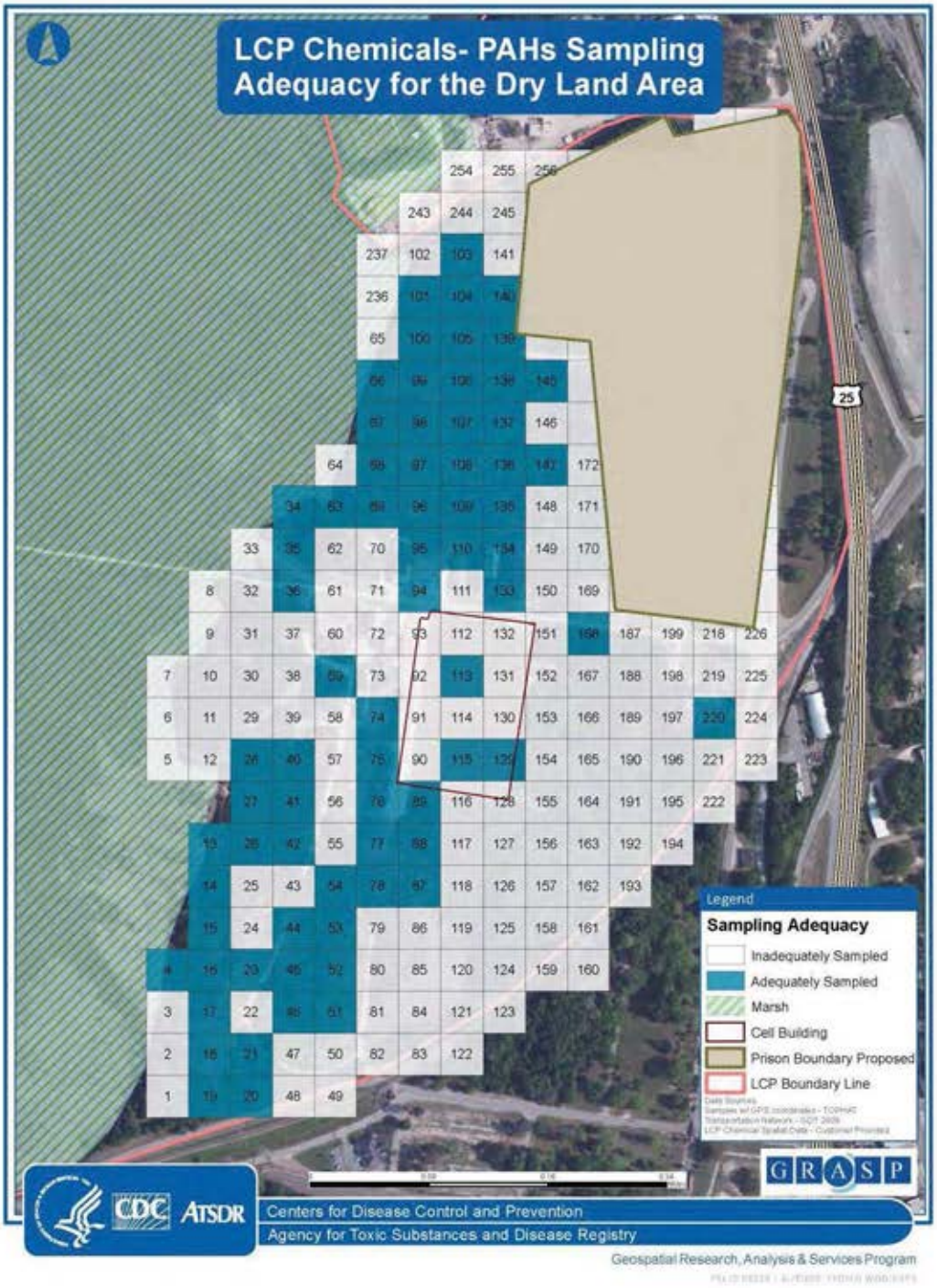
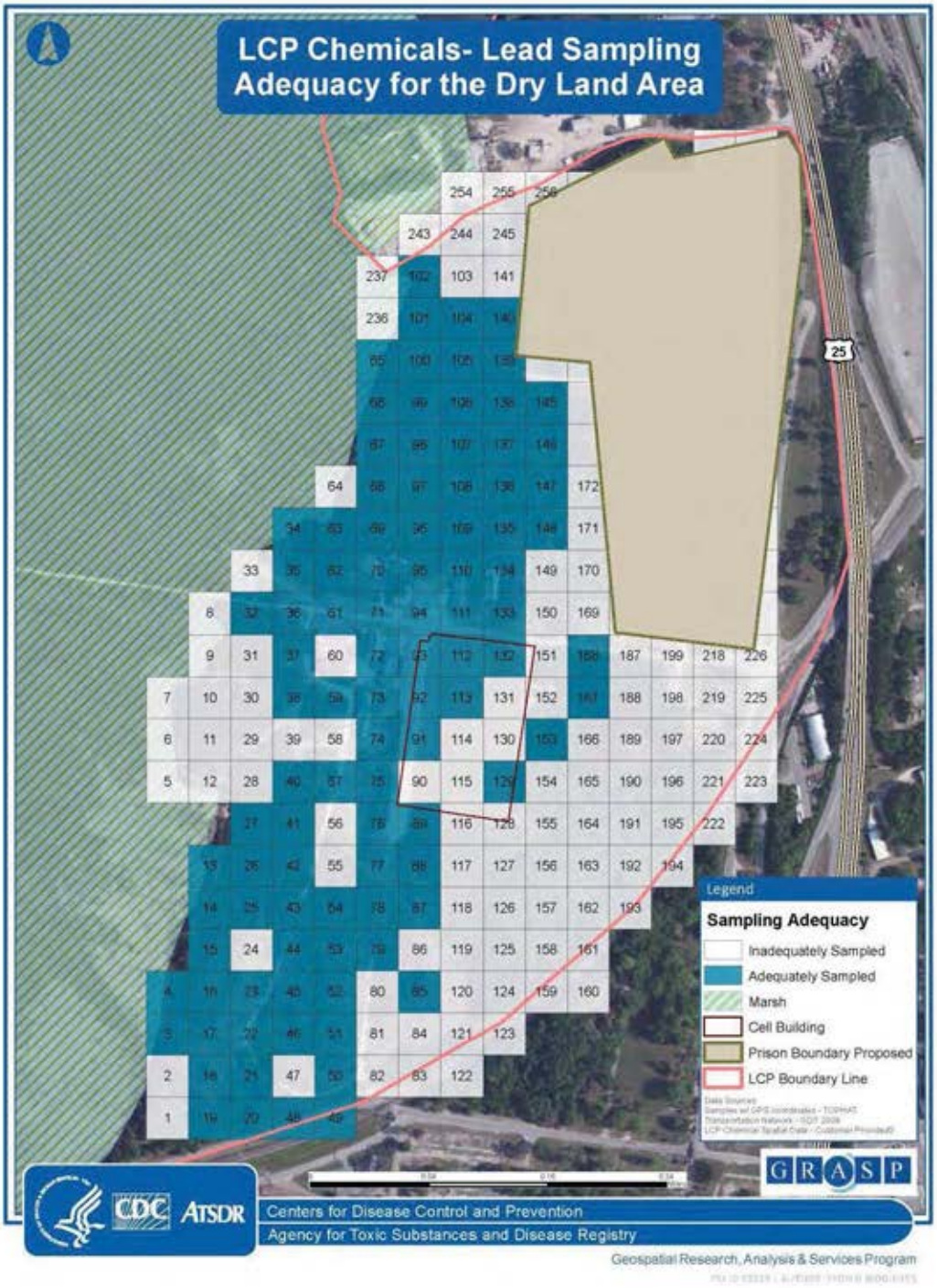


Figure 25. Adequacy of Sampling for Lead in the Dry-land Area



IV.G.3. The Altamaha Canal

In July 2011, Honeywell collected sediment and fish tissue samples from a segment of the former Brunswick-Altamaha Canal ("the Altamaha Canal") south of the LCP Chemical Site (EPS 2011). Honeywell conducted the sampling in response to a recommendation by ATSDR to further characterize the sediment and fish tissue in the Altamaha Canal that lies south of the LCP Chemical site. This section of the canal was identified by ATSDR as a potential pathway for onsite contaminant migration. The sampling was conducted to provide information on the potential for human exposure due to (1) direct contact with contaminants in surface sediments and (2) consumption of contaminated fish or shellfish from the canal.

When the canal was constructed in the mid-1800s, it served as a transportation point between harbors in Brunswick and the Altamaha River, which lies approximately 12 miles to the north (EPS 2011). A portion of the canal once traversed the shoreline area along the western edge of the LCP property but has since been filled in. Today there is no visible presence of the canal on the LCP property. According to Honeywell, there is no direct surface water communication between the LCP marsh and the canal (EPS 2011).

IV.G.3.a. Sediment Sampling

Surficial sediment samples (upper 6 inches) were collected from twenty locations within the canal section between the West 9th Street (northern limit) and the T Street (southern limit). Each sample is comprised of a five-point composite taken along an approximate 1000-ft stretch of the canal. The sampling locations and analytical results are shown in Figures 29 through 33. The sediment sampling results are summarized in Table 13.

Table 13. Recent Sampling Results, July 2011, for Sediment in an Offsite Portion of the Altamaha Canal (ppm)

	Contaminant	*Comparison Value*	*Min Conc.*	*Max Conc.*
Sediment	PCBs	0.35	0.01	**2.3**
	Mercury	5*	0.04	4.96
	cPAHs	0.096†	0.07	**0.69**
	Lead	None	5.82	45.2
	Dioxin	0.000035±	0.000021	**0.000127**

*indicates comparison value for methylmercury
† indicates comparison value for benzo(a)pyrene
±indicates ATSDR's comparison value of 35 ppt for soil

The concentration of lead in sediment from the canal is at or near background lead levels in soils (i.e., 7 ppm) (ATSDR 1992) and the concentration of mercury is below ATSDR's comparison value; therefore, lead and mercury in sediment will not be evaluated further. The levels of PCBs, cPAHs, and dioxin exceed ATSDR's comparison values and therefore will be evaluated further in the public health implications section of this report.

It should be noted that PCBs, specifically Aroclor 1268,were detected in every sediment sample.

It should also be noted that the concentrations of all contaminants (PCBs, mercury, PAHs and lead) except dioxin are higher at the northernmost sampling location, which is also closest to the LCP Chemical site. The general trend is for higher concentrations to be closer to the site (north) and to decrease as the canal flows south. This spatial trend suggests that contaminants might have migrated from the site into the Altamaha Canal.

IV.G.3.b. Fish Tissue Sampling

Fish and shellfish were collected from areas near the southern terminus of the canal (Figure 31) using gill nets, cast nets, and crab traps. Nets were place approximately every 1000 linear feet of canal. The following types and numbers of finfish and shellfish were collected:

- ≠ 1 spotted sea trout
- ≠ 1 red drum
- ≠ 7 striped mullet
- ≠ 15 blue crabs
- ≠ 108 white shrimp

Three replicate samples from each finfish and shellfish species were tested (except for red drum and spotted sea trout where only one fish of each was caught). Finfish were scaled and filleted; only the edible portion was collected for testing. Shellfish were also processed to remove only edible tissue for testing. Fish tissue samples were analyzed for metals (including mercury and lead), PCBs and PAHs. The results for PCBs and mercury are summarized in Table 14.

It should be noted that Aroclor 1268 was the only PCB congener detected in fish tissue, which suggests that the LCP Chemicals Site is the likely source.

Table 14. Results of Fish and Shellfish Tissue Sampling Altamaha Canal, 2011			
FINFISH	***Contaminant***	***Concentration (µg/kg-ww)****	***No. Fish in Sample***
Red Drum	PCBs (1268)	21	1
	Mercury	88.3	
Striped Mullet	PCBs (1268)	290	3
	Mercury	12.3	
Striped Mullet	PCBs (1268)	260	2
	Mercury	14.9	
Striped Mullet	PCBs (1268)	200	2
	Mercury	12.8	
Spotted Sea trout	PCBs (1268)	81	1
	Mercury	117	
SHELLFISH	***Contaminant***	***Concentration (µg/kg-ww)****	***No. Fish in Sample***
Blue Crab	PCBs (1268)	14	4
	Mercury	67.2	
Blue Crab	PCBs (1268)	21	6
	Mercury	69.2	
Blue Crab	PCBs (1268)	9.4	5
	Mercury	107	
Shrimp	PCBs (1268)	14	36
	Mercury	18.7	
Shrimp	PCBs (1268)	16	36
	Mercury	22.3	
Shrimp	PCBs (1268)	16	36
	Mercury	21.2	

*µg/kg-ww = microgram per kilogram wet weight; dry weight will likely be higher when accounting for the moisture content

Figure 26. Sampling Locations Showing Concentration of PCBs in Sediment in Altamaha Canal, 2011 Just South of the LCP Chemicals Site.

Figure 27. Sampling Locations Showing Concentration of Mercury in Sediment in Altamaha Canal, 2011 Just South of the LCP Chemicals Site.

Figure 28. Sampling Locations Showing Concentration of PAHs in Sediment in Altamaha Canal, 2011 Just South of the LCP Chemicals Site.

Figure 29. Sampling Locations Showing Concentration of Lead in Sediment in Altamaha Canal, 2011 Just South of the LCP Chemicals Site.

Figure 30. Sampling Locations Showing Concentration of Dioxins in Sediment in Altamaha Canal, 2011 Just South of the LCP Chemicals Site.

Figure 31. Sampling Locations for Finfish and Shellfish Collection,
Altamaha Canal South of the LCP Chemicals Site.

V. PUBLIC HEALTH IMPLICATIONS

The public health implication section evaluates whether people's health could be affected should the site become residential or commercial. We know that contact with soil results in soil ingestion that could lead to exposure to contaminants in soil. If that exposure is high enough, it could cause harmful effects in people. This section describes the harmful effects that might be possible from exposure to contaminants in soil. This evaluation was a major component of the public release of the report in September 2010.

Since that time, EPA has collected more soil samples, particularly around the former theater and the pond in the northwest corner of the site. These new data are evaluated for the first time in this report. In addition, EPA collected sediment and fish samples from the Altamaha Canal that exists just south of the LCP site. This section evaluates whether eating fish from the Altamaha Canal might cause harmful effects.

V.A. Soil Ingestion

Children and adults can come in contact with chemicals in soil by accidentally swallowing small amounts of soil that cling to their hands when they put their hands in or near their mouths. This exposure is greatest for preschool children because of their frequent hand-to-mouth activity. When chemically contaminated soil is tracked indoors, people also can be exposed to chemicals by swallowing contaminated dust that clings to their hands. Preschool children, on average, swallow more soil and dust than people in any other age group. This is because some preschoolers often have close contact with soil and dust when they play, and because they tend to engage frequently in hand-to-mouth activity. The amount of soil that people ingest daily is typically somewhere between 30 milligrams to 200 milligrams (ATSDR 2005b; EPA 1997; Calabrese 1997). To put this amount in perspective, it is approximately equal to a pinch (or less than $^{1}/_{32}$ teaspoon) to $^{1}/_{8}$ teaspoon of soil.

V.B. Soil Pica Behavior

Pica behavior, or the eating of non-food items, is well known in children. Children have been observed eating paint chips, matches, paper, clay, soil, and numerous other non-food items. Children who eat large amounts of soil have a behavior called "soil-pica." Soil pica behavior is most likely to occur in preschool children as part of their normal exploratory behavior. Children between the ages of 1 and 2 years have the greatest tendency for soil-pica behavior, and this tendency diminishes as they become older. The exact percentage of children who eat soil is not known. Studies have reported that soil pica behavior occurs in as few as 4 out of every 100 children (i.e., 4%) or in as many as 21 out of every 100 children (i.e., 21%) (Barltrop 1966; Robischon 1971; Shellshear 1975; Vermeer and Frate 1979). A study by ATSDR and the Colorado Department of Health and Environment found 21% of preschool children with soil pica behavior in a predominantly Hispanic population. About 10% of preschool children ate soil within 2

weeks of their parents being interviewed (ATSDR 2005b). Studies on children with soil pica behavior have shown that they can eat up to a teaspoon of dirt (or 5,000 milligrams) (Stanek and Calabrese 2000; Calabrese and Stanek 1993; Calabrese *et al*. 1989; Wong 1988).

Limited information is available concerning how often and how long soil pica behavior occurs in children. Some preschool children might eat soil once during their preschool years, while others might go through a stage of eating soil several times during a week, or even over several months. Soil-pica behavior might occur for several days in a row, or a child might skip days between eating soil (Calabrese and Stanek 1998; Calabrese and Stanek 1993; Wong 1988; ATSDR 2001).

When estimating the intake of chemicals from soil pica behavior, ATSDR estimates a dose assuming that some children eat soil 3 times a week. Because soil pica behavior is habitual, it is reasonable to assume that this behavior can occur for several weeks to several months, especially during late spring, summer and early fall when preschool children might spend more time outdoors (ATSDR 2001).

V.C. Estimating Contact with Chemicals in Soil

As described previously, one way contact with chemicals in soil occurs is from swallowing contaminated soil that clings to a person's hands. The amount of chemical that is swallowed is called a dose. Factors that are important in estimating the dose of chemicals include the following:

- ≠ the average concentration of chemicals in soil,
- ≠ how much soil is ingested,
- ≠ how frequently someone ingests soil, and
- ≠ a person's weight.

The following equation is used to estimate chemical dose in people from swallowing soil:

$$\textit{Chemical dose} = \frac{\textit{(chemical concentration in soil, mg/kg)x(mg soil swallowed)x(exposure frequency)x(0.000001 kg/mg)}}{\textit{person's weight in kg}}$$

The resulting chemical dose is milligrams of chemicals per kilogram body weight per day or milligram per kilogram per day (mg/kg/day). A range of chemical doses are possible because different values can be used for various parameters in the equation. For example, the amount of soil ingested varies from about 100 mg for a typical child, to 200 mg for some children, and to 5,000 mg for children with soil pica behavior (ATSDR 2005b; ATSDR 2001; Calabrese 1997). Weight can also vary from 10 kg for a 1-year-old child to 35 kg for elementary age children, and 60 kg for women to 70 kg for men. Since site-specific information is usually not available, we assume that all of the chemical that is swallowed will cross the gut into the body. Therefore, because of differences in weight

and differences in soil intake, the estimated dose of a chemical can vary within an age group and between age groups.

The resulting dose is milligram chemicals per kilogram body weight per day (mg/kg/day). When very small doses are calculated it is often easier to view the doses as micrograms chemicals per kilogram body weight per day (µg/kg/day). A microgram is one-thousandth of a milligram. Therefore, an estimated dose of 0.005 mg/kg/day is the same as 5 µg/kg/day. Most of the doses in this report are presented as µg/kg/day.

To determine whether harmful effects might be possible from ingesting contaminated soil, ATSDR compares the estimated chemical dose to the Agency's "health guideline" dose for that chemical. ATSDR's health guidelines are called Minimal Risk Levels (MRLs) and they are developed for three exposure periods: acute (less than 2 weeks), intermediate (2 weeks to 1 year), and chronic (1 year or more). MRLs are available for oral exposure and for inhalation exposure. We will use the chronic, oral MRL as a guide because the principle route of exposure at the LCP Chemicals site is from swallowing soil and because residential exposures are likely to occur for many years. When appropriate, we may use the acute and intermediate MRLs as a guide, for instance, when evaluating worker exposures that take place for periods less than a year.

An MRL is a chemical dose below which noncancerous harmful effects are not expected. It is important to remember that MRLs cannot be used to evaluate cancer. Cancer risk is evaluated using another method, which will be explained later in the public health assessment. MRLs are derived by reviewing animal and human studies to identify either the lowest level known to cause harmful effects or identifying a level that will not cause harmful effects. Most MRLs are set anywhere from 3 to 1000 times below these effect or no effect levels. Therefore, when an MRL is exceeded, it does not mean that harmful effects will occur but rather that more toxicological evaluation is needed to determine if harmful effects might be expected. This additional toxicological evaluation involves comparing the estimated chemical dose to effect and no effect levels and reviewing additional toxicological information to decide if harmful effects might be expected.

A useful tool in deciding if the estimated dose exceeds an oral MRL or some other health guideline is the use of hazard quotients (HQ). An HQ is a number that shows whether the MRL has been exceeded. If the HQ is greater than 1, then the estimated dose for a chemical exceeds the MRL and further toxicological evaluation is needed. If the HQ is less than one, the estimated dose for a chemical is below the MRL and non-cancerous harmful effects are not expected. Using the HQ allows the reader to look at a table showing multiple dose estimates for various age groups and to easily see if the estimated doses are greater than or lower than the MRL.

The formula for determining the HQ follows:

$$HQ = \frac{\textit{estimated dose of a chemical in mg/kg/day}}{\textit{MRL in mg/kg/day.}}$$

The same HQ can be calculated by using the estimated dose in µg/kg/day and converting the MRL to µg/kg/day.

V.D. Uncertainty in Deciding Harmful Effects

Some uncertainty exists in deciding whether harmful effects are expected because uncertainty exists in estimating the chemical dose in people. This uncertainty exists because we are not sure exactly how much soil people ingest daily, although we have a fairly good idea. As mentioned previously, most children swallow about 100 milligrams of soil and dust daily while some children may swallow up to 200 mg daily. Similarly, adults may swallow only a few milligrams of soil and dust daily or they may swallow 100 mg or more, for instance, if they have frequent contact with soil from yard work or gardening. Uncertainty also comes from deciding the body weight to use for various age groups. In addition to these factors, uncertainty comes from deciding the chemical concentration in soil to use in estimating dose. These uncertainties result in a range of doses that can be estimated for various age groups. One way to encompass this uncertainty is to use average values to estimate the dose to get an estimated dose that represents exposure for most people. For example, to estimate the chemical dose for most children, ATSDR uses 100 milligrams of soil and dust ingested daily. Because ATSDR wants to protect all people from harmful chemicals, it is possible to estimate the highest dose that might be expected in a population. For example, ATSDR uses 200 milligrams of soil and dust ingested daily to represent the chemical dose in the small percentage of children with high soil intake. This dose is presented in the tables.

In addition to the uncertainty that comes from estimating a chemical dose, uncertainty could exist in the human and animal studies that identify the doses that cause harmful effects or the doses that cause no harmful effects. This uncertainty varies with each chemical. When an MRL is exceeded or if an MRL is not available, the estimated chemical dose in people is compared to the doses from human and animal studies that cause harmful effects and to doses that show no effect. This comparison along with a review of other information in ATSDR's chemical-specific toxicological profile is used to decide what harmful effects might be expected.

Uncertainty also exists that is specific to the LCP Chemicals Site. First, uncertainty exists from using soil samples that were collected 15 years ago. These soil samples may not represent current conditions at the site. Second, uncertainty also comes from not knowing how much chemical contamination below the surface will actually become surface soil during construction activity. And lastly, some 1990's data were not useable because of data quality issues, thus not only were fewer samples available but also this made some areas of the site inadequately sampled.

V.E. Background Information About Cancer

Cancer is a complex subject and some background information is provided before discussing cancer evaluations of specific chemicals. The probability that residents of the

United States will develop cancer at some point in their lifetime is 1 in 2 for men (44.9 %) and 1 in 3 (38.5%) for women. Stated another way, half of all men and one-third of all women will develop cancer in their lifetime (ACS 2009). This probability is based on medical data collected on all types of cancer, regardless of whether the cause was identified, the case was successfully treated, or the patient died (directly or indirectly) from the cancer.

Factors that play major roles in cancer development include:

- ≠ Lifestyle (what we eat, drink, smoke; where we live);
- ≠ Natural (including sunlight) and medical radiation;
- ≠ Workplace exposures;
- ≠ Drugs;
- ≠ Socio-economic factors; and
- ≠ Chemicals in our air, water, soil, or food.

Infectious diseases, aging, and individual susceptibility, such as genetic predisposition, are also important factors in cancer development (ATSDR 2000, ACS 2009, NTP 2005).

We rarely know environmental factors or conditions responsible for the onset and development of cancer. For some occupational exposures or for the use of specific drugs, we do have some understanding of cancer development (Tomatis *et al*. 1997). Overall cancer risks can be reduced by eating a balanced diet, getting regular exercise, having regular medical exams, and avoiding high risk behaviors, such as tobacco use and excessive alcohol consumption. Proper safety procedures, appropriate personal protective equipment, and medical monitoring programs can decrease cancer risks in the workplace (ACS 2009).

V.E.1. How to estimate and interpret cancer risk

The EPA has a method for estimating the cancer risk from chemical exposure. The cancer risk is estimated by multiplying the estimated dose for a population by what is called a cancer slope factor. The resulting number is an estimate of the number of cancers in a population over a lifetime that might result from the chemical exposure. The equation for estimating cancer risk follows:

Cancer risk = estimated lifetime dose x cancer slope factor

The resulting risk of cancer is called an excess cancer risk because it is the risk of cancer above the already existing background risk of cancer discussed above.

This additional cancer risk estimate from chemical exposures is often stated as 1×10^{-4}, 1×10^{-5}, or 1×10^{-6} (or 1E-4, 1E-5, or 1E-6). Using 1×10^{-6} (or 1E-6) as an example, it means that a population of one million people exposed to a carcinogen over a lifetime (70 years) at a specific dose may have one additional case of cancer because of the exposure. This estimated cancer risk is in addition to the 412,000 cases expected in

this population of 1 million men and women over a lifetime. The "one-in-a-million" risk level is generally regarded as a low risk. If the exposed population is small, it is difficult to prove that cancer cases in a community are the result of chemical exposures, especially given the large number of people that get cancer from other causes.

An estimated additional cancer risk of 1×10^{-4} means that a population of 10,000 people exposed for a lifetime (70 years) at a certain chemical dose may have one additional cancer case. This one case is in addition to the 4,120 cases expected in this population of 10,000 men and women over a lifetime. This risk is 100 times higher than the one in a million risk described in the previous paragraph. Although a "one-in-ten thousand" risk level may be viewed as a high increased risk, it is good to understand the exposure assumptions that went into estimating this risk.

Mathematically, the excess cancer risk is an estimate of the 95% upper confidence limit of additional cancer risk for adults or children with similar exposures. For this reason, the risk is presented as the number of cancers that might occur in a large number of people (e.g., 10,000, 100,000 or 1,000,000) with similar exposures. The true risk is not known, but will likely be lower. When we talk about the additional or excess cancer risk, we mean the risk above and beyond what is considered background or normal. It is important to remember that we cannot determine an individual's cancer risk but rather the estimated cancer risk refers to the risk for a population of people with similar chemical exposure.

V.F. Chemical-specific evaluations

As mentioned previously, ATSDR is concerned about people's contact with soil if land on the LCP Chemicals Site is developed in the future as residences or as commercial or industrial businesses. If a home or business is built on certain grids, contaminated soil from various depths could be moved so that contaminants are now at the surface. It is not possible to predict the concentration of contaminants at the surface from future soil movement. Therefore, ATSDR used the current contaminant soil concentration from samples up to 5 feet below the surface to estimate an average contaminant concentration for a grid. The groundwater at the site is approximately 5 ft. below ground surface. In addition to looking at contamination from 0 to 5 ft. in depth, ATSDR estimated contaminant concentration from 0 to 2 ft. in depth. The reasons for looking at this depth are (1) contaminant concentrations might be different in the top few feet, and (2) construction activity might be limited to a more shallow depth. The following chemical-specific subsections describe ATSDR's evaluation of each chemical of concern for these two scenarios, residences and businesses.

V.F.1. Polychlorinated Biphyenls

V.F.1.a. ATSDR's Health Guideline for PCBs

ATSDR has a chronic oral MRL of 0.00002 milligram per kilogram per day (mg/kg/day), which is the same as 0.02 microgram per kilogram per day (µg/kg/day). When deriving

an MRL, ATSDR scientists review the toxicological literature to identify the lowest doses in either animals or humans that cause harmful effect. These doses are referred to as the lowest observed adverse effect level (LOAEL). When appropriate, ATSDR scientists select one of these LOAELs to derive the MRL. For some chemicals, the MRL is derived from a dose that does not cause harmful effects. This dose is referred to as the no observed adverse effect level (NOAEL). For PCBs, ATSDR derived the chronic oral MRL from a LOAEL identified in a monkey study. The lowest dose identified to cause harmful effects in monkeys' immune system is 0.005 mg/kg/day (or 5 µg/kg/day). Monkeys who were exposed daily to this PCB dose for 23 months showed reduced antibody response when the monkeys were injected with sheep red blood cells. To derive the chronic MRL, ATSDR divided the LOAEL of 5 µg/kg/day by an uncertainty factor of 300, which resulted in 0.016 µg/kg/day. This dose was rounded to 0.02 µg/kg/day and became the chronic oral MRL.

For now, it is important to know that estimated PCB doses in people who come in contact with LCP soils will be compared to ATSDR's chronic oral MRL for PCBs of 0.02 µg/kg/day.

V.F.1.b. Estimating Human Doses of PCBs and PCB Hazard Quotients

As mentioned previously, doses were estimated using a range of soil ingestion rates for various age groups. Preschool children were assumed to swallow 200 milligrams of soil daily, while elementary-age children, teenagers, and adults were assumed to swallow 100 milligrams of soil daily. Average body weights were selected for each age group. These and other parameters used to estimate PCB doses in people are shown in Appendix B, Table B1.

The estimated dose of total PCBs for each age group is shown in Table 15 for various PCB average concentrations ranging from 1 ppm to 139 ppm. The resulting estimated dose is presented as micrograms total PCBs per kilogram body weight per day (or µg/kg/day). The estimated dose of total PCBs ranges from 0.001 µg/kg/day in adult men who have daily contact with 1 ppm total PCBs in soil to 2.78 µg/kg/day in 1-year-old children who have daily contact with 139 ppm total PCBs in soil.

As mentioned previously, the PCB HQ is an easier way to determine if the estimated dose is less than or greater than the chronic MRL. The PCB HQ was derived by dividing the estimated PCB dose by the chronic oral MRL of 0.02 micrograms/kg/day. The PCB HQs for various age groups are shown in Table 16 for average soil concentrations of 1, 5, 10, 25, 50 and 139 ppm total PCBs. These PCB HQs are for the people in each age group with high soil intake who might live in a grid having the specified average PCB concentration. People in each group with average or typical soil intake have PCB HQs that are about 2 to 4 times lower than people with high soil intake.

Table 15. Chronic estimated doses for total PCBs by age group for total PCB concentrations ranging from 1 ppm to 139 ppm.						
Age Group	***Average Total PCB Concentrations in ppm***					
	1	***5***	***10***	***25***	***50***	***139***
	Chronic estimated dose in µg/kg/day					
Preschool children (1 yr.)	0.020	0.10	0.20	0.50	1.0	2.78
Preschool children (3 yr.)	0.01250	0.0625	0.125	0.3125	0.625	1.7375
Elementary school children	0.00286	0.01429	0.02857	0.07143	0.14286	0.39714
Teenagers	0.00182	0.00909	0.01818	0.04545	0.09091	0.25273
Adult men	0.00143	0.00714	0.01429	0.03571	0.07143	0.19857
Adult women	0.00167	0.00833	0.01667	0.04167	0.08333	0.26806
Chronic oral MRL in µg/kg/day	0.02	0.02	0.02	0.02	0.02	0.02

Table 16. PCB HQs for total PCB soil concentrations ranging from 1 ppm to 139 ppm.						
Age Group	***PCB Concentrations in ppm***					
	1	***5***	***10***	***25***	***50***	***139***
	Chronic PCB HQ					
Preschool children (1 yr.)	1	5	10	25	50	139
Preschool children (3 yr.)	0.6	3	6	16	31	87
Elementary school children	0.10	0.7	1	4	7	20
Teenagers	0.10	0.5	0.9	2	5	13
Adult men	0.07	0.4	0.7	2	4	10
Adult women	0.08	0.4	0.8	2	4	12

The resulting PCB HQs shown in Table 16 vary by age group and by PCB soil concentration. Whenever the PCB HQ is below 1, then the estimated dose is below the chronic oral MRL and non-cancerous harmful effects are not expected. When the PCB HQ exceeds 1, then the estimated dose exceeds the chronic oral MRL. What follows is brief summary of the PCB HQs shown in Table 16:

- ≠ For one-year-old children with high soil intake, the PCB HQ is 1 when PCB concentrations are 1 ppm. For grids that have an average concentration of 5, 10, 25, 50, or 139 ppm, the PCB HQ for 1-year-old children with high soil intake is 5, 10, 25, 50, or 139, respectively.
- ≠ For 3-year-old children with high soil intake, the PCB HQ is below 1 when average PCB soil concentrations are 1 ppm. The PCB HQ is 3, 6, 16, 31, and 87 when average soil concentrations are 5, 10, 25, 50, and 139, respectively.
- ≠ For elementary age children with high soil intake, the PCB HQ is below 1 for average PCB concentrations of 1 and 5 ppm. The PCB HQ is 4, 7, and 20 when average soil concentrations are 25, 50, and 139 ppm, respectively.
- ≠ For adults, the PCB HQ is below 1 for average PCB concentrations of 1, 5, and 10 ppm. The PCB HQ is 2, 4, and 12 when average soil concentrations are 25, 50, and 139 ppm, respectively.

The PCB HQs described previously are shown graphically in Figure 32. The PCB HQs show that as average total PCB concentrations for a grid exceed about 5 ppm in soil, the PCB HQs for preschool children exceed ATSDR's chronic oral MRL. As average total PCB concentrations exceed about 25 ppm, the PCB HQs for older children and adults exceed ATSDR's chronic oral MRL. Depending on the average total PCB concentration for a grid, the PCB HQ for various age groups exceeds ATSDR's oral MRL for PCBs, thus prompting a more thorough toxicological evaluation to determine if harmful effects are expected.

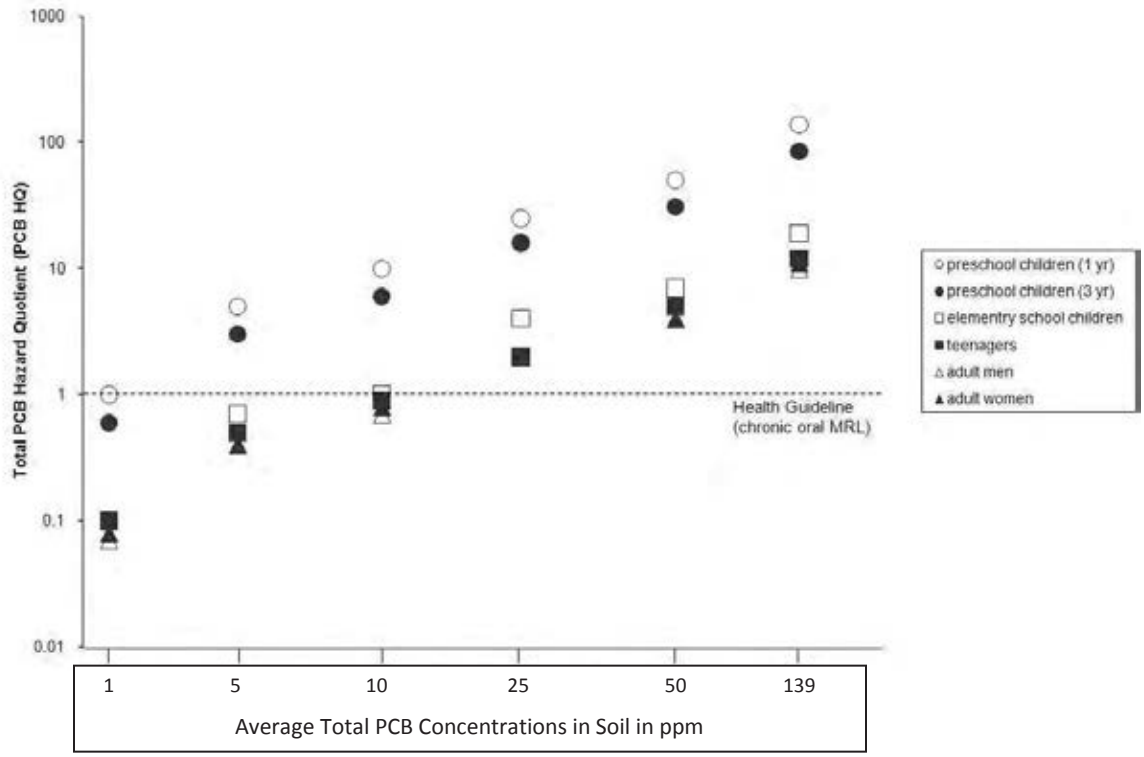


Figure 32. The Total PCB hazard quotient (PCB HQ) for various age groups are shown for average soil concentrations ranging from 1 ppm to 139 ppm. The hazard quotient is an indicator of where the estimated dose is in relation to ATSDR's health guideline for PCBs (i.e., the chronic MRL). When the HQ is below 1, the estimated dose is below ATSDR's chronic oral MRL for PCBs and harmful effects are not expected. Whenever the HQ is greater than one, which is the case for preschool children when average PCB levels exceed 5 ppm in soil, then a more thorough toxicological evaluation is needed to decide if harmful effects might be expected. As average PCB soil concentrations exceed 25 ppm, all age groups have PCB HQs that exceed one.

V.F.1.c. Human Studies and PCBs

As part of a more thorough toxicological evaluation, ATSDR will describe the human and later the animal studies that show the harmful effects of PCBs. This review is not an

exhaustive review of the known harmful effects of PCBs but rather focuses on the lowest PCBs doses that cause harmful effects. These studies are more relevant to deciding what harmful effects might be expected in a human population exposed to low levels of PCBs from the environment.

Recent human studies have shown that small increases in serum PCBs are associated with harmful effects in people involving the reproductive, immune, cardiovascular, and neurological systems. Table B2 in Appendix B summarizes these studies. Specific information about each study follows.

1. The results of a prospective health study showed a 33% reduction in male births for women at the 90th percentile compared to women at the 10th percentile for serum PCB levels. Thus, women with higher PCB levels are more likely to have female children. The authors concluded that each 1 part per billion (ppb) increase in serum PCBs was associated with a 7% decrease in the number of male births. Mean serum (whole-weight) PCB levels were 5.4 ppb with a range of 3.1 ppb to 8.7 ppb for the 10th and 90th percentile, respectively. The authors caution that the findings could be due to other contaminants, metabolites, or PCBs (Hertz-Picciotto 2008).

2. Increasing serum (whole-weight) PCB levels were associated with slightly longer menstrual cycles, increasing the cycle by about a day. The authors stated weaker associations were found for serum PCB levels and irregular menstrual cycles. Serum PCB levels ranged from less than 1 ppb to greater than 5 ppb, and the effect appears in the groups with PCB levels greater than 3.75 ppb. The authors point out that an important limitation to the study is recall bias since women had to answer questions about their menstrual cycles (Cooper 2005).

3. Other human studies have shown lower birth weight for infants exposed during pregnancy via maternal body burdens of PCBs. In one study, this effect persisted to age 4 for children with the highest PCB exposure. Reduced weight persisted in another study in infants at 3 months of age. The consistency with which this finding has been demonstrated strengthens the position that PCBs cause developmental effects. It should be pointed out that birth weight is a sound indicator of newborn development and health (ATSDR 2000).

4. Cord blood PCB levels at birth was associated with impaired learning of a performance task in nine-year-old children. Low-level PCB exposure results in an inability to withhold or delay inappropriate responses, which is a measure of attention and impulse control. Mean cord PCBs levels were 1 ppb. Similar effects were seen in children with lead exposure (mean blood lead level = 4.6 µg/dL) and methyl mercury exposure (mean hair = 0.56 ppm) (Stewart 2006).

5. Serum (lipid-standardized) PCBs were associated with prevalence of cardiovascular disease in women (but not men). Lipid-standardized serum PCB levels ranged from less than 141 ppb to greater than 651 ppb (Ha 2007).

6. Using job characteristics as an indicator of PCB exposure, women (but not men) with the highest suspected PCB exposure had excess mortality from Parkinson disease (SMR = 2.96, CI = 1.08-6.42) and dementia (SMR = 2.04, CI = 1.12-3.42) (Steenland 2006).

7. A two-fold increased incidence of adult-onset diabetes in women (but not men) was associated with higher serum (whole-weight) PCB levels ranging from 5 ppb to greater than 10 ppb. The increased incidence of diabetes was observed in the people with serum PCB levels greater than 5.1 ppb compared to people with serum PCB levels below 5 ppb (Vasiliu 2006).

8. Diabetes

   About 1 out of every 12 Americans (or 23 million) has diabetes, a disease in which the body does not produce or properly use insulin. Insulin is a hormone that is needed to convert sugar, starches and other food into energy the body needs to function properly. About 1 in 5 Americans (or 57 million) have pre-diabetes, a condition that occurs when a person's blood sugar levels are higher than normal but not high enough for a diagnosis of diabetes.

   The cause of diabetes continues to be a mystery, although both genetics and environmental factors appear to play roles. Certain risk factors have been shown to be associated with diabetes. People who are overweight or obese or who are physically inactive are more likely to develop diabetes. Diabetes also leads to unhealthy cholesterol levels, which can affect people's cardiovascular health, leading to hardening of the arteries and heart disease. People also have inherent risk factors that might increase their risk of diabetes. These factors include age, race, gender, and family history (American Diabetes Association 2009).

   In addition to these risk factors, some chemicals, such as PCBs, have been associated with diabetes. As mentioned previously, a two-fold increased incidence of adult-onset diabetes in women (but not men) was associated with higher serum (whole-weight) PCB levels ranging from 5 ppb to greater than 10 ppb. The increased incidence of diabetes was observed in people with serum PCB levels greater than 5.1 ppb compared to people with serum PCB levels below 5 ppb (Vasiliu 2006).

   People with diabetes also are sensitive to air pollution found both indoors and outdoors. Breathing in harmful particles from air pollutants (for example, vehicle exhaust, industrial emissions, and haze from burning fossil fuels) may increase their risk of heart attack and stroke. A recent study found that in adults living with diabetes the ability of their blood vessels to control blood flow was decreased on days with high particulate matter pollution in the air. Decreased blood flow has been associated with an increased risk of heart attack, stroke, and other heart problems. Other studies have shown that when air pollution levels are high,

people with diabetes have higher rates of hospitalization and death related to cardiovascular problems (EPA 2009d, Goldberg 2001, Zanobetti 2002).

Numerous other human studies have shown an association with PCB exposure and adverse effects, including effects on fertility, growth and development, the immune system and the nervous systems. These studies are described in ATSDR's Toxicological Profile for Polychlorinated Biphenyls and the World Health Organization's (WHO)Concise International Chemical Assessment 55, Polychlorinated Biphyenyls (ATSDR 2000, WHO 2003).

V.F.1.d. Animal Studies and PCBs

Numerous studies have demonstrated that PCBs will cause harmful effects in monkeys at low levels (ATSDR 2000). These studies, many of which are described in ATSDR's Toxicological Profile for PCBs, are summarized in Table B3 in Appendix B.

The most sensitive endpoints identified in animal studies showed developmental, immunological, and dermal effects in monkeys at daily doses of 5 µg/kg/day to 7.5 µg/kg/day. The exposure duration for most of these monkey studies was 23 to 72 months, although one study showed neurological effects in infant monkeys after 5 months exposure. At slightly higher daily doses (i.e., 20 to 40 µg/kg/day), PCBs caused fetal and post-partum deaths in pregnant monkeys along with significantly reduced conception rate and decreased serum cholesterol (ATSDR 2000). The specific effects are described below.

V.F.1.d.1. Immune System Effects in Animals

Low-level PCB exposure in monkeys showed reduced IgM and IgG antibody and a temporary reduction in B lymphocytes in response to sheep red blood cells. While this effect was observed at a daily dose of 5 µg/kg/day Aroclor 1254[1] in monkeys, this and other immunological effects are observed at higher doses. For example, at a daily dose of 200 µg/kg/day Aroclor 1248 for 11 months, monkeys showed decreased anti-SRBC hemolysin titers. At a daily dose of 800 µg/kg/day in guinea pigs for 8 weeks, guinea pigs showed decreased gamma globulin-containing cells in lymph nodes. At very high doses (500 to 1,300 µg/kg/day) ranging from 1 to 6 months, mice showed increased susceptibility to leukemia virus and increased sensitivity to bacterial endotoxin (ATSDR 2000).

V.F.1.d.2. Skin Effects in Animals

Low-level PCB exposure in monkeys at 5 µg/kg/day exposed for 72 months has been shown to damage fingernails and toenails. At slightly higher doses (e.g., 100 µg/kg/day for 2 months), harmful effects in monkeys included facial edema, acne, inflammation of

[1] Aroclor 1254 is a commercial mix of various PCB compounds with an average chlorine content of 54%.

hair follicles, and hair loss. Longer exposure at 100 µg/kg/day in monkeys also caused fingernail loss and cellular changes in the gums (ATSDR 2000).

V.F.1.d.3. Developmental Effects During and After Pregnancy in Animals

Developmental effects refer to effects that occur during gestation and following birth as the infant grows. In animals, lower birth weight and hyperpigmentation of the skin was reported in offspring of monkeys treated before mating and during gestation with 30 µg/kg/day Aroclor 1016. Similarly, monkeys exposed during pregnancy to 5 µg/kg/day (Aroclor 1254) and via breast milk after birth for 22 weeks resulted in offspring with inflamed and enlarged tarsal glands[2], as well as nail and gum lesions (ATSDR 2000).

V.F.1.d.4. Neurological Effects in Animals

PCB exposure in juvenile monkeys for 20 weeks at a daily dose of 7.5 µg/kg/day showed changes in behavioral performance in non-spatial and spatial discrimination reversal tasks. Specifically, treated monkeys showed decreases or variable increases in response latencies across three tasks of non-spatial discrimination reversal as well as retarded acquisition of a delayed alternation task and increased errors at short delay task responses. The study investigators interpreted these findings as a learning and performance decrements. Interestingly, the resulting serum PCB levels after 20 weeks of exposure was 1.8 ppb to 2.8 ppb, levels similar to what is found in the general US population (ATSDR 2000).

V.F.1.d.5. Summary of Health Effects in Humans and Animals

In summary, low-level PCB exposure at 5 to 7.5 µg/kg/day in animals can be expected to cause the following harmful effects:

- ≠ Small changes in immune function as evidenced by a weakened response to an antigenic challenge,
- ≠ Mild damage to fingernails and toenails,
- ≠ Inflamed oil-producing glands associated with the eyes
- ≠ Gum recession, and
- ≠ Learning and performance decrements.

In addition, recent human studies have shown that small increases in serum PCB levels are associated with the following:

- ≠ Fewer male births,
- ≠ Problems with attention and impulse control in children
- ≠ Lower birth weight in children,

[2] The tarsal glands (or meibomian glands) are a special kind of sebaceous glands at the rim of the eyelids. They supply sebum, an oily substance that stops evaporation of the eye's tear film, prevents tear spillage onto the cheek, and makes the closed lids airtight. Glands are located on the upper and lower eyelids.

≠ Longer menstrual cycles in women,
≠ An increase in cardiovascular disease in women (but not men),
≠ Increased death from Parkinson disease and dementia in women (but not men), and
≠ An increase in diabetes in women (but not men).

Unfortunately, it is not possible to assign daily PCB doses to these human studies. Some insight into daily doses might be gleaned from Rice's and Hayward's monkey studies. In a 20 week exposure study, infant monkeys were dosed daily at 7 µg/kg/day. The PCB mixture consisted of congeners that are commonly found in human breast milk. After 20 weeks exposure, PCB levels were 1.7-3.5 ppm in fat and 1.8–2.8 ppb in blood. These levels (1.8–2.8 ppb) are very similar to blood levels (0.8–1.5 ppb) that are typically found in the US general population who do not frequently eat fish (ATSDR 2000). Therefore, the dose of 7 µg/kg/day can be considered an environmentally relevant dose for humans.

V.F.1.e. Groups with Increased Sensitivity to PCBs

Other subpopulations that are potentially more susceptible to PCBs include people with incompletely developed glucuronide conjugation mechanisms (Calabrese and Sorenson 1977; Lester and Schmid 1964), such as people with Gilbert's Syndrome. Gilbert's Syndrome is a relatively common and benign congenital liver disorder that is characterized by mild, fluctuating increase in serum bilirubin, and is estimated to occur in 3–7% of the adult population (American Liver Foundation 2000). Persons with hepatic infections may have decreased glucuronide synthesis, making them more sensitive because of their decreased capacity to detoxify and excrete PCBs (Calabrese and Sorenson 1977). People with compromised liver function, such as in the case of liver cirrhosis or hepatitis B, also could be considered to be more susceptible to PCB toxicity (ATSDR 2000).

V.F.1.f. Uncertainty About the Toxic Effects of PCBs

Some uncertainty exists when deciding whether PCBs are harmful to humans because commercial mixtures of PCBs are made of different combinations of the 209 PCB chemicals. The basic structure of PCBs is a biphenyl ring, which can have from 1 to 10 chlorine molecules attached, thus the name polychlorinated biphenyl. Commercial mixtures of PCBs are classified into several groups depending upon the percent chlorination of the biphenyl compound. One common commercial name used in the U.S. is Aroclor, which is followed by a four digit number that represents the percent chlorine by weight. Examples of commonly produced Aroclors and the average chlorine content are as follows:

Aroclor 1016	42% chlorine
Aroclor 1232	32% chlorine
Aroclor 1242	42% chlorine
Aroclor 1248	48% chlorine
Aroclor 1254	54% chlorine
Aroclor 1268	68% chlorine.

Many of the animal studies use one of these commercial Aroclor mixtures to assess PCB toxicity. For chronic exposures greater than 1 year, the lowest level known to cause harmful effects in monkeys (i.e., 5 µg/kg/day) used Aroclor 1254; therefore, some uncertainty exists when using this value to assess the harmful effects of other Aroclor mixtures. A slightly different situation exists for intermediate exposures of two weeks to one year. The basis for the lowest dose known to cause harmful effects in monkeys (7.5 µg/kg/day) used a mixture of PCBs that simulated breast milk. The next lowest intermediate dose known to cause harmful effects is 100 µg/kg/day. Aroclor 1242, Aroclor 1248, and Aroclor 1254 cause harmful effects at this dose.

Additional uncertainty exists when deciding if harmful effects might be expected because very little toxicological information is available on Aroclor 1268; therefore, ATSDR relied upon toxicological information available on the other Aroclors, particularly Aroclor 1254.

V.F.1.g. Possible Health Effects from PCBs If the Site Becomes Residential

The estimated doses in various age groups with high soil ingestion have already been presented in Table 15, which is repeated here. Because the doses are small, the table shows estimated PCB doses in micrograms/kg body weight/day or µg/kg/day. For comparison, ATSDR's chronic oral MRL for PCBs also is shown in µg/kg/day.

Table 15. Chronic estimated doses for total PCBs by age group for total PCB concentrations ranging from 1 ppm to 139 ppm.

Age Group	***PCB concentrations in ppm***					
	1	***5***	***10***	***25***	***50***	***139***
	Chronic estimated dose in ug/kg/day					
Preschool children (1 yr.)	0.02	0.1	0.2	0.5	1.0	2.78
Preschool children (3 yr.)	0.013	0.063	0.13	0.31	0.62	1.74
Elementary school children	0.003	0.014	0.029	0.071	0.14	0.4
Teenagers	0.002	0.009	0.018	0.045	0.091	0.25
adult men	0.001	0.007	0.014	0.036	0.071	0.2
adult women	0.002	0.008	0.017	0.042	0.083	0.23
Chronic oral MRL in µg/kg/day	0.02	0.02	0.02	0.02	0.02	0.02

Depending on the age group and the average PCB concentration in a grid, estimated doses range from well below 0.02 µg/kg/day (i.e., the chronic MRL) to the highest dose of 2.78 µg/kg/day in one-year-old children who live on soil containing 139 ppm total PCBs.

Because some estimated doses exceed ATSDR's chronic oral MRL of 0.02 µg/kg/day, it is necessary now to compare those doses to doses that cause harmful effects to decide if harmful effects might be expected.

Figure 33 shows the estimated doses in various age groups that exceed the chronic oral MRL. These doses are shown in relation to doses in monkey studies that are known to cause harmful effects. The highest estimated dose is 2.8 µg/kg/day in one-year-old children and this dose is roughly 2 times below 5 µg/kg/day, the lowest level known to cause harmful effects in monkeys.

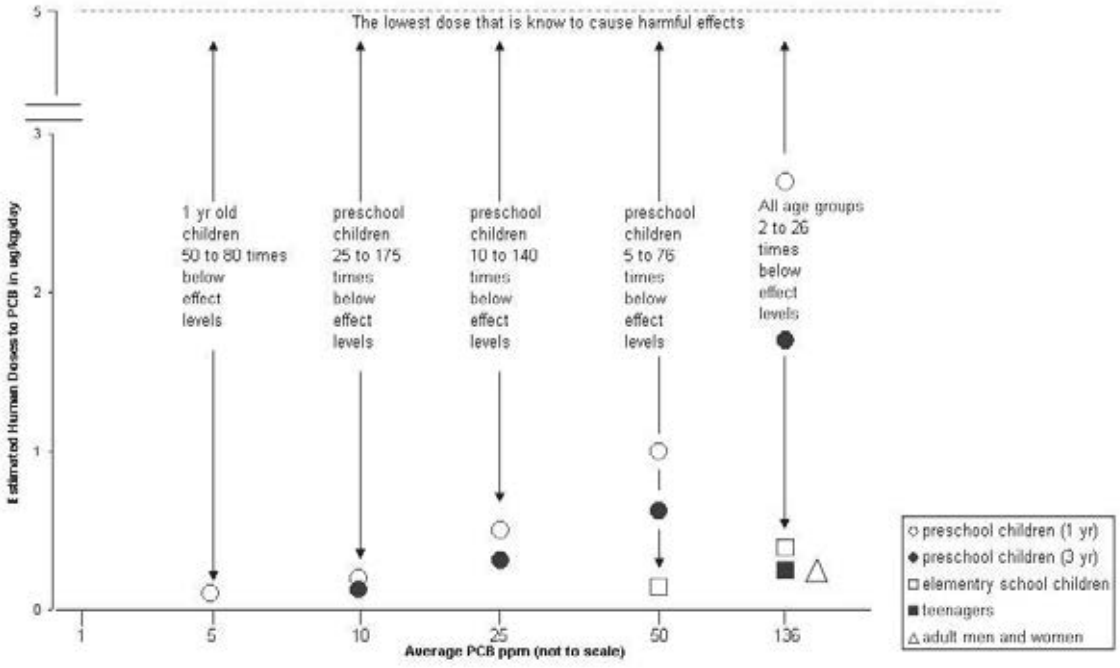


Figure 33. This graph shows the relationship between the estimated PCB doses in various groups in comparison to the lowest dose in monkeys known to cause harmful effects (i.e., 5 µg/kg/day). For example, at 139 ppm PCBs in soil, the estimated dose in 1-year old preschool children (as shown by the open circle on the far right side of the graph) is about 2 times below the lowest dose known to cause harmful effects. The estimated dose in adults (as shown by the open triangle on the far right side of the graph) is 26 times below levels known to cause harmful effects in monkeys..

The other estimated doses can be described as follows:

- ≠ At 5 ppm PCBs in soil, the estimated doses in one- and three-year-old preschool children are 50 to 80 times below the lowest effect level,
- ≠ At 10 ppm PCBs in soil, the estimated doses in preschool and elementary-age children are 25 to 175 times below the lowest effect level,
- ≠ At 25 ppm, the estimated doses in preschool, elementary-age, teenagers, and adults are 10 to 140 times below the lowest effect level,
- ≠ At 50 ppm, the estimated doses in preschool, elementary-age, teenagers, and adults are 5 to 70 times below the lowest effect level, and
- ≠ At 139 ppm, the estimated doses in preschool, elementary-age, teenagers, and adults are 2 to 25 times below the lowest effect level.

A useful concept in evaluating risk is the margin of exposure. The margin of exposure is the difference between the estimated dose and the dose that causes harmful effects and derived using the following formula:

$$\text{Margin of Exposure} = \frac{\text{Lowest Effect Level from a Study}}{\text{Estimated dose}}$$

The margin of exposure for various age groups at different average PCB soil concentrations is described in the previous bullets. The margin of exposure provides insight into how close an estimated dose is to the doses that cause harmful effects. For example, a margin of exposure of five means that the estimated dose is five times below levels that have been shown to cause harmful effects. The margin of exposure for various age groups is shown in Table 17. It should be noted that ATSDR's chronic oral MRL is 250 times below the lowest level known to cause harmful effects in monkeys. ATSDR provided margin of exposures down to 1 ppm, which is the level that corresponds to the chronic, oral MRL.

Table 17. Chronic margin of exposure to PCBs for various age groups

Age Group	***PCB Concentrations in ppm***					
	1	***5***	***10***	***25***	***50***	***136***
	Chronic Margin of Exposure					
Preschool children (1 yr.)	250	50	25	10	5	2
Preschool children (3 yr.)	400	80	40	16	8	3
Elementary school children	1,750	350	175	70	35	13
Teenagers	2,750	550	275	110	55	20
Adult men	3,500	700	350	140	70	25
Adult women	3,000	600	300	120	60	22
Commercial workers	5,096	1,019	510	204	102	37

Children have the greatest risk of experiencing harmful effects from exposure to PCBs that remain in LCP soils because their estimated doses are close to the effect level of 5 µg/kg/day, particularly at the higher PCB concentrations. Children exposed to average PCB concentrations that exceed about 1 to 5 ppm and adults exposed to average PCB concentrations that exceed about 10 to 25 ppm might experience the following harmful effects from PCBs:

- ≠ Small changes in immune function as evidenced by a weakened response to an antigenic challenge,
- ≠ Mild damage to fingernails and toenails,
- ≠ Inflamed oil-producing glands associated with the eyes
- ≠ Gum recession,
- ≠ Learning and performance decrements,

- ≠ Fewer male births,
- ≠ Problems with attention and impulse control
- ≠ Lower birth weight,
- ≠ Longer menstrual cycles in women,
- ≠ An increase in cardiovascular disease in women (but not men),
- ≠ An increase in deaths from Parkinson disease and dementia in women (but not men), and
- ≠ An increase in diabetes in women (but not men) (ATSDR 2000).

Six grids exceed EPA's 1994 target action level of 25 ppm total PCBs, while 41 grids have average total PCB concentrations greater than 1 ppm (see Table 18). The location of these grids is shown in Figure 34.

The previous results were derived using soil samples with a depth of 0 to 5 ft. The justification for using 0 to 5 ft. is that future site development might bring soil to the surface that was previously up to 5 feet below the surface. One concern is that more contaminated soil is nearer the surface, and this more contaminated soil might have a greater chance of becoming surface soil in the future because of construction activity. Therefore, ATSDR calculated statistics using soil samples with a depth of 0 to 2 ft.

Using soil samples with a depth of 0 to 2 ft. showed similar results as using 0 to 5 ft. At 0 to 2 ft., 6 grids exceed EPA's 1994 target action level of 25 ppm and 41 grids exceed 1 ppm total PCBs. More uncertainty exists in these average concentrations because fewer soil samples are available from the 0 to 2 ft. depth.

Table 18. Grids That Have Average PCB Concentrations Greater than 1 ppm

Grid #	***Average PCB Concentration in ppm***		***Grid #***	***Average PCB Concentration in ppm***
93	138.6		75	2.6
58	122.0		94	2.4
114	53.0		38	2.4
53	42.3		70	2.3
90	40.9		92	2.2
60	34.0		39	2.1
89	20.6		42	1.9
111	15.8		8	1.6
37	11.9		69	1.5
128	10.5		154	1.4
55	9.0		112	1.4
76	7.3		74	1.4
10	7.0		152	1.4
91	6.2		153	1.4
56	5.6		71	1.3
155	5.6		77	1.3

Table 18. Grids That Have Average PCB Concentrations Greater than 1 ppm				
Grid #	***Average PCB Concentration in ppm***		***Grid #***	***Average PCB Concentration in ppm***
110	4.0		133	1.3
95	3.5		197	1.1
59	3.3		17	1.1
73	2.6		134	1.0
118	2.6			

V.F.1.h. Possible Health Effects in Children with Soil Pica Behavior

As mentioned previously, somewhere between 4% and 21% of preschool children could have soil-pica behavior. Preschool children with soil-pica behavior swallow much more soil than children typically do from putting their hands in their mouth. Therefore, preschool children with soil-pica behavior will have a much greater intake of PCBs in soil.

Using PCB concentrations ranging from 1 ppm to 139 ppm, the estimated doses for 1 year-old and 3 year-old preschool children are shown in Table 19 for soil-pica behavior that occurs 3 days a week. The intermediate MRL for PCBs is shown because soil pica behavior is intermittent (ATSDR 2001).

Table 19. Estimated PCB doses in preschool children with soil-pica behavior at various total PCB concentrations. Doses are estimated for soil-pica occurring three times a week						
Age Group	***PCB Concentrations in ppm***					
	1	***5***	***10***	***25***	***50***	***139***
	Dose in ug/kg/day					
Preschool children, 1 year old, soil pica 3/week	0.21	1.1	2.1	5.4	11	30
Preschool children, 3 years old, soil pica 3/week	0.13	0.7	1.3	3.3	7	19
Intermediate oral MRL	0.03	0.03	0.03	0.03	0.03	0.03

All of the estimated doses in preschool children with soil-pica behavior shown in Table 19 exceed ATSDR's intermediate oral MRL of 0.03 µg/kg/day. For example, the estimated doses in children with soil-pica behavior who swallow soil containing 139 ppm total PCBs range from 19 to 30 µg/kg/day. These doses are significantly greater than the intermediate oral MRL of 0.03 µg/kg/day.

The PCB HQs for children with soil-pica behavior are shown in Table 20. As mentioned previously, whenever an HQ exceeds 1, the estimated dose exceeds the intermediate oral MRL. The HQ exceeds 1 for all PCB concentrations shown in Table 20. Because the estimated PCB doses exceed the intermediate oral MRL, further toxicological evaluation is needed.

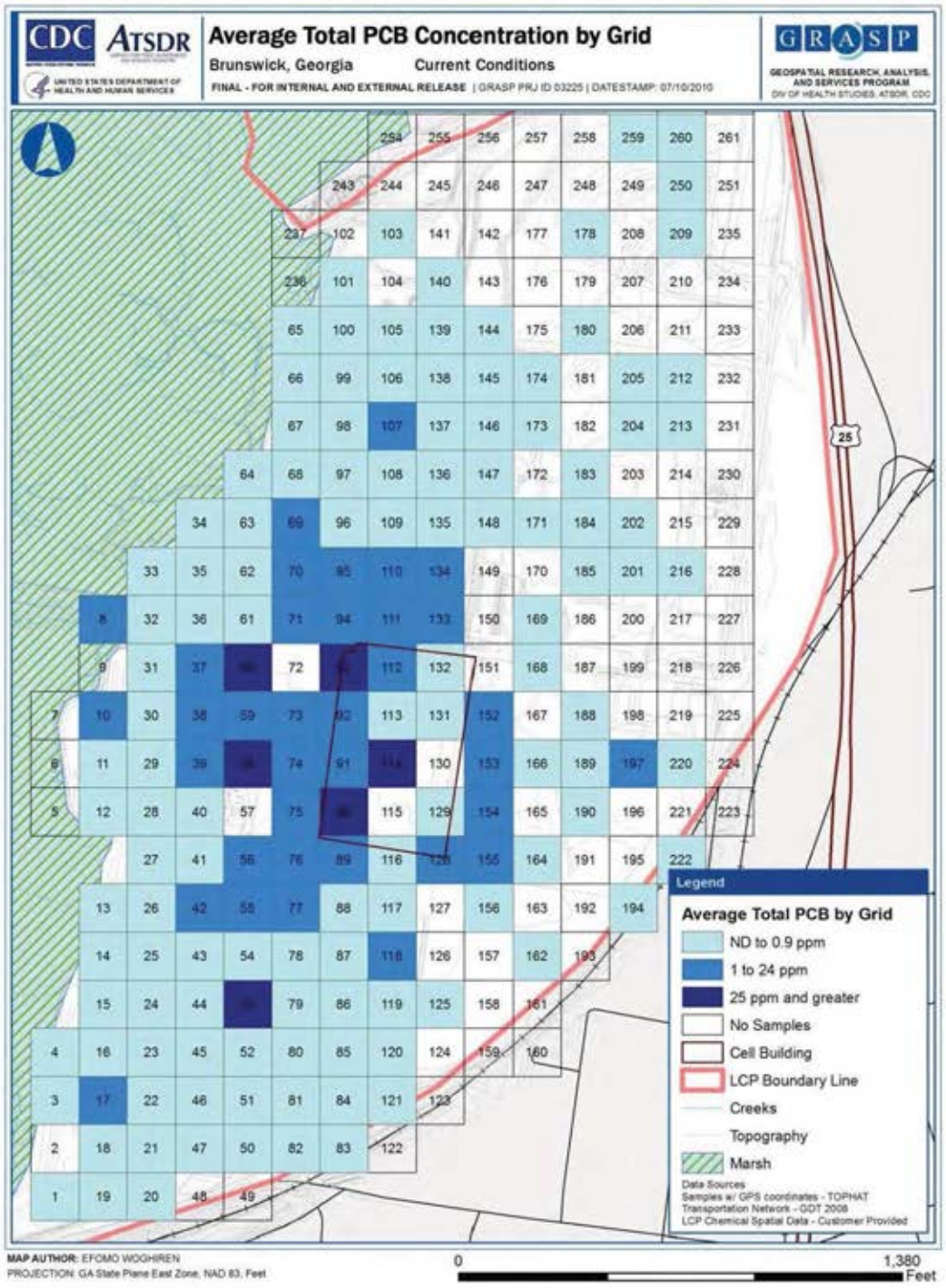


Figure 34. As indicated by the dark blue, six grids exceed EPA's 1994 target action level of 25 ppm PCBs. As indicated by medium blue, 41 grids have average PCB levels between 1 and 24 ppm. Children exposed to average PCB concentrations that exceed about 1 to 5 ppm and adults exposed to average PCB concentrations that exceed about 10 to 25 ppm might experience harmful effects from PCBs.

The lowest PCB dose known to cause harmful effects in monkeys from intermediate exposures (i.e., 2 weeks to 1 year) is 7.5 µg/kg/day, which is the same study as previously described for chronic exposure. This study showed that young monkeys were impaired in their ability organize their behavior temporally and to learn from the consequences of previous actions (Rice 2000)

Table 20. Hazard quotient (HQ) for children with soil-pica behavior						
Age Group	***PCB Concentrations in ppm***					
	1	***5***	***10***	***25***	***50***	***139***
	Intermediate HQ					
Preschool children, 1 year old, soil pica 3 times/week	7	36	71	179	357	992
Preschool children, 3 years old, soil pica 3 times/week	4	22	45	112	223	620

The following comparisons can be made from the estimated doses in children with soil-pica behavior (see Table 20).

- ≠ At 139 ppm PCBs in soil, the estimated doses range from 19 to 30 µg/kg/day. These doses exceed the lowest level known to cause harmful effects in monkeys (i.e., 5 µg/kg/day).
- ≠ At 25 ppm PCBs in soil, the estimated doses range from 3 to 5 µg/kg/day. These doses are just below the lowest level known to cause harmful effects in monkeys.
- ≠ At 5 ppm PCBs in soil, the estimated doses range from 0.7 to 1.1 µg/kg/day. These doses are about seven times below the levels known to cause harmful effects in monkeys.
- ≠ At 1 ppm PCBs in soil, the estimated doses range from 0.1 to 0.2 µg/kg/day. These doses are 35 to 75 times below levels known to cause harmful effects in monkeys.

Because their brains are still developing, children with soil-pica behavior at the doses described previously are at risk of impaired learning and performance. Children could be impaired in their ability organize their behavior and to learn from mistakes.

The next lowest dose known to cause harmful effects in monkeys is 100 µg/kg/day. Numerous monkey studies have shown that PCBs can cause harmful effects to the immune system, endocrine system, liver, stomach, skin, and eye. These studies are summarized in ATSDR's Toxicological Profile for PCBs (ATSDR 2000).

The following harmful effects have been demonstrated in monkeys dosed with 100 µg/kg/day for periods ranging from 2 months to 8 months:

- ≠ Lipid accumulation in the liver, small areas of dead cells in the liver, and increased liver enzyme in the blood (Barsotti 1976),
- ≠ Decreased antibody response to sheep red blood cells (Truelove 1982),

- ≠ Decreased thyroid (T_3 and T_4) hormones (Andrews 1989),
- ≠ Cyst formation in cells lining the stomach (Becker 1979),
- ≠ Facial swelling (Becker 1979)
- ≠ Skin acne (Barsotti 1976)
- ≠ Hair loss (Barsotti 1976)
- ≠ Red eyes (Becker 1979)
- ≠ Swelling of eyelids (Gray 1993),
- ≠ Increased bone density (Andrews 1989), and
- ≠ Lack of weight gain (Becker 1979).

One-year-old children with soil-pica behavior might be expected to experience these harmful effects if they had frequent contact with soil containing 10 ppm or more total PCBs. Their estimated doses are about 50 times below the 100 µg/kg/day effect level (see Table 20). Three-year-old children with soil-pica behavior might be expected to experience these harmful effects if they exhibit soil-pica behavior 3 times a week on soil containing 25 ppm or more total PCBs. Their estimated dose is 30 times below the 100 µg/kg/day effect level. Contact with soil containing 139 ppm total PCBs yields estimated doses in three-year-old children with soil-pica behavior that are 3 to 5 times below the 100 µg/kg/day effect level.

V.F.1.i. Possible Health Effects in Workers

Since specific plans have not been identified as to the eventual use of the property, ATSDR evaluated the possibility of harmful effects for two categories of workers: commercial/industrial workers, and excavation workers.

Once the property is developed, commercial workers and industrial workers might come in contact with contaminated soil. The contact is assumed to be long-term, chronic exposure occurring for many years. Therefore, ATSDR compared estimated doses in these workers to its chronic oral MRL for PCBs. Excavation workers are likely to be exposed for periods less than a year as they move soil during construction activity. Therefore, their estimated doses are compared to ATSDR's intermediate oral MRL for PCBs.

The estimated doses for commercial and industrial workers are shown in Table 21 should these workers ingest 100 mg soil daily, 5 days a week. Estimated doses also are provided for excavation workers should these workers ingest 330 mg soil daily, 5 days a week.

Table 21. Estimated doses of PCBs for commercial and industrial workers						
Age Group	*PCB Concentrations in ppm*					
	1	*5*	*10*	*25*	*50*	*139*
	Estimated dose in µg/kg/day					
Commercial/Industrial workers	0.00098	0.0049	0.0098	0.025	0.049	0.13
Chronic oral MRL in µg/kg/day	0.02	0.02	0.02	0.02	0.02	0.02
Excavation workers	0.0034	0.017	0.034	0.084	0.168	0.47
Intermediate oral MRL in µg/kg/day	0.03	0.03	0.03	0.03	0.03	0.03

As shown in Table 21, the estimated doses in commercial and industrial workers exceed the chronic oral MRL of 0.02 µg/kg/day when average PCB levels exceed about 25 ppm. Six grids have average PCB levels that exceed 25 ppm (see Table 18). At 25, 50, and 139 ppm PCBs in soil, commercial and industrial workers have estimated doses of 0.025, 0.049, and 0.13 µg/kg/day, respectively. The estimated dose of 0.1 µg/kg/day exceeds the chronic oral MRL of 0.02 µg/kg/day and is about 50 times below the lowest dose known to cause harmful effects in monkeys (i.e., 5 µg/kg/day). Workers exposed to 0.1 µg/kg/day PCBs might experience the following harmful effects from PCBs:

- ≠ Small changes in immune function as evidenced by a weakened response to an antigenic challenge,
- ≠ Mild damage to fingernails and toenails,
- ≠ Inflamed oil-producing glands associated with the eyes
- ≠ Gum recession,
- ≠ Learning and performance decrements,
- ≠ Fewer male births,
- ≠ Longer menstrual cycles in women,
- ≠ An increase in cardiovascular disease in women (but not men),
- ≠ An increase in deaths from Parkinson disease and dementia in women (but not men), and
- ≠ An increase in diabetes in women (but not men) (ATSDR 2000).

ATSDR assumed that excavation workers might conduct excavation activities for 6 months while developing the site. Therefore, the most appropriate health guideline to use is ATSDR's intermediate oral MRL for PCBs, which is developed for exposure periods of 2 weeks to 1 year. ATSDR's intermediate oral MRL for PCBs is 0.03 µg/kg/day. For excavation workers, estimated doses exceed the intermediate oral MRL when average PCB concentrations in soil exceed 10 ppm. Because the intermediate oral MRL is exceeded, a more detailed toxicological evaluation is warranted to decide if harmful effects are expected.

The basis for the intermediate MRL is a study involving infant monkeys, which is not appropriate to use when evaluating the risk for adults. More appropriate studies involve older monkeys and rats. These studies show that harmful effects in animals result from exposure to 100 µg/kg/day for periods of 2 to 8 months (Barsotti 1976, Becker 1979, Andrew 1989, ATSDR 2000). The following harmful effects were observed in older monkeys and rats at 100 µg/kg/day :

- ≠ Skin acne
- ≠ Hair loss
- ≠ Swelling and reddening of the eyelids and facial edema,
- ≠ Liver damage (e.g., lipid accumulation, localized cell death, liver enzyme in the blood),
- ≠ Cysts in the stomach lining,
- ≠ No weight gain,
- ≠ Increased bone density in the femur

At 10 and 25 ppm PCBs, the estimated doses in excavation workers are 0.03 and 0.08 µg/kg/day, which are at or below the intermediate MRL. Therefore, non-cancerous harmful effects are not expected. At 50 and 139 ppm total PCBs in soil, the estimated doses in excavation workers are 0.17 to 0.47 µg/kg/day. These estimated doses in excavation workers are 200 to 600 times below doses that cause harmful effects in animals. Non-cancerous harmful effects in excavation workers are not expected.

In summary, workers who have contact with PCBs in some areas on the site could be at risk of small changes in immune function, mild damage to fingernails and toenails, and damage to oil glands around the eyes. In addition, excavation workers who have contact with PCBs in some areas on the site could be at risk of skin problems (e.g., acne, hair loss), damage to the eyes, face, stomach, liver, and bones.

V.F.1.j. PCBs and Cancer

The carcinogenicity of PCBs in humans has been investigated in retrospective, cohort, mortality studies that investigated cancer in exposed workers, and in case-control studies of environmental exposure that examined associations between serum or adipose tissue levels of PCBs and the occurrence of cancer. Some of the mortality studies suggest that occupational exposures to PCBs were associated with cancer at several sites, particularly the liver, biliary tract, intestines, and skin (melanoma). A report of liver cancer in Japanese victims who were poisoned by PCBs appears to support the occupational liver cancer data. There is no clear association between occupational exposures to PCBs and cancer in other tissues, including the brain, hematopoietic, and lymphatic systems. Case-control studies of the general population are inconclusive with respect to associations between environmental exposures to PCBs and risk of breast cancer or non-Hodgkin's lymphoma, although there are preliminary indications that particular subgroups of women may be at increased risk for breast cancer. Overall, the human studies provide some evidence that PCBs are carcinogenic. There is conclusive evidence, however, that

commercial PCB mixtures are carcinogenic in animals on the basis of induced tumors in the liver and thyroid (ATSDR 2000).

The human studies examining the cancer causing effect of PCBs often have methodological limitations. However, the evidence, taken in totality, indicates a potential cancer causing effect from PCBs. EPA determined that the human data are inadequate, but suggestive, of carcinogenicity. Using animal data, EPA classifies PCBs as a probable human carcinogen (TOXNET 2009). The U.S. Department of Health of Human Services through its National Toxicology Program has designated PCBs as a probable human carcinogen; and, the International Agency for Research on Cancer (IARC) designates PCBs as probably carcinogenic in humans (ATSDR 2000, IARC 2009).

It should be pointed out that the EPA recommends using total PCBs to estimate cancer risk rather than the commercial designations of PCBs into the various Aroclor groups (EPA 2009b).

V.F.1.k. Estimated Cancer Risk If the LCP Chemicals Site Becomes Residential

Numerous studies have shown that several commercial mixtures of PCBs (i.e., Aroclors 1016, 1242, 1254, and 1260) have caused liver and thyroid cancer in rats at doses ranging from 1 mg/kg/day to 5.4 mg/kg/day (or 1,000 µg/kg/day to 5,400 µg/kg/day). The EPA used these studies to generate a cancer slope factor that can be used to estimate an increase in the number of cancers if people come in contact with PCBs in soil for long periods. Because we are looking at future residential development, two cancer risks will be estimated, one for children who live at a house for 18 years and another for adults who live at the same house for 52 years. The estimated cancer risk is for children and adults with high soil intake. The estimated cancer risk for children and adults with typical soil intake is about half of the risk estimated for children and adults with high soil intake.

Table 22 shows the estimated cancer risk at various PCB soil concentrations for children and adults with high soil intake if the LCP Chemicals Site becomes residential. For example, if children with high soil intake live at a property with 139 ppm PCBs in soil for 18 years, their estimated cancer risk is 6 in 10,000. Stated another way, if 10,000 children lived at properties with 139 ppm PCB in soil, one might expect 6 extra cases of cancer. Adults who live at properties for 52 years with 139 ppm PCB in soil have an estimated cancer risk of 3 in 10,000. A lifetime cancer risk is not provided since it is unlikely that children will continue to live in the house as adults for an additional 52 years. It should be pointed out that the cancer risk is greater for children with 18 years of exposure than it is for adults with 52 years of exposure. The estimated cancer risk at 5 ppm PCBs in soil is 2 in 100,000 for children and 1 in 100,000 for adults.

So the public can understand the estimated cancer risk and scientific notation presented in Table 22, the same risks are presented in Table 23 as extra cases of cancers if a million people are exposed to PCBs in soil. For example, if one million children have daily contact with soil containing 139 ppm PCBs, about 600 extra cases of cancers might occur from 18 years of exposure.

In summary, if the site becomes residential, children might have an increased risk of cancer if they have contact with PCB in soil above 5 ppm. Adults might have an increased risk of cancer at PCB soil levels above 10 ppm.

V.F.1.l. Estimated Cancer Risk in Workers If the LCP Chemicals Site Is Developed

If the site is developed in the future, workers doing excavation work and commercial or industrial workers might come in contact with PCBs in soils. The estimated cancer risks for outdoor commercial or industrial workers are shown in Table 24 should these workers ingest 100 mg soil daily, 5 days a week for 20 years. The estimated cancer risk also is provided for excavation workers should these workers ingest 330 mg soil daily for half a year.

The estimated cancer risk for commercial/industrial workers who have contact with soil containing 139 ppm PCBs for 20 years is 8E-5 (or 8 x 10^{-5}). This means that if 100,000 workers had contact with soil containing 139 ppm PCBs for 20 years, 8 additional cases of cancers might occur. The estimated cancer risk for excavation workers who have contact with soil containing 139 ppm PCBs for 6 months is 7E-6 (or 7 x 10^{-6}). This means that if 1,000,000 workers had contact with soil containing 139 ppm PCBs for 20 years, 7 additional cases of cancers might occur. The cancer risk in workers at various PCB concentrations in soil are shown in Table 24. So the public can understand the estimated cancer risk and scientific notation presented in Table 24, the same risks are presented in Table 25 as extra cases of cancers if a million workers are exposed to PCBs in soil at 1, 5, 10, 25, 50 or 139 ppm.

In summary, an increased risk of cancer might exist for commercial and industrial workers who have daily contact with PCBs in soil above 25 ppm. The estimated cancer risk for excavation workers is low.

Table 22. Estimated cancer risk at various PCB soil concentrations for children and adults with high soil intake if the LCP Chemicals Site becomes residential in the future. The estimated cancer risk is for children and adults with high soil intake. The estimated cancer risk for children and adults with typical soil intake is about half the risk shown this table.

Age Group	*PCB soil concentrations in ppm*					
	1	*5*	*10*	*25*	*50*	*139*
	*Increase in Cancer Risk**					
Children's cancer risk, 18 years	4 E-6	2 E-5	4 E-5	1 E-4	2 E-4	6 E-4
Adult cancer risk (av. for men and women), 52 yrs.	2 E-6	1 E-5	2 E-5	6 E-5	1 E-4	3 E-4

* Cancer risk estimates are rounded to one significant figure.

Table 23. Estimated cancer risk at various PCB soil concentrations for children and adults if one million people are exposed. Cancer numbers are rounded to one significant figure.						
Age Group	***PCB soil concentrations in ppm***					
	1	***5***	***10***	***25***	***50***	***139***
	Estimated number of cancers if one million people are exposed					
The estimated number of cancers if a million children are exposed to PCBs in soil for 18 years at various PCB concentrations.	4	20	40	100	200	600
The estimated number of cancers if a million adults are exposed to PCBs in soil for 52 years	2	10	20	60	100	300

Table 24. Estimated cancer risk at various PCB soil concentrations for commercial/industrial and excavation workers on the basis of future site development.						
Age Group	***PCB soil concentrations in ppm***					
	1	***5***	***10***	***25***	***50***	***139***
	Increase in Cancer Risk*					
Outdoor commercial/industrial worker cancer risk, 20 yrs.	6 E-7	3 E-6	6 E-6	1 E-5	3 E-5	8 E-5
Excavation worker, 1/2 yr.	5 E-8	2 E-7	5 E-7	1 E-6	2 E-6	7 E-6

* Estimated cancer risks are rounded to one significant figure.

Table 25. Estimated cancer risk at various PCB soil concentrations for commercial/industrial and excavation workers on the basis of future site development. Cancer risks are rounded to one significant figure.						
Age Group	***PCB soil concentrations in ppm***					
	1	***5***	***10***	***25***	***50***	***139***
	Estimated number of cancers if one million workers are exposed					
The estimated number of cancers if one million commercial/industrial workers are exposed to PCBs in soil for 20 years	0.6	3	6	10	30	80
The estimated number of cancers if one million excavation workers are exposed to PCBs in soil for 6 months	0.05	0.2	0.5	1	2	7

V.F.1.m. Uncertainty in Cancer Risk Estimates

Some uncertainty exists in these cancer risk estimates. It is important to remember the assumptions that went into estimating these cancer risks. These assumptions are as follows:

- ≠ The PCB-contaminated areas of the site will become residential,
- ≠ PCB contamination that is below the surface will be moved to the surface during construction thus allowing human contact,
- ≠ The average PCB concentration calculated using the current contaminant levels represents the level of future exposure,
- ≠ For the residential scenario, children will live on the property for 18 years or adults will live on the property for 52 years,
- ≠ For the commercial/industrial scenario, adults will have contact with the soil for 20 years,
- ≠ Children and adults will have high soil intake from hand-to-mouth activity, and
- ≠ The carcinogenicity of the various groups of PCBs are similar.

V.F.2 Mercury

V.F.2.a. The Chemistry of Mercury in Soil

During operations at the LCP facility, elemental mercury was used as part of the chemical reactions to produce chlorine. These processes resulted in mercury-containing waste that was discharged to soil and to the nearby marsh, as well as off-gassing of elemental mercury from the cell buildings to ambient air. Over the years, elemental mercury in soil and sediment is likely to be transformed into divalent mercury salts, such as mercuric chloride, mercuric hydroxide, and mercuric sulfide and to organic mercury. In soil, most of the mercuric salts become bound to the organic matter in soil by reacting with sulfur- and oxygen-containing areas in aromatic and aliphatic chemicals. These aromatic and aliphatic chemicals are part of the organic humic component of soil. Some mercuric salts also can be bound to soil minerals, while a small portion can remain as elemental mercury or dissolved mercury (Schuster 1991, Stevenson 1994, Renneberg and Dudas 2001, Biester 2002).

When soil is contaminated with industrial hydrocarbons, some of the mercuric salts can react with sulfur- and oxygen-containing areas of these hydrocarbons, much like it does with organic matter in soil (CCME 1997, Renneberg and Dudas 2001). Renneberg and Dudas have analyzed soil that was contaminated with mercury 20 to 30 years ago. They found 62% to 85% of the mercury in the soil samples was associated with organic matter. Several soil samples showed small amounts of mercury bound to hydrocarbons (i.e., less than 5%), although one sample showed almost 30%. The percentage of mercury bound to minerals ranged from 5% to 10% for some samples and 20% to 30% in other samples. One soil sample showed that elemental mercury made up 30% of the remaining mercury

in soil. The authors were not able to identify the specific chemical form of mercury in each sample (Renneberg and Dudas 2001).

In 2003, EPA collected 10 sediment samples from the nearby marsh and performed laboratory tests to speciate the mercury. The organic mercury typically was 45% with individual marsh sediment samples ranging from 3% to 86% organic mercury. The other major component consisted of mercury in a mineral lattice, mercuric chloride, or elemental mercury. The mineral or elemental component typically was 41% with individual marsh sediment samples ranging from 0% to 72% (EPA 2010). These results are consistent with the previously cited studies. It is important to remember that these are marsh sediment samples and may or may not accurately represent the speciation of mercury in soils.

These results show that a large proportion of mercury in soil at the LCP Chemicals Site is likely to be organic mercury and this mercury is now bound to the organic humic content of soil. However, other forms, such as inorganic mercuric salts, and possibly elemental mercury, might also be present. Because mercury in soil becomes bound to organic molecules, ATSDR will use health guidelines developed for organic mercury, specifically methylmercury.

V.F.2.b. Health Guideline for Mercury

Several health guidelines exist for mercury and they vary depending upon its chemical form. EPA has an oral Reference Doses (RfD) for organic mercury (i.e., methylmercury) and ATSDR will use this health guideline to evaluate exposure to mercury in soil should the site be developed (see Table 26). The EPA defines RfDs as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure in the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious [non-cancerous] effects during a lifetime.

Table 26. Oral health guideline for mercury used to evaluate exposure to mercury in soil should the site be developed.

Chemical	*Exposure Period*	*Type*	*Agency*	*Value in mg/kg/day*	*Value in µg/kg/day*
Methyl Mercury*	Lifetime	Chronic RfD	EPA	0.0001	0.1

*Methylmercury is an organic form of mercury.

V.F.2.c. Estimating Human Doses to Mercury and Mercury Hazard Quotients

The parameters used to estimate mercury doses in children and adults if the site becomes residential are shown in Appendix B, Table B1. As mentioned previously, preschool children were assumed to swallow 200 milligrams of soil daily, while older children and

adults were assumed to swallow 100 milligrams of soil daily. These soil intake rates represent the group of children and adults with high soil intake.

The estimated mercury doses for each age group for average mercury soil concentrations ranging from 1 to 1,470 ppm are shown in Table 27. Because the doses are small, the table shows estimated mercury doses in µg/kg/day. Depending on the age group and the average mercury concentration in a grid, estimated doses range from well below the health guideline for organic mercury of 0.1 µg/kg/day to the highest estimated dose of 29 µg/kg/day in 1-year-old children who live on soils containing an average of 1,470 ppm mercury in soil.

The mercury HQ for various average mercury concentrations was derived by dividing the estimated mercury dose in µg/kg/day by the chronic, oral RfD for organic mercury, which is 0.1 µg/kg/day. The resulting mercury HQs shown in Table 28 vary by age group and by the average mercury concentration in soil. What follows is a brief summary of these mercury HQs:

- ≠ For one-year-old children, the mercury HQ is 1 when average mercury soil concentrations are 5 ppm. The mercury HQs are 3, 4, 17, 59, and 294 when average mercury soil concentrations are 15, 20, 85, 296, and 1,470, respectively.
- ≠ For 3-year-old children, the mercury HQs are 1.9, 2.5, 11, 37 and 184 when average mercury soil concentrations are 15, 20, 85, 296, and 1,470 ppm.
- ≠ For elementary-age children, the mercury HQs are 2.4, 8.5, and 42 when average mercury soil concentrations are 85, 296, and 1,470 ppm, respectively.
- ≠ For teenagers, the mercury HQs are 1.5, 5.4, and 27 when average mercury soil concentrations are 85, 296 and 1,470 ppm, respectively.
- ≠ For adults, the mercury HQs range from 1.4, 4.9, and 25 when average mercury soil concentrations are 85, 296 and 1,470 ppm, respectively.

These mercury HQs are shown graphically in Figure 35. The HQs show that as a grid's average mercury concentration in soil exceeds 15 to 20 ppm, the HQ exceeds 1. Whenever the HQ of 1 is exceeded, further toxicological evaluation is necessary to determine if harmful effects might be expected.

Organic Mercury Studies

As part of a more thorough toxicological evaluation, ATSDR will describe the human and animal studies that show the harmful effects of mercury. This review is not an exhaustive review of the known harmful effects of mercury but rather it focuses on the lowest organic mercury doses that cause harmful effects since these studies are more relevant to deciding what harmful effects might be expected in a human population exposed to low levels of organic mercury from the environment.

Table 27. The estimated doses of mercury at various mercury concentrations in soil						
Age Group	***Mercury concentrations in ppm***					
	1	***15***	***20***	***85***	***296***	***1470***
	Chronic estimated dose in µg/kg/day					
Preschool children (1 yr.)	0.02	0.3	0.4	1.7	5.92	29.4
Preschool children (3 yr.)	0.012	0.19	0.25	1.06	3.7	18.38
Elementary school children	0.003	0.04	0.06	0.24	0.85	4.2
Teenagers	0.002	0.03	0.04	0.16	0.54	2.67
Adult men	0.001	0.02	0.03	0.12	0.42	2.1
Adult women	0.002	0.02	0.03	0.14	0.49	2.45
EPA's RfD for organic mercury in µg/kg/day	0.1	0.1	0.1	0.1	0.1	0.1

Table 28. Mercury HQs for various age groups and mercury soil concentrations.						
Age Group	***Mercury concentrations in ppm***					
	1	***15***	***20***	***85***	***296***	***1470***
	Chronic Methylmercury HQ					
Preschool children (1 yr.)	0.20	3.0	4.0	17.0	59.2	294
Preschool children (3 yr.)	0.13	1.9	2.5	10.6	37	184
Elementary school children	0.03	0.4	0.6	2.4	8.5	42
Teenagers	0.02	0.3	0.4	1.5	5.4	27
adult men	0.01	0.2	0.3	1.2	4.2	21
adult women	0.02	0.3	0.3	1.4	4.9	25

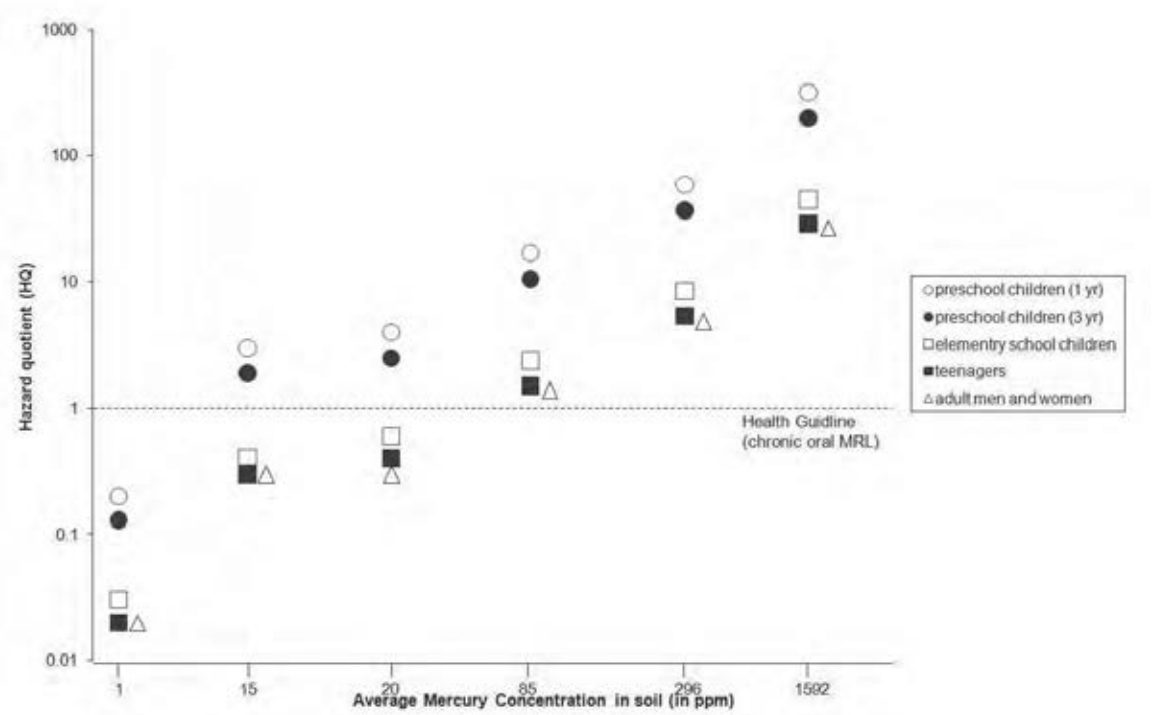


Figure 35. This graph shows the mercury HQ for various age groups at average mercury soil concentrations ranging from 1 to 1,470 ppm. At 1 ppm mercury in soil, the HQs are less than 1 indicating that the estimated doses are below health guideline; therefore, harmful effects are not expected. At 15 to 20 ppm mercury in soil, the HQ for 1-year-old children ranges from 3 to 4. At 85 ppm mercury in soil, all age groups exceed the HQ of 1. At average mercury soil concentrations of 15 or higher, the mercury HQ exceeds 1; therefore, additional toxicological evaluation is needed to determine if harmful effects might be expected.

Several environmental pollution episodes brought to light that contamination of the environment with organic mercury can cause serious harmful effects in humans. In Japan, a local chemical company dumped organic mercury-containing waste into a bay and river that ended up as high levels in fish and shellfish eaten by local residents. Another poisoning episode occurred in Iraq where adults and children ate grain treated with a methylmercury-containing fungicide. These initial human poisoning episodes prompted much research into understanding the harmful effects of organic mercury with the goal of identifying the lowest human doses that might be expected to cause harmful effects.

Several human studies have been conducted that have evaluated the neurological effects of methylmercury exposure in children. A long-term human study of children from the Faroe Islands, a small group of islands in the North Atlantic Ocean, which is affiliated with Denmark, began in 1986 and focused on children born to women who lived on the islands. This population relies heavily on seafood and whales as a source of protein. The investigators used various tests that monitor child development. They concluded that cord

blood mercury levels in the mother at birth were associated with harmful effects in children at age 7 years involving language, attention and memory, and to a lesser extent visual/spatial and motor functions (Grandjean *et al* 1997). Follow-up studies at age 14 years showed similar findings (Debes *et al* 2006). Another human study was conducted in New Zealand in 1978. This study focused on 61 children who were exposed *in utero* to high mercury levels that resulted from their mother's consumption of 4 or more fish meals a week. The authors showed a decrease in children's intelligence quotient (IQ) at age 6 with increasing exposure to methylmercury as measured by their mother's hair mercury levels at birth (Kjellstrom 1991, Crump 1998). The third study came from the Republic of Seychelles, where 85% of the population relies on local seafood for protein. Average ocean fish consumption in this population is 12 meals a week (Davidson 1998). The Seychelles study initially did not find harmful effects in children as they grew older. The investigators report that they occasionally found adverse effects in children but attributed these effects to chance because of the large number of tests being performed (Myers 2003, Davidson 2006, Myers 2009). Much more information about the harmful effects of methylmercury is available in ATSDR's Toxicological Profile for Mercury (ATSDR 1999).

The EPA developed a RfD using a mathematical model that estimates a 5% response in children for neurological effects[3]. Using the Faroe Islands study, EPA determined that the mercury concentration in maternal blood that causes a 5% adverse response in children ranged from 46 to 79 ppb. This mercury concentration in blood equates to a range of 0.8 to 1.5 µg mercury per kilogram per day (µg /kg/day) as a dietary intake. This dose was divided by an uncertainty factor of 10 to arrive at the Reference Dose of 0.1 µg/kg/day. This approach is supported by the U.S. National Academy of Science, which recommended that EPA use the Faroe Islands Study and 58 ppb mercury in cord blood as a LOAEL for deriving their health guideline (NRC 2000).

V.F.2.d. Uncertainty About the Harmful Effects of Methylmercury

It is well-established that high doses of methylmercury will cause neurological effects and will damage other organ systems within the human body. The debate about methylmercury toxicity centers on the lowest dose at which harmful effects might be expected. The Faroe Islands study clearly shows harmful neurological effects in a population that obtains most of its methylmercury exposure from eating whale meat and blubber, although some exposure also comes from other seafood. Similarly, the New Zealand study shows harmful neurological effects in a population that obtains most of its methylmercury exposure from eating seafood. The debate exists because the Seychelles study could not identify consistent harmful effects in a population that relied heavily on seafood. It should be noted that the Seychelles study occasionally identifies an adverse association with methylmercury exposure but the authors conclude that the associations are due to chance because so many tests were administered.

[3] More precisely, EPA estimated the lower 95th concentration of mercury in maternal blood that gave a 5% response for neurological effects in offspring at 7 years of age.

As described previously, the U.S. National Academy of Science through its National Research Council reviewed all three studies and in 2000 recommended that a dose response model be used to estimate the dose at which a 5% adverse response might be expected in children who were exposed *in utero,* that is, during fetal development in the womb. They used the Faroe Islands study to identify a lower 95th percentile of the dose that causes a 5% adverse neurological response. They also conducted an additional mathematical analysis using data from the New Zealand and Seychelles studies and stated that those studies support the results of the Faroe Islands study (NRC 2000).

The investigators of the Seychelles study also conducted a similar dose response analysis. Their conclusion supports in part the conclusion of the National Academy of Science. The Seychelles investigators concluded that they could not exclude a low risk of adverse effects at the upper range of mercury levels in the Seychelles study because of the limited number of data points in the upper ranges (Davidson *et al*. 2004).

Therefore, some uncertainty might exist about the precise lowest dose of methylmercury that might be expected to cause harmful effects. The National Academy of Sciences has recommended that it is reasonable to assume that some risk of harmful effects might be expected in children who were exposed *in utero* to methylmercury at 58 ppb methylmercury in cord blood. This concentration in cord blood equates to 12 ppm mercury in maternal hair (NRC 2000). A cord blood concentration of 58 ppb methylmercury and 12 ppm maternal hair equates to about 1 µg/kg/day methylmercury as a dietary dose, the LOAEL that served as the basis for EPA's derivation of its RfD (EPA 2009a).

V.F.2.e. Possible Health Effects from Methylmercury If the Site Becomes Residential

The estimated doses in various age groups with high soil ingestion have already been presented in Table 27. Because the doses are small, the table shows estimated methylmercury doses in µg/kg/day. For comparison, EPA's Reference Dose for methylmercury also is shown in µg/kg/day.

Depending on the age group and the average methylmercury concentration in a grid, estimated doses range from well below the EPA's RfD of 0.1 µg/kg/day to the highest dose of 29 µg/kg/day in one-year-old children who live on soil containing 1,470 ppm mercury. The estimated doses can be described as follows:

- ≠ At 1 ppm methylmercury in soil, all the estimated doses are below EPA's RfD,
- ≠ At 15 and 20 ppm methylmercury in soil, the estimated doses in one- and three-year-old children exceeds EPA's RfD,
- ≠ At concentrations greater than 85 ppm PCBs in soil, the estimated doses in all age groups exceed EPA's RfD.

Because the estimated doses exceed EPA's RfD for methylmercury of 0.1 µg/kg/day, it is necessary now to compare the estimated doses in various age groups to doses that can cause harmful effects to decide if harmful effects might be expected.

Figure 36 shows the estimated doses in various age groups that exceed EPA's RfD for methylmercury. These doses are shown in relation to the RfD of 0.1 µg/kg/day and in relation to the lowest dose in humans (i.e., 1 µg/kg/day) that might be expected to cause harmful effects to the neurological system in 5% of children.

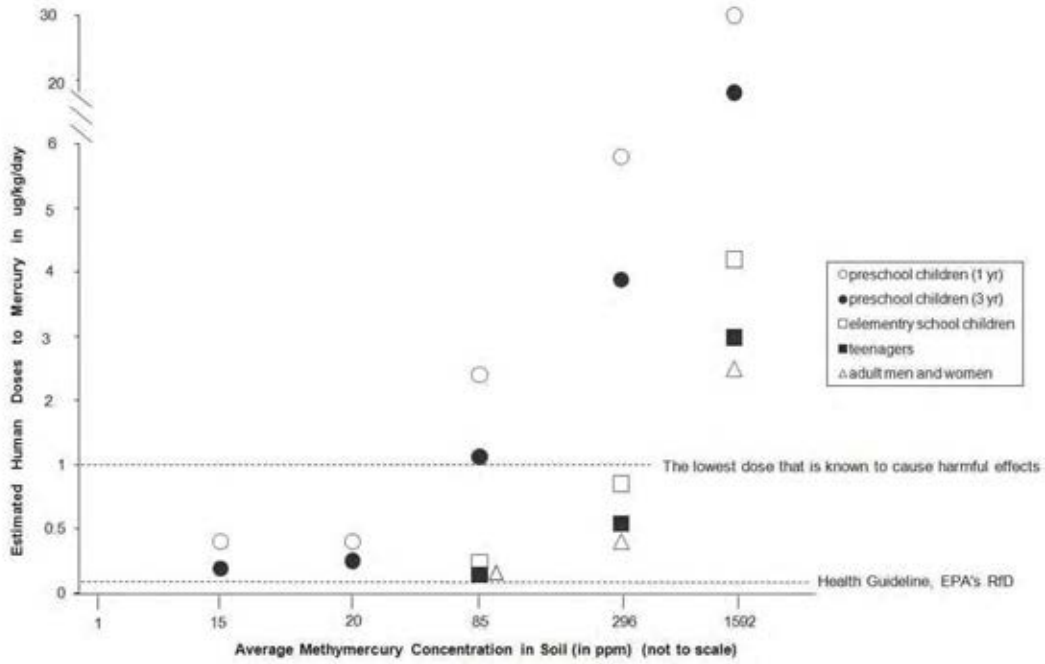


Figure 36. This figure shows the estimated dose in various age groups for various average mercury concentration in soil ranging from 15 ppm to 1,470 ppm. The estimated doses at 1 ppm are below the health guideline for methylmercury of 0.1 µg/kg/day and are not shown. At average soil concentrations of 15 ppm and 20 ppm, the estimated doses in preschool children exceed EPA's RfD. At an average concentration of 85 ppm and 296 ppm in soil, the estimated doses in all age groups exceed the RfD; and, the estimated doses in preschool children exceed the lowest dose known to cause harmful effects in humans. At an average concentration of 1,470 ppm, the estimated doses in all age groups exceeds the lowest dose known to cause harmful effects in humans.

The highest estimated dose in women is 2.5 µg/kg/day for women who live on soil containing 1,470 ppm mercury. This estimated dose is twice the dose that is expected to cause harmful neurological effects to the fetus during pregnancy. Some children born to women exposed to this dose while pregnant might experience neurological effects involving language, attention and memory, and to a lesser extent visual/spatial and motor functions. Preschool children who live on properties containing 1,470 ppm mercury have estimated doses of 20 to 32 µg/kg/day and are at risk of similar harmful effects. Preschool children who live on soil containing 85 ppm mercury have estimated doses of 1 µg/kg/day and also are at risk of harmful effects. At 20 ppm mercury in soil, estimated mercury doses in preschool children range from 0.2 to 0.4 µg/kg/day. They have a small risk of harmful effects from mercury in soil.

Some uncertainty exists in these conclusions. First, uncertainty exists in estimating how much mercury people will contact in surface soil if the site becomes residential. This uncertainty comes from assuming that soil below the surface (e.g., several feet down) could become the surface soil (e.g., the top few inches) that people contact during their daily activities. Uncertainty also exists from using soil samples that were collected 15 years ago. These soil samples may not represent current conditions at the site.

Second, some uncertainty exists concerning the risk of harmful effects from mercury in soil. The chemical form of mercury in soil at the LCP Chemicals Site has not been well-established, although analytical studies have been conducted on marsh sediment. Studies by EPA in 2003 showed that almost half the mercury in marsh sediment was bound to organic molecules. Other scientific studies evaluated the weathering of elemental mercury in soil over time. These studies showed that most of the mercury was bound to organic molecules (Renneberg and Dudas 2001). Therefore, ATSDR assumed that the mercury in soil at the LCP Chemicals Site was organic mercury. There's some uncertainty whether the mercury bound to organic molecules in soil would have the same or similar toxicity as methylmercury. Nevertheless, it seems reasonable to assume that grids with average mercury concentrations as high as 1,470 ppm mercury in soil pose some risk to women and children if the site becomes residential.

Ten grids exceed EPA's 1994 target action level of 20 ppm mercury in soil. The location of these grids is shown in Figure 37 and the average mercury concentration in each grid is shown in Table 29. The half-acre grids on the site that are a concern if the site becomes residential are grids 53, 55, 60, 90, 93, 112, 113, 114, 118, and 128.

The previous results were derived using 1990s soil samples with a depth of 0 to 5 ft. The justification for using 0 to 5 ft. is that future site development might bring soil to the surface that was previously up to 5 feet below the surface. One concern is that more contaminated soil is nearer the surface, and this more contaminated soil might have a greater chance of becoming surface soil in the future because of construction activity. Therefore, ATSDR calculated statistics using 1990s soil samples with a depth of 0 to 2 ft. Using soil samples with a depth of 0 to 2 ft. showed overall somewhat similar results as using 0 to 5 ft. At 0 to 2 ft., 5 grids exceed EPA's 1994 target action level of 20 ppm and four of these grids are found in Table 29. More uncertainty exists in these five concentrations because fewer soil samples are available from the 0 to 2 ft. depth.

Table 29. Grid number and average mercury concentrations greater than 20 ppm in soil	
Grid #	***Average Mercury Concentration in Soil (ppm)***
113	1,470
93	296
112	271
90	184
60	85
128	81
114	41
118	30
53	24
55	23

V.F.2.f. Possible Health Effects for Workers

Since specific plans have not been identified as to the eventual use of the property, ATSDR evaluated the possibility of harmful effects for two categories of workers: commercial/industrial workers, and excavation workers.

Once the property is developed, commercial and industrial workers might come in contact with contaminated soil for extended periods. The contact is assumed to be long-term, chronic exposure occurring for many years. Therefore, ATSDR compared estimated doses in these workers to EPA's RfD for organic mercury. Excavation workers are likely to be exposed for periods less than a year as they move soil during construction activity. No health guidelines are available for organic mercury for exposure periods of less than one year; therefore, the estimated doses will be compared directly to doses from human and animal studies to decide if harmful effects might be expected.

The estimated doses for commercial and industrial workers are shown in Table 30 should these workers ingest 100 mg soil daily, 5 days a week. Estimated doses also are provided for excavation workers should these workers ingest 330 mg soil daily, 5 days a week.

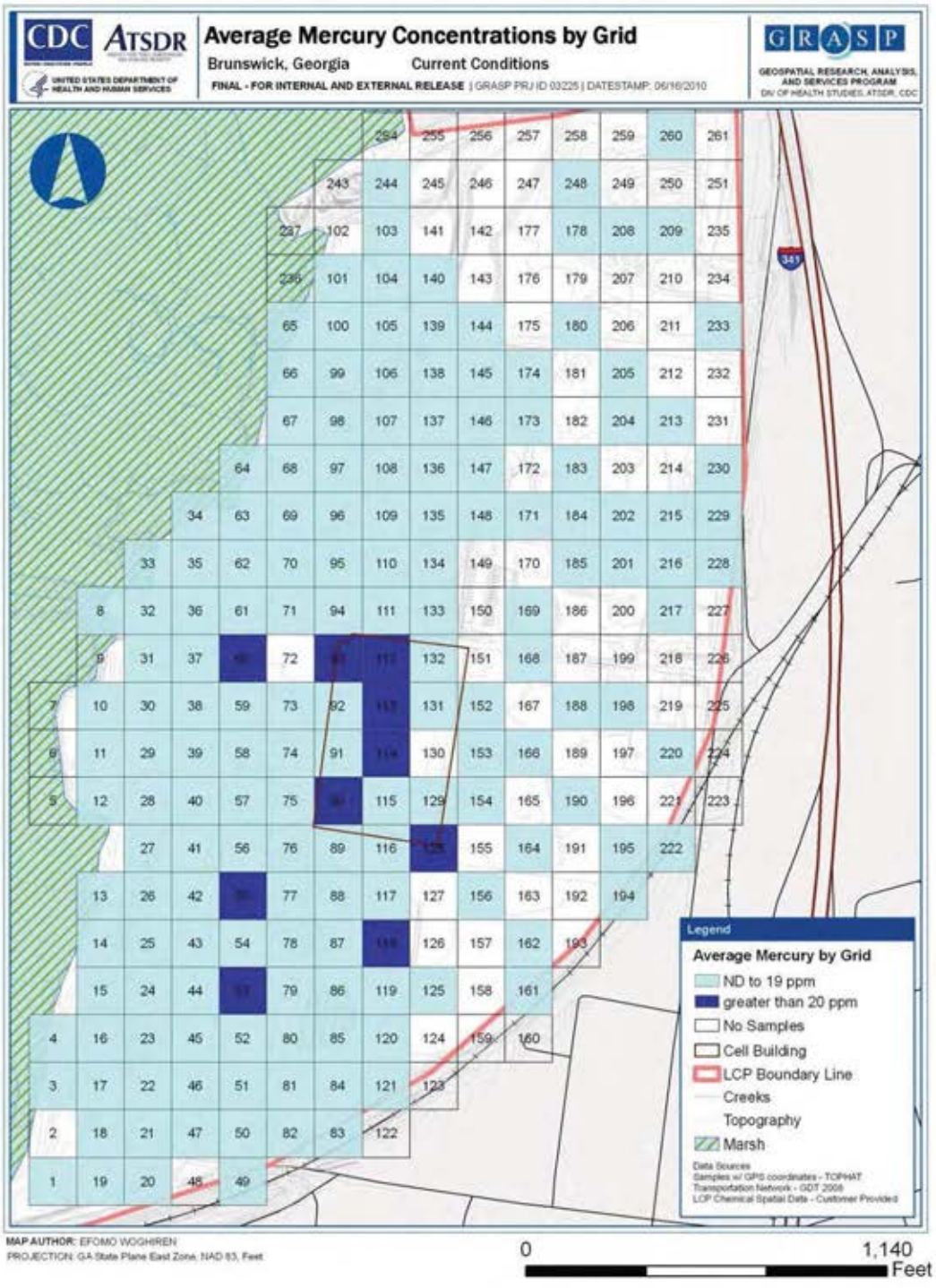


Figure 37. This figure shows the ten grids in dark blue where average mercury levels in soil 0 to 5 ft. exceed EPA's 1994 target action level of 20 ppm. If these grids become residential, mercury in soil is a health concern. Most of the dark blue grids are associated with the former mercury cell building, indicating these soils are still highly contaminated with mercury (see Table 29).

For grids with average mercury concentrations ranging from 184 ppm to 1,470 ppm, the estimated doses for commercial/industrial workers range from 0.2 to 1.4 µg/kg/day. These estimated doses exceed EPA's chronic RfD of 0.1 µg/kg/day. Four grids have estimated doses that exceed EPA's chronic RfD. The average mercury concentration for these grids is 184 ppm (grid 90), 271 ppm (grid 112), 296 ppm (grid 93), and 1,470 ppm (grid 113) (see Table 29).

Table 30. Estimated mercury doses in commercial/industrial workers and in excavation workers if the site is developed.

Age Group	***Mercury Concentrations in ppm***					
	1	***15***	***20***	***100***	***296***	***1470***
	Estimated dose in ug/kg/day					
commercial workers	0.0010	0.015	0.020	0.1	0.29	1.44
excavation workers	0.0034	0.051	0.067	0.34	1.00	4.95

As mentioned previously, the EPA used a mathematical model to estimate a 5% response for neurological effects in children who were exposed *in utero*[4]. Using the Faroe Islands study, EPA determined that an intake of 0.8 to 1.5 µg /kg/day is expected to cause a 5% adverse response in children exposed *in utero*. This intake is supported by the U.S. National Academy of Science, which estimated a mercury intake of 1 µg/kg/day to be associated with a 5% response (NRC 2000). Therefore, an intake of about 1 µg/kg/day in female workers can be considered a LOAEL for adverse effects to the developing fetus from exposure to organic mercury.

Pregnant commercial or industrial workers who have contact with mercury in soil in grids 90, 93, 112, and 113 are at risk of exposing their developing fetus to mercury at doses that are expected to cause harmful effects. Some children born to women exposed to these doses might experience neurological effects involving language, attention and memory, and to a lesser extent visual/spatial and motor functions. The mercury soil levels in these grids range from 184–1,470 ppm.

Male and female workers who have contact with soil from grid 113, which has an average of 1,470 ppm mercury, also are at risk of harmful effects. Their estimated dose of 1.4 µg /kg/day is roughly 35 times below levels known to cause harmful effects in monkeys and cats. Male and female workers who have prolonged contact with soil mercury at this grid might experience damage to their neurological system, such as diminished sensitivity to pain, diminished touch, decreased fine motor performance, impaired vision, and impaired hearing, (Charbonneau 1976, Rice and Gilbert 1982, Rice 1989, ATSDR 1999).

Excavation workers exposed to mercury in soil at 1,470 ppm have an estimated dose of about 5 µg /kg/day. It seems unlikely, however, that this dose would be sustained for

[4] More precisely, EPA estimated the lower 95th concentration of mercury in maternal blood that gave a 5% response for neurological effects in offspring at 7 years of age.

more than a few weeks or maybe a month or so before they move on to other grids with lower mercury contaminant levels. If they moved on to the grid containing 296 ppm mercury, their estimated dose would be 1 µg /kg/day. These doses would average out to be about 2 or 3 µg /kg/day over the course of a few weeks or a few months. Exposure at these doses for a few months might cause an increase in a certain type of brain cell called reactive glia cells (Charleston 1994, ATSDR 1999). This increase is a mild adverse response to mercury exposure; however, it does not result in any symptoms of mercury poisoning.

It should be noted that soil beneath the cell building area is likely to have high levels of mercury since this area was not excavated to remove highly contaminated mercury in soil below the surface. Any future excavations in this area could result in mercury exposure for workers who have direct contact with soil and groundwater, or who breathe mercury vapors. Therefore, appropriate worker protection guidelines should be used to prevent exposure and to ensure that mercury in air is not a public health concern.

V.F.3. Lead

V.F.3.a. Levels in Soil at the LCP Chemicals Site

Using half-acre grids, average lead levels in soil (0-5 ft.) exceeded EPA's target action level of 400 ppm in seven grids. Average lead levels in these grids are 745 ppm (grid 136), 728 ppm (grid 48), 692 ppm (grid 103), 590 ppm (grid 93), 513 ppm (grid 59), 422 ppm (grid 60), and 411 ppm (grid 411). The distribution of average lead levels in grids can be described as follows:

- ≠ 7 grids have average lead levels above 400 ppm
- ≠ 6 grids have average lead levels in the 300 ppm range,
- ≠ 10 grids have average lead levels in the 200 ppm range,
- ≠ 29 grids have average lead levels in the 100 ppm range,
- ≠ 110 grids have average lead levels below 99 ppm.

V.F.3.b. CDC's Reference Level for Lead and Recent Human Studies on the Effects of Lead

Using data from the National Health and Nutrition Examination Survey (NHANES), the Centers for Disease Control and Prevention (CDC) has established a reference value for lead in children aged 1 to 5 years. This new reference value is based on the U.S. population of children aged 1-5 years and was selected based on the blood lead level in the top 2.5% of children. Currently, the reference value is 5 micrograms lead per deciliter (µg/dL) of blood. This reference value replaces CDC's historical value of 10 µg/dL.

More information about CDC's new reference value as well as CDC's recommendations concerning elevated blood lead in children can be found at these CDC websites:

- http://www.cdc.gov/nceh/lead/ACCLPP/activities.htm, and
- http://www.cdc.gov/nceh/lead/tips.htm.

CDC replaced its blood lead 'level of concern' with a reference value following recommendations in January 2012 from CDC's Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP 2012). As the advisory committee and CDC pointed out, scientific research has clearly shown that blood lead levels below 10 µg/dL cause serious harmful effects in children. Table C1 in Appendix C summarizes some of these studies.

Blood lead levels below 10 µg/dL have been shown to cause neurological, behavioral, immunological, and developmental effects in young children. Specifically, lead causes or is associated with the following harmful effects:

- Decreases in intelligent quotient (IQ),
- Attention deficit hyperactivity disorder (ADHD),
- Deficits in reaction time,
- Problems with visual-motor integration and fine motor skills,
- Withdrawn behavior,
- Lack of concentration,
- Issues with sociability,
- Decreased height,
- Changes in kidney function, and
- Delays in puberty, such as breast and pubic hair development, and delays in menarche.

V.F.3.c. Estimating Children's Lead Exposure from Soil Lead Levels

The EPA has developed a model to estimate the contribution of soil lead to children's blood lead level. The model is called the Integrated Exposure Uptake Biokinetic (IEUBK) model and the current version is IEUBKwin version 1.1 build 11. More information about the IEUBK model can be found at this EPA web address: http://www.epa.gov/superfund/lead/products.htm#guid. After identifying a set of exposure parameters (e.g., lead concentrations in soil, water, air), the model estimates the percentage of children up to 7 years old that exceed a specified blood lead level. In most situations, the EPA's goal is to limit exposure to lead in soil such that a typical child exposed for 7 years (0 to 84 months) would have an estimated risk of no more than 5% of exceeding a specified blood lead level. When EPA ran the model in the mid-1990s for the LCP Chemicals Site, the standard practice was to set the target blood lead level to 10 µg/dL, CDC's historical level of concern at the time (EPA 1998). For the LCP Chemicals Site, the EPA used the model to select their initial soil lead action level of 500 ppm. They have since lowered the action level to 400 ppm. See this web address for a listing of EPA's recommended default parameters for the IEUBK model: http://www.epa.gov/superfund/lead/guidance.htm#training.

Because CDC has a new reference value for lead in children, ATSDR ran the IEUBK model using 5 µg/dL (instead of 10 µg/dL) as the target blood lead level and using the following default parameters recommended by EPA:

- ≠ Lead in air (0.1µg/m^3),
- ≠ Lead in drinking water (4 µg/L),
- ≠ Soil/dust ingestion (0.085 to 0.135 g/day),
- ≠ Drinking water (0.2 to 0.59 L/day),
- ≠ Maternal blood lead (1 µg/dL),
- ≠ Dietary lead intake (1.95 to 2.26 ug/day),
- ≠ Geometric standard deviation of blood lead levels (1.6), and
- ≠ Bioavailability (30%).

The results show that if a child lives on soil for 7 years containing 400 ppm lead, the child has a 40% risk of exceeding a blood lead level of 5 µg/dL (see Figure 38). Stated another way, if 100 children lived for 7 years on soil containing an average of 400 ppm lead, 40 children out of 100 would be expected to have blood lead levels that exceed 5 µg/dL, the current CDC reference level.

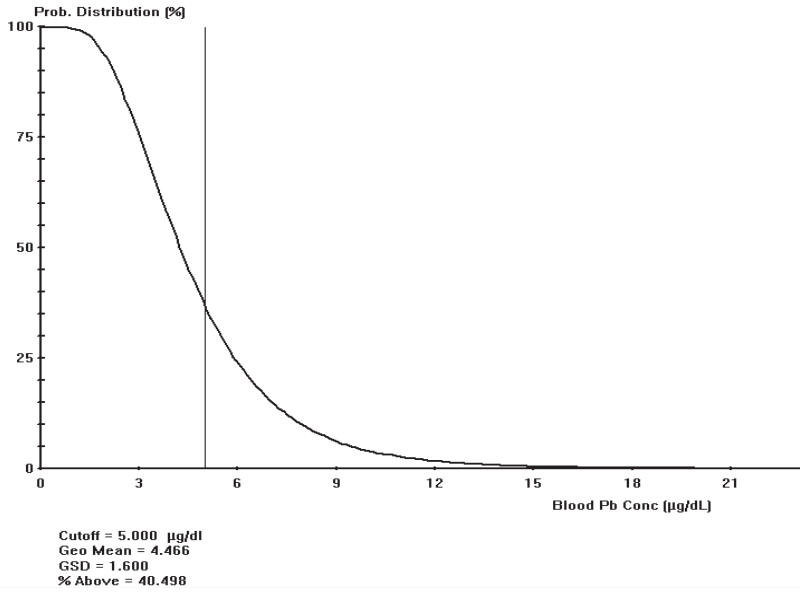


Figure 38. This figure shows the expected distribution of blood lead levels in children using EPA's target action level for lead (i.e., 400 ppm) and CDC reference level for blood lead (i.e., 5 µg/dL). At 400 ppm lead in soil and at a target blood lead level of 5 µg/dL, 40% of children who live there for 7 years (0 to 84 months) might be expected to exceed 5 µg/dL. The geometric mean blood lead level in this population of children would be 4.5 µg/dL.

The IEUBK model also can be run to identify the soil lead concentration that would result in no more than a 5% risk that children's blood lead levels would exceed 5 µg/dL after 7 years of exposure (see Figure 39). The IEUBK model shows that at 154 ppm lead in residential soil, children have a 5% risk of exceeding CDC's reference level of 5 µg/dL. It should be noted that EPA is currently reviewing the IEUBK model in light of CDC's new reference level for lead.

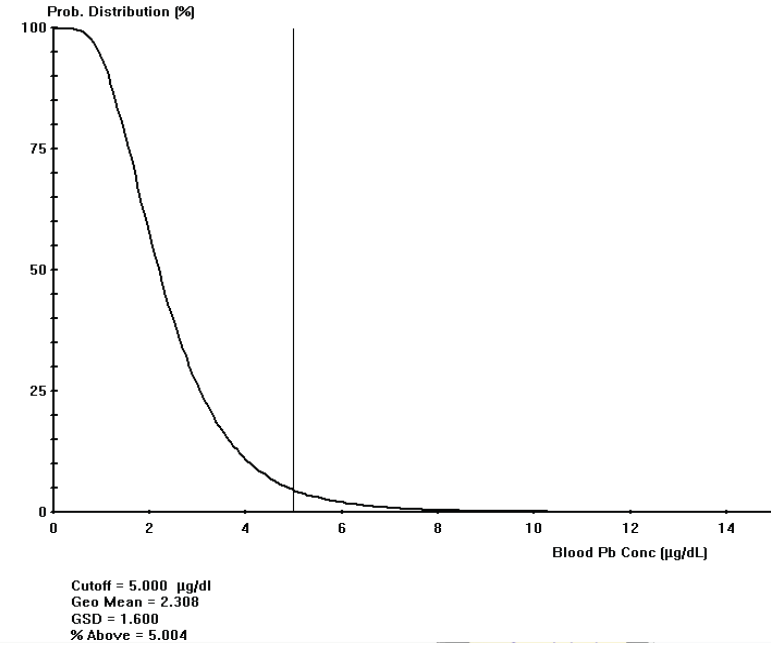


Figure 39. This figure shows the expected distribution of blood lead levels in children after 7 years of exposure (0 to 84 months) if the target blood lead level is set at 5 µg/dL and the average soil lead level is set at 154 ppm. The IEUBK model shows that at 154 ppm lead in residential soil, children have a 5% risk of exceeding CDC's reference level of 5 µg/dL.

V.F.3.d. Possible Health Effects from Lead If the Site Becomes Residential

Most grids on the LCP property have low levels of lead in soil and do not present a health concern for future residential, commercial, or industrial development. However, seven grids have average lead levels that exceed EPA's target action level of 400 ppm and the average lead level in soil at these grids are a health concern if residential properties are built on them. An additional 21 grids have average soil lead levels between 154 ppm and 399 ppm; these grids also are a health concern if residential properties are built on them.

If the site becomes residential, exposure to lead in soil at these levels could increase children's blood lead levels and result in the following harmful effects:

- ≠ Small decreases in IQ,
- ≠ An increase in attention deficit hyperactivity disorder,
- ≠ Reduced attention span,
- ≠ Lack of concentration,

- ≠ Decreased fine muscle skills,
- ≠ Withdrawn behavior,
- ≠ Decreased height,
- ≠ Small delays in puberty, and
- ≠ Small changes in kidney function (Braun 2006, Lanphear 2000, Lanphear 2005, Bellinger 1992, Bellinger 2003, Selevan 2003, Walkowiak 1998, and Burbure 2006, ATSDR 2007).

The location of the grids that are a health concern for lead is shown in Figure 40. Table 31 shows the average lead concentration in soil for each of these grids.

Table 31. Grid Number and Average Lead Concentration in Soil for Those Grids That Are a Health Concern if the Site Becomes Residential

ATSDR Grid #	*Average Soil Lead in ppm*		*ATSDR Grid #*	*Average Soil Lead in ppm*
136	745		96	280
48	728		34	272
103	692		147	250
93	590		37	245
59	513		8	245
60	422		51	237
54	411		73	214
33	394		78	214
58	390		107	208
99	376		97	190
50	371		76	175
111	354		89	170
49	341		53	169
52	292		26	157

The previous results were derived using soil samples with a depth of 0 to 5 ft. Using soil samples with a depth of 0 to 2 ft. showed somewhat similar results as using 0 to 5 ft. At 0 to 2 ft., nine grids have average lead levels that exceed 500 ppm and 36 grids have average lead levels between 154 ppm and 499 ppm. For comparisons, these data are presented in Table 32.

Table 32. Comparison of number of grids that exceed 500 ppm or 154 ppm using soil samples of various depths		
	Greater than 400 ppm average lead	***154 to 399 ppm average lead***
# Grids (0-5 ft.)	7	21
# Grids (0-2 ft.)	9	36

V.F.3.e. Estimating Blood Lead Levels in Workers

The EPA also has an adult lead model that can be used to estimate blood lead levels in the developing fetus. The model is often used for women of child-bearing age to estimate blood lead levels in the developing fetus because the developing fetus is likely to be more sensitive than adult women. More information about EPA's adult lead model can be found at this EPA web address: http://www.epa.gov/superfund/lead/products.htm (EPA 2009c).

Using 5 µg/dL as the target blood lead level, the adult lead model estimates a 5% risk that fetal blood lead levels will exceed 5 µg/dL when average soil lead levels are 773 ppm. No grids exceed the average lead level of 773 ppm, although two grids with averages of 745 ppm and 728 ppm (grids 136 and 48) approach this concentration (see Table 31). The parameters used in the adult lead model are shown in Table 33. The adult lead model assumes that the typical worker is exposed for 219 days a year (approximately 44 weeks). Should women work longer (e.g., 50 weeks a year), their blood lead levels would exceed 5 µg/dL at three grids (grids 136, 48, and 103). Should they be pregnant, their exposure to lead in soil would put their unborn fetus at risk of the harmful effects previously mentioned.

V.F.3.f. Uncertainty About Lead in Soil

Some uncertainty exists in these conclusions about the risk of harmful effects from lead in soil. Uncertainty exists in estimating children's exposure to lead in soil if the site becomes residential because of uncertainties in the model and because construction activity is likely to alter the concentration of lead in soil that children contact. Uncertainty also exists in estimating adult's exposure to lead in soil for the same reason. In addition, uncertainty exists from using soil samples that were collected 15 years ago. These soil samples may not represent current or future conditions at the site.

Table 33. Parameters used in EPA's adult lead model to generate the soil concentration that is expected to result in a 5% risk that a fetus will have blood lead levels that exceed 5 µg/dL.			
Variable	***Description of Variable***	***Units***	***Model Parameters***
$PbB_{fetal,\ 0.95}$	95^{th} percentile PbB in fetus	µg/dL	5
$R_{fetal/maternal}$	Fetal/maternal PbB ratio	--	0.9
BKSF	Biokinetic Slope Factor	µg/dL per µg/day	0.4
GSD_i	Geometric standard deviation PbB	--	1.8
PbB_0	Baseline PbB	µg/dL	1.0
IR_S	Soil ingestion rate (including soil-derived indoor dust)	g/day	0.05
$AF_{S,\ D}$	Absorption fraction (same for soil and dust)	--	0.12
$EF_{S,\ D}$	Exposure frequency (same for soil and dust)	days/yr	219
$AT_{S,\ D}$	Averaging time (same for soil and dust)	days/yr	365
Soil Lead Concentration	The soil lead concentration that results in a 5% risk that the fetus will have blood lead levels that exceed 5 µg/dL	ppm	773

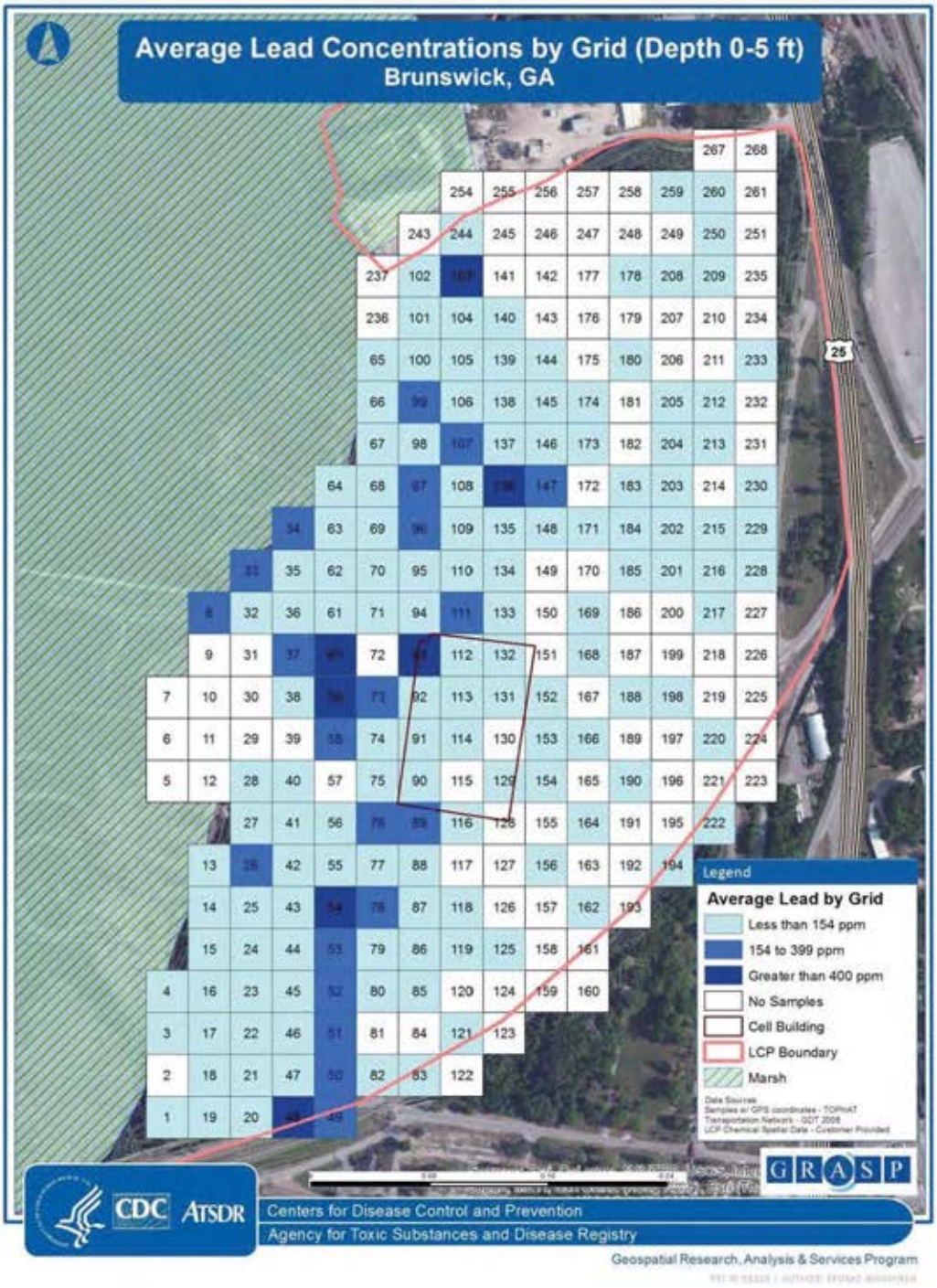


Figure 40. This figure shows the seven grids in dark blue that exceed EPA's target action level for lead of 400 ppm. An additional 21 grids have average lead levels between 154 ppm and 399 ppm. If these half-acre grids become residential in the future, they are a health concern for children.

V.F.4. Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals with a similar chemical structure and are formed during the incomplete burning of coal, oil, gas, wood, or other organic substances. The PAHs detected in soils from the LCP Chemicals Site are most likely residues from distillation of crude oil that occurred during historical site operations (McNamara 2010). There are more than 100 different PAHs, which occur as complex mixtures in the environment. PAHs can be grouped into the non-carcinogenic PAHs and the carcinogenic (cancer-causing) PAHs (or cPAHs). Table 34 shows the PAHs that were most frequently detected in soils from the LCP Chemicals Site and indicates whether the specific PAH is in the non-carcinogenic or carcinogenic group.

PAHs are composed of carcinogenic and non-carcinogenic PAHs. To evaluate the risk of cancer, an approach is used from the California Environmental Protection Agency (Cal EPA) that converts the total PAH concentration to a total carcinogenic PAH concentration in a sample (CalEPA 2005). Based on the toxicity of benzo(a)pyrene, this approach uses potency factors specific for each carcinogenic PAH to change the concentration of that PAH to a benzo(a)pyrene equivalent concentration. Thus, the benzo(a)pyrene equivalent concentration of various individual carcinogenic PAHs in a soil sample are summed to give the total carcinogenic PAHs (cPAH) for that sample.

The CalEPA PEFs for each cPAH are shown in Table 34. This concentration is used to estimate the dose in BaP equivalents and the cancer slope factor for BaP along with the duration of exposure is used to estimate the risk of cancer from ingesting soil with cPAHs. The exception to this approach is samples with dibenz(a,h)anthracene. This cPAH has its own cancer slope factor; therefore, a separate cancer risk is estimated for this cPAH and combined with the cancer risk estimated using the BaP equivalent concentration.

More information about how to estimate cancer risk from PAHs can be found at these websites:

- ≠ http://oehha.ca.gov/air/hot_spots/pdf/May2005Hotspots.pdf
- ≠ http://cfpub.epa.gov/ncea/iris_drafts/recordisplay.cfm?deid=194584
- ≠ http://www.health.state.mn.us/divs/eh/risk/guidance/pahmemo.html

Table 34. The carcinogenic and non-carcinogenic PAHs that were detected most frequently in soils from the site are shown along with descriptive information about the PAHs. This information is described further in the text and is used to evaluate the risk of harmful effects

Substance Name	*Cancer Slope Factor* $(mg/kg/day)^{-1}$	*Potency Equivalency Factor*	*# Samples > ND*	*Total # Samples*	*% Detection*
Carcinogenic PAHs (cPAH)					
Benzo(a)pyrene	7	1	72	651	11.1
Benzo(a)anthracene		0.1	90	651	13.8
Benzo(b)fluoranthene		0.1	56	568	9.9
Benzo(k)fluoranthene		0.1	44	567	7.8

Table 34. The carcinogenic and non-carcinogenic PAHs that were detected most frequently in soils from the site are shown along with descriptive information about the PAHs. This information is described further in the text and is used to evaluate the risk of harmful effects					
Substance Name	***Cancer Slope Factor*** $(mg/kg/day)^{-1}$	***Potency Equivalency Factor***	***# Samples > ND***	***Total # Samples***	***% Detection***
Benzo(b and/or k)fluoranthene		0.1	17	84	20.2
Indeno(1,2,3-cd)pyrene		0.1	43	651	6.6
Chrysene		0.01	116	651	17.8
Dibenz(a,h)anthracene	4		18	650	2.8
Naphthalene	None	None	90	650	13.8
Non-carcinogenic PAHs (PAH)					
Pyrene			139	651	21.4
Phenanthrene			143	651	22
2-Methylnaphthalene			126	631	20
Fluoranthene			69	651	10.6
Benzo(g,h,i)perylene			70	651	10.8
Anthracene			72	650	11.1
1-Methylnaphthalene			107	462	23.2
Acenaphthene			15	649	2.3
Fluorene			14	650	2.2
Acenaphthylene			18	650	2.8

V.F.4.a. Estimating Human Doses of PAHs

The parameters used to estimate doses in children and adults if the site becomes residential are shown in Appendix B, Table B1. As mentioned previously, preschool children were assumed to swallow 200 milligrams of soil daily, while older children and adults were assumed to swallow 100 milligrams of soil daily. These soil intake rates represent the group of children and adults with high soil intake.

Two cancer risks were estimated and then combined to get a total cancer risk. The first cancer risk was estimated using cPAH concentrations and represents the cancer risk from ingesting benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, indeno(1,2,3-cd)pyrene, and chrysene. A separate cancer risk was estimated from ingesting dibenz(a,h)anthracene because this PAH has its own cancer slope factor. The two cancer risks were combined to represent the total cancer risk from all cPAHs in soil.

The average cPAH concentration and the dibenz(a,h)anthracene concentration are shown in Table 35 for the grids with the highest average concentrations. The grids with the highest average cPAH concentration was grid 93 with an average concentration of 29 ppm on the basis of two soil samples. The low number of samples increases the

uncertainty about the average cPAH concentration for this grid. Five other grids have average cPAH concentrations ranging from 1.6 ppm to 9.6 ppm.

Table 35. The grids are listed with the highest average cPAH concentration and dibenz(a,h)anthracene concentration.

Grid Number	*Average cPAH Concentration in ppm*	*Average dibenz(a,h)anthracene in ppm*	*# samples*
93	29.4	0	2
15	9.6	1.9	5
28	2.6	0	4
26	2	0.3	5
14	2	0.3	6
33	1.6	1.4	2

The estimated cPAH doses for various age groups exposed to an average of 1.6 or 29.4 ppm cPAHs in soil are shown in Table 36. Because the doses are small, they are shown as µg/kg/day. These doses are used to estimate cancer risk for the cPAHs in soils. Depending on the age group, estimated doses range from 0.002 µg/kg/day in adults to 0.58 µg/kg/day in 1 yr old preschool children.

In addition to cPAH doses, estimated doses were also calculated for dibenz(a,h)anthracene. Those doses ranged from 0 µg/kg/day for those grids with no dibenz(a,h)anthracene to 0.038 µg/kg/day for preschool children who live on soil containing 1.9 ppm dibenz(a,h)anthracene.

Table 36. Estimated cPAH doses in various age groups exposed to an average concentration of 1.6 or 29.4 ppm cPAHs in soil

Age Group	*1.6 ppm cPAHs*	*29.4 ppm cPAHs*
	cPAH Dose µg/kg/day	
Preschool children (1 yr)	0.0320	0.5880
Preschool children (3 yr)	0.0200	0.3675
Elementary age children	0.0046	0.0840
Teenagers	0.0029	0.0535
Adult men	0.0023	0.0420
Adult women	0.0027	0.0490
Commercial/Industrial workers (20 years)	0.0016	0.0288
Excavation workers (6 months)	0.0054	0.099

V.F.4.b. Possible Health Effects From PAHs If the Site Becomes Residential

The greatest concern from PAH exposure is the potential for cPAHs to cause cancer. The concern is for cancer because non-cancerous effects are not expected at the soil levels found at the LCP site. Human studies has shown that exposure to PAHs is associated with lung and skin cancers in humans. The estimated dose of cPAHs can be multiplied by EPA's cancer slope factor for benzo(a)pyrene and the number of years of exposure to estimate the cancer risk from exposure to cPAHs in soil. The formula for estimating cancer risk follows:

Estimated Cancer Risk =

(cPAH Dose x Cancer Slope Factor) x (# years / 70 years)

The estimated dose for each age group can be used to estimate a cancer risk for that age group. The cancer risks for the 3 age groups that represent children can be added to give the estimated cancer risk for children who live on a property for 18 years. The estimated cancer risk for adults is the average of cancer risk for men and women assuming 52 years of exposure.

A similar procedure is followed to estimate the cancer risk from exposure to dibenz(a,h)anthracene. This approach uses the estimated dose of dibenz(a,h)anthracene and the cancer slope factor that is specific to dibenz(a,h)anthracene. The cancer risks estimated from both cPAHs and dibenz(a,h)anthracene are added to arrive at a total cancer risk from carcinogenic PAHs.

The estimated cancer risks in children and adults who live on soil containing the highest cPAH levels are shown in Table 37. So that the reader can understand the scientific notation, the same cancer risks are presented in Table 38. The grids with elevated levels of carcinogenic PAHs are shown in Figure 41.

Grids 15 and 93 have the highest estimated cancer risks ranging up to 1E-4 (grid 15) and 3.2E-4 (grid 93) for children if they live within these grids for 18 years. The cancer risk for adults is slightly lower. The highest cancer risk estimate is 3.2E-4. This means that should 100,000 children live for 18 years on soil containing 29.4 ppm cPAHs (grid 93), about 30 extra cancer cases might be expected. For adults who live for 52 years on grid 93, their estimated cancer risk is 2.5E-4. This means that should 100,000 adults live for 52 years on soil with 29.4 ppm cPAHs, about 25 extra cases of cancer might be expected. In summary, if the site becomes residential, children and adults might have an increased risk of cancer if they have contact with cPAHs in soil above 2 ppm.

The estimated cancer risks shown in Tables 37 and 38 likely underestimate the cancer risk from carcinogenic PAHs. The EPA is reviewing and updating the potency factors for cPAHs and will be adding more CSFs for various PAHs. These changes will result in a higher cancer risk estimate once EPA makes them final. More information about EPA's potency estimates for cPAHs can be found at

http://cfpub.epa.gov/ncea/iris_drafts/recordisplay.cfm?deid=66193&utm_medium=email&utm_source=govdelivery and http://cfpub.epa.gov/ncea/iris_drafts/recordisplay.cfm?deid=194584.

Table 37. Estimated cancer risks in children and adults who live on certain grids with elevated levels of carcinogenic PAHs in soil (using scientific notation). The estimated cancer risk is for children and adults with high soil intake. The estimated cancer risk for children and adults with typical soil intake is about half the risk shown this table

Grid Number	*Cancer Risk*		*# samples*
	Children	*Adults*	
93	3.2E-4	2.5E-4	2
15	1.1E-4	9E-5	5
28	2.8E-5	2.2E-5	4
26	2.5E-5	1.9E-5	5
14	2.5E-5	1.9E-5	6
33	2.6E-5	2.0E-5	2

Table 38. Estimated number of cancer cases if 100,000 children or 100,000 adults were exposed to carcinogenic PAHs in soil in certain grids. The estimated cancer risk is for children and adults with high soil intake. The estimated cancer risk for children and adults with typical soil intake is about half the risk shown this table

Grid Number	*Estimated Number of Cancers if 100,000 Children or 100,000 Adults Are Exposed to Carcinogenic PAHs in Soil**		*# samples*
	Children	*Adults*	
93	30	25	2
15	10	9	5
28	3	2	4
26	3	2	5
14	3	2	6
33	3	2	2

*Estimated cancer risks are rounded to whole numbers.

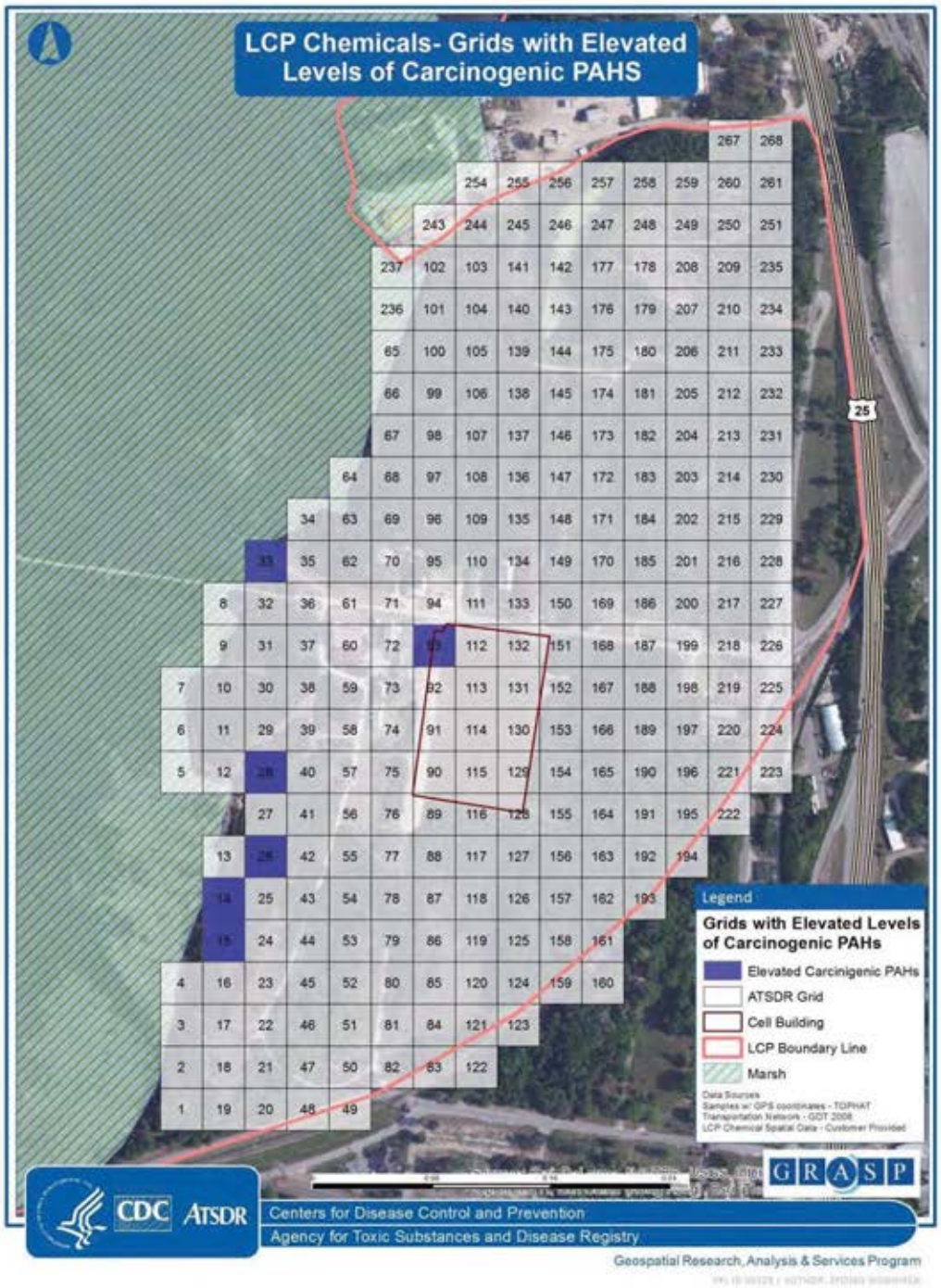


Figure 41. This figure shows the six grids in dark blue where residents might be at elevated risk of cancer from PAHs in soil if the site becomes residential in the future.

V.F.4.c. Possible Health Effects in Workers

Excavation workers who have contact with soil containing cPAHs have negligible risk of harmful effects because their exposure is very low and because their exposures last only a few months. Commercial or industrial workers who have contact with cPAHs in soil have a moderate increased risk of cancer if they have contact with soil in grids 15 and 93. Their estimated cancer risk is 2 (grid 15) or 6 (grid 93) extra cases of cancer for 100,000 workers exposed.

V.F.4.d. Uncertainty in Cancer Risk Estimates

It is important to remember the assumptions that went into estimating these cancer risks. The assumptions are as follows:

- ≠ The PAH-contaminated areas of the site will become residential or commercial/industrial,
- ≠ PAH contamination that is below the surface will be moved to the surface during construction thus allowing human contact,
- ≠ The average cPAH and dibenz(a,h)anthracene concentrations calculated using the current contaminant levels represent the level of future exposure,
- ≠ For the residential scenario, children will live on the property for 18 years or adults will live on the property for 52 years,
- ≠ For the commercial/industrial scenario, adults will have contact with the soil for 20 years, and
- ≠ Children and adults will have high soil intake from hand-to-mouth activity.

In addition, uncertainty exists for grids 33 and 93 because only 2 soil samples were collected. Also, uncertainty exists from using soil samples that were collected 15 years ago. These soil samples may not represent current or future conditions at the site. Nevertheless, the soil samples show that some residual cPAH contamination may still exist at the LCP dry-land area.

V.G. Mixture Effects from PCB, Methylmercury, and Lead

Several studies have shown that PCB, methylmercury, and lead have a mixture effect. Children exposed to low levels of PCBs, methylmercury, and lead showed impaired learning of a performance task. Specifically, children prenatally exposed to PCBs (as well as methylmercury and lead) responded excessively, with significantly lower inter-response times and fewer re-enforcers earned across the test session. In other words, low-level PCB, methylmercury, and lead exposure results in an inability to withhold or delay inappropriate responses, which are measures of attention and impulse control. Mean cord serum PCB level was 0.96 ppb. Maternal hair mercury levels averaged 0.56 ppm, while postnatal blood lead levels averaged 4.6 µg/dL in children aged 2 to 4 years, which are similar to levels found in the US population (Stewart 2006). The impairments of each chemical were statistically independent of the other chemical. While these tests do not prove the chemicals acted synergistically (i.e., greater than just additive), the author

concluded that it is reasonable to assume that the chemicals act in an additive manner (Stewart 2006).

Three grids (53, 60, and 93) have elevated levels of PCBs, lead, and mercury. Eight grids have elevated levels of PCB and lead (8, 58, 59, 73, 76, 89 and 111); and, five grids have elevated levels of PCBs and mercury (55, 112, 114, 118, and 128). Should these grids be developed for residential purposes, children could be at risk for problems with attention and impulse control. See Figure 42 for the location of these grids. Table 39 shows the concentrations of each chemical.

Table 39. Grids with either two or three chemicals above levels of concern

Grid # Residential	***Combination***	***PCB***	***Lead***	***Mercury***
		Average Concentration in ppm		
93	PCBs, Lead, Mercury	139	590	296
53	PCBs, Lead, Mercury	42	169	24
60	PCBs, Lead, Mercury	34	422	85
8	PCBs, lead	1.6	245	0.5
37	PCBs, Lead	12	245	6
58	PCBS, Lead	122	390	18
59	PCBs, Lead	3	513	7
73	PCBs, Lead	3	214	16
76	PCBs, Lead	7	175	13
89	PCBs, Lead	21	170	13
111	PCBs, Lead	16	354	10
90	PCBs, Mercury	41	146	184
55	PCBs, Mercury	9	9	23
112	PCBs, Mercury	1.4	119	271
114	PCBs, Mercury	53	15	41
118	PCBs, Mercury	3	4	30
128	PCBs, Mercury	11	--	81

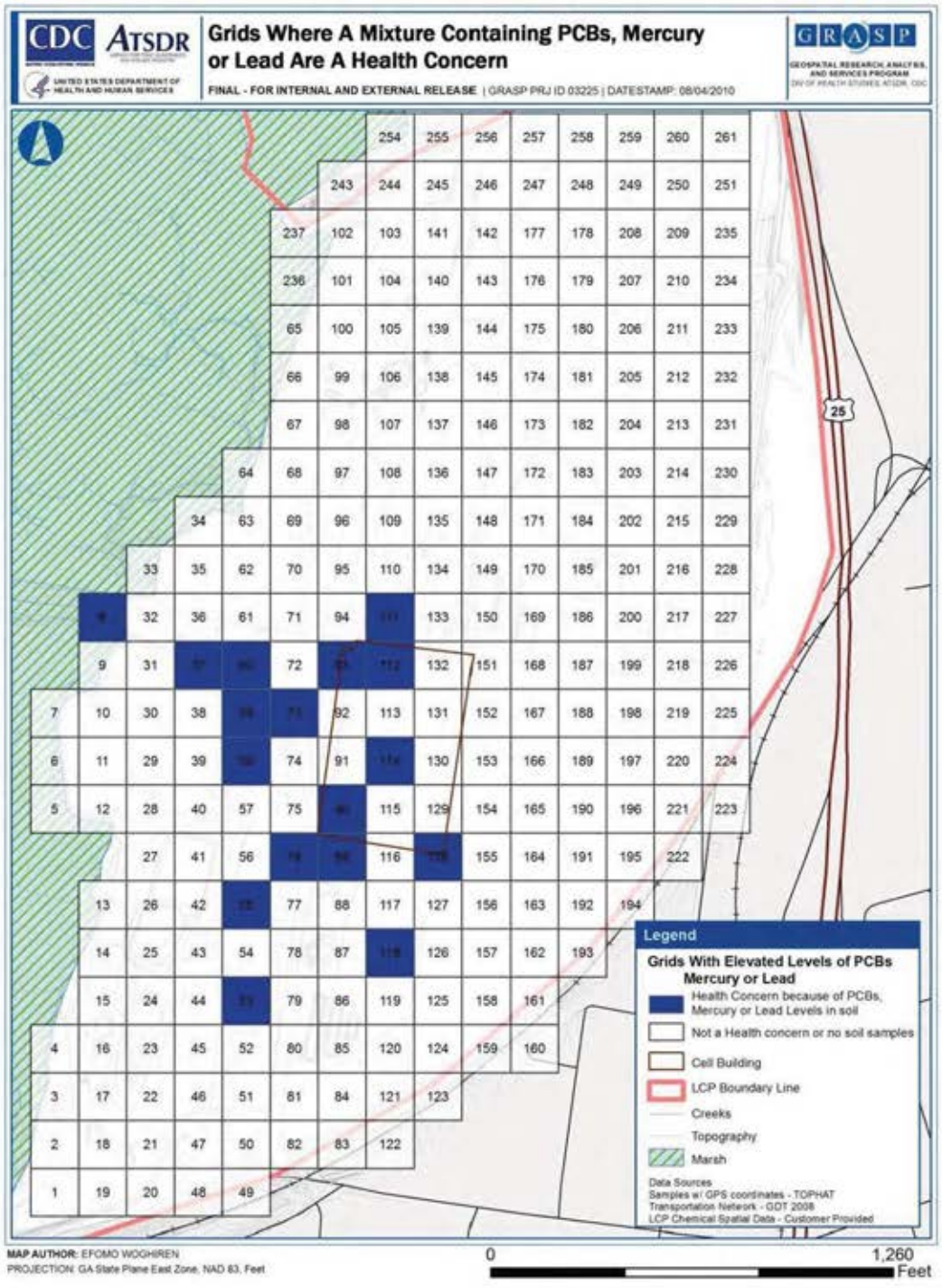


Figure 42 shows those grids that are a health concern because of a possible mixture effect from a combination of PCBs, mercury, or lead in soil. The combination of chemicals in these grids could act together to cause harmful effects.

V.H. Public Health Implications of New LCP Data Collected in 2010-2011

This section describes the public health implications of environmental samples collected from the LCP Chemicals Site in 2010 and 2011. This evaluation was not part of the evaluation presented in the fall 2010 public release document. This new evaluation focuses on several areas:

- ≠ Dioxin in soil from the dry-land area,
- ≠ PCBs and PAHs in soil from the former drive-in theater,
- ≠ PCBs, mercury, and PAHs in sediment and surface water from the on-site pond, and
- ≠ PCBs, mercury, and PAHs in sediment and PCBs and mercury in fish from the Altamaha Canal, south of the LCP Chemicals Site.

V.H.1. The Dry-land Area

As stated previously, composite soil samples for dioxins reported as TCDD-equivalent concentrations exceeded ATSDR's comparison level for soil (35 ppt) in two sampling areas (SA). The maximum TCDD-equivalent concentration from SA 8 is 120 ppt and from SA 2 is 46 ppt (See Figure 13). This section will evaluate whether a health concern exists should a home or business be built on SA 8 or SA 2.

V.H.1.a. Health Guidelines for Dioxins

The EPA has an RfD for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). As a reminder, an RfD is an estimate of a daily oral exposure in the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. Because TCDD is so toxic, very small doses can cause harmful effects. The RfD for TCDD is 7×10^{-10} mg/kg/day (or 0.0000000007 mg/kg/day or 0.0007 ng/kg/day). A nanogram (ng) is one millionth of a milligram (mg).

Two human epidemiologic studies were chosen as the basis for deriving the RfD (Baccarelli *et al*., 2008; Mocarelli *et al*., 2008). Both of these studies evaluated a human population exposed to TCDD from a 1976 industrial accident in Seveso, Italy. Baccarelli *et al*. reported increased levels of thyroid stimulating hormone (TSH) in newborns exposed to TCDD *in utero.* An increase in TSH in humans indicates a possible dysregulation of thyroid hormone metabolism. The study authors related TCDD concentrations in maternal plasma to newborn TSH levels using a linear regression model. Based on this regression modeling, EPA defined the LOAEL to be a neonatal TSH level of 5 microunits/milliliter (µU/mL). Using the Emond human PBPK model, the corresponding daily oral intake at the LOAEL is calculated to be 0.020 nanogram (ng)/kg day. Adequate levels of thyroid hormone are essential in the newborn and young infant because this is a period of active brain development. Thyroid hormone disruption during pregnancy and in newborns can lead to neurological deficiencies in newborns, particularly in attention and memory (EPA 2012).

In another study, Mocarelli *et al*. (2008) reported decreased sperm concentrations and decreased motile sperm counts in men who were exposed as boys (1–9 years of age) at the time of the Seveso accident in 1976. The lowest exposure group in the Mocarelli *et al*. study (68 ppt serum TCDD) is designated as a LOAEL. Using the Emond PBPK model, EPA calculated the LOAEL over the 10 year period to be 0.02 ng/kg/day (EPA 2012). Mocarelli *et al*. (2000) also reported a lower male to female sex ratio in offspring of men exposed to TCDD less than 20 ng/kg, which supports the findings of reproductive effects involving sperm (EPA 2012, ATSDR 2012). EPA divided the LOAEL of 0.02 ng/kg/day from the Baccarelli and Mocarelli studies by an uncertainty factor of 30 to arrive at the RfD of 0.0007 ng/kg/day (or 7 x 10^{-10} mg/kg/day).

In summary, exposure to TCDD *in utero* can cause neurological problems in newborns, such as problems with memory and attention. In addition, exposure to TCDD *in utero* or as young boys can cause health effects later in life, such as:

- ≠ Decreased number of sperm,
- ≠ Decreased counts of motile sperm, and
- ≠ Fewer male offspring as adults.

More information about the effects of TCDD and other dioxins can be found at EPA's IRIS website (http://www.epa.gov/iris/subst/1024.htm) and at ATSDR's Addendum for chlorinated dibenzo dioxins (http://www.atsdr.cdc.gov/toxprofiles/cdds_addendum.pdf).

V.H.1.b Estimating Human Doses of Dioxins and Dioxin Hazard Quotients

As mentioned previously, TCDD-equivalent doses were estimated using a range of soil ingestion rates for various age groups. Hereafter, TCDD equivalents will be referred to as dioxins. Preschool children were assumed to swallow 200 milligrams of soil daily, while elementary-age children, teenagers, and adults were assumed to swallow 100 milligrams of soil daily. Average body weights were selected for each age group. These and other parameters used to estimate dioxin doses in people are shown in Appendix B, Table B1.

Figure 43 shows the location of SA 8, which covers portions of grids 127 to 130 and 152 to 156. EPA's composite soil sample contained dioxins at 120 ppt. The estimated dose (in ng/kg/day) of dioxins for each age group is shown in Table 40 for exposure to 120 ppt dioxins in residential soil. As shown by the HQs of 2.1 and 3.4, the estimated doses in preschool children (0.0015 and 0.0024 ng/kg/day) are two to three times higher than the RfD of 0.0007 ng/kg/day. The doses for preschool children require further evaluation to determine the risk of harmful effects from exposure to dioxins in soil should SA 8 within the site become residential. As shown by HQs ranging from 0.2 to 0.5, the doses in older children and adults are below the RfD. Older children and adults are not at risk of harmful, non-cancerous effects.

Table 40. Estimated doses and hazard quotients (HQ) in children and adults exposed to 120 ppt dioxin in residential soil. The estimated doses in preschool children exceed the RfD (HQ = 2.1 and 3.4), while the estimated doses in older children and adults are below the RfD		
	Dose	**HQ**
Age Groups	**ng/kg/day**	
Preschool children (1 yr old)	0.0024	3.4
Preschool children (3 yr old)	0.0015	2.1
Elementary school children	0.00034	0.5
Teenagers	0.00022	0.3
Adult men	0.00017	0.2
Adult women	0.0002	0.3
RfD	0.0007	

The estimated doses for preschool children (0.0015 and 0.0024 ng/kg/day) exceed the RfD (0.0007 ng/kg/day) by two to three fold. The doses for preschool children range from 8 to 13 times below the levels that are thought to cause harmful effects in humans. Because their doses approach those that might cause harmful effects, preschool male children who have contact with soil containing 120 ppt dioxins could be at risk of the following harmful effects after puberty:

- ≠ Decreased number of sperm,
- ≠ Decreased counts of motile sperm, and
- ≠ Fewer male offspring as adults.

The estimated dose for pregnant women is below the RfD; therefore, they and their developing fetus are not at risk of harmful effects.

Another area on site (SA 2) also contained dioxin but at lower levels (i.e., 46 ppt). Should this area become residential, children and adult would not be at risk of harmful effects because their estimated exposures are at or below the RfD.

V.H.1.c. Estimated Cancer Risk from Dioxins If the LCP Chemicals Site Becomes Residential

Several agencies have evaluated the cancer-causing ability of dioxins. The Department of Health and Human Services (DHHS) has determined that it is reasonable to expect that TCDD may cause cancer in humans. The International Agency for Research on Cancer (IARC) also has determined that TCDD can cause cancer in people. Previously, the EPA had determined that TCDD and a mixture of TCDD is a probable human carcinogen; however, EPA is currently reviewing their opinion about the carcinogenic effects of dioxins (ATSDR 1998, EPA 2012).

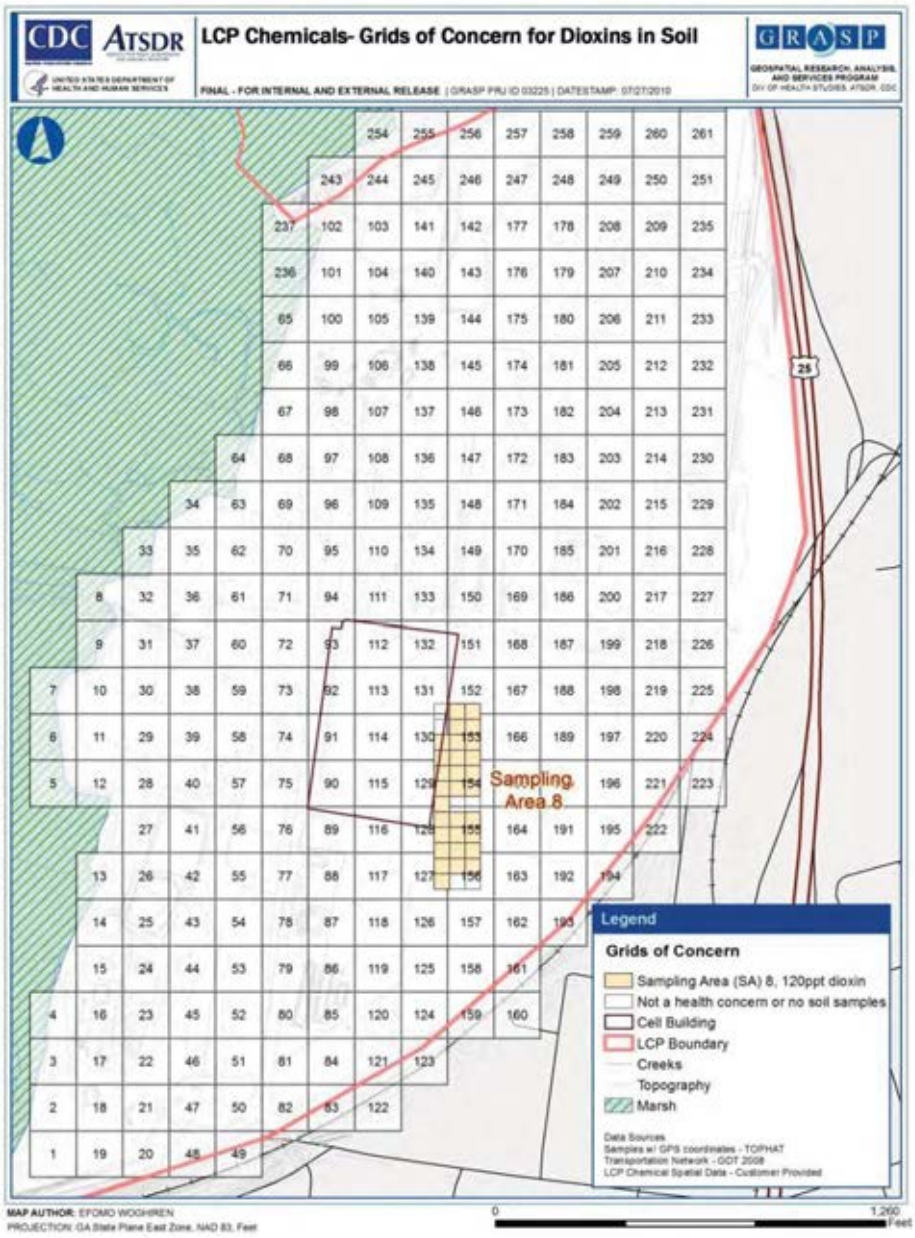


Figure 43. This figure shows the location of sampling area 8 (SA 8), which has dioxins in soil at 120 ppt.

Human studies have shown that TCDD can cause liver cancer and might be associated with lung, colon, prostrate, breast, lymphatic, and hematopoietic cancers (ATSDR 2012). Rodent studies have confirmed that TCDD can cause cancer at multiple sites, including the liver, lung, mouth, and thyroid (ATSDR 1998, 2012).

As mentioned previously, a cancer slope factor (CSF) method can be used to estimate cancer risk using the following formula:

Cancer risk = estimated lifetime dose x cancer slope factor

The California Environmental Protection Agency (CalEPA) has developed a CSF for dioxins, specifically 1.3E5 $(mg/kg/day)^{-1}$. Using CalEPA's CSF, the cancer risk for children exposed to 120 ppt in soil for 18 years is 2 extra cases of cancer for every 10,000 children exposed. The cancer risk for adults exposed to 120 ppt in soil for 50 years is 2 extra cases of cancer for every 10,000 adults exposed. Therefore, a high risk of cancer could exist for children and adults should SA 8 be developed for residential use (see Figure 43).

The EPA is re-evaluating the cancer risk for dioxins and has a draft CSF under review. The estimated cancer risks at LCP could be higher or lower depending on the final CSF that EPA chooses.

In conclusion, should SA 8 be developed as a residential neighborhood, a high risk of cancer exists for children and adults, and preschool children could be at risk of reproductive effects once they reach adulthood.

V.H.1.d. PCBs and cPAHs in Soils from the Former Drive-in Theater

From 1994 to 2010, EPA collected surface and subsurface soil samples from the former drive-in theater area. The results of these sampling events were previously presented in Table 10. PCBs and cPAHs exceeded ATSDR's screening values for residential soils; therefore, those two chemicals will be evaluated further in this section.

It should be noted that Glynn County purchased approximately 32 acres from the northeastern portion of the site, which includes the theater area and an on-site pond. The county plans to build a detention center on this property. Therefore, this portion of the site will not be residential and will be evaluated only for future adult exposures for workers and prisoners at the prison. Appendix B, Table B1 shows the parameters used to estimate adult doses from soil ingestion. Prison inmates were assumed to ingest soil daily and guards were assumed to ingest soil 5 days a week. Insufficient data exist to estimate a reliable average for the theater area; therefore, ATSDR used the maximum concentration of PCBs and cPAHs (see Table 41).

The estimated PCB doses in prison inmates and guards are far below ATSDR's chronic, oral MRL for PCBs. Therefore, non-cancerous harmful effects are unlikely. The risk of cancer in prison inmates and guards is well below one in a million. The estimated dose of cPAHs in prison inmates and guards results in a cancer risk of three in a million.

Table 41. Maximum soil concentrations of PCBs and cPAHs in the theater area.	
Contaminant	***Soil Concentration in ppm***
PCBs	0.57
cPAHs	1.3

V.H.1.e. The On-Site Pond

As previously mentioned, the levels of PCBs, mercury, cPAHs, and lead in surface water and sediment from the on-site pond are not a health concern.

V.H.2. Altamaha Canal

V.H.2.a. Sediment

The Altamaha Canal once traversed the LCP Chemicals Site and a portion of the canal, which is influenced by the tides, still exists south of the LCP Chemicals Site. Sediment samples (upper 6 inches) were collected from twenty locations along the canal from its northern limit at West 9th Street to its southern outflow at T Street. The canal flows into the adjoining marsh where the outflow drains to Academy Creek and eventually to the East River and to the lower portion of the Turtle River. Each sample is comprised of a five-point composite taken along an approximate 1000-ft stretch of the canal. The sampling locations and individual results are shown in Figures 29 through 33. The average concentration of PCBs, cPAHs, and dioxin are presented in Table 42.

When adults or children visit or play along the banks of the Altamaha Canal, they could ingest small amounts of sediments from hand to mouth activity. ATSDR assumed that adults visit the canal once a week to fish and that elementary-age children and teenagers play along the canal three times a week. Because of their age, preschool children are unlikely to play along the canal. It should be noted that even if adults and children visit or play along the canal every day, the same conclusions are reached.

ATSDR evaluated the risk of harmful effects from exposure to PCBs, cPAHs, and dioxins and reached the following conclusions.

- ≠ The estimated dose of PCBs for adults and children who visit or play along the canal is well below ATSDR's chronic, oral MRL for PCBs. Therefore, harmful non-cancerous effects are not likely. The estimated cancer risk is less than one in 10 million.

- ≠ The estimated dose of cPAHs for adults and children who visit or play along the canal results in a cancer risk well below one in a million.

≠ The estimated dose of dioxins for adults and children who visit or play along the canal is well below EPA's RfD for dioxin. Therefore, harmful, non-cancerous effects are not likely. The estimated cancer risk for children and adults is 1 in a million.

In summary, the estimated exposure to PCBs, cPAHs, and dioxins in sediment is below health guidelines and the risk of cancer is insignificant.

Table 42. Average concentration of PCBs, cPAHs, and dioxin in sediment collected from the Altamaha Canal south of the LCP Chemicals Site

Contaminant	***Average Concentration in ppm***
PCBs	0.17
cPAHs	0.24
Dioxin	0.00007*

*0.00007 = 70 ppt

V.H.2.b. Fish and Shellfish from the Altamaha Canal

V.H.2.b.1. GDNR Fish and Shellfish Advisory

The Georgia Department of Natural Resources (GDNR) has issued a fish advisory for the Buffalo, Turtle, South Brunswick, and Brunswick Rivers as well as their tributary creeks, such as Purvis and Gibson Creeks, the closest creeks to the LCP Chemicals Site. Figure 44 shows these rivers and creeks in relation to the LCP Chemicals Site, which borders the Turtle River. In Tables 43, 44, 45, and 46, GDNR describes the fish advisory for several sections of the Turtle River system, which includes:

≠ Purvis and Gibson Creeks,
≠ Buffalo River and upper Turtle River upstream of Georgia Highway 303,
≠ Middle Turtle River between Georgia Highway 303 and channel marker 9, and
≠ South Brunswick River and lower Turtle River from channel marker 9 downstream to channel marker 27 at DuBignon's and Parsons Creek (channel marker 27) (GDNR 2012).

Depending upon mercury and PCB levels in the edible portion of various fish and shellfish from the areas listed in the previous bullets, GDNR recommends one of four consumption guidelines:

- ≠ No restrictions,
- ≠ One meal per week,
- ≠ One meal per month, and
- ≠ Do not eat.

This approach allows the greatest flexibility in informing residents about fish consumption. For example, GDNR recommends that residents not eat Atlantic croaker taken from Purvis or Gibson Creeks because the edible portion is highly contaminated with PCB 1268–the PCB most commonly found at the LCP Chemicals Site (see Table 43). GDNR recommends that residents limit consumption of red drum and flounder taken from these creeks to one meal per week because of PCB and mercury levels in the edible portion of those fish. Similar recommendations exist for the upper, middle, and lower Turtle River and adjoining rivers and creeks.

Table 43. GDNR's fish consumption recommendations for Purvis and Gibson Creeks (see Figure 44).

Turtle River System: ***Satilla River Basin***
Purvis and Gibson Creeks , (St. Simons Estuary)

Species	Site Tested	Recommendation	Chemical
Atlantic Croaker	Purvis & Gibson Creeks	Do Not Eat	PCBs
Southern Kingfish (whiting), Black Drum, Spot, Spotted Seatrout		1 meal/month	PCBs
Sheepshead		1 meal/month	PCBs, Mercury
Striped Mullet		1 meal/week	PCBs
Red Drum, Flounder		1 meal/week	PCBs, Mercury
Blue Crab		1 meal/week	Mercury
Shrimp		No Restrictions	
Clams, Mussels, Oysters	Not applicable	Do Not Eat	Shellfish Ban *
* Shellfish Ban: National Shellfish Sanitation Program. For information see Coastal Resources Division website: http://crd.dnr.state.ga.us			

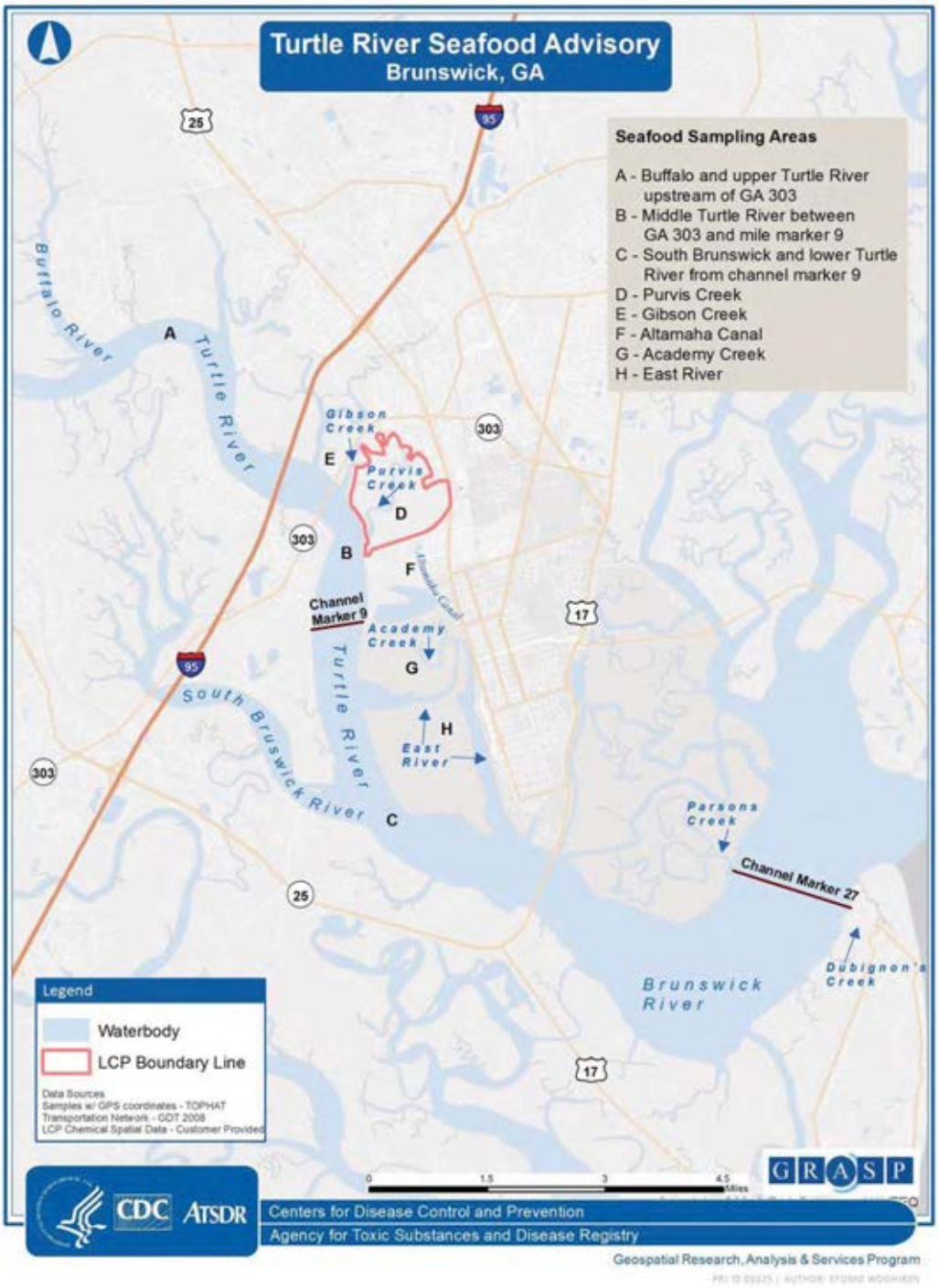


Figure 44. This figure shows the Turtle River system and highlights portions of the river system (see A, B, C, D and E) that are pertinent to GA DNR's fish advisory. The Altamaha Canal (see F) is located just south of the LCP Chemicals Site and connects to Academy Creek, the East River, and lower portion of the Turtle River (See G, H, and C).

Table 44. GDNR's fish consumption recommendations for the Buffalo and Turtle Rivers upriver of Georgia Highway 303 (see Figure 44).

Upper Turtle & Buffalo Rivers (St. Simons Estuary) *Satilla River Basin*

Species	Site Tested	Recommendation	Chemical
Spotted Seatrout, Spot, Southern Kingfish (whiting), Atlantic Croaker	Turtle and Buffalo Rivers, Upriver of Georgia Hwy 303	1 meal/month	PCBs
Red Drum, Black Drum, Striped Mullet		1 meal/week	PCBs
Sheepshead		1 meal/week	PCBs, Mercury
Blue Crab		1 meal/week	Mercury
Shrimp, Flounder		No Restrictions	
Clams, Mussels, Oysters	Not applicable	Do Not Eat	Shellfish Ban *
* Shellfish Ban: National Shellfish Sanitation Program			

Table 45. GDNR's fish consumption recommendations for the middle Turtle River between Georgia Highway 303 and channel marker 9 (see Figure 44)

Middle Turtle River (St. Simons Estuary) *Satilla River Basin*

Species	Site Tested	Recommendation	Chemical
Spot	State Hwy 303 to Channel Marker 9	Do Not Eat	PCBs
Spotted Seatrout, Sheepshead, Striped Mullet, Southern Kingfish (whiting)		1 meal/month	PCBs
Black Drum		1 meal/week	PCBs
Red Drum, Flounder		1 meal/week	PCBs, Mercury
Blue Crab		1 meal/week	Mercury
Shrimp		No Restrictions	
Clams, Mussels, Oysters	Not applicable	Do Not Eat	Shellfish Ban *
* Shellfish Ban: National Shellfish Sanitation Program			

Table 46. GDNR's fish consumption recommendations for the South Brunswick and lower Turtle Rivers from channel marker 9 downstream to Dubignon's and Parsons Creeks (See Figure 44).

Lower Turtle & South Brunswick Rivers (St. Simons Estuary) ***Satilla River Basin***

Species	Site Tested	Recommendation	Chemical
Atlantic Croaker, Spot	Turtle River (From Channel Marker 9) and South Brunswick River (Downstream to Dubignon and Parsons Creeks)	1 meal/month	PCBs
Spotted Seatrout, Black Drum, Southern Kingfish (whiting)		1 meal/week	PCBs
Red Drum, Sheepshead, Striped Mullet, Blue Crab, Shrimp, Flounder		No Restrictions	
Clams, Mussels, Oysters	Not applicable	Do Not Eat	Shellfish Ban *
* Shellfish Ban: National Shellfish Sanitation Program			

The 2013 GDNR fish advisories for rivers, lakes, and estuaries in Georgia, including the Turtle River system, can be found at this website: http://www.gaepd.org/Documents/fish_guide.html. To view their brochure, click on "Guidelines for Eating Fish from Georgia's Waters, 2012".

GDNR also has brochures that provide information and recommendations specifically on women who eat fish and shellfish. These brochures cover specific geographic regions within Georgia, and the one for Brunswick, Georgia, states:

> Extensive studies have been performed on the Turtle River System, and Terry and Dupree Creeks. Assessment of contaminants in the species sampled suggests striped mullet and bivalves (oysters, clams, etc.) from this area should not be eaten. Consumption of all other finfish and blue crabs should be limited to once a month for women of childbearing age. However, in most areas there is no restriction on the amount of shrimp that can be eaten from these waters (GDNR 2012).

The brochure "A Woman's Guide to Eating Fish and Seafood in Coastal Georgia" can be downloaded from http://www.gaepd.org/Files_PDF/gaenviron/fish_advisory/wfcg_coastal.pdf.

V.H.2.b.2. Mercury in Fish and Shellfish from the Altamaha Canal

As mentioned previously, EPA collected fish and shellfish samples in 2011 from the tidally influenced Altamaha Canal that flows south of the LCP Chemicals Site. Table 47 shows the average mercury levels in fish and shellfish collected from the canal in 2011. These levels can be compared to fish and shellfish collected from the Turtle River System in 2002. This comparison shows that mercury levels in red drum, mullet, blue crab, and shrimp from the Altamaha Canal are similar to or below the levels found in the same fish and shellfish groups from the Turtle River. Mercury levels are closest to levels in fish and shellfish from the lower Turtle River south of the site. This similarity is probably due to the fact that the Altamaha Canal is connected to the lower Turtle River via Academy Creek and the East River (see Figure 44). Thus, influence by tidal cycles, fish and shellfish move from the lower Turtle River via the East River and Academy Creek to the Altamaha Canal. Comparison data for sea trout from the Turtle River were not available. However, the concentration of mercury in the one sea trout from the Altamaha Canal (0.117 ppm) is lower than average levels reported by the U.S. Food and Drug Administration in a national survey (0.235 ppm) (http://www.fda.gov/food/foodsafety/product-specificinformation/seafood/foodbornepathogenscontaminants/methylmercury/ucm115644.htm).

It should be noted that the red drum and sea trout samples consisted of one fish of each species; therefore, the actual levels in other fish of these species that might be caught in the Altamaha Canal is highly uncertain.

Table 47. Average mercury levels in edible fish and shell fish tissue are provided for Altamaha Canal as well as for various sections of the Turtle River system north of, adjacent to, and south of the LCP Chemicals Site. Data are not available for sea trout from the Turtle River System for 2011 so average mercury levels are reported from an FDA survey.

Date and Location	***Mercury concentrations in mg/kg-wet weight (ppm-ww)***				
	Red Drum	***Mullet***	***Sea Trout***	***Blue Crab***	***Shrimp***
2011 Altamaha Canal	0.09	0.013	0.117	0.081	0.02
2002 Upper Turtle and Buffalo Rivers (north of LCP)	0.27	0.02	NA	0.51	0.05
2002 Middle Turtle River, including Purvis and Gibson Creeks (adjacent to LCP)	0.32	0.02	NA	0.68	0.09
2002 Lower Turtle River south of the site, including South Brunswick and Brunswick River (south of LCP)	0.15	0.01	NA	0.31	0.04
FDA national survey			0.235		

NA = not available

V.H.2.b.3. Mercury Dose Estimates in Fishers

Information about fish intake rates is provided in Table 48. The basis for these rates comes from Burger *et al*., who reported fish consumption rates for adult fishers along the Savannah River between Georgia and South Carolina (Burger *et al*. 2001; Burger *et al*. 1999).[5] Burger also estimated the rates for women at 68% of male intake rates (Burger 2000). The rates for children were estimated using the ratio of adult to children portion sizes reported by EPA (EPA 2011).

[5] The Savannah River is about 80 miles from Brunswick, Georgia.

Table 48. Daily fish consumption rates (95th percentile and median) reported by Burger et al. (2001) for fishers along the Savannah River between Georgia and South Carolina.

Population	***95th %***		***Median***
	oz./day		***oz./day***
Black male	6.6		1.8
White male	4.8		0.7
Black female	4.5		1.2
White female	3.2		0.5
Children 3 to 5 years	1.8		0.5
Children 6 to 10 years	2.5		0.7
Children 11 to 15 years	3.6		1
Children 16 to 17 years	4.1		1.1

The daily fish consumption rates shown in Table 48 do not mean that people eat fish every day. The rates were derived by taking the survey results and reporting them as a daily intake and using those rates to derive daily rates for women and children as previously explained. For example, for children 3 to 5 years old who are typical (median) fish consumers (0.5 oz./day), they could have fish consumption patterns that might look like this:

- ≠ One 3.5 oz. fish meal a week,
- ≠ Two 1.8 oz. fish meals a week, or
- ≠ Three 1 oz. fish meals a week.

These combinations of weekly fish meals represent a daily rate of 0.5 oz./day. For children 3 to 5 years who are high (95%) fish consumers (1.8 oz./day), their consumption pattern might look like this:

- ≠ Three 4.2 oz. fish meals a week,
- ≠ Four 3.2 oz. fish meals a week, or
- ≠ Five 2.5 oz. fish meals a week.

What follows is a sample dose calculation for children 3 to 5 years old who are high consumers of sea trout from the Altamaha Canal, which contain 0.117 ppm (or mg/kg) mercury.

$$\text{Dose} = \frac{\text{Mercury Concentration in Fish} \times \text{Daily Fish Consumption Rate} \times \text{Conversion Factor}}{\text{Body Weight}}$$

$$\text{Dose} = \frac{\left[[0.117 \text{ mg/kg} \times 1000 \text{ µg/mg}] \times [1.8 \text{ oz/day} \times 28.35 \text{ gm/oz} \div 1000 \text{ gm/kg}]\right]}{17 \text{ kg}^{6}}$$

Dose = 0.35 µg/kg/day

This dose exceeds the RfD of 0.1 µg/kg/day and approaches the effect level of 1 µg/kg/day.

As mentioned previously, children and the fetus are particularly sensitive to the effects of mercury. ATSDR reached the following conclusions about adults and children with typical (i.e., median) and high (i.e., 95th percentile) fish consumption:

≠ Typical and high fish consumers of mullet and shrimp have estimated exposures to mercury that are below EPA's RfD for mercury. The levels of mercury in mullet and shrimp from the Altamaha Canal are not a health concern.

≠ Typical fish consumers of blue crab, red drum, and sea trout have estimated exposures to mercury that are below EPA's RfD for mercury. The levels of mercury in blue crab, red drum, and sea trout are not a health concern for typical fish consumers.

≠ High fish consumers of blue crab, red drum, and sea trout have estimated exposures to mercury that exceed EPA's RfD for mercury. Their mercury exposure approaches the level that causes harmful effects. Young children and children born to pregnant women who are high consumers of blue crab, red drum, and sea trout might experience neurological effects involving language, attention and memory, and to a lesser extent visual/spatial and motor functions. The levels of mercury in blue crab, red drum, and sea trout are a health concern for high fish consumers.

Some uncertainty exists in the conclusions for sea trout and red drum because only one fish of each species was collected from the Altamaha Canal.

These findings support the fish advisory issued by the GDNR for the lower Turtle River, which is based in part on mercury levels in blue crabs, sea trout, and king fish. Residents should follow GDNR's fish advisory for the lower Turtle River by restricting their

[6] µg = micrograms; mg = milligrams; oz = ounces; gm = grams; kg = kilograms

consumption of certain fish species from the Altamaha Canal and from the lower Turtle River. See Table 46 for more information about the state's fish consumption recommendation for the lower Turtle River.

V.H.2.b.4. PCBs in Fish and Shellfish from the Altamaha Canal

Table 49 shows the average PCB levels in fish and shellfish collected in 2011 from the Altamaha Canal. These levels can be compared to fish and shellfish collected in 2002 from the Turtle River system. This comparison shows that PCB levels in red drum, mullet, sea trout, blue crab, and shrimp from the Altamaha Canal are below the levels found in the same fish and shellfish groups from the Turtle River. It should be noted that the red drum and sea trout samples from the Altamaha Canal consisted of one fish of each species; therefore, the actual levels in other fish of these species that might be caught in the Altamaha Canal is highly uncertain.

ATSDR estimated the dose of PCBs from eating various fish and shellfish from the Altamaha Canal and reached the following conclusions about adults and children with typical (i.e., median) and high (i.e., 95th percentile) fish consumption:

≠ Typical and high fish consumers of red drum, blue crab, and shrimp have estimated exposures to PCBs that are at or below ATSDR's chronic oral MRL. PCB levels in red drum, blue crab, and shrimp are not a health concern for harmful, non-cancerous effects.
≠ Typical fish consumers of sea trout have estimated exposure to PCBs that are at ATSDR's chronic oral MRL. High fish consumers of sea trout have estimated exposure to PCBs that exceed the chronic oral MRL and approach levels that put them at risk of harmful, non-cancerous effects.
≠ Typical and high fish consumers of mullet have estimated exposure to PCBs that exceed ATSDR's chronic oral MRL and approach levels that put them at risk of harmful, non-cancerous effects.

High consumers of sea trout and typical and high consumers of mullet might experience the following harmful effects:

≠ Small changes in immune function as evidenced by a weakened response to an antigenic challenge,
≠ Mild damage to fingernails and toenails,
≠ Inflamed oil-producing glands associated with the eyes
≠ Gum recession,
≠ Learning and performance decrements,
≠ Fewer male births,
≠ Problems with attention and impulse control
≠ Lower birth weight,
≠ Longer menstrual cycles in women,
≠ An increase in cardiovascular disease in women (but not men),

- ≠ An increase in deaths from Parkinson disease and dementia in women (but not men), and
- ≠ An increase in diabetes in women (but not men) (ATSDR 2000).

In addition to these harmful effects, monkey studies have shown that 4 year old monkeys experience learning and performance decrements when exposed to 7.5 µg/kg/day PCBs from birth to 20 weeks. These studies showed that young monkeys exposed during early life were impaired in their ability to organize behavior temporally, and monkeys were impaired in their ability to learn from the consequences of previous actions. Stated another way, monkeys showed an inability to change an already established response strategy and were unable to prevent inappropriate responses (ATSDR 2000). According to the author, these impairments are consistent with features demonstrated by children with attention deficient hyperactivity disorder (Rice 2000). Therefore, children and especially preschool children, with their nervous systems still developing, may be a particularly susceptible group. These conclusions are supported by human studies that show small changes in serum PCB concentrations are associated with harmful effects to the neurological systems.

Children and adults who frequently eat mullet from the Altamaha Canal also have an increased risk of liver and thyroid cancers. Should 10,000 children eat mullet frequently for 18 years, 3 extra cases of cancer might be expected. Should 10,000 adults eat mullet frequently during their adult life, 10 extra cases of cancers might be expected.

The GDNR has issued a fish advisory for the lower Turtle River, which tidally influences the Altamaha Canal. The advisory is based in part on PCB levels in mullet, red drum, sea trout, and blue crab. For fish and shellfish taken from the Altamaha Canal, residents should follow GDNR's fish advisory for the lower Turtle River. According to GDRN's advisory, residents should restrict their consumption of mullet to one meal per month and their consumption of red drum, sea trout, and blue crab to one meal per week. See Table 46 for more information about the state's fish consumption recommendation for the lower Turtle River and Tables 43-45 for other parts of the Turtle River system.

Table 49. Average PCB levels in edible fish and shell fish tissue are provided for the Altamaha Canal as well as for various sections of the Turtle River system north of, adjacent to, and south of the LCP Chemicals Site. Data are not available for sea trout from the Turtle River System for 2011 so average mercury levels are reported from an FDA survey.

Date and Location	*PCB concentrations in mg/kg-wet weight (ppm-ww)**				
	Red Drum	*Mullet*	*Sea Trout*	*Blue Crab*	*Shrimp*
2011 Altamaha Canal	0.02	0.25	0.08	0.015	0.015
2002 Upper Turtle and Buffalo Rivers (north of LCP)	0.25	1.4	NA	0.16	0.1
2002 Middle Turtle River, including Purvis and Gibson Creeks (adjacent to LCP)	0.14	2.6	NA	0.02	0.23
2002 Lower Turtle River south of the site, including South Brunswick and Brunswick River (south of LCP)	0.11	0.36	NA	0.1	0.1

*The only PCB detected in fish and shellfish was Aroclor 1268, the most predominant Aroclor at the LCP Chemicals Site.
NA = not available

V.I. Summary of Grids That Are a Health Concern

In summary, numerous grids have elevated levels of mercury, PCBs, lead, PAHs, or dioxins that are a public health concern if the site becomes residential in the future. Figure 45 shows 66 grids that have at least one contaminant that is a health concern if the site becomes residential in the future. Figure 46 shows the nine grids that are a public health concern if the site becomes commercial or industrial in the future. Stated another way, 33 acres are a health concern should the site become residential, and about 5 acres are a health concern should the site become commercial or industrial.

The previous discussions about PCBs, mercury, lead, PAHs, and dioxins provide the justifications for these conclusions. Some uncertainty exists in these conclusions. The reasons for this uncertainty are described previously in the PHA.

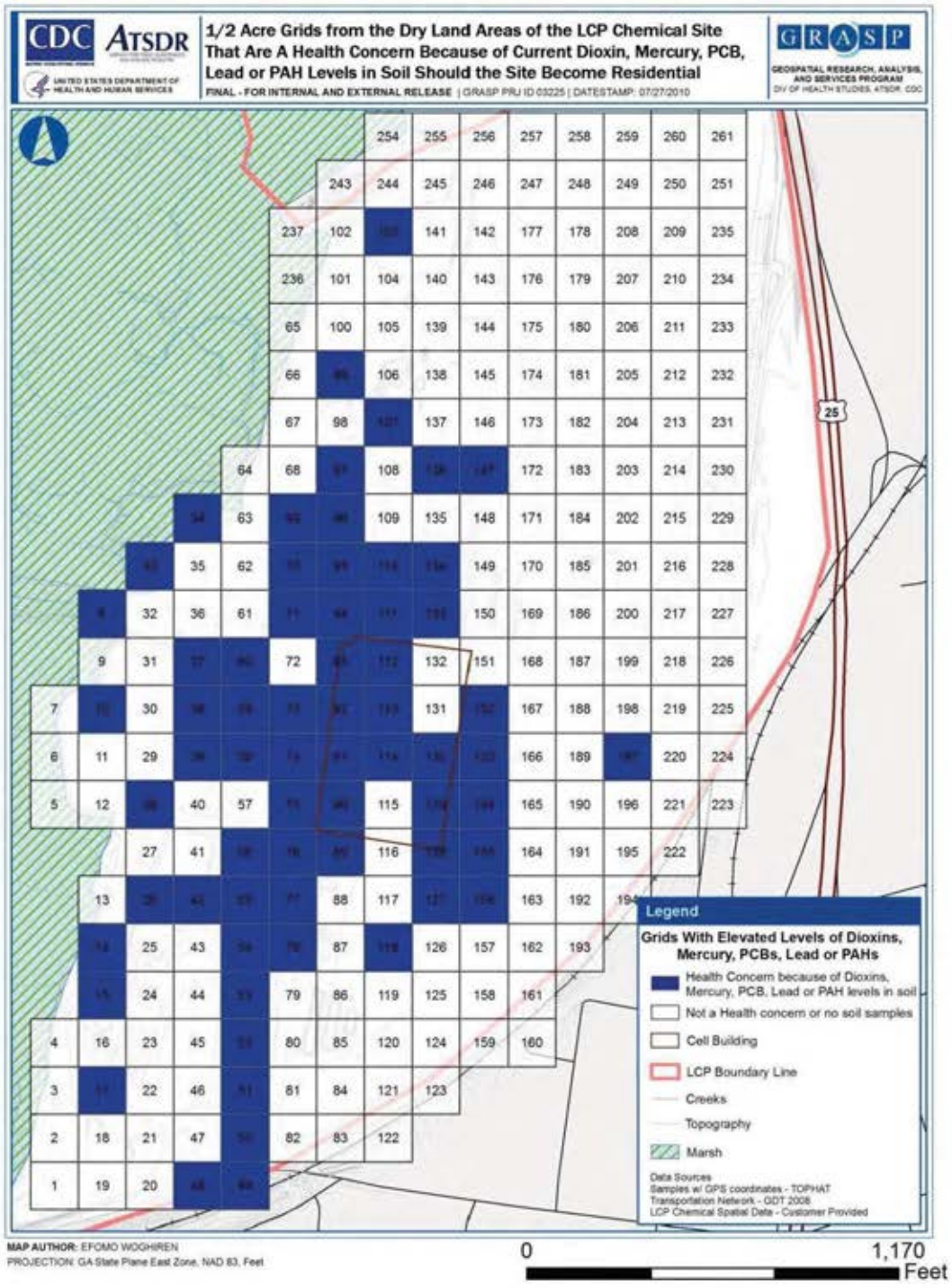


Figure 45. This figure shows the 65 grids that are a health concern if the site becomes residential in the future.

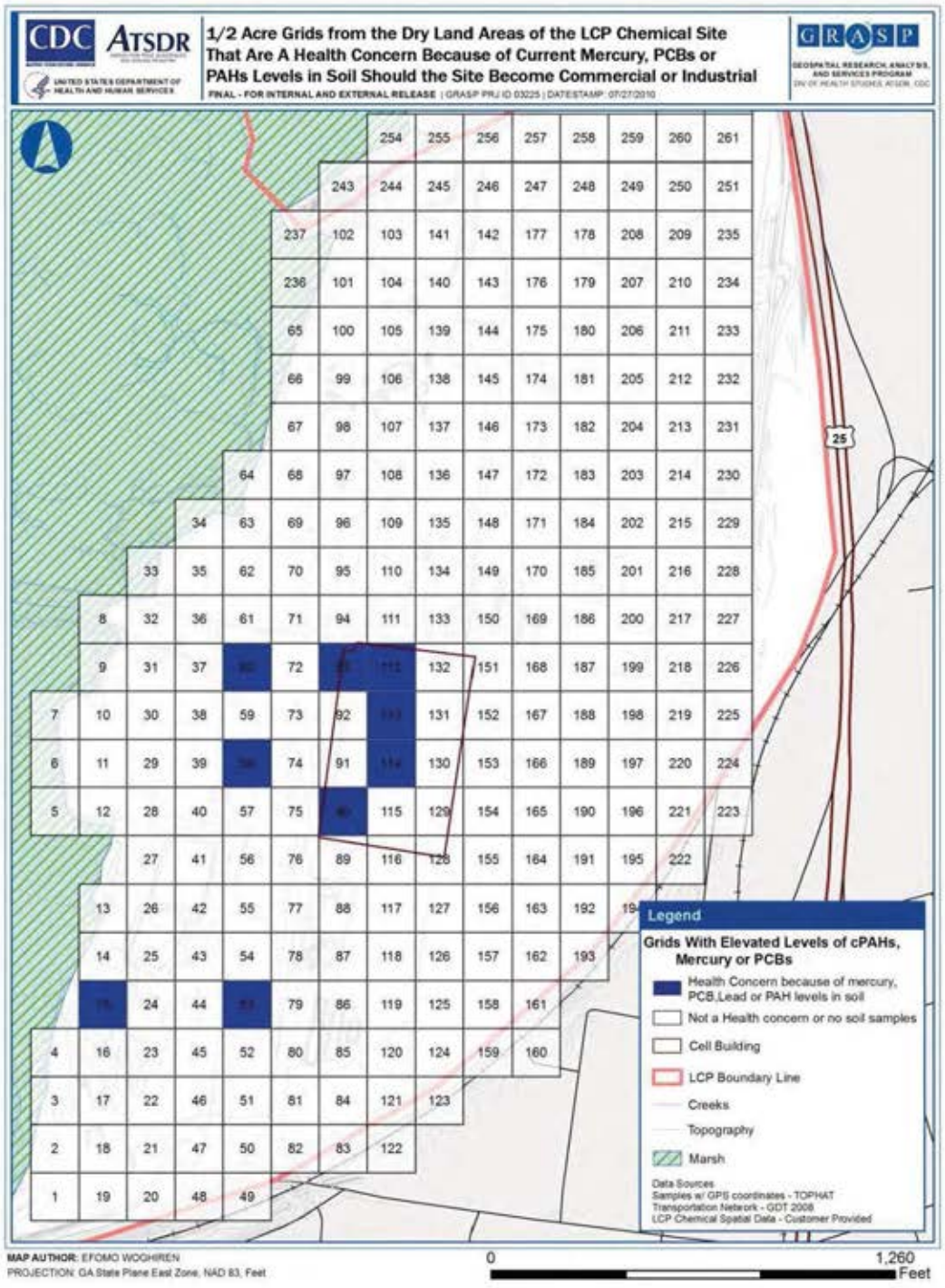


Figure 46. This figure shows nine grids that are a health concern if the site becomes commercial or industrial in the future.

VI. COMMUNITY HEALTH CONCERNS

When performing a public health assessment, ATSDR gathers health concerns from people living in the community. The health concerns that people express help direct the focus of the evaluation. For the LCP Chemicals Site, ATSDR gathered concerns from the community on several occasions dating from October 2004 until present. ATSDR received numerous health concerns from residents who live near the LCP Chemicals site or who worked for LCP Chemicals when it was operating. Below is a list of the health concerns expressed by community members:

1. Community Concern: Residents reported numerous health concerns that they thought might be related to living near the LCP Chemicals Site. Their health concerns fall into these general categories: respiratory, skin, muscular, metabolic, neurological, cardiovascular, and reproductive. A list of their specific health concerns follows:

chronic sinus infections	allergies	hay fever
eczema	arthritis	diabetes
high cholesterol	hives	fatigue
shortness of breath	hypertension	ear infection
poor circulation	sinus infection	hysterectomy
low birth weight	hearing problems	speech problems
glaucoma	low potassium	bones ache
rash	heart trouble	cataracts
stroke	brain tumor	liver disease
breathing problem	nose bleeds	stomach cancer
hardening of the arteries	lung cancer	fibroid tumors
bone deterioration	cancer	fertility problems
poor vision	birth defect	nausea
migraines	bronchitis	poor memory
iron deficiency	bruise easily	heart attack
skin conditions	hair loss	dizziness
balance problems	shortness of breath	heart murmur
visual problems	light headedness	agitation
joint pain	congestive heart failure	slow learning
heart racing	blackouts	confusion
forgetfulness	poor eyesight	prostate cancer
sores on arms and legs	ringing sound in ears	difficulty concentrating
breakout of bumps on skin	getting oxygen to the brain	
sensitive to temperature changes	long and short term memory loss	
difficulty with blood flow to the brain	sarcoidosis (immune disease)	

ATSDR Response: Many of the people with the health conditions or symptoms listed previously report that they lived in the Arco neighborhood for many years or they had family members that worked at the LCP Chemicals facility. Unfortunately, it is not possible to know if these health conditions or symptoms

are related to the LCP Chemicals Site. Some residents report smelling chemicals that they believe were coming from the LCP Chemicals facility when it was operating; however, we could not confirm that the smell was coming from the facility because it happened so many years ago and because, to our knowledge, no air monitoring data are available in nearby neighborhoods.

2. Community Concern: Residents are concerned about contaminated water.

ATSDR Response: ATSDR is currently unsure if any private wells are impacted by site-related contaminants. During our site visit in July 2009, we noticed numerous private wells in a neighborhood immediately north of the LCP Chemicals Site on the following roadways: Manning Street, Deloach Street, Fader Lane, Roadway Street, Cedar Avenue, Robarts Road, and Lakeside Circle. We also noticed private wells in a neighborhood immediately south of the LCP Chemicals Site on the following roadways: Sycamore Street and Baines Bluff Road. Groundwater flow at the site is westward toward the marsh; therefore, it is unlikely that private wells north, south, and east of the site could be contaminated.

If you currently receive your household water from a municipal source (e.g., city water), then your water should be safe to drink.

3. Community Concern: Another resident is concerned about historical air contamination when the LCP Chemical Plant was operating.

ATSDR Response: ATSDR believes that it is likely that past operations at the site created conditions where contaminants were dispersed in the air to nearby, off-site locations. A review of past soil sampling conducted in the Arco neighborhood suggests that mercury levels were elevated in some soil samples well above background levels. It seems reasonable to assume that mercury may have been deposited as a result of aerial releases from LCP operations when the facility was actively making chlorine.

However, we have no emissions data from the facility to review and no air samples in the Arco neighborhood during that time period. Therefore, it is not possible for us to state with certainty that aerial releases occurred in the past, or for us to quantify the exposures from these releases if they did occur. Therefore, ATSDR cannot reach a conclusion about whether historical air releases could have exposed nearby residents and caused adverse health effects.

4. Community Concern: Residents are concerned about soil contamination.

ATSDR Response: On-site soil contamination is addressed in this document. Off-site soil contamination, such as in the Arco neighborhood, has been addressed in previous evaluations done by this agency. A summary of those reports can be

found in Section II.G above. Generally, off-site soils do not contain contamination levels high enough to result in adverse health effects.

5. Community Concern: Several residents are concerned about having eaten seafood (shrimp, fish, and crabs) from the Turtle River. Some residents report eating seafood for many decades (e.g., 1960s, 1970s, and 1980s). They report the following signs and symptoms:

> Resident #1: This person has experienced hypertension, diabetes, dizziness, memory loss, balance problems, numbness around the fingers and toes, shortness of breath, heart murmur, sudden headaches, and visual problems.
>
> Resident #2: This person is now experiencing light-headedness, headaches, agitation, diabetes, join pain, and vision problems.
>
> Resident #3: This person is now experiencing memory loss, diabetes, high blood pressure, dizziness, loss of equilibrium, agitation, no feeling in lower extremities, pain around neck and shoulder, congestive heart failure, numbness in fingers, poor vision, heart racing, blackouts, confusion, and forgetfulness.
>
> Resident #4: This person is experiencing diabetes, hypertension, lightheaded, dizziness, loss of equilibrium, stroke, heart attack, long and short-term memory loss, numbness in right side, and difficulty breathing.

ATSDR Response: It is not possible to know if the health conditions, signs, or symptoms described previously are the result of having eaten fish from the Turtle River or from the creeks closest to the LCP Chemicals site (i.e., Purvis and Gibson Creeks).

Residents who caught and ate fish and blue crab frequently from Purvis and Gibson Creeks and from the Turtle River were at greater risk of harmful effects from mercury and PCBs. Pregnant women and their unborn child as well as young children were at greatest risk of harmful effects. It is difficult to be precise because the amount of mercury and PCB intake from eating fish varies with the portion size, the type of fish eaten, and the location the fish came from. In general, pregnant women who ate several fish meals a month were at risk of having children with neurological effects from mercury. Children born to women and young children who ate fish and blue crab frequently from Purvis and Gibson Creeks and from the Turtle River might experience neurological effects involving problems with language, attention and memory, and to a lesser extent visual/spatial and motor functions.

Residents who ate several fish meals a month for several decades were also at greater risk of liver and thyroid cancers because of PCBs in fish and blue crabs. It is important to remember that someone who ate fish or blue crabs from the Purvis

and Gibson Creeks or the Turtle River only a few times are not likely to experience harmful effects from mercury and PCBs. The risk of harmful effects is for those people who for several decades regularly ate several fish and blue crab meals a month from these areas.

The Georgia Department of Natural Resources has issued a fish advisory for the Buffalo, Turtle, and Brunswick Rivers and their tributary creeks. This fish advisory provides advice about the number of fish meals that are safe to eat from these rivers. An example of the fish advisory for Purvis and Gibson Creeks is shown below. The fish advisory for other areas along these rivers are provided elsewhere in this report and at the GDNR website: http://www.gaepd.org/Documents/fish_guide.html.

Turtle River System: ***Satilla River Basin***
Purvis and Gibson Creeks , (St. Simons Estuary)

Species	Site Tested	Recommendation	Chemical
Atlantic Croaker	Purvis & Gibson Creeks	Do Not Eat	PCBs
Southern Kingfish (whiting), Black Drum, Spot, Spotted Seatrout		1 meal/month	PCBs
Sheepshead		1 meal/month	PCBs, Mercury
Striped Mullet		1 meal/week	PCBs
Red Drum, Flounder		1 meal/week	PCBs, Mercury
Blue Crab		1 meal/week	Mercury
Shrimp		No Restrictions	
Clams, Mussels, Oysters	Not applicable	Do Not Eat	Shellfish Ban *
* Shellfish Ban: National Shellfish Sanitation Program. For information see Coastal Resources Division website: http://crd.dnr.state.ga.us			

6. Community Concern: Residents are concerned that the Altamaha canal remains contaminated.

ATSDR Response: Figure A12 (Appendix A) shows the Altamaha Canal as it exists today. This tidal canal begins just south of W. 9th Street and flows to the marsh at T Street. A portion of the Altamaha canal was also located on the LCP Chemical property when it was operating (Figure A13 in Appendix A). During EPA's cleanup activities, contamination was detected in the on-site portion of the Altamaha canal. These on-site portions of the canal have been excavated and filled. However, it is possible that contamination could have been transported to off-site portions of the canal while the LCP facility was operating and before the on-site portions were filled in. The tidal nature of Altamaha Canal most likely facilitated the off-site migration of contaminants from the LCP property along with surface water runoff during heavy rains.

This off-site transport of site-related contaminants is supported by the recent fish samples that were collected from the Arco Quarry Pond (ATSDR 2008). Fish

samples from the pond showed elevated levels of mercury and Aroclor 1268. The presence of Aroclor 1268 in fish tissue from the Arco Quarry Pond is significant because Aroclor 1268 is the predominant Aroclor associated with LCP Chemical waste. The Arco Quarry Pond is located approximately 700 feet south of the southern boundary of the LCP Chemicals Site. During ATSDR's site visit in July 2009, the wooded area around the pond had been cleared and a fence erected to prevent access to pond and surrounding land. The Altamaha Canal currently ends at the Arco Quarry Pond, although it is unclear at this time if the canal and pond are connected.

ATSDR does not currently have sampling data from the existing portion of the Altamaha Canal to support or rule out the possibility of off-site migration of contamination in the canal. Therefore, we will recommend that sediment and fish sampling be conducted to address this data gap. On the basis of this recommendation, EPA collected fish and shellfish samples from the Altamaha Canal in 2011.

VII. CONCLUSIONS

ATSDR has evaluated environmental data from the LCP Chemicals Superfund Site in Brunswick, Georgia, which is located off of Ross Road. The focus of this public health assessment is the 133 acres of dry-land between Ross Road and the marsh. ATSDR divided the 133 acres into half-acre grids to determine whether a grid would be a concern for future residential or commercial development. Some of these grids were found to contain elevated soil levels of mercury, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), lead, and dioxins.

ATSDR's overall conclusion is that if the LCP Chemicals Site becomes residential, 66 half-acre grids have at least one chemical in soil that poses a health risk for children and adults. If the site becomes commercial or industrial, 9 half-acre grids have at least one chemical in soil that poses a health risk for workers. See Figures 45 and 46 for the location of these grids. Some uncertainty exists in this overall conclusion because uncertainty exists in the amount of chemical exposure that will occur after the site is developed and some dry-land areas were inadequately sampled.

ATSDR has more detailed conclusions about the LCP Chemicals Site that fall into two categories: (1) conclusions presented in the 2010 Public Health Assessment for the LCP Chemicals Site that was released for public comment, and (2) new conclusions based upon recent environmental data that was not available for the 2010 PHA.

VII.A. Conclusions from the 2010 Public Health Assessment for the LCP Chemicals Superfund Site

The basis for conclusions presented in the 2010 public health assessment for the LCP Chemicals Site comes from environmental samples collected by EPA predominantly in the 1990s, although a few samples were collected in the early 2000s.

1. Conclusions about PCBs in dry-land soils

   If certain dry-land areas of the LCP Chemicals Site become residential, polychlorinated biphenyls (PCBs) in soil in 41 half-acre grids on the site pose a health risk for children and adult. If certain dry-land areas of the LCP Chemicals Site become commercial or industrial, PCBs in soil in six half-acre grids on the site pose a health risk for commercial and industrial workers.

   Children and adults who come in contact with high PCBs in soil might experience harmful effects to the immune, dermal, nervous, developmental, and reproductive systems. Specific health effects include:

   - ≠ Small changes in immune function as evidenced by a weakened response to an antigenic challenge,
   - ≠ Mild damage to fingernails and toenails,
   - ≠ Inflamed oil-producing glands associated with the eyes
   - ≠ Gum recession,
   - ≠ Learning and performance problems,
   - ≠ Problems with attention and impulse control,
   - ≠ Fewer male births,
   - ≠ Lower birth weight,
   - ≠ Longer menstrual cycles in women,
   - ≠ An increase in cardiovascular disease in women,
   - ≠ An increase in deaths from Parkinson disease in women,
   - ≠ An increase in deaths from dementia in women, and
   - ≠ An increase in diabetes in women (ATSDR 2000).

   Children and especially preschool children, with their nervous systems still developing, may be a particularly susceptible group if they come in contact with high PCBs levels in soil in some areas.

   Commercial and industrial workers also are at risk of harmful effects if they have contact with soil in six half-acre grids of the site with the highest PCB levels. Their estimated exposure to PCBs could cause the same health effects as listed previously.

   Daily contact with PCBs in soil over many years poses a high cancer risk for children and adults should the site become residential. PCBs in soil pose a moderate cancer risk for workers if the site becomes commercial or industrial. Such exposure could

put residents and workers at increased risk for several cancers, including cancers of the liver, thyroid, biliary tract, intestines and skin.

Some uncertainty exists when deciding if harmful effects might be expected because very little health information is available on the most common type of PCBs found in LCP soils. Therefore, ATSDR relied upon health information from other types of PCBs. Uncertainty also exists in estimating how much PCBs people will contact once the site is developed and from using results from soil samples that were collected 15 years ago. These soil samples may not represent current or future conditions at the site. In addition, some dry-land areas were insufficiently sampled.

Six half-acre grids on the site exceed the EPA's 1994 clean-up level for PCBs of 25 parts per million (ppm) while 41 grids have average PCB concentrations greater than 1 ppm. In the text of this report, see Table 4 for a list of grids that are a concern because of residual PCB contamination and see Figure 34 for their location.

2. Conclusions about mercury in dry-land soils

If certain dry-land areas of the LCP Chemicals Site become residential, mercury in soil in 10 half-acre grids on the site poses a health risk for children and for the developing fetus if women are pregnant.

If certain dry-land areas of the LCP Chemicals Site become commercial or industrial, mercury in soil in four half-acre grids on the site poses a health risk for the developing fetus if a female worker is pregnant. One of these half-acre grids also poses a health risk for women who are not pregnant and for men.

For women who live in the 10 half-acre grids on the site with high mercury concentrations in soil, the estimated intake of mercury from soil approaches or exceeds levels that cause harmful neurological effects to the fetus during pregnancy. Children born to these women might experience neurological effects involving language, attention and memory, and to a lesser extent visual/spatial and motor functions. The estimated exposure levels in preschool children who live in these areas also approach or exceed levels that could harm their health. They are at risk of the same neurological effects.

Mercury in soil in four half-acre grids on the site also poses a risk for commercial and industrial workers if the site is developed. Pregnant workers who have contact with mercury in soil in these areas are at risk of exposing their developing fetus to mercury levels that might cause harmful effects after birth. Some children born to women exposed to these levels might experience neurological effects involving language, attention and memory, and to a lesser extent visual/spatial and motor functions.

Male and female workers who have prolonged contact with soil from the one half-acre grid with the highest remaining mercury contamination also are at risk of harmful effects. Their estimated exposure level might result in damage to their

neurological system, such as diminished sensitivity to pain, diminished touch, decreased fine motor performance, impaired vision, and impaired hearing.

Some uncertainty exists concerning the risk of harmful effects from mercury in soil. The chemical form of mercury in soil at the LCP Chemicals Site has not been well-established, although scientific studies from marsh sediment show that almost half the mercury is organic mercury. Therefore, ATSDR assumed that most of the mercury in soil at the LCP Chemicals Site was organic mercury. There's some uncertainty about whether the organic mercury bound to soil would cause harmful effects. In addition, uncertainty exists in the mercury concentrations in surface soil following development of the site and uncertainty exists from using the results from soil samples that were collected 15 years ago. These soil samples may not represent current or future conditions at the site.

Ten half-acre grids exceed EPA's 1994 clean-up level of 20 ppm mercury in soil. See Table 29 for a list of the 10 grids that are a concern because of residual mercury contamination and see Figure 37 for their location.

3. Conclusions about lead in dry-land soils

If certain dry-land areas of the LCP Chemicals Site become residential, lead in soil in 28 half-acre grids on the site poses a health risk for children.

If the site becomes residential, exposure to lead in soil at these 28 half-acre grids could increase children's blood lead levels and result in the following harmful effects:

≠ small decreases in IQ,
≠ an increase in attention deficit hyperactivity disorder,
≠ reduced attention span,
≠ lack of concentration,
≠ decreased fine muscle skills,
≠ withdrawn behavior,
≠ decreased height,
≠ small delays in puberty, and
≠ small changes in kidney function.

Some uncertainty exists in this conclusion because uncertainty exists in estimating children's exposure to lead in soil if the site becomes residential. Uncertainty also exists from using the results of soil samples that were collected 15 years ago. These soil samples may not represent current or future conditions at the site.

See Table 31 for a list of the 28 half-acre grids that are a concern because of residual lead contamination and see Figure 40 for their location.

4. Conclusions about PAHs in dry-land soils

   If certain dry-land areas of the LCP Chemicals Site become residential, polycyclic aromatic hydrocarbons (PAHs) in soil in six half-acre grids on the site pose a health risk for children and adults. If certain dry-land areas of the LCP Chemicals Site become commercial or industrial, PAHs in soil in two half-acre grids on the site pose a health risk for workers.

   Daily contact with PAHs in residential soil over many years poses a moderate risk of certain cancers for children and adults. Similarly, workers also have a moderate risk of certain cancers should some areas become commercial or industrial. Such exposure could put residents and workers at increased risk for lung and skin cancers.

   Some uncertainty exists in these conclusions because uncertainty exists in estimating how much PAHs people will contact once the site is developed. Uncertainty also exists from using the results from soil samples that were collected 15 years ago. These soil samples may not represent current or future conditions at the site.

   See Table 35 for the list of half-acre grids that are a concern because of residual PAH contamination and see Figure 41 for their location.

5. If certain dry-land areas of the LCP site become residential, exposure to a mixture of PCBs, methylmercury, or lead in soil could harm the health of children.

   If the site becomes residential, exposure to a mixture of PCBs, mercury, or lead in soil could impair learning and lead to an inability to withhold or delay inappropriate responses. These impairments are a measure of attention and impulse control.

   Three grids have elevated levels of PCBs, lead, and mercury. Eight grids have elevated levels of PCB and lead; and, five grids have elevated levels of PCBs and mercury. Should these grids be developed for residential purposes, children could be at risk for problems with attention and impulse control. See Figure 42 for the location of these grids.

6. If certain dry-land areas of the LCP Chemicals Site become residential, contact with soil containing a mixture of PCBs, mercury, and lead (or a combination of these) could harm the health of children.

   Studies have shown that children exposed to low levels of PCBs, mercury, and lead showed impaired learning of a performance task, resulting in problems with attention and impulse control.

   Three grids have elevated levels of PCBs, lead, and mercury; eight grids have elevated levels of PCB and lead; and, five grids have elevated levels of PCBs and mercury. See Figure 42 for the location of these grids.

VII.B. New Conclusions Based Upon Recent Environmental Data

The basis for these conclusions comes from environmental samples collected by EPA after 2010. Many of these samples were collected in response to recommendations from ATSDR in the December 2010 public release version of this report.

1. Conclusions about Dioxins in the Dry-land Area

   In 2011, EPA collected soil samples from eight, dry-land areas and measured dioxin levels. One 30 half-acre area contained dioxins in soil that is a public health concern for children and adults should this area become residential.

   Daily contact with dioxins in soil in this one area over many years poses a high risk of cancer for children and adults. Human studies have shown that dioxin can cause liver cancer and might be associated with cancers of the lung, colon, prostrate, breast, blood, and lymphatic system. Rodent studies have confirmed that dioxin can cause cancer at multiple sites, including the liver, lung, mouth, and thyroid.

   In addition, preschool male children who have daily contact with these soils could be at risk of reproductive effects once they reach adulthood. As adults, they might experience problems with (1) decreased number of sperm, (2) decreased number of motile sperm, and (3) fewer male offspring

   The location of this 30 half-acre area contaminated with dioxin is shown in Figure 43 and is labeled as sampling area 8.

2. Conclusions about the Former Theater Area

   In 2010, EPA collected soil samples from the former theater area in the northeast section of the site. Glynn County plans to build a detention center in this area so ATSDR evaluated the risk for adult workers and inmates who might come in contact with chemicals in soil. Mercury, lead, and PCBs in soil from the former drive-in theater area are not a health concern.

   The mercury and lead levels in soil in the former theater area were either below ATSDR's screening levels or the levels were at or near background levels in soils. Therefore, harmful effects from mercury and lead in soil are not likely.

   The exposure of prison inmates and adult workers to PCBs in soil would be at levels far below ATSDR's health guideline for PCBs. Therefore, PCBs in soil are not likely to cause harmful, non-cancerous effects. The risk of cancer from daily exposure to PCBs in soil is insignificant.

3. Conclusions about the On-Site Pond

   In 2010, EPA collected surface water and sediment samples from the on-site pond in the northwest corner of the dry-land area. The levels of PCBs, mercury, PAHs, and lead in surface water and sediment from the on-site pond are not a health concern.

   Levels of PCBs, mercury, PAHs and lead in the on-site pond were either below ATSDR's comparison values or at background levels. In addition, the pond does not serve as a source of drinking water nor does the pond support fish.

4. Conclusions about Sampling Sufficiency for the Dry-land Area

   Some dry-land areas do not have adequate sampling data; therefore, it is difficult to draw conclusions regarding potential health impacts from soils in these areas. Most of the insufficiently sampled areas are in the southeastern portion of the site (including the cell building area) and in the western dry-land area closest to the marsh. For other areas that have been sufficiently sampled, we are able to draw conclusions about potential health impacts.

   One reason for the limited sampling in some areas is that EPA decided that some environmental data were unusable because of data quality issues. In addition, some areas were not sampled because LCP Chemicals did not perform industrial activities on certain portions of the site. However, numerous industries occupied the site before LCP's chlor-alkali facility, and those industries could have disposed of waste throughout the property.

   Approximately half of the grids are considered sufficiently sampled for making a health conclusion for the chemicals PCBs, mercury, and lead. That means that half of the grids require additional sampling in order to be sure that those areas are not contaminated.

   See Figures 22 through 25 for the dry-land areas considered to have adequate sampling data.

5. Conclusions about Sediment from the Altamaha Canal South of the LCP Chemicals Site

   In 2011, EPA collected sediment samples from a portion of the Altamaha Canal that exists south of the LCP Site. ATSDR evaluated the risk of harmful effects from exposure to PCBs, mercury, PAHs, and dioxins in sediment along the Altamaha Canal. Adults and children who visit or play along the canal would not be exposed to contaminants in sediment at levels that would cause harmful, non-cancerous effects. It is unlikely that contact with these chemicals in sediment would cause cancer.

These chemicals are not a health concern in Altamaha Canal sediment because:

≠ The concentration of lead in sediment from the canal is at or near background lead levels in soils and is unlikely to cause harmful health effects from direct contact,
≠ The concentration of mercury is below ATSDR's comparison value; therefore, mercury in sediment is unlikely to cause harmful health effects from direct contact,
≠ The estimated exposure to dioxins and PCBs for adults and children who visit or play along the canal is well below ATSDR's and EPA's health guidelines. Therefore, harmful non-cancerous effects are not likely. The estimated exposure to PCBs, PAHs, and dioxins for adults and children who visit or play along the canal results in insignificant cancer risks.

6. Conclusions about Mercury in Fish and Shellfish from the Altamaha Canal South of the LCP Chemicals Site

In 2011, EPA collected fish and shellfish samples from the canal. ATSDR estimated exposure to mercury from eating various fish and shellfish from the Altamaha Canal and reached the following conclusions about adults and children with typical and high fish consumption:

≠ Mercury levels in mullet and shrimp from the Altamaha Canal are not a health concern.
≠ Mercury levels in blue crab, red drum, and sea trout are not a health concern for typical fish consumers but are a health concern for high fish consumers.

Depending upon age and race, high fish consumers eat about 2 to 7 ounces of fish and shellfish daily. Typical fish consumers eat about a half to 2 ounces of fish daily. These daily fish consumption rates do not necessarily mean that people eat fish every day. Their fish consumption averages out to the rates previously described. For example, someone with a daily fish consumption rate of 2 ounces might eat one 14 ounce fish meal a week or two 7 ounces fish meals a week. This frequency and amount of fish consumption averages out to two ounces of fish eaten daily.

≠ Typical and high fish consumers of mullet and shrimp from the Altamaha Canal have estimated exposures to mercury that are well below levels that cause harmful effects. Typical fish consumers of blue crab, red drum, and sea trout from the Altamaha Canal have estimated exposures to mercury that are well below levels that cause harmful effects.
≠ High fish consumers of blue crab, red drum, and sea trout from the Altamaha Canal have estimated exposures to mercury that approach levels that can cause harmful effects in young children and in children born to pregnant women who are high consumers. These children might experience neurological effects involving language, attention and memory, and to a lesser extent visual/spatial and motor functions.

Some uncertainty exists in the conclusions for sea trout and red drum because only one fish of each species was collected from the Altamaha Canal.

7. Conclusions about PCBs in Fish and Shellfish from the Altamaha Canal South of the LCP Chemicals Site

Fish and shellfish from the Altamaha Canal were also found to contain PCBs. ATSDR estimated exposure to PCBs from eating various fish and shellfish from the Altamaha Canal and reached the following conclusions about adults and children with typical and high fish consumption:

≠ PCB levels in red drum, blue crab, and shrimp are not a health concern for harmful, non-cancerous effects.
≠ PCB levels in sea trout are not a health concern for typical fish consumers, but are a health concern for high fish consumers.
≠ PCB levels in mullet are a health concern for typical and high fish consumers.

The basis for these decisions is:

≠ Typical and high fish consumers of red drum, blue crab, and shrimp have estimated exposures to PCBs that are well below levels that can cause harmful, non-cancerous effects. Typical fish consumers of sea trout have estimated exposures to PCBs are well below levels that can cause harmful, non-cancerous effects.
≠ High fish consumers of sea trout and typical and high fish consumers of mullet have estimated exposure to PCBs that approach levels that can cause harmful, non-cancerous effects.

High consumers of sea trout and typical and high consumers of mullet might experience the following harmful effects to the immune, dermal, nervous, developmental, and reproductive systems. Specific health effects include:

≠ Small changes in immune function as evidenced by a weakened response to an antigenic challenge,
≠ Mild damage to fingernails and toenails,
≠ Inflamed oil-producing glands associated with the eyes
≠ Gum recession,
≠ Learning and performance problems,
≠ Problems with attention and impulse control,
≠ Fewer male births,
≠ Lower birth weight,
≠ Longer menstrual cycles in women,
≠ An increase in cardiovascular disease in women,
≠ An increase in deaths from Parkinson disease in women,
≠ An increase in deaths from dementia in women, and
≠ An increase in diabetes in women (ATSDR 2000).

Children and especially preschool children, with their nervous systems still developing, may be a particularly susceptible group.

Children and adults who frequently eat mullet from the Altamaha Canal for many years also have a high increased risk for several cancers, including cancers of the liver, thyroid, biliary tract, intestines and skin.

The results of the fish and shellfish sampling from the Altamaha Canal support the current fish advisory for the Turtle River system issued by the Georgia Department of Natural Resources (GDNR). The Altamaha Canal is tidally connected to the lower Turtle River through several waterways and GDNR has fish and shellfish consumption advice specifically for the lower Turtle River. See Table 46 for more information about the state's fish and shellfish consumption recommendations for the lower Turtle River.

VIII. RECOMMENDATIONS

VIII.A. Recommendations for the 2013 Public Health Assessment for the LCP Chemicals Site

ATSR recommends

1. Restricting some LCP Chemicals Site areas from residential development unless further steps are taken to prevent contact with PCB, mercury, lead, PAH, and dioxin contamination that remains in soil on the property.

2. Restricting some LCP Chemicals Site areas from commercial or industrial use unless further steps are taken to prevent contact with PCB, mercury, and PAH contamination that remains in soil on the property.

3. Additional soil sampling in and around the former cell building's footprint if future plans include development of this area because of residual soil contamination.

4. Additional sampling in areas where sampling data are limited. In general, the western portion of the site has been sampled more than the eastern portion. Particular attention should be given to the former cell building area should the land use change and to future enclosed structures built above the caustic brine pool area.

5. Continued monitoring of fish and shellfish in the Turtle River and in the marsh near the LCP Chemicals Site. The Georgia DNR continues to monitor seafood in the area and to maintain the fishing advisory for the Turtle River System.

6. Continuation of the GDNR's fish advisory for the Turtle River System. The major components of this advisory are provided in Tables 43-46 of this health assessment.

GDNR's recommendations for the lower Turtle River (see Table 46) apply for fish obtained from the Altamaha Canal.

The 2013 GDNR fish advisories for rivers, lakes, and estuaries in Georgia, including the Turtle River system, can be found at this website: http://www.gaepd.org/Documents/fish_guide.html. To view their brochure, click on "Guidelines for Eating Fish from Georgia's Waters, 2013".

In addition, GDNR has a brochure, 'A woman's guide for eating fish and seafood from coastal Georgia'. This brochure is available at http://health.state.ga.us/pdfs/environmental/chemhazard/fish%20consumption/wfcg_coastal.pdf

VIII.B. Recommendations for the 2010 Public Health Assessment for the LCP Chemicals Site

ATSDR made these recommendations in the 2010 Public Health Assessment for the LCP Chemicals Site when the assessment was released for public comment.

ATSDR recommended

1. Collecting sediment and fish samples from the existing portion of the Altamaha Canal that flows south of the LCP Chemicals Site to determine whether mercury and PCBs have migrated to and contaminated portions of the canal. In response to this recommendation, EPA collected sediment and fish samples in 2011 from the Altamaha Canal.

2. Collecting sediment, water, and fish samples from the on-site pond to determine whether site-related contaminants are present. In response to this recommendation, EPA collected sediment samples in 2010 from the on-site pond. Fish samples could not be collected from the on-site pond because the pond does not support fish.

3. Collecting soil samples from the on-site theater area. In response to this recommendation, EPA collected soil samples from the theater area in 2010.

4. Continued monitoring of fish and shellfish in the Turtle River and in the marsh near the LCP Chemicals Site. The Georgia DNR continues to monitor seafood in the area and to maintain the fishing advisory for the Turtle River System.

5. Developing health education and community involvement activities to ensure that the findings of this public health assessment are presented to the community, which includes residents who live in the area, elected government officials, and ATSDR's government partners. In September 2010, ATSDR met with elected officials and the agency's government partners and held public meetings to educate and involve the community.

IX. PUBLIC HEALTH ACTION PLAN

1. As part of its health education and community involvement activities at the LCP Chemicals Site, ATSDR met with elected officials and held public meetings in September 2010 as part of the public release of this health assessment. These meetings informed the public and government agencies about the risk from future development at the LCP Chemicals Site in Brunswick, Georgia. As part of these meetings, we also answered questions from elected officials and from concerned residents.

2. During the development of the public health assessment, ATSDR met with US EPA, Honeywell (the principle responsible party), and Glynn Environmental Coalition (a local environmental group) to inform them of our progress and initial findings. One outcome of these meetings was that EPA and Honeywell collected soil, sediment, and seafood samples that are now part of the final release of this public health assessment.

3. ATSDR will inform news outlets, elected officials, and the Glynn Environmental Coalition of the findings in this final release of the LCP Chemicals Public Health Assessment.

4. ATSDR will correspond with staff members from the U.S. Environmental Protection Agency, Region IV to inform officials about our findings and recommendations in this public health assessment.

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APPENDIX A

Site Maps

Figure A1. LCP Chemicals Site Boundary Map Showing Marsh, Purvis Creek, and Dry-land Area

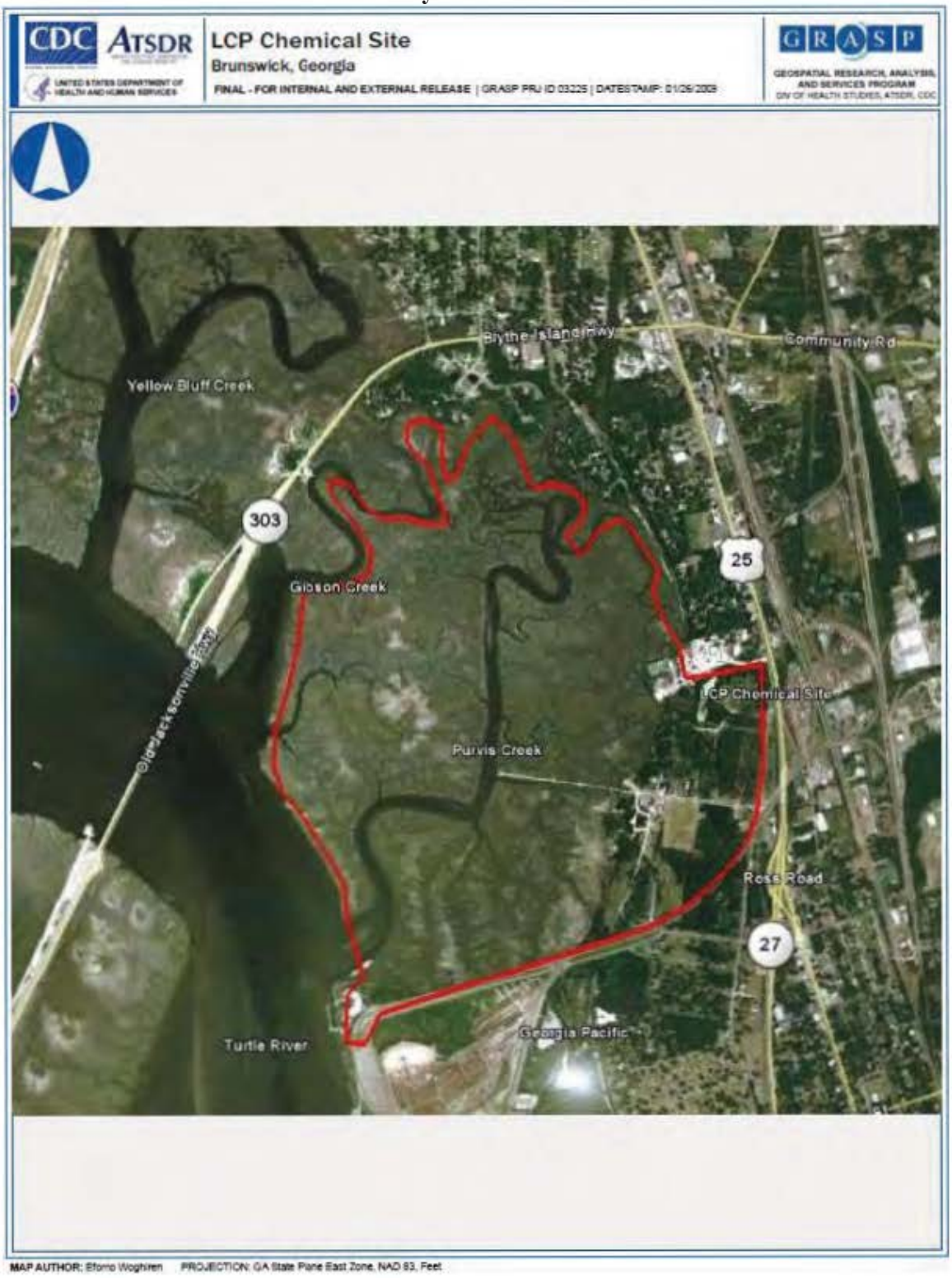


Figure A2. Site Map Showing Current Onsite Structures on Dry-land Area with Marsh in Background (March 2004)

Figure A3. Site Map Showing Onsite Pond and Theater –Current View 2010

Figure A4. Site Map of Dry-land Area Showing Location of Various Activities and Buildings When LCP Was Operational

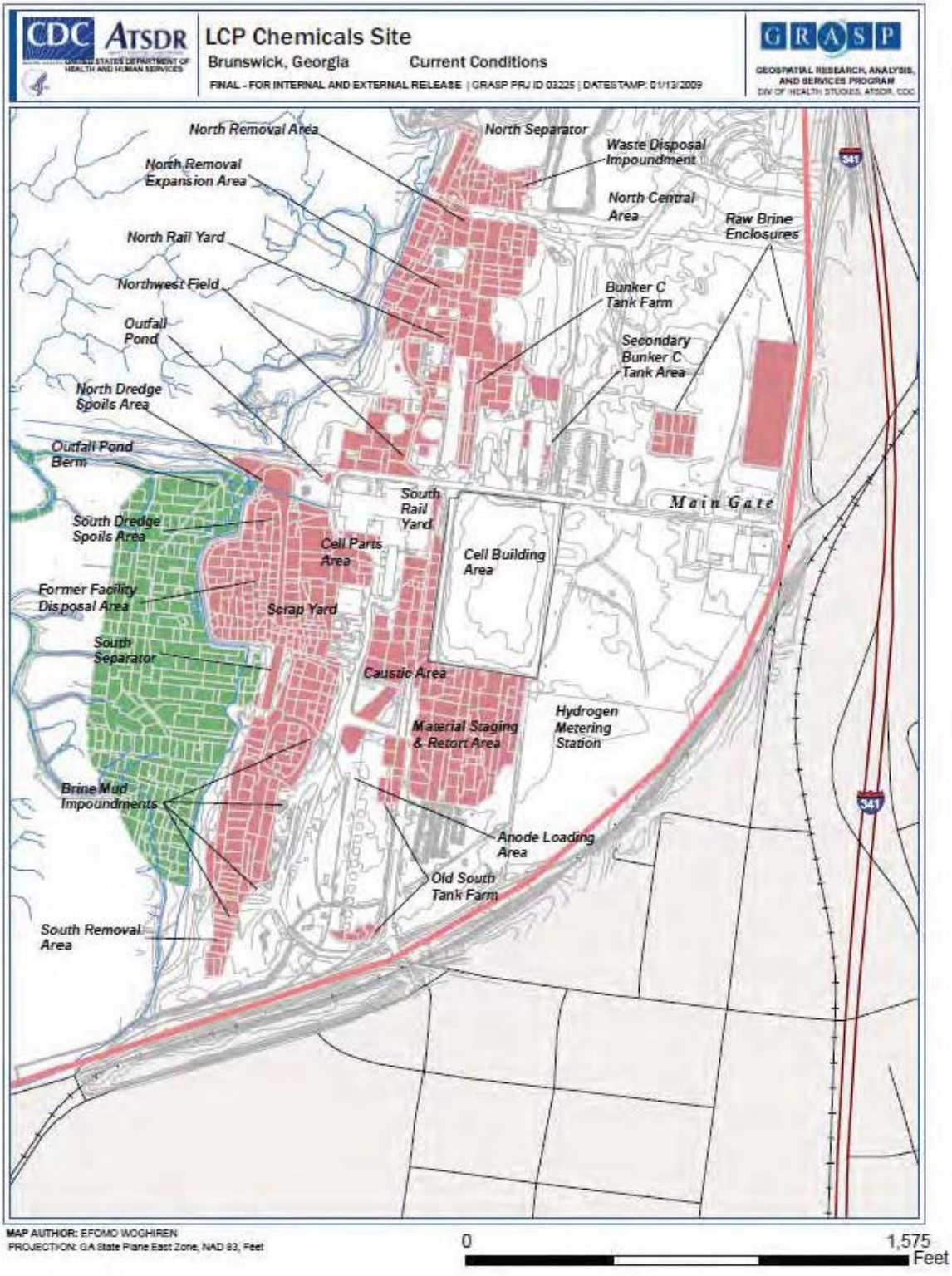


Figure A5. LCP Chemical and Surrounding Area 2010 Demographic Map

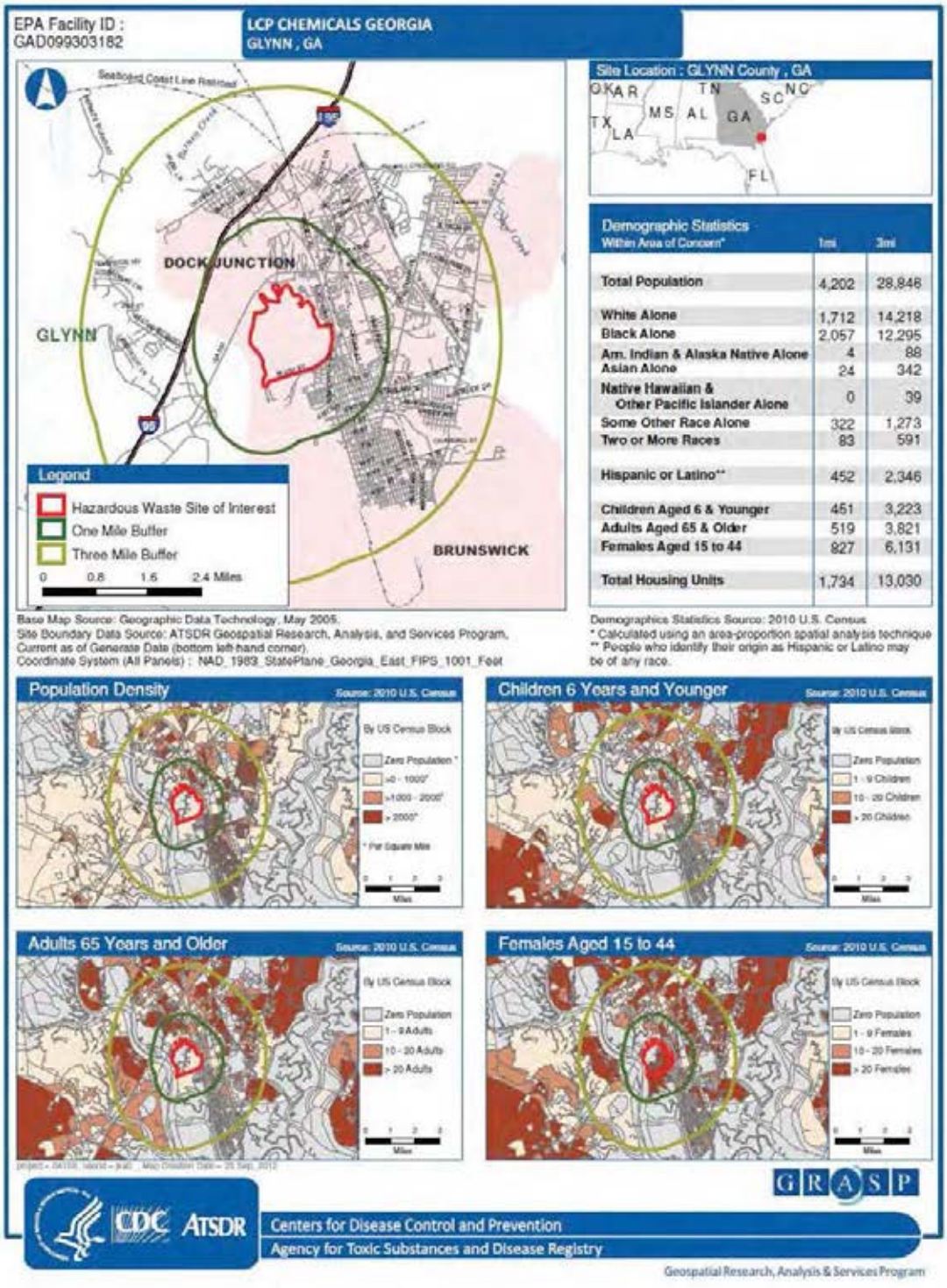


Figure A6. Historical Photo Showing Off-site Tank Farms

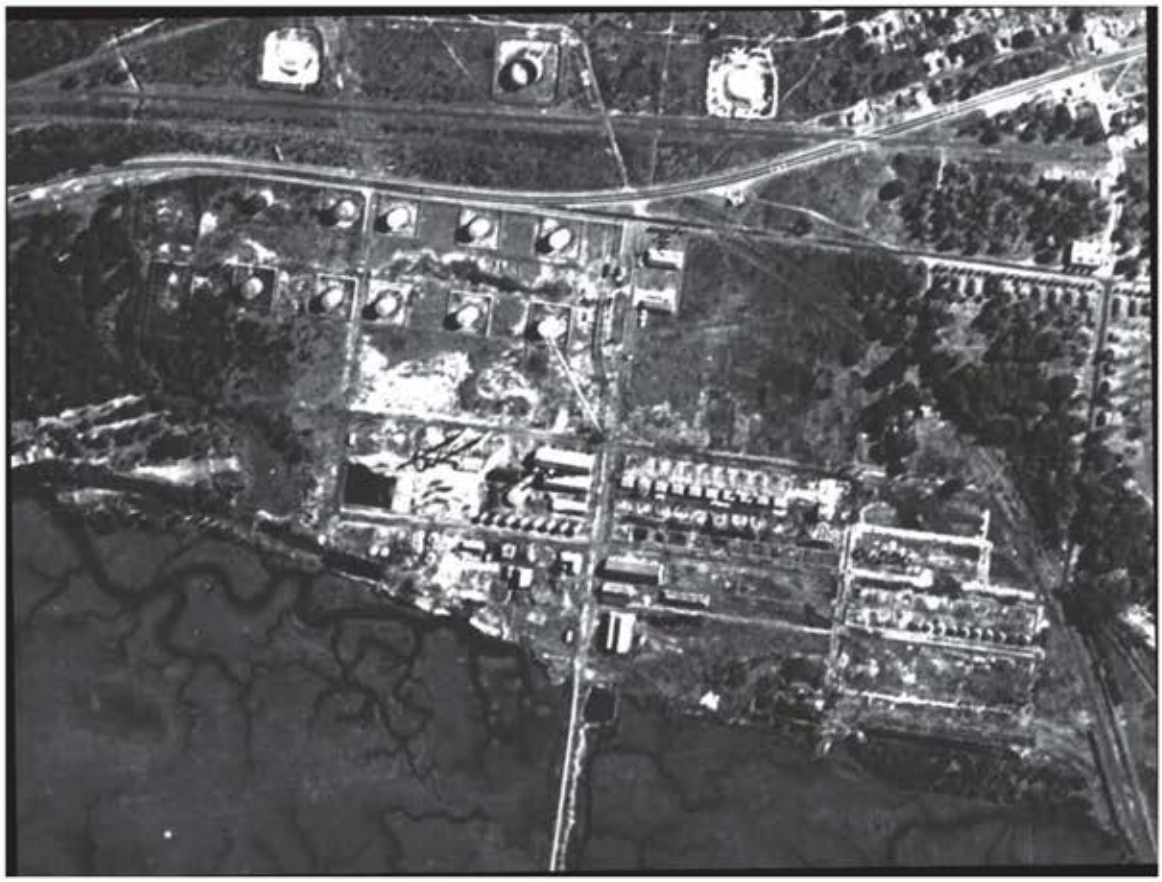


Figure A7. Off-Site Former Tank Farm Area
Mercury Sampling Locations and Concentrations

Figure A8. Off-Site Former Tank Farm Area – Historical Photo Underlay Mercury Sampling Locations and Concentrations

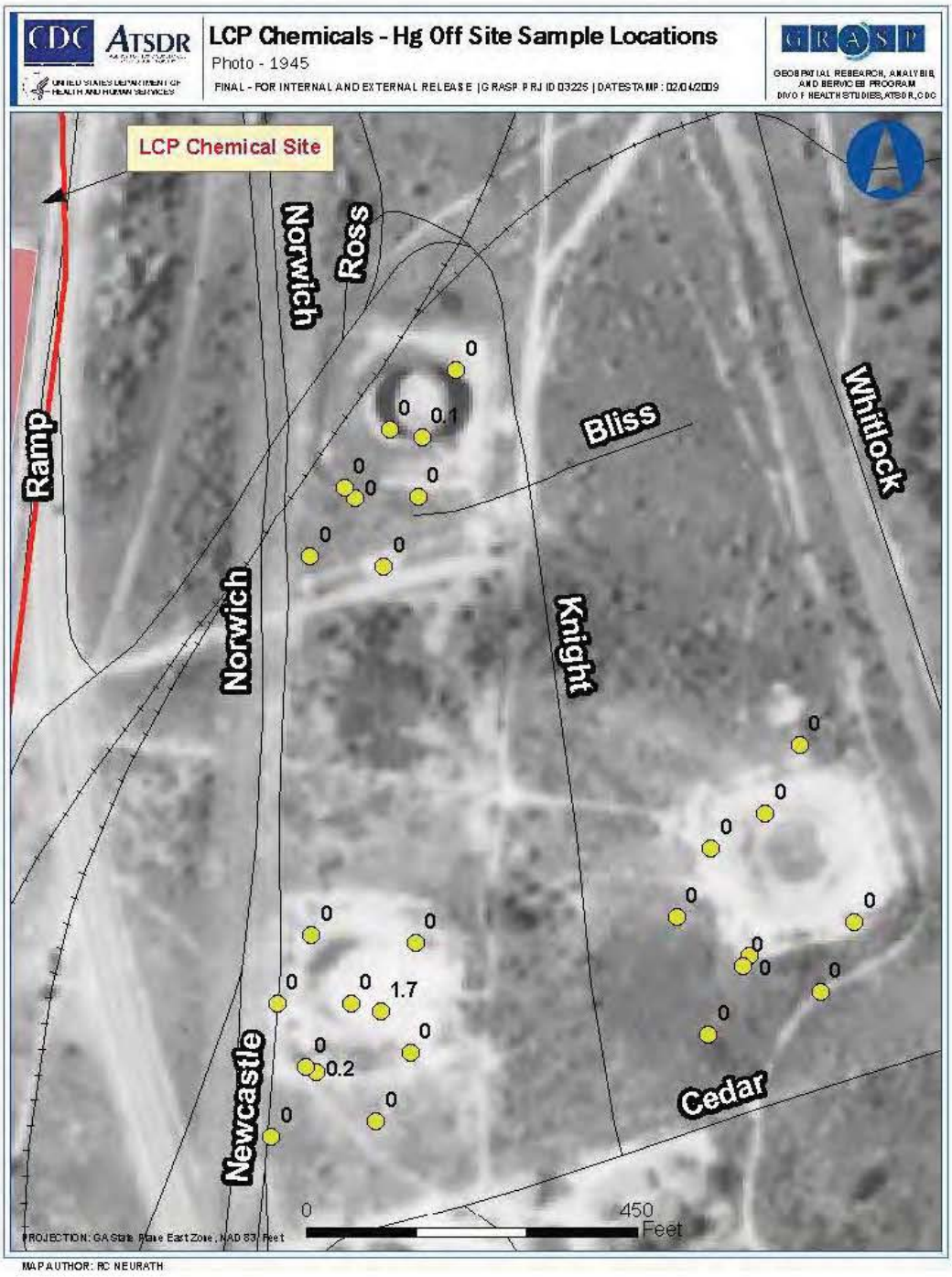


Figure A9. Off-Site PCB Sampling Locations

Figure A10. Former Tank Farm Areas
PCB Sampling Locations and Concentrations

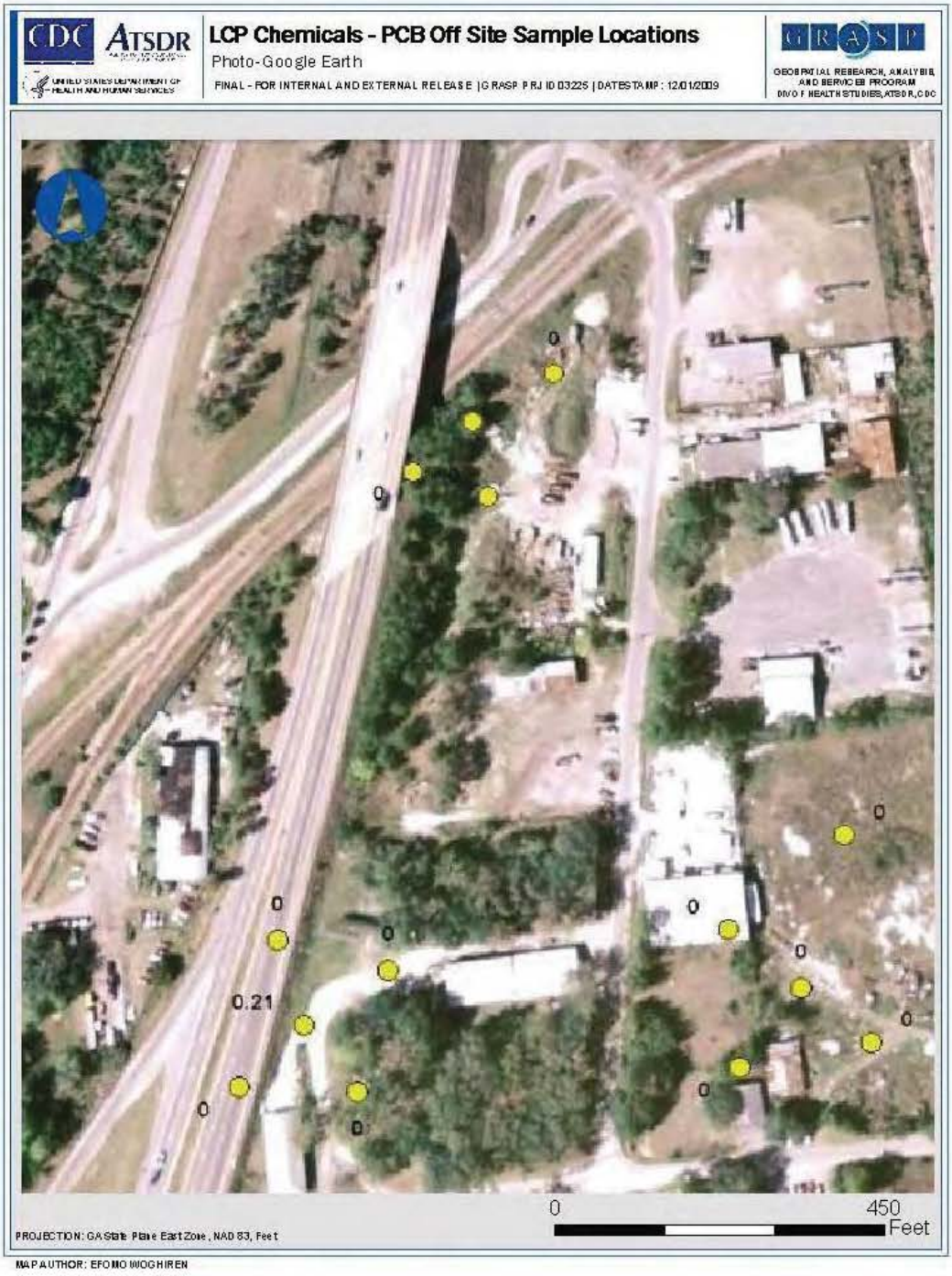


Figure A11. Former Tank Farm Areas
Lead Sampling Locations and Concentrations

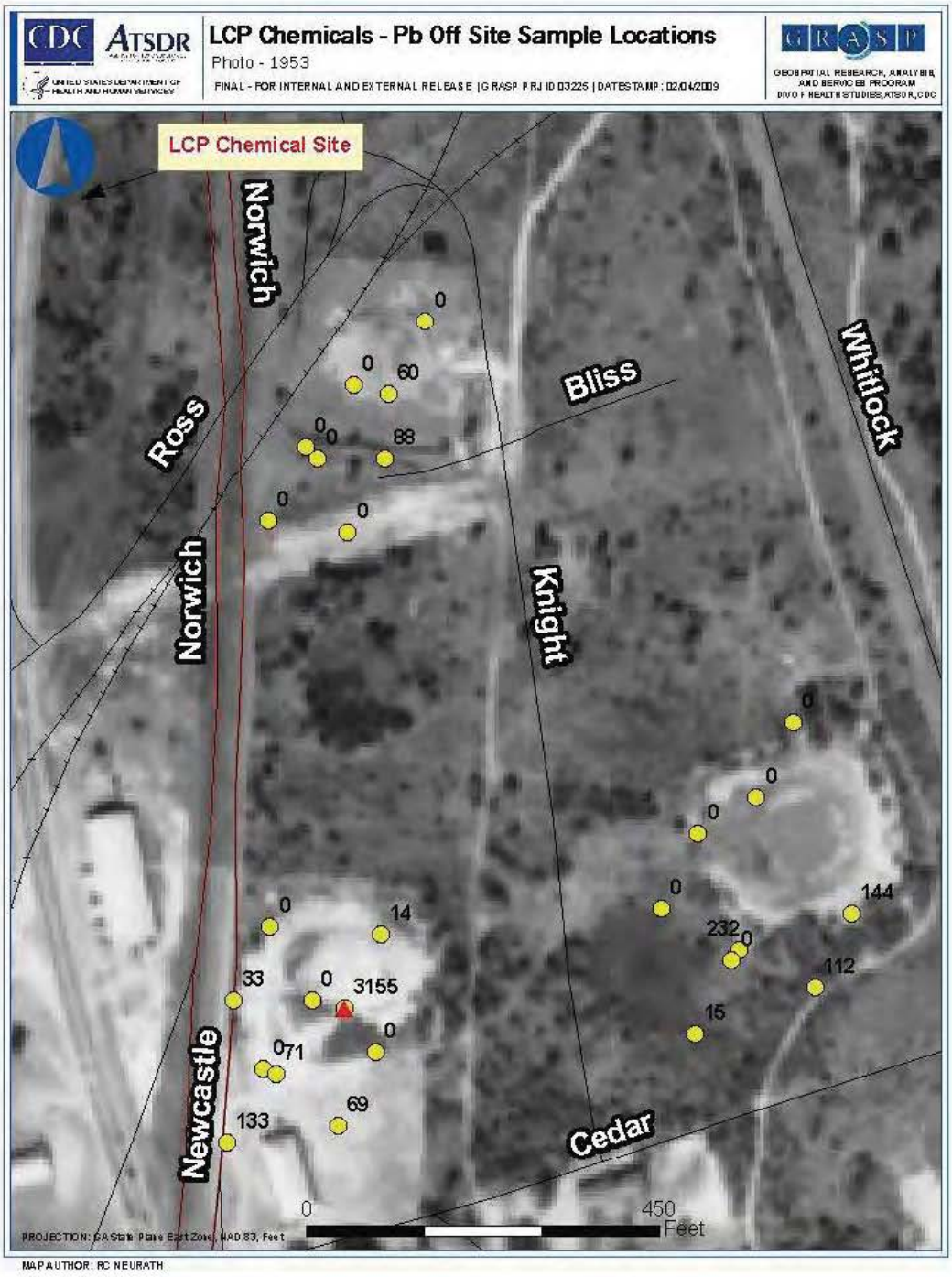


Figure A12. The Altamaha Canal 2010

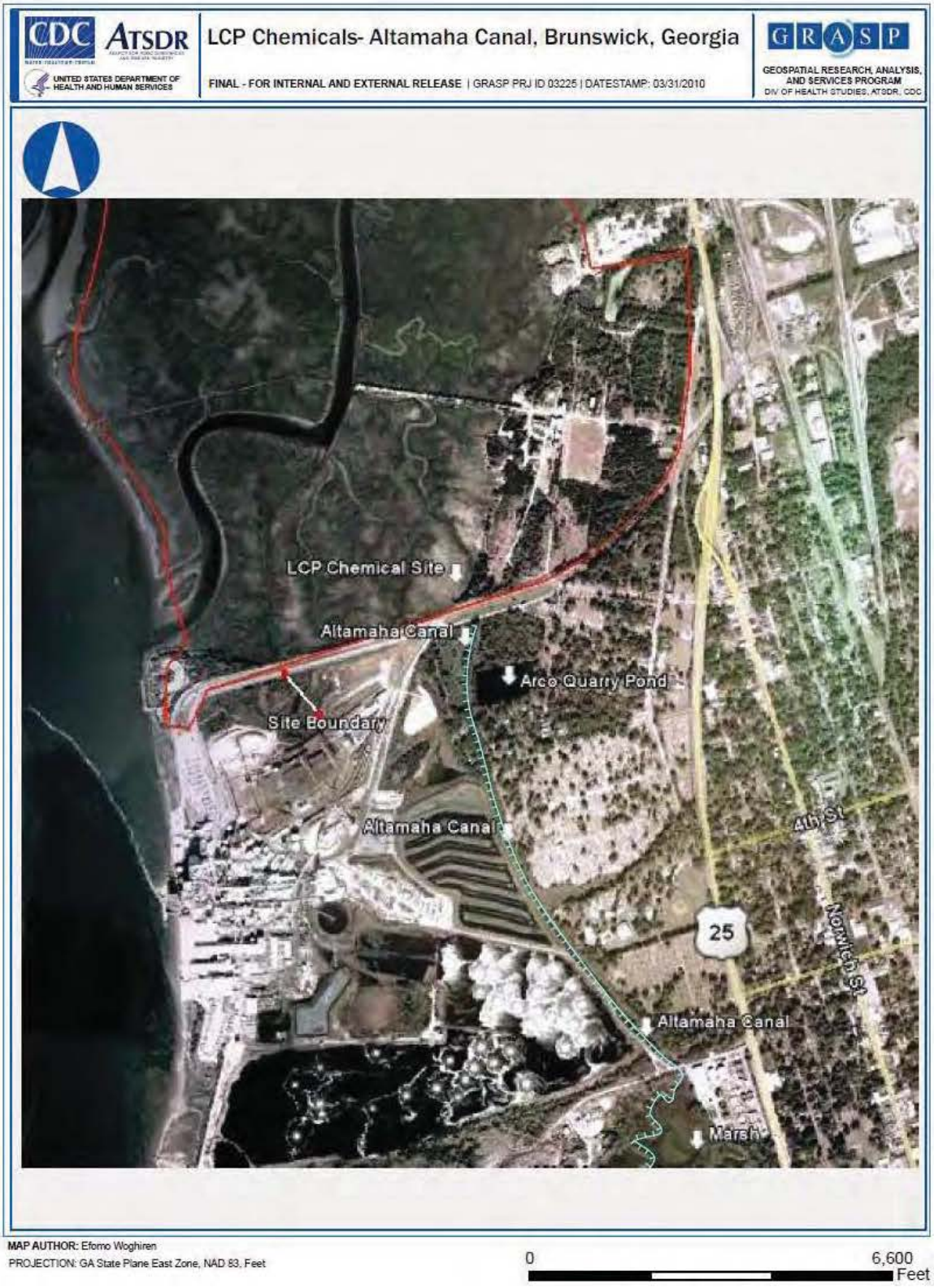
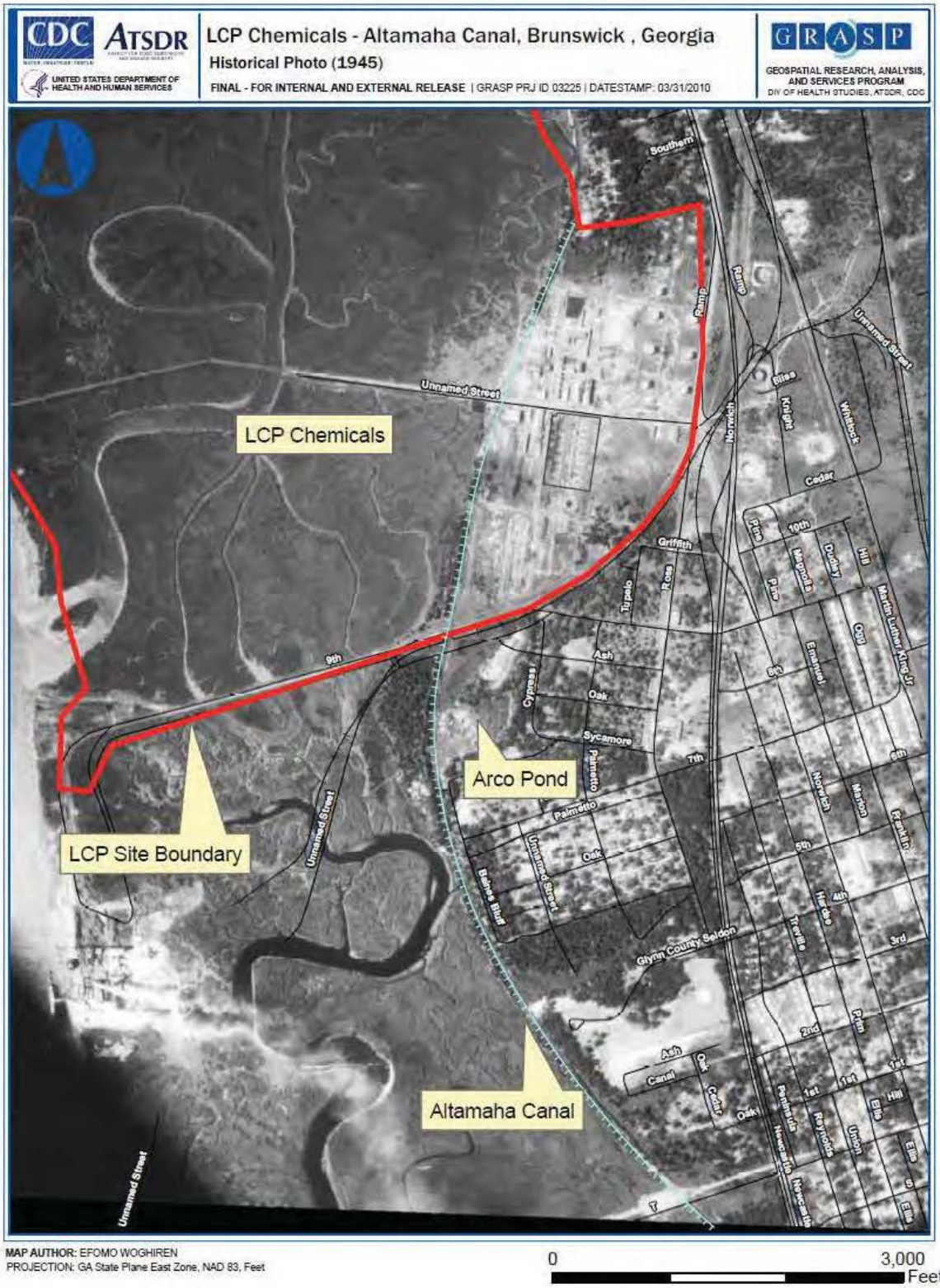


Figure A13. Altamaha Canal (1945) Showing Historical On-site Location



APPENDIX B

Parameters Used to Estimate Chemical Dose in Various Age Groups and Summary of Human and Animal Studies Demonstrating the Harmful Effects of PCBs at Low Levels

Table B1. Parameters used to estimate chemical dose in various age groups		
Parameter	***Quantity***	***unit***
Body weight--preschool children 1 yr	10	kg
Body weight--preschool children 3 yr	16	kg
Body weight--elementary school children	35	kg
Body weight--teenagers	55	kg
Body weight--pica children	10	kg
Body weight--adults men	70	kg
Body weight--adult women	60	kg
Soil intake--preschool children	200	mg/day
Soil intake--elementary school children	100	mg/day
Soil intake--teenagers	100	mg/day
Soil intake--pica children	5000	mg/day
Soil intake--adults	100	mg/day
Soil intake-- outdoor commercial workers	100	mg/day
Soil intake--excavation workers	330	mg/day
Exposure factor, residents	1	---
Exposure factor, workers	0.687	--
Exposure factor, excavation workers	0.714	--
Exposure factor for pica behavior (3 days a week)	0.429	--

Table B2. Human Studies Demonstrating the Harmful Effects of PCBs at Low Levels.						
Target	***Study duration***	***Effect Level***	***System***	***Harmful Effects***	***Chemical Form***	***Reference***
Human	Follow-up at 25 years	>5.1 ppb serum PCB (whole weight, not standardized for lipids)	Immunological (endocrine disruptors)	2-fold increased incidence of adult-onset diabetes in women (but not men) with higher serum PCB levels compared to non-detect group. Serum PCBs ranged 5 ppb to 10 ppb.	Not specified	Vasiliu 2006
Human	Prospective cohort study (5 year follow-up)	Serum PCB whole weight (not standardized for lipids) Mean = 5.4 ppb Median = 4.7 ppb 10^{th} = 3.1 ppb 90^{th} = 8.7 ppb	Reproductive	33% reduction in male births for women at the 90^{th} % compared to women at the 10^{th} % Each 1 ppb increase in serum PCB associated with 7% decrease in # male births. Maternal exposure to PCBs may be detrimental to the success of male sperm or to the survival of male embryos. Findings could be due to contaminants, metabolites or PCBs themselves.	Total PCBs and PCB congeners #105 #110 #117 #137 #138 #153 #170 #187	Hertz-Picciotto 2008
Human	Prospective cohort study (recruitment 1959-1965)	Serum PCB whole weight <1 to > 5 ppb Effect observed in 3.75-	Reproductive	Increasing serum PCB levels associated with slightly longer menstrual cycles, increasing by about 1 day.	Total PCBs PCB congeners # 28 # 138 # 52 # 153 # 74 # 170	Cooper 2005

Table B2. Human Studies Demonstrating the Harmful Effects of PCBs at Low Levels.						
Target	***Study duration***	***Effect Level***	***System***	***Harmful Effects***	***Chemical Form***	***Reference***
		4.99 ppb group Effect not statistically significant for serum PCB standardized to lipid (but samples were not fasting)		Weaker evidence for an association with irregular cycles No association with bleeding duration and volume, or dysmenorrhea. Important limitation is recall bias when answering questions about menstrual cycle.	# 105 # 180 # 118 # 194	
Human	NHANES cross-sectional study 1999-2002	Congener concentrations reported Calculated total serum PCBs standardized for lipids <25% = 141 ppb 25th to <50th = 243 ppb 50th to <75th = 370 ppb ≥ 75th = 651 ppb	Cardiovascular	PCBs positively associated with prevalence of CVD among women (but not men). Odds ratio for dioxin-like PCBs 50-<75th % = 2 ≥75th% = 5 Odds ratio for non-dioxin like PCBs 25th to <50th % = 1.2 50th to < 75th % = 1.2 ≥75th % = 3.8	Dioxin-like PCB congeners: 74, 118, 126 156 169 Non-dioxin like PCB congeners: 99, 138, 153, 170, 180, 187	Ha M-H 2007
Human	9.5 years	Total PCBs At birth:	Neurological/ Developmental	Impaired learning of a performance task in children exposed to PCBs,	Total PCBs via sum of all congeners	Stewart 2006

Table B2. Human Studies Demonstrating the Harmful Effects of PCBs at Low Levels.						
Target	***Study duration***	***Effect Level***	***System***	***Harmful Effects***	***Chemical Form***	***Reference***
		Mean cord PCB = 0.96 ppb Maternal hair, Mercury Prenatal = 0.56 ppm Prenatal cord Pb = 1.81 µg/dL Postnatal Pb = 4.6 µg/dL (at 2 to 4 years)		methylmercury, and lead. Children prenatally exposed to PCBs responded excessively, with significant lower inter-response times and fewer re-enforcers earned across the session. (In other words, low-level PCB exposure results in an inability to withhold or delay inappropriate responding, which are measures of attention and impulse control) Exposure to either methylmercury or lead (postnatal only) predicted statistically significant impairments of a similar magnitude to those for PCBs. The associated impairments of all three chemicals were statistically independent of one another.		
Human	Occupational,	> 90 days employment	Neurological	No overall (men/women	Not specified	Steenland

Table B2. Human Studies Demonstrating the Harmful Effects of PCBs at Low Levels.						
Target	***Study duration***	***Effect Level***	***System***	***Harmful Effects***	***Chemical Form***	***Reference***
	Retrospective mortality study	Mean = 5.3 years PCB levels not specified Groups classified into low exposure and high exposure		combined) excess of Parkinson disease, amyotrophic lateral sclerosis, or dementia. Women had an excess mortality from amyotrophic lateral sclerosis, ALS (SMR = 2.26, CI = 1.08-4.15) (SMR = standardize mortality ratio) Among the highest exposed women (based on job-exposure matrix), women had an excess mortality from Parkinson disease (SMR = 2.96, CI = 1.08-6.42) and dementia (SMR = 2.04, CI = 1.12-3.42). Loss of dopaminergic cells in the brain is the hallmark pathologic sign of Parkinson disease. Studies indicate that exposure to PCBs decreases dopamine levels in rats and monkeys.		2006

<table>
<tr><th colspan="6">Table B2. Human Studies Demonstrating the Harmful Effects of PCBs at Low Levels.</th></tr>
<tr><th>Target</th><th>Study duration</th><th>Effect Level</th><th>System</th><th>Harmful Effects</th><th>Chemical Form</th><th>Reference</th></tr>
<tr><td></td><td></td><td></td><td></td><td>Conclusion: suggestive data of an effect of PCBs on neurodegenerative disease for women</td><td></td><td></td></tr>
<tr><td>Human</td><td>NHANES Cross-sectional study 2003-2004</td><td>Not applicable</td><td>Blood</td><td>Serum background levels of PCBs in US population.

Note: serum PCB levels change with year of sample and with age, making it difficult to compare these levels with human studies reported above.

<table><tr><td colspan="2">Total PCBs</td></tr><tr><td>Serum whole weight</td><td>Serum lipid standardized</td></tr><tr><td>GM= 0.8 ppb</td><td>GM = 134.4 ppb</td></tr><tr><td>95%= 3.53 ppb</td><td>95%= 530.7 ppb</td></tr></table>GM = geometric mean</td><td>Total PCBs
Congener-specific PCBs</td><td>Patterson 2009</td></tr>
</table>

Table B2. Human Studies Demonstrating the Harmful Effects of PCBs at Low Levels.

Target	*Study duration*	*Effect Level*	*System*	*Harmful Effects*	*Chemical Form*	*Reference*
				Serum whole weight PCBs in ppb Age-group: Geometric mean / 95th percentile 12-29: 0.3 / 0.7 20-39: 0.5 / 1.5 40-59: 1.2 / 3.2 60+: 2.3 / 5.9		
Human	9 months	< 1,04 to > 2.17 pg TEQ/g lipid	Developmental/ Immunological	Multivariate analyses showed independently and significantly decreased free T4 (FT4) × thyroid stimulating hormone with increasing non-ortho PCBs ($r = -0.2$; $p < 0.05$). This suggests that significant FT4 feedback alterations to the hypothalamus result from *in utero* exposure to non-ortho PCBs.	Non-ortho PCBs	Wang 2005

Table B3. Animal Studies Demonstrating the Harmful Effects of PCBs at Low Levels.							
Target	***Study duration***	***Effect Level in µg/kg/day***	***System***	***Harmful Effects***	***Chemical Form***	***ATSDR Study #****	***Reference***
Monkey	23 months Daily	5	Immunological	Reduced IgM and IgG antibody response to sheep red blood cells	1254	148	Tryphonas 1989
Monkey	37 months Daily	5	Dermal	Elevated and separated toenails	1254	136	Arnold 1993a, 1993b
Monkey (female)	48 months ppm 37; ppw 22 daily	5	Developmental	Inflammation of tarsal glands, nail lesions, gum recession, reduced IgM antibody levels to sheep red blood cell in infant offspring	1254	160	Arnold 1995
Monkey	72 months	5	Developmental	Inflammation of tarsal glands, nails and nail beds in infants	1254	160	Arnold 1995
Monkey	20 weeks Daily, starting at birth	7.5	Neurological	Changes in behavioral performance in non-spatial and spatial discrimination reversal tasks at 3, 4.5, and 5 years of age. Treated monkeys showed decreases and variable increases in response latencies across three tasks of nonspatial discrimination reversal as well as retarded acquisition of a delayed	15 PCBs similar to breast milk	87	Rice 1997, 1998 Rice and Hayward 1997, 1999a

Table B3. Animal Studies Demonstrating the Harmful Effects of PCBs at Low Levels.							
Target	***Study duration***	***Effect Level in µg/kg/day***	***System***	***Harmful Effects***	***Chemical Form***	***ATSDR Study #****	***Reference***
				alternation task and increased errors at short delay task responses. Rice interpreted the findings as a learning/performance decrement.			
Monkey	20 weeks Daily, starting at birth	7.5	Developmental	Lowered IgM and IgG antibodies to sheep red blood cell, temporary decrease in B lymphocytes	15 PCBs similar to breast milk	113	Arnold 1999
Monkey (female)	48 months ppm 37; ppw 22 Daily	20	Developmental	Fetal and post-partum deaths in 4 of 4 impregnated monkeys	1254	160	Arnold 1995
Monkey	37 months Daily	20	Blood	Decreased mean platelet volume	1254	136	Arnold 1993a, 1993b
Monkey	37 months Daily	20 LOAEL 5 NOAEL	Reproductive	42% reduced conception rate	1254	152	Arnold 1995
Monkey	37 months Daily	40	Hepatic	Decreased serum cholesterol	1254	136	Arnold 1993a, 1993b
Monkey	72 months	40	Dermal	Nail and nail bed changes	1254	137	Arnold 1997

* The ATSDR study number can be found in Table 3-2 in ATSDR's Toxicological Profile for PCBs and is provided as a reference to the study being described. Additional description of the study can be found in ATSDR's profile at this internet address; . http://www.atsdr.cdc.gov/ToxProfiles/tp.asp?id=142&tid=26

** ppm = post partum month; ppw = post partum week

Appendix C

Summary of Scientific Studies
Evaluating the Effects of Lead Below 10 µg/dL

Table C1. Summary of scientific studies evaluating the effects of lead below 10 µg/dL.			
Blood Lead Level µg/dL	*Effect*	*Results/Conclusions*	*Author*
2.1	IQ	1. Peak (lifetime) blood lead concentration down to 2.1 µg/dL showed an inverse relationship with IQ for children at 6 years. 2. Lifetime average blood lead levels in children up to 6 years old, showed a 4.9 pt. decrease in IQ in children with average lifetime blood with blood lead level between 5 and 9.9 compared to children below 5 µg/dL.	Jusko 2007
< 10 µg/dL	Immune System	Pre- and post-natal blood lead levels below 10 µg/dL can alter children's adrenocorticol responses to acute stress. The behavioral and health consequences yet to be determined	Gump 2007
> 2	ADHD	Children (4 to 15 years) with blood lead levels between 2 - 5 µg/dL had a 4.5 fold higher risk of ADHD	Braun 2006
< 7.5	IQ	Children with blood lead levels up to 7.5 µg/dL have a greater decrease in IQ scores compared to children with higher blood lead levels. IQ decreases 3.9 points for children with blood lead levels between 2.4 - 10 µg/dL	Lanphear 2005
5 to 10	IQ	Data shows IQ decreased 3 to 5 pts. when blood lead levels increase from 5 to 10 µg/dL. IQ at 5 and 7 yrs. not related to peak lead levels of 20-44 µg/dL at 2 years of age	Chen 2005
1 to 10	IQ	An increase from 1 to 10 µg/dL blood lead is associated with 7.4 point decrease in IQ in children 3 to 5 years. From 10 to 20 µg/dL, IQ declines 2 points. Greater decrease in IQ from 1 to 10 when compared to higher blood lead levels	Canfield 2003
< 5	IQ	Blood lead levels below 5 µg/dL associated with deficits in cognitive and academic skills. Every 1 µg/dL increase in blood lead associated with ≠ 0.7 pt. decrease in math scores ≠ 1 pt. decrease in reading scores ≠ 0.1 pt. decrease in nonverbal reasoning ≠ 0.5 pt. decrease in short-term memory	Lanphear 2000

Table C1. Summary of scientific studies evaluating the effects of lead below 10 µg/dL.			
Blood Lead Level µg/dL	*Effect*	*Results/Conclusions*	*Author*
10.4	IQ	Lead at low levels of exposure probably has a small harmful effect on the performance of children in ability and attainment tests. Authors remark no evidence of a threshold	Fulton 1987
< 5	IQ	IQ at 10 years inversely related to blood lead levels at 2 years. Data suggest that inverse relationship persisted at blood lead levels < 5 µg/dL. Slope of dose response is greater at levels below 10 µg/dL	Bellinger 2006
3	Neurobehavior	3 µg/dL blood lead associated with deficits in attention, including executive function	Selevan 2003
5	Neurobehavior	5 µg/dL blood lead associated with deficits in reaction time, visual-motor integration, fine motor skills, off-task behaviors, and withdrawn behaviors	Selevan 2003
<10	Behavior	Blood Pb levels below 10 in 3 yr old children associated with small effects on behavior (e.g., cannot concentrate, quickly shifts from one thing to another) as measured by the destructive subscale. Between 10 and 20 µg/dL, blood lead causes a very small increase effect on behavior.	Wasserman 1998
1.86 all < 10	Behavior	Lead was significantly inversely related to teacher ratings of girls' sociability and classroom social competence.	Hubbs-Tait 2007
4.2 to 9	Attention	In a population with mean blood lead level of 4.2 µg/dL and 90% blood lead of 9 µg/dL, sustained attention negatively affected by lead levels	Walkowiak 1998
3	Height	Compared to 1 µg/dL, lead at 3 µg/dL associated with decreased height	Selevan 2003
3	Development	3 µg/dL associated with delays in breast and public hair development in African-American and Mexican-American girls. Also delayed menarche by 3.6 months. White girls showed non-statistically significant delays. Conclusion: 3 µg/dL causes delays in puberty	Selevan 2003

Table C1. Summary of scientific studies evaluating the effects of lead below 10 µg/dL.			
Blood Lead Level µg/dL	*Effect*	*Results/Conclusions*	*Author*
3.4	Behavior	Data suggest that social and emotional dysfunctions may be expressions of increased lead exposure. 3.4 µg/dL (SD 2.4) associated with total problem behavior scores Increases in tooth lead associated with internalizing and externalizing scores. Weaker association between tooth lead and extreme problem behavior. Cord blood not associated with later behavioral problems	Bellinger 1994
>5.5	Renal	Inverse relationship between serum levels of creatinine, B2-microglobulin, cystatin C and blood lead, suggesting renal hyperfiltration (i.e., increased glomerular filtration rate (x = 7.8 µg/dL)	Burbure 2006
> 1.5 to 10 µg/dL	Behavior	Children 8 to 15 years of age have an increased likelihood of conduct disorder (persistent behavioral patterns that violate social rules and the rights of individuals). Children with CD display aggression towards other people and animals and intentionally destroy others= property and chronically steal and deceive.	Braun 2008
4.8 µg/dL (cord)	Behavior in infants	Prenatal lead exposure was related to increased frenetic movement in neonates at 11 months. Frenetic movement is associated with hyperactivity and thus consistent with primate studies that have identified agitation as an early behavioral effect of lead and increased hyperactivity in childhood. This impaired ability to maintain attention and regulate one's behavior could be one of the earliest signs of lead neurotoxicity and a possible basis for later cognitive dysfunction. After removing children with blood lead levels greater than 10 µg/dL, authors still observed decrements in sustained attention.	Plusquellec 2007

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Appendix D

Glynn Environmental Coalition
Seafood Advisory Brochure

Reduce Risk from Fish You Catch and Eat

Fish Age & Size

Generally, older and larger fish may be more contaminated than younger, smaller fish.

Fish Cleaning to Reduce Risk

Removing skin and fatty areas reduces some contaminants by 25 to 50% but does not remove mercury.

Cooking Methods to Reduce Risk

GOOD
Broiling
Baking
Grilling

OKAY
Deep-fat frying (do not reuse oil)

POOR
Pan frying

Women and Small Children

Children under seven and women who are pregnant, nursing, or may become pregnant should:

- **not eat mullet from advisory areas**
- **limit meals of fish and blue crabs to one per month from advisory areas**

Don't stop eating fish and seafood. They provide one of the best sources of protein and Omega-3 fatty acids. Get seafood from other sources than advisory areas.

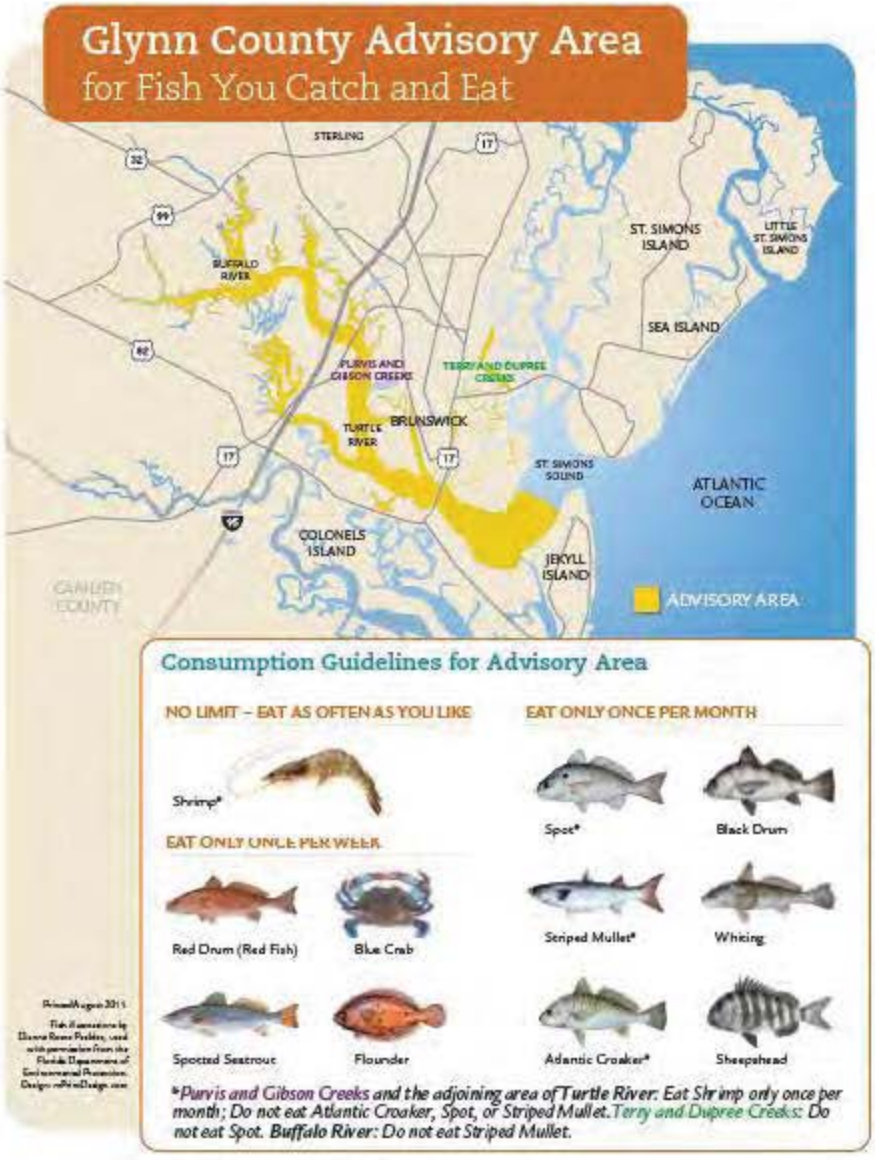
For More Information

GEC
Glynn Environmental Coalition
P.O. Box 2443
Brunswick, GA 31521
(912) 466-0934

COASTAL HEALTH DISTRICT
Glynn County Health Department
150 Scranton Connector
Brunswick, GA 31525
(912) 262-2300

GEORGIA
Georgia Department of Natural Resources
One Conservation Way
Brunswick, GA 31520
(912) 262-7218

Program support provided by:
MARAD
Sea Grant Georgia


Glynn County Advisory Area
for Fish You Catch and Eat
STERLING
BUFFALO RIVER
PURVIS AND GIBSON CREEKS
TERRY AND DUPREE CREEKS
TURTLE RIVER
BRUNSWICK
ST. SIMONS ISLAND
LITTLE ST. SIMONS ISLAND
SEA ISLAND
ST. SIMONS SOUND
ATLANTIC OCEAN
COLONELS ISLAND
JEKYLL ISLAND
GLYNN COUNTY
ADVISORY AREA
Consumption Guidelines for Advisory Area
NO LIMIT – EAT AS OFTEN AS YOU LIKE
Shrimp*
EAT ONLY ONCE PER WEEK
Red Drum (Red Fish)
Blue Crab
Spotted Seatrout
Flounder
EAT ONLY ONCE PER MONTH
Spot*
Black Drum
Striped Mullet*
Whiting
Atlantic Croaker*
Sheepshead
*Purvis and Gibson Creeks and the adjoining area of Turtle River: Eat Shrimp only once per month; Do not eat Atlantic Croaker, Spot, or Striped Mullet. Terry and Dupree Creeks: Do not eat Spot. Buffalo River: Do not eat Striped Mullet.

APPENDIX E

EPA's Quadrant Mapping/Sampling Unit Method for Dioxins Collected in 2011 and ATSDR's Sampling Area Designations

Honeywell divided the site into 4 separate quadrants, which is consistent with the sampling design used in the Human Health Risk Assessment for the site (EPS 2010). Each quadrant contained 1 to 3 different sampling units. Incremental Sampling Methodology (ISM) samples were collected from each sampling unit within each quadrant. Each ISM sample was comprised of multiple equal-mass aliquots of soil collected from 0 to 3 inches below ground surface. For each sampling unit, a replicate sample was taken; two replicates were taken in sampling unit 1. A total of three (2 of which were replicates) ISM samples were collected from Quadrant 1. A total of six (3 of which are replicates) ISM samples, two per sampling unit, were collected from Quadrants 2, 3 and 4 (EPS 2011). ATSDR selected the higher of the two replicate sampling results in our evaluation.

Figure 12 illustrates the quadrants and sampling units established by Honeywell for the site.

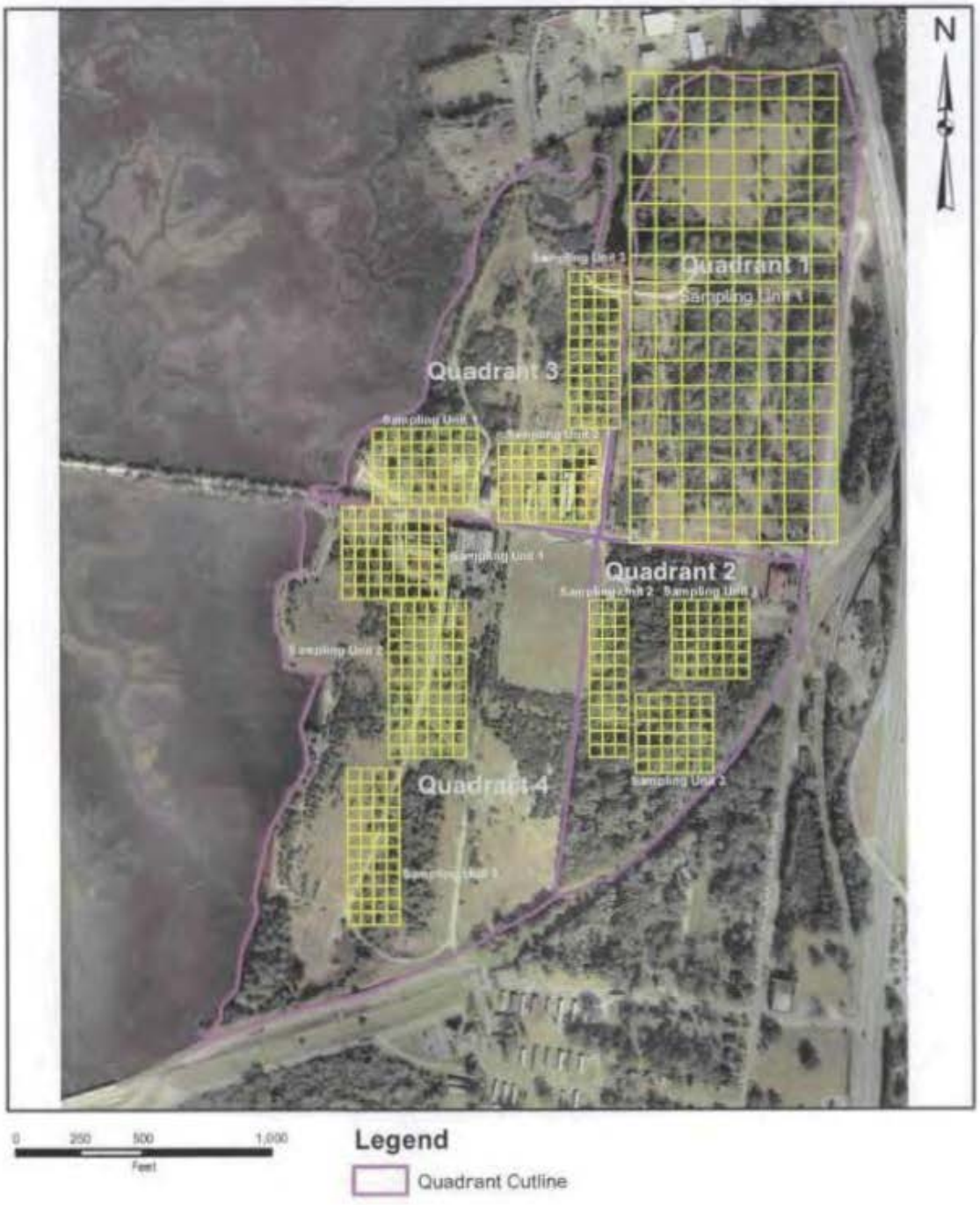
ATSDR consecutively numbered the sampling units (1 through 10) for ease of description. ATSDR's numbering system goes from left to right, top to bottom.

For comparison purposes, the table below shows Honeywell's sampling units and the corresponding numbered sampling area used by ATSDR:

Table 9. Honeywell's sampling units and ATSDR's sampling areas

Honeywell's Quadrant	*Equals*	*ATSDR's Sampling Area Designation*
Quadrant 3, Sampling Unit 1	=	1
Quadrant 3, Sampling Unit 2	=	2
Quadrant 3, Sampling Unit 3	=	3
Quadrant 1, Sampling Unit 1	=	4
Quadrant 4, Sampling Unit 1	=	5
Quadrant 4, Sampling Unit 2	=	6
Quadrant 4, Sampling Unit 3	=	7
Quadrant 2, Sampling Unit 2	=	8
Quadrant 2, Sampling Unit 3	=	9
Quadrant 2, Sampling Unit 1	=	10

Figure 12. LCP Chemicals Site Showing EPA Quadrants and Sampling Units



APPENDIX F
RESPONSE TO COMMENTS

ATSDR released this public health assessment in September 2010 for public comment. We received and responded to comments (shown below) and made changes to the public assessment, as appropriate. The page numbers cited in the responses that follow are to the 2010 public comment release of this public health assessment.

1. **Comment**: The PHA places undue emphasis on a hypothetical future use of the LCP property as a residential development. The PHA fails to acknowledge that the LCP Chemicals Site has been used in an industrial capacity for the last 100 years and that the property remains zoned for commercial/industrial use. The current property owner (Honeywell) has no intention of developing the property for residential use and will be placing institutional controls on the property, restricting future use of the property for commercial use only.

   ATSDR Response: ATSDR's evaluation included residential development as a future use because residential development was considered in EPA's assessment of the property (e.g., EPA's draft Human Health Risk Assessment considers a future on-site resident in the exposure assessment) and because residential use has not been ruled out. Although Honeywell claims in some reports that the site is intended to remain industrial, they acknowledge the potential for some mixed land use of the property and/or the possibility that some portion of the site might be used as residential property in the future. Therefore, ATSDR believes it prudent to evaluate all possible future scenarios to be protective of public health.

2. **Comment**: There are a number of statements in Section II.B. (Site History) for which the Draft Remedial Investigation/Feasibility Study (RI/FS) Report for Operable Unit 3 (OU3) (i.e., "EPS 2007b") is cited. Most of the statements attributed to that reference misrepresent information and/or specific statements presented therein[7]. The PHA should be revised in a manner that either removes all such "EPS 2007b" citations in Section II.B. Alternatively, the wording in Section II.B should be altered in a manner to accurately reflect the wording from the cited documents[8].

[7] Some examples of improper citations occurs on page 2 of the PHA, bullets 1, 2, 4, and 5 with respect to "releases" and references to "large quantities". EPS 2007b is also mis-referenced on page 16 of the PHA where the statement begins "Wastes laced with contaminants…".

[8] Please also note that there appear to be several instances of improper citation references in the document. For example, the first citation of an "EPS 2007" reference appears on page 2; however it is listed with a "b" suffix. The citation of "EPS 2007a" does not appear until page 15. The "a" and "b" suffixes on these references should be reversed. In Section II.B (page 2), there is a citation of "EPA 2007b." There is no "EPA 2007b" in the reference list and given its proximity to the other "EPS 2007b" citations, it is likely that the ATSDR intended to cite "EPS 2007b." There are also numerous citations of "EPA 2009" within Section II. There are four EPA 2009 references in the reference list (each labeled with a, b, c, or d suffix). However, none of these references seem likely to support the statements attributed to the "EPA 2009"

ATSDR Response: This section has been revised.

3. **Comment**: There are a number of statements in the PHA that describe residual contaminated soil within the footprint of the former cell building (e.g., pages 24, 28, 29, 85, 86, 105). None of these statements acknowledge that the cell buildings were razed and the entire area capped and enclosed with a chain link fence as part of the EPA Removal Action in 1994-97. This cap and chain link fence surrounding the area is an effective barrier to human exposure to conditions in the underlying soil (that were also characterized as part of the site investigation). By ignoring the cap and fence, ATSDR's conclusion that there is "a health concern if the site becomes commercial or industrial in the future" (page 105, Figure 22) overstates the risk in at least five of the nine grids. Section IV.C.1, which describes the decommissioning and removal actions in the cell building area, should describe the construction of the soil cap over the razed structures and the chain link fence surrounding this area. The PHA figures should also be modified accordingly.

ATSDR Response: Several sections were revised to acknowledge the construction of the soil cap over the razed cell building structures and the installation of the chain link fence.

Also, we did consider the soil cap and fence in our evaluation of the site. Although we believe that exposures may be mitigated by the presence of the cap and fence in the short term, we think it important to acknowledge the presence of significant residual contamination in case land use changes are considered for the future. The cell building area should be carefully re-evaluated and further characterized if structures are to be built on or near the capped area in the future.

4. **Comment**: The PHA correctly identifies Aroclor 1268 as the primary form of polychlorinated biphenyl (PCB) present in site soils. Neither EPA nor ATSDR, however, have developed default toxicity criteria for Aroclor 1268. The PHA evaluates the Aroclor 1268 using the toxicity criteria developed by those agencies for Aroclor 1254 and goes on to generically characterize the "uncertainty" associated with the toxicological evaluation of Aroclor 1268. There is evidence in the scientific literature to support the conclusion that Aroclor 1268 is considerably less toxic than Aroclor 1254.[9,10] The PHA should be revised to acknowledge that

---

citation in Section II. The March 31, 2009 Addendum to the Human Health Baseline Risk Assessment appears in the reference list as "EPS 2009", but is never cited in the document.

[9] Warren, D. A., Kerger, B. D., Britt, J. K. and James, R. C. (2004). Development of an oral cancer slope factor for Aroclor 1268. *Regulatory Toxicology and Pharmacology,* 40: 42-53.

the "uncertainty" associated with the use of the Aroclor 1254 toxicity criteria to evaluate Aroclor 1268 results in a more conservative assessment of potential toxicity.

ATSDR Response: In the absence of substantial toxicity data on Aroclor 1268, it is prudent public health practice to use health guidelines and toxicity information from other mixtures of Aroclor. This approach is commonly used by public health agencies to evaluate Aroclor mixtures. The articles cited by the commenter also have considerable uncertainty so it is not certain that Aroclor 1268 is less toxic than Aroclor 1254. ATSDR has appropriately acknowledged the uncertainty in using health guidelines and toxicity information for Aroclor 1254. ATSDR did not make the suggested change.

5. **Comment**: Section IV.E.2 discusses the presence of "clinker material" at a residential property on Clairmont Lane and suggests that this area be investigated (see page 115). As described in the PHA, the presence of clinker material was the subject of an investigation and removal action conducted by Georgia Environmental Protection Division in 2004. Neither that investigation nor this PHA present demonstrable evidence linking the clinker material to the LCP Chemicals Site. In fact, the material is common to many industrial operations and is known to be associated with other industrial sites in Brunswick. Given that its relevance to this PHA has not been established, it should be removed from the PHA.

ATSDR Response: In the PHA, ATSDR maintains that the alleged disposal sites may not be associated with the LCP Chemicals site. We elected to include the suspected disposal areas in this document because community members raised concerns regarding these areas and because some evidence exists to suggest a connection with past industrial activities in the area, not limited to activity by LCP Chemicals.

6. **Comment**: ATSDR created half-acre grids as "exposure units" that were used to segregate and evaluate the site sampling data. The use of a small exposure unit grid results in the conclusion that many of the grids lack sufficient data to characterize the condition of each grid. This analysis fails to acknowledge that many areas of the site, however, did not warrant the same density of site characterization as did other areas of the site, because of a lack of historical industrial activity in those areas. ATSDR should consider using a more appropriate grid size such as one-acre grids so that there would be fewer instances where ATSDR concludes that there was a "lack of sufficient data".

ATSDR Response: While it is known that industrial activity occurred predominantly in the western portion of the LCP property, on-site disposal of

[10] Simon, T., Britt, J. K. and James, R. C. (2007). Development of a neurotoxic equivalence scheme of relative potency for assessing the risk of PCB mixtures. *Regulatory Toxicology and Pharmacology,* 48: 148-170.

industrial waste could have occurred anywhere on the property during the 83 years that industrial operations took place. The disposal locations are uncertain for the first half of the 20th century when petroleum refining (1919-1935), electric generation (1937-1950s), and paint and varnish manufacturing (1941-1955) took place. The chlor-alkali operations clearly took place in the western portion of the site, although disposal of waste could have occurred anywhere on the property even during these operations. This information is described in more detail the background section of the PHA.

In addition, increasing the grid size to one acre will not change substantially the conclusion that eastern portions of the site are poorly characterized. The basis for half-acre grids is the assumption that the site could be developed for residential, commercial, or industrial activity. Without specific information on future land use, the most prudent grid size to evaluate human exposure is a half-acre. ATSDR did not make the suggested change.

7. Comment: In this PHA the evaluation of potential health effects associated with lead exposure in site soil includes the derivation of a soil lead comparison level of 141 ppm based on the EPA's Integrated Exposure Uptake Biokinetic (IEUBK) model, using the model's default input parameters and a target of 5% of children's blood lead levels exceeding 5 µg/dL. The use of this blood lead target for this purpose is not consistent with Centers for Disease Control (CDC), EPA guidance, and standard practice. The CDC established 10 µg/dL as its "blood lead level of concern" in 1991, and a revision of the 10 µg/dL level of concern was considered and rejected by CDC's Advisory Committee on Childhood Lead Poisoning and Prevention (ACCLP) in 2005. The ACCLP revisited this issue at a recent meeting,[11] without reaching consensus. The committee voted to form a working group to study the issue further. The EPA has long relied on the 10 µg/dL level of concern for establishing cleanup levels for lead in soils and there is no evidence that these levels are not protective of public health. In fact, one of the primary issues confronting the CDC as it considers revisions to the [sic] its level of concern is that no effective interventions have been demonstrated to further reduce blood lead levels in children who already have levels at or below 10 µg/dL.[12] Given this set of circumstances, the ATSDR's use of a 5 µg/dL target blood lead level to draw conclusions about the need for remedial actions to protect the health of hypothetical future residents is arbitrary and out of step with current policy and guidance from the EPA and CDC

ATSDR Response: **On January 4, 2012, CDC's Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) recommended that CDC adopt the 97.5 percentile for children 1 to 5 years old as the reference value for designating elevated blood lead levels in children. The 97.5% currently is 5**

[11] The ACCLP meeting was held in Atlanta, Georgia on November 16-18, 2010.

[12] Brown, MJ and Rhodes, GG. (2008). Guest Editorial: Responding to Blood Lead Levels <10 µg/dL, Environmental Health Perspectives, 116: A60-A61

µg/dL. This came about because of the numerous studies that show health effects at levels below 10 µg/dL. Furthermore, the advisory committee recommended that CDC stop using the phrase 'blood lead level of concern.' (ACCLPP 2012)[13]. The advisory committee's report to CDC and CDC's response is available at http://www.cdc.gov/nceh/lead/acclpp/acclpp_main.htm.

CDC has accepted the advisory committee's recommendation, has dropped the use of the term, 'level of concern', and has adopted the 97.5th percentile as CDC's reference value for lead.

In addition, in a letter dated January 16, 2008 from Dr. Henry Falk (Director, Coordinating Center for Environmental Health and Injury Prevention, CDC) to Mr. Robert Meyers, (Principal Deputy Assistant Administrator, EPA), CDC comments on EPA's use of 10 µg/dL in the IEUBK model to derive the national ambient air quality standard for lead[14]. CDC points out that CDC has developed several blood lead levels (BLL) where CDC recommends public health action (e.g., > 70 µg/dL, > 45 µg/dL, > 15 µg/dL, and 10 µg/dL). Thus, CDC states, "there is no single CDC level of concern". CDC further states that 10 µg/dL should not be used as a safe level, and that 10 µg/dL has frequently been misinterpreted as a toxicological threshold. CDC cautions that using 10 µg/dL as a target for deriving lead standards (and by inference soil clean up level) is an inappropriate interpretation of CDC's historical 10 µg/dL. CDC states that the use of 10 µg/dL in EPA's IEUBK model could needlessly expose children to levels of lead known to adversely affect academic performance and success later in life.

Because CDC's current reference level for lead in children is 5 µg/dL, ATSDR did not make the suggested change.

8. **Comment**: Excerpt from LCP PHA, Site History, Page 2 –

> "ARCO Petroleum (1919-1935), a successor of the Atlantic Refining Company, operated the site as a petroleum refinery that refined crude oil into fuel and oils. At one time, over 100 process and storage tanks were present on site. ARCO is reported to have released large amounts of petroleum products and wastes onto the ground (EPS 2007b)."

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[13] [ACCLPP] Advisory Committee for Childhood Lead Poisoning Prevention. 2012. Low Level Lead Exposure Harms Children: A Renewed Call for Primary Prevention, Report of the Advisory Committee on Childhood Lead Poisoning Prevention of the Centers for Disease Control and Prevention, January 4. Available at http://www.cdc.gov/nceh/lead/acclpp/acclpp_main.htm. [accessed 5 May 2013].

[14] Falk H. 2008. Letter from Henry Falk, Coordinating Center for Environmental Health and Injury Prevention, CDC, to Robert J. Meyers, Principal Deputy Assistant Administrator, US EPA, Washington DC. January 16.

The boundaries of operations on the site during the 1919 to 1935 period have not been described. Areas that are now considered to be off-site are actually part of the original ARCO Petroleum operations area. The boundaries of the site for each operational period described in the Site History section of the Public Health Assessment (PHA) should be described and figures produced and included. Figure A4 should also be accompanied by figures of the land boundaries for all operational periods in the Site History section.

ATSDR Response: It is beyond the scope of the PHA to define and describe all historical site boundaries and it is not needed to perform the evaluation of current on-site and off-site locations. Therefore, this suggestion was not implemented. For example, the current boundaries of the Superfund site, as described by EPA Region 4, do not encompass all the areas where tanks were historically located. However, we still evaluated soil sample results available for these off-site areas. See Figure A6.

9. **Comment**: The commenter served on the seafood consumption advisory group formed to consult and review the results of a seafood consumption study in Brunswick conducted by the state health department.[15] The Principal Investigator of the study was taken to the subsistence fishing areas on the Brunswick peninsula and an effort was made to introduce her to the subsistence fishers. The study design was changed to select only those that owned boats and fished from boats, even though the advisory group objected. The commenter is concerned that the participants in the study do not represent the African-American community and subsistence fishers in the area.

ATSDR Response: The study was conducted by the Glynn County Health Department through a cooperative agreement and funding from ATSDR. The study design targeted three groups: commercial, recreational, and subsistence fishers. The target groups had to meet three criteria:

1. **Consumed or caught seafood from the Turtle River or its tributaries in Glynn County;**
2. **Lived in Glynn County for at least the last two consecutive years prior to the study; and**
3. **Had not been employed at the LCP Chemicals Site since 1956, in order to exclude individuals who may have had occupational exposure to mercury.**

[15] Final Report, Consumption of Seafood and Wild Game Contaminated with Mercury – July 1999.

Much effort went into finding local fishers using multiple methods to identify the target groups. The various methods include:

- **6,200 surveys were distributed to local schools, businesses, agencies, industries, community groups, churches, and professional and civic organizations.**
- **Residents in private homes in the target geographical areas were contacted by door-to-door canvassing**
- **Screening surveys were left at homes of those who could not be contacted during the door-to-door canvassing.**
- **Surveys were distributed at fishing piers, bridges, boat ramps, businesses, and homes adjacent to affects waterways, fish camps, bait and tackle shops, and to the local commercial seafood industry.**
- **The survey was published several times in the local newspapers and the GCHD Hazardous Waste Site Newsletter with instructions on submitting the completed survey for enrollment.**
- **Television and radio coverage was used extensively throughout the recruitment period.**

Of the 282 eligible residents in the target group of recreational, commercial, or subsistence fishers

- **214 (76%) were interviewed,**
- **156 (55%) completed a dietary diary, and**
- **139 (49%) provided urine samples.**

Of the 101 (65%) target group participants who self-reported which type of fisher they were

- **97 (96%) classified themselves as recreational fishers,**
- **3 (3%) identified as commercial, and**
- **1 (1%) identified as subsistence fisher.**

It's important to note that the study results reflect characteristics of recreational white fishers and do not necessarily apply to commercial or subsistence fishers.

No effort was made to select residents who only owned boats or who fished from boats. It should be pointed out, though, that portions of the Turtle River and its tributaries under the advisory are only accessible by boat. Several fishing areas along the shore or from a bridge are possible but the survey did not attempt to distinguish which method was used to catch fish nor was any effort made to not select persons who fish from the shore. The text already explains that the study results do not necessarily apply to the African-American community, who were underrepresented in the target study group.

10. **Comment:** This study design overlooks people of color, who are the predominant population on the Brunswick peninsula bordering the most contaminated areas and the subsistence fishing locations. The PHA correctly states, "It should be noted that African-Americans made up only 4% (9 out of 197) of the people who participated in the study; therefore, the findings of this study may not apply to the African-American community in the Brunswick area." But, the statement should be strengthened to reflect that the most likely to consume contaminated seafood and be the impacted subpopulation – the subsistence fisher population – was not included in the study. Furthermore, the study participants were aware of the advisories and by virtue of having boats could fish outside the advisory areas when obtaining seafood for consumption.

ATSDR Response: ATSDR agrees with the comment that African-Americans are underrepresented in the Brunswick fish study and has already stated this in the main text. According to the 2010 U.S. census, African-Americans make up 26% of the population of Glynn County. Within four miles of the LCP Chemicals site, African-Americans make up almost 40% of the population.

For this reason, we have used information about fish consumption from an African-American population to evaluate fish contaminant levels from the Altamaha Canal. A study of fishers along the Savannah River showed that African-Americans

- **eat more fish meals per month than whites (average, 5.4 vs. 2.9),**
- **eat larger portions than whites (average, 13.7 oz vs . 13.1), and**
- **eat more fish per month than whites (average, 75 ounces vs. 41 ounces).[16]**

It is reasonable to assume that African-Americans in Brunswick, Georgia, are similar to African-Americans along the Savannah River when it comes to fish-eating habits. Therefore, African-Americans who fish along the Turtle River are likely to have higher exposure to mercury from eating fish than whites.
The commenter states that the study participants were aware of the advisories and by virtue of having boats could fish outside the advisory areas when obtaining seafood for consumption. This statement is consistent with one of the conclusions of the Brunswick fish study, which states that most study participants do not fish in the restricted area and the few that do are aware of the advisory.

ATSDR has added several of these points to the main text of the PHA.

11. **Comment:** Regarding the Brunswick fish study, the conclusions of the Glynn County Health Department are of little value and might mislead the public and lead to underestimating the risks from consuming contaminated seafood.

[16] Burger J, Stephens WL, Boring CS, et al. 1999. Factors in exposure assessment: ethnic and socioeconomic differences in fishing and consumption of fish caught along the Savannah River.

Therefore, ATSDR should consider clarifying language in this section to fully reveal the significant flaws in the study methods.

ATSDR Response: The conclusions in the Brunswick fish study apply to persons who responded to the survey and to some extent to non-responders with similar demographic variables. It should not be applied to African-Americans who may fish in restricted areas of the Turtle River and its tributaries. ATSDR has modified the text to make this point more clear.

12. **Comment**: There were other significant flaws in the study, such as educating the study participants to the risk from contaminated seafood prior to the 24 hour urine collection.

ATSDR Response: Awareness of the fish advisory was present long before the Brunswick fish study was conducted. It is not possible to avoid some of the bias that comes with knowing about the dangers of mercury in fish and the effect that knowledge may have had on someone's fish-eating habits. The timeline of events for the study included the following in this order:

- **Administer a screening survey to identify target and control groups,**
- **Administer a detailed survey to identify signs/symptoms and diseases as well as details of fish catching and eating habits,**
- **Complete a dietary diary over a two-week period,**
- **Collect a 24-hr urine sample.**

Additional bias could have been introduced because persons may have changed their fish-eating habits during the two week dietary period when study participants monitored their own fish intake. Even so, the dietary diary showed that residents tended to underestimate their fish intake when filling out those parts of the detailed survey that dealt with their fish consumption. Additional information has been added to the main text of the PHA.

13. **Comment**: Hair testing would have provided a history of exposure and interjected less bias into the study methods and design.

ATSDR Response: Blood and hair testing are more appropriate methods for identifying exposure to methylmercury from fish consumption. The Brunswick fish study decided to use urine to monitor mercury levels for two reasons. First, 10% to 30% of organic (e.g., methyl) mercury may be excreted in the urine. Therefore, the investigators thought that the large amounts of mercury in fish would still show up in fish consumers as elevated mercury urine levels. Secondly, the investigators thought that participation would be higher if non-invasive urine samples were required rather than invasive blood samples. In addition, there could have been problems with collecting hair samples in some older men because of insufficient hair for a sample.

Unfortunately, collecting urine samples diminishes the ability to identify low to moderately exposed individuals. In addition, the selection of 20 ug/L as a reference value was too high. Although not available at the time of the 1999 Brunswick fish study, the 4th National Report on Human Exposure to Environmental Chemicals shows that 2 or 3 ug/L (or 2 ug/g creatinine) would be a more appropriate reference level to identify excessively exposed individuals. The following levels are reported by the 4th National Report for the three 2-year reporting periods covering 2003 to 2008:

	Geo Mean	95th percentile
Urinary Mercury µg/L	**0.44-0.47**	**2.6-3.2 µg/L**
Urinary Mercury µg/g creatinine	**0.44-0.46**	**2.3 µg/g**

The 4th National Report is available at this web address: http://www.cdc.gov/exposurereport.

Additional information has been added to the main text of the LCP PHA.

14. Comment: The section on page 22 of the PHA concerning PCBs should include a section "How PCBs Were Used at the Site". The graphite anodes impregnated with PCBs were used in the chlor-alkali cells. Electricity was passed through the anode to crack the salt brine solution into chlorine, and caustic soda. The electric current created great heat and produced byproducts such as hydrogen and dioxin/furan. Within the chlor-alkali cells, the PCBs were exposed to heat and chlorine as the graphite anode was consumed. Further clarification about how dioxin/furans are produced during the chlor-alkali process, and why dioxin/furans can be presumed to be co-located with PCBs should be included in the PHA. Furthermore, a clear statement that testing for dioxin/furans is needed on the uplands before further residential or commercial development should be included in the section concerning PCBs, dioxin, and in the conclusions and recommendations.

ATSDR Response: Generally, specific comments regarding chemical production and/or use at a site are determined by the regulatory agency conducting the environmental investigation. Although we can include general information about the chlor-alkali process, we do not have specific information about how the chemicals were produced or used at *this* site. Therefore, we would refer the commenter to EPA documents for a more specific explanation of the chlor-alkali process.

We were able to use third party studies and professional experiences to make the case for why dioxins/furans are presumed to be co-located with PCBs. We cite the evidence we used to support our conclusion.

Honeywell conducted further sampling for dioxins in upland soils in 2011. ATSDR evaluated that data and provided recommendations and conclusions based on our evaluation of the data.

15. **Comment**: The discussion of the dioxin/furan group of chemicals should be included in the PCB section. Since PCBs and dioxin/furan were co-located, the removal action was premised upon dioxin/furan being removed with the PCBs. Therefore, the presence of PCBs is presumptive evidence of dioxin/furan. The lack of dioxin/furan data for the uplands is not "data" indicating the chemicals are not present.

ATSDR Response: Honeywell conducted further sampling for dioxins in upland soils in 2011. ATSDR evaluated that data and provided recommendations and conclusions based on our evaluation of the data.

16. Comment: Excerpt from page 43 of the PHA:

"A total of 45 samples were tested for dioxins. Of the 45 samples tested, 6 were surface water samples and 1 was a groundwater sample. Two sediment samples were collected to determine background concentrations. The 36 remaining samples were sediment samples collected from the marsh and from selected off-site locations. " "…Dioxin concentrations in sediment ranged from non-detect to 0.003 ppm. ATSDR's comparison value for dioxin in soil is 0.00005 ppm. Eight samples exceeded ATSDR's comparison value of 0.00005 ppm. No samples for dioxins were collected from the dry-land area."

The source areas for the dioxin found in sediment and surface water can reasonably be expected to be on the upland portions of the site, and these areas should be identified prior to any commercial or residential use of the site.

ATSDR Response: Honeywell conducted further sampling for dioxins in upland soils in 2011. ATSDR evaluated that data and provided recommendations and conclusions based on our evaluation of the data.

17. **Comment**: Excerpt from LCP PHA, Residual Mercury Levels in Soil, Page 29

"The maximum mercury concentration at the site from a single soil sample is 10,400 ppm and is located in the footprint of the cell building area (Grid #113). The highest average mercury concentration for any grid (Grid #113) is 1,470 ppm and is also located in the former cell building area."

The PHA authors have correctly noted that the Cell Building area is poorly characterized. Still, the testing conducted found 10,400 ppm, or 1.4% mercury in the soils. Considering that the mercury leaked to a cement floor and then flowed through cracks in the concrete, even higher levels could be present in the soil

below the Cell Building area. The sampling did not extend further than 5 feet (also around the groundwater table), which means the potential for significant amounts of mercury below the groundwater table exists. More vertical and horizontal characterization is needed in the Cell Building area and should be recommended in the PHA.

ATSDR Response: We acknowledge the lack of proper characterization of the cell building area and recommend additional sampling should the area be considered for future development.

18. **Comment**: The PHA should note that excavation activities in the Cell Building area have the potential to expose workers and the general public. Any work in the Cell Building area should be scheduled for times of the year with the coolest temperatures.

ATSDR Response: ATSDR acknowledges that significant contamination remains beneath the cell building. EPA and/or its contractors will be responsible for developing a plan that is protective of workers and the general public during excavation activities at the site. If requested, ATSDR staff are available to review worker protection plans.

19. **Comment**: The cell building area was not analyzed as thoroughly as the other areas of the LCP Chemicals Site during the EPA Emergency Response and Removal Action since it was assumed extensive remediation would be needed in this area, which has been delayed at this point for 14 years. With soil mercury levels in excess of 1% reported and limited data, the PHA should strongly recommend another timely assessment when the data are obtained.

ATSDR Response: We acknowledge the lack of proper characterization of the cell building area and recommend additional sampling should the area ever be considered for future development.

20. **Comment**: The huge quantity of mercury in the cell building area and the very limited delineation of the vertical and horizontal extent continue to be a concern, as is the continued contaminated groundwater discharge from the uplands to the marsh. The upland contamination, groundwater, and marsh cannot be independently analyzed for risk since they are so interconnected. What happens in one unit directly affects the others.

ATSDR Response: ATSDR agrees that significant mercury contamination is likely to exist in soils beneath and adjoining the footprint of the former cell building. This soil contamination is likely still contributing to groundwater contamination beneath the footprint and is likely still migrating towards and entering the nearby marsh. Several types of risk can exist from this contamination in the environment. There could be risk from direct contact or from breathing air should the soils be disturbed or the area developed for

commercial or residential use. This risk is described in the PHA. In addition, the remaining mercury that contaminates the soil and groundwater is migrating into the marsh and continues to contribute to mercury levels in fish and shellfish from the marsh.

21. **Comment**: Excerpt from LCP PHA, Residual Dioxin Levels in the Marsh (page 42)

    "Dioxins, or chlorinated dibenzo-p-dioxins (CDDs), are a class of structurally similar chlorinated hydrocarbons. The basic structure is comprised of two benzene rings joined via two oxygen bridges at adjacent carbons on each of the benzene rings. Dioxins is a term used interchangeably with 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCCD or TCDD). TCDD is the most toxic form of the numerous dioxin compounds."

    The similarity between the structures of PCBs and Dioxin/furans should be included in this discussion. Also, a TEQ that includes the dioxin, furans, and PCBs at the site should be incorporated into the PHA.

ATSDR Response: The discussion now includes more information about the structures of PCBs and dioxins/furans. WHO TEQs have been included for dioxins/furans for upland soils sampled in 2011.

22. **Comment**: Excerpt from the LCP PHA.

    "Dioxins are not intentionally produced and have no known use. They are the by-products of various industrial processes (i.e., bleaching paper pulp, and chemical and pesticide manufacture) and combustion activities (i.e., burning household trash, forest fires, and waste incineration) (ATSDR 2006)."

    The production of dioxin/furans in the chlor-alkali process should be discussed in this section. At a minimum, how PCBs would react in the presence of heat, pressure, chlorine, oxygen, and hydrogen should be discussed.

ATSDR Response: Generally, specific comments regarding chemical production and use at a site are detailed in reports by the investigative/regulatory agency. We have included general information regarding the formation and fate of dioxins and PCBs in the environment.

23. **Comment**: The figures and tables identifying the grids of concern are a helpful tool in describing where the areas of concern are located, and where additional remedial activities are needed. The PHA is organized in a manner to present the information in an easy to understand and use format.

ATSDR Response: Thank you for the comment.

24. **Comment**: The figures with grids in the PHA are great. If you could use a color to designate the grids where there was no data to make a determination about risk, I think this would strengthen the PHA and would not infer contamination was not present. Currently, the way the PHA is written, it makes it appear the grids identified as contaminated and having risk are the only ones that need be of concern.

ATSDR Response: We have added a map that shows grids that are not adequately sampled.

25. **Comment:** The Salt Dock area is mentioned in the PHA but not discussed. PCB contaminated anodes were removed from this area. The sampling in the salt dock location was minimal and did not sample at depths over 1 foot. The PHA should note that sampling at deeper levels is needed in the Salt Dock area to determine risk from subsurface soils.

ATSDR Response: The Salt Dock area was not considered a significant potential source for exposures because the land use is industrial and the contamination, if any, is at deeper levels. Additional sampling should be considered if the land use changes.

26. **Comment**: Since significant areas of the Site have been allowed to be re-forested, significant soil disturbance should be expected with any future development activity. The PHA should note that potential for exposure and elevated surface soil contaminant levels may occur as a result of soil disturbance.

ATSDR Response: The PHA includes language which acknowledges the potential for surface and subsurface soils to be disturbed during future development. We consider all upland soils (surface and subsurface) to contribute to any potential exposures.

27. **Comment**: The lack of PCB data for the cell building area should be noted. Several more of the grids could contain elevated PCB levels since the cell building area is where the PCB impregnated anodes were used. The lack of PCB data for the cell building area, and other areas, are not data that PCBs are not present or a risk does not exist in these areas. The PHA should note this lack of data and that the adjoining grids do have elevated levels of PCBs. The grids where there is a lack of data are 72, 57, 115, 126, 127, 128, 129, 130, 150, 151, and 165. The number of grids identified as having elevated levels of PCBs (and therefore dioxin/furan) in Figure 14 on Page 66 could be much higher if the PCB data was available. The same comment applies to areas where mercury, lead, and PAH data was not present for a grid due to the lack of data.

ATSDR Response: The commenter makes a valid point. The number of grids of concern could be higher if we had adequate data to analyze for each grid.

We have now included new figures (Figures 22-26) to show the grids/areas where there is inadequate sampling data to make a health call. There are separate figures for each contaminant of concern. These figures should be considered in conjunction with the grids that are determined to be a health concern.

28. **Comment**: ATSDR was asked to consider these references concerning dioxin production and the chlor-alkali process.

    http://www.americanchemistry.com/chlorine/sec_content.asp?CID=1131&DID=5124&CTYPEID=107

    http://yosemite.epa.gov/R1/npl_pad.nsf/148bf278d6a49a3f85256aef005e1bff/94dd5df1d9c0ab95852570c20063f11a!OpenDocument

    "From the late 1800s to the 1960s, chlorine and other chemicals (e.g., caustic soda, hydrogen, chloroform) were produced using electrolytic cells in "cell houses" at the former facility. Diaphragm cells, and also possibly mercury cells, produced chlorine for use in the manufacture of paper at the adjacent pulp mill. The mercury and other contaminants associated with that process, including dioxin and PCBs, were disposed on-site."

    Env Sci Pollut Res 15 (2) 96 – 100 (2008). Dioxin – Contemporary and Future Challenges of Historical Legacies Dedicated to Prof. Dr. Otto Hutzinger, the founder of the DIOXIN Conference Series Roland Weber, Mats Tysklind and Caroline Gaus, POPs Environmental Consulting, Ulmenstrasse 3, 73035 Goeppingen, Germany, Department of Chemistry, Umeå University, 901 87 Umeå, Sweden, National Research Centre for Environmental Toxicology (EnTox), The University of Queensland, 39 Kessels Road, Coopers Plains 4108, Australia

    "The beginning of the chlorine industry and Dioxin history. It has long been recognized that significant CDDs/PCDFs (Dioxins) formation during industrial processes commenced in the early twentieth century with the chloro alkali process and the subsequent high volume production of organochlorines."

    http://www.gcmonitor.org/downloads/Dioxins_India_Study.pdf
    http://www.portaec.net/library/pollution/dioxins/dioxfaq.html "Dioxin has even been identified at the root of chlorine chemistry: in the sludges and residues from the chlor-alkali process, in which chlorine gas is produced by passing a powerful electric current through salt-water.

    http://abstracts.co.allenpress.com/pweb/setac2005/document/56870
    http://abstracts.co.allenpress.com/pweb/setac2005/document/56870

The LCP Chemicals Site is mentioned in this article (site in southeast Georgia).

ATSDR Response: Thank you for the references; they were considered.

29. **Comment**: If you could obtain the Glynn County data concerning diabetes, thyroid function and growth hormone disruption, and hepatic function, this information should be in the PHA. Also, the intelligence quotient (IQ) data for the schools serving the population within the contaminated seafood advisory area. The IQ data should be broken down by grade and school. I believe you can do this without identifying the individual schools. Socio-economic data can be used to reduce the statistical deviation of the target population.

ATSDR Response: It is not possible to link county level data for health conditions (e.g., diabetes, thyroid function, etc.) to chemical exposure from the LCP Chemicals Site (e.g., mercury, PCBs, etc.). Therefore, providing descriptive statistics about health conditions has no ability to determine whether contamination of the environment has increased rates of various health conditions (e.g., diabetes) in Glynn County. The same situation applies to descriptive data about IQ. It is not possible to identify children who were exposed to chemicals from the LCP Chemicals Site; therefore, it is not possible to determine whether contamination of the environment has decreased IQ scores in the area.

30. **Comment**: Glynn County established a tumor registry several years back. You might want to look at the data to see if there are any unusual patterns. Since the tumor registry has been recording data for several years now, there might be enough information to avoid the dreaded "Insufficient number of persons to be statistically significant".

ATSDR Response: When evaluating cancer rates for specific geographic regions (e.g., a county), it is likely that some cancer rates will be higher than expected and this will be useful information for the community. However, it would not be possible to link any increased cancer rates with possible exposure to cancer-causing chemicals from the LCP Chemicals Site. The reason for this is that we cannot identify a sufficient number of persons in the county who were exposed to cancer-causing chemicals from the LCP Chemicals Site. For this reason, ATSDR will not evaluate cancer rates at the county level.

31. **Comment**: Has there been any mercury air monitoring at the LCP Chemicals Site in the last 10 years? The information would be helpful to have in the PHA.

ATSDR Response: ATSDR is not aware of any mercury air monitoring at the LCP Chemical site.

32. **Comment**: Also, a recommendation to do monitoring during any land disturbance activities. This would support the intent to have the ROD and Consent Decree explicitly state the minimum number and placement of air monitors at the site during any remedial activity or land disturbance.

ATSDR Response: A determination regarding what monitoring, if any, is needed is made by the Agency supervising the cleanup. The details of any air monitoring plan should be made on a case-by-case basis.

33. **Comment**: Please add these studies to the PHA.

Yang CY, Wang YJ, Tsai PC, Chen PC, Tsai SJ, Guo YL *. Exposure to a mixture of polychlorinated biphenyls and polychlorinated dibenzofurans resulted in a prolonged time to pregnancy in women. Environ Health Perspect 2008;116:599-604.

Wang SL, Tsai PC, Yang CY, Guo YL*. Increased risk of diabetes and polychlorinated biphenyls and dioxins: A 24-year follow-up study of the Yucheng cohort. Diabetes Care 2008;31:1574-1579.

Hsu PC, Pan MH, Li LA, Chen CJ, Tsai SS, Guo YL*. Exposure in utero to 2,2',3,3',4,6'-hexachlorobiphenyl (PCB 132) impairs sperm function and alters testicular apoptosis-related gene expression in rat offspring. Toxicol Appl Pharmacol 2007;221:68-75.

Hsu JF, Guo YL, Liu CH, Hu SC, Wang JN, Liao PC. A comparison of PCDD/PCDFs exposure in infants via formula milk or breast milk feeding. Chemosphere 2007;66:311–319.

Chen HL, Su HJ, Wang YJ, Guo YL, Liao PC, Chen CH, Lee CC. Interactive effects between CYP1A1 genotypes and environmental polychlorinated dibenzo-p-dioxins and dibenzofurans exposures on liver function profile. J Toxicol Environ Health 2006;69:269-281.

Lambert GH, Needham LL, Turner W, Patterson DG, Lai TJ, Guo YL*. Induced CYP1A2 activity as a phenotypic biomarker in humans highly exposed to certain PCBs/PCDFs. Environ Sci Technol 2006;40:6176-6180.

Chen HL, Su HJ, Guo YL, Liao PC, Hung CF, Lee CC. Biochemistry examinations and health disorder evaluation of Taiwanese living near incinerators and with low serum PCDD/Fs levels. Sci Total Environ 2006;366:538-548.

Tsai PC, Huang WY, Lee YC, Chan SH, Guo YL*. Genetic polymorphisms in CYP1A1 and GSTM1 predispose humans to PCBs/PCDFs-induced skin lesions. Chemosphere 2006;63:1410-1418.

Lee CC, Yao YJ, Chen HL, Guo YL, Su HJ. Fatty liver and hepatic function for residents with markedly high serum PCDD/Fs levels in Taiwan. J Toxicol Environ Health 2006;69:367-380.

Yang CY, Yu ML, Guo HR, Lai TJ, Hsu CC, Lambert GH, Guo YL*. The endocrine and reproductive function of the female Yucheng adolescents prenatally exposed to PCBs/PCDFs. Chemosphere 2005;61:355-360.

Wang SL, Su PH, Jong SB, Guo YL, Chou WL, Päpke O. In utero exposure to dioxins and polychlorinated biphenyls and its relations to thyroid function and growth hormone in newborns. Environ Health Perspect 2005;113;1645-1650.

Hsu PC, Lai TJ, Guo NW, Lambert GH, Guo YL*. Serum hormones in boys prenatally exposed to polychlorinated biphenyls and dibenzofurans. J Toxicol Environ Health A 2005;68:1447-1456.

Guo YL, Lambert GH, Hsu CC, Hsu MML. Yucheng: Health effects of prenatal exposure to polychlorinated biphenyls and dibenzofurans. Int Arch Occup Env Health 2004;77:153-158.

Hsu PC, Huang WY, Yao WJ, Wu MH, Guo YL*, Lambert GH. Sperm changes in men exposed to polychlorinated biphenyls and dibenzofurans. JAMA 2003;289:2943-2944.

Lai TJ, Liu XC, Guo YL*, Guo NW, Yu ML, Hsu CC, Rogan WJ. A cohort study of behavioral problems and intelligence in children with high prenatal polychlorinated biphenyls exposure. Arch General Psychiat, 2002;59:1061-1066.

ATSDR Response: When deciding what PCB-induced harmful effects that residents might experience should the site become residential, ATSDR estimated the amount of their PCB exposure (or dose) from soil ingestion. A toxicologist from ATSDR then reviewed the literature to identify harmful effects that might be possible based on these site-specific, estimated doses from future exposure. The discussion of possible harmful effects was limited to those effects that might occur at or near the site-specific estimated doses. The possible health effects are described in the text and a summary of the human and animal studies that served as a basis for the described health effects are provided in Appendix B in Table B2 and Table B3. If appropriate, these articles will be added to the public health assessment.

34. **Comment**: At a minimum, the PHA should identify all areas where there is insufficient data for one or more chemicals, metals, or other hazards (all on one map, and in the text). A section for just data deficiencies would be desirable and helpful for the RI/FS and post removal sampling.

ATSDR Response: The PHA now includes a discussion regarding areas where sampling is inadequate to make public health decisions. The PHA also includes maps that identify those areas of sufficient and insufficient sampling.

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Distribution and sources of PCBs (Aroclor 1268) in the Sapelo Island National Estuarine Research Reserve

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Abstract Aroclor 1268 is a highly chlorinated PCB mixture that was released into the aquatic environment near Brunswick, GA (BR), as a result of decades of local industrial activity. This extensive contamination has led to US EPA Superfund designation in estuarine areas in and around Purvis Creek, GA. Roughly 50 km to the northeast is the Sapelo Island National Estuarine Research Reserve (SI) where previous studies have documented unexpectedly high Aroclor 1268-like PCB levels in blubber and plasma samples of resident bottlenose dolphins. This result led to a collaborative effort to assess the PCB patterns and concentrations in SI sediment and fish (as potential vectors for PCB transfer to SI resident dolphins). Thirty SI randomly assigned stations were sampled for sediment PCB levels. Additionally, fish were collected and analyzed from SI (n=31) and BR (n=33). Results were pooled with regional assessments of PCB concentrations from South Carolina and North Carolina in an effort to determine the association of Aroclor 1268 levels in SI samples. Results indicated that PCB levels in sediment and fish are much lower in the SI estuary compared to BR sediment and fish concentrations. However, PCB congener profiles for both sediments and fish were similar between the two locations and consistent with the Aroclor 1268 signature, indicating possible transport from the Brunswick area. A likely source of Aroclor 1268 in dolphins from SI is contaminated fish prey.

Keywords Aroclor 1268 · PCB · Regional assessment · Sapelo Island NERRs

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Introduction

Numerous environmental studies have described the magnitude and distribution of PCBs attributed to Aroclor 1268 contamination in the Brunswick, GA, area attributed to the LCP Superfund site (Kannan et al. 1997, 1998; Maruya and Lee 1998). This site was listed on the US EPA National Priorities List (Superfund) in 1994 after nearly 75 years of industrial activities. Contaminants of concern at this site include several metals (Hg, Cr, and Pb) as well as PAHs and PCBs (Aroclor 1268). Aroclor 1268 is an uncommon mixture of PCB congeners dominated by octa- through deca-chlorinated homolog groups (>90 % of total PCB content) (Ishikawa et al. 2007; Kannan et al. 1997). The composition of Aroclor 1268 is dominated by a suite of PCB congeners (IUPAC nomenclature) including 180, 187, 194, 196, 199, 200, 201 202, 206, 207, 208, and 209. Environmental sampling in and around Brunswick, GA, has revealed high levels of Aroclor 1268 contamination in sediments, invertebrates (blue crab), commercially important fishes, turtles, birds, (Kannan et al. 1998) as well as bottlenose dolphins (Balmer et al. 2011; Kucklick et al. 2011, Pulster et al. 2009).

Sapelo Island (SI) is a barrier island located roughly 50 km northeast of the LCP site. SI is mostly undeveloped and is home to NOAA's Sapelo Island National Estuarine Research Reserve (SI NERR). This reserve was established in 1976, but this designation follows decades of agricultural use beginning in the 1800s as well as conservation and land-management efforts led by the State of Georgia. Historically, SI has been lightly populated and used mainly for agriculture and coastal environmental/ecological research (SI NERR Management Plan 2008). In 2007 and 2008, blubber samples from bottlenose dolphins resident to the SI NERR were reported to have elevated levels of PCBs (Kucklick et al. 2011) and these elevated levels of PCBs were suggested to be associated with Aroclor 1268 contamination from the LCP site (Balmer et al. 2011). To date, the levels of PCBs reported in dolphins from the SI estuary are some of the highest values reported for coastal dolphin studies (Kucklick et al. 2011) and in contrast to the undeveloped nature of SI.

The present study was undertaken to characterize the distribution and congener composition of PCBs in sediments and fish in the SI NERR in order to investigate possible linkages between the previously documented PCB concentrations in dolphins and Aroclor 1268 contamination at the LCP Superfund site in Brunswick, GA. The study was a component of a larger study that examined the overall ecological condition of the SI NERR (Balthis et al. 2012). A reserve-wide assessment of ecological conditions, including concentration of chemical contaminants, was lacking prior to this study.

Methods

Station assignment, sample collection, and preservation

Sampling stations (n=30) were randomly assigned within the SI NERR boundary using a generalized stratified methodology detailed in Balthis et al. (2012). Sediment samples were collected during June 2009 from each station (Fig. 1a.) using a 0.04-m^2 Young grab sampler. The top 2–3 cm from multiple grabs at each station was removed, composited for analysis, and frozen. While on station, researchers attempted to collect

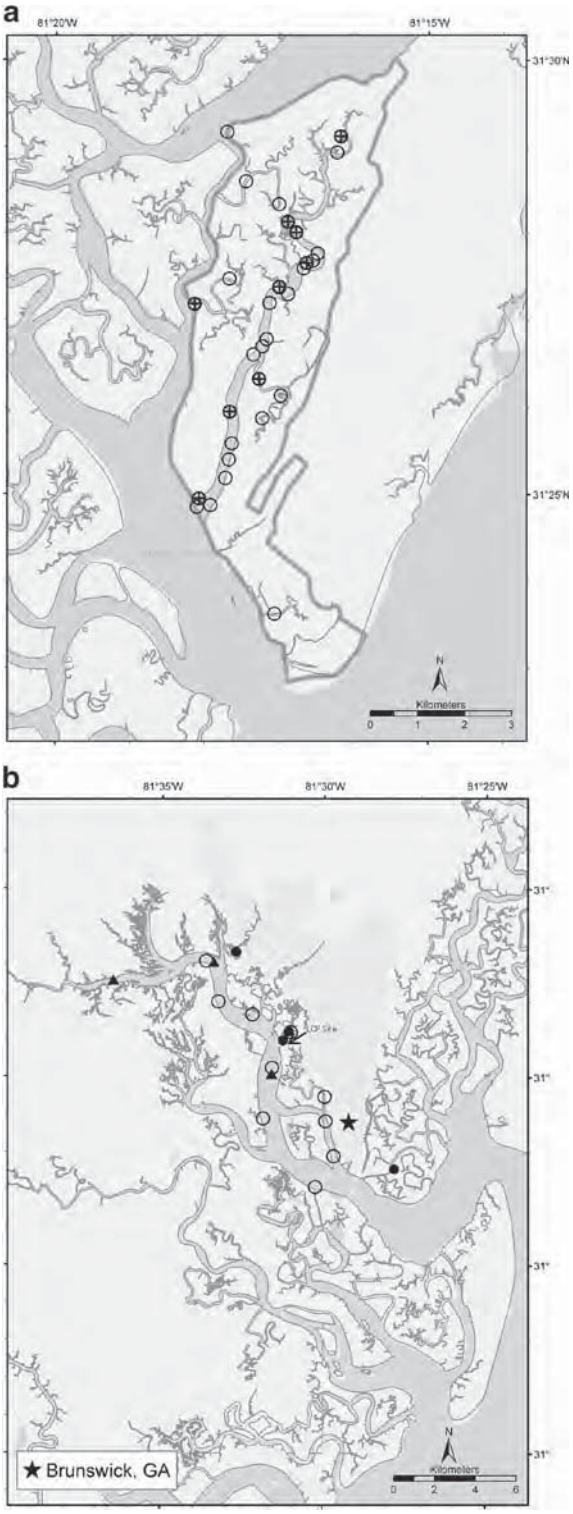

Fig. 1 **a** Sampling stations from within the Sapelo Island NERR; *open circles* are stations where sediment was collected; *cross-hatched circles* are stations where sediment and fish were collected. **b** Stations from the greater Brunswick, GA, estuarine system. *Open circles* are archival sediment samples, *closed triangles* are stations where fish were collected by GA DNR (7/2009), *closed circles* are stations where fish were collected by the authors for this study

specific species of fish by either hook and line or cast net. Targeted species included *Mugil cephalus* (striped mullet), *Micropogonias undulatus* (Atlantic croaker), *Cynoscion nebulosus* (spotted seatrout), *Paralichthys lethostigma* (southern flounder), *Sciaenops ocellatus* (red drum), *Menticirrhus sp*. (whiting), *Bairdiella chrysoura* (silver perch), and *Leiostomus sp*. (spot) based on human recreational consumption or predation by dolphin. Individual fish were wrapped in solvent-rinsed aluminum foil, frozen, and transported to the laboratory. Concurrently and in order to reduce collection costs during this field study, similar fish species were also captured by cast net or obtained from Georgia Department of Natural Resources Annual Shrimp Trawls from estuarine locations near the LCP Superfund site (Fig. 1b.). All samples were transported to National Centers for Coastal Ocean Science (NCCOS) laboratories in Charleston, SC, and stored frozen (−40 °C) until analyzed. Sediment was not collected from Brunswick, GA, estuaries during this study, although sediment from the Turtle-Brunswick River Estuary (TBRE) near the LCP site was previously collected by NOAA staff and has been consistently maintained at the Charleston, SC, facility since collection in 1996 (Long et al. 1998). These archival samples were re-extracted and analyzed for this study to serve as a positive environmental Aroclor 1268 signature.

Sediment extraction and analysis

Sediment samples were thawed and approximately 10 g of wet sediment was extracted using pressurized fluid extraction (PFE) (ASE 200, Dionex Inc.). Prior to extraction, each sediment aliquot was combined with ~27 g of anhydrous sodium sulfate and homogenized using a mortar and pestle. The dried mixture was transferred into a 33 mL ASE cell and spiked with a suite of labeled ^{13}C-PCB congeners (Cambridge Isotope Laboratory, Inc.) and extracted with a mixture of dichloromethane and acetone (50:50 volume fraction). The volume of the resulting extract was reduced under nitrogen and passed through an SX-3 gel permeation column (GPC, J2 Scientific, Inc.) to remove lipids, pigments, and sulfur. Post-GPC extracts were again evaporated under nitrogen to ~1 mL and further cleaned via solid phase extraction (SPE) using ~2 g of 5 % water-deactivated alumina. The final extract was solvent exchanged into hexane and the final volume was adjusted to ~0.5 mL. A recovery standard (^{13}C-δ-hexachlorocyclohexane) was added prior to instrumental analysis in order to evaluate extracted internal standard recoveries.

Tissue preparation and fillet analysis

Fish were prepared by partially thawing the fish, descaling, and removing each fillet with the skin included. At least 20 g of tissue was required for homogenization in Teflon™ containers using a ProScientific Tissue Homogenizer with a titanium or stainless-steel homogenization probe. Wet tissues (~5 g) were weighed into anhydrous sodium sulfate (~33 g) and ground to dryness. Dried samples were transferred into 33 mL ASE extraction cells, spiked with internal standard as above, and samples were extracted by PFE with 100 % dichloromethane. Samples were passed through GPC and SPE cleanup steps, and the final extract was solvent exchanged into hexane. The final volume was diluted to ~0.5 mL. Prior to instrumental analysis, ^{13}C-δ-HCH was also added as a recovery standard to these extractions.

Sample analysis and data quality assurance

Samples were analyzed using an Agilent 6890 GC equipped with a 5973 Mass Selective Detector (MSD; EI mode). GC parameters included a DB-5ms column (J&W; 30 m×0.25 mm diameter×0.25-μm film thickness) and a Programmable Temperature Vaporization (PTV) inlet. Concentrations of 88 PCB congeners were determined for both sediments and tissues. Blanks, fortified samples, and SRMs (NIST 1941b Organics in Marine Sediment and 1944 New York/New Jersey Water Way Sediment for sediment and NIST 1947 Lake Michigan Fish Tissue and 2977 Mussel Tissue (Organic Contaminants and Trace Elements) for tissues) were used to ensure data quality. Recoveries of method spikes and matrix spikes averaged (standard deviation) 103.8 (21.2)% and 98.6 (20.4)%, respectively. NIST SRMs 1941b for sediments and NIST SRMs 1947 and 2977 for tissues were also analyzed; PCB congener concentrations were within 10 % (SRM 1941b), 5 % (SRM 1947), and 20 % (SRM 2977) of certified values.

Data analysis

Congener patterns of PCBs in sediment and fish from both Brunswick and Sapelo NERR were compared to other regional datasets for sediment and fish tissues

from coastal South Carolina (Van Dolah et al. 2013) and North Carolina NERRs (Cooksey et al. 2008). Fish collections for the SC and NC projects were collected in a similar manner as samples for this study. These datasets were chosen because each represented approximately the same spatial scale, were analyzed using similar protocols, and the targeted fish species were similar in nature.

Descriptive statistics for sediment and fish were determined (on a per sample basis) for total PCB (PCB_t), defined as the sum of the 65 PCB congeners common to all four regional assessments. The congener-specific proportion of PCB_t was calculated as well. The geometric mean and the standard error of the mean are reported throughout the manuscript. The standard error of the mean was calculated by determining the standard deviation of the natural log-transformed data that was reportable, converting the transformed data ($exp^{\wedge stdevln}$) and dividing by the square root of the count data.

The PCB data was also reduced to include 22 congener peaks that were measured across all projects and associated with Aroclor 1268 as detailed in previous publications (Ishikawa et al. 2007; Maruya and Lee 1998; Pulster and Maruya 2008). The PCB congener list (PCB_r) used to define regional differences included 29 congeners (PCBs 3, 8/5, 18, 20, 28/31, 44, 52, 77, 101/90/89, 105, 118/106, 126, 149, 153, 170/190, 180/193, 187, 194, 202, 206, 207, and 209) and is similar to the list used by Pulster et al. (2005) to evaluate regional differences in PCB composition in the southeastern USA. This list of 22 congeners includes 7 congeners (PCBs 180/193, 194, 206, 209, 187, 202, and 207) that are of importance to Aroclor 1268 and account for ~75 % of the Aroclor 1268 profile (Maruya and Lee 1998; Kucklick et al. 2011). The proportion of PCB_r to PCB_t was then calculated, and sites were compared using an ANOVA (SAS version 9.3) for both sediments and tissues. The congener pattern observed in archived Brunswick, GA, sediments collected in 1996 and reanalyzed for this study has previously been associated with Aroclor 1268 (Kannan et al. 1997; Maruya and Lee 1998).

Results

General description of sediments

The mean sediment concentration for PCB_t for the SI NERRS was 0.205 ng/g dry weight (dw) (standard error (SE) of 0.637 ng/g dw). Station concentrations ranged from 0.015 to 3.84 ng/g dw (Table 1). No station exceeded published sediment toxicity guidelines such as the effects range low (ERL; 22.7 ng/g dw) or effects range median (ERM; 180 ng/g dw) (Long et al. 1995) or the probable effects level (PEL; 189 ng/g dw) (Canadian environmental quality guidelines 2002). For comparison, PCB_t concentrations from archived and reanalyzed Brunswick, GA, sediment samples averaged 79.3 ng/g dw (SE 2.47 ng/g dw) and ranged from 5.37 to 4200 ng/g dw. Five of the 10 archived BR stations had PCB levels that exceeded the ERM (180 ng/g dw), and three of the remaining five stations had PCB levels greater than the ERL (22.7 ng/g dw) (Long et al. 1995). Congener profiles were similar in both SI and BR sediment samples. Dominant congeners (in descending rank order; 1–3) for both locations (Table 2) were PCB 206, 209, and 202, accounting for nearly 70 % of PCB_t. The remaining congeners (rank order 4–10) included PCB 194, 187, 207, 195, 198, 180/193, and 52 for BR sediments and PCB 187, 153, 194, 99, 52, 28/31, and 183 for SI sediments.

General description of analyzed fish fillets

A total of 22 fish fillets from the SI NERR were analyzed for PCBs and included *M. cephalus* (n=9), *M. undulatus* (n=3), *C. nebulosus* (n=3), *Menticirrhus sp.* (n=1), *B. chrysoura* (n=3), *S. ocellatus* (n=2), and *P. lethostigma* (n=1). PCB_t concentrations averaged 3.90 (SE 0.577)ng/g wet weight (ww) (Table 3) and individual fillet concentrations ranged from 0.60 (silver perch) to 41.0 (whiting)ng/g ww. A total of 29 fillets were analyzed from the area around Brunswick, GA (BR), and species included *M. undulatus* (n=8), *Menticirrhus sp.* (n=1), *M. cephalus* (n=9), *B. chrysoura* (n=4), *C. nebulosus*

Table 1 PCB_t sediment concentrations (reported as the geometric mean) from BR, SI, SC (van Dolah et al. 2013), and NC (Cooksey et al. 2008)

Site	PCB_t concentration±standard error (ng/g dry mass)	PCB_r/PCB_t proportion
BR	79.3 (2.47)	0.967
SI	0.205 (0.637)	0.904
SC	0.107 (0.3.06)	0.382
NC	0.005 (0.15.1)	0.212

Table 2 Rank order (by congener proportion) of the congeners from BR, SI, SC (van Dolah et al. 2013), and NC (Cooksey et al. 2008) sediments and the associated PCB_t congener proportion

Rank order	BR_sediment	SI_sediment	SC_sediment	NC_sediment
1	PCB 206 (0.611)	PCB 206 (0.665)	PCB 52 (0.079)	PCB 206 (0.589)
2	PCB 209 (0.121)	PCB 209 (0.104)	PCB 66 (0.071)	PCB 37 (0.226)
3	PCB 202 (0.094)	PCB 202 (0.049)	PCB 110 (0.067)	
4	PCB 194 (0.056)	PCB 187 (0.049)	PCB 153 (0.050)	
5	PCB 187 (0.043)	PCB 153 (0.019)	PCB 18 (0.041)	
6	PCB 207 (0.036)	PCB 194 (0.018)	PCB 15 (0.038)	
7	PCB 195 (0.004)	PCB 99 (0.015)	PCB 156 (0.036)	
8	PCB 198 (0.004)	PCB 52 (0.015)	PCB 99 (0.035)	
9	PCB 180/193 (0.003)	PCB 28/31 (0.009)	PCB 92 (0.035)	
10	PCB 52 (0.003)	PCB 183 (0.008)	PCB 101/90/89 (0.024)	

(n=1), and *Leiostomus sp*. (n=6). Tissue fillet concentrations of PCB_t at BR averaged 141 ng/g ww (SE 0.478 ng/g ww) and ranged from 32.0 to 838 ng/g ww (Table 3). Congener profiles were again similar in both SI and BR tissue samples (Table 4). Dominant congeners for both BR and SI included PCB 206, 187, and 202, accounting for between ~45 % (SI) and 65 % (BR) of the PCB_t. The remaining congeners included PCB 194, 209, 207, 183, 180/193, 153, and 154 for BR tissues and PCB 153, 194, 180/193, 99, 209, 101/90/89, and 183 for SI tissues.

Species-specific descriptive statistics are found in Table 5. Comparisons were limited to those species for which there were matched data from the SI NERR and Brunswick, GA, and the sample size was greater than one from both regions (silver perch, mullet, and Atlantic croaker). Mean tissue concentrations were generally between 50 and 100 times greater in fish from the Brunswick, GA, sites relative to the fish from SI. Additionally, when PCB_t for fish was compared to US EPA consumption guidelines (four meals per month) (U.S. EPA 2000), all fish from Brunswick exceeded the lower threshold for non-cancer risks (23 ng/g ww), and of these, 24 exceeded the upper threshold of 47 ng/g ww for non-cancer risks. Only two fish collected from the SI NERR exceeded the lower non-cancer threshold, and none exceeded the upper threshold. An additional 10 fish from the SI NERR were found to have PCB_t concentrations above the lower cancer-risk threshold of 5.9 ng/g ww; five had concentrations that also exceeded the upper cancer-risk endpoint of 12 ng/g ww (Fig. 2.).

Table 3 PCB_t tissue (fillet) concentrations (reported as the geometric mean) from BR, SI, SC (van Dolah et al. 2013), and NC (Cooksey et al. 2008)

Site	PCB_t concentration±standard error (ng/g wet mass)	PCB_r/PCB_t proportion
BR	141 (0.478)	0.881
SI	3.90 (0.577)	0.824
SC	2.93 (0.451)	0.464
NC	0.087 (17.0)	0.470

The dominant congeners in both sediments (Table 2) and tissues (Table 4) from both SI and Brunswick, GA, were PCB 206, 202, and 187 and also included PCB 209, 194, 180/193, and 207. This profile was similar to the Aroclor 1268 profile described in Maruya and Lee (1998) for fish from Purvis Creek near Brunswick, GA.

Regional comparison

The mean PCB_r/PCB_t proportions for sediments ranged from 0.212 (NC) to 0.967 (BR). SI sediments matched closely (0.904) with the BR sediment PCB_r proportion. Results from the ANOVA (least squares means comparison) comparing the PCB_r/PCB_t proportion indicated significant differences between BR and both NC and SC datasets while BR and SI PCB_r proportions for sediments were not different (p=0.936). PCB_r proportions for SI sediments were different from both NC and SC as well (p<0.0001). NC and SC were not significantly different (p=0.106). A similar trend was observed in PCB_r/PCB_t tissue proportions. Mean proportions ranged from 0.881 (BR) to 0.464 (SC). BR and SI PCB_r proportion (tissue) results were not significantly different (p=0.736). PCB_r tissue proportions from SI

Table 4 Rank order (by congener proportion) of the congeners from BR, SI, SC (van Dolah et al. 2013), and NC (Cooksey et al. 2008) fish fillets and the associated PCB_t congener proportion

Rank order	BR_tissues	SI_tissues	SC_tissues	NC_tissues
1	PCB 206 (0.311)	PCB 206 (0.170)	PCB 153 (0.159)	PCB 187 (0.401)
2	PCB 202 (0.181)	PCB 187 (0.143)	PCB 99 (0.093)	PCB 206 (0.388)
3	PCB 187 (0.148)	PCB 202 (0.130)	PCB 15 (0.047)	PCB 101/90/89 (0.057)
4	PCB 194 (0.063)	PCB 153 (0.093)	PCB 63 (0.043)	PCB 153 (0.049)
5	PCB 209 (0.045)	PCB 194 (0.032)	PCB 12 (0.037)	PCB 99 (0.042)
6	PCB 207 (0.034)	PCB 180/193 (0.029)	PCB 180/193 (0.035)	PCB 95 (0.037)
7	PCB 183 (0.034)	PCB 99 (0.028)	PCB 118/106 (0.028)	PCB 180/193 (0.029)
8	PCB 180/193 (0.028)	PCB 209 (0.023)	PCB 52 (0.019)	PCB 44 (0.016)
9	PCB 153 (0.020)	PCB 101/90/89 (0.023)	PCB 66 (0.013)	
10	PCB 154 (0.012)	PCB 183 (0.022)	PCB 202 (0.012)	

were different from both NC and SC as well ($p<0.0001$). NC and SC were not significantly different ($p=0.999$). Sediments from BR and SI shared 6 of the 10 most influential congeners, and there were no congeners among the 10 highest rank-ordered congeners that were shared among all four sediment datasets (Table 2). For tissues, 8 of 10 rank-ordered congeners were shared between BR and SI tissues and two congeners (PCB 153 and 180/193) were identified in each of the four regional datasets (although the ranks differed; Table 4).

Discussion

Sediment PCB_t concentrations in the SI NERR (0.015–3.84 ng/g dw) did not exceed the published ERL or ERM (Long et al. 1995) at any station, and concentrations were similar to other coastal assessments along the NC and SC coasts (Bergquist et al. 2011; Cooksey et al. 2008; Sanger et al. 2008; Van Dolah et al. 2013). Sediment PCB_t concentrations reported along the South Carolina coast over a 10-year (2000–2010) period ranged from not detectable (nd)–30.5 ng/g dw (annual

Table 5 Descriptive statistics for PCB_t (ng/g ww) in fish fillets collected in the SI NERR and the greater Brunswick, GA, estuary; no significant differences for lipid fraction were identified between locations and between species

Species	Count	Arithmetic mean lipid fraction (standard deviation)	Arithmetic mean (standard error) concentration (ng/g ww)	Concentration range (ng/g ww)
Sapelo Island				
Silver perch	3	0.0042 (0.0013)	1.34 (1.96)	0.604–18.8
Spotted seatrout	3	0.0115 (0.0036)	8.14 (0.38)	4.44–18.5
Striped mullet	9	0.0216 (0.0149)	3.32 (0.17)	1.61–7.08
Atlantic croaker	3	0.0249 (0.0165)	5.16 (0.47)	5.84–11.0
Whiting	1	0.0218	25.2	
Southern flounder	1	0.0013	0.873	
Red drum	2	0.0111 (0.0087)	2.17 (1.20)	0.877–13.3
Brunswick				
Silver perch	4	0.0320 (0.0252)	146 (0.51)	107–478
Spotted seatrout	1		42.3	
Spot	6	0.0253 (0.0327)	69.1 (0.56)	33.3–770
Striped mullet	9	0.0141 (0.0030)	207 (0.23)	32.0–838
Atlantic croaker	8	0.0482 (0.0425)	150 (0.27)	70.3–779
Whiting	1	0.0187	188	

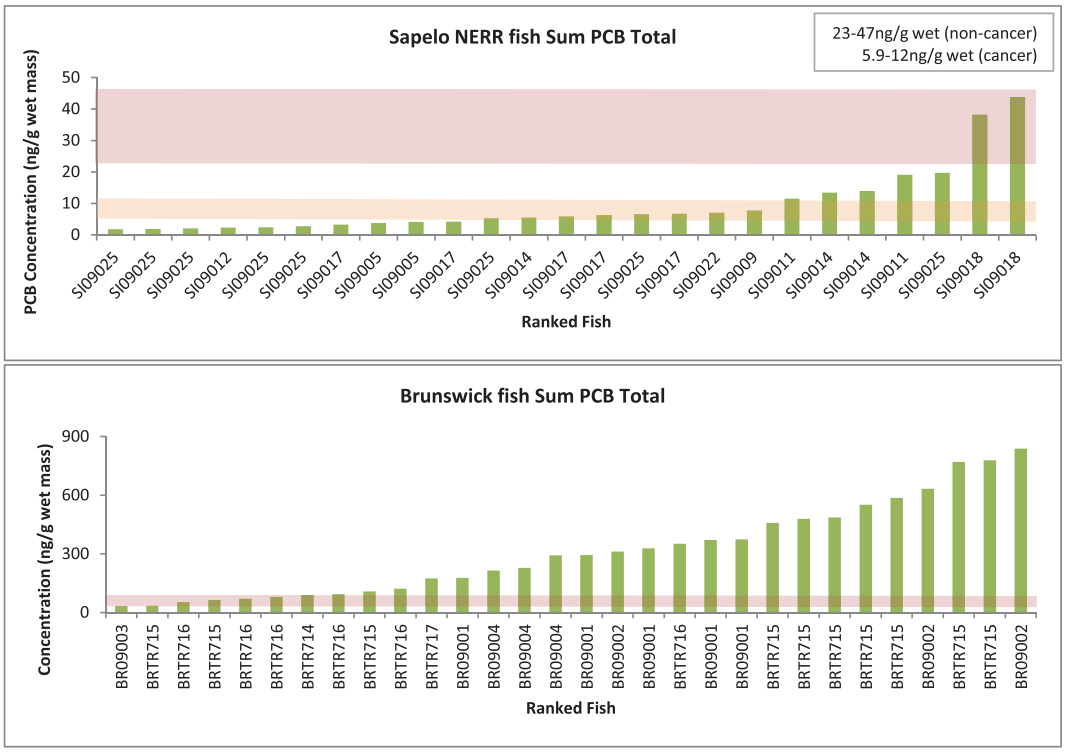

Fig. 2 Rank-ordered arithmetic mean fillet PCB_t concentrations from SI and BR fish plotted in relation to the US EPA cancer and non-cancer fish consumption limits estimating four meals per month (U.S. EPA 2000)

mean 0. 750 ng/g dw) (Bergquist et al. 2009; Van Dolah et al. 2013; VanDolah et al. 2004, 2006). The dominant congeners reported for SC sediments were PCBs 138/163/164, 44, 52, and 153 (Bergquist et al. 2009; VanDolah et al. 2004, 2006). The mean PCB_t sediment concentration reported for NC NERR was 0.240 ng/g dw (range, nd–1.24 ng/g dw), dominated by PCB 206, but there were very few congener detections reported (Cooksey et al. 2008) (Table 2). PCBs were not detected in sediment from the Grays Reef National Marine Sanctuary, 32 km off the coast of Sapelo Island, GA (Balthis et al. 2007).

Several publications have highlighted the need for information on the trophic transfer of PCBs from sediments and prey species to apex and sentinel species such as coastal dolphins (Balmer et al. 2011; Kucklick et al. 2011; Pulster et al. 2005). Prey species from the Brunswick, GA, area had relatively high levels of PCBs (32.0 to 838, mean 141 ng/g ww), in agreement with other reports from the Brunswick area (Balmer et al. 2011; Pulster et al. 2005). Concentrations of PCB_t recently reported in SC fish range from 1.49 to 15.1 (mean 5.06)ng/g ww (Van Dolah et al. 2013), and the dominant congeners expressed in these fish were PCBs 153, 99, and 15. Reported PCB_t concentrations in fish from NC NEER ranged from 0.29 to 4.03 (mean of 1.36)ng/g ww and were primarily driven by PCBs 187, 101/90/89, and 206 (Cooksey et al. 2008). Concentrations reported in fish from SI NERR ranged from 0.604 to 41.0 (mean 3.90)ng/g ww (current study). The congener patterns from SI NERR were more similar to the pattern found in samples from Brunswick estuaries and dominated by congeners PCBs 206, 187, and 202 (Table 4). The rank order of the Aroclor 1268 specific congeners for sediment and tissues follows the typical Aroclor 1268 pattern described by Kannan et al. (1998) and Maruya and Lee (1998).

The similar congener patterns in both sediment and tissues and the expected decrease in PCB concentration in SI relative to BR strongly indicate that PCB transport into SI NERR has occurred and could be attributed to several environmental routes, although the question of how Aroclor 1268 came to occur in SI cannot be defined in this experimental design. It is well documented that PCB transport occurs via downstream sediment transport (Feng et al. 1998). Feng et al. (1998) described a

10-fold decrease over an approximately 80-km stream transect along the Hudson River. In the case of transport from BR to SI, our data seem to indicate a 100-fold decrease over a similar spatial scale. Another possible route of PCB movement is through the migration of fish populations, realizing that fish migration is species and season dependent. There are subtle differences in PCB homolog patterns in fish from SI and BR (Table 4). Congener patterns appear to be relatively similar for the more highly chlorinated congeners (homolog groups 7, 8, 9, and 10), though congeners in homolog groups 4, 5, and 6 are enhanced in SI fish compared with BR. It is interesting to note that several congeners found in SI tissue were not often detected in SI sediment samples. For example, PCBs 105, 110, 177, 188, and 195 were detected in tissues but not detected in SI sediments. It seems that the PCB profiles between SI and BR are more similar for tissues than sediments and may indicate that tissues are a more likely source of transport, thus identifying fish as an influential vector for PCBs to be passed onto predators found in the SI NERR. Balmer et al. (2011) reported distinct dolphin populations that are resident in SI and distinct from dolphin populations found in the BR estuary; yet both populations exhibited clear Aroclor 1268-type congener patterns in blubber samples. Understanding the presence of an Aroclor 1268-type pattern in SI as observed in this study implies an influence from the likely source (BR) and helps define needed research into predator/prey associations and Aroclor 1268 movement mechanisms into this protected estuary.

US EPA consumption guidelines (U.S. EPA 2000) were used in an attempt to understand potential risks associated with the levels of PCB found in fish from Sapelo Island, NERR. Total PCB levels in some SI NERR fish exceeded US EPA lower and upper endpoints for cancer risks (48 %>5.9 ng/g ww and 16 % >12 ng/g ww, respectively) and the lower endpoint for non-cancer/systemic-health risks (6.5 %>23 ng/g ww) based on predictions associated with consumption of four 8-oz meals per month (U.S. EPA 2000); none exceeded the upper non-cancer endpoint of 47 ng/g ww. Due to the restricted access to the SI NERR (boat only), the extent of recreational or subsistence fishing that occurs in these waters is unclear. All fish from BR exceeded both the lower and upper endpoints for cancer risks and the lower endpoint for non-cancer risks; most (73 %) also exceeded the upper non-cancer endpoint. Mullet and croaker from Purvis Creek (adjacent to the LCP site in Brunswick, GA) are identified in Georgia EPD publications as "do not eat," and red drum and flounder are listed as "1 meal per month" due to PCB contamination (Guidelines for Eating Fish from Georgia Waters 2010).

While SI PCB levels in both sediment and fish were considerably lower than the PCB levels found in Brunswick, GA, the congener patterns strongly suggest transport of Aroclor 1268 away from the LCP site and into the SI NERR (Tables 1, 2, 3, and 4). The rank order for the first four congeners (based on proportion) is identical in both SI and BR sediment samples from 1994 that were reanalyzed for this study (PCB 206>199>203/196>208), and 8 of the 10 most abundant congeners are similar between BR and SI sediments. Congeners 153 and 52 are among the 10 most abundant congeners from SI and are not associated with published Aroclor 1268 patterns (Maruya and Lee 1998; Kucklick et al. 2011), and this signal likely indicates ambient background PCBs (Hoekstra et al. 2003). Kucklick et al. (2011) showed a high correlation of PCB153 with coastal human population supporting the assertion of PCB 153 as an indicator of general urban PCB contamination (non-Aroclor 1268). Congener profiles follow a similar pattern of agreement in tissues (Table 4). Congener ranks are identical for PCB 199>206>203/196>202>187 and 8 of the 10 most abundant congeners are again the same in both SI and BR tissues.

An earlier study examined dolphin prey species from three coastal regions including Brunswick, GA; Jacksonville, FL, to the south; and Savannah, GA, to the north of the LCP site (Pulster et al. 2005). Using discriminant analysis, these authors reported that the Aroclor 1268 patterns (using congeners 194, 138, 180, and 196) were recognizable to the south (in samples from Jacksonville, FL) but not in PCB profiles from Savannah. This apparent pattern movement is not specific to fish, as Aroclor 1268 specific signatures in turtles were reported as far south as Port Canaveral, FL (Ragland et al. 2011). Our data clearly indicated that the SC and NC datasets were distinct and different from SI and BR data for both sediments and tissues.

In closing, while the magnitude of PCB contamination at the SI NERR is much lower than that in the Brunswick, GA, area near the LCP site, the similarity of congener profiles suggests that much of the PCB contamination at the SI NERRS is likely due to transport from the LCP site. Sediment advection may account for the PCB transport into SI as only a small proportion of

highly contaminated BR sediment could explain the PCB levels found in SI. Additionally, PCB transport could also be a result of fish migration from BR into SI. The more similar PCB patterns were found between tissue PCB profiles. Fish tissue concentrations occasionally exceed US EPA human-health guidelines for caner and non-cancer health endpoints (based on consumption of four 8-oz meals per month). Without better understanding of the amount of prey dolphins consume, it may be difficult to gauge if consumption of SI resident fish is enough to explain the high levels of PCB reported in SI resident dolphin populations. Generally, the Aroclor 1268 signature around BR and SI appears to be closely bounded to the north. Future research includes similar estuary wide assessments in northern Florida and southern South Carolina to help better understand the extent of the movement of Aroclor 1268 along the southeastern coast and especially among coastal-protected research areas (NERRs).

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Satilla RIVERKEEPER®

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March 9, 2105

Dear Mr. Jackson,

Please see the comments below from Satilla Riverkeeper regarding the LCP Chemicals Superfund site proposed cleanup plan.

1. Area of Contamination vs. Area Designated for Remediation

- EPA's chosen cleanup plan for the LCP Chemicals site is inadequate identifying only 24 acres of marsh to be remediated. This is a problem because 81 acres of the march is heavily contaminated and should be removed for the good of public and environmental health. If this cleanup plan proceeds as planned the responsible parties would leave behind 57 acres of contaminated marsh with high levels of mercury and polychlorinated biphenyls (PCBs). These leads us to numerous questions…

- How is it known that only 81 acres of the 670+ acres of marshland at the LCP site is in need of remediation?
- Is it true that 33 of these target 81 acres were not chosen for remediation because of concern over temporary damage to restorable marshland?
- If these 33 acres were included despite the damage to the marsh that might result, how would the amount and time frame of damage to the marsh compare to the risk to people that remains from leaving LCP-contaminated sediments in those 33 acres?
- Has this comparison of risk been the subject of a scientific risk assessment?

Recommendations: The EPA should reevaluate their original cleanup plan and add the additional 57 acres of contaminated marsh, originally left out of the proposal, for cleanup.

2. Sediment Removal vs. Capping

- Capping and thin-cover placement methods are not an acceptable means of cleaning up a heavily contaminated tidal salt marsh. Both of these methods cover up contaminated soils rather than removing them forever. How can the EPA claim that thin-cover placement or caps is well studied method for site cleanup when there are less than ten thin layer caps at contaminated sites in the United States and these are mostly in lakes or bays? The thin-layer capping examples in the plan include estuarine, river, and tidal flats, of which are all systems with different hydrologies and cannot be adequately compared with salt marsh ecosystems. With this information it is obvious that the proposed capping plans are not applicable to the LCP site and is, at best, a science experiment in the field. This plan also does not seem very logical as natural storm events like hurricanes and sea level rise will bring an increased risk that the contaminated sediments will once again be disturbed and the capping work will ultimately fail.

- Thin-cover placement or enhanced natural recovery is not a sustainable recovery method. This thin layer of sediment, six inches or less will not be adequate to contain any contaminants in the marsh bed. Storm surge, the bottom of a boat passing by, and benthic infaunal invertebrates will disturb the layer. *Spartina* can also accumulate these pollutants and will continue to release them into the food web.

- Because of the high toxicity levels of the contaminated area in question and the proposed thin covering layer offered by the engineered cap, this plan, would be at best, just experimental when one considers an 8 or 9 foot tide and a meandering intertidal creek that is always present and on the move.

- What assurances can be given that capping contaminated sediments in place (rather than removing them) can withstand storm intensities at least comparable to that required for coastal construction?
- Does storm preparedness for coastal construction require structures to withstand FEMA-determined flood levels, and 120 mph wind speed?
- What similar storm preparedness standards will be required for the capping project?
- Even with capping, might a storm with upland flooding and 120 mph winds suspend contaminated sediments in the LCP-contaminated sediments and spread them over the upland landscape into residential neighborhoods and businesses?
- During a flooding storm, would contaminated sediments settle onto roadways, where they could be further spread on the tires of roadway traffic, and suspended as dust into the air?
- Will construction criteria for a contaminant cap include even stricter minimum storm standards (based on higher flood levels and more powerful winds) in order to address the public risk of contaminant exposure during and after a storm?
- If a storm penetrates the cap, would contaminants spread far and wide once a bolus of contaminated sediments is suspended in coastal waters?
- Could any and all of the contaminants be spread by a storm, including mercury, lead, Aroclor 1268, PCBs, PAHs, dangerous dioxins, and others? If not, which would not be spread by a storm?
- Did the EPA consider containment of the contaminated areas with a coffer dam and complete removal as one of the remedies in the Feasibility Study? If not, why not? Would a coffer dam or other containment structure facilitate removal without reintroducing the contaminated sediments in to the estuary?)
- Did the EPA model reintroduction of contaminants into the marsh via benthic organisms and the Spartina life cycle? If not, why not?

Recommendations: Do not waste time and money on capping projects that don't remove the contaminants from the environment. Please consider sediment removal to keep these contaminants from further entering the food web over the next century.

3. Restoring Vegetative Communities after Cleanup

- The proposed cleanup plan proposed by the EPA will include the removal of native marsh vegetation, which is critical for the health of the ecosystem as well as the neighboring estuarine systems. The proposed cleanup plan relies heavily on the assumption that marsh vegetation will re-grow on its own within two years. While it is possible that vegetation will begin to regrow, it is unlikely that the marsh will be fully restored in just two growing seasons.

- Have marsh vegetative restoration efforts been conducted at the LCP Site? If so, were they successful and should be repeated?

Recommendations: The EPA should modify their proposed cleanup plan to include a re-planting program in order to speed up recovery of the ecosystem post-remediation. We recommend focusing on natives such as *Spartina*, which is native to the salt marshes of coastal Georgia. *Spartina* will attractive native wildlife which will help speed up the ecosystem recovery process.

4. Human Health Assessment

- The human health assessment in the proposed plan does not adequately account for the risks posed by the contaminants to humans around the estuary. The two most harmful chemicals are mercury and Arclor 1268. Defined in the plan are high quantity fish consumers, adults that eat 40 fish meals per year for 20 years, and a recreational fish consumer as someone who eats 26 meals per year for 30 years. The differences between the two consumer categories are too small. The EPA should make more realistic assumptions like the Sapelo Island Study presented to the EPA Remedial Project Managers and Stakeholder Agencies for the LCP Site on September 3, 2014, which suggests a more appropriate number if meals in between 100 and 150 per year.

- Will the EPA increase the high quantity fish consumer number to 150 meals per year to reflect the actual consumption level observed in coastal Georgia populations?

-The posted fish consumption signs and public information on this subject is not an adequate source of information to alert the fishing and our seafood consuming public living in the contaminated areas where people rely heavily on seafood for their sustenance.

- How many signs has the EPA posted in the 20 years since the serious threat to human health was identified?
- Where are the EPA posted signs located?
- What is the EPA budget to maintain the signs over the past 20 years, and for sign placement and maintenance required until seafood is safe to eat?

- Over four thousand people live within a one mile radius of the LCP Superfund site. Over 400 of these citizens are 6 years or under and over 800 of these are women of child bearing age. In considering the many components of this major problem to one of our important coastal cities, the EPA must revise their fish consumption estimates and be cognizant of the health of those citizens that have already become affected with these

toxins. This will take a voluntary testing program to learn about the human cost from this timely exposure to highly toxic contaminants now lurking in our marshes, soil, creeks, rivers, and now our coastal ocean bottom.

- What warning signs have been posted in the estuary and at boat ramps to keep people from to keep boaters and swimmers from coming into contact with contaminated sediments?
- Who is responsible for these signs now and into the future?
- Are contaminated crabs still entering the public food supply?
- Are the sets of floats that are sometimes visible in waters adjacent to the LCP site from commercial or residential crab traps?
- Have the people most likely to have been contaminated by LCP-tainted seafood been tested? Have sufficient numbers of people been tested for LCP contaminants?
- Has testing included those who eat large amounts of fish and shellfish from St Andrew Sound, Jekyll Sound, Jointer Creek, Christmas Creek, and the Satilla River estuary?
- How many people have consumed large quantities of fish and shellfish from those waters during the decades of contamination at the LCP site?
- Has an effort been made to warn those people and to suggest that they be tested?
- Among the contaminants allowed to remain in sediments at the LCP site, are any mutagenic or teratogenic, as well as carcinogenic? If so, what will be the risk of mutations and birth defects from human exposure to LCP-contaminated sediments, water, or seafood collected from impacted waters?
- Did the EPA consider three congeners, PCBs 138, 153, and 180, were particularly higher in women with endometriosis? If not, why not?

Recommendations: The fish consumption numbers should be increased based on detailed surveys of local fishermen. In this area 40 fish meals a year is an underestimate. Some residents eat fish every day and depend on it for their survival. A more appropriate number would be 150 meals per year, and this number is obtained from people actually consuming seafood in coastal Georgia.

5. Ecological Risk Assessment

- One of the sites used to compare the levels of sediment chemicals at LCP is only four miles from the LCP site at Troup Creek and has shown to be contaminated with the same chemicals.

Recommendations: The EPA should use a cleaner site for comparison. Choose a proper control site that has low to no levels of these contaminants. The available data from the US National Park Service sampling and analysis at Cumberland Island and Fort Pulaski would fulfill this need. Unlike the LCP data, this data is not of questionable quality.

6. Contamination in the Satilla River

- The dangerous spread of the contamination beyond the salt marsh is obvious proof that the so called site boundaries established by the EPA are far from being trustworthy.

These site boundaries could never be reliable when they only include the local marsh, the peripheral soil and the local groundwater. Sapelo is far offshore and the Satilla River has also been demonstrated to be contaminated with PCB 206 (most abundant congener in Aroclor 1268; ≥ 5.0 ppb) produced and dumped by the LCP plant (Backer and Mellard 2014). We now know that the data on Aroclor 1268 which is considered to have come from the LCP plant is showing up in our dolphin population, *Tursiops truncatus*, the ocean bottom sediments and in the blood of residents 25 miles offshore in Sapelo Island.

- Does the spin of the Earth (Coriolis effect) tend to turn local river discharges southward, which over the decades could have put contaminated sediments suspended at the LCP site into these areas, and along the beaches of Cumberland Island and into Christmas Creek?

Recommendations: The site boundaries must be rewritten and extend to all areas where these LCP toxins can be sampled and demonstrated with assurance.

Other Questions for Consideration

- What lasting risks to human health will remain after remediation? Who will be responsible for these and what remedies or recourse will they have?
- How safe will the environment be?
- Will children be safely able to swim and boat in Purvis Creek or in the nearby open waters of Gibson Creek and Turtle River?
- Will people be able to safely eat fish and shellfish caught in the vicinity?
- Will warning signs be needed, and if so, who will be responsible for the warnings?

Documents used for preparation:

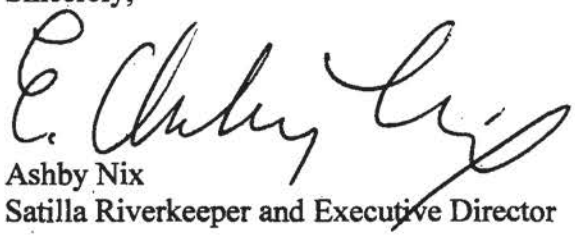
1) U.S. ENVIRONMENTAL PROTECTION AGENCY SUPERFUND PROPOSED PLAN, LCP CHEMICALS SUPERFUND SITE. OPERABLE UNIT 1
2) BASELINE ECOLOGICAL RISK ASSESSMENT FOR THE ESTUARY AT THE LCP
CHEMICAL SITE IN BRUNSWICK, GEORGIA
3) OSHA Resource conservation and recovery act. Management of PCB.
4) Fisherman of Sapelo Island David Goldman AP
5) 2010 US Census Bureau
6) Polychlorinated Biphenyls USEPA Hazardous Waste 2014
7) Glynn county Health Department Seafood Consumption
8) US Department of Health and Human Services Toxic substances 2012
9) US Environmental Protection Agency 2014 Superfund site
10) POLYCHLORINATED BIPHENYLS (PCBs) IN GEORGIA COASTAL ENVIRONMETS AND POPULATIONS (Backer and Mellard 2014)

We would like to thank you and the EPA for hosting an EPA Public Comment meeting back in December of 2014 at the Brunswick public library. Though this event was well attended, it was poorly planned and did not serve the people of the community informatively, simply due to venue size and the lack of good communication on the part of the EPA. The EPA released its Administrative Record only 26 hours before the public comment meeting took place. The people of Brunswick who have been directly impacted

by the LCP Chemicals Superfund site for decades deserve the EPA's upmost effort with communication and the flow of information to the public. We request that the EPA grant the communities of Brunswick a proper EPA Public Comment meeting that is well advertised to potentially interested parties and nearby residents.

If there are any questions you may have about our comments, please contact us at 912-510-9500 or riverkeeper@satillariverkeeper.org

Sincerely,



Ashby Nix
Satilla Riverkeeper and Executive Director

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STANDING COMMITTEES
Judiciary – Non-Civil
Insurance
Public Safety and Homeland Security – Secretary
Juvenile Justice – Vice Chairman
Appropriations – Chairman Public Safety Sub Committee

January 20, 2015

Mr. Galo Jackson
US Environmental Protection Agency, Region 4
Superfund Remedial Branch
Waste Management Division
61 Forsyth Street, SW
Atlanta, GA 30303

Dear Mr. Jackson,

I write regarding the LCP Chemicals Superfund Site in the City of Brunswick, Georgia, and the Proposed Plan issued by the U.S. Environmental Protection Agency (US EPA) and the GA Environmental Protection Division (GA EPD) on December 4, 2014. Specifically, on behalf of my constituents in Georgia District 179, which includes the superfund site, I request that the period for submitting public comment be extended at least sixty (60) days.

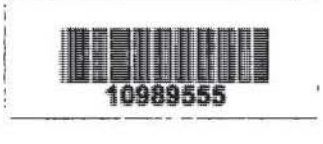
Since 1996, the LCP Chemicals Superfund site has been on the National Priorities List, ranking among the highest priorities among sites of known releases of toxic and hazardous substances. The citizens within my district and interested parties need more time to review and assess the decades of collected data and the alternatives assessments that have informed the US EPA's Proposed Plan. This information was only just compiled and made available to the public on December 3, 2014. While I appreciate the initial extension of time for public review (to February 2, 2015), the review period is still not sufficient.

I respectfully request that the US EPA extend the public comment period by 60 more days for interested parties to have adequate time to respond with their written comments. This would create a new deadline for public comment of March 31, 2015. I would appreciate a prompt response to this request.

Sincerely,

Representative Alex Atwood

cc: Jeff Cown, Chief - GA EPD Land Protection Branch



BRUNSWICK-GOLDEN ISLES CHAMBER OF COMMERCE

1505 Richmond Street, Second Floor
Brunswick, Georgia 31520
Telephone (912) 265-0620
FAX: (912) 265-0629
www.brunswickgoldenisleschamber.com

March 10, 2015

To: Mr. Galo Jackson, EPA Project Manager, LCP Project

Subject: EPA Region IV Proposed Plan to Remediate LCP Chemicals Marsh in Brunswick, Georgia

The Brunswick-Golden Isles Chamber of Commerce appreciates the opportunity to submit comments regarding the proposed marsh remedy for the former LCP Chemicals site in Brunswick. The Chamber has been following the activities at this site since LCP's shutdown in the 1990's. We understand that it is a complex site that required extensive studies. However, we also believe that the site has now been thoroughly investigated.

We don't purport to comprehend the technical details of EPA's proposed plan, but we understand from the EPA public meeting and the Honeywell presentations to the Chamber's Board of Directors, the Brunswick City Commission and the Brunswick Rotary Club, that it is based on scientifically sound principals and will be environmentally protective. We support the approval and implementation of your recommended remedy as soon as possible. It is in the best interest of Glynn County and the City of Brunswick to advance the cleanup and to redevelop the site, safely and expeditiously.

Sincerely,

M. H. Woodside
President

FROM: Norman Meade, National Oceanic and Atmospheric Administration

TO: Galo Jackson, USEPA RPM

CC: Jim Brown, Georgia Department of Natural Resources
Spud Woodward, Georgia Department of Natural Resources
Strant Colwell, US Fish & Wildlife Service
Tom Dillon, Dillon Environmental Consulting

SUBJECT: LCP Natural Resource Trustees Comments on the OU1 (Marsh) Proposed Plan for the LCP Superfund Site, Brunswick, GA

DATE: January 29, 2015

On behalf of the LCP Natural Resource Trustees ("Trustees"), we would like to take this opportunity to provide comments on the subject Proposed Plan (PP) from a natural resource damage assessment (NRDA) perspective. Please contact me with any questions or concerns.

1. The subject PP concludes that Alternative 6 is the preferred alternative for remedial action in the LCP Marsh. The three major components of this alternative are: 1) dredging 7 acres of the LCP Ditch and Eastern Creek, 2) installation of armored caps in 6 acres of tidal creeks, 3) application of a thin layer sand cap (6-9 inches) over 11 acres of marsh largely along either side of the Eastern Creek. For reasons given below, the Trustees believe this remedial action may not restore the injured natural resources as quickly as the other alternatives that were considered. Moreover, Alternative 6 may not represent a permanent solution to environmental contamination at the LCP Marsh and the larger Turtle-Brunswick River Estuary.

a. The LCP Ditch and Eastern Creek were dredged in 1998-1999 along with approximately 13 acres of saltmarsh in Domain 1. Now, 15 years later, the LCP Ditch and Eastern Creek must be dredged again. Without a more comprehensive remedial action (i.e., Alternative 2 in the PP), the Trustees are concerned that re-dredging these tidal creeks now may not restore the marsh to its baseline condition.

b. The PP describes armoring material for the capped tidal creek areas as "coarse sand and/or gravel". This appears to be inconsistent with the descriptions in Appendix H of the 2013 Feasibility Study which specify an "armor stone layer for erosion protection" (§3.3.1) or an "armor stone cap" (Table H-4). Furthermore, the placement of an armored stone layer (or any hard substrate) on top of 6 acres of capped tidal creek areas, will likely result in the development of oyster reef communities similar to those currently found on large pieces of concrete that line

the LCP Ditch. While oyster reef communities can provide important ecological services, in this particular case, a 6-acre attractive nuisance will likely be created if Alternative 6 is implemented. This is because oysters efficiently bioaccumulate site contaminants such as mercury, lead and Aroclor 1268 thus making these contaminants available to higher trophic level organisms; e.g., blue crabs, black drum. As a result, capping 6 acres of tidal creeks under Alternative 6 may actually ***enhance*** entry of site contaminants into the marsh food web. This possibility must be studied as part of the post-remedial monitoring plan.

c. The arguments presented in support of installing a thin layer (6-9 inches) sand cap over 11 acres of LCP salt marsh as a method of reducing the risk to the benthic community are unconvincing. At the very least, placing sand over silty vegetated marsh surface may alter the benthic community and hydrology in ways not foreseen by the modeling that was performed.

d. The PP (page 29) provides a justification for the thin layer cap saying, "Thin-cover placement is best suited for wetlands or marsh environments where tidal energy and potential erosion is at a minimum.". This minimal tidal energy requirement seems inconsistent with the LCP marsh's 7-10 foot semi-diurnal tidal range and periodic high energy storm events. EPA's National Remedy Review Board expressed a similar view in their March 28, 2014 Memo saying, "The Board is concerned about the long-term permanence aspects of the proposed thin cover placement" (page 5, March 28, 2014 Memo). "Long-term effectiveness and permanence" is the first Primary Balancing Criteria that EPA is required to use when evaluating remedial alternatives. Dredging certainly meets this criterion especially when compared to the more questionable thin layer (≈6-9 inches) capping in a system experiencing large daily tidal fluctuations and periodic high energy storm events. EPA's National Remedy Review Board echoed this same concerns when they recommended to EPA Region 4 that they "consider a contingent remedy approach due to the uncertainty regarding the long-term permanence aspect of the proposed thin cover and capping components of alternative 6" (page 5, March 28, 2014 Memo). The permanence and effectiveness of the thin layer capping will need to be studied as part of the post-remedial monitoring.

e. It is not exactly clear in the PP how Preliminary Remedial Goals (PRGs) and Cleanup Levels (CULs) were derived and whether they are protective of human health and the environment. For example, the ranges of PRGs for the protection of the Benthic Community (page 22 of the PP) are greater than the ecologically protective Remedial Goal Objectives (RGOs) initially developed in the Baseline Ecological Risk Assessment (BERA) (see page 92 of the BERA and the values below). The recommended CULs in the PP are higher still (page 42 of the PP and below). These CULs represent the highest value in the range of PRGs in the PP. The PP does not clearly explain how these PRGs and CULs can drift ever higher, yet still be protective of the benthic community. Further, the PP does not explain whether a similar progressive relaxation of PRGs and CULs was allowed for fish and wildlife receptors.

COC	BERA RGOs →	PP PRGs →	PP CULs
Mercury	1.4-3.2 ppm	4-11 ppm	11 ppm
Aroclor 1268	3.2-12.8 ppm	6-16 ppm	16 ppm
tPAH	0.8-1.5 ppm	4 ppm	4 ppm
Lead	41-60 ppm	90-177 ppm	177 ppm

2. As noted above, approximately 13 acres of saltmarsh were excavated and backfilled with clean material in 1998-1999. Visual observations afterwards suggested very rapid recovery of the saltmarsh vegetation (see 2-year post-removal photo in Figure 2-10 of the 2013 OU1 Feasibility Study). Despite this site-specific experience of rapid recovery, the subject PP opts for other less permanent methods of remediation. The PP also repeatedly states that additional dredging and excavation would create unnecessary "destruction", "unwarranted harm" and "significant damage", which is not supported by the evidence. EPA's National Remedy Review Board reached a similar conclusion stating, "The PRPs do not provide any site-specific information to indicate that marsh restoration at this site is particularly difficult and, in fact, earlier removal actions have excavated and restored wetlands at the site already." (pages 6-7, March 28, 2014 Memo). In their Memo, the Remedy Review Board recommended dredging the 6 acres of tidal creek currently slated for capping under Alternative 6.

3. The above comments are offered from the perspective of the LCP NRDA Trustees, which differs slightly from that of EPA. At Superfund sites, the Trustees are charged with: 1) restoring ecological services back to baseline (if possible) and 2) compensating the public for interim losses through restoration projects. As a general rule, more thorough cleanups at a Superfund site translate into smaller interim losses and a more rapid return to baseline. Consequently, the LCP NRDA Trustees would rather see implementation of a more aggressive remedial action. However, the NRDA Trustees also recognize that important uncertainties are always present in ecological risk assessments and evaluations of remedial alternatives. Therefore, if Alternative 6 is implemented, the Trustees strongly urge that a comprehensive, science-based monitoring plan be designed and implemented. The plan should be capable of quantifying the rate of recovery (return to baseline) soon after the remedial action. Additionally, the plan should incorporate specific numerical "triggers" for further clean up action as described in §8.0 of the PP. The importance of post-remedial monitoring was also cited in EPA's National Remedy Review Board's March 28, 2014 memo. The Trustees concur with the Board's recommendation to develop a fish tissue monitoring plan using extant EPA guidance; i.e., Sediment Assessment and Monitoring Sheet (SAMS) #1 " Using Fish Tissue Data to Monitor Remedy Effectiveness" (2008) which can be found at http://www.epa.gov/superfund/health/conmedia/sediment/documents.htm.

Atlantic Richfield Company

REMEDIATION MANAGEMENT
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March 16, 2015

Mr. Galo Jackson
U.S. Environmental Protection Agency – Region IV
61 Forsyth Street
Atlanta, GA 30303

Sent Electronically

RE: LCP Chemical Site
Glynn County
Brunswick, GA

Dear Mr. Jackson:

On behalf of the Atlantic Richfield Company, attached are comments provided to EPA in response to the Agency's request for public comment on its Proposed Remedial Action Plan for the Marsh (OU1) at the LCP Brunswick Chemical Site. Please include Atlantic Richfield's comments in the administrative record for the Site.

Atlantic Richfield appreciates this opportunity to provide input into the administrative process.

If you have any questions, please let me know.

Respectfully,

Paul Taylor

Paul Taylor
Strategy Manager – OB&C Portfolio

Attachment

March 16, 2015

Atlantic Richfield Company Comments

United States Environmental Protection Agency (USEPA) Region 4

Superfund Proposed Plan

LCP Chemicals Superfund Site Operable Unit 1

City of Brunswick, Glynn County, Georgia

Atlantic Richfield Company (AR) offers the following comments for the Administrative Record on the USEPA Region 4's Superfund Proposed Plan for the LCP Chemicals Superfund Site (Site), Operable Unit (OU) 1, located in the City of Brunswick, Glynn County, Georgia. OU1 includes the 670+ acre tidal marsh and Purvis Creek system adjacent to the LCP property.

AR has been identified as one of the remaining, viable Potentially Responsible Parties (PRPs) at the Site, along with Honeywell International and the Georgia Power Company. AR's involvement as a PRP arose from one of its corporate predecessor's ownership and operation of an oil refinery and terminal on the LCP property between 1919 and 1955. As a PRP, AR has been involved in the thorough and lengthy remedial investigation/feasibility study (RI/FS) that has culminated in USEPA's Proposed Plan.

1. Disagreement on USEPA's Assertions Regarding Potential Benthic Invertebrate Risks

The USEPA includes an assertion in the Proposed Plan that there are risks to benthic invertebrate communities from the 4 designated chemicals of concern (COCs) in OU1. To that end, one of the Remedial Action Objectives established by USEPA for OU1 is to:

> *"Reduce risks to benthic organisms exposed to contaminated sediment to levels that will result in self-sustaining benthic communities with diversity and structure comparable to that in appropriate reference areas."*

This is based on flawed and highly uncertain conclusions in USEPA's Baseline Ecological Risk Assessment (BERA) for OU1 that do not comport with the results of site-specific studies that have been conducted to address potential risks to these organisms. These studies, which include both measures of sediment toxicity in laboratory assays, as well as benthic community surveys (i.e., collection, identification and counts of the organisms in sediments from various sampling locations), clearly demonstrate that there is no difference between the OU1 results

and those from a reference/background study site in the Brunswick Estuary (facts that are acknowledged by USEPA both in the BERA and the Proposed Plan). Therefore, the "*..self-sustaining benthic communities with diversity and structure comparable to that in appropriate reference areas.*" identified as an RAO by USEPA has already been met within OU1 under current conditions and should be recognized as such.

In addition, statistical analyses of the sediment chemistry and toxicity data for OU1 in the BERA clearly showed that there are no demonstrable relationships between these factors for the identified COCs. As such, the USEPA's conclusion of risk to benthic communities within OU1 is incorrect, and the calculation of Preliminary Remediation Goals (PRGs) for benthic invertebrate communities was inappropriate. In fact, the OU1 BERA notes that the development of PRGs for the protection of benthic invertebrates is "highly uncertain with poor accuracies" and that "only conservative assumptions were used" for this purpose. The resultant PRGs were equivalent to the conservative sediment screening benchmarks. This conservatism and dismissal of the actual risk findings for the site is inappropriate in a baseline risk assessment under USEPA risk assessment guidance. AR recommends USEPA modify the administrative record to correctly reflect the lack of relationship between sediment chemistry and toxicity for the identified COCs when commenting on the current understanding of the actual risk associated with OU1.

2. <u>Disagreement with the Inclusion of PAHs and Pb as Risk Management Issues for OU1 in the Proposed Plan</u>

The USEPA clearly acknowledges that there are no findings of unacceptable risk to human health, fish or wildlife from PAHs or Pb in OU1 of the Site. These chemicals only remain as identified COCs due to the assertion by USEPA that they could possibly cause risk to benthic invertebrate communities, as discussed above.

AR believes that PAHs and Pb are very minor issues for OU1, as they do not pose a bio-accumulative (food web) unacceptable risk to humans, fish or wildlife of any kind or by any means of exposure, and their concentrations in the majority of the hundreds of sediment samples that have been collected within OU1 do not exceed either the conservative sediment benchmarks that are used by regulatory agencies as a means to rule out potential risk, or the respective PRGs that were established by USEPA from the BERA. While a low number of sediment samples collected in OU1 contained concentrations of PAHs and/or Pb that exceeded such screening benchmarks, that does not demonstrate risk. Instead, it suggest that further assessment of potential risk was warranted. That assessment came in the form of extensive sediment toxicity and benthic community measures (as described in comment 1 above). These site-specific measures showed toxicity levels and communities metrics that were comparable with the reference/background area studied. In the absence of the remedy being proposed to manage exposure to PCBs and Hg, AR believes that the distribution and concentrations of PAHs

and Pb in the OU1 marsh/creek system would not warrant any further response action. As such, any reduction of exposure to PAHs and Pb achieved by the Proposed Plan is simply a minor added benefit of the remedy developed to address PCBs and Hg.

3. Agreement with the Superfund Recommended Alternative

AR believes that the recommended alternative within the USEPA's proposed plan is appropriate, sustainable, and protective of human health and the environment. The remedial action recommended in the proposed plan has been developed through a careful evaluation process that takes into account the extensive data and information collected at the Site over more than two decades including: conservative human health and ecological risk assessments performed by the USEPA; a previous large-scale (i.e., 13 acre) removal response action for the marsh (completed in 1999); and a detailed RI/FS that evaluates the range of potential remedial alternatives for OU1 all pursuant to the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund) and utilizing evaluation criteria set forth in the National Contingency Plan (NCP). USEPA's proposed remedy will substantially reduce exposure to polychlorinated biphenyls (PCBs) and mercury (Hg) that have been determined by USEPA to pose an unacceptable risk to humans, fish and wildlife within OU1. It will also serve to reduce exposure to other chemicals that exist in sediments in portions of the marsh and creek (i.e., other metals and polycyclic aromatic hydrocarbons [PAHs]) that do not pose unacceptable risks to humans or fish/wildlife, but exceed conservative sediment screening levels in limited areas of OU1). A follow-up monitoring plan and Superfund Five Year Review process will be included as part of the Record of Decision (ROD) and serve to ensure remedy effectiveness post-implementation.

4. Agreement Regarding Primary Remedial Risk Management Drivers

The USEPA clearly and appropriately acknowledges in the Proposed Plan that the remedy is primarily based on management of potential risks from PCBs and Hg to humans, fish and wildlife (i.e., the primary risk drivers for the site), and that there are no findings of unacceptable risk to human health, fish or wildlife from other chemicals in OU1. AR agrees with this approach and focus.

AR appreciates USEPA's consideration of these comments and looks forward to USEPA's response and the final Record of Decision.

Aquafine
CORPORATION

3963 DARIEN HIGHWAY
BRUNSWICK, GEORGIA 31525

PROCESSING EQUIPMENT AND CHEMICALS

TELEPHONE: 912-265-2000
TELEFAX: 912-265-3000

To: U.S. Environmental Protection Agency

Pls return

Superfund Proposed Plan

LCP Superfund Site

Gentlemen- in accordance with your public comment solicitation dated November 16, 2015 current deadline extended to March 16, 2015, I have reviewed your six alternative plans for remediation of the LCP superfund site and respectfully offer comments and another alternative (7).

WE strongly agree that your proposed alternative 6 is preferred choice for the excellent reasons recited in your superfund proposed plan dated November 2014 as it minimizes sediment removal ,sediment capping, and thin cover placement lost. The least transfer of contaminated soil and least importation of good soil is the best overall outcome for the environment. All efforts should be made to avoid transfer and internment of toxic contaminants to other sites even with good safeguards in place. This avoids any risk of transferring pollution to another site regardless of how well protected the new repository is.

email: iannicelli@aquafinecorp.com

To: U.S. Environmental Protection Agency

Alternate Proposal 7 (AZorb™)

The best of all worlds would be to separate the pollutants in the most secure form that advanced technology can offer. We wish to propose a new, efficient low cost method for accomplishing this objective.

During the past ten years our company, has devised, reduced to practice and published a new breakthrough in pollution control technology that(AZorb™) combines the following advantages.

1) Broad spectrum sorption of heavy metals, organic pollutants, sanitary waste, and noxous gases.

2) High capacity

3) Low cost

4) Produced by economic remediation of a world wide waste and trial (red mud)

5) Stable after sorption (TCLP results)

Our pollution control reagent is prepared by the simple step of sulfidizing red mud, the waste by product of the Bayer process for extracting alumina from bauxite. Because of its broad range of sorbtive properties, our reagent has been trade named AZorb™.

Testing by an independent environmental laboratory has shown that AZorb does not release any of its sulfidized red mud pollutants (TCLP tests). It has also been shown that AZorb is equal to or better than ion exchange resins and avoids the expense for resin regeneration. Regeneration of resin merely transfers sorbed contaminants to another facility! With reference to use of AZorb at the LCP site, one preferred application would be to berm the LCP Domain near South Purvis Creek and install a HiFlo type thickener and ancillary filter as shown in the attached flow sheet(to recover AZorb™).

Installation of a thickener using AZorb™ would eliminate the cost of sediment removal, capping, the LCP Domains, and need to transfer polluted soil to a secure land fill!

We can produce and supply AZorb at our cost, probably less than twenty five cents per pound FOB Brunswick, GA.

Joseph Iannicchi Ph.D.
M.I.T.

Attachments: 2012 Seattle paper, CEN Article, Resume, and WestTech thickener installation

Cc: Governor- Nathan Deal

State Representative- Earl Carter

State Senator - William Ligon, Jr

U.S. senator- Johnny Isakson

U.S. Senator- David Perdue

Mr. Milton Woodside- Glynn Chamber of Commerce

Bcc: Mr. Dan Parshley- Glynn Environmental Coalition

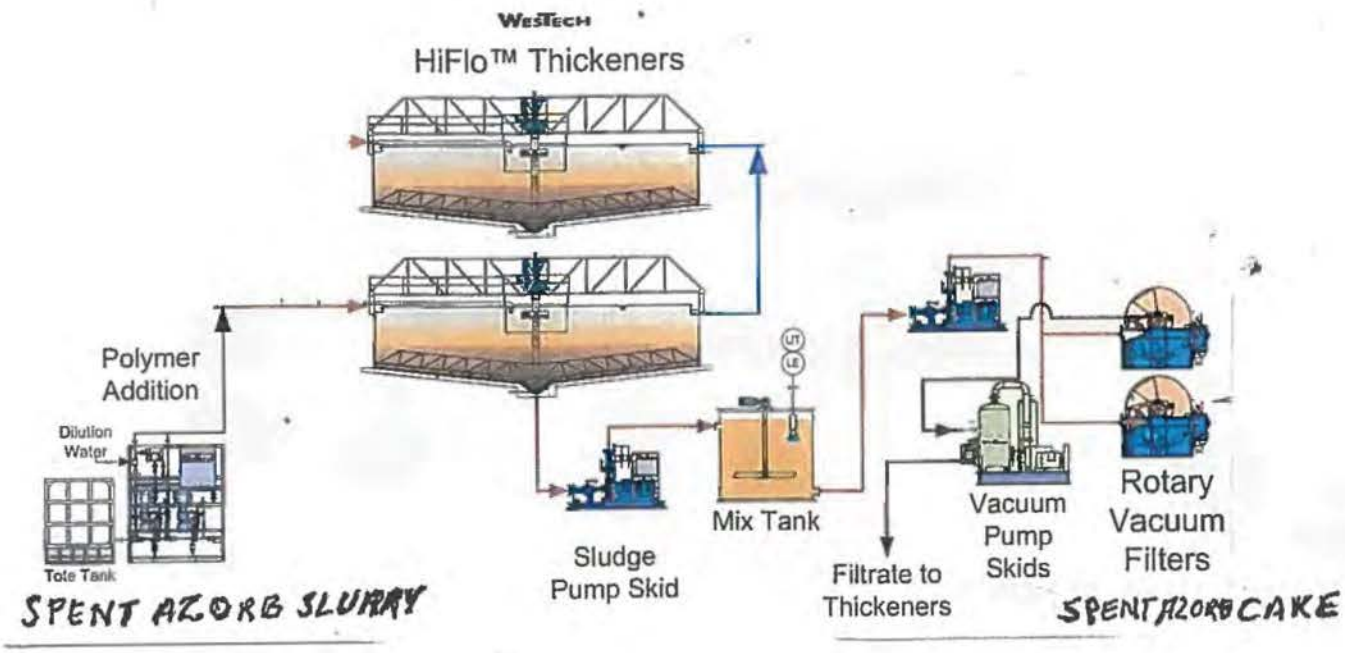
WesTech
HiFlo™ Thickeners
Polymer Addition
Dilution Water
Tote Tank
SPENT AZORB SLURRY
Sludge Pump Skid
Mix Tank
Filtrate to Thickeners
Vacuum Pump Skids
Rotary Vacuum Filters
SPENT AZORB CAKE

Figure 9 – Sediment Remedy Alternative 4: Sediment Removal – 18 Acres

IANNICELLI, JOSEPH

EDUCATION

1951	S.B., Massachusetts Institute of Technology, Chemistry
1955	Ph.D., Massachusetts Institute of Technology, Organic Chemistry, minor in Patent Law.

EXPERIENCE

1987 – Present	Founder of Aero-Instant Spray Drying Services, Brunswick, Georgia, which conducts toll or custom spray drying of non-hazardous materials on ten Niro dryers. One of the leading custom spray drying firms in the U.S.
1986 – Present	Co-founder with John Williamson and vice president of IMPEX (Industrial Minerals Process Equipment Corporation), a distributor of proprietary and major lines of wet process equipment used in mineral processing including: blungers, vibrating screens, clarifiers, filters, and calciners. Carry out test work and process development for domestic and international clients. Produce up to truckload quantities of processed industrial minerals from new deposits. Plan and design complete turnkey industrial minerals plants for U.S. and overseas clients. Projects include $16 million turnkey calciner for Thiele Kaolin and $18 million turnkey kaolin plant in Zhanjiang, China.
1971 – Present	Founder and chief executive officer of Aquafine Corporation, 3963 Darien Highway, Brunswick, Georgia. Distributor and manufacturer's representative for major lines of wet processing equipment used in kaolin and industrial minerals industries. Founded and operated Culligan of Georgia, Inc.
1971 – 1996	Exclusive world-wide representative for Pacific Electric Motor Company, Oakland, California. Product: magnetic separators. Sold thirty (30) large industrial magnetic separators (about 75% of total sold) and a number of smaller units to customers in the U.S., England, Germany, Finland, China, and Australia. Maintains the most complete high intensity magnetic separation laboratory and pilot plant in the U.S.
1971 – 1996	Niro Atomizer, Inc., Columbia, Maryland, and Copenhagen, Denmark. Products: spray dryers, evaporators, fluid bed dryers. Represented Niro in Georgia, which has the highest concentration of large dryers in the world. Sold 95% of spray dryers acquired by kaolin firms in the U.S. Maintains laboratory, pilot plant, and small industrial dryers (Aero-Instant).
1969 – 1971	Technical Director, Clay Division, J.M. Huber Corporation, Huber, Georgia. In charge of new process and product development in kaolin beneficiation and mineral modification. Head of a group of sixty-five (65) technical and non-technical personnel, which serviced a $20-million per year division (1970) having four plants in Georgia and South Carolina. Inventor of approximately one hundred (100) U.S. and foreign patents. Responsible for first commercial use of

high gradient magnetic separation, now in use throughout the kaolin industry worldwide.

1963 – 1968 Assistant Technical Director, Research Manager, and, previous to that, Research Supervisor, Clay Division, J.M. Huber Corporation, Huber, Georgia. Developed novel mineral beneficiation processes and equipment for high extraction magnetic separation, high shear leaching of iron minerals in clay, high-pressure comminution of clay slurries, selective anatase froth floatation, and fine media milling, spearheaded all phases of commercial development of surface modified specialty clays (Nulok, Nucap, Nupak, and Polyfil) from inception to pilot plant to commercial production and sales.

1960 – 1963 Research Supervisor, Central Research Division, J.M. Huber Corporation, Borger, Texas. Supervised research on clays, synthetic silicates and on production of carbon black by catalytic pyrolysis of hydrocarbons, reinforcement of elastomers and plastics with various natural, synthetic, and modified pigments.

1955 – 1960 Research Chemist, E.I. DuPont de Nemours & Company, Dacron Research Laboratory, Kinston, North Carolina. Headed special development projects at:

Pioneering Research Laboratory
Textile Fibers Department
Wilmington, Delaware 1958 – 1960

Carothers Research Laboratory (nylon)
Textile Fibers Department
Wilmington, Delaware 1957 – 1958

Technical Laboratory (dyes)
Organic Chemicals Department
Deepwater, New Jersey 1956

Member of the team that developed
T-62 and T-64 dyeable, anti-pilling Dacron

1951 – 1955 Teaching Assistant, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Summer projects in M.I.T. Metallurgy Department (corrosion of chromium/molybdenum/alloys) and at the Explosives Division of E.I. DuPont de Nemours & Company, Gibbstown, New Jersey.

AWARDS

2012 Recipient SME-AIME Robert Earll McConnell Award for "Invention, development, and commercialization of high gradient magnetic separator".

Iannicelli, Joseph

AFFILIATIONS

New York Academy of Science
Technical Association of the Pulp & Paper Industry
(Chairman, Pigments Committee 1970 – 1971)
American Institute of Mining, Metallurgical, and Petroleum Engineers
Member since 1974
Specialty Minerals Co-Chairman 1982
Surface Treated Minerals Chairman 1989
Robert Earll McConnell Award Committee 1993
Robert Earll McConnell Committee Chairman 1995 & 1996
American Institute of Chemists (Fellow)
American Chemical Society
Clay Minerals Society
M.I.T. Educational Council
American Society for Testing and Materials
American Ceramic Society
Canadian Pulp & Paper Industry
Pilots International Association
American Management Association

BIOGRAPHIES

Who's Who in America
Who's Who in the World
American Men of Science
Who's Who in Science and Engineering
Who's Who in Commerce and Industry
Who's Who in the South and Southwest
Dictionary of International Biography

CIVIC ACTIVITIES

Chairman, Glynn Union of Taxpayers 1995 – 1996
President, Jekyll Island Citizens Association 1993 – 1995
President, Georgia Tidewater Conservation Association 1991 – 1992
Foreman, Glynn County Grand Jury 1989
Member, M.I.T. Educational Council 1963 – 1971
Member, Glynn County Board of Education 1998 – 2002, chairman 2002

Patents

Magnetic Separation of Clays

4,424,124	Method and Magnetic Separator for Removing Weakly Magnetic Particles from Slurries of Minute Mineral Particles
3,471,011	Process for Improving the Brightness of Clays (U.S.)
3,667,689	Method for Producing Mineral Products (U.S.)
423,983	Australian Patent
269,729	Austrian Patent
1,122,523	British Patent
22,382	Chilean Patent
15,464	Columbian Patent
1,490,027	French Patent
1,571,552	German Patent
32,475	Greek Patent
106,550	Indian Patent
93,981	Mexican Patent
146,075	New Zealand Patent
46,253	Portuguese Patent
664,718	South African Patent
330,184	Spanish Patent
14,084	Turkish Patent
19,725	Venezuelan Patent

High Extraction Magnetic Separator

1,347,396	British Patent
935,126	Canadian Patent
2,111,986	German Patent
163,020	New Zealand Patent
55,388	Portuguese Patent
389,169	Spanish Patent

Other U.S. Patents

3,052,653	Metallic Phosphonate Containing Polyester
3,068,207	Process for Increasing the Dyeability of Linear Condensation Polymer Esters with Chelatable Dyes
3,193,344	Process for Bleaching Clay
3,193,398	Mastic Compositions
3,201,200	Modified Carbon Black Production
3,203,765	Production of Carbon Black
3,224,582	Kaolin Clay Beneficiation
3,290,165	Surface Modified Pigments
3,320,027	Clay Bleaching Under Non-Oxidizing Atmospheres

3,323,932	Antioxidant Carbon Black
3,335,020	Modified Carbon Blacks
3,390,120	Polyurethanes Containing Amino Organosilane Modified Clay
3,414,422	Chemically Treated Clays
3,442,677	Chemically Treated Clays
3,561,999	Metallic Stearate Coated Clays and the Process of Producing Same
3,556,416	Apparatus for Shearing Solids in a Solids-Liquid Suspension
3,567,680	Surface Modified Pigments and Methods for Producing Same and Elastomers Containing Same
3,661,515	Method of Brightening Kaolin Clay by Removing Organic Contaminants
3,667,688	Method for Shearing Solids in a Solids-Liquid Suspension
3,667,689	Methods for Producing Mineral Products

Patents Unassigned

3,984,309	Magnetic Separator
3,999,958	Coal Beneficiation

Assigned to Aquafine Corporation

1,104,066	Canadian Patent, Thin-Section-Matrix Magnetic Separation Apparatus and Method
1,215,821	Canadian Patent, Removing Total Reduced Sulfur Compounds from Industrial Gases
1,216,732	Canadian Patent, Fluidization Process for Removing Total Reduced Sulfur Compounds from Industrial Gases
1,576,158	UK Patent, Apparatus for Separating Particles from a Fluid-Particle Mixture
2,149,389A	UK Patent Application, Fluidization Process for Removing Total Reduced Sulfur Compounds from Industrial Gases
2,149,389B	UK Patent Application, Fluidization Process for Removing Total Reduced Sulfur Compounds from Industrial Gases
2,346,822B	UK Patent, Continuous Filament Matrix for Magnetic Separator
4,079,002	Thin-Section-Matrix Magnetic Separation Apparatus and Method
4,552,734	Fluidization Process for Removing Total Reduced Sulfur Compounds from Industrial Gases
4,552,735	Process for Removing Total Reduced Sulfur Compounds from Industrial Gases Using Manganese Dioxide
4,713,225	Method for Removing Organic Reduced Sulfur Compounds
4,923,688	Wet Scrubber Process for Removing Total Reduced Sulfur Compounds from Industrial Gases
5,112,796	Manganese Dioxide Impregnated Filter
5,128,027	Method for Removing Mineral Slimes from Kaolin Clay
5,376,605	Process for Beneficiating Minnesota Kaolin
5,397,754	Method of Brightening Kaolin Clay by Thermal Oxidative Decarboxylation of Organic Contaminants
6,180,005	Continuous Filament Matrix for Magnetic Separator
6,224,777	Continuous Filament Matrix for Magnetic Separator
7,601,319B2	Process for the Manufacture of Monobasic Potassium Phosphate
7,686,401B1	Method for Sub-Glacial Mineral Reconnaissance and Recovery

Sulfidized Red Mud Sorbent for Toxic Substances

7,763,566B2 Method and Composition for Sorbing Toxic Substances
7,807,058B2 Method and Composition for Sorbing Toxic Substances (CIP-1)
8,080,172B2 Method and Composition for Controlled Heat Release And Disposable Chemical Heater Utilizing Same
8,231,711B2 Sorption Processes - FGS
8,236,185B2 Methods for Using Sulfidized Red Mud – Sedimentation
8,377,310 B2 Method and Composition For Sorbing Toxic Substances – SRM + RM
8,382,991 B2 Method of Sorbing Discolored Organic Compounds from Water

Foreign Filings Pending

Sulfidized Red Mud - Europe, China, Canada

Publications and Presentations

Iannicelli, J. "SRM – A New Sorbent for Toxic Substances" Paper Presented at the 2012 SME/AIME Annual Meeting, Seattle, WA, February 19th – 23rd, 2012.

Iannicelli, J. "Evolution of High Gradient Magnetic Separation" Paper Presented at the 2010 SME/AIME Annual Meeting, Haydn Murray Symposium, February 28th – March 3rd, 2010.

Iannicelli, J. and J. Pechin, M. Ueyama, K. Ohkura, K. Hayashi, and K. Sato, A. Lauder and C. Rey, "Magnetic Separation of Kaolin Clay Using a High Temperature Superconducting Magnet System". Paper presented at the Applied Superconductivity Conference, August 29, 1996, Pittsburgh, PA.

Iannicelli, J., "High Tech Pigments by Novel Processing Methods". Paper presented at the AIME/SME Annual Meeting, February, 1990, Salt Lake City, UT.

Iannicelli, J., "Polymer Reinforcement with Amino and Mercaptosilane Grafted Kaolin". Paper presented at the AIME/SME Annual Meeting, February, 1990; Salt Lake City, UT.

Iannicelli, J., "The Iannicelli TRS Scrubber". Paper presented at the TAPPI Environmental Conference, April, 1986, New Orleans, LA.

Iannicelli, J., "New Trends in World-Wide Exploration of Kaolin Resources". International Clay Minerals Conference, 1985, Denver, CO.

Iannicelli, J., "Role of Kaolin Tailings Ponds in Conservation". Paper presented at the Society of Mining Engineers of AIME Fall Meeting, October 16-18, 1985, Albuquerque, NM; Preprint No. 85-395.

Iannicelli, J., "Kaolin Review 1985"; Engineering & Mining Journal 1986.

Iannicelli, J., "Beneficiation of Bauxite to Refractory Grade Quality by High Intensity Magnetic Separation"; AIME 1984.

Iannicelli, J., "Kaolin Review 1984"; Engineering & Mining Journal 1985.

Iannicelli, J., "Paramagnetic Separation in Ultrafine Industrial Minerals and Coal"; AIME 1983; pp. 105-115.

Iannicelli, J., "Kaolin Review 1983"; Engineering & Mining Journal 1984.

Iannicelli, J., "Cost Reduction Efforts Helped Industry Through Difficult Year in 1982"; Engineering & Mining Journal; March, 1983.

Iannicelli, J., "Advances in Large Spray Dryers". Paper presented at the Society of Mining Engineers of SME-AIME Annual Meeting, February 14-18, 1982, Dallas, TX; Preprint No. 82-38.

Iannicelli, J., "Evaluation of Comparison of Cross Field and Solenoid Field Magnetic Filters". Prepared for the Electric Power Research Institute, Inc., Research Project S106-1, 1981, Palo Alto, CA;.

Iannicelli, J., "Developments in the Kaolin Industry and Opportunities for Technology Transfer". Presented at the Niro Atomizer Kaolin Seminar, 1981, Hilton Head, SC.

Iannicelli, J., "Expansion and Soft Market Squeeze Profits in 1981"; Engineering & Mining Journal; March, 1981.

Iannicelli, J., "Production Plateaus in Unsettled Year of 1980"; Engineering & Mining Journal; March, 1981.

Murray, H.H. and J. Iannicelli, "High Intensity Magnetic Beneficiation of Industrial Minerals—A Survey". Study supported by The National Science Foundation (RANN); Project #GY 44129.

Iannicelli, J., "New Developments in the High Extraction Magnetic Filtration of Kaolin Clay". Paper presented at XIII International Mineral Processing Congress, June, 1979, Warsaw, Poland.

Iannicelli, J., "Record Year in 1979 Spurs Industry Expansion"; Engineering & Mining Journal; March, 1980.

Iannicelli, J., "High Intensity, High Gradient Magnetic Separation as a New Process Tool". Paper presented at the National Science Foundation Workshop, November, 1978, Columbia University, Sterling Forest, NY.

Iannicelli, J., "Kaolin—Record 1978 Output and Sales Promise a Bright Future"; Engineering & Mining Journal; March, 1979, pp. 121-122.

Halaka, N.J., J. Iannicelli, and J.A. Negrych, "Upgrading Ione Refractory Kaolins by High Extraction Magnetic/Filtration". Paper presented at the Society of Mining Engineers of AIME Fall Meeting and Exhibit, October 19-21, 1977, St. Louis, MO; Preprint No. 77-H-400.

Iannicelli, J., "High Intensity, High Gradient Magnetic Separation as a New Process Tool". Paper presented at the Joint Meeting of the American Institute of Chemical Engineers, Central Florida and Peninsular Florida Sections, May 20-22, 1977, Clearwater Beach, FL.

Iannicelli, J., "Kaolin; Production Reaches New High in '77"; Engineering & Mining Journal; March, 1978; pp. 188-192.

Iannicelli, J., "New Developments in Magnetic Separation". IEEE Transactions on Magnetics, Vol. MAG-12, No. 5; September, 1976; pp. 436-443. Paper presented at the Magnetic Desulfurization Symposium, March 23-25, 1976, Auburn University, Auburn, AL.

Iannicelli, J., "Development of High Extraction Magnetic Filtration by the Kaolin Industry of Georgia". IEEE Transactions on Magnetics, Vol. MAG-12, No. 5; September, 1976. Paper presented at the Magnetic Desulfurization Symposium, March 23-25, 1976, Auburn University, Auburn, AL.

Iannicelli, J., "High Extraction Magnetic Filtration Applications in Kaolin and Paper Making". Paper presented at the TAPPI Coating Conference, May 17-18, 1976, Boston, MA.

Iannicelli, J., "Development of High Extraction Magnetic Filtration by the Kaolin Industry of Georgia". Georgia Geologic Survey, Information Circular No. 49, published Atlanta; 1978; pp. 44-52. Paper presented at the Twelfth Forum on Geology of Industry of Industrial Minerals, April 22-24, 1976, Atlanta, GA.

Iannicelli, J., "Kaolin—Modest Recovery, High Prices in 1976"; Engineering & Mining Journal; March, 1977; pp. 139-140.

Iannicelli, J., "High Extraction Magnetic Filtration of Kaolin Clay". Paper presented at the Society of Mining Engineers of AIME Annual Meeting, February 22-26, 1976, Las Vegas, NV; Preprint No. 76-H-7.

Iannicelli, J., "High Extraction Magnetic Filtration of Kaolin Clay and Mineral Slimes". Filtration & Separation, January/February, 1976; pp. 15-18. Paper presented at the Magnetics Conference, April 14-17, 1975, London, England.

Iannicelli, J., "Extraction Magnetic Filtration of Kaolin Clay"; Clays and Clay Minerals, Vol. 24, Pergamon Press 1976; pp. 64-68. Paper presented at the International Clay Conference, July 16-23, 1975, Mexico City, Mexico.

Iannicelli, J., "Assessment of High Extraction Magnetic Filtration"; Document PB-240 880/5WW; National Science Foundation (RANN) ISRU, June 17, 1974, Washington, D.C. Available from the National Technical Information Service (NTIS).

Iannicelli, J., "Grade Structure and Applications of Coating Clays". Presented at the Canadian Pulp and Paper Association Meeting, 1970, Montreal, Canada.

Maynard, R.N., N. Millman, and J. Iannicelli, "A Method for Removing Titanium Dioxide Impurities from Kaolin". Clays and Clay Minerals, Vol. 17, Pergamon Press 1969; pp. 59-62.

Iannicelli, J., "Factors Affecting Performance of Organo Clay Coating Agents in Fertilizers". Presented at the Fertilizer Round Table, 1968, Washington, D.C.

Libby, P.W., J. Iannicelli, and C.R. McGill, "Elastomer Reinforcement with Amino Silane Grafted Kaolin". Presented at the Spring Meeting of the Division of Rubber Chemistry, American Chemical Society, Inc., 1967, Montreal, Canada.

Iannicelli, J., and N. Millman, "Relation of Viscosity of Kaolin—Water Suspensions of Montmorillonite Content of Certain Georgia Clays". Presented at the XIV National Conference on Clays and Clay Minerals, 1966, Berkeley, CA.

SULFIDIZED RED MUD
A NEW SORBENT FOR TOXIC SUBSTANCES

JOSEPH IANNICELLI, AQUAFINE CORP, BRUNSWICK, GA

ABSTRACT

A powerful improved sorbent is produced by sulfidizing red mud, a noxious by-product from the Bayer extraction of alumina from bauxite. Sulfidized red mud (SRM) sorbed 90 to 100% of the following metals from laboratory solutions of Cr, Co, Ni, Cu, Zn, Se, Ag, Cd, Hg, Pb, Th, U. Discolored organic compounds (DOC) are also sorbed (90%). Sulfidization of red mud is accomplished under ambient or relatively mild conditions using exemplary compounds such as H_2S, Na_2S, K_2S, $(NH_4)_2S$, and CaS_x. Sulfur content ranges from 0.2% to 10% above the residual sulfur in red mud. The sulfidization reaction blocks leaching of metals naturally present in red mud. In some cases, (As, Mn, Sr), mixtures of sulfidized red mud plus red mud are more effective than sulfidized red mud alone. Sulfidized red mud has applications for cleaning raw industrial process water as well as effluent wastewater (and gases) for the entire range of industrial processes.

BACKGROUND

Red mud is a noxious by-product and pollutant of the production of alumina from bauxite by the process invented by Karl Bayer in 1887. This process relies on the selective solubility of aluminous minerals in hot (125 - 250°C) sodium hydroxide solution and the insolubility of the remaining minerals (iron, titanium, and silica) which are either insoluble or react and re-precipitate. The insoluble, iron rich residue can contain 17.4 to 37.5% (Fe). Red mud is a complex mixture of finely divided hydrated iron oxides and a wide range of lesser minerals containing Al, Na, Ti, Si, Ca, Mg plus traces of over a score of other elements including Cr, Ni, Cu, Pb, Se, Hg, As, Th, etc.

The resulting red mud has strong sorptive and complexing properties and is the subject of scores of publications. Because of its preparation, red mud is intensely alkaline, with pH values of 13 and above, but also may contain and leach toxic metals. This creates serious problems with its storage in tailings impounds which poses a toxic hazard for wildlife and personnel, and creates widespread contamination of ground water. Reduction of pH below 10 is necessary for safe storage and many sorptive applications.

It is estimated that 150 million tonnes of red mud is produced and impounded per year and that about 2.5 billion tonnes is currently stored worldwide.

Hazards of storing highly caustic and toxic red mud has been brought into focus by the bursting of a red mud impound at Ajka, Hungary on October 4th, 2010 which released 700,000 tonnes of red mud over 40 square kilometers, killing ten people and hospitalizing 120 others. Neutralization of red mud can be accomplished with waste acid, or by washing red mud with large amounts of sea water (typically 12 to 18 times the volume of red mud). This requires seaside location, large settling basins, and of course the ability to discharge waste water back to the sea.

Red mud has been proposed as a sorbent for heavy metals, cyanides, phosphates, and the like. However, the sorptive and release properties of red mud are not always compatible.

Depending on the source of a particular red mud, it can leach out significant amounts of toxic pollutants such as radioactive thorium, uranium, chromium, barium, arsenic, copper, zinc, cobalt, as well as lead, cadmium, beryllium, and fluorides.

Red mud is a very hydrophilic high pH slime which is difficult to dewater by filtration or sedimentation means. This also complicates and limits its utility as a sorbent in aqueous systems.

The potential problems involved with use of red mud to control pollution are highlighted in an e-newsletter article entitled "The Great Red Mud Experiment that Went Radioactive". This experiment conducted by the Western Australian Agricultural Department involved placing 20 tonnes of Alcoa red mud per hectare on pastureland in order to stop unwanted phosphorous from entering waterways. An unintended result of this experiment was that runoff waters showed excessive quantities of copper, lead, mercury, arsenic, and selenium. Emaciated cattle grazing on treated land exhibited high chromium, cadmium, and fluoride levels. Furthermore, each hectare contained up to 30 kilograms of radioactive thorium. The disastrous red mud application test was abruptly terminated after five years.

It is evident that extreme caution must be exercised in selecting, treating, and testing red mud before attempting to use it to sorb toxic compounds.

Furthermore, the capacity of red mud to capture and hold toxic substances such as mercury and related metals often is not adequate to eliminate traces of these metals in leachate. The possibility also exists that sorption of one toxic pollutant may release other pollutants. Therefore, use of red mud as a sorbent to purify water is problematic.

As a result of intensive investigations on methods for neutralizing and using red mud, an Australian based company, Virotec, has developed a line of red mud based products covering a wide range of pollution control applications. Virotec uses a variety of methods to neutralize red mud. These involve use of natural sea water (up to 13 washings), evaporatively concentrated sea water, saline or hard groundwater brines, salt lake brines, industrial waste brines and even solid salts.

APPLICATIONS FOR SULFIDIZED RED MUD

Heavy metal contaminated liquids and flue gases from various sources (ground, stream, runoff, mines, petroleum, industrial waste) are among the most dangerous and difficult environmental problems facing the world today. Among these metals are mercury, chromium, cobalt, nickel, copper, zinc, silver, gold, cadmium, lead, selenium, and transuranic elements. Mercury contamination of the environment is the subject of increasing attention because it eventually accumulates at high levels in bodies of large predatory fish such as tuna, swordfish, and shark. A major concern is the atmospheric release of mercury from coal fired power plants, currently estimated at 46 tons per year in the United States. The Environmental Protection Agency (EPA) has identified women of childbearing age as especially threatened because of possible neurological damage to unborn children. It is estimated that 8% of women in this category have a methyl mercury blood level above 5.8 ppb.

On Dec. 14, 2000, the EPA issued a determination that their agency must propose new regulations under the Clean Air Act to control mercury emissions from coal and oil fired power plants by Dec. 15, 2003. One proposal was to reduce mercury emissions from power plants 90% by 2007. According to an article in Forbes, such regulation "could cost the power industry at

least 8.58 billion dollars per year." More recent proposals such as the Clear Skies Act call for a 70% reduction in mercury emissions over 15 years. New decision in 2016.

Sulfidized red mud is a powerful sorbent for remediating polluted sources such as groundwater, wastewater, mine runoff, petroleum streams, and industrial waste. Of particular interest is sorbing heavy metals such as mercury (Hg), chromium (Cr), lead (Pb), copper (Cu), zinc (Zn), silver (Ag), cadmium (Cd), selenium (Se), thorium (Th), and uranium (U) from such sources. The metals may be present as free elements, ions, or in compounds with other elements.

Of special interest is remediation of over 30,000 mine drainage streams where the alkalinity of sulfidized red mud would be useful.

PREPARATION OF SULFIDIZED RED MUD

The sorbent is prepared by the sulfidation of red mud, which contains hydrated ferro ferric oxides derived from the Bayer processing of bauxite ores. Sulfidation can be achieved by reacting red mud with one or more sulfidizing compounds such as H_2S, Na_2S, K_2S, $(NH_4)_2S$, and CaS_x. Unlike red mud, which is very hydrophilic, sulfidized red mud is lyophobic. As a result, sulfidized red mud has much faster dewatering rates than red mud.

The relative amount of sulfidizing agent is selected so that the sulfur content of the reaction product is from about 0.2 to about 10% above the residual sulfur content of the red mud. The weight ratio of sulfidizing compound to red mud will vary with the type of sulfidizing compound used and the desired level of sulfidation for a particular end use. Most often, the sulfidizing compound and red mud are combined at a weight ratio usually from about 1:25 to about 1:6. Conditions under which red mud can be sulfidized depend on such factors as the type of sulfidizing compound(s) and the intended use of the resulting sorbent. In some cases, sulfidation can be accomplished by mixing red mud and the sulfidizing compound at ambient temperature and atmospheric pressure. In general, higher sulfur contents can be obtained when the reaction is carried out at slightly elevated temperatures and/or elevated pressures. Sulfur content in the reaction product is affected by sulfur content of the sulfidizing agent. For example, compounds such as calcium polysulfide, usually yield products having higher sulfur contents.

When using gaseous sulfidizing compounds, such as hydrogen sulfide (H_2S), it is often preferred to conduct the reaction at slightly elevated temperature and/or elevated pressure to increase the rate of reaction and the sulfur content of the resulting sorbent. Suitable reaction temperatures range from about 40 to 200°C., often from about 80 to 120°C. The reaction pressure typically ranges from about 30 to about 70 psi (absolute).

USE OF SULFIDIZED RED MUD

In a typical application, the sorbent is slurried with a medium containing the contaminant(s) to be extracted. The sorbent, which forms a complex with the contaminant(s), can then be separated from the slurry using one or more conventional techniques such as filtration, sedimentation, or centrifugation.

In an alternative application, sulfidized red mud sorbent is processed into pellets using conventional pelletizing or extrusion equipment. The pellets can be used in filters of

conventional construction in a variety of industrial or consumer filtration applications, including filters for preparing potable water.

It has been found that sulfidized red mud sorbent is effective for sorbing various contaminants, such as mercury, which are not effectively sorbed by red mud. On the other hand, red mud itself is effective for sorbing other contaminants, such as arsenic, which are not efficiently sorbed by sulfidized red mud. For treatment of media having contaminants in both categories, use of red mud and sulfidized red mud in tandem, either in the same sorbent composition or in sequential treatment stages (e.g., red mud followed by sulfidized red mud) can be more advantageous than using either sorbent alone.

RM 1. Preparation of Red Mud. A 1kg sample of red mud received from Sherwin Alumina Company of Corpus Christi, TX was slurried at 15% solids in demineralized water and filtered on a Buchner funnel. The resulting filter cake was re-slurried with demineralized water, re-filtered, and used as the starting material in Example 2.

SRM 2. Preparation of Sulfidized Red Mud Using Hydrogen Sulfide (H_2S). Washed red mud (100g) from Example 1 was slurried in demineralized water at 15% solids and the stirred slurry was saturated with hydrogen sulfide for 30 minutes at ambient temperature. The sample was dried overnight at 100°C. and the resulting cake was pulverized.

SRM 3. Preparation of Sulfidized Red Mud Using H_2S Under Pressure in a Parr Bomb. The sulfidation procedure of Example 2 was repeated using a Laboratory Parr Bomb. After saturation of the slurry with hydrogen sulfide gas, the bomb was sealed and heated four hours at 100°C., while stirred. The bomb was then cooled, depressurized and the contents filtered, dried, and pulverized.

SRM 4. Preparation of Sulfidized Red Mud Using Ammonium Sulfide $(NH_4)_2S$. Red mud (200g) was dispersed in 600 grams of deionized (DI) water in a Waring Blender for 5 minutes. Ammonium sulfide (10g) was added and the slurry was heated with stirring on a hot plate for 1 hour at 60°C. It was then filtered and dried at 90°C.

SRM 5. Preparation of Sulfidized Red Mud Using Sodium Sulfide (Na_2S). The procedure of Example 2 was repeated using sodium sulfide instead of ammonium sulfide.

SRM 6. Preparation of Sulfidized Red Mud Using Calcium Polysulfide (CaS_x). The procedure of Example 2 was repeated using 33.5g of 30% solution of Cascade, calcium polysulfide.

Table 1. Sulfur Content of RM-1 and SRM (2-6)

CODE	DESCRIPTION	EXAMPLE	S (wt%)
RM-1	Red Mud	1	0.19
SRM-2	Sulfidized Red Mud H_2S	2	0.48
SRM-3	Sulfidized Red Mud H_2S with Pressure	3	0.90
SRM-4	Sulfidized Red Mud $(NH_4)_2S$	4	0.46
SRM-5	Sulfidized Red Mud Na_2S	5	0.62
SRM-6	Sulfidized Red Mud CaS_x	6	1.19

A more complete analysis of RM-1, SRM (3-6) is given in Table 2. The analysis reveals that filtration and washing during preparation of sulfidized red mud extracts sodium chloride (except for SRM-5) and increases concentration of Fe_2O_3 in red mud. It is significant that very small amounts of reacted sulfur have such a strong effect on the chemical and physical properties of red mud.

Table 2. Analysis of RM-1, SRM (3 -6).

		Weight %						PPM		
CODE	DESCRIPTION	Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	Fe_2O_3	Cr	Pb	Cu
RM-1	Control	4.73	0.12	17.1	8.23	1.14	39.9	1258	144	119
SRM-3	H_2S (b)	3.94	0.14	14.6	9.14	1.38	46.2	1506	180	138
SRM-4	$(NH_4)_2S$	4.39	0.13	17.9	9.24	1.26	42.3	1379	176	146
SRM-5	Na_2S	5.20	0.11	17.2	8.41	1.29	41.5	1272	159	130
SRM-6	CaS_x	4.44	0.09	16.2	8.41	1.29	41.2	1364	165	138

Leaching of RM-1 vs. SRM-2. In part (a), a slurry of red mud (50g) and demineralized water (450ml) was prepared, mixed for 30 minutes, and filtered. The filtrate was acidified with 2ml concentrated nitric acid and analyzed by ICP using EPA3050 and EPA6010 methods. In part (b), the procedure of part (a) was repeated using sulfidized red mud (SRM-2). Results are given in Table 3 and show that leachate from sulfidized red mud (SRM-2) gave a much reduced content of heavy metals (low parts per billion) than leachate from the red mud (RM-1) in every case, except Cd, where the difference was insignificant.

Table 3. Metal Concentration in Leachate (ppm)

	Hg	As	Cd	Cr	Pb	Se
SRM-2	0.0026	ND*	0.0013	0.0044	ND	ND
RM-1	0.0032	0.096	ND	0.0510	0.0064	0.017

*ND – Not detectable, below limits.

Mercuric Solution (3.5ppm) Sorption by SRM-3. Ten grams of sulfidized red mud SRM-3 was slurried 30 minutes with 1kg demineralized water containing 3.5ppm mercury (5.66ppm mercuric nitrate). The slurry was filtered and analyzed for mercury (Hg^{++}) by ICP (Method EOA 245.1).

The procedure was repeated using 22.0 ppm and 41.0 ppm mercury solutions (11-12), (13-14).

Results of tests 9-14 are summarized in Table 4 and demonstrate the superior performance of sulfidized red mud compared to red mud for sorption of mercuric ion from aqueous solutions.

Table 4. SRM-3 vs RM Mercuric Ion Sorption from Aqueous Solutions

Example	Mercuric Concentration in Filtrate	% Sorbed
Control Solution	3.5 ppm	
9 RM-1	0.56 ppm	84
10 SRM-3	0.2 ppm	94.3
Control Solution	22.0 ppm	
11 RM-1	8.0 ppm	64

12 SRM-3	0.22 ppm	99
Control Solution	41.0 ppm	
13 RM-1	23.4 ppm	43
14 SRM-3	0.04 ppm	99.9

Example 15 Mercury (metal) Sorption from Vapor Phase by SRM-3 and RM-1 (Spray Absorbed). In part (a), one gram of mercury metal was placed in a two necked round bottom (RB) flask on a supported heating mantle. One neck of the flask was open and the second neck was connected with a Teflon® tube to an aperture in the inlet duct of a spray dryer. The mercury was heated to 300°C. A slurry of 580g SRM-3 in 450ml demineralized water was sprayed by a rotary atomizer operating at 30,000 rpm. The feed rate of SRM-3 was regulated to produce an outlet temperature of 100°C from the dryer.

In part (b), the procedure of part (a) was repeated using RM-1 instead of SRM-3. The mercury content of the spray dried SRM from part (a) and the RM from part (b) are tabulated in Table 5 and show that the SRM had a significantly improved sorption of mercury.

Table 5. Mercury Sorption by Spray Dried SRM-3 and RM-1.

	Sorbed Hg Concentration (ppm)
15 (a) SRM-3	61.0
15 (b) RM-1	8.1

SRM-3 absorbed 7.5 times more mercury as RM-1 when spray dried at 300°C inlet and 100°C outlet in the presence of an air stream containing mercury heated to 250°C. Sulfidized red mud is significantly superior to red mud as a sorbent for elemental mercury metal vapor.

Example 16 Mercury (metal) Sorption from Vapor Phase by SRM-3 and RM-1 (Spray Absorbed). Example 15 was repeated except that a slurry of 100g SRM-3(a) and also 100g of RM-1 in 900ml demineralized water were spray dried (b). Samples 16a and 16b were analyzed for mercury.

This experiment was then repeated using 100g RM-1 and also 100g SRM-3 to furnish samples 16c and 16d, which were analyzed. The results of tests 16(a) – (d) are shown in Table 6 below.

Table 6. Mercury Sorption from Vapor Phase

		Sorbed Hg Concentration (ppm)
16 (a) SRM-3	1st pass	95
16 (b) SRM-3	2nd pass	340
16 (c) RM-1	1st pass	43
16 (d) RM-1	2nd pass	48

As evident from Table 6, SRM-3 is about twice as efficient as RM-1 on the 1st pass and about seven times as efficient as RM-1 on the second pass. The results show that the affinity of SRM-3 for mercury vapor improves with increased exposure to mercury, indicating an induction effect.

Sorption of mercury by scrubbing gases with sulfidized red mud has important potential for reducing mercury contamination of both freshwater and saltwater bodies.

Table 7 below summarizes the results of Examples 19 – 28 using the general procedure of Example 9. The last column indicates the amount (in wt %) of the target ion that was removed by SRM. The results with thorium are especially significant.

Table 7. Summary of Examples 19-28 SRM-3 vs. RM-1

Example	Element	Control Solution Ppm	RM-1 Filtrate ppm	SRM-3 Filtrate ppm	% Removed by SRM-3
19	Chromium III	2.240	0.018	0.005	99.8
20	Copper II	1.550	0.028	<0.004	99.99
	Copper II	6.250	0.054	0.038	99.4
	Copper II	30.50	0.073	0.040	99.9
21	Zinc II	1.850	0.035	0.009	99.5
	Zinc II	2.380	0.103	0.022	99.1
22	Silver I	3.15	ND*	ND**	99.99
23	Gold I	0.703	ND	0.227	67.7
24	Cadmium II	1.850	0.035	0.009	99.5
25	Lead II	2.0	0.058	0.007	99.7
26	Selenium	2.5	2.1	0.24	90.4
27	Thorium IV	0.956	0.054	ND	99.99
	Thorium IV	4.93	0.260	ND	99.99
	Thorium IV	10.50	0.564	ND	99.99
	Thorium IV	19.40	0.921	ND	99.99
28	Uranium II	1.13	0.074	0.04	96.5
	Uranium II	10.1	2.45	0.494	95.1
	Uranium II	38.0	6.90	3.95	89.6

*ND: Not detectable.

**ND: Essentially quantitative removal of Thorium was obtained by SRM-4.

Example 29 Comparison of SRM and RM for Sorption of As, Co, Mn, and Sr. The procedure of Example 9 was repeated using solutions of arsenic (III), arsenic (V), cobalt II, manganese (II), and strontium (I), with results summarized in Table 21.

Table 8. Comparison of SRM-3 and RM-1 sorption

Element	Control Solution ppm	RM-1 Filtrate ppm	% Removed	SRM-3 Filtrate Ppm	% Removed
Arsenic III	0.60	0.11	81.6	0.36	40
Arsenic V	1.60	0.21	86.9	1.15	28
Cobalt II	2.75	0.013	99.5	0.046	98.3
Manganese II	1.63	0.135	91.7	0.548	66.4
	2.10	0.72	65.7	0.792	62.3
Strontium II	1.90	0.10	94.7	1.10	42.1
	9.0	0.08	99.1	4.60	48.9
	27.0	0.19	99.3	11.0	59.3

These experiments reveal that sorption of red mud (RM-1) is significantly better than SRM-3 in the case of As (III), AS (V), Mn (II), and Sr (II). However, the use of red mud as a sorbent is restricted by leaching of undesirable elements which can cause serious problems. Use of sulfidized red mud in combination with red mud is useful because sulfidized red mud prevents undesirable leaching of toxic metals from red mud itself.

Example 30 Sorption of Hg (II) by Various SRMs. Summarized in Table 9 below.

Table 9. Sorption of Hg(II) by SRM (3-6)

	Concentration of Hg(II) in Original Solution (ppm)	Concentration After Treatment With SRM (ppm)	% Removed
SRM 4	4.5	0.001	100
5% $(NH_4)_2S$	19.6	0.0229	99.9
SRM 5	4.5	0.449	90.0
5% Na_2S	19.6	3.68	81.2
SRM 6	4.5	0.005	99.9
5% CaS,	19.6	3.16	83.8
SRM 3	4.5	0.004	99.9
H_2S pressure	19.6	0.02	99.9

SRM-3, 4, and 6 gave excellent sorption results from solutions of Hg(II) at two concentrations (4.5 ppm and 19.6 ppm). It is significant that SRM-4 reduced Hg to 1 ppb, thus meeting current drinking water standards (3 ppb maximum).

Ammonium sulfide treatment red mud (SRM-4) was the most effective sorbent despite the fact it had the lowest S content. SRM-5 prepared by treatment of red mud with Na_2S was much less effective than SRM-4.

Example 35 Sedimentation Rates of SRM-4 and RM-1. In the course of tests on metal sorption from aqueous solutions by sulfidized red mud and red mud, it was found that in all cases, sulfidized red mud exhibited significantly faster filtration rates than red mud. Red mud is very hydrophilic but conversion of red mud to sulfidized red mud transforms it to a lyophobic sorbent which is more readily dewatered. The unexpected improvement of dewatering behavior is shown in the following experiment.

A dispersion of 50 grams of RM-1 in 500ml demineralized water was prepared by rapid mixing in a Waring Blender for 10 minutes. The experiment was repeated using 50 grams of SRM-3 in 500ml demineralized water.

Both freshly prepared slurries were allowed to settle undisturbed at ambient temperature (25°C) for a period of 23 hours. After 23 hours, the RM-1 dispersions had settled to give a clear supernatant layer of only 1cm. The remaining slurry consisted of dispersed RM-1 with no visible sediment.

During a 23 hour period, the SRM-3 slurry settled to furnish a sedimentary layer about 3cm deep and a clear supernatant layer 11.5cm above the sediment.

These results clearly show the significant alteration of surface chemistry and dewatering characteristics of red mud by relatively small degrees of sulfidation.

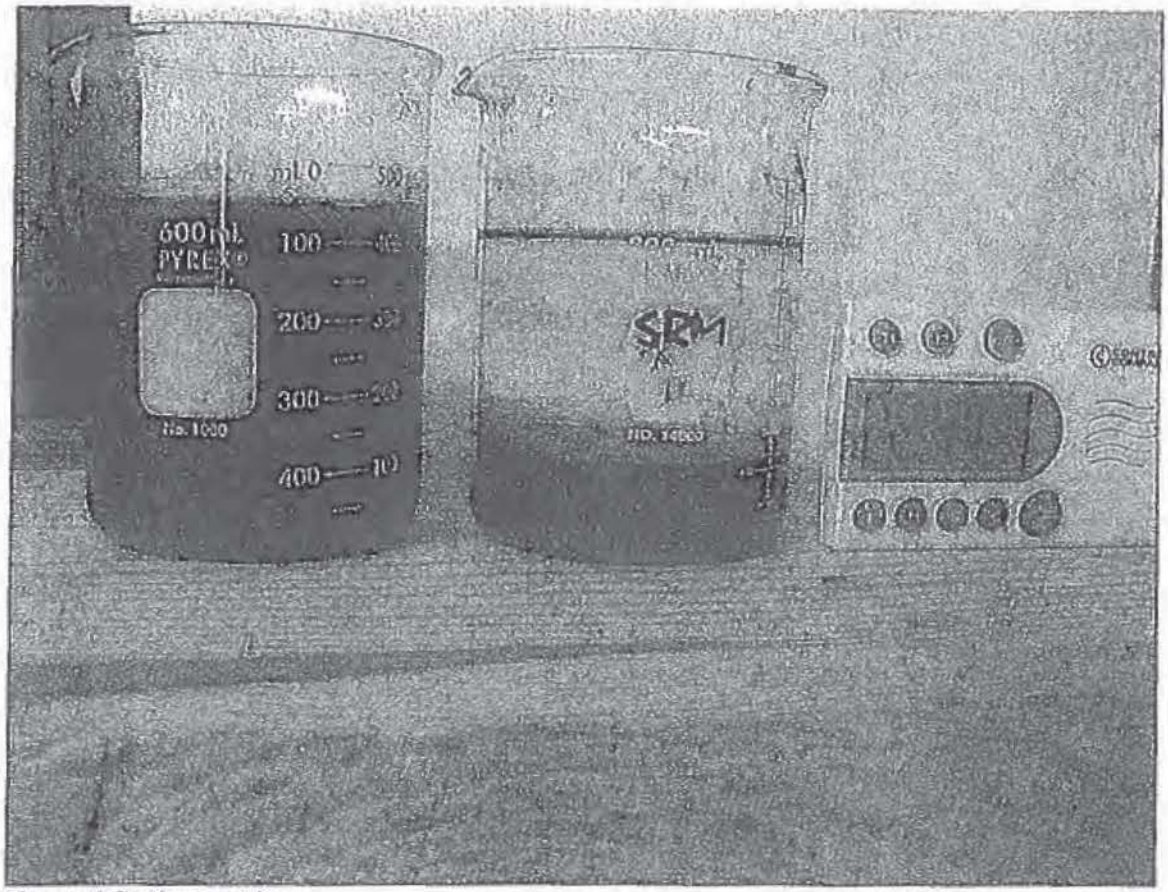

Figure 1 Sedimentation.

Example 36 Clarification of Okefenokee Swamp Water with SRM-4. 500ml of Okefenokee Swamp water (Sample I) was adjusted to pH7 with dilute NaOH and mixed with 10 grams of SRM-410 (made with 10% ammonium sulfide) in a Waring Blender at high speed for 5 minutes. The mixture was transferred to a beaker and allowed to stir an additional hour using a magnetic stirrer.

The suspension was filtered and the color value of the filtrate was determined with a LaMotte TC-3000e colorimeter. Another 10 grams of SRM-410 was then added and the procedure was repeated a second time (2nd Pass). The filtrate was again evaluated for color. Results are given in Table 26 and showed that the treated sample was nearly colorless (over 90% reduction in absorbance).

Table 26. Absorbance Testing of Okefenokee "Black" Water (Sample I)

Sample Designation	Color Value (CV) (375nm)
Control Untreated	247
1st Pass SRM-410	38.9
2nd Pass SRM-410	18.8

Another sample of Okefenokee "Black" Water (Sample II) was treated with sulfidized red mud according to the above procedure. The absorbance was reduced 90% to nearly colorless as shown in Table 27 (2 passes) and Figure 2.

Table 27. Okefenokee "Black" Water (Sample II)

Sample Designation	Absorbance*
Control Untreated	0.063
Sample II	0.0063

*Fisher Genesys5 Spectrophotometer 500nm

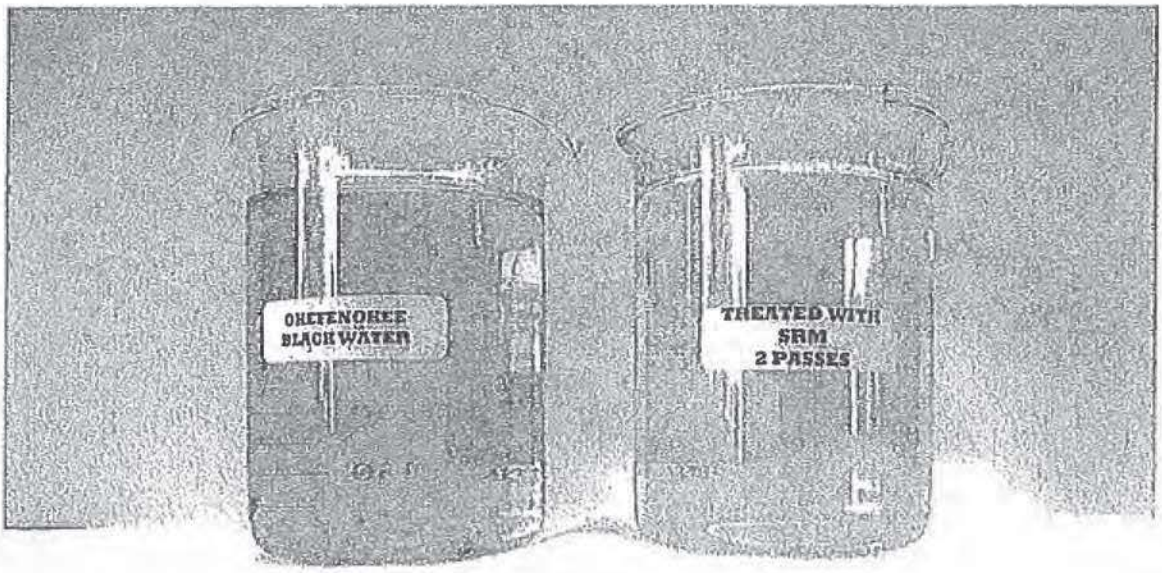

Figure 2 Okefenokee "Black" Water DOC Removal.

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AQUAFINE

MUD MAN Iannicelli poses with a sample of his sulfidized red mud sorbent, called Azorb.

MAKING THE MOST OF RED MUD

An octogenarian chemist's latest invention turns hazardous aluminum mining waste into a material for CLEANING UP WATER

STEPHEN K. RITTER, C&EN WASHINGTON

JOSEPH IANNICELLI is an inventor unlike any other you might have met. He is the 84-year-old president of Aquafine Corp., a Brunswick, Ga., company that supplies spray-drying and magnetic separation equipment and provides laboratory services for industrial mineral processing. Iannicelli holds dozens of patents for technologies used to purify kaolin, a white aluminum silicate mineral that is essential to making paper, cosmetics, paint, and sorbents for water treatment.

Iannicelli has amassed a small fortune since he graduated from Massachusetts Institute of Technology with a Ph.D. in organic chemistry back in 1955, when he helped develop a biosynthetic method to make penicillin. After working for DuPont on textile fiber polymers and for J. M. Huber Corp. on kaolin, he launched Aquafine in 1971.

In conversations, Iannicelli spontaneously recalls the details of his diverse inventions. His firm baritone leaves the listener hanging on his every word as he weaves a tale to explain how he lately came to be interested in playing with red mud.

Known formally as bauxite residue, red mud is the noxious by-product of the Bayer process for extracting aluminum from bauxite ore. Aluminum mining leaves behind a staggering 120 million metric tons per year of the salty, highly alkaline, heavy-metal-laden material, according to the International Aluminium Institute, a London-based trade organization. The aluminum industry has long tried to find ways to recycle the environmentally problematic red mud. But so far there have been few safe and economical large-scale applications.

"Red mud is a curse," Iannicelli observes. "There is no shortage of simple, ingenious solutions for dealing with most categories of environmental pollution, including red mud. The deciding factors on implementation are cost and safety."

Iannicelli's solution for red mud is to treat the abundant material with cheap sulfur compounds. Doing so locks in trace metals and improves the material's sorbent properties, he says, so it can be used for cost-effective wastewater treatment and in other environmental remediation applications. He calls the sulfidized red mud Azorb.

In the Bayer process, strip-mined bauxite is treated with hot caustic soda (sodium hydroxide), which selectively dissolves aluminum from an array of other mineralized metals. The end product is alumina, Al_2O_3, which is the feedstock for producing aluminum metal.

But for every ton of alumina extracted, more than a ton of red mud is produced. Bauxite processors recycle the caustic soda and pump the residual red sludge into huge settling ponds. When as much water is removed as possible, the material can be chemically treated to lower the pH and planted over with vegetation.

The scourge of red mud burst into the public's eye in October 2010 when a settling pond in Hungary ruptured. A flash flood of red sludge gushed through several small towns, killing 10 people by drowning and injuring more than 100 others by burning their skin and irritating their eyes and lungs.

Iannicelli isn't the first person to think about getting his hands dirty with red mud to help prevent such disasters. Australia-based industrial waste management firm Virotec has developed a process to neutralize red mud with copious amounts of seawater or brine. The resulting material is generally used to remediate mining sites, but it is also used as filler to make bricks and as a sorbent to trap metals and phosphorus in wastewater.

Aluminum producer Alcoa has a process to carbonate red mud using CO_2 from industrial gas streams. The resulting "red sand" is used to make cement and in road construction. Others have developed processes to recover iron and rare-earth metals from red mud. But so far, only 2 million metric tons of red mud is being repurposed annually—less than 2% of the amount being generated.

ONCE ALUMINUM is extracted from bauxite, the remains are a porous matrix of metals—a mineral skeleton, Iannicelli explains. As much as half of red mud is iron oxide, from which it gets its rusty color. Other major components include aluminum, silicon, titanium, calcium, and sodium oxides. The material includes trace amounts of other metals, including radioactive uranium.

With a high surface area, red mud is a natural sorbent capable of grabbing heavy metals and organic contaminants and sequestering them. But red mud can also leach toxic heavy metals, which is an environmental concern.

Iannicelli's sulfidation process involves treating red mud with sulfur compounds under ambient conditions or with mild heating. Any of a number of sulfur compounds will do the job, he says, including Na_2S, $(NH_4)_2S$, and H_2S. In the sulfidation reaction, sulfur atoms bind to vacant spots on metals throughout the skeletal network, locking the metals into place and preventing them from leaching.

Sulfidation also tunes the red mud so

that it has significantly higher sorbent capacity than untreated red mud, Iannicelli says. He has been testing Azorb's sorbent capabilities in side-by-side tests with untreated red mud using solutions of different metal salts.

Azorb removes better than 90% of most metals from aqueous solutions, Iannicelli says. His team has achieved better than 99% removal rates for metals of concern such as cadmium, chromium, lead, and mercury. The sulfidized red mud is not as efficient at removing arsenic, manganese, and strontium as red mud itself, Iannicelli says. But he suggests mixtures of red mud and sulfidized red mud might be an option for some applications. Once used, the material would be placed in a landfill.

"This work is certainly a very interesting study to detail the removal of a wide range of different species," says Justin Hargreaves, a chemist at the University of Glasgow, in Scotland. "Particularly interesting is that consideration has been given to the possibility of the red mud systems being sources of contaminants themselves and the application of sulfided and nonsulfided red mud combinations to optimize removal efficacies."

Hargreaves and his colleagues have been treating red mud with methane, a readily available by-product of oil refining and landfills. Red mud catalytically decomposes methane to form hydrogen and an iron-carbon composite. The Glasgow researchers think the inexpensive magnetic composite material could be used to remove impurities such as arsenic and chromate from drinking water in developing countries.

Iannicelli has also tested Azorb to clean up water discolored with natural dissolved organic compounds, such as tannins and lignin. This is a problem encountered when the effluent of pulp and paper mills is discharged into rivers. Although such water isn't always considered polluted, when water clarity is unnaturally impacted the effluent is in violation of the intent of clean water laws.

With that in mind, Iannicelli has shown that Azorb readily traps and removes discolored compounds from Okefenokee Swamp water. Iannicelli also has been working with Altamaha Riverkeeper, a nonprofit environmental stewardship organization that is concerned with discolored water in the Altamaha River, which drains central Georgia. The discolored water there mostly comes from a Rayonier wood pulp mill that manufactures cellulose fibers used in plastics and as an absorbent material in products such as diapers. In preliminary tests on the river water, Azorb removed the discolored compounds, Iannicelli says.

Iannicelli also owns a colonial-era rice plantation in Georgia. The plantation is no longer farmed, but it is home to a mobile home park that has its own wastewater treatment facility. As a licensed wastewater engineer, Iannicelli has carried out water treatment tests using Azorb. His team found that Azorb removes phosphorus and fecal coliform bacteria, the major contaminants of concern in wastewater, to below detection levels.

Not content to stop there, Iannicelli had technicians with the Jekyll Island State Park Authority in Georgia test Azorb on municipal wastewater. They obtained similar results, providing an independent confirmation of phosphorus and bacteria removal.

Iannicelli has also talked with scientists at a large coal-fired power plant about the prospects of using Azorb to remove mercury and selenium, the two metals of greatest concern in scrubber gas wastewater.

"There is a long history of attempts to

BY COMPARISON As a rule of thumb, 4 metric tons of bauxite yields 2 tons each of alumina and red mud, and in turn 1 ton of aluminum metal.

Global production in 2012, metric tons

Bauxite production	Alumina production	Red mud
258 million	101 million	120 million

1 ton of aluminum ≈ 70,000 cans

SOURCE: International Aluminium Institute

INTERNATIONAL ALUMINIUM INSTITUTE (BAUXITE, ALUMINA); SHUTTERSTOCK (CAN, RED MUD)

"Red mud is a curse."

reformat red mud for beneficial use, with none to my knowledge having proved successful on a large scale," says Ian T. Burke, an environmental scientist at the University of Leeds, in England. Burke remains skeptical that the abundant red mud can safely be used.

Last year, Burke led a team that took a look at three of the most hazardous trace metals in the Hungarian red mud: arsenic, chromium, and vanadium. The researchers found that arsenic and chromium are not in bioavailable states and posed low risk. But vanadium is in the bioavailable V^{5+} state and could be a long-term problem.

"MANY STUDIES that deal with red mud as an absorbent focus on the uptake of metals or nutrients," Burke continues. "But they do not give enough consideration to the quality of the treated water—that is, is it suitable for discharge to rivers?"

Burke also has questions about the long-term stability of new mineral phases in the sulfidized material and how it will hold up when used as a sorbent. "Much more detailed work seems to be required before this material could actually be used," Burke believes.

Futility has been the name of the game with red mud, adds geologist Katy Tsesmelis, a communications manager at the International Aluminium Institute. "We receive lots of project proposals that may have a sound scientific basis but could never be scaled up," Tsesmelis notes. She says there are also lots of attempts made to reuse red mud that never come to light. It's possible someone already tried sulfidized red mud.

But Tsesmelis emphasizes that the industry continues to invest in research. "The industry as a whole is working hard to remediate and reuse bauxite residue."

Iannicelli isn't discouraged by the lack of success so far in using red mud. He now has multiple patents for the sulfidation process and is eager to make commercial quantities of Azorb. He expects the cost to be as little as 10 cents per lb, less than half the cost of similar sorbents. And the first major application might be this year, cleaning up discolored pulp and paper mill effluent.

"I think the time is ripe to turn cheap red mud into an inexpensive material that can help solve some serious environmental problems," Iannicelli says. "I don't have all the answers yet. But as a chemist, I want to do good for the chemical industry," ■

Jackson, Galo

From: Jimmie Ann Abner [redacted]
Sent: Saturday, March 07, 2015 10:01 PM
To: Jackson, Galo
Subject: LCP CHEMICALS SUPERFUND SITE PROPOSED FOR THE MARSH

Dear Mr. Jackson,

I have lived on St. Simons Island, GA for over 30 years, which is only a few miles from the cleanup site, so I feel that I can speak as a "local" when it comes to writing to you about my concerns with the proposed cleanup plan of the LCP chemicals site.
I'll try to be brief.

1. What are your goals with the cleanup? Is it possible to have healthy wildlife, fish, and dolphins once you've finished with this work?

2. What happens with the site once you all have finished cleaning up your proposed area? Will you come back and test the area for the dangerous chemicals as long as there is still contaminants present?
This needs to be clearly stated in the proposal. If it's there, I haven't found it. You need to monitor this site; it's not fair to any of us who live here for it to be a one-time job. We desperately need this entire place cleaned up; not just a small area.

3. It is my understanding that the marsh around the site is contaminated with mercury and PCBs. If this is true, then all the marsh should be removed,

4. What is the medical risks to women as far as the continued contamination that you will NOT be cleaning up?

Please ask yourself if you would be willing to live anywhere near this site.

Regards,

Jimmie Ann Abner
[redacted]

Jackson, Galo

From: Albonanova [redacted]
Sent: Monday, March 16, 2015 12:14 PM
To: Jackson, Galo
Subject: GA

Dear Mr. Jackson,
Please make sure the EPA takes measures to thoroughly clean up the toxic chemical sites around Brunswick/Saint Simons Island that affect our rivers, Saint Simons Sound, the soil and ground/drinking water which spreads like underground rivers, and of course seriously affects our health and all children in the area.
Sincerely,
Virginia Balbona
Sent from my iPhone

Jackson, Galo

From: Janice Browning <[redacted]
Sent: Saturday, March 07, 2015 10:21 PM
To: Jackson, Galo
Subject: LCP Chemical site cleanup

Dear Mr. Jackson,

There are some concerns I have with the proposed cleanup at the contaminated LCP Chemical site.

I can't understand the longterm goals of your work.

Are you only going to cleanup a small area within the poisoned, contaminated site?
What is the point of only doing this area? The whole contaminated area needs to be cleaned up.
I haven't seen where you will be back to monitor your work. You need to monitor this entire site for years.

I want to see healthy fish, dolphins, turtles, and animals freely roam this marsh and water. That is my goal and it should be EPA's goal also.

I am sincerely asking for long-term site monitoring; don't leave us high and dry with acres of still contaminated marsh and water.

As far as the thin layer cover, I think that's just a trick. Have you seen our strong tides? How could this possibly work for any length of time?

I have been a resident of St. Simons Island for a long time and consider myself as a very concerned citizen. Please reconsider your proposal and ask yourself is this really a credible cleanup of one of the most contaminated sites in the United States!

Regards,

[redacted]

Jackson, Galo

From: Janice Browning [redacted]
Sent: Sunday, March 08, 2015 8:40 PM
To: Jackson, Galo
Subject: more thoughts and concerns about the superfund cleanup site

Dear Mr. Jackson,

Yesterday evening I sent an email to you about LCP Chemicals contamination cleanup in Brunswick, Georgia. I have some additional thoughts and concerns.

Will the EPA require annual monitoring for mercury and PCBs in all the fish (whole fish and fillets) that people eat and also that dolphins, mink, raccoons, otters, estuarine turtles, snails, and fiddler crabs eat? If not, why not?

My next questions are:

What monitoring has the EPA conducted on a regular basis for the past 20 years?

What monitoring data is the EPA using to compare before and after the cleanup and coverup of the contamination?

When will the EPA evaluate the cleanup (dates for evaluation, and how frequent will the EPA evaluate), what will be the specific evaluation factors (numerical goals) and specifically what will be done if the numerical goals are not reached?

What will fiddler crabs do to the thin layer cap?

Thank you in advance for your time; I look forward to hearing from you with answers to all my thoughts and concerns.

Regards,

Janice Browning

30303893199

USE THIS SPACE TO WRITE YOUR COMMENTS

Your input on the Proposed Plan for the LCP Chemicals Superfund Site is important in helping EPA select a remedy for the site. Please use the space below to write your comments. Then fold and mail. A response to your comments will be included in the Responsiveness Summary, an Appendix to the Record of Decision.

Note: In order to permit the community ample time to review and comment on this Proposed Plan, a 30 day extension to the initial 30 day comment period has been allowed for, concluding the comment period on February 2, 2015.

Your 53 page proposal for long term monitoring "Chemical measurements in tissues of fish and shellfish" with nothing about monitoring dolphins! Putting a thin layer of sand was tried in Seattle Bay, Wash. & failed. After 20 years why are you giving such a short time period for the community to respond?

1/26/15 **NAME:** Penn Clarke

ADDRESS: PENN CLARKE
[redacted]

PENN CLARKE
Name [redacted]
Address [redacted]
City [redacted] State [redacted] Zip [redacted]

N METRO
GA 301
21 JAN '15
PM 1 L

,2 1010 0000 7199 2936

PLACE STICKER AT TOP OF ENVELOPE TO THE RIGHT OF THE RETURN ADDRESS. FOLD AT DOTTED LINE
CERTIFIED MAIL™

7012 1010 0000 7199 2936

Galo Jackson
Superfund Remedial Branch
Waste Management Division
61 Forsyth St., SW
Atlanta, GA 30303

FROM:
CARR USPS
TRK# 70121010000071992936
RCVD 01/23/2015 15:22

TO: JACKSON-VELASCO , GALO
BR: REMEDIAL
CUB: WEST
PCS: 1

FLR: 11 MSC: 1
JACKSON-VELASCO , G

Jackson, Galo

From: PATTI CLAUSON [redacted]
Sent: Monday, March 16, 2015 6:22 PM
To: Jackson, Galo
Subject: Clean up Brunswick/St. Simons please

Dear Mr. Jackson,
As a citizen and a resident of Georgia I urge to please clean up the toxic wetlands, rivers, waterways and surrounding land in the Brunswick area.
It is crucial to health of our children. We know that they are the most at risk for all of the obvious reasons. But the wildlife that you and I both admire and adore is not expendable.
Please commit yourself to reestablishing a healthy, clean environment.
Respectfully submitted,
Patricia Clauson

Sent from my iPhone

Jackson, Galo

From: WILLIAM D CORSON [redacted]
Sent: Tuesday, March 03, 2015 6:59 PM
To: Jackson, Galo
Cc: Glynn Environmental Coalition
Subject: Please make sure my homeland is protected

I was born in Brunswick in 1950. I lived in Glynn County until 1975. My parents bought waterfront property on the west shore of Blythe Island in the late 1950s. My wife and I now own the "old place" on Blythe. We vacation there often and look forward to flshing and crabbing. Growing up in a "Paper Mill" family, I am aware of the great contribution industry can make to a community. As a geologist for the US Army Corps of Engineers for 30 years, I have experience to know, industry has a responsibility to leave a community as clean as possible. Glynn county marshes were not polluted in the area LCP built before LCP and LCP should clean up to an acceptable, livable level before clean up efforts are stopped.

We are all stewards of this plant. Let us be good stewards.
Sam Corson
[redacted]
Brunswick, GA[redacted]
[redacted]

Jane Fraser
[redacted]

March 16, 2015

Galo Jackson
U.S EPA Region 4
61 Forsyth Street, SW
Atlanta, GA 30303-8960
Jackson.galo@epa.gov

Mr. Jackson,

I am very concerned about the LCP Superfund Site documents NOT addressing the risks to a woman's health from the chemicals in the seafood. How these chemicals hurt the health of men and women is quite different, and it appears the EPA is using a "one size fits all" approach to human health and the cleanup at the LCP Chemicals Superfund Site.

At a minimum, the Human Health Baseline Risk Assessment should acknowledge polychlorinated biphenyls, also known as PCBs, and dioxin and furan chemicals are associated with women contracting endometriosis, a very painful disease. Very often, doctors perform a hysterectomy to prevent further instances of endometriosis along with removal of these growths in the abdomen.

The EPA extensively quotes a study conducted in the Brunswick, Glynn County area (DHHS, 1999), which found over 50% of the women surveyed had already had a hysterectomy. When considering the wide age range of women surveyed, this is a shocking statistic.

Will the EPA include information about how the chemicals at the LCP Chemicals Superfund Site can hurt a woman's health?

Will the EPA plan a cleanup that will reduce these chemicals to levels that will not cause endometriosis in women?

Will the EPA call in experts to assist the EPA in finding the level to clean up to that will end the risk of endometriosis from the LCP Chemicals Superfund Site?

The LCP Chemicals Superfund Site documenters do not appear to have any information about how the chemicals hurt woman's health. I have provided several references below for use in the EPA decision-making process and plan for cleaning up the marsh.

Will the EPA include these studies in the LCP Chemicals Superfund Site documents?

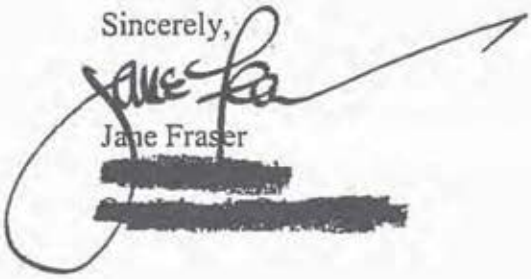
Will the EPA use these documents to plan a cleanup that not only protects men, but women, too?

Potera, C. Women's Health: Endometriosis and PCB Exposure. Environ Health Perspect. Jul 2006; 114(7): A404.
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1513298/
Toxicologist Elena De Felip of the Istituto Superiore di Sanità in Rome and her colleagues measured 11 PCB congeners that are most abundant in human tissue. In 80 women aged 20 to 40, the sum of all congeners was 1.6 times higher in the 40 women diagnosed with endometriosis than in controls. Three congeners, PCBs 138, 153, and 180, were particularly higher in women with endometriosis. These three congeners have been reported to have estrogenic activity and to interfere with hormone-regulated processes.
Bruner-Tran, K.L., Kevin G. Osteen, K.G., Dioxin-like PCBs and Endometriosis. Syst Biol Reprod Med. 2010 Apr; 56(2): 132–146.
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2867352/
Specifically, if the majority of PCBs and other toxicants have limited activity, the TEQ may not correlate with disease status since a weak AhR agonist could limit the actions of a more potent compound. For example, using primary rat hepatocytes Chen and Bunce (2004) demonstrated that PCB 153, which binds the aryl hydrocarbon receptor (AhR) without inducing CYP1A1 transcription, has no impact on TCDD-mediated CYP1A1 induction when TCDD is present at low levels, but antagonizes the effects of a high dose treatment. Since PCB 153 binds the AhR, this ligand will compete with TCDD for available binding sites, resulting in antagonism when all sites are bound. If more binding sites are present than can be occupied by all ligands, no competition exists; thus, depending on the activity of all ligands, there may be an additive, synergistic or no change in effect.
Louis G.M., Weiner JM, et al. Environmental PCB exposure and risk of endometriosis. Hum Reprod. 2005 Jan;20(1):279-85. Epub 2004 Oct 28.
http://www.ncbi.nlm.nih.gov/pubmed/15513976

Conclusion - These data suggest that anti-estrogenic PCBs may be associated with the development of endometriosis.

Thank you for your consideration of these comments on the Proposed Plan for the LCP Chemicals Superfund Site marsh.

Sincerely,



Jane Fraser
[redacted]

Jackson, Galo

From: Jane Frase[redacted]
Sent: Monday, March 16, 2015 10:50 AM
To: Jackson, Galo
Subject: LCP Superfund-Women's Concerns

March 16, 2015

Galo Jackson U.S EPA Region 4
61 Forsyth Street, SW
Atlanta, GA 30303-8960
Jackson.galo@epa.gov

Mr. Jackson,

I am very concerned about the LCP Superfund Site documents NOT addressing the risks to a woman's health from the chemicals in the seafood. How these chemicals hurt the health of men and women is quite different, and it appears the EPA is using a "one size fits all" approach to human health and the cleanup at the LCP Chemicals Superfund Site.

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http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2867352/

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Thank you for your consideration of these comments on the Proposed Plan for the LCP Chemicals Superfund Site marsh.

Sincerely,

[redacted]

January 21, 2015

Mr. Galo Jackson
US Environmental Protection Agency, Region 4
Superfund Remedial Branch
Waste Management Division
61 Forsyth Street, SW
Atlanta, GA 30303

Good afternoon Mr. Jackson,

I'm writing on behalf of myself, my family, and our business, SouthEast Adventure Outfitters regarding the LCP Chemicals Superfund Site in the City of Brunswick, Georgia, and the Proposed Plan issued by the U.S. Environmental Protection Agency (US EPA) and the GA Environmental Protection Division (GA EPD) on December 4, 2014. Specifically, I'm requesting that the period for submitting public comment be extended at least sixty days.

Since 1996, this site has ranked as a high priority in terms of toxicity, and after so many years an increase in 60 days hopefully is not an unreasonable request. We'd really appreciate more time to review and assess the decades of collected data and the alternatives assessments that have informed the US EPA's Proposed Plan. I was raised in Coastal GA only miles from this site and am raising our two kids not too far away on St. Simons. For these and future generations we do appreciate your consideration.

Respectfully, please consider extending the public comment period by 60 more days for interested parties to have adequate time to respond with their written comments. This would create a new deadline for public comment of March 31, 2015.

Sincerely,

Michael Gowen

[redacted]

Copy:
Jeff Cown, Chief - GA EPD Land Protection Branch

Jackson, Galo

From: Marla Henderson [redacted]
Sent: Friday, March 13, 2015 5:33 PM
To: Jackson, Galo
Subject: Apologies....

My apologies Mr. Jackson, I meant to address you by your last name instead of addressing it to Mr.Galo (I do my best).
Thanks in advance for taking the time to read this letter. I think it will give you a clearer picture of what is happening in Glynn County.

Begin forwarded message:

From: Marla Henderson [redacted]
Subject: Brunswick Superfund sites
Date: March 13, 2015 4:22:57 PM CDT
To: Jackson.galo@epa.gov

Mr.Galo,

I want to thank you for turning your attention to such a serious situation that many have ignored for decades. I won't go into my entire personal history regarding being poisoned by these toxins because it would take pages, but will share a few of the highlights. I grew up near many of the SuperFund sites, and have been very sick from about the age of five on, and in my life I have had eighteen bouts of serious pneumonia, chronic leukemia, neurological issues due to chemical toxins in my brain, and many other serious diagnoses. I was in and out of hospitals…once having wires drilled into my head while awake (at the teaching hospital in Augusta, Georgia) because they were trying to find out why I was having seizures that started at twenty (I do not have epilepsy), their next step was to shave my head and insert a metal plate. An angel of a nurse came in and told me I should leave b/c they didn't know what was wrong with me and I was being used as a guinea pig! All the nurses worse suits like people wear at contamination sites because it was when AIDS was just coming to light, and they were concerned that is what i had, but of course I didn't thank goodness. Can you imagine the fear and grief I felt? I was the age of a college kid and my life was just supposed to be taking off. Then I ended up at the Boston Children's Hospital under the care of a John Hopkins trained doctor who was smart enough to realize I had chemical poisoning, so at the age of 20 (I had had to leave college because of being so sick) he sent my blood work to a lab specializing in chemical poisoning. They wrote him a personal note saying they had never seen such high levels of dioxin and mercury in a living human being, and it was a miracle I was alive. They didn't even know to test for toxaphene or other chemicals. I have been told the same by many doctors, even recently, that they were expecting me to pass at any time. I am a fighter, and although there have been many times I was so sick I wanted to die, I kept on for my family (who also have many health problems related to this situation) and for my Godchildren (one of whom grew up on Saint Simons Island and had leukemia at four, his Mother has had breast cancer, his Grandfather liver cancer, and Grandmother died from cancer that had spread all over her body. So this isn't an issue that just affects the poor or the African American community which many believe, it reaches even the wealthy on Saint Simons Island/Sea Island many of whom are unaware. I grew

up in Glynn County so I know all about racism/elitism and it disgusts me. I know that this is in part is what has stalled a thorough clean up.

I like everyone from the community do not want this issue to affect tourism, jobs or embarrass my hometown. Having said that, I care more about keeping people healthy, especially the children who have no voice. But if something is not done about this local scenario, it will eventually make its way into the larger public. I had a friend who was a producer on Oprah's show, she approached me and got us into the final five potential shows that would be airing before Ms.Winfrey retired from that job. The show was to be on the effect of chemical toxicity in the environment and its link to health. I have also been approached by 60 minute producers etc. I have spoken with Erin Brockovich. It is like a volcano that is waiting to blow. While some might not pay attention to sick humans, they do pay attention to tv, and also a place that has the most toxic dolphins in the world.
I would rather see this cleaned up quietly, I know many would prefer that as well. Before that time, there should be signs all around the rivers, land, buildings and notices should be sent to residents about the contaminated ground water until outside, knowledgeable and unbiased parties agree that the danger has been eliminated.

My paternal Grandmother worked in the shipyards during WWII as a way to help her country. I am sure she was exposed to God knows what and she died of cancer. My father has struggled with cancer as well.- He fished every weekend, often in Turtle River, while we played, packing the mud on our bodies like kids do, not knowing we were releasing poison into our systems. We had an entire freezer filled with fish, shrimp and crab that we ate on almost a daily basis. Because I had so many health problems, I tried to eat right/live healthy, exercise (when I was strong enough), and instead of drinking coca cola like most good Southerners, I drank water. Unbeknownst to me, I was drinking poison. We swam in the creeks, and took baths in this contaminated ground water. I also attended Altama Elementary school where it took thirty years after I had left for them to shut the school down because of the high levels of toxaphene STILL in the soil/water. To say this situation has affected my life adversely would be a gross understatement. It has kept me from having children which was my greatest dream, the financial stress was largely responsible for the dissolution of my first and only marriage, and I have spent just about every penny I have ever earned keeping myself alive. My insurance dropped me when I was in my twenties because the doctors could not figure out what was wrong until it was too late. It ruined my credit. That makes things very hard. I have spent years in and out of bed, often in a semi comatose state with all kinds of issues that I know relate directly back to a compromised immune system due to early childhood chemical poisoning, a time when my brain and body and many systems were still forming. I have tried to chelate the toxins out but they are so deeply embedded in my organs (I have been told by doctors) that I become deathly ill when an attempt is made (I tried anyway). I lost my business and all belongings recently which was devastating because I like to work, it is all I have in my life in many ways. As my body ages, it gets harder to stay well. This living nightmare has cost me almost everything, and while it is too late for me in many ways, it isn't too late to clean it up so that other local children won't suffer the way I have for 40+ years. Do you have children or grandchildren Mr.Jackson? I am sure you are someone who has a heart and compassion. If you can't do it for strangers, please think about the children you love and how you would want this to be handled to protect them from harm.

I am asking/pleading for you to help make this right. I have read over many comments that are being submitted, as well as the important questions you are being asked, that need to be answered honestly. I will not go there as surely this has been made very clear by others. I wanted to show you a personal side of this disastrous matter, in the hopes it will inspire you to do

what needs to be done to thoroughly clean this mess up, to not do it half way. I pray that the team of lawyers and PR people that the corporations have hired do not win this battle. It is wrong for them to even try. Money means nothing if you don't have your health. I learned that first hand. They would feel differently if it were their sister, mother, father, child who was sick. I will continue to follow what I hope is positive progress in this matter because besides me, there are many who have been affected.

Most Sincerely,
Marla Henderson

[redacted]