ROLLING KNOLLS LANDFILL SUPERFUND SITE
FEASIBILITY STUDY ASSESSMENT

Prepared for

The Office of Environmental Policy and Compliance

Department of the Interior

Prepared by

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1 Introduction and Objective

The U.S. Department of the Interior (DOI), on behalf of the U.S. Fish and Wildlife Service (FWS), collectively the Agencies, has reviewed the Rolling Knolls Feasibility Study (FS) Report (Revised Draft, Geosyntec, July 2018a) (the FS). The draft FS is a key long-term management remediation assessment report for the Rolling Knolls Landfill Superfund Site (the Site) in Chatham Township, New Jersey (NJ), (Figure 1).

The Site is a former sanitary landfill that was abandoned by its owner/operator in 1968 and is roughly defined by the extent of the identified landfill wastes (approximately 168 acres, Figure 2; CDM Smith 2014). The Great Swamp National Wildlife Refuge (GSNWR aka the Refuge) (Figure 1), owned by the United States Government and operated by the FWS, covers 7,768 acres. The eastern and southern portions of the Site/landfill (35 acres) are within the GSNWR (Geosyntec Consultants, Inc. 2018b). As a DOI bureau who manages the Refuge, the FWS is a not only a stakeholder with significant interest in the Site's remediation, FWS, as a federal land manager (FLM), must ensure that actions within the Refuge comply with federal law; the NCP identifies FLMs as the "lead agency" for CERCLA actions on federally-managed lands.

The objective of this assessment is to evaluate the effectiveness of remedial action alternatives identified in the draft FS as they relate to the impacts on the Refuge. The Agencies have expressed apprehension that the remedial action alternatives set forth in the draft FS do not fully address their concerns in their role as managers of the Refuge (USDOI 2018). Principal among the concerns is that only one of the proposed alternatives (Alternative 5) has the potential to directly reduce impairment to the Refuge. An unimpaired environment complies with the Refuge's Comprehensive Conservation Plan (CCP), the DOI Environmental Compliance Memorandum (ECM) (See DOI 2018), and all other Applicable or Relevant and Appropriate Requirements (ARARs) for the Refuge portion of the Site (DOI 2018). Alternative 5 would cap the waste on the entire landfill, including the portion on the Refuge, without any removal or consolidation of waste material on the Refuge. Though not the ideal remedy for the Refuge, if done correctly with a cap that is appropriately restored with native vegetation, Alternative 5 is the most viable of the proposed options. Alternative 5 also proposes to construct the landfill cap with offsite material. This would require extensive truck traffic through the local residential community. However, FWS has suggested an approach that would reduce the truck traffic and better meet the Refuge CCP, the DOI ECM, and ARARs (FWS 2018).

This assessment integrates a review of the draft FS, as well as supporting documents including, the Remedial Investigation (RI) Report, Rolling Knolls Landfill Superfund Site (Geosyntec Consultants, Inc. 2018b); the Baseline Ecological Risk Assessment (BERA) (Integral December 2016); and, the Baseline Human Health Risk Assessment (BHHRA) (CDM Smith, July 2014). Summary conclusions from this assessment are presented in the following section.

2 Summary Conclusion

1. Surface soils on the Refuge property have been contaminated by lead (Pb), polychlorinated biphenyls (PCBs) and other chemicals related to landfill wastes at concentrations in excess of the proposed cleanup goals identified in the draft FS (Geosyntec Consultants, Inc. 2018a) and at concentrations posing significant risk to Refuge ecological receptors. The draft FS presents two remediation alternatives (Alternatives 3 and 5) that include capping source landfill waste. Only Alternative 5 proposes to directly reduce impairment to the Refuge. Alternative 5 would cap the waste on the entire landfill, including the portion on the Refuge, without any removal or consolidation of waste material. Though not the ideal remedy for the Refuge, if done correctly with a cap that is appropriately restored with native vegetation, Alternative 5 is the most viable of the proposed options. Alternative 5 also proposes to construct the landfill cap with offsite material. This would require extensive truck traffic through the local residential community. However, FWS has suggested an approach that would reduce the truck traffic and better meet the Refuge CCP, the DOI ECM, and ARARs (FWS 2018).

   Either Alternative 3 or 4 could be modified to address FWS' concern that all the source landfill waste at the Site be properly contained and better align with the goals of CERCLA as established in the National Contingency Plan (USEPA 1994). Alternative 3 could be modified to require removal of the source landfill waste from the Refuge, consolidation of the removed waste, as well as the landfill waste on the private portion of the site, and capping the entire consolidated waste. Alternative 4 also could be modified to include removal and offsite disposal of contaminated source landfill waste in excess of the cleanup goal on the Refuge and capping the remaining source landfill waste on the Site. Both modified alternatives would address the Refuge's concerns if the disturbed areas were also vegetated with native species.

   FWS has repeatedly expressed preference for an alternative that includes removal of waste and contaminated soil from the Wilderness Area and reestablishing native vegetation; consolidating removed material on private portions of the landfill and capping it with the clay that is available onsite; and, establishing native warm season grasses/meadow mix on the cap (e.g., FWS 2018). In addition to aligning with FWS' preference, an alternative featuring removal of waste and contaminated soil/sediment from the Wilderness Area, as opposed those reliant on capping waste left in place, would fully align with CERCLA's FS alternative criterion (USEPA 1988) of reducing the toxicity, mobility and volume of waste, as well providing the most effective long-term solution to the problem.

   The Agencies request that ecological, wildlife risk-based soils preliminary remediation goals (PRGs) be calculated for the key chemicals of potential ecological concern (COPECs) (See Table 3), that the draft FS Section 4 be modified accordingly, and that the PRGs be used to help guide the evaluation of soils remedial action alternatives affecting the Refuge.

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2. Sediments on the Refuge property have been contaminated by heavy metals (e.g., mercury and Pb) and organics (e.g., PCBs) related to landfill wastes at concentrations posing significant risk to Refuge ecological receptors. Alternatives in the draft FS that allow source waste to remain without proper containment will allow this migration pathway to continue to exist and would not meet the Refuge CCP and the DOI ECM requirements, nor comply with other Refuge ARARs (DOI 2018). Alternative 4 could be modified to address the Refuge's concerns by consolidating the contaminated soil and source waste on the Refuge onto the private portion of the landfill and capping the consolidated waste area to prevent further migration of contaminants into the surface water and sediment of the Refuge.

   It is important to note that this assessment found the sediment information collected in Black Brook during the RI was insufficient to determine the nature and extent of contamination, particularly with respect to upstream sources. Since Black Brook sediments have not been adequately characterized, the associated risk has not been fully assessed. However, If Alternative 3 or 4 was modified to include consolidation and containment of the contaminated soil and landfill related waste affecting Black Brook sediment, additional sediment characterization would not be necessary to make the determination of whether uncontained source waste could remain on the Site, as currently proposed in several alternative in the draft FS.

3. Groundwater contamination (from heavy metals) related to landfill wastes has impacted the Refuge. Contaminants are reported at concentrations in excess of promulgated New Jersey groundwater quality limits. New Jersey groundwater quality limits are potentially applicable requirements. Only one alternative in the draft FS (Alternative 5) has the potential to prevent further migration of contaminants from the landfill waste into the groundwater. The remaining alternatives allow source landfill waste to remain onsite without containment. The RI (Geosyntec Consultants, Inc. 2018a) concluded that, "Black Brook likely receives hydrologic input from groundwater discharge," and groundwater flows from the Site and east to Refuge property, which indicates that the contaminated groundwater plume from the Site can be expected to discharge into surface waters on the Refuge at some point (if it is not currently). This represents a likely complete exposure pathway to human and ecological receptors within the Refuge. As the draft FS (Geosyntec Consultants, Inc. 2018a) notes, source removal activities within the landfill/Site may be expected to create a 'slug' of even more contaminated groundwater. At a minimum, the proposed draft FS alternatives need to be modified to adequately contain the source landfill waste to eliminate the groundwater exposure pathway and potential surface water impacts on the Refuge.

4. Significant data gaps and data assessment errors were identified in the draft FS characterization data. A subsequent review of the final RI surface soil characterization data indicates that

important lead concentration data on the Refuge Area of Interest (RAOI) are not in that document. Additionally, a comprehensive assessment of sediment contamination and its associated impacts was not conducted to support alternatives that would allow source landfill waste to remain onsite without containment, which presents a limiting data gap for FS decision making. These errors and omissions raise concerns regarding the quality of the FS and the remediation alternatives proposed.

3 Approach

The objective of this assessment is to determine if the remedial alternatives proposed in the draft FS adequately address the risk associated with contamination identified on the Refuge and comply with Refuge requirements documented in the Refuge CCP, the DOI ECM, and other ARARs or present remedies acceptable to FWS as the FLM. The draft FS, RI, BERA, and BHHRA are large summary documents that, in turn, are supported by other documents and reports (e.g., work plans, technical memoranda, etc.). In order to meet the objective, the assessment focused on identifying the important, representative risks and the proposed remedial actions. Accordingly, the approach was to evaluate the Refuge portion of the Site by reviewing the summary documents considering four assessment questions:

1. Has the Refuge been impacted by landfill wastes?
2. If the Refuge has been impacted, is the impact significant and impairing?
3. If the Refuge has been significantly impacted, do the remedial/removal alternatives proposed in the FS address the Agencies' concerns?
4. Are there other remedial/removal alternatives or modifications of existing remedial/removal alternatives that would address the Agencies concerns?

The eastern and southern portion of the Site/landfill includes approximately 35 acres that are located on the Refuge (i.e., DOI-managed property). The assessment considered the extent of impacts in the landfill portion of the Refuge and the potential extension of those impacts into the surrounding Refuge, referred to as the RAOI in Figure 2. The RAOI is approximately 150 acres. This RAOI captures the relevant assessment data and represents a bounding of the Refuge area where landfill waste impacts and associated risk are documented and/or most likely to be found.

A summary of the draft FS alternatives with their key feature(s) relative to the Agencies' concerns is provided below:

Alternative	Key Features Relative to Agencies Concerns [a]
Landfill 1[b]	No Action
Landfill 2	Site controls (i.e., Institutional Controls, Fencing and Signage);
Landfill 3	Capping of selected areas to reduce overall risk, remediation of "Areas of Particular Concern (APCs)", and remediation of non-vegetated areas of soil contamination above remediation goals. (Note: only one APC was identified in the RAOI, associated with soil sample SS-118 south of the Landfill.)
Landfill 4	Excavation and off-site disposal of selected areas to reduce overall risk, remediation of APCs, and remediation of non-vegetated areas of soil contamination above remediation goals. (Note: only one APC was identified in the RAOI, associated with soil sample SS-118.)
Landfill 5	Capping of all landfill material.
Groundwater 1	No Action with naturally occurring "Constituent of Concern (COC)" reductions.
Groundwater 2	Source control, institutional controls, COC reduction by ongoing natural processes, long term monitoring with potential need to make adjustments to the remedy in the future.
Groundwater 3	Source control, institutional controls, COC reduction by ongoing natural processes, long term monitoring with implementation of a contingent remedy.

[a] To address the area of the Refuge significantly impacted by the Site/landfill, and to comply with the Refuge CCP, the DOI ECM, and all other ARARs.
[b] The draft FS refers to these alternatives as "Soil" alternatives; however, they address the source landfill waste as well as the soils contaminated by the landfill waste and are more appropriately labeled as "Landfill" alternatives.

4 Assessment

This section presents the impact on the RAOI from contamination of surface soils, sediments and groundwater, and evaluates the effectiveness of proposed remedial action alternatives identified in the draft FS as they relate to those impacted media.

4.1 Surface Soil Contamination

Pb has been identified as a chemical of potential ecological concern (COPEC) (Integral Consulting, Inc. 2016). For purposes of this assessment, Pb was selected as a representative COPEC on the premise that appropriate remedial action requirements for Pb would also apply to the other contaminants present. There are other COPECs posing significant risks to receptors including vermivorous birds and mammals and they are discussed later in this section.

Data presented in the RI and BERA indicate prevalent occurrences of Pb in surface soils on the landfill, outside and inside the RAOI. For purposes of risk management decision-making, the BERA grouped all surface soils together on a Site-wide basis (Integral Consulting, Inc. 2016). This site-wide approach carried over into the FS where APCs were identified for remediation (Geosyntec Consulting 2018b). No considerations for the Refuge's sensitivities or requirements were observed in this decision. A review of the draft FS data tables (e.g., Geosyntec Consulting 2018a, Table B-3A) revealed that no PRGs were established specifically for the Refuge. For purposes of this assessment, the benchmark Pb concentration of 400 mg/kg, which is the Preliminary Remediation Goal (PRG) used for other recreational facilities at the Site (e.g., the ball field and the shooting range), was used as a benchmark for assessing the Refuge conditions as well. Note that while the RI identifies RAOI Pb soil concentrations equal to or exceeding 400 mg/kg (identified as the direct contact soils remediation standard [DCSRS]), the FS proposes a Pb surface soil PRG of 2700 mg/kg based on protection of a human heath, assuming site-specific trespasser exposure scenario assumptions in accordance with New Jersey Alternative Remediation Standard (ARC) provisions (Geosyntec Consultants, Inc. 2018d).

The following assessment addresses surface soil Pb concentrations reported only on the RAOI and considers whether the site-wide approach in the FS addressed the Agencies concerns. A geographic information system (GIS) was used to isolate the 56 surface soil samples located within the RAOI, based on their coordinates and their depth. Only RI soil samples collected from the surface were included in this assessment, though the RI included some samples collected at depth. Locational data were obtained from GIS Shapefiles provided to DOI by USEPA or digitized from georeferenced figures from the BERA (Integral Consulting, Inc. 2016). The distinction between soil and sediment samples in the RI is confusing because some samples identified as "soil" were submerged under water at the time of collection (e.g. SS-162), and some samples identified in the RI as "sediment" were not submerged at the time of collection (e.g., SD-61). It is unclear exactly how these samples were used to characterize the Site within the RI. For the purposes of this evaluation and to evaluate the potential areal extent of contamination on the RAOI, the surface soil samples within the RAOI that were re-classified as a sediment matrix (e.g., SS-162) were evaluated with the other soil matrix samples; this use is also consistent with the approach taken in the RI for other areas of the Site (Geosyntec Consulting 2018b, Section 4.9.2). Therefore, Table 1 consists of data obtained from the RI Table B-3A (surface soils concentrations) and some RI sediment data obtained from RI Table B-7A. The BERA Pb surface soil data used for this evaluation came from BERA Figure 4-5b (Integral Consulting, Inc. 2016).

Some of the soil sample locations within the RAOI were not relevant from an ecological risk perspective and so they were eliminated from the assessment. Specifically, at soil sample locations SS-180 and SS-181 (located in the south/southeast section of the RAOI), only deep samples were collected (beginning at eight and nine feet below ground surface, respectively). Therefore, no representative surface soil COPEC data was available from those locations. Also of note, for sample location SS-191 (also located in the south/southeast section of the RAOI), RI Table B-3A indicates that the sample was only submitted for VOC analysis (i.e., metals such as Pb and other known, Site-specific COPECs were not analyzed for). The analytical results for SS-191 are also reported as "no exceedances" on the RI soil sample analytical results figure (Geosyntec Consulting 2018a, RI Figure 4-1d), which is inappropriate.

A summary of the distribution of surface soil Pb concentrations identified on the RAOI from the RI and BERA reports is provided in Table 1. The rationale behind Table 1 is to compare surface soil Pb concentrations with a range of recognized ecological risk benchmark concentrations in order to illustrate the extent of soil Pb contamination levels relative to well-documented points of reference.

Table 1 identifies the number (i.e., count) of surface soil Pb samples located on the RAOI and highlights the number of concentrations exceeding a benchmark concentration of ecological risk and other parameters that are indictors of the extent and magnitude of Pb impacts. The data summarized in Table 1 was obtained from the RI (Geosyntec Consultants, Inc. 2018b, Figures 4-1a, 4-1b, 4-1d and their associated tables) and BERA Supplemental Data (Integral Consulting, Inc. 2016). The sample locations are illustrated on Figures 3 and 4 of this document and are described below.

The comparisons presented in Table 1 indicates the following.

1. Many RAOI surface soil sample locations (50 of 56 [89%]) had Pb concentrations exceeding the background benchmark concentration of 38.4 mg/kg, which is the 75th percentile concentration of the background sample population. The background comparison concentration was determined from sample locations on the Refuge east of the landfill (Geosyntec Consultants, Inc 2018b).

2. Pb concentrations in 20 (36%) of the 56 RAOI surface soil samples exceed the proposed 400 mg/kg benchmark Pb concentration. Many of these exceedances were found in the eastern, southern and southeastern portions of the RAOI (Figure 4).

3. Many of the surface soil Pb measurements that are below the 400 mg/kg benchmark Pb concentration exceed Ecological Soil Screening Levels (SSLs). Ecological SSLs are conventional nationwide screening values that are typically accepted by federal government entities, including the Agencies, and viewed as point-of-departure expectations for evaluating ecological risk on federal property. Two of the Ecological SSLs for Pb (Mammal, 56 mg/kg; and Plants, 120 mg/kg) are notably more conservative, and therefore, more protective than the proposed 400 mg/kg benchmark concentration or the 2700 mg/kg proposed PRG.

4. Numerous surface soil Pb concentrations exceed NOAEL- and LOAEL-based concentrations that would be protective of species of concern identified in the BERA. The protective benchmark concentrations shown in Table 1 were calculated from the tables found in BERA Appendix H using the same exposure and toxicity assumptions listed in those tables. Notable observations from Table 1 include:

   - For the American robin, representative of vermivorous birds, 98% of the Pb soil samples (55 of 56) exceed the estimated NOAEL benchmark concentrations and 84% (47 of 56 samples) exceed the LOAEL benchmark. It should be noted that the NOAEL concentration is lower than the background benchmark concentration.

   - In the case of the Short-tailed shrew, representative of small vermivorous mammals, 55% of the soil samples (31 of 56) exceed the estimated NOAEL Pb benchmark concentration and 36% (20 of 56 samples) exceed the LOAEL benchmark.

   - For the meadow vole, representative of small herbivorous mammals, 30% of the soil samples (17 of 56) exceed the estimated NOAEL benchmark concentration and 2% (1 sample in 56 samples) exceed the LOAEL benchmark. Though only one sample exceeds the LOAEL benchmark, the relatively low sampled densities around these high concentration samples results in large areas of uncertainty that conservative risk management must conclude are also similarly contaminated. Specifically, at sample location SS-115, the nearest sample locations are 175 ft. to the east, 392 ft. to the south/southwest, 538 ft. to the west, and 463 ft. to the north.

5. Six soil samples (11%) in the RAOI, exceed the calculated 95% upper confidence limit (95% UCL) on the mean exposure point concentration (EPC) of 1,521 mg/kg. This EPC calculation approach is consistent with conventional USEPA guidance (1997). EPCs found in the BERA for the GSNWR (Appendix H) were based on estimates of the mean (average) concentration.

   Using this conventional health protective USEPA technique indicates that the RAOI-wide (56 samples) Pb EPC would be well in excess of the calculated benchmark concentrations shown in Table 1, with the exception of the meadow vole LOAEL benchmark.

   As noted, EPCs, and subsequent Hazard Quotients (HQs) found in the BERA for the GSNWR (Appendix H) were based on estimates of the mean (average) concentration, and therefore, are not as protective as would be the case had the 95% ULC EPC been used.

   According to the FS, "The results of the BERA indicate that exposures to COPECs in the environmental media at the Site do not pose an ecological concern for most of the evaluated receptors and that there is low potential for risk to vermivorous birds and mammals from exposure to metals and PCBs based on food chain models for the short-tailed shrew and American robins" (Geosyntec Consultants, Inc. 2018a). This citation appears to be the premise for not addressing ecological risks, including those on the Refuge, in the draft FS. This assessment does not support that conclusion. The contrasts shown in Table 1 (i.e., numerous exceedances of ecological protective benchmark concentrations) and the conventionally estimated EPC of 1521 mg/kg compared to protective benchmark concentrations derived from BERA assumptions (e.g., the 1521 mg/kg 95% UCL EPC vs. the Short-tailed shrew LOAEL benchmark of 464 mg/kg), demonstrate that, contrary to the sweeping finding statement in the FS (…" the Site does not pose an ecological concern for most of the evaluated receptors….”), the Pb concentrations in the RAOI, and in all likelihood many other COPECS concentrations measured on the RAOI, do in fact pose significant risk and ecological concerns.

6. The last entry in Table 1 indicates that 1 RAOI sample location (2%) exceeded the landfill PRG of 2700 mg/kg reported in the FS. As indicated in the Table 1 footnote C, this PRG was computed under New Jersey Alternative Remediation Standards (ARS) based on human heath site-specific trespasser exposure scenario assumptions. The distinction between the landfill PRG designated to protect a human trespasser on the Refuge and the benchmark concentrations in Table 1, illustrate a stark disparity between interpretations of the threat posed by Pb (and likely other COPECs) on the Refuge.

Table 1 – Summary of Reported Refuge Area of Interest Pb Soil Contamination and Comparisons to Benchmarks

Surface Soil Parameter	Number	Percent of RAOI Samples	Remark / Source
RAOI Surface Soil Samples	56	-	From RI Tables B-3A, B-7A and BERA 2016 Supplemental data
Number Exceed Background 75th Percentile (38.4 mg/kg)	50	89%	RI Appendix I, Figure A 27
Number Exceed 400 mg/kg (Benchmark Pb Concentration) [A]	20	36%	From RI Tables B-3A, B-7A and BERA 2016 Supplemental data
Exceed Eco SSL Mammal (56 mg/kg) [B]	45	80%	Conservative Federal (USEPA) benchmark
Exceed Eco SSL Plants (120 mg/kg) [B]	33	59%	Conservative Federal (USEPA) benchmark
Exceed Eco SSL Soil Invertebrate (1700 mg/kg) [B]	4	7%	Conservative Federal (USEPA) benchmark
Exceed American robin NOAEL Benchmark (~ 11 mg/kg)	55	98%	Benchmark estimated from BERA Tables in Appendix H (Integral Consulting, Inc. December 2016)
Exceed American robin LOAEL Benchmark (~ 50 mg/kg)	47	84%	Benchmark estimated from BERA Tables in Appendix H (Integral Consulting, Inc. December 2016)
Exceed Short-tailed shrew NOAEL Benchmark (~ 130 mg/kg)	31	55%	Benchmark estimated from BERA Tables in Appendix H (Integral Consulting, Inc. December 2016)
Exceed Short-tailed shrew LOAEL Benchmark (~ 464 mg/kg)	20	36%	Benchmark estimated from BERA Tables in Appendix H (Integral Consulting, Inc. December 2016)
Exceed meadow vole NOAEL benchmark (~ 906 mg/kg)	17	30%	Benchmark estimated from BERA Tables in Appendix H (Integral Consulting, Inc. December 2016)
Exceed meadow vole LOAEL benchmark (~3223mg/kg)	1	2%	Benchmark estimated from BERA Tables in Appendix H (Integral Consulting, Inc. December 2016)
Exceed RAOI Pro UCL Lognormal 95% UCL Exposure Point Concentration (EPC) (1521 mg/kg)	6	11%	1521 mg/kg, a conservative EPC consistent with USEPA (1997)
Exceed "Landfill" PRG (2700 mg/kg)	1	2%	2700 mg/kg, identified in the FS as the PRG for the landfill[C].

- Not Applicable

[A] The 400 mg/kg benchmark is noted in the RI figures as the NJDEP Residential Direct Contact soil standard (Geosyntec Consultants, Inc. 2018a). The same value (400 mg/kg) is used in the draft FS as the PRG for recreational users at the Site (ball field, shooting range) (Geosyntec Consultants, Inc. 2018b). NJDEP requires the filing of a deed notice when a remedial action is implemented that allows the residual contaminant concentrations to exceed the NJDEP residential direct contact soil remediation standards. N.J.A.C. 7:26E-5.2(a)(4). Thus, a cleanup that does not achieve 400 mg/kg in the Refuge would not comply with NJDEP remediation requirements unless the United States, as the property owner, agrees to a deed notice.

[B] Ecological Soil Screening Level (Eco SSL) (USEPA 2005).

[C] Computed based on human heath Site-Specific Trespasser Exposure Scenario assumptions (Geosyntec Consultants, Inc. 2018d).

NOAEL = No Observed Adverse Effect Level; LOAEL = Lowest Observed Adverse Effect Level; 95% UCL is the ninety-five percent upper confidence level of the arithmetic mean.

Table 1 Summary - The observation that a significant number of soil samples within the RAOI have Pb concentrations exceeding background (89%) shows that the RAOI has been impacted by the landfill wastes. Additionally, 20 soil samples (36%) in the RAOI exceed the proposed benchmark Pb concentration of 400 mg/kg. Many soils concentrations reported in the RAOI exceed the NOAEL- and LOAEL-based benchmark concentrations indicating that risks to ecological receptors exist. Many soil samples exceed conservative Ecological SSL screening benchmarks. This assessment contradicts the FS premise that the results of the BERA indicate that exposures to COPECs in the environmental media at the Site do not pose an ecological concern for most of the evaluated receptors and that there is low potential for risk to vermivorous birds and mammals from exposure to metals (and likely to PCBs) based on food chain models for the short-tailed shrew and American robins.

Figure 3 – Figure 3 illustrates several main points of impact revealed by the assessment on the RAOI property from Table 1. Features of Figure 3 include:

- A grid of 0.019 Ha (2045 ft^2) cells across the RAOI, which represent an array of small herbivorous mammal exposure areas such as the meadow vole (the meadow vole was identified in the BERA as the representative species for this receptor group). As indicated, the meadow vole home range is relatively small compared to the potentially impacted area of the RAOI. The question marks on Figure 3 mark boundaries beyond which insufficient data exists for the Agencies to make an assessment of impacts (i.e., the extent is not delineated).

- A gradient of Pb concentrations across the RAOI is apparent. As indicated in the legend, and marked by the colors of the lead sample results, four general groupings of results are identified:

    - Green dot: Results less than or equal to background (38.4 mg/kg);
    - Blue dot: Results greater than background and less than 130 mg/kg (Short-tailed shrew NOAEL Benchmark);
    - Yellow dot: Results greater than 130 mg/kg and less than 400 mg/kg;
    - Orange dot: Results greater than the proposed benchmark Pb concentration 400 mg/kg and less than 906 mg/kg (the concentration estimated to be protective of the meadow vole based the NOAEL);
    - Red dot: Results greater than 906 mg/kg.

- Based on this assessment, the RAOI has been adversely impacted by Pb contamination associated with the landfill wastes and that the impact is significant. Proposed remedial alternatives in the draft FS that do not fully contain the source landfill waste to prevent further migration of Pb into the Refuge do not adequately address contamination on the RAOI. The selection of any of these alternatives for the Site would not comply with NJDEP remediation requirements, the Refuge CCP, the DOI ECM requirements, or other Refuge ARARs (DOI 2018).

- As indicated above and illustrated on Figure 3 a significant portion of the soils with Pb contamination exceeding the Table 1 benchmarks on the RAOI are found in the South/Southeast impacted area of the RAOI. An area of approximately 17.8 acres contains all the sample locations with Pb concentrations higher than the 400 mg/kg benchmark concentration and includes measured concentrations as high as 6,170 mg/kg. Furthermore, this area is only characterized by 23 samples (i.e., approximately only 1.3 samples per acre; see also discussion below regarding Figure 4). Potentially, localized regions or 'hot spots' could be present that have not been identified. As indicated on Figure 3, relative to the herbivorous mammal exposure areas (the 2045 ft^2 cells, voluminous uncharacterized areas are present in the South/Southeast impacted area of the RAOI.

Figure 4 – The extent of lead contamination in the RAOI is further illustrated in Figure 4. Polygons were created to delineate approximate areas of contamination exceeding the key benchmarks. The polygon boundaries were determined based on their proximity to adjacent samples, the Pb concentrations of adjacent samples, and professional judgment. A review of the data illustrated on Figure 4 results in the following observations.

- Three main areas of Pb contamination are delineated on the RAOI: Northeast/East, South/Southeast, and West areas

- Three of the key benchmark concentrations identified in Table 1 are used to assess and interpret the extent of soils Pb contamination:

    - Purple shading identifies areas exceeding the 906 mg/kg meadow vole NOAEL-based protective benchmark concentration.
    - Pink shading identifies areas exceeding the assessment benchmark concentration of 400 mg/kg.
    - Gray shading identifies areas exceeding the 130 mg/kg Short-tailed shrew NOAEL-based protective benchmark concentration.

- RAOI soil sample locations where these benchmarks are exceeded are shown and the approximate area of soils impacted is included in the inset table.

The information provided in Figure 4, indicates the following:

1. It appears that a significant area of the impacted RAOI area surface soils may contain Pb concentrations exceeding the meadow vole NOAEL-based protective benchmark concentration of 906 mg/kg, including:
    - The Northeast/East (9.7 acres).
    - The South/Southeast portion (16.3 acres).
    - The West area (0.7 acres), which is located outside of the landfill boundary/currently-defined Site.

Overall, it is estimated that approximately 26.7 acres of soil could be impacted on the RAOI with Pb concentrations exceeding the meadow vole NOAEL-based protective benchmark concentration of 906 mg/kg. Given the relatively small meadow vole home range and the large RAOI area impacted, it is conceivable that a significant portion of the small mammal population, as represented by the meadow vole, could be at risk from Pb concentrations above the NOAEL benchmark.

2. Based on the distribution of contaminant concentrations, it is likely that a sizable portion of the RAOI may contain areas where Pb surface soil concentrations exceed the assessment benchmark concentration of 400 mg/kg including:

    - The Northeast/East portion (9.7 acres).
    - The South/Southeast portion (17.8 acres).
    - The West area may contain up to 2.8 acres of soils at concentrations exceeding 400 mg/kg (the contamination was not bounded through sampling to the west). This location is also outside of the landfill boundary.

    Overall, it is estimated that approximately 30.3 acres of impacted soil could exist on the RAOI with Pb concentrations exceeding the benchmark Pb concentration of 400 mg/kg.

3. Figure 4 also indicates that a significant area of the impacted RAOI area surface soils may contain Pb concentrations exceeding the Short-tailed shrew NOAEL-based protective benchmark concentration of 130 mg/kg, including:

    - The Northeast/East (11.1 acres).
    - The South/Southeast portion (23.8 acres).
    - The West area (2.8 acres). The contamination was not bounded through sampling to the west. This location is also outside of the landfill boundary.

    Overall, it is estimated that approximately 35 acres of soil could be impacted on the RAOI with Pb concentrations exceeding the meadow vole NOAEL-based protective benchmark concentration of 130mg/kg. Given Short-tailed shrew's home range of ~ 1 acre (0.39 hectare) and the potentially large RAOI area impacted (37.7 acres) it is conceivable that a significant portion of the small mammal population, as represented by the Short-tailed shrew, could be at risk from Pb concentrations above the 130 mg/kg NOAEL benchmark.

Based on the discussion above, proposed remedial alternatives in the draft FS that do not fully contain the source landfill waste and cover existing contaminated soil to prevent further migration of Pb into the Refuge do not adequately address Pb contamination on the RAOI. The selection of any of these alternatives for the Site would not comply with the NJDEP remediation requirements, the Refuge CCP, the DOI ECM requirements, or other Refuge ARARs (DOI 2018).

Figure 5 – This assessment clearly indicates that landfill related contamination on the RAOI, while widespread, is not uniform. There are likely localized areas of elevated COPEC concentrations or "hot spots" that, given the home range of representative species (e.g., meadow vole ~ 2045 ft2), could present significant exposure potential. For example, twenty-three surface soil sample points (a subset of the total 56 RAOI sample points) are located in the South/Southeast area and plotted in Figure 5 below (and illustrated in Figures 3 and 4).

Figure 5 illustrates that:

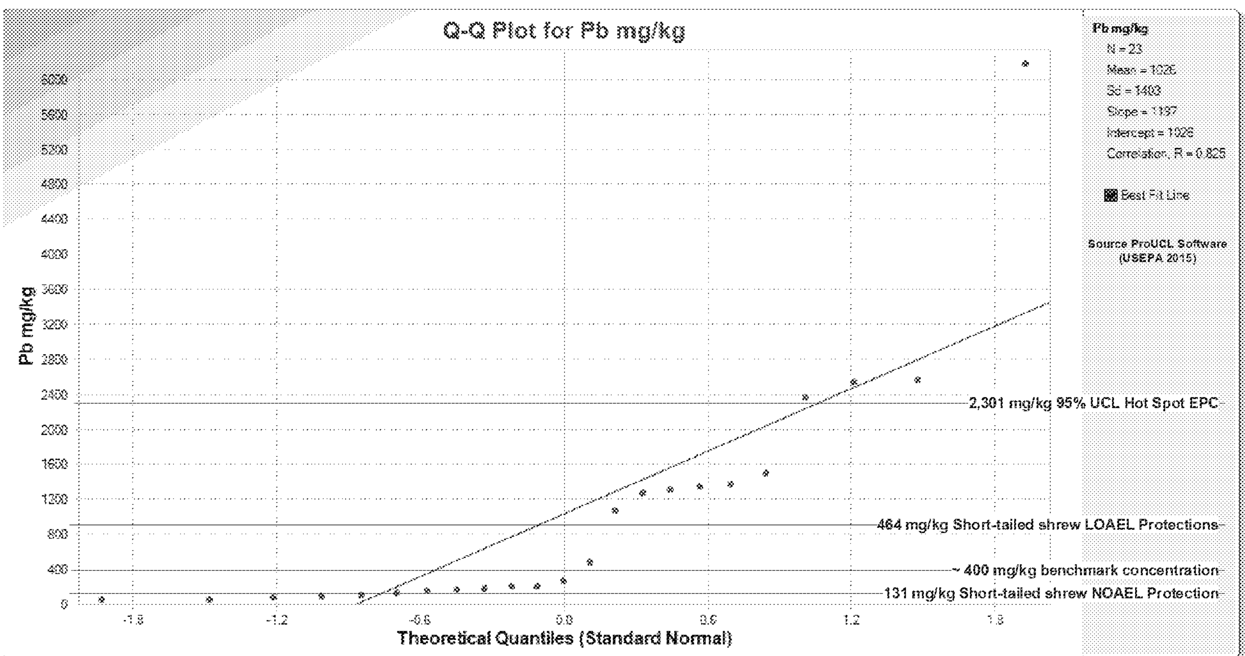
1. Eleven samples in the RAOI South/Southeast area (48%) exceed the 400 mg/kg benchmark concentration.

2. Ten of the 23 samples (43%) in the RAOI South/Southeast area of the landfill exceed the 464 mg/kg LOAEL-based concentration that would be protective of the Short-tailed shrew.

3. Fifteen of the 23 samples (65%) in the RAOI South/Southeast area of the landfill exceed the 130mg/kg NOAEL-based concentration that would be protective of the Short-tailed shrew.

4. The 95% UCL EPC computed for RAOI South/Southeast area of the landfill of 2,301 mg/kg is illustrated. Notably, it is well above Pb 400 mg/kg benchmark, as well as LOAEL, and NOAEL protective concentrations. This indicates a significant potential for exposure to small mammals with home ranges that approximate the entire area of a hot spot.

Figure 5 - Distribution of Surface Soil Pb in South/Southeast Impacted Area of the RAOI and Comparisons to Relevant Benchmarks.



Figures 3, 4 and 5 Summary – The RI and BERA data for soils indicate that Pb contamination exceeding the 400 mg/kg benchmark concentration, as well as the NOAEL-based vermivorous birds and mammals and small herbivorous mammal protection concentration are exceeded in a relatively large area of the Refuge lying within the landfill boundaries. The potential also exists for hot spots of elevated concentrations and relatively large uncharacterized areas exceeding the proposed benchmark Pb concentration 400 mg/kg, as well as the NOAEL-based protection concentrations. The potential for hot spots is exemplified by the assessment of the South/Southeast portion of the RAOI likely extends to the Northeast/east and West impacted areas as well where sample density is actually less than in the South/Southeast area. The questions marks on Figures 3 and 4 show areas where sampling data may be insufficient to determine the extent of Pb impacts and the outer boundaries of existing contamination. Uncertainties associated with the low sample densities limit the ability to fully evaluate the risk, but the data are sufficient to demonstrate the substantial impact of the landfill on the Refuge and the need for the proposed alternatives in the FS to contain the source landfill waste.

The meadow vole home range is only about 2,045 ft^2 (approximately 45 ft. x 45 ft.), and the distance between surface soil samples is often greater than 45 ft. (certainly within the RAOI). An examination of the existing soils data indicates that many 2,045 ft^2 areas (i.e., meadow vole home ranges) are present where Pb concentrations exceed either the NOAEL- or possibly the LOAEL-based protective concentrations. These observations indicate that site characterization is not adequate to support proposed alternatives that do not fully contain the source landfill waste to prevent further migration of Pb and other contaminants into the Refuge.

This section is focused on the distribution of surface soil Pb concentrations reported on the RAOI documented in the RI and BERA reports with the purpose of highlighting the occurrences of Pb contamination associated with landfill wastes which pose ecological risks. The BERA also indicates that other landfill waste-related COPECs are present in elevated concentrations that may pose a direct risk or contribute to ecological risk in soils on the RAOI. This information is indicated in Table 2.

Table 2 - Additional Meadow Vole NOAEL HQs and HIs Within the GSNWR (Refuge)

(from BERA Table H3-21 [Integral Consulting, Inc. 2016])

COPEC	HQ
PCB-TEQ Congeners (mammals)	1.3
PCDD/ F-TEQ Congeners (mammals)	21
Hazard Index (HI)	**22.3**
COPEC	HQ
Cadmium	1.4
Chromium	5.7
Lead	1.9
Methyl mercury	45
Nickel	1.1
Selenium	5.3
Zinc	1
Hazard Index (HI)	**61.4**
Source: Table H3-21. Meadow vole Dietary NOAEL HQs based on Terrestrial - Within GSNWR Mean EPCs (BERA, Integral Consulting, Inc. 2016). Note these are based on mean concentrations estimates and the samples used in the mean calculation may not align exactly with the RAOI samples.	

As indicated in Table 2, HQ's exceeding 1.0 (indicative of potential adverse effects) associated with Refuge soils and the Meadow vole are not limited to Pb. Notable are the HQ's greater than 1.0 (e.g., PCDD/F-TEQ Congeners for mammals = 21 and Methyl mercury = 45). Moreover, the summed HIs of 22.3 and 61.4 (assuming similar or additive effects discussed in USEPA Guidance [1997]) are significant. Further insight into the potential effects of COPECs other than Pb, based on LOAEL considerations, is found in the BERA (Integral Consulting, Inc. 2016). BERA Figures 5-2a, 5-2b, and 5-2c show HQ's greater than 1.0 for the meadow vole's terrestrial exposure to soils in the Refuge for PCDD/F–TEQ Congeners (for mammals), methyl mercury, and selenium.

Much of the assessment above has focused on the herbivorous meadow vole, in part due the vulnerability implied by its small home range, the large RAOI area impacted coupled with the likelihood of hot spots. However, there are other significant Refuge receptors including vermivorous mammals (as represented by Short-tail shrew) and vermivorous birds (represented by the American robin) potentially impacted by contamination on the Refuge. Pb has been used as an indicator COPEC for this assessment. However, there are many other COPECs in addition to Pb. These factors taken together result in a significant concern that the FS has not adequately addressed ecological risk posed by landfill waste on the Refuge. The foundation for this concern is expressed in the BERA results gleaned from the dietary HQ's presented in Appendix H, which are based on average EPCs computed from samples within the GSNWR (See Table 3).

Inspection of Table 3 demonstrates numerous NOAEL and LOAEL HQ exceedances of significant magnitude (i.e., well over 1.0) for the Short-tailed shrew and the American robin. The exceedances include PCBs, Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzo-p-Furans (PCDDF) and numerous heavy metals, including Pb.

Considering the extent of impact to the Refuge exemplified by the Pb assessment above, it is plausible that a similar assessment for the COPECs shown on Table 3 would also reveal wide spread impacts on the Refuge for those COPECs. Comparable widespread impacts for the COPECs and receptors in Table 3 would further substantiate the finding that proposed remedial alternatives in the draft FS that do not fully contain the source landfill waste and cover or remove existing contaminated soil to prevent further migration of COPECs into the Refuge do not adequately address the Agencies FLM responsibilities, concerns, or preferences. The selection of any of the Landfill alternatives proposed in the draft FS for the Site that do not directly address the contamination within the Refuge, would not comply with the NJDEP remediation requirements, the Refuge CCP, the DOI ECM requirements, or other Refuge ARARs (DOI 2018).

Table 3 - Dietary HQ's Based on Average EPCs from Samples Within the GSNWR

Short-tailed shrew	NOAEL HQ	LOAEL HQ
Total PCBs	3.2	1.6
PCB–TEQ Congeners (mammals)	54	6.8
PCDDF-TEQ Congeners (mammals)	16	2.6
Barium	4.2	1.6
Cadmium	26	3.8
Chromium	130	22
Lead	27	7.5
Methyl mercury	74	15
Selenium	22	10
Vanadium	21	10
Zinc	6.2	0.77
American robin	**NOAEL HQ**	**LOAEL HQ**
Total PCBs	4.1	0.56
PCB–TEQ Congeners (avian)	46	4.6
PCDDF-TEQ Congeners (avian)	47	4.7
Barium	23	12
Cadmium	33	11
Lead	180	34
Methyl mercury	53	41
Selenium	32	14
Vanadium	35	17
Zinc	25	15

Source: NOAEL and LOAEL HQs based on Terrestrial - Within GSNWR Mean EPCs in BERA Appendix H (Integral Consulting 2018).

Table 4 summarizes the soils assessment described in this section with respect to the RAOI as discussed in Section 3.

Table 4 - Assessment Summary Impacts of Surface Soil Contamination of RAOI Soils within the Site

Assessment Point	Finding
Has the Refuge been impacted by landfill wastes?	Yes- At least 89% of the soil samples analyzed for Pb on Refuge property exceed the established Pb background comparison metric.
If the Refuge has been impacted, is the impact significant and impairing?	Yes - Pb contamination in RAOI soils is significant. 36% of surface soil samples exceed the 400 mg/kg. 30% of soil samples exceed the small herbivorous mammals 906 mg/kg NOAEL benchmark concentration (the meadow vole is a surrogate for this receptor group). Many soils samples, at least 80%, exceed Eco SSLs for mammalian species. ○ An estimated 30.3 acres may exceed the proposed 400 mg/kg Pb benchmark concentration. ○ An estimated 26.7 acres may exceed the 906 mg/kg NOAEL benchmark concentration for protection of small herbivorous mammals. Other COPECs including PCB-TEQ congeners, PCDDF/TWQ, cadmium, chromium, methyl mercury, nickel, selenium, and zinc either pose elevated risk or significantly contribute additively to the small herbivorous mammals' risk, as well as vermivorous birds and mammals. Given the small home range of small herbivorous mammals, significant areas have not been characterized and the risk to these mammals could be even greater, as indicted in Table 3.
If the Refuge has been significantly impacted, do the remedial/removal alternatives proposed in the FS address the Agencies' concerns?	As described in the draft FS, only Alternative 5 would fully contain the source landfill waste at the Site and cover some, but not all, of the impacted areas of the Refuge to address the Agencies' concerns. As proposed, the remaining draft FS Alternatives would allow significant source landfill waste to remain onsite without being contained to prevent further exposures or migration of Pb and other COPECs onto the Refuge. FS Figure 4-1 identified one APC (SS–118) on the RAOI (Geosyntec Consulting, Inc. 2018a). Figure 3 of this document identifies a much larger APC including the North/Northeast, South/Southeast, and the Western impacted refuge areas, an estimated 37.7 acres potentially impacted at Pb concentration exceeding Pb benchmark concentrations.

Are there other remedial/removal alternatives or modifications of existing remedial/removal alternatives that would address the Agencies concerns?	The Agencies have stated that alternatives that include full removal of contaminated materials from the Refuge most closely align with the requirements of the Refuge CCP, the DOI ECM and other ARARs. Alternative 4 could be expanded to include removal of all areas on the RAOI where the Pb benchmark concentration is exceeded. The material removed from the Refuge could be consolidated on the source landfill waste on the private portion of the Site and capped. If implemented, this modified alternative would most closely address the Agencies requirements.

4.2 Sediment Contamination

This section evaluates the extent of contamination and impacts on sediments within the RAOI. The evaluation uses data and analysis presented in the BERA, as well as, data presented in the RI. The evaluation proceeded in two steps. First, the BERA, completed in 2016, was reviewed to identify sediment COPECs and develop a preliminary understanding of the nature of ecological impacts with emphasis on Black Brook. Secondly, using the BERA COPECs, the broader nature and extent of impacts was evaluated by reviewing the RI sediment data, completed in 2018, for Black Brook, Loantaka Brook, and other locations on the RAOI to better understand the wider extent of impacts associated with the BERA COPECs.

1. Step 1 - Initial Assessment of 2016 BERA COPECSs and BERA Supplemental Data

Sediment contamination has been identified as an issue of ecological concern and COPECS were evaluated in the BERA (Integral Consulting, Inc. 2016). The locations of BERA sediment data used in this evaluation are displayed on Figure 6. Figure 6 shows the location of sediment data collected and presented in the both the BERA and the RI. Notable in Figure 6 is the amount of RI sediment data that were not used in the BERA. Additionally, within the BERA sediment data, large areas were not sampled. Specifically, sediment samples were not evaluated in the BERA within Black Brook from the up-gradient location of SED 017, to sediment samples SED 006 and SED 007 (in close proximity to each other) on the eastern border of the landfill, which is a reach of approximately one mile (Figure 6). Additionally, there were no sediment samples evaluated between SED 007 and the most down gradient location, SED 018, which is also an approximately one mile reach (Figure 6). Overall, the reach from upgradient to downgradient sample locations is nearly two miles. Two additional sediment samples (SED 008 and SED 009) located in South/Southeast impacted area of the RAOI were included in the BERA. Concentration data used in this assessment was taken from the BERA, Figure 4-3 (Integral Consulting, Inc. December 2016) and the RI (Geosyntec Consultants, Inc. 2018a, Table B-7A).

Table 5 presents the distribution of the BERA sediment concentrations reported on the RAOI. The analytical results from six sediment samples were used in the BERA. The purpose of Table 5 is to provide a comparison of measured sediment COPEC concentrations to relevant ecological risk benchmarks. The BERA identified eight sediment COPECs. Table 5 comparisons are intended to inform risk managers of the extent of sediment contamination relative to recognized points of reference. Site-specific benchmark evaluation concentrations were not developed in the BERA. To facilitate gauging the significance of the sediment contamination COPEC concentrations, common screening values from the public domain are provided in Table 5, including:

- USEPA Assessment and Remediation of Contaminated Sediments Program (ARCS) Threshold Effects Levels (TEL) and Probable Effects Levels (PEL) (USEPA 1996).
- State of New Jersey Ecological Screening Criteria (ESC) Lowest Effects Level (LEL) and Severe Effects Levels (SEL) (NJDEP 2009).

The key observations from Table 5 include:

- All eight sediment COPECs are reported in BERA sediment samples located on RAOI property adjacent to the landfill/Site at concentrations exceeding the highest sediment concentration reported in up gradient stream sediment samples. The up-gradient locations are presumably un-impacted by the landfill wastes. This indicates that landfill wastes are probable contributors to the observed elevated concentrations on the RAOI. Notably:
  - Mercury (Hg) was reported at elevated concentration in five of the six (83%) RAOI sediment samples.
  - Total PCBs, copper (Cu), and Pb were reported in four of the six RAOI sediment samples (67%) at elevated concentrations.
  - Barium (Ba) was reported as exceeding the highest sediment concentration reported in up gradient (non pond) sediments (i.e., background) in three of the six (50%) RAOI sediment samples.
  - Total Dichlorodiphenyltrichloroethane related constituents aka (DDx), nickel (Ni) and zinc (Zn) concentrations exceeded up gradient maximum concentrations in 33% of the RAOI sediment samples.

The observation that a high proportion of sediment COPECs reported in the RAOI sediments exceed the upgradient concentrations indicates that landfill related wastes have impacted the sediments adjacent to, and downgradient of the Site.

- Comparing the measured concentrations in six RAOI sediment samples to sediment toxicity TEL benchmarks developed by USEPA (1996) indicates:
  - An 83% exceedance rate for Cu, Pb, and Hg.
  - A 67% exceedance rate for Total DDx, Total PCBs, and Zn.
  - The Ni exceedance rate (of the TEL) is 33%.

- The Ni exceedance rate (of the TEL) is 33%.

USEPA (1996) notes that the TELs are possible-effects benchmark concentrations and that concentrations below the TEL are unlikely to result in adverse effects (USEPA 1996).

- Comparing the observed concentrations to sediment toxicity to PELs developed by USEPA (1996) indicates:
  - A 50% exceedance rate for Pb.
  - A 33% exceedance rate for Total PCBs, Cu, Hg, and Zn.
  - The PEL exceedance rate for Ni was 17% (1 sample) and none of the sample locations exceeded the PEL for Total DDx.

According to USEPA, concentrations in excess of the PEL are likely to result in adverse effects (USEPA 1996).

- Additional comparisons with the State of New Jersey's conservative Lowest Effects Levels (LEL) are included in Table 5, which indicate:
  - A 100% exceedance rate for Total DDx.
  - Exceedance rates of 83% (5 out of 6) for Cu, Pb and Hg.
  - A 67% exceedance rate for Total PCBs, Ni, and Zn.
- Comparing the RAOI sediment concentrations with New Jersey's Severe Effects Levels (SEL) indicate:
  - Exceedance rates of 33% (2 out of 6) for Cu, Pb and Hg.
  - A 17% exceedance rate (1 in 6) for, Ni, and Zn.

Of interest is the profile of sediment COPECs in the flowing reach of Black Brook illustrated in Table 6 (See Figures 6 and 7 for locations). The relatively long run of Black Brook through the Refuge from the upgradient boundary, to SED 006 and SED 007 on the eastern border of the landfill, to SED 018 is nearly two miles (up-gradient sample location SED 017, is not actually on the Refuge [Figure 6]). Table 6 provides a comparison of sediment contaminant concentrations on the Refuge to NJ criterion at these locations. Notable are the consistent exceedances in samples SED 006 and SED 007.

Table 5 – Summary of RAOI Sediment BERA COPEC Contamination and Comparisons to Benchmarks

Chemicals of Potential Ecological Concern (COPEC) from BERA Figure 4-3	Units	Summary and Comparison to Upgradient Sediments				Comparisons of BERA SEDs 006, 007, 008, 009, 015, 018 to Benchmarks											
		No. of RAOI Sediment Samples [a]	Highest Upgradient Sediment (Non-Pond) Background Concentration [b]	No. of RAOI Exceeding Highest Upgradient Sediment Background Concentration [c]	Percentage of RAOI Samples Exceeding Highest Upgradient Sediment Background Concentration	ARCS TEL Sediment Screening Benchmark [d]	No. RAOI Sediments Exceeding ARCS TEL Sediment Screening Benchmark	Percentage RAOI Sediments Exceeding ARCS TEL Sediment Screening Benchmark	ARCS PEL Sediment Screening Benchmark [d]	No. RAOI Sediments Exceeding ARCS PEL Sediment Screening Benchmark	Percentage RAOI Sediments Exceeding ARCS PEL Sediment Screening Benchmark	NJDEP LEL [f]	No. RAOI Sediments Exceeding NJDEP LEL Screening Benchmark	Percentage RAOI Sediments Exceeding NJDEP LEL Screening Benchmark	NJDEP SEL [g]	No. RAOI Sediments Exceeding NJDEP SEL Screening Benchmark	Percentage RAOI Sediments Exceeding NJDEP SEL Screening Benchmark
Total DDx	µg/kg	6	15	2	33%	5.28	4	67%	572	0	0%	7	6	100%	12,000	0	0%
Total PCBs	µg/kg	6	42	4	67%	59.8	4	67%	676	2	33%	59.8 [h]	5	83%	530,000	0	0%
[redacted]																	
Barium	mg/kg	6	166	3	50%	-	-	-	-	-	-	-	-	-	-	-	-
Copper	mg/kg	6	55.8	4	67%	31.6	5	83%	149	2	33%	16	5	83%	110	2	33%
Lead	mg/kg	6	98.1	4	67%	35.8	5	83%	128	3	50%	31	5	83%	250	2	33%
Mercury	mg/kg	6	0.23	5	83%	0.18	5	83%	1.06	2	33%	0.174	5	83%	2	2	33%
Nickel	mg/kg	6	29.9	2	33%	22.7	2	33%	48.6	1	17%	16	4	67%	75	1	17%
Zinc	mg/kg	6	29.4	2	33%	121	4	67%	459	2	33%	120	4	67%	820	1	17%

[a] SEDs 006, 007,008, 009, 015, 018 (BERA Figure 4-3)
[b] From SEDs 010, 011, 016, 017 (BERA Figure 4-3)
[c] Comparison to the highest up gradient non pond concentration is a not necessarily a conservative metric. Other comparisons, (e.g., to the median up gradient concentration) would be more conservative.
[d] USEPA Assessment and Remediation of Contaminated Sediments Program (ARCS) (USEPA 1996). The Threshold Effects Level (TEL) level is the geometric mean of the 15th percentile in the effects data set and the 50th percentile in the no effects data set. It is a concentration that represents the upper limit of the range dominated by no effects data. Concentrations above the TEL may result in adverse effects to these organisms; concentrations below the TEL are unlikely to result in adverse effects. These are possible-effects benchmarks. For PCBs the high-risk value was used. The ARCS effects concentrations were developed for the amphipod *Hyallella azteca* and midge *Chironomus riparius* which are widespread and abundant species associated with sediment ecosystems systems in North America. The BERA included toxicity tests using these species.
[e] USEPA Assessment and Remediation of Contaminated Sediments Program (ARCS). The Probable Effect Level (PEL) is the geometric mean of the 50th percentile in the effects data set and the 85th percentile in the no effects data set. It represents the lower limit of the range of concentrations usually associated with adverse effects. A concentration greater than the PEL is likely to result in adverse effects to these organisms. These are probable-effects benchmarks. For PCBs the High-Risk value is presented. The ARCS effects concentrations were developed for the amphipod *Hyallella azteca* and midge *Chironomus riparius* which are widespread and abundant in sediment ecosystems in North America. The BERA included toxicity tests using these species.
[f] NJDEP 2009. Ecological Screening Criteria (ESC) Table. Lowest Effects Levels (LELs) indicate concentrations at which adverse benthic impacts may begin to occur (level tolerated by most benthic organisms). Water column species and wildlife are potentially at risk via biomagnification (food chain toxicity) if site-related sediment concentrations of PCBs, organochlorine pesticides, or mercury are at or above the LEL. Other known biomagnifiers without ecological screening criteria (ESC) warrant case-by-case evaluation.
[g] NJDEP 2009. Severe Effects Levels (SELs) indicate severe impacts to the benthic community in most cases studied. For non-polar organics (PAHs, organochlorine pesticides, PCBs), the SEL is calculated from a site-specific total organic carbon (TOC) level. The concentrations here have not been adjusted for sediment organic carbon; however, previous studies have shown that dry weight sediment quality guidelines predict sediment toxicity as well or better than organic carbon-normalized sediment quality guidelines in field collected sediments (MacDonald et al. 2000). For this reason, these values were not adjusted for site-specific TOC.
[h] NJDEP 2009. USEPA Region 5, RCRA Ecological Screening Levels (ESLs) represent a protective benchmark (e.g., water quality criteria, sediment quality guidelines/ criteria, and chronic no adverse effect levels) for 223 contaminants and are not intended to serve as cleanup levels but are intended to function as screening levels. http://www.epa.gov/reg5rcra/ca/ESL.pdf
- No comparable information for barium.
BERA - Baseline Ecological Risk Assessment, Rolling Knolls Landfill, Chatham, New Jersey, Integral Consulting, Inc., 2016.
µg/kg - micrograms per kilogram
mg/kg - milligrams per kilogram
NJDEP - New Jersey Department of Environmental Protection
RAOI - Refuge Area of Interest
Total DDx - Sum of measured concentrations of dichlorodiphenyltrichloroethane (DDT) and its metabolites
Total PCBs - Sum of measured concentrations of polychlorinated biphenyls
Table 5 revised by Applied Intellect, LLC on September 16, 2019

Table 6- Profile of COPECS in Black Brook Based on 2016 Data From the BERA

COPEC	Units	SED 017 Upstream (2016)	SED 006 (2016)	SED 007 (2016)	SED 018 Downstream (2016)	USEPA PEL	NJ SEL
Total DDx	µg/kg	15 J	ND (32U J)	434	9.7	572	12,000
Total PCBs	µg/kg	42 J	1,560	2,900	ND (270 U)	676	530,000
Barium [a]	mg/kg	166 J	526 J	795 J	94.9	-[a]	-[a]
Copper	mg/kg	55.8 J	311 J	1,290 J	36.4 J	149	110
Lead	mg/kg	98.1 J	358 J	1,580 J	52.9 J	128	250
Mercury	mg/kg	0.23 J	2.6 J	8.2 J	0.28 J	1.06	2
Nickel	mg/kg	29.4 J	46.6 J	131 J	11.4 J	48.6	75
Zinc	mg/kg	294 J	814 J	3,240 J	69.3 J	459	820

Sediment data source: BERA Figure 4-3.
PEL: Probable Effects Level
SEL: Severe Effects Level
Yellow highlighting indicates exceedance of either the PEL, SEL, or both.
[a] Sediment quality comparison data for Barium not identified.
Table 6 revised by Applied Intellect, LLC on September 16, 2019

The data presented in Table 6 indicates an apparent and significant increase in sediment COPEC concentrations from upstream (SED 017) to sample locations SED 006 and SED 007, followed by concentrations diminishing in the down-gradient sample. This pattern supports the position that the landfill is a source of contamination in Black Brook on the RAOI.

2. **Step -2 Expanded Assessment Using 2018 RI Data and the Eight BERA COPECs.**

To better understand the broader nature, extent, and potential impacts of sediment contamination along Black Brook, Loantaka Brook, and other RAOI locations, RI data that were reported as exceeding the RI ecologically-based screening level (EBSL) were reviewed and are summarized in Table 7 (Black Brook) and Table 8 (Loantaka Brook and South/Southeast Area of RAOI). The sample locations referred to in Table 6 are identified in Figures 6 and 7 (these are the same locations reported on RI Figures 4-4a and 4-4b (Geosyntec Consulting, Inc. 2018b).

Table 7 presents BERA COPECs (2016) concentrations measured in the RI sediment samples collected in Black Brook in 2008 and 2014. The Black Brook 2008 and 2014 RI data were extracted from the 2018 RI Figures 4-4a and 4-4b. The locations of these samples are shown on Figures 6 and 7 in addition to the Black Brook sediment locations used in the BERA (discussed in Table 5 above). It should be noted that the data extracted from these figures have not been reviewed for correctness and omissions. Additional evaluation of the applicable sediment data is warranted.

Table 7 - Sediment Results for Eight BERA COPECs in the 2018 RI Data Along Black Brook

(Note the RI Figures 4-4a and 4-4b Posted Only Sediment Analytical Results Greater than NJDEP Ecologically-Based Screening Levels)

Chemicals of Potential Ecological Concern (COPEC) from BERA Figure 4-3	Unit	Black Brook Upstream			Black Brook Upstream of Vernal Ponds		Vernal Ponds		Black Brook Downstream of Vernal Ponds		
		SD 34 (2008)	SD 35 (2008)	SD 36 (2008)	SD 22 (2008)	SD 23 (2008)	SD 38 (2014)	SD 44 (2014)	SD 24 (2008)	SD 25 (2008)	SD 26 (2008)
Total DDx [A]	µg/kg	-	-	-	-	-	-	-	-	-	-
4,4-DDE	µg/kg	9.2	6	7.1	6	9.5	29	-	6.2	5.2	-
DDD	µg/kg	-	24	-	12	17	150	67	11	-	-
o,p-DDD	µg/kg	-	11	-	8.8	-	78	25	-	-	-
o,p-DDE		-	-	-	-	-	17	9.2	-	-	-
Total PCBs [A]	µg/kg	-	-	-	82	160	1300	864	-	-	-
Aroclor 1254	µg/kg	-	-	-	82	160	690	350	-	-	-
Aroclor 1260	µg/kg	-	-	-	-	-	240	64	-	-	-
Barium	mg/kg	-	-	-	-	-	-	-	-	-	-
Copper	mg/kg	28.3	21.1	32.7	71.8	102	618	135	94.8	61.3	19.1
Lead	mg/kg	116	62.9	-	150	242	845	160	208	117	-
Mercury	mg/kg	0.32	-	-	0.46	0.84	4.4	0.89	0.84	0.41	0.26
Nickel	mg/kg	22.9	-	-	24.3	35.6	70.2	58.3	39.8	23.1	-
Zinc	mg/kg	135	128	125	293	660	2270	637	497	333	-

- Not reported as exceeding NJDEP Ecologically-Based Screening Levels.
Source of Sample Locations: RI Figure 2-7 (Geosyntec Consultants, Inc. 2018a).
Source of Data: RI Figures 4-4a and 4-4b (Geosyntec Consultants, Inc. 2018a).
Source of COPECS: BERA Figure 4-3. (Integral Consulting, Inc. 2016).
[A] Note the RI data contained specific analyte data for DDx and Total PCBs which is included.
See Figure 6 for sample locations.
(Year Collected)

Key observations from Table 6 include:

- The RI sediment data profile from upstream to downstream corresponds with that found in Table 5 for the BERA sediment data. COPEC concentrations are lower upstream (SDs 34, 35 and 36) and increase as the Brook runs along the east side of the landfill on the RAOI (SDs 23 and 23).
- The highest number of COPEC exceedances and the highest concentrations are reported in the vernal ponds (SDs 38 and 44), which are on the eastern edge of the landfill and in close proximity to SED 006 and SED 007 (from the BERA).
- The sediment concentrations in locations downstream of the vernal ponds show a decrease in concentration (SDs 24, 25, and 26), which is consistent with the pattern observed in Table 5.

The presence and concentrations of COPECs in the RI sediment data throughout the entire reach of Black Brook on the RAOI reinforces the position that the landfill has significantly impacted sediment on the adjacent Refuge property. The BERA (Integral Consulting, Inc. 2016) notes that the presence of contamination in sample SED 017 suggests that at least some of the contamination measured in downstream samples came from an upstream source. This is corroborated in part by the COPEC profiles for SD 34, 35, and 36. Additional upstream sources may have contributed to the COPEC contaminant profile presented in Tables 6 and 7; however, the data clearly show an increase in the number of COPECs exceeding New Jersey's EBSLs (EBSL) and an increase in concentrations in the reach adjacent to the Site. The highest sediment impacts noted in the BERA at SED 006 and SED 007, and reported in the RI at the vernal ponds, are in close proximity to one another and immediately east of the landfill. The sediment locations adjacent to the Site that are contaminated with BERA COPECs are consistent with overland flow patterns identified in the conceptual site surface water flow model presented in the RI (RI Figure 6-1a) (Geosyntec Consultants, Inc. 2018a), which indicate that inputs from the landfill/Site to these locations would be likely.

An additional observation is the lack of characterization data for the ponds located within the same reach (see Figure 7), at the north/northeast corner of the Site, which would likely act as settling basins for upgradient contaminant sources. From a conceptual transport, fate and risk assessment perspective, those obvious sediment sample location targets were apparently not evaluated by previous studies and represent a significant characterization data gap. COPECs were measured in upgradient sediments (though at lower concentration levels). The significance of this gap is evidenced by the occurrence of COPECs in the vernal ponds located on the eastern edge of the Site (Figure 7, SD-38 and SD-44), which would be expected to accumulate sediments similarly. Moreover, surface water flowlines (defined by Geosyntec Consulting inc. [2018a]) indicate that one of the ponds (which is apparent in all aerial photographs, but not identified in the RI [Geosyntec 2018a]) would have received surface water flow from Site contaminated areas (Figure 7).

Overall, the evaluation of the information presented in Tables 6 and 7 indicates a potentially significant ecological impact in Black Brook from the landfill. The apparent characterization data gap indicates that the full extent of ecological impact in Black Brook from the landfill has not been determined.

The nature, extent, and potential impacts of sediment contamination along Loantaka Brook and other RAOI locations were also reviewed using the RI data and are summarized in Table 8. Table 8 presents concentrations of the eight sediment COPECs (identified in the 2016 BERA) in RI sediment samples collected in Loantaka Brook, in the South/Southwest portion of the RAOI. The locations of these samples are shown on Figures 6 and 7.

Important observations from Table 8 include:

- The pattern evident in Table 8, with the exception SD-9, indicates a trend of increasing occurrence of COPECs with concentrations exceeding EBSLs, and increasing concentrations from upstream locations (SDs -7, -8, -10, -11) to locations parallel and west of the landfill (Loantaka Brook Downstream [mid-stream] SDs -13, -14, -15). The number of COPEC exceedances and concentrations decreases further downstream. This is illustrated by the appearance of COPECS at SDs 14 and 15 (noted as mid-stream), and in the vernal ponds.
- The vernal ponds located near the southwest corner of the Site (SDs -35, -36, -37; See Figure 7) are not part of the Loantaka Brook flow path; they are located on the South/Southwest portion of the RAOI as is SD-27. The highest occurrence of COPECs exceeding EBSLs and the highest concentrations are reported in SD -35 and -36 samples collected from the vernal ponds.
- The occurrence of COPECs exceeding EBSLs and their concentrations in Loantaka Brook samples decrease in the reach downstream, south of the landfill (e.g., SD-28, -29, -30, -31).

The notable exception of the profile is upstream sample SD-9, which is recognized in the RI as an upstream location exceeding the EBSL (Geosyntec Consultants, Inc. 2018a). The RI does not explain the SD-9 results; however, in contrast with the four other upstream samples, it is distinctive.

Overall, the pattern illustrated in Table 8 suggests that the Loantaka Brook sediments on the RAOI and at the vernal ponds have been impacted by the landfill. This pattern is consistent with the conceptual site flow model presented in RI Figure 6-1a (Geosyntec Consultants, Inc. 2018a).

3. The BERA (Integral Consulting, Inc. 2016) noted conditions suggesting toxicity in sample SED 007 attributable to metals, most likely Pb and Zn, based in part on a moderate potential for bioavailability effects. This datum addresses only divalent metals (Integral Consulting, Inc. 2016). The BERA does not directly assess the potential impacts associated with the organic sediment COPECS in Black Brook such as PCBs and DDx. The BERA uses references to other investigations and research to reach analogous conclusion that PCBs in the on-site ponds would not result in adverse effects (Integral Consulting, Inc. 2016) and apparently by extension, to other Site sediments.

Table 8 - Sediment Results for BERA COPECs from the 2018 RI Along Loantaka Brook and South/Southeast Area of RAOI

(Note the RI Figure 4-4b Posted Only Sediment Analytical Results Greater than NJDEP Ecologically-Based Screening Levels)

Chemicals of Potential Ecological Concern (COPEC) from BERA Figure 4-3	Unit	Loantaka Brook Upstream					Loantaka Brook Downstream (mid-stream [A])					Vernal Ponds Area (south RAOI Area)				Loantaka Brook Downstream			
		SD 7 (2008)	SD 8 (2008)	SD 9 (2008)	SD 10 (2008)	SD 11 (2008)	SD 12 (2008)	SD 13 (2008)	SD 14 (2008)	SD 15 (2008)	SD 16 (2008)	SD 27 (2008)	SD 35 (2014)	SD 36 (2014)	SD 37 (2014)	SD 28 (2008)	SD 29 (2008)	SD 30 (2008)	SD 31 (2008)
Total DDx [B]	µg/kg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4,4-DDE	µg/kg	-	-	13	-	-	-	-	10	16	-	-	13	8.6	-	-	-	-	-
DDD	µg/kg	-	-	-	-	-	-	-	-	-	-	-	22	-	-	-	-	-	-
o,p-DDD	µg/kg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
o,p-DDE	µg/kg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2,4-DDT	µg/kg	-	-	8.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DDT	µg/kg	-	-	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total PCBs [B]	µg/kg	-	-	120	-	-	-	-	-	-	-	-	164	-	-	-	-	-	-
Aroclor 1254	µg/kg	-	-	120	-	-	-	-	-	-	-	-	82	-	-	-	-	-	-
Aroclor 1260	µg/kg	-	-	-	-	-	-	-	-	-	-	-	58	39	26	-	-	-	-
Barium	mg/kg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Copper	mg/kg	-	-	58.3	-	-	-	16.6	57.3	69.7	-	23.8	79.9	118	37.4	-	18.1	-	-
Lead	mg/kg	-	-	74.3	-	-	-	-	-	64.3	-	-	167	294	90.9	-	59.5	-	-
Mercury	mg/kg	-	-	-	-	-	-	-	-	-	-	-	0.78	1	0.42	-	-	-	-
Nickel	mg/kg	-	-	38.1	-	-	-	-	24.3	38.9	-	-	22	34.1	12.4	-	-	-	-
Zinc	mg/kg	-	-	224	-	-	-	-	192	255	-	-	365	541	185	-	-	-	-

- Not reported as exceeding NJDEP Ecologically-Based Screening Levels.
Source of Sample Locations: RI Figure 2-7 (Geosyntec Consultants, Inc. 2018a).
Source of Data: RI Figures 4-4b (Geosyntec Consultants, Inc. 2018a).
Source of COPECS: BERA Figure 4-3. (Integral Consulting, Inc. 2016).
[A] The RI designated these as downstream locations (Geosyntec Consultants, Inc. 2018a). The mid-stream term is used here in reference to their relative proximity to upstream and downstream locations.
[B] Note the RI data contained specific analyte data for DDx and Total PCBs which is included.
See Figure 6 for sample locations.
(Year Collected)

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As indicated previously in Table 6, SED 007 also contained the organic contaminants DDx and Total PCBs at a concentration of 434 µg/kg and 2900 µg/kg, respectively; SED 006 contained PCBs at 1560 µg/kg, though DDxs was not detected in SED 006. Both COPECs (DDX and PCBs) are lipophilic with a potential for bioconcentration and potentially result in exposure at higher trophic levels, possibly to the piscivorous (fish consumption) level. The BERA did not address this possibility at this location.

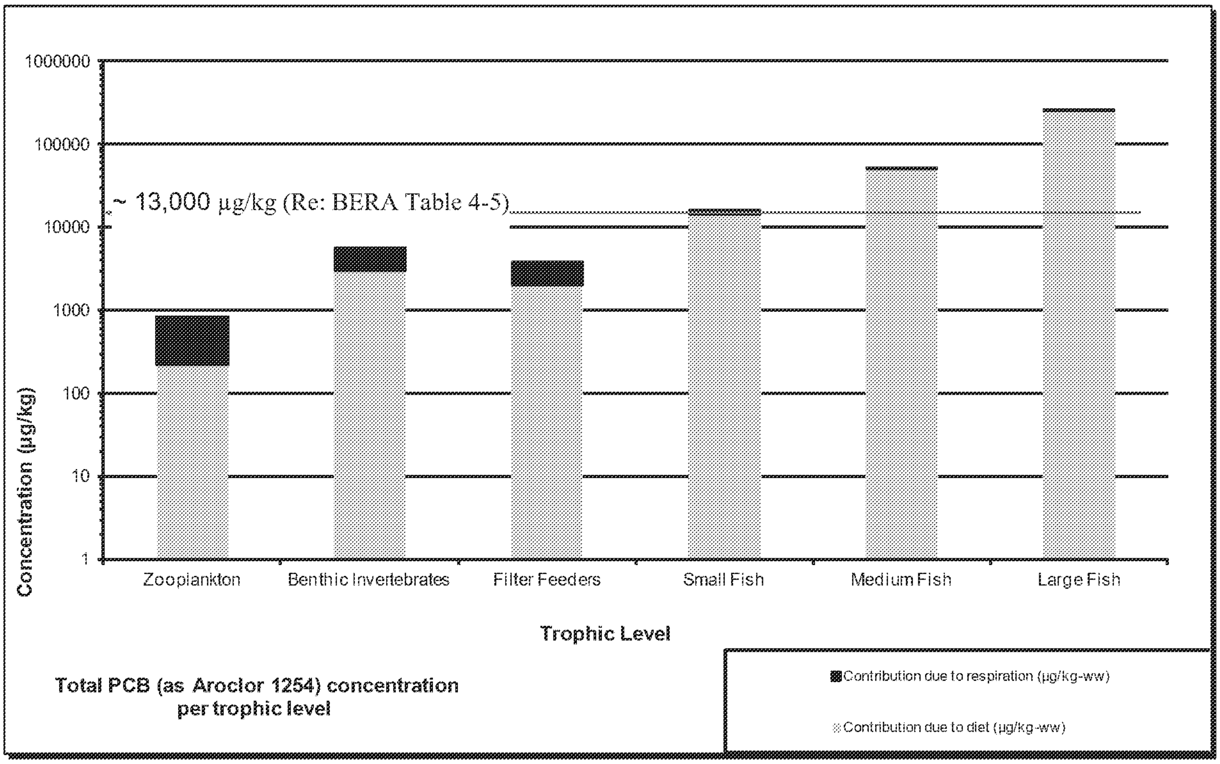
A screening level compartmental calculation for total PCBs modeled as Aroclor 1254 was developed to explore the plausibility that these lipophilic COPECs may bioaccumulate and is illustrated in Figure 8 below. The model uses the SED 007 total PCB concentration of 2900 µg/kg, the locally measured total organic carbon content of 14.3%, and a conventional USEPA compartmental ecosystem screening model (USEPA 2009). The model treats the sediment as a continuous source, represented by the SED 007 data, at steady state equilibrium, functioning in hydraulic connection with the surface water (e.g., Black Brook).

In the case of Total PCBs (modeled as Aroclor 1254), the model predicts fish concentrations exceeding the BERA tissue derived benchmark of 13,000 µg/kg. The model also predicts concentrations in benthic invertebrates in the range of 3,000 µg/kg. The BERA did not provide tissue benchmark concentrations for benthic invertebrates, so the significance of this estimated exposure is uncertain.

Figure 8 presents a conservative screening level calculation that is suggestive of a potential for PCB bioaccumulation and exposure to higher trophic levels. Additionally, the BERA did identify high concentration to benchmark based HQ's for SED 007 and SED 006 and noted that the results suggest a potential for benthic toxicity at these locations (Integral Consulting Inc., 2016). Additionally, the analysis presented in Table 8 (vernal ponds samples SDs 38 and SD 44) and illustrated on Figure 7 indicates that elevated concentrations of lipophillic organics are present in this vicinity of Black Brook.

In light of the potential for PCB bioaccumulation and exposure to higher trophic levels (Figure 8), and because the BERA did not evaluate the potential for PCB bioaccumulation and exposure to higher trophic levels, the evaluation of impacts at SED 006 and SED 007 is not complete and indicates that the ecological impacts of sediment contamination have not been sufficiently characterized. Additionally, while the BERA addressed potential PCB impacts at the on-site ponds, it did not address bioaccumulation of the lipophilic COPECs in other segments of Black Brook or the vernal ponds in the vicinity SED 006 and SED 007. Given the potential for multi trophic-level fish exposure on the Refuge, further characterization would be necessary before consideration could be given to alternatives in the FS that do not fully contain the source landfill waste to prevent further migration of PCBs and other COPECs.

Figure 8 – Potential Bioaccumulation of PCB from Sediment Sample SED 007 Screening Level Calculation



Variable	Unit	Parameter	Remark
PCB Sediment concentration	µg/kg	2900	SED 007 BERA (Modeled as Arochor 1254)
Log Kow	-	6.98	EPI Suite (USEPA 2012)
Koc	L/kg	8.52E+04	EPI Suite (USEPA 2012)
Fraction Organic Carbon (foc)	-	0.143	BERA (SED 007)
Water Solubility	µg/L	9.394	EPI Suite (USEPA 2012)
Kd	L/kg	1.22E+04	Koc * foc
Pore water concentration	µg/L	2.38E-01	PCB Sediment concentration / Kd
Water column concentration	µg/L	2.38E-03	Assume 100 less than pore water (well below solubility)
Ecosystem inputs	Various	-	KABAM Defaults (USEPA 2009)

KABAM: Kow (Based) Aquatic Bioaccumulation Model uses a chemical's octanol-water partition coefficient to estimate uptake and elimination through respiration and diet of organisms in different trophic levels. It is a general screening tool used here as a conservative gauge of potential magnitude of impact.
Source: USEPA Environmental Fate and Effects Division, Office of Pesticide Programs.

Summary Sediment Contamination: Overall, this sediment assessment indicates that the landfill wastes are contributors to the elevated sediment contaminant concentrations on RAOI property. The consistent exceedance of recognized ecological impact benchmarks indicates a significant impact. This assessment is generally consistent with the BERA (Integral Consulting 2016), which noted:

- Sediment COPEC concentrations in the RAOI exceeding up gradient benchmark (non pond) concentrations are found for the six BERA sediment samples (e.g., mercury in five of six samples, Total PCBs, Cu, and Pb in four of six samples).

- Comparison of sediment concentration to benchmarks indicates that many of the COPEC concentrations exceed New Jersey ecological sediment benchmark concentrations, most notably at sediment sample locations SED 006 and SED 007.

- The BERA found high concentrations relative to benchmark-based HQ's for SED 007 and SED 006 and noted that the results suggest there may be potential for benthic toxicity at these locations.

- It is plausible that lipophilic COPECs, particularly PCBs and DDx may bioaccumulate, and in the case of PCBs reach concentrations in fish exceeding the tissue derived toxicity benchmark of 13,000 µg/kg. If remedial alternatives are considered that do not fully contain the source landfill waste to prevent further migration of these contaminants, the toxicity impact of benthic invertebrate PCB tissue concentrations in the range of 3,000 µg/kg should be evaluated.

- The BERA states that the field collection of soil, sediment, and surface water samples was conducted during the initial RI period (2007 through 2015) and acknowledges that initial RI data collected through 2011 were presented and summarized in a Site Characterization Summary Report. These data were also summarized in a Data Gaps Sampling and Analysis Plan Results Technical Memorandum (Integral Consulting, Inc. December 2016). Additionally, the BERA points out that the spatial distribution of the COPECs, based on the 2016 BERA supplemental field investigation results, are discussed in BERA Section 4 by media. The BERA states that the spatial distribution of the full dataset will be discussed in the RI report. Ostensibly, the RI sediment data (collected in 2008 and 2014) were available when the BERA was being completed; therefore, it is unclear as to why the RI data were not fully integrated into the risk assessments.

As indicated above, the sediment data presented in the RI shows that numerous chemicals and locations exceeded the New Jersey EBSL. However, the RI data were not integrated into the BERA. The BERA focuses only on conditions present at the on-site ponds, but the RI reveals numerous chemicals and locations in Black Brook and Loantaka Brook where the New Jersey EBSL were exceeded. Additionally, both reports appear to overlook the large ponds located within the northeast reach of Black Brook, which would potentially act as settling basins or sinks for contaminated sediments from upstream. Based on the assessment above, a comprehensive assessment of sediment contamination on the RAOI does not exist, which presents a data gap if alternatives are going to be considered that do not fully contain the source landfill waste to prevent further migration of these contaminants.

Table 9 summarizes this assessment of sediment impacts in terms of the approach of reviewing from the RAOI Agencies perspective.

Table 9 - Assessment Summary - Impacts on RAOI Sediments

Assessment Point	Finding
Has the Refuge been impacted by landfill wastes?	Yes- Sediment concentrations in Black Brook, most notably SEDs 006 and 007, upstream of the vernal ponds, and the vernal ponds significantly exceed up gradient concentrations. Additionally, sediments in Loantaka Brook and the vernal ponds south of the landfill and on the Refuge are impacted.
If the Refuge has been impacted, is the impact significant and impairing?	Yes – Many of the reported sediment concentrations exceed USEPA Probable Effects Levels (PELs) and State of New Jersey Severe Effects Levels (SELs) and NJDEP EBSLs. Notable are Black Brook sediment locations 006 and 007 where either the PEL or SEL is exceeded for the COPECS in either one or both of these samples. Additionally, the BERA cited high concentration to benchmark-based HQ's for SED 007 and SED 006 and noted that the results suggest there may be potential for benthic toxicity as these locations. Black Brook sediment samples upstream of the vernal ponds and from the vernal ponds themselves significantly exceed NJDEP EBSLs benchmarks. Similar exceedances of EBSLs are found in Laontaka Brook and in the vernal ponds south of the landfill are observed. The number of COPECs exceeding EBSL and the concentrations are not as significant as those seen in Black Brook near SEDs 006, 007, and the vernal ponds in the same vicinity. Additionally, bioaccumulation is possible from organic COPECs on the RAOI and not adequately addressed in the BERA. Based on the assessment above, a comprehensive assessment of sediment contamination on the RAOI does not exist to support consideration of alternatives that do not fully contain the source landfill waste to prevent further contaminant migration. This data gap would need to be addressed before such alternatives could be considered in the FS decision-making.
If the Refuge has been significantly impacted, do the remedial/removal alternatives proposed in the FS address the Agencies' concerns?	None of the draft FS Alternatives specifically address migration of contaminants from the source landfill waste to the sediments within the Refuge. Alternative 5 is the only alternative that would fully contain the landfill waste to prevent further migration of contaminants into the surface water and sediment of the Refuge. The alternative would not address the contaminated sediment in Black Brook, although FS Figure 6-3 indicates that Alternative 5, would cap

Table 9 - Assessment Summary - Impacts on RAOI Sediments

	the SED 006 and 007 locations. While capping or removal of all contaminated sediment within the Refuge may not be feasible, the FS should fully evaluate available alternatives.
Are there other remedial/removal alternatives or modifications of existing remedial/removal alternatives that would address the Agencies concerns?	For sediments, the Agencies primary concern is the continued migration of contaminants from the source landfill waste onto the Refuge, including Refuge sediments. Alternatives proposed in the draft FS could be modified to provide additional options for fully containing the source landfill waste and removing or containing Refuge environmental media contaminated by this waste. With respect to existing contaminated sediment on the Refuge, alternatives for removal and capping should be evaluated. Alternatives that include full removal of contaminated materials from the Refuge most closely align with the requirements of the Refuge CCP, the DOI ECM and other ARARs. However, alternatives that fully contain the contaminated material may also comply with these requirements.

4.3 Groundwater Contamination

Groundwater underlying the RAOI has been impacted (Geosyntec Consultants 2018a, Figure 4-2). Table 10 summarizes the extent of groundwater contamination impacts on the RAOI stemming from landfill related wastes.

Table 10 – Summary of RAOI Groundwater Contamination

Well	No. Consitiuents Exceeding New Jersey Groundwater Standards [a]	Summary
MW - 2	4	Dissolved Metals
MW - 4	4	Dissolved Metals
MW-12	5	Dissolved Metals
MW -14	4	Dissolved Metals
MW - 19	5	Dissolved Metals and Benzene
X-1	6	Dissolved Metals
X-2	4	Dissolved Metals
X-3	3	Dissolved Metals
Source: RI Figure 4-2 (Geosyntec Consultants, 2018)		
[a] N.J.A.C. 7:9C Ground Water Quality Standards		

The locations of these wells are illustrated on Figure 9.

The FS notes that, although the shallow aquifer is identified by New Jersey as a Class IIA potable aquifer, it is not currently used nor is it practically available for drinking water because under New Jersey Department of Environmental Protection (NJDEP) regulations (N.J.A.C. 7:9D-2.3) potable wells must have a well casing that is at least 50 feet deep. In the RI, this point is made that from a potential exposure pathway perspective, no current risk of exposure exists (Geosyntec Consultants, Inc. 2018). Notwithstanding, the NJDEP's classification applies to the Site and remediation will have to be completed to meet the State and possibly Federal standards. State and Federal groundwater quality standards are potentially applicable, chemical-specific requirements.

Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), final remedies must attain ARARs. FS Table 4-1 lists chemical-specific ARARs for the Site including:

- New Jersey's Remediation Standards (N.J.A.C 7:26D; 7:9B; 7:9C) as Potentially Applicable ARARs;
- Federal Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs; 40 CFR141.11-.16, and .60-.63) as To Be Considered Chemical ARARs; and,
- New Jersey Safe Drinking Water New Jersey Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (N.J.S.A. 58:12A-1 et seq.) as To Be Considered Chemical Specific ARARs.

FS Table 4-1 does not provide rationale for the categorizations presented (Geosyntec Consultants 2018b). The final ARARs determination, normally specified in the Record of Decision (ROD), typically establishes the requirement for attaining groundwater quality standards including those relevant to the RAOI. Additionally, the FS notes that a consideration in the identification of *general response actions* (GRA) for groundwater is that 35 acres of the landfill are located within a wilderness area as defined by the Wilderness Act within the GSNWR (Geosyntec Consultants 2018a). The fact that the RAOI is federal property and has been identified in the GRA may invoke the SDWA MCLs as Applicable Requirements (as opposed to those 'To be Considered').

The FS identified the following three groundwater alternatives:

- Alternative 1 – No Action;
- Alternative 2 – Source Control, Monitoring, and Institutional Controls; and
- Alternative 3 – Source Control, Monitoring, and Institutional Controls, with a Contingent Remedy.

Alternative 1 is acknowledged as not capable of meeting chemical-specific ARARs.

Alternatives 2 and 3 identify compliance with chemical-specific ARARs as *Will be Complied With (WBWC)* "Pursuant to the ARAR, applicable standards and regulations will be complied with during remedial design and actions" (Geosyntec Consultants, Inc. 2018a). The detailed analysis of groundwater alternatives does not specifically address how the alternatives will affect COCs with concentrations exceeding potential ARARs in groundwater on Refuge property.

The RI (Geosyntec Consultants, Inc. 2018b) stated that, "Black Brook likely receives hydrologic input from groundwater discharge," and groundwater flows from the Site and east to Refuge property, which indicates that the contaminated groundwater plume from the Site can be expected to discharge into surface waters on the Refuge at some point (if it is not currently). This represents a likely complete exposure pathway to human and ecological receptors within the Refuge. As the draft FS (Geosyntec Consultants, Inc. 2018a) notes, source removal activities within the Site may be expected to create a 'slug' of even more contaminated groundwater. The proposed FS alternatives need to be modified to adequately address groundwater and potential surface water impacts on the Refuge.

Table 10 - Assessment Summary Impacts of RAOI Groundwater

Assessment Point	Finding
Has the Refuge been impacted by landfill wastes?	Yes- Groundwater concentrations in the 8 RAOI wells have been impacted.
If the Refuge has been impacted, is the impact significant and impairing?	Yes – Many of the reported concentrations exceed State of New Jersey water quality requirements for dissolved and total metals. Benzene requirements are exceeded in one 1 well. New Jersey's groundwater quality requirements are identified as possible chemical specific applicable requirements (ARARs).
If the Refuge has been significantly impacted, do the remedial/removal alternatives proposed in the FS address the Agencies' concerns?	The draft FS implies that groundwater alternatives 2 and 3 will achieve ARARs at some point in time. However, the 8 RAOI wells that have been impacted are not specifically addressed in the detailed analysis of alternatives. The potential future impacts to surface water from contaminated groundwater discharges will need to be evaluated to support consideration of alternatives that do not fully contain the source landfill waste to prevent further migration of contaminants into the groundwater.
Are there other remedial/removal alternatives or modifications of existing remedial/removal alternatives that would address the Agencies concerns?	It is not clear if other groundwater alternatives or modifications of groundwater alternatives 2 or 3 will ensure compliance with chemical specific ARARs. However, modification of the landfill alternatives to expand options for fully containing the source landfill waste would likely address the Agencies' concerns with continued migration of contaminants into the groundwater.

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ED_004977_00109894-00037

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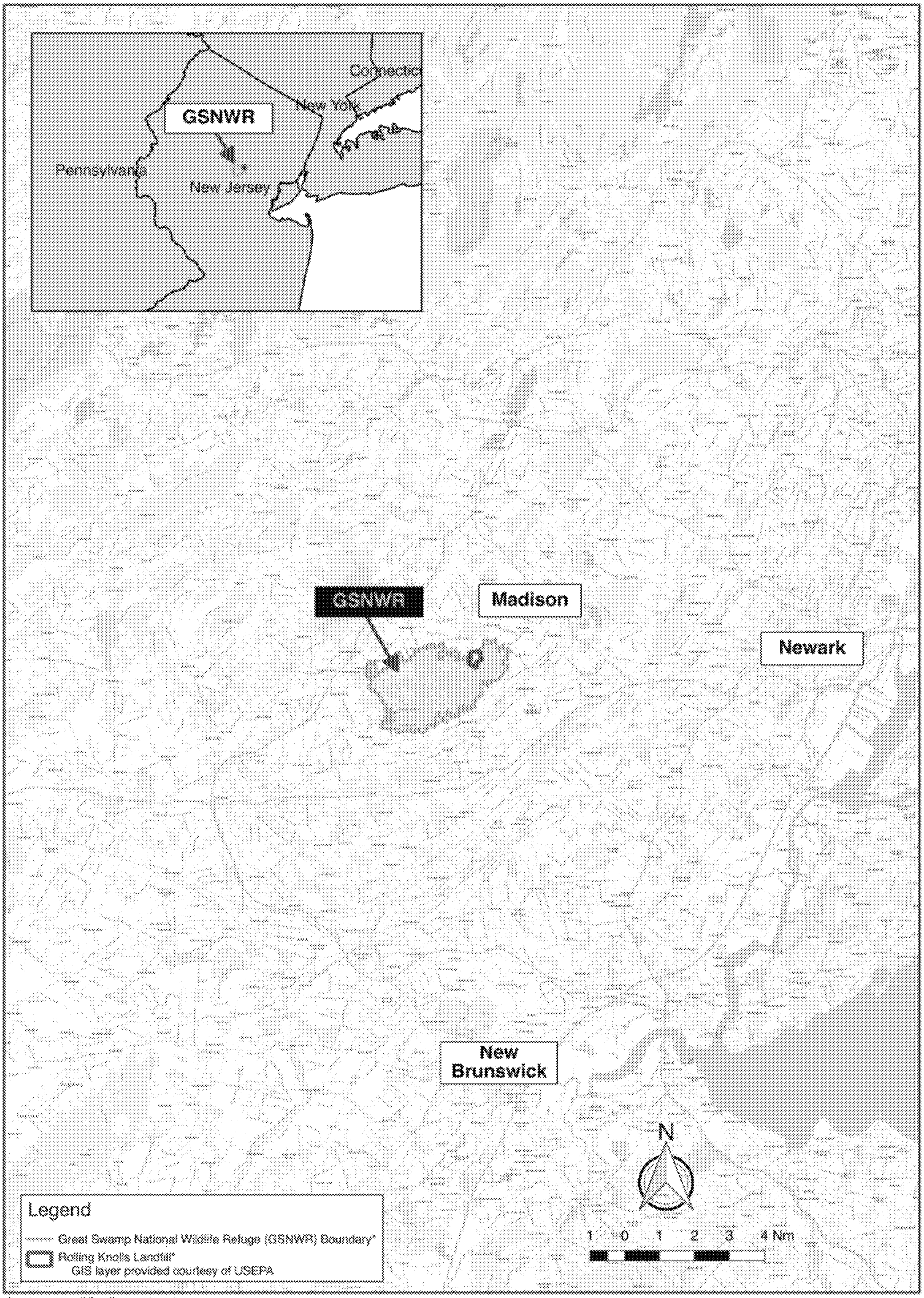
FIGURES

FIGURE 1 - Great Swamp National Wildlife Refuge Location Map



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Detailed map layer from Wikimedia
(3/1/19)

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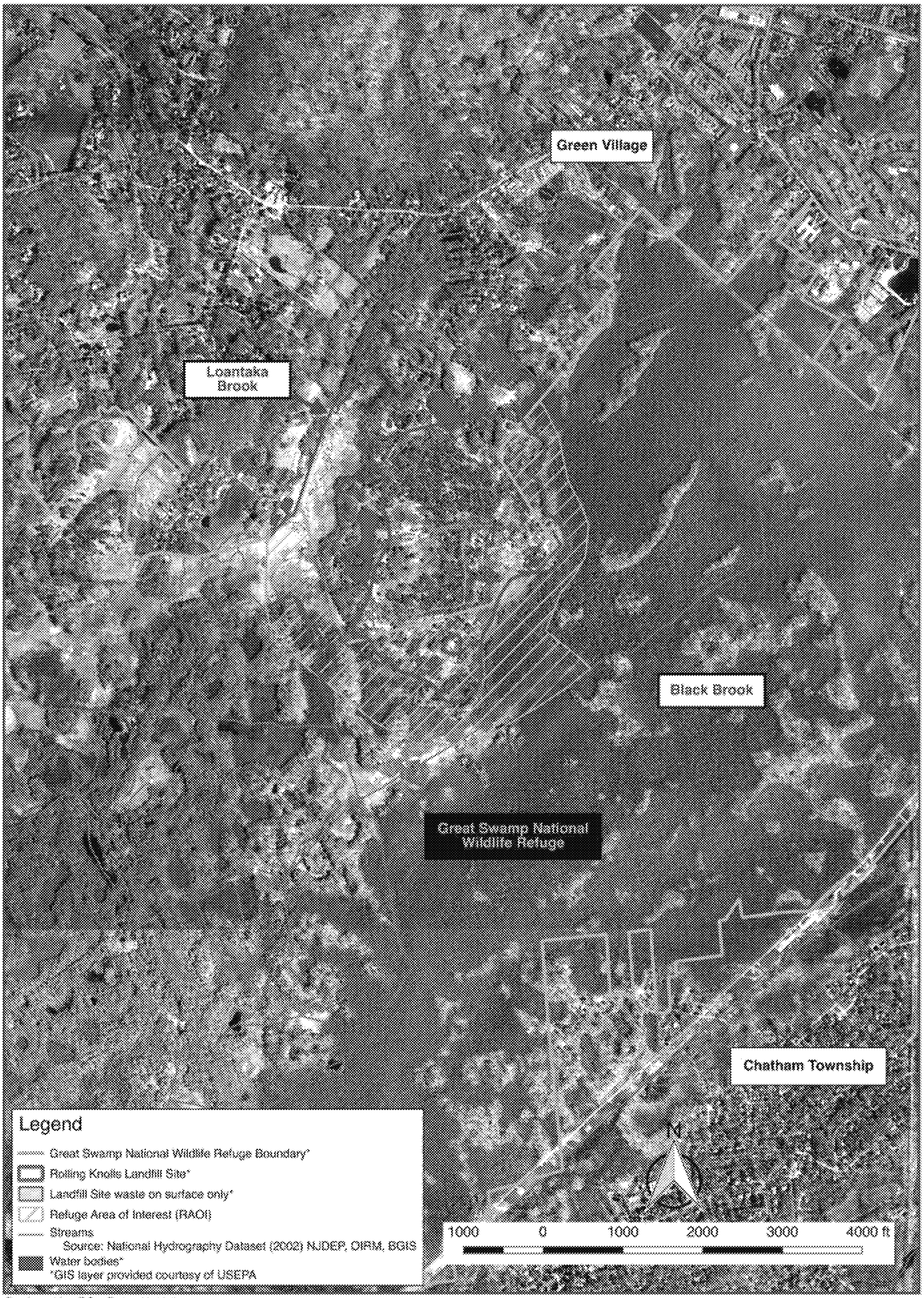
FIGURE 2 - Great Swamp National Wildlife Refuge/Rolling Knolls Site Area Map



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Aerial Images from USGS, April 2015

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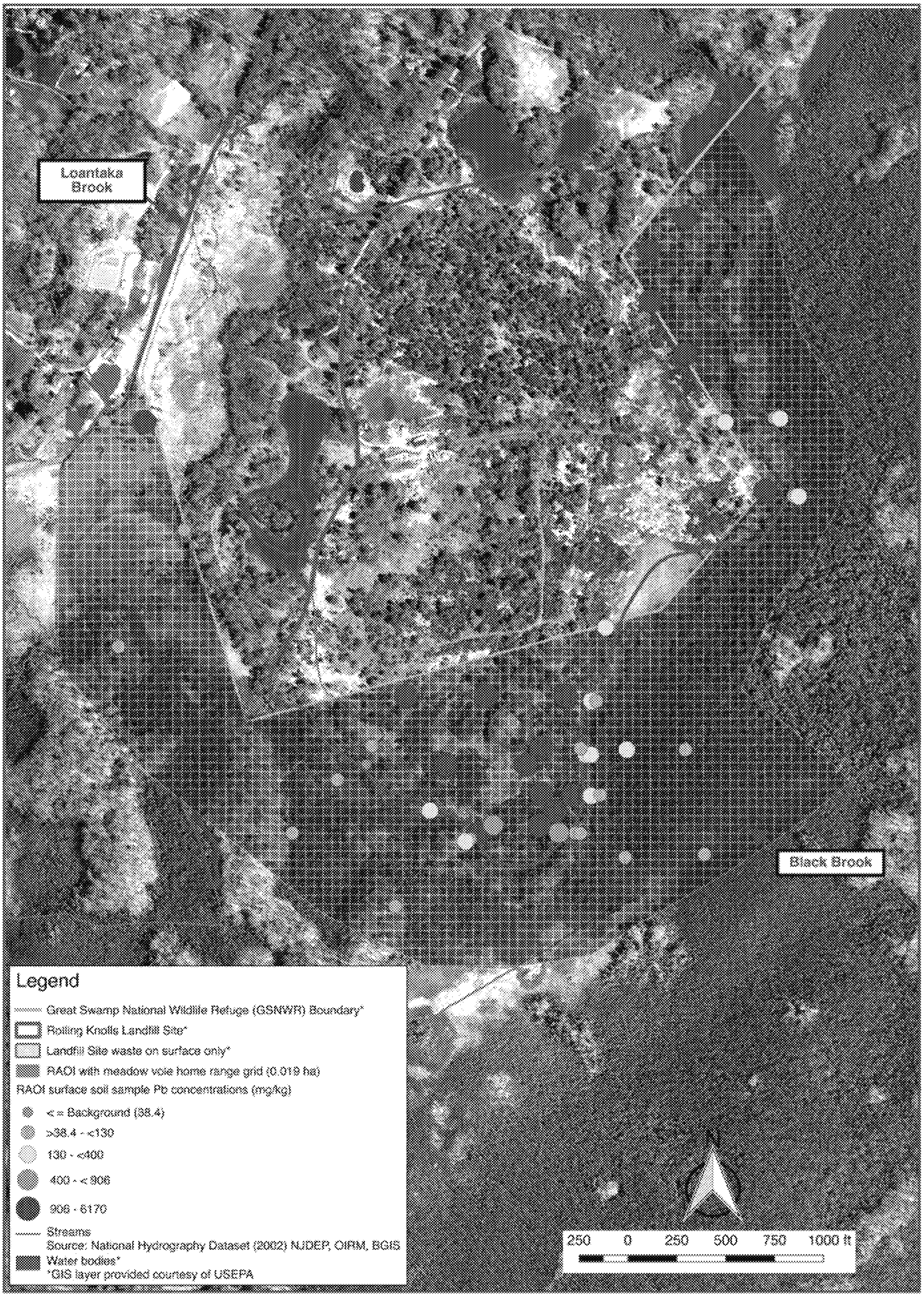
FIGURE 3 - Refuge Area of Interest
Pb Surface Soil Soil Concentrations



Produced by: PS Date: 4/11/19
Aerial images from USGS, April 2015

Figure shows RAOI surface soil Pb concentrations with a 0.019 ha (2045 ft2) grid representing the meadow vole home range.**

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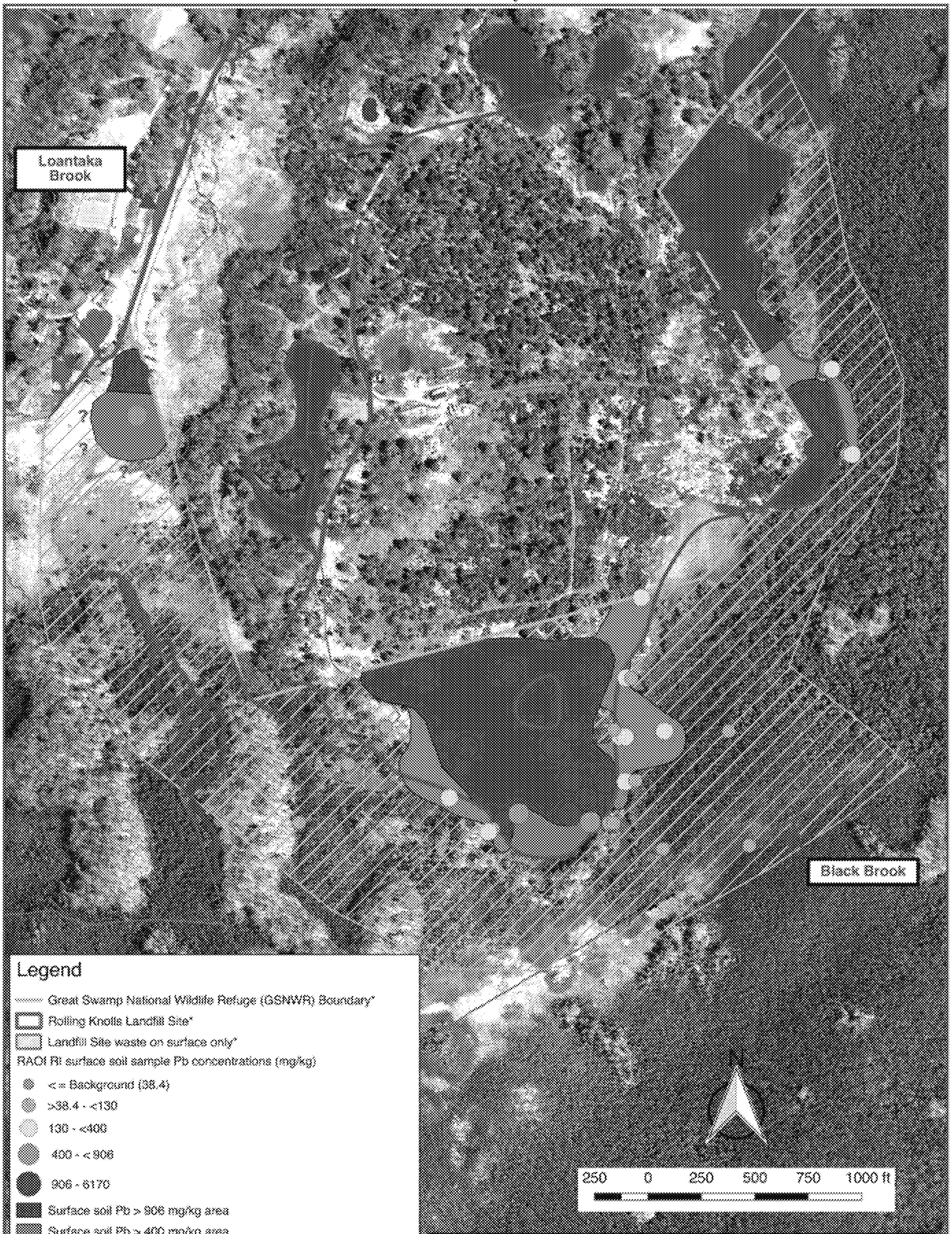
**Question marks (?) show areas where elevated Pb concentrations are not delineated.

FIGURE 4 - Refuge Area of Interest
Pb Surface Soil Impacted Areas



Pb Impacted Refuge Area	Acres > 130 mg/kg	Acres > 400 mg/kg	Acres > 906 mg/kg
Northeast/East	11.1	9.7	9.7
South/Southeast	23.8	17.8	16.3
West	2.8	2.8	0.7
Total Areas Impacted	37.7	30.3	26.7

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Aerial images from USGS, April 2015

Figure shows RAOI surface soil Pb concentrations with estimated areas impacted with concentrations above the 130 mg/kg NOAEL for protection of the Short-tailed shrew, the 400 mg/kg Pb benchmark conc., and the 906 mg/kg NOAEL for protection of the Meadow vole.**

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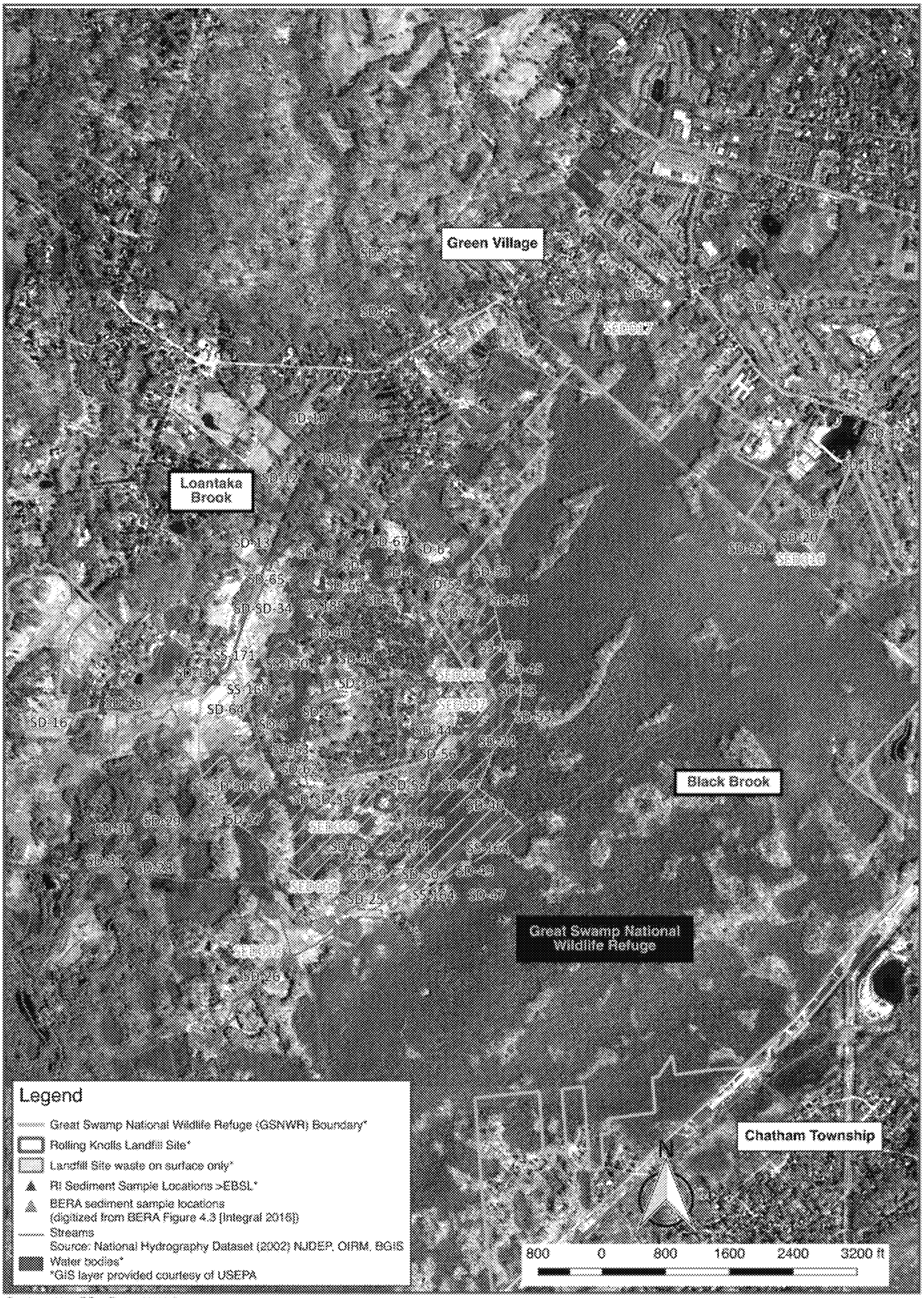
**Question marks (?) show areas where RAOI elevated Pb concentrations are not delineated.

FIGURE 6 - Sediment Sample Locations

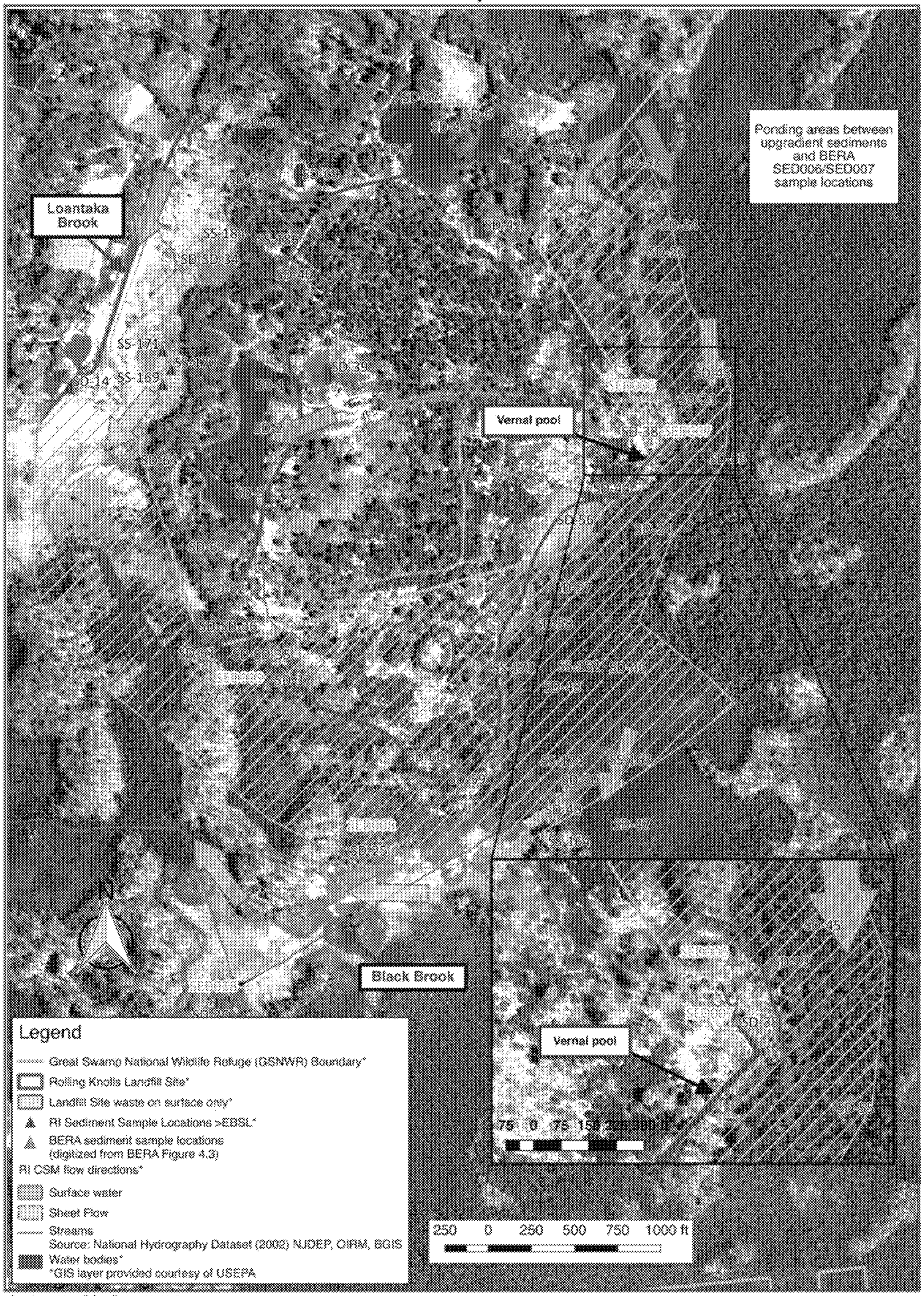


Produced by: PS Date: 4/11/19
Aerial images from USGS, April 2015

Sediment sample locations from the BERA and RI sediment sample locations that exceeded the RI ecologically based screening level (EBSL)

Geotic Solutions LLC

FIGURE 7 - Refuge Area of Interest
Sediment Sample Locations



Produced by: PS Date: 4/11/19
Aerial images from USGS, April 2015

Sediment sample locations from the BERA and RI locations that exceeded the ecologically based screening level located near and within the RAOI

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FIGURE 9 - Refuge Area of Interest
Monitoring Well Locations and Groundwater Flow

Produced by: PS Date: 4/12/19
Aerial images from USGS, April 2015

Groundwater monitoring well locations and general groundwater flow directions as reported in the Remedial Investigation Report (Geosyntec 2018b)

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