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Screening Level Ecological Risk Assessment For the Westinghouse Hematite Site Rev. 1

Prepared for :

Westinghouse Electric Company LLC

Hematite Facility
3300 State Road P
Festus, Missouri 63028
(314) 810-3375

Prepared by:

Integrated Environmental Management, Inc.
2705 North Main Street
Suite 202
Findlay, Ohio 45840
(419) 423-4701

and

Conestoga-Rovers and Associates Inc.
559 West Uwchlan Avenue, Suite 120
Exton, Pennsylvania 19341
(773) 380-9933

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ACRONYMS

ABB	Asea Brown Boveri
BGS	below ground surface
CE	Combustion Engineering Inc.
CSM	conceptual site model
DCE	dichloroethylene
DOE	U. S. Department of Energy
ECU	Envirocare of Utah
EPA	U. S. Environmental Protection Agency
MDNR	Missouri Department of Natural Resources
MNA	monitored natural attenuation
NPDES	National Pollutant Discharge Elimination System
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	perchloroethylene
pCi/g	picoCuries per gram
^{239}Pu	plutonium-239
RI	remedial investigation
SAIC	Science Applications International Corporation
SVOC	semivolatile organic compound
TCE	trichloroethylene
VOC	volatile organic compound
WEC	Westinghouse Electric Company LLC

1.0 INTRODUCTION

This screening level ecological risk assessment (SLERA) evaluates the potential risks to ecological receptors, from materials released or disposed of at the Westinghouse Electric Company,LLC (WEC) Hematite Property (the Property) in Hematite, Missouri. Ecological risk assessment is intended to provide risk managers with information sufficient to determine whether remedial actions are necessary to protect the environment from toxic chemicals or other hazards at a site. The SLERA is the first step in what may evolve to be a multi-step ecological risk assessment process. At the conclusion of a SLERA, three possible outcomes are possible.

1. The information is determined to be sufficient to dismiss potential ecological risk, and no further action is necessary.
2. The information is determined to be insufficient to dismiss potential ecological risk, and further data gathering or data analyses are recommended to better understand the risk.
3. The information is determined to be sufficient to conclude that potential ecological risks are unacceptable, and remedial action is warranted.

This SLERA relied on background information and data collected as part of the Remedial Investigation (RI) report (SAIC 2007. "*Remedial Investigation Report for the Westinghouse Hematite Site*, Revision 1" Report Number EO-05-002, January, 2007). As part of that investigation, samples of soil, sediments, surface water and groundwater were collected and analyzed for a variety of chemicals and radionuclides.

1.1 SITE BACKGROUND INFORMATION

The area considered by this SLERA is a former nuclear fuel-cycle manufacturing facility that is located on 228 acres of property near the village of Hematite, Missouri (Figure 1.1). This area is currently owned by WEC. WEC ceased facility operations in June 2001, and WEC is proceeding with site characterization, and decommissioning of the facility.

In the following text, three general areas will be discussed. The term "Facility" is used to describe the central portion of the property, encompassing approximately 18 acres containing the historic primary operations area, Site Pond and burial pits areas. The term "Site" refers to the Facility and nearby areas potentially impacted by Facility operations. The entire 228 acres, which includes large areas of forest and some pastureland, is termed the "Property". This terminology follows that used in the RI.

According to the RI, nuclear-related operations at the Hematite Facility began in 1955 with the purchase of the Property, which then consisted of farmland, by Mallinckrodt Chemical Works. The Hematite Facility became operational in July 1956, producing uranium metals for the nuclear fuel program of the U. S. Navy (SAIC 2007).

Mallinckrodt Chemical Works and related entities operated the Hematite Facility until 1961, when ownership was transferred to a joint venture called United Nuclear Corporation. UNC continued to produce uranium products for the Federal government.

In 1971, UNC and Gulf Oil Corporation (Gulf) entered into a joint venture, forming the Gulf United Nuclear Fuels Corporation (GUNFC), which owned and managed the Hematite Facility until late 1973, when Gulf acquired UNC's interest in GUNFC. General Atomic Company (GAC) a partnership involving Gulf, owned the Hematite Facility from January 1974 through May 1974 when Combustion Engineering, Inc. (CE) purchased the Hematite Facility from GAC. . Asea Brown Boveri (ABB) purchased the stock of CE in 1989, and CE began operating the Hematite Facility as ABB Combustion Engineering. In April of 2000, WEC purchased the nuclear operations of ABB, including the Hematite Facility. WEC ceased operations at the Facility in June 2001 and is proceeding with site decommissioning and remediation.

Since the beginning of industrial activity, the primary activity at the Facility has been the manufacture of uranium metal and compounds from natural and enriched uranium. In addition, the Facility also recovered uranium scrap and, to a limited degree, processed thorium compounds. More detailed discussion of the Facility and its history can be found in the RI (SAIC 2007). In addition to uranium and thorium, technetium-99 has been identified at the Site, entering plant processes as a contaminant in incoming feedstock.

In addition to radionuclides, chlorinated solvents were used in various process operations and cleaning at the Facility. According to the RI sampling, a number of other compounds, including polycyclic aromatic hydrocarbons (PAH) and heavy metals, may also have been elevated by activities at the Facility. PAHs were not used in the manufacturing process; they are probably associated with runoff from the parking lots.

These compounds have the potential to impact plants and animals inhabiting this area. Thus, the following Screening Ecological Risk Assessment (SLERA) addresses potential risks from Facility-related chemicals to ecological resources. A SLERA determines if current information is sufficient to dismiss ecological risk, or whether more information needs to be collected or analyzed to more definitively assess the risk.

1.2 SUMMARY OF AVAILABLE DATA

To assess the nature and extent of contamination, the subsurface soils (Figure 1.2), surface soils (Figure 1.3), sediments (Figure 1.4), surface water (Figure 1.5), and groundwater (Figure 1.6) were sampled and analyzed for the RI. In general, samples were analyzed for metals, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and pesticides and polychlorinated biphenyls (PCBs). Given the Facility's history, these samples were also analyzed for a variety of radionuclides.

Information on sampling locations, sampling techniques, and analytical methods is provided in the RI (SAIC 2007). The RI also presents evaluations of the resulting data.

2.0 OVERVIEW OF THE ECOLOGICAL RISK ASSESSMENT PROCESS

This SLERA follows U.S. Environmental Protection Agency (USEPA) guidance. As described in USEPA guidance (USEPA 1997), the Ecological Risk Assessment process can involve up to eight steps, described as follows:

Step 1. Screening-level problem formulation and ecological effects evaluation: This first step consists of a basic description of the site and its habitats and known hazards and their likely modes of ecotoxicity. This information is then analyzed to determine whether there are complete or potentially complete exposure pathways from known sources. This information is combined into a preliminary Conceptual Site Model.

Step 2. Screening-level exposure estimate and risk calculation: The second step of the ecological risk screening includes the exposure estimate and risk calculation. Risk is estimated based on maximum exposure concentrations compared to ecotoxicity screening values from Step 1 and screening quotients of constitutents of potential concern (COPCs) are presented. A screening quotient less than 1 indicates the COPC alone is unlikely to cause adverse ecological effects.

The SLERA can produce only three outcomes: 1) Information is adequate to determine that ecological risks are negligible; 2) Information is inadequate to make a decision; or 3) Information indicates a potential adverse ecological effect exists. The risk assessment process is continued if either of the latter two conclusions is reached.

Step 3. Baseline ecological risk assessment (BERA) problem formulation: The results of the screening assessment, in coordination with site-specific data, are used to assess the scope and goals of the BERA. The following should be completed at the end of this step: refine preliminary COPCs; further characterize ecological effects; review and refine information on contaminant transport and fate, exposure pathways, and ecosystems potentially at risk; select assessment endpoints; develop conceptual model with testable hypotheses; and analyze uncertainties associated with the risk assessment.

Step 4. Study design and data quality objective process: The conceptual model is completed during this step of the BERA, and measurement endpoints are developed based on the model. The conceptual model is used to determine the study design and the data quality objectives. The products of this step include a work plan and sampling and analysis plan, detailing the data analysis methods, exposure parameters, data reduction and interpretation methods, and statistical analyses.

Step 5. Field verification of sampling design: The sampling design, testable hypotheses, exposure pathway models, and measurement endpoints are examined to ensure they are appropriate and that they can be implemented.

Step 6. Site investigation and analysis phase: This step includes all of the field sampling and surveys that are part of the BERA. The data collected during this phase are evaluated on existing and potential exposure and ecological effects outlined in Steps 1 to 5.

Step 7. Risk characterization: This step consists of risk estimation and risk description. Data on exposure and effects are used to characterize risk based on assessment endpoints. The product of this step is the identification of a threshold for effects on the assessment endpoint(s) as concentrations ranging from levels found to pose no ecological risk to levels likely to produce adverse ecological effects.

Step 8. Risk management: This phase involves balancing risk reductions associated with remediation of the site with the potential effects of the remediation itself.

Steps 1 and 2 comprise the SLERA, while Steps 3 through 8 are the BERA. The following analysis will be limited to the SLERA. This SLERA will also follow other appropriate guidance, including:

- Screening Level Ecological Risk Assessment Protocol for Hazardous Waste Combustion Facilities, USEPA/530-D-99-001A, August 1999;
- Risk Assessment Guidance for Superfund, Volume II: Environmental Evaluation Manual, Interim Final, USEPA/540/1-89/001, March 1989;
- Framework for Conducting Ecological Risk Assessment, USEPA/630/R-92/001, February 1992;
- Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessment, USEPA/540/R-97/006, June 1997;
- USEPA Region I Supplemental Risk Assessment Guidance for the Superfund Program, Draft Final, USEPA 901/5-89-001, June 1989;
- USEPA Region I Risk Updates No. 4, November 1996; and
- EcoUpdate Intermittent Bulletins.

2.1 RELATIONSHIP OF THIS SLERA TO MISSOURI GUIDANCE

Missouri also has draft guidance for conducting ecological risk assessments (MDNR 2005). The ecological risk assessment process according to Missouri's draft guidance consists of the following three-step process:

Level 1 Ecological Risk Assessment
The level 1 ecological risks assessment consists of a survey to determine if the site contains ecological receptors and whether those ecological receptors could be exposed to chemicals that occur on-site. If habitat exists and exposure pathways to ecological receptors are complete, the risk assessment should proceed to Level 2.

Level 2 Ecological Risk Assessment
In this step, the maximum concentrations of chemicals measured in each medium are compared to Ecological Screening Values (ESVs). If the maximum concentrations exceed ESVs, then the risk assessment can proceed to either remediation or to Level 3.

Level 3 Ecological Risk Assessment
In the third level, detailed site-specific evaluations are recommended, as recommended by USEPA guidance on performing risk assessment. These detailed site-specific analyses are planned, in co-ordination with Missouri Department of Natural Resources (MDNR).

Although the terminology in USEPA and Missouri guidance differs, the summaries provided above indicate that Levels 1 and 2 of the Missouri guidance are functionally equivalent to Steps 1 and 2, respectively, of the USEPA 8-Step ERA process. Level 3 of the Missouri guidance corresponds to Steps 3 through 8 of the USEPA process. Consequently, this SLERA based on USEPA guidance satisfies the intent of the draft Missouri guidance for a Level 1 and Level 2 risk assessment, although the exact structure, placement of information, and terminology differ.

3.0 STEP 1: SCREENING-LEVEL PROBLEM FORMULATION AND ECOLOGICAL EFFECTS EVALUATION

As described in USEPA guidance (USEPA 1997), this first step of the SLERA provides a basic overview consisting of the following information:

- The Site history, in terms of land-use and potential chemical releases.
- The "environmental setting" of the Site. This is the natural and unnatural habitats that occur at the Site and whether these habitats are "potentially contaminated or otherwise disturbed" (USEPA 1997).
- The "assessment endpoints", which are the species, biological communities, or habitats that will be the primary focus of the risk assessment.
- The contaminants known or suspected to occur at the site.

The first bullet, the basic Site history, was provided previously in section 1.1, "Site Background Information." Information pertaining to the other bullets is presented below.

3.1 ENVIRONMENTAL SETTING

A reconnaissance of the Property was conducted by an experienced Field Ecologist, Dr. Steven Jones of CRA, on April 27, 2005 to assess habitat value, flora and fauna, and exposure pathways. The Wetland and Surface Water Assessment, prepared by SAIC (2004), was also used to describe the available habitat. Although the approximately 18 acres occupied by the Facility contain minimal habitat, the surrounding 210 acres contains a variety of aquatic and terrestrial habitats (Figure 3.1). These habitats are described below.

3.1.1 PONDS AND LAKES

3.1.1.1 SITE POND

The Site Pond is located in the western portion of the Property. The pond is approximately 0.5 acre in size, and water depth is shallow (SAIC 2004). The pond, which originates south of State Highway P, is created by a concrete dam approximately 1,200 feet south of State Highway P. The primary source of water for the Site Pond is the Site Spring. Surface runoff from the surrounding area, including the Site, State Highway P and an on-site parking lot to the east, also provides water to the Site Pond. One NPDES-permitted discharge also supplies water to the pond. This discharge is for stormwater collected from the roofs, ground surface drains, and parking lot. Outflow from the Site Pond is into the Site Tributary.

Watercress (*Nasturtium officinale*) and duckweed (*Lemna sp.*) were observed on the surface of the Site Pond at the time of the March 27, 2005 site reconnaissance. Vegetative

cover surrounding the Site Pond is grass that appears to be mowed on a regular basis. Several mature trees, including slippery elm (*Ulmus rubra*) and silver maple (*Acer saccharinum*) are scattered throughout the area. Numerous birds were either observed or heard calling in the vicinity of the Site Pond. Species observed include Red-eyed vireo (*Vireo olivaceus*), Common flicker (*Colaptes auratus*), and Green heron (*Butorides striaus*).

3.1.1.2 EAST LAKE

The East Lake is located in the eastern portion of the Property. The East Lake is approximately 3.7 acres in size. The primary source of inflow for this water body is the East Lake Tributary, which originates off-Property and enters the property in the eastern portion of the property at State Highway P. Flow out of the East Lake is through a water control structure. The water level in the East Lake was high at the time of the site reconnaissance. The Wetland and Surface Water Assessment prepared by SAIC (2004) identifies the depth of the East Lake as ranging from few feet at the north end to over 10 feet at the south end.

Aquatic vegetation near the edge of the East Lake includes waterweed (*Elodea sp.*) and a variety of sedges (*Carex sp.*) and rushes (*Juncus sp.*). Mature trees, including willow (*Salix sp.*), slippery elm, and sycamore (*Platanus occidentalis*) also occur around the edges of the East Lake.

Several species of wildlife were observed in the vicinity of the East Lake during the site reconnaissance. Groups of mallard (*Anas platyrhynchos*) and Canada geese (*Branta canadensis*) were observed in the water. Bank swallow (*Riparia riparia*) were observed foraging over the water. A bullfrog (*Rana catesbeiana*) was heard calling from the edge of the East Lake.

3.1.1.3 EVAPORATION PONDS

The Evaporation Ponds are two small, less than 0.25 acres in total, man-made open waters located in the southern portion of the Facility. A few shrubs and small trees are present along the edge of this water body. The majority of the area surrounding the Evaporation Ponds is grass that is mowed on a regular basis. A chain-link fence limits access to the Evaporation Pond. Some previous soil removal activities occurred within these ponds.

3.1.2 WATER COURSES

The Property is drained by one permanent stream, Joachim Creek, and several small un-named ephemeral watercourses that drain into Joachim Creek. To facilitate discussion, the latter are identified as Site Creek, Lake Virginia Creek, North Creek, and Northeast Site Creek. These provide habitat for aquatic and semi-aquatic species.

3.1.2.1 JOACHIM CREEK

Joachim Creek forms the southern boundary of the Property. Flow is from southwest to northeast and is perennial. The stream width varies from 50 feet to 70 feet. Water depth observed during the March 2005 site reconnaissance ranged from approximately one foot to pools five feet in depth or more. Joachim Creek is deeply incised with very steep, sparsely vegetated banks on either side of the stream. The potential for bank erosion is high. Sparsely vegetated gravel bars are present at several locations within the stream. The north (Westinghouse) side of Joachim Creek is forested. Land cover on the south side of the creek is a mix of forest, residential, and agriculture.

An abundance of wildlife was observed within and adjacent to Joachim Creek during the site reconnaissance. A group of Hooded mergansers (*Lophodytes cucullatus*), Great blue heron (*Ardea herodias*), and green heron were observed in Joachim Creek. Numerous bank swallow were also observed foraging over the water surface along the length of stream bordering the Property. A softshell turtle (*Apalone spinifera*) was observed basking near the eastern boundary of the Property. Raccoon tracks were also observed along the banks of Joachim Creek.

Several tributaries flow through the Property and into Joachim Creek. These tributaries are described in the following sections.

3.1.2.2 SITE CREEK

The Site Creek originates as overflow from the Site Pond, flows underneath the Union Pacific Railroad tracks, through an upland forest, and forms a confluence with the Lake Virginia Tributary near the western Property boundary. According to the topographic map, Site Creek is an ephemeral stream. Its flow is augmented by two NPDES-permitted discharges from the facility: the stormwater-discharge to Site Pond, which was discussed previously, and a sanitary waste discharge just below the outfall to Site Pond. Width of the Site Creek is approximately 10 feet and water depth is 6 to 8 inches. The substrate of the Site Creek is gravel and coarse sand. The Site Creek is bordered by relatively dense vegetation along its length, with the exception of the area where it flows through a culvert under the railroad tracks. The banks are vegetated with grasses and forbs. Secondary growth forest borders both sides of the creek.

3.1.2.3 LAKE VIRGINIA TRIBUTARY

The Lake Virginia Tributary enters the Property along the southwestern boundary of the Property, flows east for approximately 500 feet, and forms a confluence with the Site Creek. The Lake Virginia Tributary flows out of Lake Virginia, approximately 3,500 feet northwest of the Property, through two sewage lagoons, and beneath the Union Pacific Railroad tracks. Once on the Property, the Virginia Lake Tributary flows in a well-defined channel through an area of dense shrub and tree growth before forming a confluence with the Site tributary. At the time of the site reconnaissance, the Lake Virginia Tributary was approximately 6 feet wide and 12 inches deep at the point of entry east of the railroad tracks. SAIC (2004) describes flow as intermittent.

3.1.2.4 LAKE VIRGINIA/SITE CREEK COMBINED TRIBUTARY

The Lake Virginia/Site Creek Combined Tributary flows west to east from the point of confluence of the Lake Virginia Tributary and Site Creek to Joachim Creek. The width of the creek is 15 to 18 feet and water depth is approximately 6 inches. Substrate is primarily gravel with some coarse sand. The Tributary is deeply incised. The banks, although steep, are vegetated with a dense growth of grasses and forbs. Secondary growth forest is on either side of the Tributary.

3.1.2.5 NORTHEAST SITE CREEK

The Northeast Site Creek originates on the north side of State Highway P and flows northwest from southeast through the Property. Two unnamed streams flow together in a forested area north of State Highway P to form a single stream. Below the confluence, the Creek is approximately 4 feet wide and has a depth of approximately 2 to 3 inches. The substrate is primarily gravel with coarse rock, but there are some areas of exposed rock. As it approaches State Highway P, the Northeast Creek widens to approximately 15 feet and has water depth of 2 to 3 inches. Substrate in this portion of the stream is gravel.

After flowing through a culvert under State Highway P, the Northeast Site Creek flows through a forested area. Within this forested area, the Creek becomes braided. The width of the braided area is approximately 50 feet and water depth within the individual channels is generally 1 to 2 inches. The substrate within the braids is gravel and silt. Fallen trees and woody debris are abundant in the channels. Tree and shrub cover provides a relatively dense vegetative cover for the channels. The Burial Pits, which are within the industrial portion of the Property, are located to the west, within 100 feet of the westernmost braid.

South of the Burial Area, the Northeast Creek flows parallel to the north side of the Union Pacific Railroad tracks and forms a confluence with the East Lake Tributary. This segment of the Northeast Creek is approximately five feet wide and has a water depth of 2 to 3 inches. The bank adjacent to the railroad right-of-way is steep. The northern bank, which blends into a forest, is relatively flat. Shrubs and saplings provide shading for this segment of the Creek.

After forming a confluence with the East Lake Tributary, the Northeast Creek flows under the railroad, through a forested area for approximately 2,500 feet and into Joachim Creek. This segment of the Creek is approximately 10 feet wide and has a water depth of 6 inches. The substrate is primarily gravel and sand, with some silt. In this area, the channel is somewhat incised and the relatively shallow, but steep, banks are densely vegetated with grasses and forbs. Canopy from a secondary growth forest provides shade for the Creek.

3.1.2.6 NORTH TRIBUTARY

The North Tributary enters the Property in a forested area on the north side of State Highway P and flows northwest to southeast, through a meadow, and forms a confluence with the North Lake Tributary. Within the forested area, the North Tributary is approximately four feet wide and has a water depth of 2 to 3 inches. The substrate is gravel with areas of large cobbles. In the meadow, the stream narrows to 2 to 3 feet and has a depth of 1 to 2 inches. Substrate in this segment of the stream is primarily gravel and sand. SAIC describes the flow of the North Tributary as intermittent.

3.1.2.7 NORTH LAKE TRIBUTARY

The North Lake Tributary originates at North Lake, which is located off-site near the northeastern Property boundary. North of State Highway P, the Tributary flows through a meadow dominated by grasses and a few scattered trees. The channel is poorly defined but generally has a width is 1- to 3 feet with a water depth of 1 to 3 inches. The substrate is primarily silt with some gravel. The North Lake Tributary forms a confluence with the North Tributary approximately 1,000 feet north of State Highway P.

South of State Highway P, the North Lake Tributary flows through a grass pasture and forms a confluence with the Northeast Site Creek at the Union Pacific Railroad tracks. The width of the channel in this segment of the Creek is 2 to 3 feet and water depth is 1 to 2 feet. The substrate is mostly silt with some gravel. Vegetative cover adjacent to the Creek is primarily grass. At the time of the site reconnaissance, there were indications that cattle had been recently grazing in the pasture.

3.1.2.8 EAST LAKE TRIBUTARY

The East Lake Tributary enters the Property at its eastern boundary near State Highway P and flows southwest into the East Lake. A small segment of the Tributary conveys water from the East Lake to a confluence with the North Lake Tributary. The channel of the Tributary is 2-3 wide and water depth was 2 to 3 inches at the time of the site reconnaissance. The banks are shallow and are vegetated with pasture grasses. Signs of the recent presence of cattle (e.g., cow pies) were observed.

3.1.3 TERRESTRIAL HABITATS

There are four primary terrestrial habitats on the property: bottomland forest, upland forest, grassland, and mixed grassland/woodland. The location and characteristics of each of the terrestrial habitats are discussed below. Figure 3.1 depicts these areas of terrestrial habitat.

3.1.3.1 BOTTOMLAND FOREST

The majority of the Property south of the plant between the Union Pacific Railroad tracks and Joachim Creek is bottomland forest. Based on a review of historical aerial photographs, SAIC identifies the age of the bottomland forest as approximately 40 years. The largest trees are generally adjacent to Joachim Creek. Dominant canopy species are silver maple, slippery elm, box elder (*Acer negundo*), green ash (*Fraxinus pennsylvanicus*), sycamore, hackberry (*Celtis occidentalis*), and black walnut (*Juglans nigra*). The shrub/sapling stratum is relatively sparse through the area, but is slightly denser in the eastern portion. In addition to the dominant canopy species, the shrub/sapling stratum includes multiflora rose (*Rosa multiflora*), tartarian honeysuckle (*Lonicera tatarica*), buckbrush (*Symphoricarpus orbiculatus*), pawpaw (*Asimina triloba*), rough dogwood (*Cornus drummondii*), and wild berry (*Rubus sp.*). The herbaceous stratum is relatively dense throughout the bottomland forest. Virginia rye grass (*Elymis virginicus*) is predominant throughout the area. Other taxa in the herbaceous stratum include saw toothed sunflower (*Helianthus grosseseratus*), pokeweed (*Phytolacca americana*), Canada goldenrod (*Solidago canadensis*), stinging nettle (*Urtica dioca*), jewelweed (*Impatiens capensi*), and cinquefoil (*Potentilla sp.*). Vines in the bottomland forest included wild grape (*Vitis sp.*), Japanese honeysuckle (*Lonicera japonica*), and poison ivy (*Toxicodendron radicans*).

Numerous species of birds were observed or heard calling during the site reconnaissance. Species observed include American robin (*Turdus migratorius*), northern cardinal (*Cardinalis cardinalis*), and Eastern phoebe (*Sayornis phoebe*). Two broad-winged

hawks (*Buteo platypterus*) were observed circling and calling in the western portion of the area, suggesting an active nest was present. Raccoon and deer tracks were also observed in the bottomland forest.

The Site Creek, Lake Virginia Tributary, Lake Virginia/Site Creek Combined Tributary, and Northeast Site Tributary flow through this lowland forest.

Another smaller area of lowland forest occurs south of State Highway P and north of the Union Pacific Railroad tracks. This area of lowland forest is immediately east of the Burial Pits. The dominant species in this area are similar to those in the lowland forest between the railroad tracks and Joachim Creek. Unlike the forest south of the tracks, the shrub/sapling stratum is much denser. The Northeast Site tributary, including the braided segment flows through this lowland forest. During the site reconnaissance, deer tracks were observed, and a cardinal was heard calling in this area.

3.1.3.2 UPLAND FOREST

Two areas of upland forest occur north of State Highway P. The larger area is in the northwestern portion of the Property. Dominant canopy species in the upland forest include white oak (*Quercus alba*), chinkapin oak (*Quercus muhlenbergii*), red cedar (*Juniperus virginiata*), and slippery elm. Generally, the percent canopy cover is 85 percent or greater, but there are several areas where canopy cover is less that 50 percent. The shrub/sapling stratum is relatively dense and consists of the saplings of the dominant canopy species and spicebush (*Lindera benzoin*). The herbaceous stratum in this upland forest is relatively sparse. May apple (*Podpphyllum peltatum*) and Virginia creeper are common taxa in the herbaceous stratum. The Northeast Site Creek flows through this area. A smaller area of upland forest occurs in the northeastern portion of the Property where the North Tributary first enters. The dominant species in this area of upland forest are similar to those in the larger area in the northwestern portion of the Property.

Numerous passerines were heard calling at the time of the site reconnaissance. A woodpecker was also heard in this area. A fence lizard (*Sceloporus undulatus*) was observed basking on the trunk of a fallen tree.

3.1.3.3 GRASS LAND

Several areas of grassland are present on the Property. Within the Facility, the Burial Pits can be classified as grassland. The area has been planted with grass that is regularly mowed. Due to the regular mowing, use of the area by ecological receptors is limited.

The areas surrounding the Evaporation Pond can also be classified as grassland. Similar to the Burial Pits, the grass in the vicinity of the Evaporation Pond is regularly mowed, and use of this grassland area by ecological receptors is also limited. The presence of a

chain link fence surrounding the Evaporation Pond excludes use of the area by larger mammals, such as deer.

Outside of the Facility, there are two areas of grassland. The larger of the two areas is associated with agricultural activities in the eastern central portion of the Property. This grassland appears to be used as grazing pasture for horses and cattle. Horses were observed in the western portion of this pasture area during the site reconnaissance. There was evidence of recent grazing activity in the eastern portion of the pasture (i.e., cow pies). The predominant taxa of grass in this area is fescue (*(Festuca sp.*). Few forbs were observed. The East Lake, East Lake Tributary, and North Tributary are located within this pasture. An unidentified ranid (frog) was observed in the North Lake Tributary during the site reconnaissance.

Another relatively large area of grassland is located in the southeastern portion of the Property. This grassland is south of the Union Pacific Railroad tracks, north of Joachim Creek, and east of the Northeast Site Tributary. This area appears to have one time been used as pasture, but has not been grazed for 2 to 3 years. Grasses are still the dominant vegetative form, but forbs are starting to invade and become more predominant. The western most portion of this grassland has been recently disturbed and vegetative cover has not yet been re-established.

3.1.3.4 MIXED GRASSLAND/WOODLAND

The fourth major habitat/cover type is mixed grassland/woodland. This habitat is characterized by a predominance of grass cover, but also has solitary or small clusters of trees. The grass in these areas is mowed periodically.

Within the Facility area, the upland area to the west for the Site Pond can be classified as mixed grassland/woodland. Trees in this area include slippery elm and silver maple. During the site reconnaissance, numerous birds were observed or heard calling in this areas, including Red-eyed vireo, Common flicker, and Green heron.

Three areas of mixed grassland/woodland occur outside the Facility area. One area is the northeastern lobe of the Property, north of State Highway P. This area appears to have historically been used as pasture, but not in recent years. Trees in this area include slippery elm, sycamore, white oak, and shagbark hickory (*Carya ovata*). The North Tributary and North Lake Tributary flow through this grassland/woodland. The second area of mixed grassland/woodland occurs in the northeastern corner of the northeastern lobe. Trees in this area are primarily red cedar. The third area of mixed grassland/woodland occurs in the eastern portion of the northwestern lobe of the Property, on the north side of State Highway P. The predominant species of tree in this mixed grassland/woodland is also red cedar.

3.1.4 WETLANDS

The Wetland and Surface Water Assessment conducted by SAIC (2004) identified a single potential wetland on the Property. The wetland is a small, isolated palustrine forested/scrub-shrub wetland located south of the Facility, between the Union Pacific Railroad and a gravel road. The dominant species in the canopy and sapling/shrub strata are slippery elm and box elder. Dominant taxa in the herbaceous stratum are Virginia rye grass and aster (*Aster sp.*). This wetland does not appear to be associated with any of the Property streams. SAIC (2004) describes this wetland as a depression with no inflows or outflows, other than direct precipitation. No wildlife was observed in this wetland during the site reconnaissance.

3.1.5 RARE, THREATENED, AND ENDANGERED SPECIES

State or federally listed rare, threatened, or endangered species can be of particular concern in an ecological assessment due to their population status and sensitivity. Available information was surveyed to determine whether any such species potentially occurred at the Property.

The bald eagle (*Haliaeetus leucocephalus*) is listed as a federally threatened species in Jefferson County, MO. Bald eagles nest near large aquatic systems (e.g., coastal areas, rivers, lakes, and reservoirs) with forested shorelines or cliffs. Throughout their range, they select large, super-canopy roost trees that are open and accessible, mostly conifers. They winter primarily in coastal estuaries and river systems of the lower 48 states and Alaska, where thousands of bald eagles migrate each fall to take advantage of salmon-spawning runs. (USFWS 2005a). The aquatic ecosystems associated with the Property -- Joachim Creek, its small tributaries, and the small ponds -- are too small to provide good eagle habitat.

The pink mucket (*Lampsilis abrupta*) is a species of mussel that lives primarily in the Meramec, Gasconade, and Black rivers, and stretches of the Osage River of Missouri (MDEC 2005). Pink muckets live in the large streams where flowing water covers beds of cobble, gravel and sand. The depth of the water can vary from 1 inch to 5 feet deep. Pink mucket shells have been found in the Sac, Big, St. Francis, and Little Black rivers; however, live pink muckets have not recently been found in these rivers (MDEC 2005).

The gray bat is a federally-listed endangered species across its entire range, which includes Missouri (USFWS 2005b). Gray bats (*Myotis grisescens*) generally live in caves year-round (USFWS 2005b). During the winter gray bats hibernate in deep, vertical caves. In the summer they roost in caves which are scattered along rivers. Gray bats eat a variety of flying aquatic and terrestrial insects present along rivers or lakes. (USFWS 2005b).

The Indiana bat is also a federally-listed endangered species that occurs in Missouri. The Indiana bat (*Myotis sodalis*) hibernate in caves, or occasionally abandoned mines, during the winter (USFWS 2005b). Indiana bats require cool, humid caves with stable temperatures for hibernation. After hibernation, Indiana bats migrate to their summer habitats where they usually roost under loose tree bark on dead or dying trees. Indiana bats also forage in or along the edges of forested areas.

In addition to the pink mucket, gray bat, and Indiana bat, the elephant ear (*Elliptio crassidens*), ebonyshell (*Fusconaia ebena*) and sheepnose mussels (*Plethobasus cyphyus*) are state listed endangered species. The elephant ear is a mussel species that is widespread but relatively rare in the Midwest and is found in large rivers in mud, sand, or fine gravel substrates (Illinois Natural History Survey 2005). Th ebonyshell mussel that is historically widespread and abundant, but rare in much of the Midwest. This species occur in large rivers in sand and gravel. The sheepnose mussel is found in medium to large rivers in gravel or mixed sand and gravel substrates and is rare throughout its range (Illinois Natural History Survey 2005).

Based on their habitat requirement, few of these threatened and endangers species are likely to occur at the Property. While eagle nests have been reported downstream at the confluence of Joachim Creek with the Mississippi River, these large birds will not routinely feed on small creeks and ponds such as those that occur at the Site. Joachim Creek, by far the largest stream-course, is also too small near the Property to be good eagle foraging habitat. Similarly, the endangered mussels described above are associated with rivers that are much larger than Joachim Creek and the small on-Property creeks.

However, the two endangered bat species might potentially occur at the Property. In addition, other non-endangered mussel species and non-endangered fish-eating birds may occur in the Property's aquatic areas. Therefore, risks to these non-threatened and endangered species will be considered in the risk assessment. Consideration of these species provides a measure of protection to the eagle and endangered mussel species in the unlikely event that they do occur on the Property.

3.2 EXPOSURE PATHWAYS /PRELIMINARY CONCEPTUAL SITE MODEL

To account for potential cumulative effects to wide-ranging biota, this SLERA considers potential risks for the entire Property as a whole. The reconnaissance indicates that the Property contains functional terrestrial and aquatic habitats. Thus, this SLERA will assume that there is potential exposure to chemicals and radionuclides in surface soils, water, sediments, and to groundwater in surficial overburden aquifers that discharge to nearby wetlands and surface waters. In general, ecological receptors are exposed to chemicals only in surface soils, by convention the upper 1 foot below ground surface

(ft bgs)[1]. That is, exposure from chemicals in deep soil to ecological receptors is assumed to be functionally incomplete[2]. This preliminary conceptual site model for non-radionuclides is presented in Figure 3.2.

Exposure to chemicals in deep bedrock aquifers was also assumed to be functionally incomplete. According to information and analyzes presented in the RI, the bedrock aquifers probably do not discharge to Joachim Creek. Although this groundwater, presumably, eventually discharges to surface water, this will occur only after considerable dilution and degradation. In addition, the primary COPCs in deep groundwater are VOCs. By their nature, the VOCs have little potential to cause ecological risk. They are generally not very toxic to ecological receptors, they are not persistent in media to which ecological receptors are exposed (e.g., surface soils, surface waters, and sediments), and they do not readily bioaccumulate via food chains. Therefore, VOCs rarely pose ecological risk at contaminated sites even before remediation.

In view of the high level of concern about radionuclides and their very long half-lives compared to the organic COPCs, a more conservative CSM is employed for radioactive compounds. The risk assessment for radioactive compounds will consider radionuclides in soil samples as deep as 3 feet below ground surface and in the deeper, bedrock aquifers. The CSM for radionuclides is identical to that presented in Figure 3.2, except that the two incomplete pathways (soil and deep groundwater) are considered complete. Exposure pathways to the deeper soil and groundwater are the same as surface soil and shallow groundwater as shown in Figure 3.2.

3.3 ASSESSMENT ENDPOINTS

Assessment endpoints are the specific ecological values that should be protected from Site-related chemicals and radionuclides. Assessment endpoints should be selected based on several factors: economic importance, importance to society, ecological importance, and sensitivity to contaminants (USEPA 1997). The following are appropriate assessment endpoints for the Property.

- Protection of the benthic invertebrate community from changes in structure and function due to site-related contaminants.

[1]The surface soil samples were actually taken in the top 6 inches. Soil sampling was undertaken primarily to address the risks of radionuclides on human health, and the top 6 inches is defined as surface soil by the Nuclear Regulatory Commission. This difference is not believed to be significant. There are a large number of surface soil samples, which are sufficient to characterize the potential risks from chemicals in soil.

[2]. Some burrowing organisms such as woodchucks and prairie dogs may be exposed to chemicals in deeper soils, primarily associated with grooming. However, the exposure from this pathway is minor compared to that associated with ingestion of chemicals in food.

- Protection of the water column community from changes in structure and function due to site-related contaminants. .
- Maintenance of populations of fish-eating wildlife similar to nearby sites not exposed to site-related contaminants.
- Maintenance of populations of wildlife foraging on aquatic insects emerging from on-site aquatic habitats.
- Maintenance of populations of worm-eating wildlife similar to those found in similar habitats not exposed to site-related contaminants.
- Maintenance of populations of predators foraging similar to those found in similar habitat not exposed to site-related contaminants.

As described previously, locally threatened and endangered species include the bald eagle, two bat species, and several freshwater mussels. Although the Property contains no adequate habitat for most of these, potential risks to these species are included in the assessment endpoints identified above. For example, the SLERA will consider potential impacts on all aquatic species in the sediments and water column. This assessment will include consideration of potential toxicity to all lifestages of endangered and non-endangered mussels. The SLERA will also consider risks to fish-eating birds and mammals, which will encompass potential risks to eagles. The assessment endpoint considering risks to insectivorous mammals and birds will be protective of the two endangered bat species.

3.4 CONTAMINANTS KNOWN OR SUSPECTED TO OCCUR AT THE SITE

By convention, contaminants known or suspected to occur at a site are termed COPCS, which stands for chemicals (or constituents or contaminants) of potential concern. According to guidance (USEPA 1991, USEPA 1997), COPCs should be selected based on an understanding of what chemicals were used and potentially released at a site. A number of acids, bases, and organic solvents were used at the Facility (SAIC 2007): anhydrous ammonia, potassium hydroxide, hydrochloric acid, nitric acid, hydrogen peroxide, isopropyl alcohol, hydrogen fluoride, trichloroethylene (TCE), and perchloroethylene (PCE). With the exception of the chlorinated solvents, none of these compounds will persist in the environment. Therefore, of these chemicals, only PCE, TCE, and their breakdown products (dichloroethylene [DCE], vinyl chloride) were considered as COPCs. The Facility also processed a number of radionuclides: thorium 232, uranium 234, uranium-235, and uranium-238. Although technetium-99 was not processed at the Facility, this radionuclide was present as a contaminant in commercial uranium materials that were used at the Facility. Decay of these radionuclides produces several other radionuclides: actinium-228, americium-241, beryllium-7, bismuth-212, bismuth-214. cesium-137, lead-212, lead-214, neptunium-237, potassium-40, protactinium-234, thallium-208, thorium-227, and thorium-234 (Howard 2005). Plutonium-239 may also be present at the Site. All of these were considered potential radionuclide COPCs.

In addition to these chemicals and nuclides, sampling of the soil, water, and sediments suggests that other compounds (e.g., PCBs, PAHs, and some metals) have also been elevated by activities at the Facility (SAIC 2007). These could have potentially been used and released to the environment. Following guidance for COPC selection provided in USEPA (1991) and the California EPA (CalEPA 1997), other COPCs were identified as those compounds that have the following characteristics:

- Are detected in on-site samples at a frequency greater than 5 percent
- Are elevated above background concentrations

The available sampling data include surface soil (usually the top 6 inches), subsurface soil taken below and often considerably below, 1 foot below ground surface, surface water, sediments, and groundwater from overburden and from bedrock aquifers. Based on the preliminary conceptual site model described in Section 3.2 above, results from subsurface soil and groundwater from bedrock aquifers were not considered in the ecological risk for non-radionuclides. Exposure pathways from these media to ecological receptors are assumed to be functionally incomplete. A more conservative conceptual site model is employed for radionuclides; data from subsurface soil down to and including samples taken 3 feet below ground surface and from deep bedrock aquifers will be considered with the radioactive compounds.

Background sample locations for all media were the same as those identified by SAIC in Appendix J of the RI (SAIC 2007). A number of statistical methods and graphical methods can be used to determine whether on-site concentrations are elevated above background. As recommended by California EPA (CALEPA 1997) and USEPA (2002), the Wilcoxon Rank Sum test is used to test whether on-site concentrations were elevated above background. As also recommended by USEPA, a conservative probability (p) level of 0.20 for the two-tailed test was employed to minimize the potential for false negatives. False negatives are instances where on-site concentrations are elevated, but the elevation is not detected by the statistical analysis. On the other hand, use of the high p level corresponds to a higher chance of false positives, instances in which on-site concentrations are not truly elevated but appear elevated simply due to chance.

Statistical analyses to determine whether on-site concentrations were elevated were not conducted with sediments because only two background samples of sediments were taken. Two samples are insufficient replication to produce adequate statistical power, especially for a heterogeneous medium like sediments. The resulting statistical testing would have too high a potential for false negatives[3]. Instead, elevation of background

[3] The two background sediments are also apparently coarser than the on-site samples. The two background sediments had lower concentrations of iron and aluminum (Table 3.2). Both metals are abundant in fine clay particles and generally rare is coarse, sandy sediment. In general, the concentrations of other metals will increase with increasing concentrations of aluminum and iron (Weisburg et al. 2000, Jones and Smith 2005). A common method to correct for this effect is to express

for chemicals measured in sediments was based on the results of the background analysis for chemicals measured in soil. Soil-bound chemicals on the Property will have been the primary source of chemicals to the sediments. Only compounds that were determined to be elevated in soil were assumed to be elevated in sediments.

3.4.1 FINAL COPCS IN SOIL

As can be seen from Figure 1.3, almost 120 surface soil locations were sampled. Approximately 2/3rds of these are concentrated in a relatively small area, less than about 18 acres of theFacility and its immediate environs. The other 40 or so surface soil samples are distributed on the approximately 220 acres of surrounding, more natural areas of the Property. As noted above in Section 3.2, this SLERA considers potential risks from the Property as a whole, so all on-Property soil samples were considered. Summary statistics for surface soil samples are presented in Table 3.1. Only compounds detected at a frequency greater than 5 percent for on-site soils are presented. Mean concentrations presented in this table and elsewhere in this report are calculated as the grand mean of all samples, including duplicates, with less than detection results estimated as ½ the detection limit.

In general, few VOCs were detected in any of the 124 on-site samples. Methylene chloride, a common laboratory contaminant, was detected at low concentrations in a high proportion of on-site and off-site samples. It was assumed to be a lab contaminant and was not retained as a COPC. Several SVOCs, primarily PAHs and several phthalates were frequently detected in on-site soils. SVOCs were not assessed in background, so any SVOC detected at a frequency greater than 5 percent was assumed to be elevated above background and classified as a COPC. A variety of pesticides and two PCB formulations, Aroclors 1254 and 1260, were also detected at generally low concentrations and low frequencies of detection. These compounds were also retained as COPCs because background samples were also not analyzed for PCBs/pesticides. All of the naturally occurring metals were detected at a frequency greater than 5 percent in on-site soils, but only a handful (calcium, chromium, copper, mercury, nickel, potassium, and selenium were elevated above background levels ($p < 0.20$, Wilcoxon-Rank Sum test). These were classified as COPCs.

One soil sample, CB-01 from the Cistern Burn Pit area, was analyzed twice, in a regular sample and field duplicate, for dioxins and furans. This sample had detectable concentrations of four of the toxic 2,3,7,8-substituted dioxin and furans (Table 3.2), although the congeners detected were primarily less toxic congeners.

metals concentrations as aluminum-normalized concentrations. Statistical analyses of aluminum-normalized concentrations indicate that no metal in sediments was elevated above background. However, the significance of this result is limited. It is based on only two background samples.

According to current theory, the different dioxin and furan congeners contribute to an aggregate dioxin-like toxicity, expressed as 2,3,7,8-TCDD toxic equivalents (TEQ). To estimate the aggregate dioxin-like toxicity in this soil sample, CRA employed the method recommended by USEPA (1999a). Measured concentrations of each 2,3,7,8-substituted dioxin/furans was first adjusted by factors to account for both the relative rate of bioaccumulation and the relative toxicity of each congener relative to relative to 2,3,7,8-TCDD. The first factor, termed the bioaccumulation equivalency factor (BEF) was obtained from USEPA (1999). BEFs are empirically derived values that estimate the bioaccumulation of different congeners relative to 2,3,7,8-TCDD for each dioxin and furan congener. The BEF adjusted congener concentration was then multiplied by the appropriate toxic equivalency factor (TEF) developed by the World Health Organization (WHO) (Van den Berg et al 1998). As mammals are more sensitive to effects of dioxins and furans, the mammalian TEF system was used. Finally, the total TEQ was calculated by summing up all the TEF and BEF adjusted concentrations congeners to produce a total TEQ for that soil. As shown in Table 3.2, the final estimated TEQ for the soil sample is very sensitive to how less than detection values are treated. Instead of a maximum and mean concentration, TCDD TEQ concentrations in presented Table 3.1 and in subsequent steps in the screening assessment correspond to estimates of the TEQ with non-detects set to ½ the detection limit and non-detects set to zero. Because no background samples were analyzed for dioxins and furans, dioxin TEQ was assumed to be elevated by Facility activities and classified as a COPC.

3.4.2 COPCS IN SEDIMENT.

Summary statistics for sediment samples are presented in Table 3.3 for those chemicals detected at a frequency greater than 5 percent in on-site samples. Although there were considerably fewer sediment samples than samples from surface soils, the results of the sediment sampling were similar to the results of soil sampling. VOCs were not generally detected in sediments, although more of the chlorinated solvents and their breakdown products were detected in sediments than in surface soils. These compounds were assumed to be site-related and retained as COPCs. Methylene chloride and acetone, two common laboratory contaminants, were detected in both on-site and off-site sediments. These were assumed to be lab contaminants and not retained as COPCs.

As was the case for soil, a variety of PAHs and several phthalates were detected in surface sediments, sometimes in high concentrations. These SVOCs were assumed to be elevated above background and retained as COPCs. Similarly, PCBs and the pesticide endrin were detected at low concentrations and low frequencies. Both were assumed to be elevated above background and retained as COPCs. All of the metals, except silver, sodium, and thallium, were detected in sediments at a frequency greater than 5 percent. Based on the background analysis conducted for soils, only calcium, chromium, copper, mercury, nickel, potassium, and selenium were assessed to be elevated by site-related activities. These were classified as COPCs.

3.4.3 COPCS IN SURFACE WATER

Summary statistics for the water column samples are presented in Table 3.4. In general, only a small number of SVOC or VOCs were detected in surface water. Except for the lab contaminant, methylene chloride, all of these organic chemicals were retained as COPCs. Most of the metals were detected in surface water, although generally at low frequencies. According to the statistical comparison to background, none of the metals were elevated above background concentrations. However, these statistical analyses are based on a small number of samples – only 8 on-site samples versus 5 background off-site samples. The background samples were taken from sampling locations upstream of the influence of the Site. This sampling frequency may be insufficient replication to provide adequate statistical power. Consequently, to be conservative, these compounds were retained as COPCs even though they are not statistically elevated above background samples.

3.4.4 COPCS IN GROUNDWATER

Summary statistics for detected compounds in groundwater are presented in Table 3.5. In 34 samples of on-site groundwater, very few SVOCs were detected at a frequency greater than 5 percent. The two that were, bis(2-ethylhexyl)phthalate and phenol, were not statistically elevated above background concentrations. The phthalates are common laboratory contaminants and was found in half of the background well samples. Phenol was detected in only 2 on-site well samples. Neither was retained as a COPC. Of the VOCs, a large number of chlorinated solvents and their breakdown products were detected in groundwater. Given their history of use at the Facility, these were classified as COPCs. Methylene chloride was again detected in on-site and off-site samples, and it was dismissed as a lab contaminant.

Total metals were analyzed in 75 on-site groundwater samples and 14 off-site samples, but dissolved metals were analyzed in only 10 onsite samples and 1 off-site sample. The number of dissolved metals samples was assumed to be too low for statistical analyses. Therefore, dissolved metals were classified as elevated or not elevated above background based on the background analysis with more numerous results for total metals. Based on these analyses, aluminum, nickel, potassium, and zinc were classified as COPCs in groundwater.

A single groundwater sample (CB-01) was analyzed for dioxins and furans. The TCDD equivalent concentration of this sample was estimated as previously described for soils. See section 3.4.1 and Table 3.2. TCDD TEQ in groundwater was not considered a COPC or considered further. The screening of groundwater chemicals is based on the assumption that there is a complete exposure pathway to ecological receptors when the groundwater discharges to nearby surface waters. Dioxins and furans are so hydrophobic that they are effectively immobile in groundwater aquifers. Therefore, no

appreciable transport of dioxins and furans in groundwater to nearby surface waters is expected. The exposure pathway is effectively incomplete.

3.5 IDENTIFICATION OF PRELIMINARY CONSTITUENTS OF POTENTIAL CONCERN (COPCS) – RADIONUCLIDES

The following radionuclides were processed at the Facility: thorium 232, uranium 234, uranium-235, and uranium-238. Technetium-99 was not processed, but was a contaminant in uranium feedstock. Howard (2004) also identified the following additional daughter and breakdown products: actinium-228, americium-241, beryllium-7, bismuth-212, bismuth-214. cesium-137, lead-212, lead-214, neptunium-237, potassium-40, protactinium-234, thallium-208, thorium-227, and thorium-234. Plutonium could also be found on-site. This presumptive COPC list was compared statistically to background soil concentration, using previously described methods. Those radionuclides that were elevated in on-site soils compared to off-site soils (Wilcoxon Rank Sum test, $p < 0.20$) were considered COPCs. Summary data for radionuclides in soil, sediment, surface water, and groundwater are presented in Tables 3.6 to 3.9.

4.0 STEP 2: SCREENING-LEVEL EXPOSURE ESTIMATE AND RISK CALCULATION

In the second step of the SLERA, COPCs and complete exposure pathways identified in Step 1 are screened in terms of their potential to cause ecological risk.

4.1 SCREENING OF NON-RADIOACTIVE COPCS

In analyses that follow, COPCs were screened for potential ecological risk to assessment endpoints using the quotient method. Specifically, screening quotients (SQ) are estimated as

$$SQ = \frac{EEC}{ESV}$$

where EEC is the estimated exposure concentration and ESV is the ecological screening value, also a concentration. In accordance with USEPA guidance, the EEC in the SLERA screening is based on the maximum concentration of each chemical detected in each medium. The mean concentration is also presented to provide perspective on average risk faced by populations of organisms. An SQ less than 1.0 indicates that the COPC alone is unlikely to cause adverse ecological effects. Risks from these chemicals can be dismissed as unlikely. Risks from chemicals with SQs > 1.0 cannot be dismissed. These chemicals are retained in the risk assessment for further analysis.

A variant of the above equation is used in sections below which estimate risks via bioaccumulation and food chain exposure. In this case, the SQ is estimated as the estimated exposure divided by the toxicity reference value (TRV), both of which are doses (mg/kg-day).

Based on the Assessment Endpoints identified previously, the risk screening will address potential risks to the following groups of animals from the following media.

- Potential effects of COPCs in surface water to water column community of on-site aquatic habitats
- Potential effects of COPCs in sediments on benthic invertebrate community inhabiting the aquatic sediments
- Potential impacts of COPCs to fish-eating wildlife foraging in on-site aquatic habitats
- Potential effects of COPCs to insectivorous wildlife foraging on insects emerging from on-site aquatic habitats
- Potential effects of COPCs in soil to worm-eating wildlife
- Potential effects of COPCs in soil to top predators foraging in terrestrial areas

4.1.1 ESVS FOR SOIL

If they were available, ESVs for chemicals in soil were taken from Ecological Soil Screening Levels (EcoSSLs) produced by the USEPA (USEPA 2000). These benchmarks have the following advantages. They are intended to be protective of ecological receptors through both direct toxicity (e.g., toxicity to plants and soil invertebrates) and indirect toxicity by bioaccumulation (e.g., toxicity after bioaccumulation to herbivores and predators). Their derivation is described in detail, and they have undergone some external review. However, for several of the metals (e.g., antimony, cadmium, vanadium, and lead), the EcoSSLs have the disadvantage of being lower than naturally occurring background concentrations. ESVs below background concentrations are of dubious scientific validity and utility. With respect to their legitimacy, ESV's below background imply that toxicity occurs to wide-ranging species from naturally occurring, wide-raging soil concentrations. With respect to their utility, ESVs below background concentrations are ineffective, because they fail to screen out naturally occurring chemicals within background concentrations. For example, soil at virtually all sites in the United States will exceed EcoSSLs for antimony and vanadium.

The EcoSSLs documents for aluminum and iron are narrative descriptions and do not provide specific screening values. According to these narratives, aluminum is assumed to be non-toxic to ecological receptors except at low pH (< 5.5), and iron is also considered to be a non-problematic constituent in soils. Consequently, neither aluminum nor iron was considered problematic in soil.

If no EcoSSLs for metals were available, Dutch MPCs (Maximum Permissible Concentrations), from Crommentuijn et al. (1997) were used as ESVs. The MPCs are estimated as the maximum amount of a metal that could be added to background concentrations without causing toxicity to most species. The derivation of the Dutch MPCs is transparent, and it is well described in the source document (Crommentuijn et al. (1997). The Dutch values also specifically incorporate background concentrations. On the other hand, these values are primarily based on direct toxicity, although potential toxicity via bioaccumulation pathways is a minor part of the derivation. These values have been recommended by USEPA (2005).

If neither EcoSSL nor Dutch MPC values were available, USEPA Region V (2000) ecological screening levels (ESLs) were used. The Region V ESLs consider toxicity by both direct toxicity and bioaccumulation, and they are derived for a wide variety of organic and inorganic compounds. On the negative side, the actual derivation of these ESVs is not presented in the source documents. In addition, the Region V ESVs for some compounds, notably metals and chlorinated pesticides and PCBs, are very conservative. These soil ESVs for metals are often one to two orders of magnitude below naturally occurring levels, rendering them scientifically suspect and inefficient as screening criteria. The ESVs for many of the chlorinated pesticides, PCB, and dioxins are so low that they are exceeded by most any detected concentration.

Calcium and potassium are essential macronutrients that have minimal potential to cause toxicity. Consequently, no ESVs are available for these metals, but potential risks from these nutrients can be discounted as unlikely. Although not classified as COPCs in soil, sodium and magnesium are also essential macronutrients whose ecological risk can be discounted as unlikely. Potential risks from these nutrients were also rejected as unlikely in the screening of these nutrients in sediments, surface water, and groundwater.

4.1.2 ESVS FOR SEDIMENTS

When available, threshold effect concentrations (TEC) values (MacDonald et al., 2000) were used to screen chemicals in aquatic sediments. The TEC values are based on a variety of other sediment quality guidelines, such as the National Oceanic and Atmospheric Administration (NOAA) ER-L (Environmental Effects Range – Low) values and Ontario's LEL (Lowest Effects Level). The TEC values are based on larger databases and more varied habitats than any of the individual sources. If a TEC value was unavailable, sediment quality values generated by the Netherlands (Crommentuijn et al. 1997) were used. These values were derived with similar methods as the Dutch soil criteria and have the same advantages. If no TEC or Dutch values were available, ESVs presented in USEPA Region V or NOAA (1999) were used.

TEC values have the advantage of being widely used and widely accepted. They are also very conservative, so that there is little chance that toxic sediments will be dismissed as non-toxic. This conservatism, however, means TEC values are useful only in screening for lack of toxicity; exceedances of TEC values does not imply that impacts are expected. Moreover, TEC values are so conservative that they are sometimes lower than naturally occurring background values, making them inefficient as screening values. Lastly, the TEC values are based on the co-incidence of sediment toxicity/observed impacts with observed concentration of a compound. Consequently,much of the information used to develop a TEC value was potentially due to toxicity from other compounds. Recent analyses indicate that the TEC values are actually simply background values (Smith and Jones 2005), rather than toxicologically based endpoints.

4.1.3. ESVS FOR SURFACE WATER AND GROUNDWATER

As a first choice, water quality criteria for aquatic life from Missouri were chosen. If no Missouri value was available, national water quality criteria (USEPA 1999b) for freshwater were used. If no national chronic water quality criteria were available, ESVs from USEPA Region V were employed. None of these sources has a manganese criterion; thus, the manganese criterion developed by Michigan was used (MDEQ 2000). In all cases, the more conservative chronic aquatic life criteria were used.

Some of the metals criteria depend on water hardness. Hardness was not measured in these water samples, but hardness values were calculated from measured calcium and magnesium concentrations (APHA 1992) as

$$\text{Hardness, mg/l as } CaCO_3 = 2.497 * [Ca] \text{ mg/l} + 4.1189 * [Mg] \text{ mg/l.}$$

Based on average calcium and magnesium concentrations, the hardness was estimated to be 260 mg/l as $CaCO_3$. Thus, metals criteria for hardness values >250 mg/l from Missouri guidance were used as ESVs for surface and groundwater.

Most of the water quality criteria for metals are applicable to dissolved metals concentrations, because adsorbed and insoluble metals pose little to no risk. Unfortunately, all of the surface water samples and most of the groundwater samples are total metals analyses. In the absence of sufficient data on concentrations of dissolved metals, the dissolved-metals criteria were applied to concentrations of total metals. The conservativeness of these comparisons should be noted. Application of surface water criteria to groundwater results is also very conservative. There will often be appreciable reductions in concentrations due to ongoing fate processes and dilution before the groundwater discharges to the nearest surface water. The conservativeness of these comparisons should also be noted.

4.2 RESULTS OF COPC SCREENING

The follow sections describe the results of the screening of soil, sediment, water, and groundwater COPCs.

4.2.1 RESULTS OF SOIL COPC SCREENING

The results of the screening of soil COPCs are presented in Table 4.1. Based on the maximum concentration, all of the metal COPCs except for the macronutrients had SQ values that exceeded 1.0. All of these metals in soil were retained for further analysis. PCBs also had SQ values above 1.0 and were retained. SQ values for most, but not all of the PAH compounds and phthalate compounds were less than 1.0. Potential risks from these COPCS can be dismissed as unlikely, and those PAH and phthalate COPCs with SQ values below 1.0 were not retained for further analysis. A small number of PAH compounds and two phthalates had SQ value above 1.0. These compounds were retained as COPCs. TCDD TEQ was also retained for further analysis.

One pesticide, endrin, had a maximum concentrations above the ESV, but this pesticide was dismissed from further consideration based on the following professional judgment. First, the maximum concentration for soil samples is based on 124 surface soil samples, and only one of those 124 samples exceeded the endrin ESV. 10.10 ug/kg. Second, endrin was detected at very low concentrations at all sites. The maximum

concentration was only 0.021 mg/kg, while mean concentrations with non-detects set to ½ the detection limit and to zero are 0.001 mg/kg and 0.0004 mg/kg, respectively. Third, these values may well be background levels. Endrin was widely used on a number of agricultural crops, and the detected concentrations are consistent with the site's previous agricultural land use. Therefore, endrin was not considered further.

4.2.2 RESULTS OF SEDIMENT COPC SCREENING

The maximum concentrations of all of the SVOC and most of metal COPCs exceeded their sediment ESVs (Table 4.2). In terms of magnitude of exceedance and mean SQ values, the PAHs would appear to be more problematic than the metals. None of the VOCs or PCB/pesticides exceeded their ESVs. The following compounds had maximum SQ value below 1.0, indicating no significant potential for risk: selenium, PCBs, endrin, 2-butanone, cis-1,2-DCE, trans-1,2-DCE, PCE, toluene, TCE, and vinyl chloride. These COPCs were not retained for further analysis.

4.2.3 RESULTS OF SURFACE WATER COPC SCREENING

Several metals were detected at concentrations above screening levels (Table 4.3). These compounds were retained for further analysis.

4.2.4 RESULTS OF GROUNDWATER COPC SCREENING

Of the metal COPCs, only aluminum and zinc exceeded their ESV (Table 4.4). The exceedance of zinc was nominal and based on the comparison of total zinc concentrations to an ESV based on dissolved zinc. Nonetheless, these two compounds were retained as COPCs. Some of the volatile organic COPCs had SQ values less than 1.0, and were not retained as COPC: 1,1,1-trichloroethane;, 1,1,2-tricholoroethane;, 1,2-dichloroethane; and chloroform. The following VOCs had SQ values above 1.0 and were retained as COPCs: 1,1-DCA, 1,1-DCE, cis-1,2-DCE, PCE, trans-1,2-DCE, TCE, and vinyl chloride. Based on the magnitude of SQ, cis-1,2-DCE, PCE, and TCE were the most problematic compounds, with maximum SQ values greater than 50.

4.3 SCREENING OF BIOACCUMULATIVE COPCS WITH FOOD CHAIN MODELS

The screening of different media conducted above pertains mostly to direct toxicity. For example, comparison of surface water and groundwater to surface water criteria addresses risks to organisms living in the surface water. Similarly, the sediment benchmarks primarily screen for direct toxicity to the benthos, organisms that live in or on the sediments. However, the COPCs may also pose risk to predators after bioaccumulation by organisms low in the food chain. Thus, the COPCs in sediments

may pose risks to predators of the benthos, if significant bioaccumulation occurs, in addition to posing direct toxicity to the benthos themselves. Potential predators of benthos include birds, such as ducks, and raccoons that feed on the aquatic benthos. After emergence, adults of the benthic insects present a complete exposure pathway from chemicals in sediments to bats, swallows, and other insectivorous birds such as redwing blackbirds. If a COPC bioaccumulates readily in food chains, as with PCBs and methylmercury, these COPCs may be passed up from the sediments through the benthos to the fish, and, from there, pose risk to fish-eating predators such as mink and herons.

In view of this potential, this SLERA considers potential toxicity of COPCs through bioaccumulation pathways as well as direct toxicity. In general, the most significant risks from soil-bound chemicals pertain to the worm predators such as shrews and woodcocks. Of terrestrial wildlife, worm-eating wildlife are generally the most exposed to soil-bound chemicals (Efroymonson et al., 1997; USEPA Region V, 2000; USEPA, 2003) for several reasons. First, the soil-to-worm pathway is, compared to soil to plant bioaccumulation, generally more efficient. Second, shrews and small worm-eating birds face high exposure due to their high rates of food consumption per unit biomass. Third, worm predators tend to have high rates of incidental soil ingestion. Exceptions to this general rule occur for compounds such as PCBs that biomagnify in terrestrial food chains. In these cases, predators at the top of food chains can be most exposed to soil-bound compounds.[4] Consequently, it is generally sufficient to consider these two ecological guilds – the top predators and the worm predators – in assessing potential for bioaccumulation risks from soil bound chemicals. In this SLERA, worm eating wildlife will be represented by shrews and woodcocks. Red tailed hawks and foxes will represent the top predators.

For COPCs in aquatic system, risks from bioaccumulation can generally be assessed by considering fish-eating wildlife and predators of aquatic benthos. In this SLERA, fish-eating wildlife will be represented by great blue herons and mink. Bats and swallows, which may feed on aquatic insects emerging from on-site sediments, will represent consumers of aquatic benthos.

To be conservative, the potential food chain exposure to COPCs was modeled using worst-case assumptions. That is, these receptors were assumed to eat only contaminated food from the Property for their entire lives. Thus, shrews and woodcocks were assumed to eat only worms from the Property, and the aerial insectivores were assumed to eat only aquatic insects emerging from the Property's aquatic environments. The total exposure for each species was modeled as

[4] In reality, risks from biomagnifying chemicals to top predators will generally be minimized by their large foraging ranges compared to the size of most contaminated sites. Consequently, the predators of soil invertebrates are often most exposed to PCBs and other biomagnifying chemicals as well as the metals and non-biomagnifying organics.

Total Dose = [food] * consumption rate * absorption efficiency + [soil] * incidental soil consumption rate * absorption efficiency + [water] * drinking rate * absorption efficiency + [air] * inhalation * absorption efficiency + [soil] * dermal absorption rate + [airborne dust] * dust inhalation * absorption efficiency.

All bracketed terms (e.g., [water]) refer to the concentration of the chemical in that medium; other values are self-explanatory. Based on the conservative methodology recommended by the USEPA (1997), absorption efficiency was assumed to be 100 percent for all pathways. On the other hand, the last three terms (exposure via air, dermal absorption, and airborne dust) can be assumed to be insignificant. Consequently, the equation collapses to:

Total Dose = [food] * consumption rate + [soil] * incidental soil consumption rate + drinking rate * [water].

Species-specific ingestion rates were taken from data supplied in USEPA (1993a) or other sources (e.g., Baron et al., 1999), when available. If specific ingestion rates were not available, rates were estimated from consumption-body mass (allometric) models as per USEPA (1993a). Body weights and ingestion rates used for the ERA's measurement receptors were based on the adult breeding female and are as presented in Table 4.5.

4.3.1 SOURCES OF TOXICITY REFERENCE VALUES (TRV)

Once exposure is estimated with the food chain models described above, the estimated exposure is then compared to a toxicity reference value (TRV). As recommended by USEPA (1997), TRVs used in the SLERA are NOAELs (no observed adverse effects levels). These are doses of a chemical shown to have no ecological effects on an organism. When the estimated exposure is divided by the TRV, it produces an SQ. As before, SQs below 1.0 indicate that that chemical is unlikely to cause impacts. SQ values above 1.0 indicate that the potential for risk cannot be dismissed with the current analysis and data. In general, TRVs were taken from Sample et al. (1996), a widely used source. Other sources were employed when no values were available from Sample et al. The TRVs and their sources are listed in Table 4.6 These TRV values were employed without modification for body size or metabolic rate.

4.3.2 ESTIMATION OF COPC CONCENTRATIONS IN PREY

The following sections present estimated COPC concentrations in prey, including worms, small rodents, aquatic benthos and adult aquatic insects, and fish.

4.3.2.1 ESTIMATION OF COPC CONCENTRATIONS IN WORMS

Onsite soils have elevated concentrations of a number of COPCs some of which will also bioaccumulate in soil invertebrates (e.g., worms) and potentially pose risk to their predators. Potential food chain exposure was modeled based on Oak Ridge National Laboratory (ORNL) models for earthworm bioaccumulation (Sample et al. 1998)[5]. This is a conservative assumption because earthworms tend to have higher bioaccumulation rates of soil chemicals than other soil macrobiota. Worm bioaccumulation was based on the regressions of the entire datasets (Table 12 of Sample et al. 1998) except for mercury, where the regression from the original dataset was employed (Table A-21). The latter exception produced higher (i.e., more conservative) estimates of mercury in worms. ORNL models predict dry-weight concentrations in worms. These were converted to wet-weight worm concentrations by dividing by 6.25, based on the USEPA (1993) data that worms are 84-percent water[6]. The final estimated concentrations are presented in Table 4.7.

Bioaccumulation of PAHs by worms was based on empirical data produced by a number of authors. On average, the empirical data suggest that worms have about 10% of the PAHs as the soil that they inhabit. (see Appendix A). No information on worm bioaccumulation of phthalates was located. However, like the PAHs, phthalates are readily metabolized by a number of taxa (Staple et al. 1997; Mackintosh et al. 2004). Thus, the worm bioaccumulation of phthalates was assumed to be similar to that observed with PAHs.

4.3.2.2 ESTIMATION OF COPC CONCENTRATIONS IN SMALL RODENTS

Once bioaccumulated by rodents and other small prey, COPCs in Property soils could impact top predators feeding in these areas. In general, bioaccumulation by small vertebrate prey of the soil COPCs was estimated with ORNL regression models (from Table 8 of Sample et al. (1998), which relate dry weight soil concentrations to dry-weight concentrations in small rodents. These values were applied to the soil COPCs (Table 4.7) and converted to wet-weight rodent concentrations with the assumption that they are 75% water.

There are no ORNL bioaccumulation models for estimating PAHs and phthalate concentrations in small rodent prey. However, both groups of compounds are readily metabolized by vertebrates. For example, data provided by Broman et al. (1990) indicate that PAH concentrations in eider ducks are about 1/10th the PAH concentrations in their food. Similarly, fish tend to have about 1/10 or less the PAH concentrations as their

[5] The ORNL models are based on studies in which the worms were allowed to void their gut contents; thus, the estimated concentrations pertain to worm tissue alone. Potential exposure to soil in the worm's gut is considered with the consumption of incidental soil ingestion. See Section 4.3.
[6] If the worm is 84-percent water, the dry-weight mass is 16 percent of the total. Total wet weight is therefore 100 percent/16 percent, or 6.25 times dry weight.

prey (Thomann and Komlos 1999). Phthalates are also readily metabolized by vertebrates (e.g., see ATSDR 2002). Thus, the concentrations of PAHs and phthalates were assumed to be 1/10th those found in worms.

4.3.2.3 COPC CONCENTRATIONS IN AQUATIC BENTHOS/ADULT AQUATIC INSECTS

Concentrations of metal COPCs in aquatic insects were predicted from regression models produced by ORNL (Bechtel Jacobs 1998a). Models based on all data (depurated and non-depurated) from Table 3 of the ORNL reference were used to predict metals concentrations. The ORNL models predict dry-weight concentrations. These were converted to wet-weight benthos concentrations by assuming that benthos were 75-percent water (Table 4.8).

PAH, PCB, and endrin concentrations in aquatic benthos were predicted from empirical results of Tracey and Hansen (1995). Tracey and Hansen present empirical biota-to-sediment accumulation factors (BSAF) values normalized to organic carbon (OC) in the sediments and lipid in the benthos. Median BSAFs for PAHs, PCBs, and pesticides were 0.29, 1.1, and 1.8, all on a gram lipid per gram OC basis. Unfortunately, organic carbon was not measured in on-site sediments. However, a relatively low value of 2 percent organic carbon would be a reasonable, somewhat conservative assumption for the on-site sediments. Aquatic invertebrates have lipid levels of about 2.0 percent (Oliver and Niimi 1988). In this case, the lipid and organic carbon concentrations cancel each other, and the final BSAFs for PAHs, PCBs, and endrin would be 0.29, 1.1, and 1.8. Little information could be found on the bioaccumulation of the phthalates.

4.3.2.4 ESTIMATION OF COPC CONCENTRATIONS IN FISH

No COPCs were retained for surface water sampling. Accordingly, the only pathway of exposure to fish-eating wildlife from sediment COPCs will be from sediments to benthos to fish bioaccumulation pathway. This two-step bioaccumulation process will limit exposure to most of the sediment COPCs. Most of the sediment COPCs, notably the PAHs and phthalates, are readily metabolized by vertebrates and some invertebrates and, thus, generally become less concentrated in upper levels of food chains (MacIntosh et al. 2004; Thomann and Komlos 1999). Of the sediment COPCs, only mercury, PCB, and possibly endrin have the potential to biomagnify in food chains (i.e., increase in concentration with passage up the food chain). Consequently, only mercury, PCBs, and endrin were considered as a potential risk to piscivores.

According to estimates in the previous sections, benthic prey should have maximum and mean concentrations of 0.055 and 0.03 mg/kg of total mercury. According to U.S. USEPA (1993b), mercury concentrations increase by about 128 percent between trophic level 2 and trophic level 3. Applying this food chain multiplier to the predicted benthos concentrations suggests maximum and mean benthos-eating fish concentrations of 0.070

and 0.04 mg/kg. As most of the mercury in fish is methyl, the mercury will be assumed to be 100 percent methyl mercury.

Concentrations of endrin and PCBs in fish were estimated with empirical BSAF estimated by Tracey and Hansen (1995). As noted above, they determined the median BSAF values, for fish consuming benthic invertebrates, to be about 1.1 for PCBs and 1.8 for pesticides. Both values are normalized to body lipids and sediment organic carbon. Warm water forage fish should have lipid levels of about 6 percent or less (USEPA 1995). Based on the previous assumption that sediments will average about 2 percent organic carbon, these parameters produce BSAF values of 3.3 for PCBs and 5.4 for endrin.

These methods will produce conservative estimates of fish concentrations at the Property. The high concentration of mercury occurs at SW-06, which is at the upper end of Site Creek. The highest PCB concentration also occurred at the upper end of Site Creek, at SW-07 (Figure 1.4). According to the topographic map, Site Creek is an intermittent stream. These sediment areas may be dry or very shallow water much of the year, which would represent obviously limited fish habitat. Samples taken immediately upstream (SW-07) and downstream (SW-1) on Site Creek had considerably lower concentrations of mercury: 0.27 mg/kg and 0.12 mg/kg, respectively. Of potentially impacted aquatic habitat in the area, the primary fish habitat is in Joachim Creek. Mercury and PCB concentrations in sediment samples taken in Joachim Creek contiguous to the Property were all less than detection.

4.3.3 RESULTS OF SCREENING OF BIOACCUMULATIVE COPCS WITH FOOD CHAIN MODELS

The results of the food chain models are presented in Table 4.9 through 4.12. The estimated risks to top predators, in both terrestrial and aquatic systems, were negligible for all COPCs even when exposure was estimated with the maximum concentration (Tables 4.11 and 4.12.) Thus, risks to top terrestrial predators and fish-eating wildlife from all COPCs can be dismissed an unlikely.

In contrast, when exposure to worm-eating wildlife is based on the maximum soil concentration, SQ values for several of the metals and the SVOCs exceeded 1.0 (Table 4.9). However, none of these SQs exceeded 10 for any COPC and when exposure was estimated with the mean soil concentration no COPC produced an SQ value greater than 1.0. A similar result was obtained with the bats and the swallows (Table 4.10). Some of the SVOC had maximum SQ values greater than 1.0. As with the worm-eating wildlife, SQs for predators of aquatic benthos all fell to less than 1.0 when exposure was estimated at the mean concentration. Because ecological risk pertains to average conditions, the nominal risk estimated with mean concentrations suggests that more refined analyses should be conducted. Therefore, a refined screening analysis will be conducted, in Section 5.0, for compounds with maximum SQs > 1.0.

4.4 SCREENING OF ECOLOGICAL RISK FROM RADIONUCLIDES

Potential ecological risks from radionuclides are screened with methods recently developed by the U.S. Department of Energy (DOE 2002). These methods were specifically developed for use at sites contaminated with nuclear fuel products, and are well described in the peer-reviewed literature (Domotor et al. 2003; Highley et al. 2003) and found acceptable by the USEPA (USEPA Region V 2004). As with ERA methodology, the first step in the DOE methodology is a screening analysis based on default, conservative assumptions and minimal site-specific data.

The DOE methods assume that ecological receptors will be adequately protected from the effects of ionizing radiation if the following maximal doses are not exceeded.

- **Aquatic Animals**. The absorbed dose to aquatic animals should not exceed 1 rad/d (10 mGy/d) from exposure to radiation or radioactive material releases into the aquatic environment.
- **Terrestrial Plants**. The absorbed dose to terrestrial plants should not exceed 1 rad/d (10 mGy/d) from exposure to radiation or radioactive material releases into the terrestrial environment.
- **Terrestrial Animals**. The absorbed dose to terrestrial animals should not exceed 0.1 rad/d (1 mGy/d) from exposure to radiation or radioactive material releases intothe terrestrial environment.

These dose limits are sufficiently low to prevent measurable impairment of reproductive capability on most sensitive species, which is the critical biological endpoint of concern for ecological receptors.

DOE estimated maximal safe concentrations for different radionuclides. As described in the DOE document, a safe or limiting concentration was estimated with the following equation

$$Limiting\ Concentration = \frac{Dose\ Rate\ Limit}{Internal\ Dose + External\ Dose_{soil\ /\ sed} + External\ Dose\ Rate_{water}}$$

In estimating the limiting concentration, the dose rate limit was set equal to the maximal allowable doses described above, e.g., 1 rad/d for aquatic organisms and terrestrial plants, or 0.1 rad/d for riparian and terrestrial animals. The limiting concentration, called the BCG (biota concentration guide), was then calculated as the medium concentration necessary to produce the dose rate limit based on both the internal dose and external doses. The internal dose is the internal exposure for radionuclides ingested in foods or potentially bioaccumulated from the water. It is calculated as the internal concentration and an internal dose conversion factor. The external dose is the external exposure from soils, for terrestrial organisms, and from water column and sediments,

for aquatic organisms. This dose is the product of the external concentration and an external dose conversion factor. In total, the denominator represents the dose per unit media concentration.

As calculated above, the BCG is the concentration of a radionuclide in soil, sediment, or water above which dose limits for protection of populations of aquatic and terrestrial biota would be exceeded, for that medium and radionuclide alone. By extension, the BCGs are concentrations below which impacts to ecological receptors are not expected. The BCGs developed by DOE are based on the most sensitive potential receptor for which radionuclide toxicity data exist (for reproductive effects) for a given constituent. Therefore, the BCGs should be considered conservative indicators of risk to most sensitive species. These BCGs are also protective of less sensitive species. The receptors used to develop BCGs are a terrestrial animal, riparian animal, aquatic animal, and terrestrial plants. However, in reality, the BCGs are based on potential effects on vertebrates because of their greater sensitivity. In general, ionizing radiation is more toxic to vertebrates than to invertebrates and plants.

In intent and function, the BCGs are equivalent to ESVs for non-radionuclides. As with ESVs, risk is screened by dividing the observed concentration of a radionuclide to its respective BCG. However, different radionuclides have the same mode of toxicity, so the quotients for different radionuclides are summed. Because the BCG values pertain to only one medium (sediments or water or soil) and one radionuclide, the total risk from all radionuclides is obtained by summing the ratios of on-site concentrations to each BCG for all media relevant to the exposure scenario. The terrestrial animal, for example, faces exposure from radionuclides in soil, via bioaccumulation pathways in its prey and forage, and in its drinking water. Thus, total risk to the terrestrial animal is the sum of observed concentrations/BCG for soil and surface water. [7]

If the sum of all fractions is greater than 1.0, then the potential exposure to ionizing radiation could potentially exceed the safe limits described above. In this case, the site does not pass the screen, and more refined analyses are required to better define the risk. DOE (2002) recommends that both the average and maximum concentrations be screened against BCGs. However, the BCGs are all based on vertebrates, none of which are really sedentary like plant or some invertebrates. Thus, the average concentrations and average quotients are more applicable to screening ecological risks from radionuclides.

The results of the screening of radionuclide COPCs are presented in Tables 4.13 and 4.14. As can be seen from Table 4.13, there is no potential for risk to ecological receptors from radionuclides observed in surface water and sediments. In the absence of data for water or sediments, the DOE methods recommend that the missing data be estimated

[7] USDOE has not published BCGs for all of the radionuclides. Thus, risks from some radionuclides, notably neptunium-237, protactinium-234, and thorium-234 cannot now be estimated.

with the available data and conservative partitioning assumption. Thus, water column concentrations for Cesium-137 and Europium-155 were estimated based on observed water column concentrations. This assessment of no risk to aquatic biota occurs even when the maximum concentration is used to estimate exposure.

The Property fails the screening when maximum soil concentrations are used to screen radionuclide risks to terrestrial receptors (Table 4.14). This failure is due, almost entirely, to a single sample result: the technetium-99 concentration of 17,100 picocuries per gram (pCi/g) from sampling location EP-11. If the maximum quotients were instead estimated at the second highest technetium concentration, 3,420 pCi/g, the sum of quotients would decline to about 1.0. Total risk calculated at the average soil and water concentrations was well below 1.0 (Table 4.14). DOE guidance suggests that risk decisions can be based on the average concentrations; based on DOE guidance, potential risks from radionuclides in soil concentrations would be dismissed. However, guidance for ecological risk for non-radionuclides generally recommends that initial screening analyses be based on maximum concentrations. Thus, radionuclides in soil will be retained for more detailed analysis.

Potential risks of radionuclides in groundwater were assessed by replacing observed surface water concentrations with maximum and mean groundwater concentrations for those COPCs measured in groundwater. This had negligible effect on the sum of quotients estimated for terrestrial biota, less than 0.1 percent increase. When maximum groundwater concentrations were considered in the risk for aquatic biota, the sum of quotients at the maximum exposure increased about 50 percent to about 0.41, while the mean quotients increased by only 3 percent to 0.061. However, this assessment conservatively retained the observed sediment concentrations. If the sediment concentrations are estimated based on the partitioning method described above and the maximum and mean groundwater concentrations, the quotients and risk would have actually decreased. Thus, risks from radionuclides in Property groundwater can also be rejected as unlikely.

5.0 REFINEMENTS TO SCREENING ANALYSIS

The screening analyses presented in preceding sections are based on default risk assessment methods that are applicable to all sites and all data sets. In the following sections, these default methods are modified to account for site-specific conditions.

5.1 RESCREENING OF COMPOUNDS WITH MAXIMUM SQ VALUES > 1

Table 5.1 present the results of the initial screening in which SQ values greater than 1.0 were generated with the maximum concentration. SQ values estimated with mean concentrations are also provided for perspective. No SQ greater than 1.0 were produced for sediment COPCs in terms of risk to fish-eating wildlife and for soil COPCs in terms of risk to top predators. Therefore, screening results for these medium/ecological receptor combinations are not presented in this summary table. Table 5.1 represents the final list of COPCs and relevant exposure pathways retained after the initial screening.

As per EPA guidance, the initial screening of COPCs was based on very conservative assumptions. Exposures were estimated with the maximum concentrations measured in soil, water, sediments, and groundwater, and these exposures were compared to conservative ESVs and TRVs. These very conservative methods are used to minimize false negatives (i.e., instances where true risks are dismissed) and to be applicable to all sites. For example, screening with the maximum concentration is intended to be sufficiently conservative at all sites, even those with preliminary and limited data sets, i.e., 10 samples or less (Simon et al. 1998).

However, basing decisions on the maximum concentration is problematic for a number of reasons. First, ecological risks pertain to average conditions; maximum concentrations are, therefore, often overly conservative estimators of true risk. Second, use of the maximum concentration is wasteful. Multiple samples are taken at sites in order to better characterize the nature and extent of contamination, and much of this information is wasted when only the maximum is considered. Third, there are methodological problems with the maximum concentration. For example, the maximum concentration is unstable; it varies with sampling intensity, generally increasing with the number of samples taken. The maximum concentration is also often an outlier and, thus, not representative of site conditions or sometimes simply erroneous.

Lastly, screening risks with maximum concentrations is inefficient, i.e., compounds are retained simply due to the conservativeness of analysis. Subsequent retention and detailed consideration of trivial compounds unnecessarily complicates risk assessments and risk communication. Based on these problems, guidance recommends that COPCs that were retained based on default conservative assumptions should be reconsidered (USEPA 1997; 2005). Specifically, these COPCs should be rescreened with more likely

concentrations and less conservative benchmarks. This rescreening can help risk assessors and risk managers differentiate between COPCs retained entirely due to a high degree of conservativeness and those COPCs that have a realistic potential to cause ecological risk. The following rescreening will relax conservative default assumptions, such as use of most conservative ESVs and estimating exposure at the maximum concentrations. Instead of the maximum concentrations, COPCs will be rescreened with the 95% UCL values. In general, these UCL values were estimated with ProUCL methods.

5.1.1 RESCREENING OF COPCS IN SEDIMENTS/RISKS TO BENTHOS

In the initial screening of sediment COPC versus ESVs protective of aquatic benthos, SQ values greater than 1.0 were generated with the maximum and, in some cases, mean concentrations of several compounds (Table 5.1). However, the mean and maximum SQ values in Table 5.1 are based on TEC values. TEC are, intentionally, very conservative ESVs that are designed to screen sediments for lack of toxicity. Exceedances of TEC values does not necessarily imply that impacts to benthos are expected. PEC (Probable Effects Concentrations) values were calculated by Macdonald et al. (2000) from the same datasets as TEC values. According to those authors, the PEC values are concentrations "above which adverse effects are expected to occur more often than not." As a conservative compromise between the two values, the geometric mean of the TEC and PEC was suggested by MDNR as an alternative screening ESV for the TEC values.

Therefore, the 95% UCL and mean concentrations of COPCs retained after the initial screening were rescreened against the geomean of the PEC and TEC values. These values were also compared to the TEC and PEC values to provide additional information. As can be seen from Table 5.2, SQ values significantly greater than 1.0 for metals generally occur only with the most conservative scenario – the 95% UCL compared to the most conservative TEC values. Less conservative comparisons for metals COPCs produced quotients below 1.0 or just marginally above. This rescreening suggests that significant risks to benthos from metals are unlikely.

In contrast, SQ values for some of the PAHs were greater than 1.0 even under the least conservative scenario – comparison of mean concentrations to the less conservative PEC values. Consequently, risks to aquatic benthos, especially those due to PAHs, cannot be dismissed as unlikely based on current information. The potential risks from PAHs to benthos remain as risks that could potentially be considered in future steps of the ecological risk assessment process.

5.1.2 RESCREENING OF SURFACE WATER COPCS

In the initial screening of surface water, several metals were retained because their maximum concentrations exceeded water quality criteria (Table 5.1). However, all of

these exceedances except aluminum were due to a single sample, SW-01 (Table 5.3). Inspection of this sample suggests that it included a substantial amount of bottom sediments. Notably, this sample had highly elevated concentrations of aluminum and iron compared to the other surface water samples, and to water samples taken upstream (SW-03) and downstream (SW-02) of this sample (Figure 1.5, Figure 5.1). In general, aluminum and iron are fairly insoluble in surface water; consequently, their inclusion, at high concentrations, in surface water samples is indicative of suspended sediment. As can be seen in Figure 5.1, the concentrations of all of the insoluble heavy metals in SW-01 were dramatically higher than concentrations observed immediately upstream and downstream. This pattern contrasts with concentrations of relatively soluble metals (calcium, magnesium, potassium, and sodium), which would not be so affected by inclusion of bottom sediments. These more soluble metals were similar at all sampling stations.

Because adsorbed metals pose little to no toxicity, the results of SW-01 were omitted from the dataset, and the remaining surface water data were rescreened. When the results from the other samples are considered, only aluminum exceeds its ESV (Table 5.3). Only this compound could be considered potentially problematic. However, aluminum could also be dismissed as unlikely to cause ecological risk for the following reasons. First, aluminum concentrations in surface water are not elevated above background. Once SW-01 is eliminated, the average on-site concentration for aluminum, 0.26 milligrams/liter (mg/l), is essentially the same as the mean for background samples, 0.23 mg/l. Secondly, it should also be remembered that the surface water samples are total metals, whereas the aluminum criterion pertains to dissolved aluminum. Finally, the chronic criterion for aluminum is conservative. In its water quality criterion document, USEPA (2002) states that "USEPA is aware of field data indicating that many high quality waters in the U.S. contain more than 87 µg aluminum/L, when either total recoverable or dissolved is measured."

This rescreening suggests that compounds in surface water have minimal potential to pose ecological risk. It should be remembered that none of these metals, including aluminum, was elevated above background concentrations in surface water even when the results of SW-01 were included. They were retained as COPCs and screened against ESV because of concerns about the power of the statistical analysis.

5.1.3 RESCREENING OF GROUNDWATER COPCS

In the initial screening of groundwater, maximum concentrations of some COPCs, notably aluminum and some of the chlorinated solvents, had maximum SQ values ranging from about 40 to over 4,000 (Table 4.4). Several caveats allay concerns about these high SQ values. First, the exceedances for metals are based on unfiltered groundwater samples. Much of the metals in these groundwater samples are likely to be adsorbed to particles. Metals adsorbed to particles are both relatively immobile in groundwater and relatively non-toxic.

Second, the very high chlorinated solvent concentrations are generally found in wells located in the middle of the industrial (Central Tract) area, notably in wells BD-06, BD-02, BD-08, LF-09, and FD-07 (Table 5.4). Concentrations of these VOCs in wells closer to receiving streams are much lower. A notable exception to this generalization is the TCE concentration, 15,000 micrograms per liter (ug/l) in well NB-72, which is located about half the distance from the Facility to Joachim Creek (Figure 1.6, Table 5.4). However, this aberrant result is contradicted by wells immediately downgradient (SW-77 and SW-73). These wells have much lower concentrations of TCE (60 ug/l and 240 ug/l, respectively). Lastly, the groundwater concentrations were compared to surface water criteria without consideration of dilution or ongoing fate processes that would occur between the wells and the receiving surface water.

5.1.4 RESCREENING OF RADIONUCLIDES IN SOIL

When risks were initially screened with the maximum concentration of radionuclides in soil, the SQ was > 1.0. However, this exceedance was due to a single result for a single radionuclide, the technetium-99 concentration of 17,100 picocuries per gram (pCi/g) from sampling location, EP-11 (Table 4.14). If exposure is estimated at 749 pCi/g, the 95% UCL for technicium-99, the SQ value falls to about 0.6, even when maximum concentrations of other radionuclides are used in the analysis. This rescreening, therefore, indicates that the risks from radionuclides in soil can be dismissed as unlikely.

5.1.5 RESCREENING OF COPCS IN SOIL/RISKS TO WORM-EATERS

In the initial screening of risks to worm-eaters, a small number of compounds had SQ_{max} values greater than 1.0. These COPCs were rescreened with exposure concentrations estimated with the 95% UCL (Table 5.5). Based on these analyses, risks from soil COPCs to worm-eating wildlife can be dismissed as unlikely. The potential exception to this was risks from TCDD TEQ.

5.1.6 RESCREENING OF COPCS IN SEDIMENTS/RISKS TO AERIAL INSECTIVORES

A small number of sediment COPCs generated SQ values greater than 1.0 in the initial screening of potential risks to aerial insectivores feeding on aquatic insects emerging from on-site aquatic systems. These SQ values were based on the following conservative assumptions: estimation of insect concentrations based on the maximum sediment concentration, assumptions that bats and swallows were resident at the site 100% of the time and ate only aquatic insects, and comparison of estimated exposure to the NOAEL. All of these assumptions will exaggerate likely risks. The average concentration is a better estimate of likely exposure, bats and swallows take a mixture of aquatic and terrestrial insects, swallows will migrate south during the winter and both species will likely forage on and off the Site. Moreover, all of the mercury in aquatic insects was

assumed to be the more toxic methylmercury. However, the mercury in aquatic insects is generally less than 50% methylmercury (Murphy 2004); and the levels found in midges and mayflies at the bottom of the sediment food chains tends to average about 25% or less (Trembly et al. 1995; Grapentine and Milani 2002).

Only two of these conservative assumptions were relaxed in the rescreening. Exposure was estimated with the 95% UCL and the mercury in adult aquatic insects was assumed to be ½ methylmercury and ½ divalent mercury. These changes reduced all SQ values to about 1.0 or less (Table 5.6). There were slight exceedances of 1.0 for two compounds, but these SQ values still contain multiple conservative assumptions.

5.2. POTENTIAL RISKS FROM HOT SPOTS

The COPC selection procedure relied on the Wilcoxon-Rank Sum test, which is a default statistical method that is applicable to most sites. However, the Wilcoxon test is non-parametric test that is insensitive to small number of hot spots, i.e., sampling location with very high concentrations. Hot spots are operationally defined by Missouri as instances where the maximum concentration is 10 fold or greater than the mean concentration (MDNR 2005). In its comments, Missouri DNR expressed concerns about potential effects of these hot spots on ecological risk.

Several metals (arsenic, antimony, cobalt, lead) had hot spots but were not retained as COPCs because on-site concentrations were not statistically elevated above background (Table 5.7). In general, the existence of hot spots does not generally affect ecological risk. Ecological risk pertains to the population of animals; therefore, risk is more appropriately evaluated at the average concentration or a conservative estimate of the average concentration, such as the 95% UCL. This general rule may, however, not apply for cases in which the hot spot occurs in a prime foraging area or in critical habitat. It is useful, therefore, to determine where the hot spots for metals occur. As can be seen from Table 5.7, the number of hot spots is limited to a small number of locations for all of these metals. (The exception is mercury, which was statistically elevated above background and was considered quantitatively in the risk assessment.) The information in Table 5.7 also indicates whether two or more metals were found at one hot spot. Several of the hot spots for one metal were also hot spots for other metals. For example, several locations in the Evaporation Pond area were hot spots for several metals. This co-incidence suggests that these outlier concentrations are not due to some sort of analytical error. The Evaporation Pond is also a place where metals could be expected to occur in high concentrations. In contrast, the hot spots for lead and cobalt do not contain high levels of other chemicals. Moreover, while the hot spot locations are found in the Facility (Figure 1.3), these are not located in areas of known disposal. These factors suggest that the hot spots for lead and cobalt are potentially analytical or reporting errors.

Furthermore, inspection of Figure 1.3 and Table 5.7 suggests that concerns about hot spots are not warranted at this Property.. Hot spot locations for these metals are limited to samples taken within the Facility, itself. This area is not prime wildlife habitat or good foraging area. It should also be remembered that a large number of samples, about 80, were taken in and around the historical processing area itself, , a substantial portion of which is covered by impermeable surfaces (e.g., buildings, parking lots, walkways, etc). Thus, each hot spot represents a very small area of soil in areas of non-habitat, further reducing the potential risk to ecological receptors from these outlier concentrations.

5.3 RISK CHARACTERIZATION

Inspection of the summary table based on the preliminary screening and most conservative assumptions suggests the following conclusions with respect to non-radionuclides. First, there is no significant potential for risk to top predators, such as hawks and foxes, foraging in the Property's terrestrial habitat. Risks to fish-eating wildlife, such as herons and mink, can also be dismissed as unlikely.

In the initial screening, several surface water COPCs were above screening criteria. However, this single sample was apparently contaminated with bottom sediments, which are not likely to be toxic. Except for this dubious sample, risks to fish and water column invertebrates from COPCS in surface water can also be dismissed as unlikely.

Concentrations of some COPCs, especially VOCs, were well above screening levels in groundwater. However, this represents a very conservative comparison of groundwater to surface water ESVs. Groundwater samples with very high VOC concentrations tended to be far from surface water discharge points. Wells close to surface water discharge points tended to have VOC concentrations that were closer to the surface water ESVs. And these more moderate groundwater concentrations will be further reduced by fate and dilution processes before and after discharge to the surface waters. This potential attenuation is illustrated by the surface water samples taken from the site, which effectively incorporate these site-specific rates of fate and dilution processes. Therefore, the results of the surface water samples, which indicated no potential for risk from VOCs, should be given greater emphasis in assessing risks.

On the other hand, the surface water sampling is not extensive. The limited sampling of surface water may not be representative of all flow conditions and levels of groundwater recharge. In view of these limitations and the very high SQ values found for some COPCs in groundwater, it might be prudent to resample the surface water again for these groundwater COPCs that were retained in the screening. Additional sampling of surface water would allay remaining concerns about potential risks of groundwater recharge to surface water receptors.

Risks to aquatic benthos from COPCs in sediments could not be dismissed with available information. These risks, however, are limited to a small area. The elevated

PAH concentrations are limited to a small number of samples in the Site Creek and Site Pond (Table 5.8), only two of which exceeded the geomean ESV for total PAHs. These high PAH concentrations are probably from stormwater runoff from the Facility's parking lot. These PAHs may also have limited bioavailability. The PAHs in sediments are almost entirely high molecular weight PAHs (Table 5.8). This suggests that the PAH contamination is mostly bits of degraded asphalt from the parking lot, as opposed to motor or diesel fuel, both of which are primarily low and medium molecular weight PAHs. PAH contained in an asphalt complex are expected to have low bioavailability and toxicity (WHO 2004). Thus, these qualitative assessments suggest that potential ecological risks are likely to be small in both areal extent and severity. This uncertainty can also be resolved with further analyses. For example, further sampling of sediments could better delineate the area of high PAHs. Evaluation of organic carbon levels in sediments would also aid assessment of potential effects. Sediment bioassays and/or macroinvertebrate surveys of these areas would also be effective ways to address this uncertainty, if the potential risks are deemed significant enough to pursue in further risk assessment activities.

Although the screening assessment for worm eating birds and mammals yielded several max SQ values > 1.0 (Table 5.1), these maximum SQ values are based on the maximum concentration of 124 soil analyses. Ecological risk pertains to populations of animals, for which the 95% UCL and mean concentrations are more useful indicators of impacts on the population. The 95% UCL and mean SQ values for the worm-eaters are well below 1.0, even though the exposure analysis still retains conservative food chain assumptions (100 percent residence, 100 percent consumption of contaminated food, comparison to NOAELs). Thus, even though this screening analysis yielded some SQ values greater than 1.0, risks to worm eating wildlife can be dismissed as unlikely when average concentrations are considered.

Estimates of risks to predators of aquatic benthos (e.g., bats and swallows) is also biased high by use of the maximum concentration and conservative exposure assumptions used in the screening food chain models. When exposure was estimated with the mean concentrations, all SQ values suggest negligible risk, but some SQ values were slightly above 1.0 when exposure was based on the 95% UCL. Nonetheless, risks from sediment COPCs to bats and swallows can be dismissed when more realistic assumptions are made about the species home ranges and foraging habits. Thus, risks to predators of aquatic benthos can be dismissed as unlikely.

Ecological risks from radionuclides in surface water and sediments can be dismissed as unlikely, even when exposure is estimated with maximum concentrations. Similarly, potential ecological risks from radionuclides in groundwater can also be dismissed as unlikely. No exceedances of screening values occurred when the terrestrial and aquatic risk scenarios were rerun with maximum groundwater concentrations of radionuclides used in place of observed surface water values. On the other hand, radionuclide risks to terrestrial animals could not be dismissed when exposure was estimated at the

maximum concentrations in soil. However, even then, the SQ value was only moderate and was almost entirely due to an outlier concentration of one radionuclide. Risks from radionuclides to terrestrial animals could be dismissed when exposure was estimated at the mean soil concentrations. Use of the mean is considered potentially more appropriate for assessing risks to radionuclides (DOE 2002). In summary, then, risks to ecological receptors from radionuclides can be dismissed as unlikely.

6.0 UNCERTAINTY ANALYSIS

This SLERA follows the methodology recommended by USEPA (USEPA, 1997). Because the USEPA intent is to avoid underestimating risk, conservative methods were employed in the risk assessment. For example, toxicological benchmarks were based on most sensitive species, and exposure analyses were based on conservative assumptions such as the maximum concentrations. With respect to consumers of soil invertebrates (the shrew and woodcock), the exposure assessment assumes that consumers will eat only earthworms. This is a conservative assessment; earthworms are highly exposed soil invertebrates (i.e., they consume soil directly) and tend to have worst-case concentrations of soil contaminants. In addition, the food chain analyses assumed 100 percent absorption of COPCs from food and incidentally ingested soil, and 100 percent residency of species on the Property. Finally, risks were screened against conservative NOAEL values. All of these factors will tend to exaggerate risk.

On the other hand, no interspecies application factors were used to translate TRVs across species. This could underestimate risk because local species could be more sensitive than the most sensitive species found in the often-limited toxicological data. Concentrations of COPCs in prey were estimated with models or empirical data, which might have underestimated actual concentrations. Some of the radionuclides did not have BCG values, so their risks could not be estimated. All of these factors would underestimate the risk.

There is also some uncertainty about the background analysis for sediments. As described in Section 3.4, the background sediment samples were too limited, only two samples, to allow a statistically valid background analysis. Therefore, the background analysis for soils, for which background sampling was extensive, was extrapolated to sediments. The uncertainty associated with this procedure is unlikely to affect the risk assessment, since metals released by the site would likely be found in both soil and sediments. However, this uncertainty could be addressed by further sampling of sediments.

There are also some exposure pathways – such as dermal absorption and inhalation -- that were not considered in the wildlife exposure models. These exposure pathways are not generally considered in ecological risk assessments because they are assumed to pose insignificant risk[8] and because these exposure pathways are difficult to estimate (Ohio EPA 2003; USEPA 2004). However, the shallow groundwater at this site is contaminated with VOC. These chemicals might pose risk to burrowing animals. Although there are no accepted methods to quantify these risks to ecological receptors, the potential significance of inhalation exposure can be assessed as follows. The human

[8]For example, the literature was reviewed, and one case was located in which an ecological risk assessment considered inhalation risks (Spring et al. 2004). This analysis found no risk to burrowing mammals despite high concentrations of TCE and PCE, 5.5 to 77 mg/L, in underlying groundwater.

health risk assessment (IEM et al. 2007) considered inhalation risk to a variety of human receptors, including construction workers working outside at the site. The total HQ for inhalation of outdoor air contaminated with vapors from surficial groundwater was estimated to be about 0.05 (see page 30 of Appendix D of IEM et al. 2007), 1/20th of a problematic level. Almost all of this risk was due PCE and TCE.

These results cannot be directly extrapolated to burrowing animals because humans are accorded higher levels of protection than animals. Notably, RfDs used to estimate human health risk typically contain 100 to 1000-fold safety factors. In the case of TCE, the inhalation RfD is equal to an air concentration, 0.04 mg/m3 (USEPA 2001), which is 1/100th to 1/1000th air concentrations which cause ecologically significant effects on laboratory animals (ATSDR 1997). In total, then, the construction worker's inhalation exposure was estimated to be 1/2,000 to 20,000 times lower than ecologically problematic levels. On the other hand, inhalation exposure will be higher for a burrowing animal than a construction worker. The worker is only at the site about 1/4th of the time, and burrow concentrations of VOCs will be higher than those at the surface. However, the total effect of this additional exposure is expected to be considerably smaller than very large safety factor inherent in the RfD and the low HQ value[9]. Consequently, failure to consider inhalation risks from VOCs in surficial groundwater likely does not represent a significant data gap.

[9] For example, a resident animal's exposure duration will be about 4 times higher than that of the construction worker. The latter is assumed to be exposed to outside air about 26% of the year: 10 hours per day and 225 days per year. There are no accepted methods for estimating air concentrations in burrows. However, risks to burrowing animal would still be negligible if burrow concentrations were 10 to 100 times higher than those estimated at the surface.

7.0 SCIENCE-MANAGEMENT DECISION INPUT POINT

Even using very conservative exposure assumptions and maximum concentration, the following COPC /exposure pathways had SQ values below 1.0: effects of COPCS in surface water to surface water biota, effects of COPCS in surface water and sediments to fish-eating wildlife, effects of COPCs in soil to top predators, and effects of radionuclides in water and sediments to aquatic and semi-aquatic biota. These can be dismissed from future consideration because they are unlikely to pose risk to ecological receptors.

Under the most conservative assumptions, several COPCs/exposure pathway combinations did have SQ values greater than 1.0 (Table 5.1). However, further consideration of risks to worm-eating wildlife from COPCs in soil is not recommended. Although SQ values based on maximum soil concentrations were greater than 1.0, ecological risks to the worm eaters are unlikely because the SQ values at the 95% UCL were less than 1.0. Worm eaters are also mobile and the high soil concentrations are localized in a few hot spots. For the same reasons, further consideration of risks to terrestrial receptors from radionuclides is not warranted. Similarly, risks to aerial insectivores, such as bats and swallow, feeding on aquatic insects emerging from aquatic sediments can also be dismissed as unlikely.

Risks associated with several other COPCs/exposure pathways could not be dismissed with confidence based on current information. VOCs in groundwater likely do not cause ecological risk to surface water receptors, but this conclusion is limited by the small number of surface water samples. This uncertainty can be addressed with further sampling of surface water. Similarly, the risks of COPCs to benthic invertebrates could be addressed with further sediment sampling, sediment bioassays, or macroinvertebrate surveys, or some combination. With respect to these two remaining risks, it should be noted that ecologically significant risks are unlikely in each case. All of these pertain to small areas of potential impact.

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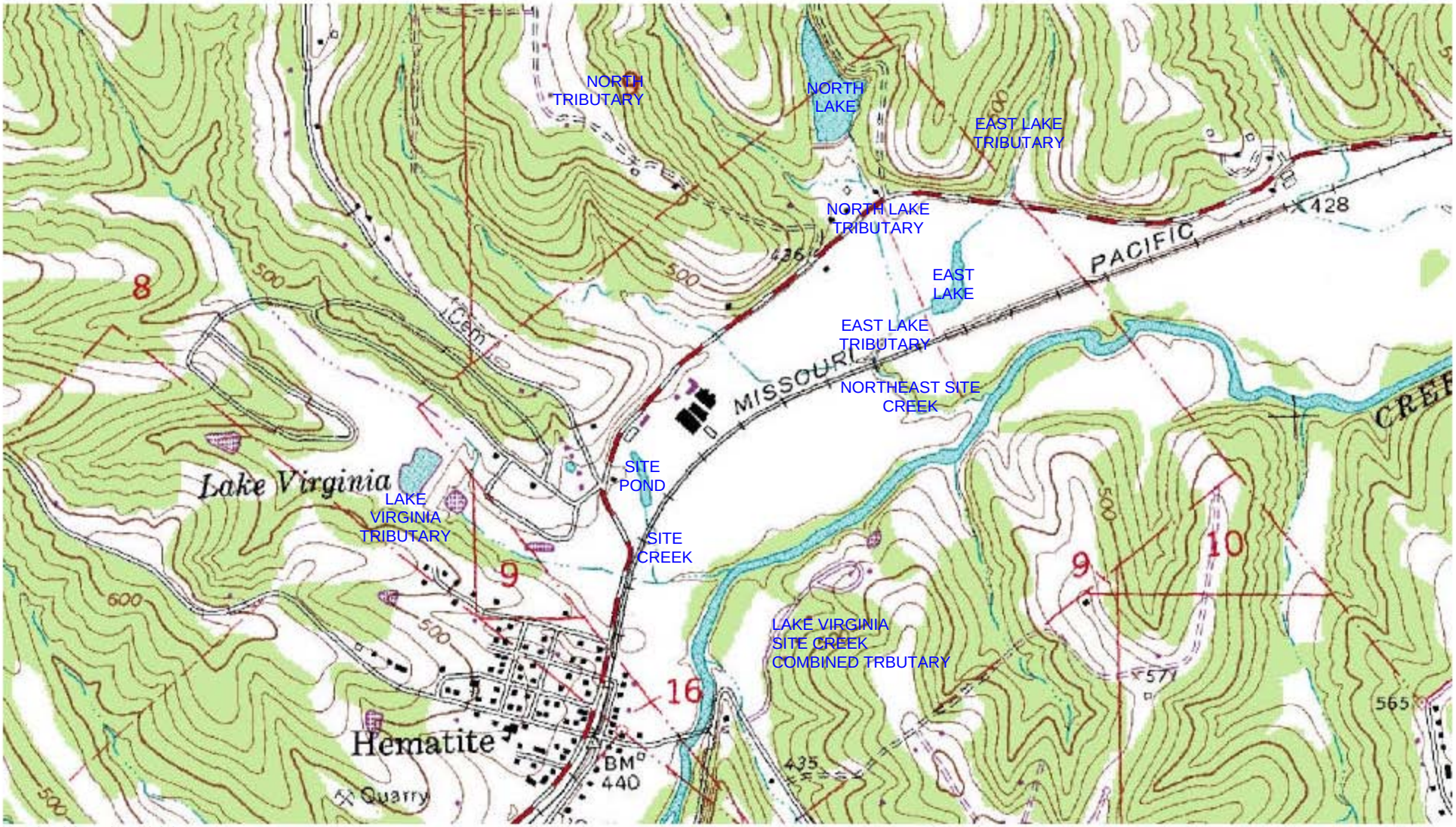
FIGURES



BASE SOURCE USGS MAP
FESTUS, MISSOURI 1964, REVISED 1982

LEGEND

PROPERTY BOUNDARY

figure 1.1

HEMATITE SITE MAP
WESTINGHOUSE FACILITY

0 600 1200ft

38008-00(SOURCE)GN-CO008 OCT 17/2005

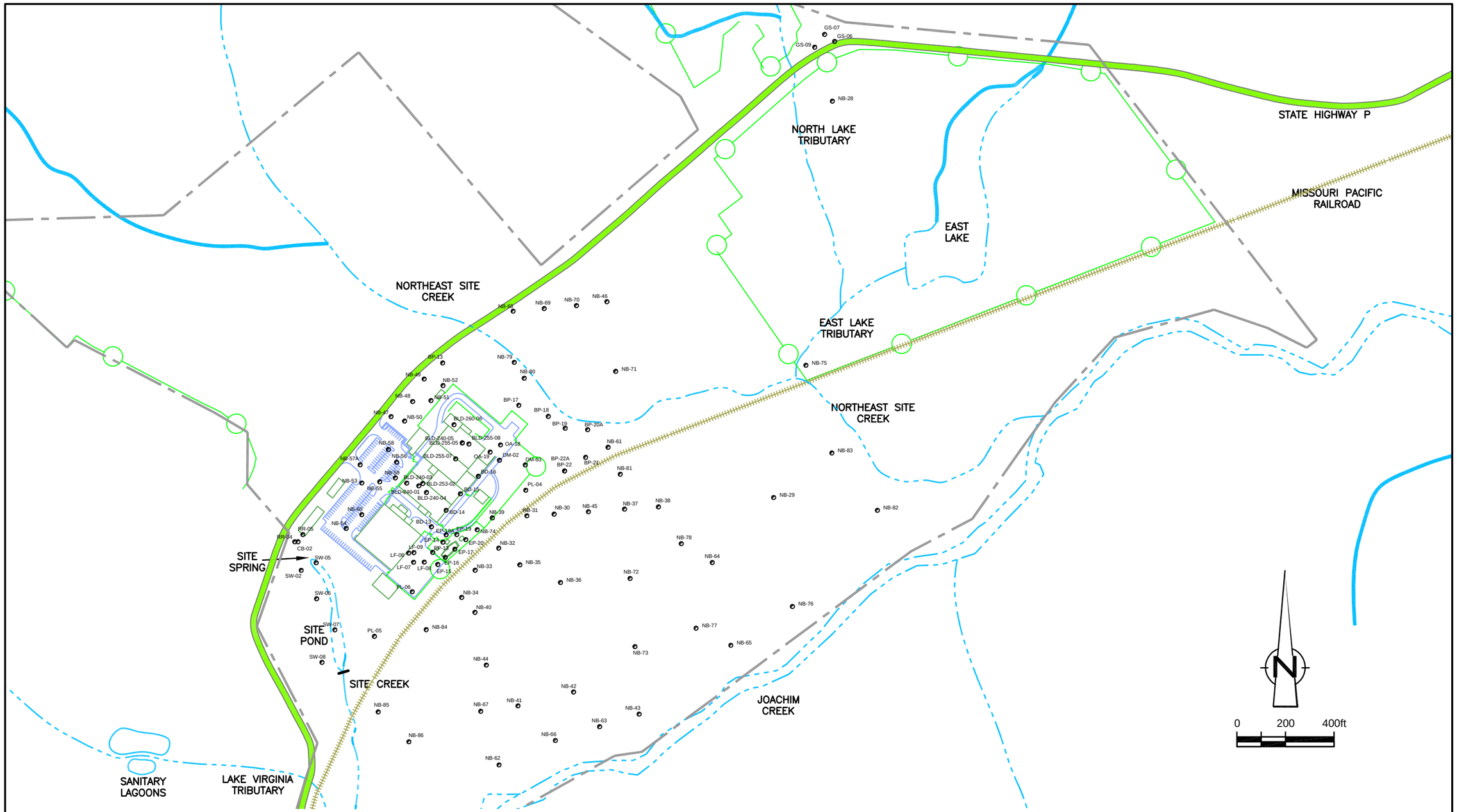


figure 1.2

SITE WIDE
SUBSURFACE SOIL LOCATIONS
WESTINGHOUSE ELECTRIC COMPANY
Hematite, Missouri

38008-00(SOURCE)GN-CO002 OCT 17/2005

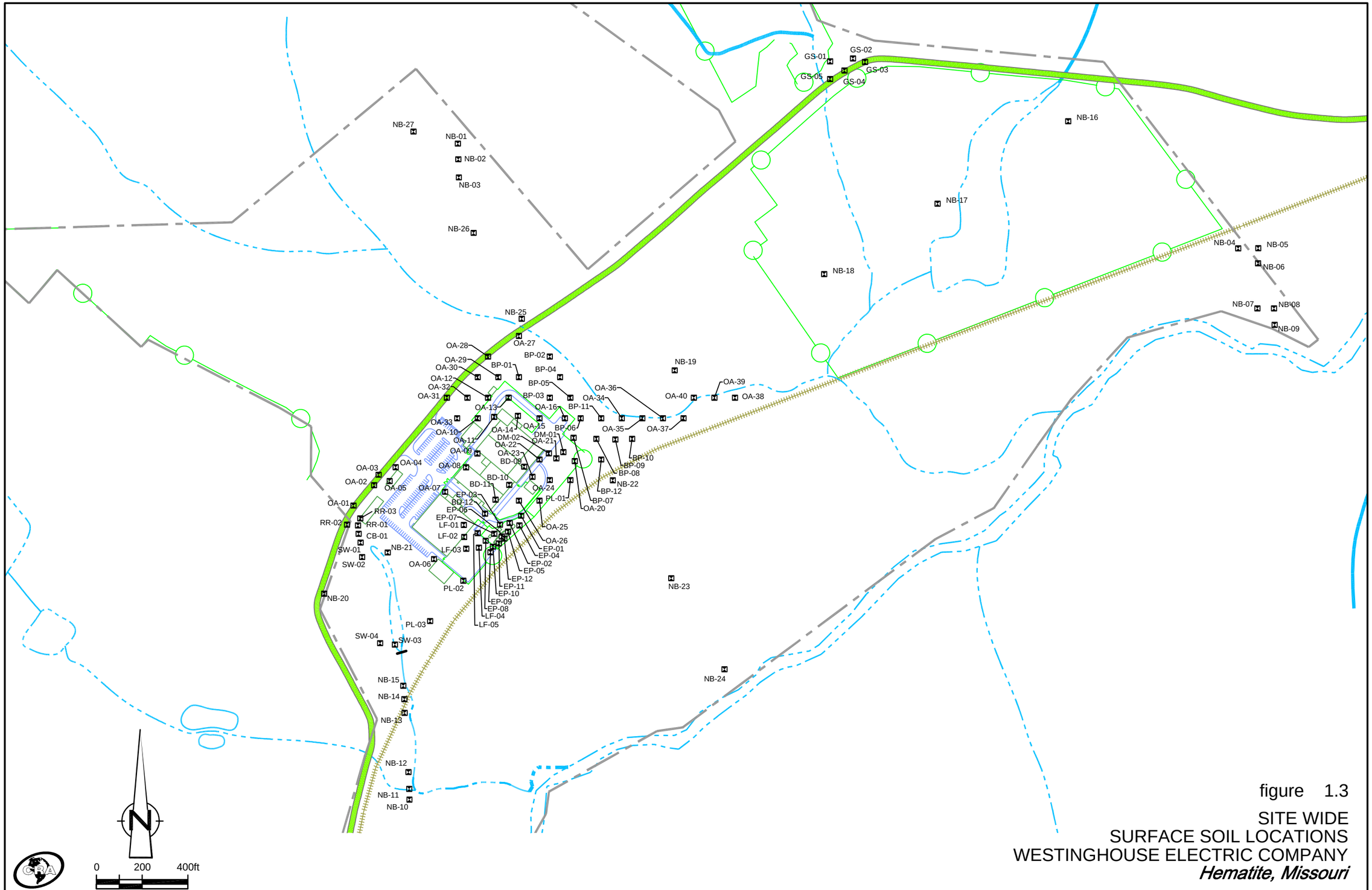


figure 1.3

SITE WIDE
SURFACE SOIL LOCATIONS
WESTINGHOUSE ELECTRIC COMPANY
Hematite, Missouri

38008-00(SOURCE)GN-CO003 OCT 17/2005

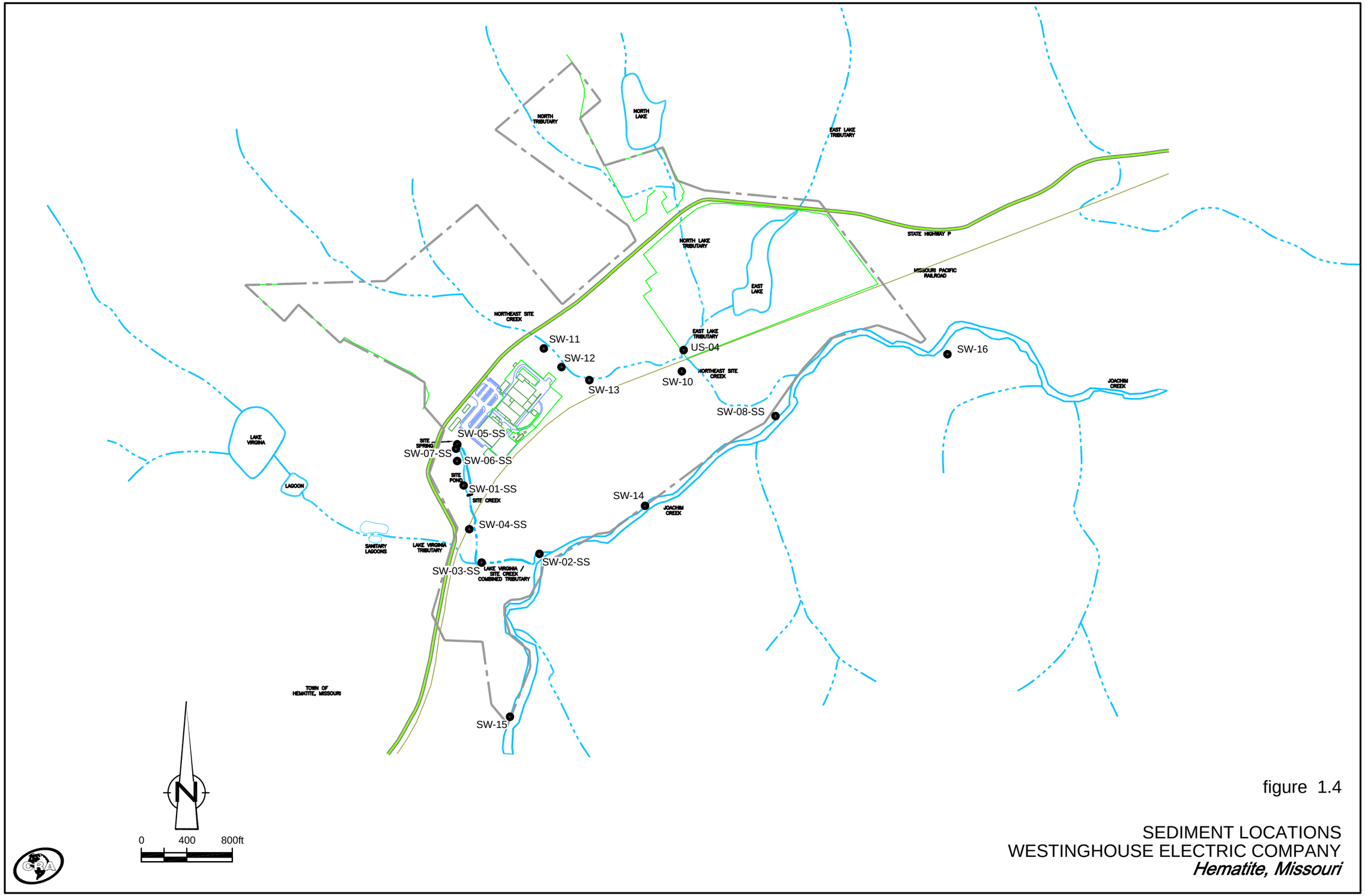


figure 1.4

SEDIMENT LOCATIONS
WESTINGHOUSE ELECTRIC COMPANY
Hematite, Missouri

38008-00(SOURCE)GN-CO004 OCT 17/2005

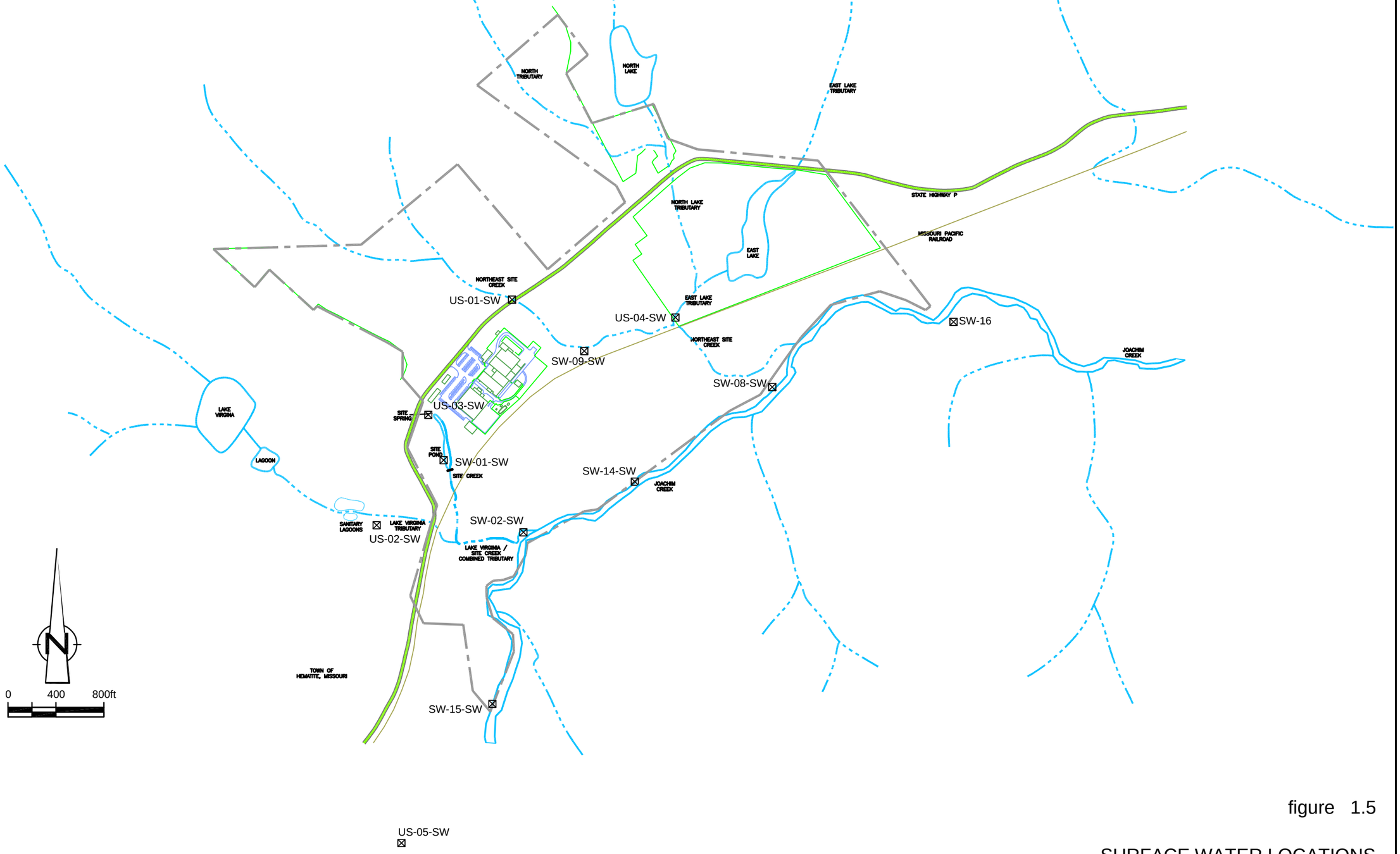


figure 1.5

SURFACE WATER LOCATIONS
WESTINGHOUSE ELECTRIC COMPANY
Hematite, Missouri

38008-00(SOURCE)GN-CO005 OCT 17/2005

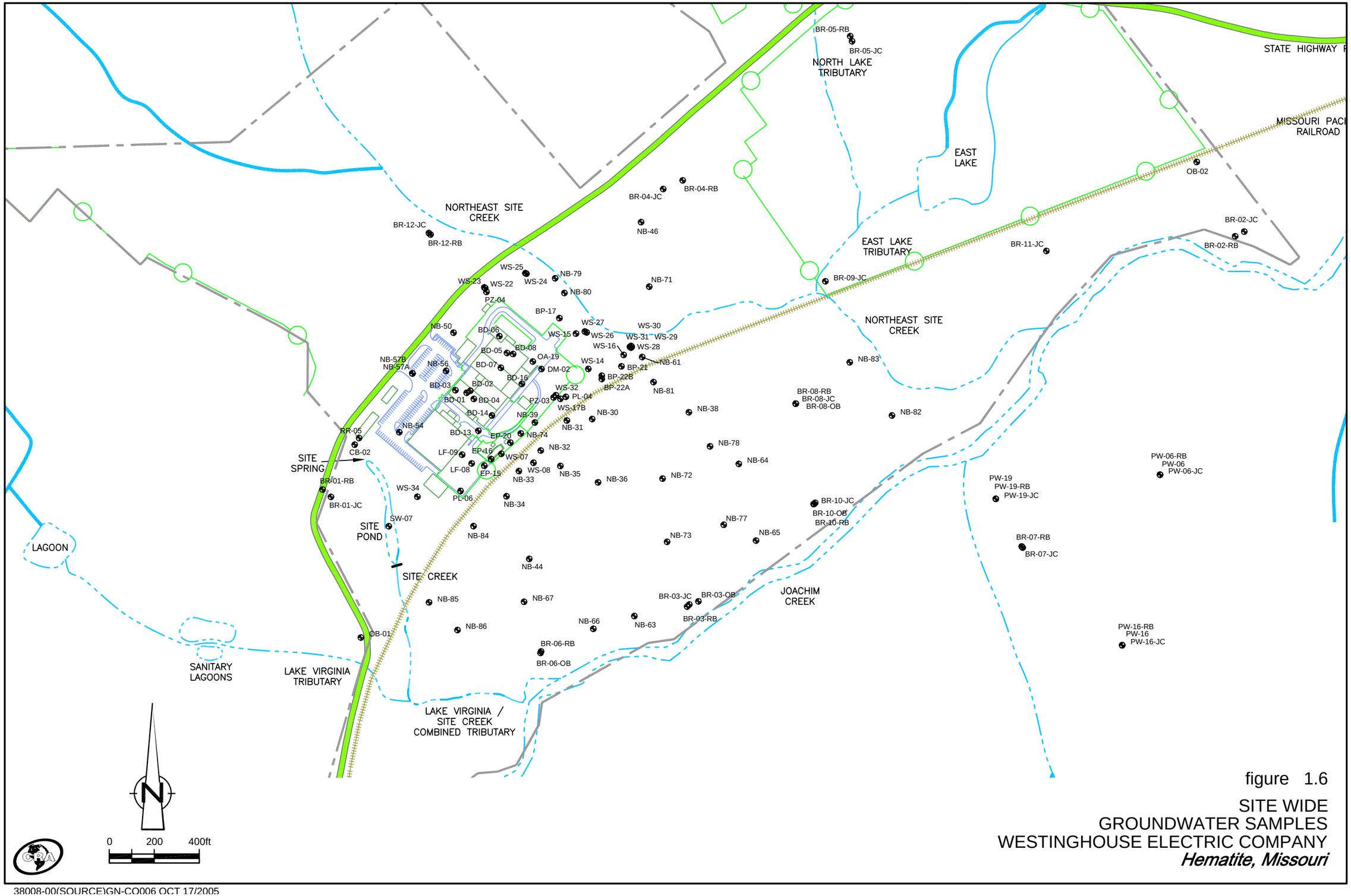


figure 1.6

SITE WIDE
GROUNDWATER SAMPLES
WESTINGHOUSE ELECTRIC COMPANY
Hematite, Missouri

38008-00(SOURCE)GN-CO006 OCT 17/2005

BASE SOURCE http://www.terraserver.microsoft.com/usgsentry.aspx?T=1&S=11&Z=15&X=1803&Y=10579&W=3&qs=%7cHematite%7cMo%7c

figure 3.1

HEMATITE PROPERTY HABITAT MAP
WESTINGHOUSE FACILITY

38008-00(SOURCE)GN-CO008 OCT 17/2005

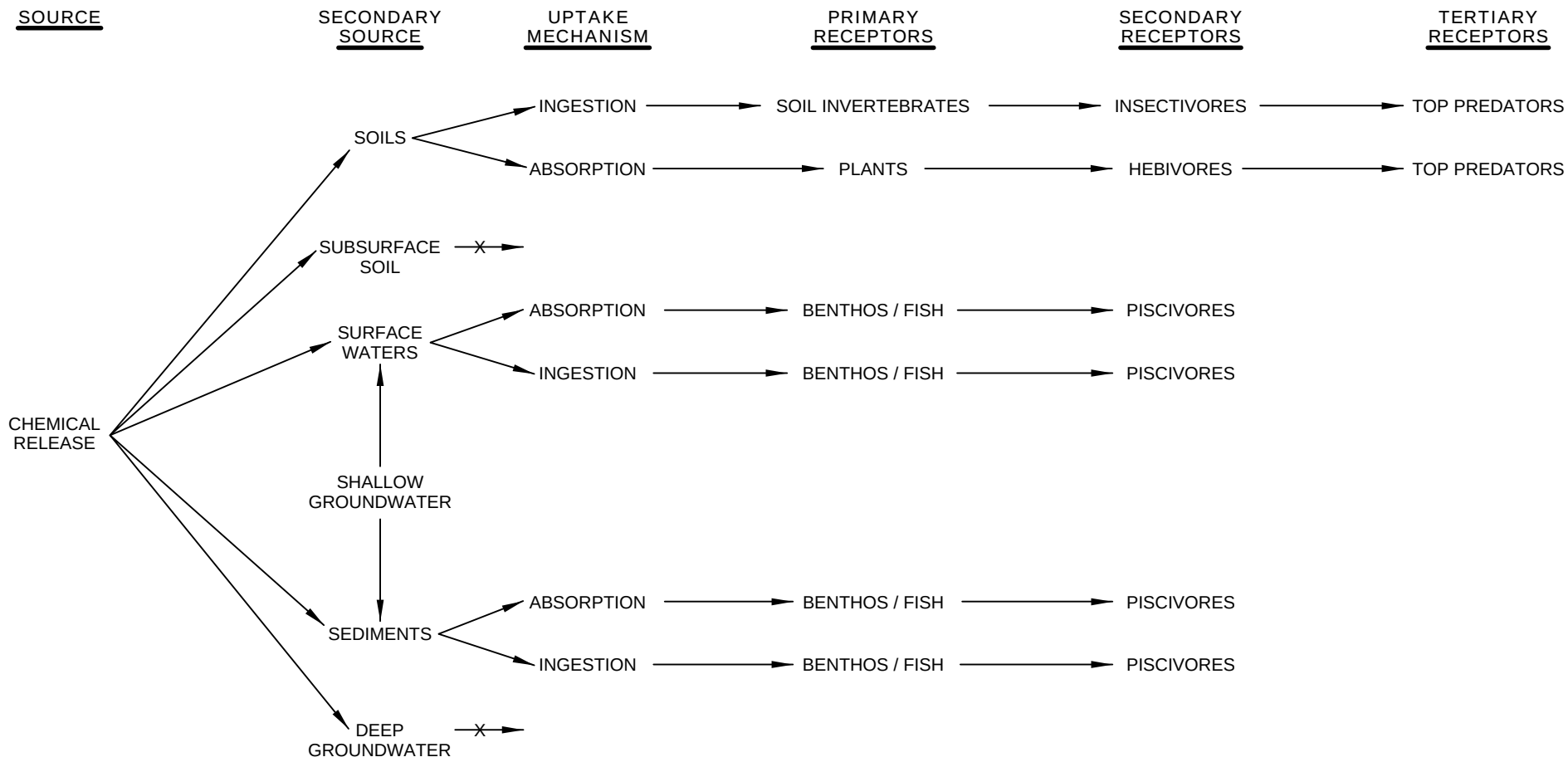


figure 3.2

LEGEND:

INCOMPLETE OR FUNCTIONALLY INCOMPLETE PATHWAY

SLERA CONCEPTUAL SITE MODEL
WESTINGHOUSE ELECTRIC COMPANY
Hematite, Missouri

38008-00(SOURCE)GN-CO007 JAN 23/2007

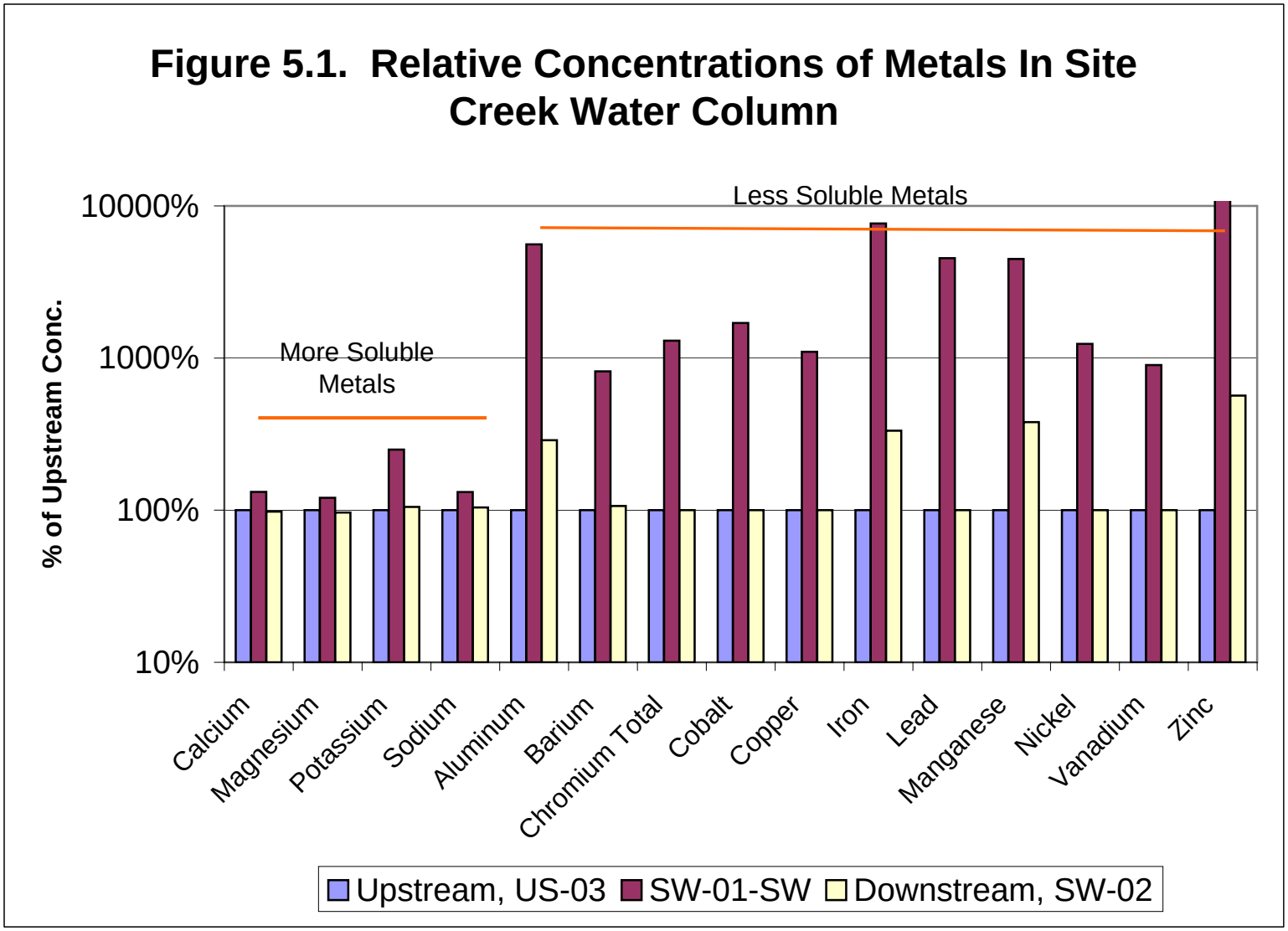


Figure 5.1. Relative Concentrations of Metals In Site Creek Water Column
% of Upstream Conc.
10000%
1000%
100%
10%
Less Soluble Metals
More Soluble Metals
Calcium
Magnesium
Potassium
Sodium
Aluminum
Barium
Chromium Total
Cobalt
Copper
Iron
Lead
Manganese
Nickel
Vanadium
Zinc
Upstream, US-03
SW-01-SW
Downstream, SW-02

TABLES

Table 3.1. Summary results for chemicals detected in on-site and background soil samples. Only compounds detected with on-site samples at frequency greater than 5% presented. "Prob.= background" is probability obstained with Wilcoxon-Rank Sum test. Note that value represented as mean concentration for TCDD TEQ is actually the maximum concentration with non-detects set to zero.

	On-Site					Background							
Parameter	Num. Of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean	Num. Of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean	Prob. = Background	COPC?	Reason for Rejection
Metals, mg/kg													
Aluminum	124	100%	24000.0	2000.0	8766.9	16	100%	17000.0	4500.0	9562.5	0.87	No	Not > Back
Antimony	124	24%	21.0	0.9	1.1	16	0%	N/A	N/A	0.5	0.59	No	Not > Back
Arsenic	124	100%	160.0	1.1	13.6	16	100%	9.6	5.1	7.1	0.54	No	Not > Back
Barium	124	100%	1500.0	24.0	182.8	16	100%	340.0	97.0	213.6	0.50	No	Not > Back
Beryllium	124	92%	5.8	0.4	0.7	16	94%	0.8	0.4	0.6	0.60	No	Not > Back
Cadmium	124	65%	11.0	0.2	0.7	16	50%	0.6	0.3	0.3	0.46	No	Not > Back
Calcium	124	100%	250000.0	860.0	41019.5	16	100%	14000.0	830.0	6220.6	**0.00**	**Yes**	
Chromium Total	124	100%	280.0	4.9	19.4	16	100%	17.0	8.0	12.2	**0.05**	**Yes**	
Cobalt	124	100%	300.0	0.9	10.3	16	100%	17.0	4.8	8.6	0.79	No	Not > Back
Copper	124	100%	1800.0	5.6	36.3	16	100%	13.0	7.6	11.1	**0.00**	**Yes**	
Iron	124	100%	61000.0	1600.0	14226.6	16	100%	26000.0	9700.0	16543.8	0.47	No	Not > Back
Lead	124	100%	1400.0	3.7	90.0	16	100%	81.0	12.0	48.9	0.35	No	Not > Back
Magnesium	124	100%	53000.0	93.0	5758.9	16	100%	5600.0	1600.0	3106.3	0.34	No	Not > Back
Manganese	124	100%	4400.0	41.0	739.1	16	100%	1100.0	240.0	647.5	0.53	No	Not > Back
Mercury	124	81%	3.4	0.0	0.2	16	56%	0.0	0.0	0.0	**0.01**	**Yes**	
Nickel	124	100%	300.0	5.3	24.5	16	100%	14.0	7.4	11.7	**0.00**	**Yes**	
Potassium	124	100%	8000.0	380.0	1787.2	16	100%	1100.0	460.0	753.1	**0.00**	**Yes**	
Selenium	124	65%	4.1	0.6	0.8	16	63%	1.0	0.6	0.6	**0.06**	**Yes**	
Silver	124	7%	2.0	0.6	0.4	16	0%	N/A	N/A	0.3	0.36	No	Not > Back
Sodium	124	32%	3300.0	120.0	369.6	16	19%	210.0	180.0	89.1	0.43	No	Not > Back
Thallium	124	6%	2.2	1.0	0.6	16	0%	N/A	N/A	0.5	0.56	No	Not > Back
Vanadium	124	100%	45.0	5.4	23.8	16	100%	39.0	16.0	26.8	0.61	No	Not > Back
Zinc	124	100%	1500.0	19.0	153.9	16	100%	310.0	33.0	155.8	0.97	No	Not > Back
PCB/Pesticides, ug/kg													
Aroclor-1254 (PCB-1254)	124	12%	540.0	21.0	35.1	**0**					No Data	**Yes**	Assumed > back
Aroclor-1260 (PCB-1260)	124	22%	560.0	3.6	39.8	0					No Data	**Yes**	Assumed > back
Total PCBs	124	100%	850.0	0.0	74.9	0					No Data	**Yes**	Assumed > back
4,4'-DDT	124	10%	25.0	1.4	2.0	0					No Data	**Yes**	Assumed > back
Endosulfan II	124	6%	4.2	0.2	1.0	0					No Data	**Yes**	Assumed > back
Endrin	124	9%	21.0	0.3	1.4	0					No Data	**Yes**	Assumed > back
Dioxins/Furans, ng/kg													
TCDD TEQ	2	100%	5.5		0.1						No Data	**Yes**	Assumed > back
SVOC, ug/kg													
Acenaphthene	124	15%	380.0	12.0	186.8	0					No Data	**Yes**	Assumed > back
Anthracene	124	17%	1100.0	27.0	212.4	0					No Data	**Yes**	Assumed > back
Benzo(a)anthracene	124	69%	6400.0	16.0	337.8	0					No Data	**Yes**	Assumed > back
Benzo(a)pyrene	124	67%	6600.0	16.0	368.3	0					No Data	**Yes**	Assumed > back
Benzo(b)fluoranthene	124	73%	7800.0	20.0	505.5	0					No Data	**Yes**	Assumed > back
Benzo(k)fluoranthene	124	44%	3200.0	25.0	283.2	0					No Data	**Yes**	Assumed > back
bis(2-Ethylhexyl)phthalate	124	19%	4700.0	79.0	263.8	0					No Data	**Yes**	Assumed > back
Butyl benzylphthalate	124	8%	220.0	29.0	205.8	0					No Data	**Yes**	Assumed > back
Carbazole	124	18%	910.0	22.0	197.4	0					No Data	**Yes**	Assumed > back
Chrysene	124	67%	8100.0	18.0	407.2	0					No Data	**Yes**	Assumed > back
Di-n-butylphthalate	124	16%	4300.0	26.0	306.5	0					No Data	**Yes**	Assumed > back
Fluoranthene	124	78%	8800.0	16.0	489.0	0					No Data	**Yes**	Assumed > back
Fluorene	124	14%	530.0	19.0	193.4	0					No Data	**Yes**	Assumed > back
Indeno(1,2,3-cd)pyrene	124	40%	5800.0	29.0	386.7	0					No Data	**Yes**	Assumed > back
Naphthalene	124	10%	100.0	25.0	200.9	0					No Data	**Yes**	Assumed > back
Pyrene	124	58%	38000.0	39.0	1438.9	0					No Data	**Yes**	Assumed > back
VOC, ug/kg													
Methylene chloride	124	80%	8.1	1.1	3.1	16	38%	23.0	N/A	3.2		No	Lab Contaminant
Tetrachloroethene	124	8%	34.0	1.6	3.5	16	0%	N/A	1.3	3.0		**Yes**	Site Use

Table 3.2. Estimation of Dioxin TEQ in Soil (Sample CB-01) and Groundwater (CB-01).

			Soil Sample CB-01, ng/kg						Groundwater CB-01, pg/l		
					ND = 1/2 DL		ND = 0			ND = 1/2 DL	
Congener	TEF	BEF	Conc.	Conc.	TEQ	TEQ	TEQ	TEQ	Conc.	TEQ	
1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF)	0.0001	0.016	11 J	12 J	1.8E-05	1.9E-05	1.8E-05	1.9E-05	1.1 J	1.8E-06	1.8E-06
1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin (OCDD)	0.0001	0.012	4600	5600 J	5.5E-03	6.7E-03	5.5E-03	6.7E-03	4.7 J	5.6E-06	5.6E-06
1,2,3,4,6,7,8-Heptachlorodibenzofuran (HpCDF)	0.01	0.39	5 U	5 U	9.8E-03	9.8E-03	0.0	0.0	50 U	9.8E-02	0.0
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (HpCDD)	0.01	0.051	94	110 J	4.8E-02	5.6E-02	4.8E-02	5.6E-02	50 U	1.3E-02	0.0
1,2,3,4,7,8,9-Heptachlorodibenzofuran (HpCDF)	0.01	0.011	5 U	5 U	2.8E-04	2.8E-04	0.0	0.0	50 U	2.8E-03	0.0
1,2,3,4,7,8-Hexachlorodibenzofuran (HxCDF)	0.1	0.076	5 U	5 U	1.9E-02	1.9E-02	0.0	0.0	50 U	1.9E-01	0.0
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (HxCDD)	0.1	0.31	5 U	5 U	7.8E-02	7.8E-02	0.0	0.0	50 U	7.8E-01	0.0
1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF)	0.1	0.12	5 U	5 U	3.0E-02	3.0E-02	0.0	0.0	50 U	3.0E-01	0.0
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (HxCDD)	0.1	0.19	5 U	5 U	4.8E-02	4.8E-02	0.0	0.0	50 U	4.8E-01	0.0
1,2,3,7,8,9-Hexachlorodibenzofuran (HxCDF)	0.1	0.63	5 U	5 U	1.6E-01	1.6E-01	0.0	0.0	50 U	1.6E+00	0.0
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (HxCDD)	0.1	0.14	5 U	5 U	3.5E-02	3.5E-02	0.0	0.0	50 U	3.5E-01	0.0
1,2,3,7,8-Pentachlorodibenzofuran (PeCDF)	0.05	0.22	5 U	5 U	2.8E-02	2.8E-02	0.0	0.0	50 U	2.8E-01	0.0
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (PeCDD)	1	0.92	5 U	5 U	2.3E+00	2.3E+00	0.0	0.0	50 U	2.3E+01	0.0
2,3,4,6,7,8-Hexachlorodibenzofuran (HxCDF)	0.1	0.67	5 U	5 U	1.7E-01	1.7E-01	0.0	0.0	0.37 Q J	2.5E-02	2.5E-02
2,3,4,7,8-Pentachlorodibenzofuran (PeCDF)	0.5	1.6	5 U	5 U	2.0E+00	2.0E+00	0.0	0.0	50 U	2.0E+01	0.0
2,3,7,8-Tetrachlorodibenzofuran (TCDF)	0.1	0.8	0.81 J	0.7 J	6.5E-02	5.6E-02	6.5E-02	5.6E-02	10 U	4.0E-01	0.0
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)	1	1	1 U	1 U	5.0E-01	5.0E-01	0.0	0.0	10 U	5.0E+00	0.0
Total TEQ, includes BEF					5.5E+00	5.5E+00	1.2E-01	1.2E-01		5.2E+01	2.5E-02

Table 3.3. Summary results for chemicals detected in sediments. Only compounds detected for on-site samples at frequency greater than 5% presented. "Prob.= background" is probability obstained with Wilcoxon-Rank Sum test. Due to insufficient number of background sediment samples, background analysis based on results of soil samples.

	On-Site					Background							
Parameter	Num. Of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean	Num. Of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean	Prob. = Background	COPC?	Reason for Rejection
Metals, mg/kg													
Aluminum	16	100%	13,000.0	660.0	5291.3	2	100%	3000.0	2500.0	2750.0	0.87 Soil	No	Not > Back
Antimony	16	6%	1.9	1.9	0.7	2	0%	N/A	N/A	0.5	0.59 Soil	No	Not > Back
Arsenic	16	100%	11.0	2.2	5.6	2	100%	5.8	3.5	4.7	0.54 Soil	No	Not > Back
Barium	16	100%	940.0	33.0	166.1	2	100%	130.0	58.0	94.0	0.50 Soil	No	Not > Back
Beryllium	16	44%	1.3	0.4	0.4	2	0%	N/A	N/A	0.2	0.60 Soil	No	Not > Back
Cadmium	16	44%	3.2	0.4	0.5	2	0%	N/A	N/A	0.1	0.46 Soil	No	Not > Back
Calcium	16	100%	22,000.0	570.0	8591.9	2	100%	5700.0	2100.0	3900.0	**0.00 Soil**	**Yes**	
Chromium Total	16	100%	48.0	8.6	16.1	2	100%	7.6	7.2	7.4	**0.05 Soil**	**Yes**	
Cobalt	16	100%	25.0	2.1	7.8	2	100%	5.6	4.1	4.9	0.79 Soil	No	Not > Back
Copper	16	94%	110.0	1.4	23.0	2	100%	4.3	4.3	4.3	**0.00 Soil**	**Yes**	
Iron	16	100%	23,000.0	4400.0	12037.5	2	100%	10000.0	6200.0	8100.0	0.47 Soil	No	Not > Back
Lead	16	100%	130.0	9.8	46.6	2	100%	35.0	15.0	25.0	0.35 Soil	No	Not > Back
Magnesium	16	100%	7,200.0	360.0	3375.6	2	100%	3400.0	1300.0	2350.0	0.34 Soil	No	Not > Back
Manganese	16	100%	5,600.0	77.0	807.9	2	100%	550.0	340.0	445.0	0.53 Soil	No	Not > Back
Mercury	16	50%	1.1	0.0	0.1	2	0%	N/A	N/A	0.0	**0.01 Soil**	**Yes**	
Nickel	16	100%	48.0	2.9	14.6	2	100%	8.6	4.8	6.7	**0.00 Soil**	**Yes**	
Potassium	16	81%	1,200.0	180.0	579.4	2	100%	340.0	250.0	295.0	**0.00 Soil**	**Yes**	
Selenium	16	50%	2.6	0.7	0.8	3	290%	2.9	2.9	0.5	**0.06 Soil**	**Yes**	
Vanadium	16	100%	33.0	9.5	20.6	2	100%	16.0	11.0	13.5	0.61 Soil	No	Not > Back
Zinc	16	100%	410.0	36.0	126.5	2	100%	140.0	23.0	81.5	0.97 Soil	No	Not > Back
PCB/Pesticides, ug/.kg													
Aroclor-1260 (PCB-1260)	16	13%	59.0	14.0	27.5	2	0%	N/A	N/A	21.3	No Data	Yes	Assumed > back
Endrin	16	6%	2.9	2.9	1.4	2	0%	N/A	N/A	1.1	No Data	Yes	Assumed > back
SVOC, ug/kg													
Acenaphthene	16	13%	580.0	12.0	271.4	2	0%	N/A	N/A	210.0	No Data	Yes	Assumed > back
Anthracene	16	13%	2,400.0	55.0	387.8	2	0%	N/A	N/A	210.0	No Data	Yes	Assumed > back
Benzo(a)anthracene	16	56%	20,000.0	62.0	1445.1	2	50%	41.0	41.0	128.0	No Data	Yes	Assumed > back
Benzo(a)pyrene	16	56%	26,000.0	71.0	1849.9	2	50%	29.0	29.0	122.0	No Data	Yes	Assumed > back
Benzo(b)fluoranthene	16	56%	48,000.0	140.0	3350.9	2	50%	39.0	39.0	127.0	No Data	Yes	Assumed > back
Benzo(k)fluoranthene	16	56%	17,000.0	47.0	1236.8	2	0%	N/A	N/A	210.0	No Data	Yes	Assumed > back
bis(2-Ethylhexyl)phthalate	16	19%	3,600.0	170.0	450.0	2	0%	N/A	N/A	210.0	No Data	Yes	Assumed > back
Carbazole	16	19%	3,500.0	37.0	423.4	2	0%	N/A	N/A	210.0	No Data	yes	Assumed > back
Chrysene	16	56%	26,000.0	82.0	1875.5	2	50%	33.0	33.0	124.0	No Data	Yes	Assumed > back
Dibenz(a,h)anthracene	16	6%	4,700.0	4700.0	541.9	2	0%	N/A	N/A	210.0	No Data	Yes	Assumed > back
Di-n-butylphthalate	16	6%	2,100.0	2100.0	379.4	2	0%	N/A	N/A	210.0	No Data	Yes	Assumed > back
Fluoranthene	16	63%	37,000.0	19.0	2675.3	2	50%	86.0	86.0	150.5	No Data	Yes	Assumed > back
Fluorene	16	13%	970.0	20.0	296.3	2	0%	N/A	N/A	210.0	No Data	Yes	Assumed > back
Indeno(1,2,3-cd)pyrene	16	50%	17,000.0	55.0	1266.3	2	0%	N/A	N/A	210.0	No Data	Yes	Assumed > back
Naphthalene	16	6%	250.0	250.0	263.8	2	0%	N/A	N/A	210.0	No Data	Yes	Assumed > back
Pyrene	16	56%	100,000.0	130.0	6666.6	2	50%	66.0	66.0	140.5	No Data	Yes	Assumed > back
VOC, ug/kg													
2-Butanone (Methyl Ethyl Ketone)	16	6%	14.0	14.0	8.3	2	0%	N/A	N/A	6.3			
Acetone	16	63%	53.0	11.0	20.7	2	50%	18.0	18.0	12.0		No	Lab contaminant
cis-1,2-Dichloroethene	16	19%	28.0	2.6	5.6	2	0%	N/A	N/A	3.2		Yes	Site use
Methylene chloride	16	44%	9.4	1.2	5.1	2	100%	10.0	1.3	5.7		No	Lab contaminant
Tetrachloroethene	16	13%	7.3	4.4	4.3	2	0%	N/A	N/A	3.2		Yes	Site Use
Toluene	16	19%	20.0	5.0	5.3	2	50%	9.5	9.5	6.3		Yes	
trans-1,2-Dichloroethene	16	6%	7.2	7.2	4.2	2	0%	N/A	N/A	3.2		Yes	Site Use
Trichloroethene	16	19%	11.0	1.6	4.2	2	0%	N/A	N/A	3.2		Yes	Site Use
Vinyl chloride	16	6%	22.0	22.0	8.8	2	0%	N/A	N/A	6.3		Yes	Site Use

Table 3.4. Summary results for chemicals detected in surface water. Only compounds detected for on-site samples at frequency greater than 5% presented. "Prob.= background" is probability obstained with Wilcoxon-Rank Sum test. Note that for compounds with only 1 detected concentration (=13% Freq. of Detection), the maximum concentrations equals the mininum detected concentration.

	On-Site					Background							
Parameter	Number of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean Conc.	Number of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean	Prob. = Background	COPC?	Reason for Rejection
Metal, ug/L													
Aluminum	8	75%	19000.0	100.0	2602.5	5	80%	500.0	100.0	226.0	0.94	**Yes**	See Text
Arsenic	8	13%	11.0	11.0	5.8	5	0%			5.0	1.00	**Yes**	See Text
Barium	8	100%	630.0	69.0	172.4	5	100%	140.0	70.0	92.6	0.36	**Yes**	See Text
Calcium	8	100%	66000.0	45000.0	52125.0	5	100%	68000.0	45000.0	54800.0	0.59	**Yes**	See Text
Chromium Total	8	13%	26.0	26.0	5.0	5	0%			2.0	1.00	**Yes**	See Text
Cobalt	8	13%	17.0	17.0	3.0	5	0%			1.0	1.00	**Yes**	See Text
Copper	8	13%	55.0	55.0	11.3	5	0%			5.0	1.00	**Yes**	See Text
Iron	8	63%	23000.0	150.0	3098.8	5	80%	660.0	110.0	268.0	0.97	**Yes**	See Text
Lead	8	13%	68.0	68.0	9.8	5	0%			1.5	1.00	**Yes**	See Text
Magnesium	8	100%	40000.0	28000.0	31500.0	5	100%	43000.0	28000.0	33600.0	0.43	**Yes**	See Text
Manganese	8	100%	1300.0	15.0	203.6	5	100%	380.0	16.0	112.8	0.75	**Yes**	See Text
Nickel	8	13%	31.0	31.0	6.1	5	0%			0.1	1.00	**Yes**	See Text
Potassium	8	100%	5000.0	1400.0	2512.5	5	100%	3600.0	1600.0	2.5	0.69	**Yes**	See Text
Sodium	8	100%	11000.0	7600.0	9487.5	5	100%	26000.0	7300.0	5.0	0.56	**Yes**	See Text
Vanadium	8	13%	45.0	45.0	10.0	5	0%			5.0	1.00	**Yes**	See Text
Zinc	8	38%	350.0	12.0	49.3	5	0%			5.0	0.39	**Yes**	See Text
SVOC, ug/L													
Fluoranthene	8	13%	1.0	1.0	4.4	5	0%	N/A	N/A	4.8		**Yes**	See Text
VOC,ug/L													
cis-1,2-Dichloroethene	8	25%	4.4	0.7	2.5	5	0%	N/A	N/A	2.5		**Yes**	Site use
Methylene chloride	8	50%	2.6	1.1	2.3	5	80%	3.3	1.1	2.2		No	Lab Contaminant
Tetrachloroethene	8	38%	2.1	0.7	2.0	5	0%	N/A	N/A	2.5		**Yes**	Site use
Trichloroethene	8	25%	0.8	0.6	2.1	5	0%	N/A	N/A	2.5		**Yes**	Site use

Table 3.5. Summary results for chemicals detected in groundwater. Only compounds detected for on-site samples at frequency greater than 5% presented. "Prob.= background" is probability obstained with Wilcoxon-Rank Sum test. Note that mean concentrations of TCDD TEQ is actually the maximum concentration with non-detects set equal to zero.

	On-site					Background							
Parameter	Number of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean Conc.	Number of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean	Prob. = Background	COPC?	Reason for Rejection
Metals, ug/L													
Aluminum	75	56%	16000	110	982	14	29%	1100	150	183	**0.06**	**Yes**	
Barium	75	100%	1300	27	199	14	100%	390	100	191	0.56	No	Not > Back
Barium (Dissolved)	10	100%	350	68	196	1	100%	150	150	150	0.56 T	No	Not > Back
Calcium	75	100%	260000	6700	67897	14	100%	110000	19000	65143	0.66	No	Not > Back
Calcium (Dissolved)	10	100%	95000	25000	56600	1	100%	72000	72000	72000	0.66 T	No	Not > Back
Chromium Total	75	13%	37	6	4	14	0%			2	0.28	No	Not > Back
Cobalt	75	31%	42	2	3	14	14%	2	2	1	0.32	No	Not > Back
Cobalt (Dissolved)	10	40%	6	2	2	1	0%			1	0.32 T	No	Not > Back
Copper	75	7%	39	19	7	14	7%	20	20	6	0.71	No	Not > Back
Iron	75	80%	38000	110	6047	14	79%	34000	230	6411	0.59	No	Not > Back
Iron (Dissolved)	10	70%	20000	450	5690	1	0%			50	0.59 T	No	Not > Back
Lead	75	20%	59	3	5	14	21%	8	3	2	0.87	No	Not > Back
Magnesium	75	100%	130000	2200	30916	14	93%	59000	9000	30107	0.58	No	Not > Back
Magnesium (Dissolved)	10	100%	46000	10000	27500	1	100%	36000	36000	36000	0.58 T	No	Not > Back
Manganese	75	100%	13000	1	1400	14	93%	3300	60	1217	0.81	No	Not > Back
Manganese (Dissolved)	10	100%	3200	4	1450	1	100%	19	19	19	0.81 T	No	Not > Back
Nickel	75	61%	150	5	13	14	14%	31	7	5	**0.02**	**Yes**	
Nickel (Dissolved)	10	60%	48	6	12	1	0%			3	**0.02 T**	**Yes**	
Potassium	75	89%	69000	1000	3469	14	86%	2700	1000	1486	**0.14**	**Yes**	
Potassium (Dissolved)	10	70%	11000	1100	2600	1	100%	2200	2200	2200	**0.14 T**	**Yes**	
Selenium	75	11%	10	5	3	14	0%			3	0.36	No	Not > Back
Sodium	75	100%	190000	3700	22943	14	100%	24000	6700	13121	0.22	No	Not > Back
Sodium (Dissolved)	10	100%	31000	3600	13940	1	100%	18000	18000	18000	0.22 T	No	Not > Back
Vanadium	75	8%	44	18	7	14	0%			5	0.46	No	Not > Back
Zinc	75	73%	650	7	49	14	50%	210	7	26	**0.08**	**Yes**	
Zinc (Dissolved)	10	60%	20	9	9	1	0%			3	**0.08 T**	**Yes**	
Dioxins/Furans, ng/kg													
TCDD TEQ	1	100%	52.48		0.02	0						No	See Text
SVOC, ug/L													
bis(2-Ethylhexyl)phthalate	34	15%	26	4	6	6	50%	9	4	6	0.38	No	Not > Back
Phenol	34	6%	10	2	5	6	0%			5	0.68	No	Not > Back
VOC, ug/L													
1,1,1-Trichloroethane	76	12%	85	2	43	14	0%			3		**Yes**	Site Use
1,1,2-Trichloroethane	76	7%	8	1	41	14	0%			3		**Yes**	Site Use
1,1-Dichloroethane	76	57%	610	1	73	14	0%			3		**Yes**	Site Use
1,1-Dichloroethene	77	55%	5100	1	147	14	0%			3		**Yes**	Site Use
1,2-Dichloroethane	76	11%	9	1	41	14	0%			3		**Yes**	Site Use
Chloroform (Trichloromethane)	76	7%	7	1	41	14	0%			3		**Yes**	Assumed > Back
cis-1,2-Dichloroethene	76	71%	19000	1	560	14	0%			3		**Yes**	Site Use
Methylene chloride	76	14%	1600	3	66	14	21%	4	3	3	0.85	No	Lab Contaminant
Tetrachloroethene	77	75%	200000	1	3472	14	0%			3		**Yes**	Site Use
trans-1,2-Dichloroethene	76	20%	700	5	54	14	0%			3		**Yes**	Site Use
Trichloroethene	76	75%	18000	1	964	14	0%			3		**Yes**	Site Use
Vinyl chloride	76	21%	1000	2	98	14	0%			5		**Yes**	Site Use

Table 3.6. Summary results for radionuclides detected in surface and subsurface (as deep as 3 feet) soils. Only radionuclides predicted to occur on site or detected for on-site samples at frequency greater than 5% presented. Concentrations in pCi/g. "Prob.= background" is probability obtained with Wilcoxon-Rank Sum test.

	On-site					Background							
Parameter	Number of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean Conc.	Number of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean	Prob. = Background	COPC?	Reason for Rejection
Actinium-228	157	61%	36.40	0.59	1.13	32	72%	1.83	0.68	0.83	0.22	**Yes**	Daughter
Bismuth-212	158	8%	41.60	1.36	0.67	32	9%	2.62	2.05	0.21	0.85	**Yes**	Daughter
Bismuth-214	159	81%	1.71	0.37	0.72	32	97%	1.15	0.53	0.81	0.73	No	Not > Back
Cesium-137	159	34%	1.79	0.12	0.12	32	9%	0.16	0.07	0.01	**0.00**	**Yes**	> Back
Lead-212	157	84%	41.20	0.18	1.33	32	100%	1.70	0.58	1.04	**0.14**	**Yes**	> Back, Daughter
Lead-214	159	89%	1.97	0.38	0.85	32	100%	1.21	0.58	0.90	0.79	No	Not > Back
Neptunium-237 (method 713R)	159	11%	2610.00	12.70	48.50	32	0%	N/A	N/A	0.00	**0.05**	**Yes**	> Back
Neptunium-237 (method 7134)	30	17%	0.04	0.01	0.00	32	6%	0.01	0.01	0.00	**0.18**	**Yes**	> Back
Plutonium 239/240	37	24%	0.03	0.003	0.003	31	6%	0.02	0.02	0.001	**0.06**	**Yes**	> Back
Potassium-40	157	88%	23.70	2.20	12.68	32	100%	16.50	8.13	12.65	**0.10**	No	Back > On-Site
Protactinium-234	157	13%	2200.00	30.50	49.67	32	0%	N/A	N/A	0.00	**0.03**	**Yes**	> Back, Daughter
Technetium-99	134	54%	17100.00	0.90	188.52	0						**Yes**	Site use
Thallium-208	157	65%	12.10	0.13	0.38	32	88%	0.59	0.16	0.31	**0.05**	**Yes**	> Back, Daughter
Thorium-228	8	100%	2.39	0.98	1.30	2	100%	1.32	1.14	1.23	0.72	No	Not > Back
Thorium-230	7	100%	1.71	0.92	1.13	0						No	
Thorium-234	155	48%	705.00	1.91	32.04	32	9%	4.03	2.20	0.30	**0.00**	**Yes**	> Back, Daughter
Uranium-234	3	100%	604.00	17.80	261.27	0						**Yes**	> Back, Site Use
Uranium-235 (method 713R)	156	33%	308.00	0.68	11.29	32	0%	N/A	N/A	0.00	**0.00**	**Yes**	> Back, Site Use
Uranium-235 (method 714R)	12	100%	23.10	0.02	2.50	32	91%	0.08	0.02	0.05	**0.06**	**Yes**	> Back, Site Use
Uranium-238	16	100%	74.30	0.37	8.55	32	100%	1.00	0.55	0.82	**0.03**	**Yes**	> Back, Site Use

Table 3.7. Summary results for radionuclides COPCs in on-site and background sediments. Concentrations in pCi/g.

	On-site					Background				
Parameter	Number of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean Conc.	Number of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean
Actinium-228	16	56%	4.63	0.58	0.73	2	50%	0.61	0.61	0.31
Bismuth-212	16	6%	7.09	7.09	0.44	2	0%	N/A	N/A	0.00
Cesium-137	16	19%	0.20	0.12	0.03	2	0%	N/A	N/A	0.00
Lead-212	15	93%	4.89	0.21	1.03	2	100%	0.53	0.14	0.34
Neptunium-237 (method 713R)	16	13%	60.30	0.03	3.77	2	0%	N/A	N/A	0.00
Neptunium-237 (method 714R)	4	50%	38.50	0.03	9.63	0				
Plutonium 239/240	4	0%	N/A	N/A	0.00	0				
Protactinium-234	16	19%	95.80	44.70	12.88	2	0%	N/A	N/A	0.00
Technetium-99	16	56%	284.00	1.36	37.75	2	0%	N/A	N/A	0.00
Thallium-208	16	50%	1.73	0.14	0.23	2	0%	N/A	N/A	0.00
Thorium-232	5	100%	5.07	0.55	1.59	0				
Thorium-234	16	25%	86.90	5.69	12.03	2	0%	N/A	N/A	0.00
Uranium-234	6	100%	937.00	2.80	201.14	0				
Uranium-235 (method 713R)	16	38%	37.30	0.18	4.10	2	0%	N/A	N/A	0.00
Uranium-235 (method 714R)	12	58%	41.70	0.02	4.18	2	50%	0.03	0.03	0.01

Table 3.8. Summary results for radionuclides COPCs in on-site and background surface water. Concentrations in pCi/L.

	On-site					Background				
Parameter	Number of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean Conc.	Number of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean
Technetium-99	8	0%	N/A	N/A	0.47	5	0%	N/A	N/A	0.00
Thorium-232	8	0%	N/A	N/A	0.01	5	0%	N/A	N/A	0.00
Uranium-234	1	100%	1.49	1.49	1.49	0				
Uranium-235	7	86%	0.14	0.03	0.07	5	20%	0.03	0.03	0.01
Uranium-238	8	100%	4.77	0.15	0.94	5	100%	0.74	0.22	0.36

Table 3.9. Summary results for radionuclides COPCs in on-site and background groundwater. Concentrations in pCi/L.

	On-site					Background				
Parameter	Number of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean Conc.	Number of Samples	Freq. Of Detection	Max. Detection	Min. Detection	Mean
Neptunium-237 (Dissolved)	6	0%	N/A	N/A	0.00	2	0%	N/A	N/A	0.00
Plutonium 238 (Dissolved)	6	0%	N/A	N/A	0.00	2	0%	N/A	N/A	0.00
Plutonium 239/240 (Dissolved)	6	0%	N/A	N/A	0.00	2	0%	N/A	N/A	0.00
Technetium-99 (Dissolved)	12	17%	2080.00	14.80	174.57	3	0%	N/A	N/A	1.67
Uranium-234 (Dissolved)	13	85%	7.68	0.12	1.96	3	100%	12.50	1.41	5.89
Uranium-235 (Dissolved)	13	46%	0.25	0.03	0.04	3	67%	0.11	0.05	0.06
Uranium-238 (Dissolved)	13	77%	1.56	0.04	0.36	3	100%	1.18	0.45	0.83
Neptunium-237	24	4%	0.02	0.02	0.00	8	0%	N/A	N/A	0.00
Plutonium-238	24	0%	N/A	N/A	0.00	9	0%	N/A	N/A	0.00
Plutonium 239/240	24	0%	N/A	N/A	0.00	9	0%	N/A	N/A	0.00
Technetium-99	101	27%	5100.00	8.64	141.14	16	6%	44.10	44.10	4.36
Uranium-234	46	83%	7.91	0.05	1.04	11	64%	12.40	0.05	1.76
Uranium-235	94	31%	0.19	0.03	0.02	15	40%	0.07	0.02	0.02
Uranium-238	102	86%	26.60	0.04	0.82	16	75%	56.30	0.06	3.86

Table 4.1. Screening of Soil COPCs. Source codes for ESVs are as follows: "Nutrient", compound is macronutrient, assumed to be non-toxic; "EcoSSL", Ecological Soil Screening Level; "Dutch", soil screening levels from the Netherlands; "EPA V", screening values produced by EPA Region V. "Max SQ" and "Mean SQ" are maximum and mean concentrations divided by ESV.

Parameter	Max. Detection	Mean	ESV	Source	Max. SQ	Mean SQ	Retained?	Rationale
Metals, mg/kg								
Calcium	250000.0	41019.5		Nutrient	0.0	0.0	No	Nutrient
Chromium Total	280.0	19.4	26.0	EcoSSL	**10.8**	0.7	**Yes**	
Copper	1800.0	36.3	40.0	Dutch	**45.0**	0.9	**Yes**	
Mercury	3.4	0.2	2.2	Dutch	**1.5**	0.1	**Yes**	
Nickel	300.0	24.5	38.0	Dutch	**7.9**	0.6	**Yes**	
Potassium	8000.0	1787.2		Nutrient	0.0	0.0	No	Nutrient
Selenium	4.1	0.8	0.8	Dutch	**5.1**	1.0	**Yes**	
PCB/Pesticides, ug/kg								
Aroclor-1254 (PCB-1254)	540.0	35.1	0.33	EPA V	**1626.5**	**105.6**	**Yes**	
Aroclor-1260 (PCB-1260)	560.0	39.8	0.33	EPA V	**1686.7**	**120.0**	**Yes**	
Total PCBs	850.0	74.9	0.33	EPA V	**2560.2**	**225.6**	**Yes**	
4,4'-DDT	25.0	2.0	170.00	EPA V	0.1	0.0	No	SQ < 1.0
Endosulfan II	4.2	1.0	119.27	EPA V	0.0	0.0	No	SQ < 1.0
Endrin	21.0	1.4	10.10	EPA V	**2.1**	0.1	No	See Text
SVOC, ug/kg								
Acenaphthene	380.0	186.8	682.00	EPA V	0.6	0.3	No	SQ < 1.0
Anthracene	1100.0	212.4	1480.00	EPA V	0.7	0.1	No	SQ < 1.0
Benzo(a)anthracene	6400.0	337.8	5200.00	EPA V	**1.2**	0.1	**Yes**	
Benzo(a)pyrene	6600.0	368.3	1520.00	EPA V	**4.3**	0.2	**Yes**	
Benzo(b)fluoranthene	7800.0	505.5	5980.00	EPA V	**1.3**	0.1	**Yes**	
Benzo(k)fluoranthene	3200.0	283.2	148000.0	EPA V	0.0	0.0	No	SQ < 1.0
bis(2-Ethylhexyl)phthalate	4700.0	263.8	925.00	EPA V	**5.1**	0.3	**Yes**	< 5%, <ESV
Butyl benzylphthalate	220.0	205.8	238.89	EPA V	0.9	0.9	No	SQ < 1.0
Carbazole	910.0	197.4	NV				No	SQ < 1.0
Chrysene	8100.0	407.2	4730.00	EPA V	**1.7**	0.1	**Yes**	
Dibenz(a,h)anthracene	440.0	216.5	18400.00	EPA V	0.0	0.0	No	SQ < 1.0
Di-n-butylphthalate	4300.0	306.5	150.00	EPA V	**28.7**	**2.0**	**Yes**	
Di-n-octyl phthalate	350.0	217.2	709000.00	EPA V	0.0	0.0	No	SQ < 1.0
Fluoranthene	8800.0	489.0	122000.00	EPA V	0.1	0.0	No	SQ < 1.0
Fluorene	530.0	193.4	122000.00	EPA V	0.0	0.0	No	SQ < 1.0
Indeno(1,2,3-cd)pyrene	5800.0	386.7	109000.00	EPA V	0.1	0.0	No	SQ < 1.0
Isophorone	200.0	217.2	139000.00	EPA V	0.0	0.0	No	SQ < 1.0
Naphthalene	100.0	200.9	99.40	EPA V	1.0	**2.0**	No	SQ < 1.0
Pyrene	38000.0	1438.9	78500.00	EPA V	0.5	0.0	No	SQ < 1.0
VOC, ug/kg								
Tetrachloroethene	34.0	3.5	9920.00	EPA V	0.0	0.0	No	SQ < 1.0

Table 4.2. Screening of Sediment COPCs. Source codes for ESVs are as follows: "Nutrient", compound is macronutrient, assumed to be non-toxic; "TEC", threshold effects concentration; "Dutch", sediment screening levels from the Netherlands; "EPA V", screening values produced by EPA Region V. "Max SQ" and "Mean SQ" are maximum and mean concentrations divided by ESV.

Parameter	Max. Detection	Mean	ESV	Source	Max. SQ	Mean SQ	Retained?	Rationale
Metals, mg/kg								
Calcium	22,000.0	8591.9	NV	Nutrient			No	Nutrient
Chromium Total	48.0	16.1	43.4	TEC	**1.1**	0.4	No	SQ about 1.0
Copper	110.0	23.0	31.6	TEC	**3.5**	0.7	Yes	
Mercury	1.1	0.1	0.2	TEC	**6.1**	0.6	Yes	
Nickel	48.0	14.6	22.7	TEC	**2.1**	0.6	Yes	
Potassium	1,200.0	579.4	NV	Nutrient			No	Nutrient
Selenium	2.6	0.8	2.9	Dutch	0.9	0.3	No	SQ < 1.0
PCB/Pesticides, ug/.kg								
Aroclor-1260 (PCB-1260)	59.0	27.5	59.8	TEC	1.0	0.5	No	SQ < 1.0
Endrin	2.9	1.4	10.0	EPA SQC	0.3	0.1	No	SQ < 1.0
SVOC, ug/kg								
Acenaphthene	580.0	271.4	6.7	EPA V	**86.6**	**40.5**	Yes	
Anthracene	2,400.0	387.8	60.0	TEC	**40.0**	**6.5**	Yes	
Benzo(a)anthracene	20,000.0	1445.1	110.0	EPA V	**181.8**	**13.1**	Yes	
Benzo(a)pyrene	26,000.0	1849.9	150.0	TEC	**173.3**	**12.3**	Yes	
Benzo(b)fluoranthene	48,000.0	3350.9	10400.0	EPA V	**4.6**	0.3	Yes	
Benzo(k)fluoranthene	17,000.0	1236.8	240.0	EPA V	**70.8**	**5.2**	Yes	
bis(2-Ethylhexyl)phthalate	3,600.0	450.0	182.0	EPA V	**19.8**	**2.5**	Yes	
Carbazole	3,500.0	423.4	NV				No	No ESV
Chrysene	26,000.0	1875.5	170.0	TEC	**152.9**	**11.0**	Yes	
Dibenz(a,h)anthracene	4,700.0	541.9	33.0	TEC	**142.4**	**16.4**	Yes	
Di-n-butylphthalate	2,100.0	379.4	110.5	EPA V	**19.0**	**3.4**	Yes	
Fluoranthene	37,000.0	2675.3	420.0	TEC	**88.1**	**6.4**	Yes	
Fluorene	970.0	296.3	77.4	TEC	**12.5**	**3.8**	Yes	
Indeno(1,2,3-cd)pyrene	17,000.0	1266.3	200.0	EPA V	**85.0**	**6.3**	Yes	
Naphthalene	250.0	263.8	180.0	TEC	**1.4**	**1.5**	Yes	
Pyrene	100,000.0	6666.6	195.0	TEC	**512.8**	**34.2**	Yes	

Table 4.2 continued								
VOC, ug/kg								
2-Butanone (Methyl Ethyl Ketone)	14.0	8.3	137.0	EPA V	0.1	0.1	0.0	SQ < 1.0
cis-1,2-Dichloroethene	28.0	5.6	654.0	EPA V	0.0	0.0	0.0	SQ < 1.0
Tetrachloroethene	7.3	4.3	195.8	EPA V	0.0	0.0	0.0	SQ < 1.0
Toluene	20.0	5.3	1220.0	EPA V	0.0	0.0	0.0	SQ < 1.0
trans-1,2-Dichloroethene	7.2	4.2	208.9	EPA V	0.0	0.0	0.0	SQ < 1.0
Trichloroethene	11.0	4.2	179.6	EPA V	0.1	0.0	0.0	SQ < 1.0
Vinyl chloride	22.0	8.8	202.0	EPA V	0.1	0.0	0.0	SQ < 1.0

Table 4.3. Screening of COPCs in Water. Source codes for ESVs are as follows: "Nutrient", compound is macronutrient, assumed to be non-toxic; "CSW", national chronic surface water criterion; "Missouri", chronic surface water from Missouri, "EPA V", screening values produced by EPA Region V. "Max SQ" and "Mean SQ" are maximum and mean concentrations divided by ESV. Hardness-based criteria estimated at 250 mg/l as $CaCO_3$.

Parameter	Max. Detection	Mean Conc.	ESV	Source	Max SQ	Mean SQ	Retained?	Rationale
Metal, ug/L								
Aluminum	19000.0	2602.5	87	CSW	**218.39**	**29.91**	YES	See Text
Arsenic	11.0	5.8	20	Missouri	0.55	0.29	No	SQ < 1.0
Barium	630.0	172.4	220	EPA V	**2.86**	0.78	YES	SQ < 1.0
Calcium	66000.0	52125.0	NA	Nutrient			No	SQ < 1.0
Chromium Total	26.0	5.0	157	Missouri	0.17	0.03	No	SQ < 1.0
Cobalt	17.0	3.0	24	EPA V	0.71	0.13	No	SQ < 1.0
Copper	55.0	11.3	16	Missouri	**3.44**	0.70	YES	SQ < 1.0
Iron	23000.0	3098.8	1000	CSW	**23.00**	**3.10**	YES	SQ =< 1.0
Lead	68.0	9.8	7	CSW	**9.71**	**1.40**	YES	SQ < 1.0
Magnesium	40000.0	31500.0	NA	Nutrient			No	SQ < 1.0
Manganese	1300.0	203.6	4460	Michigan	0.29	0.05	No	SQ < 1.0
Nickel	31.0	6.1	113	Missouri	0.27	0.05	No	SQ < 1.0
Potassium	5000.0	2512.5	NA	Nutrient			No	SQ < 1.0
Sodium	11000.0	9487.5	NA	Nutrient			No	SQ < 1.0
Vanadium	45.0	10.0	12	EPA V	**3.75**	0.83	Yes	SQ < 1.0
Zinc	350.0	49.3	233	Missouri	**1.50**	0.21	Yes	SQ < 1.0
SVOC, ug/L								
Fluoranthene	1.0	4.4	8	EPA V	0.12	0.54	No	SQ < 1.0
VOC,ug/L								
cis-1,2-Dichloroethene	4.4	2.5	78	EPA V*	0.06	0.03	No	SQ < 1.0
Methylene chloride	2.6	2.3	430	EPA V	0.01	0.01	No	SQ < 1.0
Tetrachloroethene	2.1	2.0	9	EPA V	0.24	0.23	No	SQ < 1.0
Trichloroethene	0.8	2.1	47	EPA V	0.02	0.04	No	SQ < 1.0

* Used ESV for trans-1,2-DCE

Table 4.4. Screening of COPCs in Groundwater. Source codes for ESVs are as follows: "Nutrient", compound is macronutrient, assumed to be non-toxic; "CSW", national chronic surface water criterion; "Missouri", chronic surface water from Missouri, "EPA V", screening values produced by EPA Region V. "Max SQ" and "Mean SQ" are maximum and mean concentrations divided by ESV. Hardness-based criteria estimated at 250 mg/l as $CaCO_3$.

Parameter	Max. Detection	Mean Conc.	ESV	Source	Max SQ	Mean SQ	Retained?	Rationale
Metals, ug/L								
Aluminum	16000	982	87	CSW	**183.9**	**11.3**	Yes	
Nickel	150	13	113	Missouri	1.3	0.1	No	SQ about 1.0
Nickel (Dissolved)	48	12	113	Missouri	0.4	0.1	No	SQ < 1.0
Potassium	69000	3469		Nutrient			No	Nutrient
Potassium (Dissolved)	11000	2600		Nutrient			No	Nutrient
Zinc	650	49	233	Missouri	**2.8**	0.2	Yes	
Zinc (Dissolved)	20	9	233	Missouri	0.1	0.0	No	SQ < 1.0
VOC, ug/L								
1,1,1-Trichloroethane	85	43	88	EPA V	1.0	0.5	No	SQ < 1.0
1,1,2-Trichloroethane	8	41	650	EPA V	0.0	0.1	No	SQ < 1.0
1,1-Dichloroethane	610	73	47	EPA V	**13.0**	**1.6**	Yes	
1,1-Dichloroethene	5100	147	78	EPA V	**65.4**	**1.9**	Yes	
1,2-Dichloroethane	9	41	190	EPA V	0.0	0.2	No	SQ < 1.0
Chloroform (Trichloromethane)	7	41	79	EPA V	0.1	0.5	No	SQ < 1.0
cis-1,2-Dichloroethene	19000	560	970	EPA V*	**19.6**	0.6	Yes	
Tetrachloroethene	200000	3472	45	EPA V	**4444.4**	**77.1**	Yes	
trans-1,2-Dichloroethene	700	54	310	EPA V	**2.3**	0.2	Yes	
Trichloroethene	18000	964	47	EPA V	**383.0**	**20.5**	Yes	
Vinyl chloride	1000	98	930	EPA V	1.1	0.1	No	SQ about 1.0

* Used ESV for trans-1,2-DCE

Table 4.5. Parameters for food chain models. " WW", "DW", and "BW" refer to wet weight, dry weight, and body weight. Parameters from EPA (1993a) except for bat, which were obtained from Baron et al. 1999.

Species	Body Weight, Kg.	Ecological guild	Contaminated Prey	Feeding Rate (kg WW / kw BW-day)	Drinking Rate (kg water / kw BW-day)	Soil Ingestion (kg DW / kg BW-day)
Brown Bat	0.007	Insectivore	Aquatic Insects	0.333	0.16	0.000
Tree Swallow	0.02	Insectivore	Aquatic Insects	0.755	0.23	0.000
Short-tailed Shrew	0.015	Primary Predator	Worms	0.53	0.223	0.009
Woodcock	0.2	Primary Predator	Worms	0.77	0.10	0.013
Red Fox	4.035	Top predator	Small mammals	0.1	0.085	0.001
Red-tailed hawk	1.2	Top predator	Small mammals	0.1	0.057	0.001
Mink	0.97	Piscivore	Fish	0.156	0.079	0.002
Great Blue Heron	2.2	Piscivore	Fish	0.18	0.045	0.002

Table 4.6. Toxicity Reference Values (TRV) and sources for food chain models. These TRVs are NOAELS (no observed adverse effects levels) . Mammal and bird TRVs for benzo(a)pyrene also applied to other high molecular weight PAHs (benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, indeno(1,2,3-cd)pyrene), and pyrene (birds only).

Constituent	TRV for Mammals			TRV for Birds		
	Test Species	TRV, mg/kg/d	Source	Test Species	TRV, mg/kg/d	Source
Chromium	Rat	2.74E+03	a	Several	2.66E+00	c
Copper	Mink	1.17E+01	a	Chick (1-day old)	4.70E+01	a
Mercury	Mink	1.00E+00	a	Japanese quail	4.50E-01	a
Methylmercury	Mink	1.50E-01	a	Duck	2.30E-02	d
Nickel	Rat	4.00E+01	a	Mallard duckling	7.74E+01	a
Selenium	Rat	2.00E-01	a	Mallard duck	5.00E-01	a
Benzo(a)pyrene*	Mouse	1.00E+00	a	Chicken	4.00E+01	e
Bis(2-ethylhexyl) phthalate	Mouse	1.83E+01	a	Ringed dove	1.10E+00	a
Butylbenzyl phthalate	Rat	1.59E+02	b	Based on DNBP	1.10E-01	a
Diethylphthalate	Mouse	4.58E+03	a	Based on DNBP	1.10E-01	a
Di-n-butylphthalate	Mouse	5.50E+02	a	Ringed Dove	1.10E-01	a
Fluoranthene	Mouse	1.32E+01	b	Chicken	4.00E+01	e
Fluorene	Mouse	1.25E+01	b	Mallard duck	1.00E+03	f
Naphthalene	Rat	1.00E+00	b	Mallard duck	1.00E+03	f
Pyrene	Mouse	7.50E+01	b	Chicken	4.00E+01	e
Aroclor 1254	Oldfield mouse	6.80E-02	a	Ring-necked pheasant	1.80E-01	a
Endrin	Mouse	9.20E-02	a	Screech Owl	1.00E-02	a
2,3,7,8-TCDD TEQ	Rat	1.00E-06	a	pheasant	1.40E-05	a

a. Sample et al. 1996
b. IRIS EPA 1998
c. EPA 2005
d. EPA 1995
e. Rigdon and Neal 1963
f. Patton and Dieter 1980

Table 4.7. Estimation of chemical concentrations in terrestrial food chain. See text for methods used to estimate prey concentrations.

Constituent	Soil Maximum	Soil Mean	Worm Maximum	Worm Mean	Small Mammal Maximum	Small Mammal Mean
Chromium	280	19.4	13.7	0.95	3.63	0.51
Copper	1,800	36.29	6.2	2.20	5.69	3.24
Mercury	3.4	0.2	0.3	0.10	0.05	0.003
Nickel	300	24.5	50.9	4.16	2.79	0.87
Selenium	4.1	0.83	0.4	0.13	0.28	0.15
PCB	0.85	0.08	0.5	0.02	0.09	0.01
TCDD TEQ	5.49E-06	1.2E-07	3.3E-06	3.6E-08	1.0E-06	1.6E-08
Benzo(a)anthracene	6.40	0.34	0.6	0.03	0.06	0.003
Benzo(a)pyrene	6.60	0.37	0.7	0.04	0.07	0.004
Benzo(b)fluoranthene	7.80	0.51	0.8	0.05	0.08	0.005
Benzo(k)fluoranthene	3.20	0.28	0.3	0.03	0.03	0.003
Chrysene	8.10	0.41	0.8	0.04	0.08	0.004
Dibenz(a,h)anthracene	0.80	0.22	0.1	0.02	0.01	0.002
Fluoranthene	8.80	0.49	0.9	0.05	0.09	0.005
Indeno(1,2,3-cd)pyrene	5.80	0.39	0.6	0.04	0.06	0.004
Pyrene	38.00	1.44	3.8	0.14	0.38	0.014
bis(2-Ethylhexyl)phthalate	4.70	0.26	0.5	0.03	0.05	0.003
Butyl benzylphthalate	0.80	0.21	0.1	0.02	0.01	0.002
Di-n-butylphthalate	4.30	0.31	0.4	0.03	0.04	0.003
Di-n-octyl phthalate	0.80	0.22	0.1	0.02	0.01	0.002

Notes: Units in mg/kg, dry weight for soil and wet weight for biota

Table 4.8 Estimation of COPC concentrations in aquatic benthos. See text for methods used to estimate concentrations in benthos.

Constituent	Units		Maximum Value in Sediments		Mean Value in Sediments		Predicted Max. in Benthos		Predicted Mean in Benthos
Chromium	mg/kg		48		16.1		1.7		1.1
Copper	mg/kg		110		7.8		11.3		5.4
Mercury	mg/kg		1.1		0.11		0.055		0.03
Nickel	mg/kg		48		14.6		1.5		2.4
Endrin	mg/kg		2.9E-03		1.4E-03		5.2E-03		2.5E-03
PCB	mg/kg		5.9E-02		2.8E-02		6.5E-02		3.0E-02
Benzo(a)anthracene	mg/kg		20.0		1.4		5.8		0.4
Benzo(a)pyrene	mg/kg		26.0		1.8		7.5		0.5
Benzo(b)fluoranthene	mg/kg		48.0		3.4		13.9		1.0
Benzo(k)fluoranthene	mg/kg		17.0		1.2		4.9		0.4
Chrysene	mg/kg		26.0		1.9		7.5		0.5
Dibenz(a,h)anthracene	mg/kg		4.7		0.5		1.4		0.2
Fluoranthene	mg/kg		37.0		2.7		10.7		0.8
Indeno(1,2,3-cd)pyrene	mg/kg		17.0		1.3		4.9		0.4
Pyrene	mg/kg		100.0		6.7		29.0		1.9
bis(2-Ethylhexyl)phthalate	mg/kg		3.6		0.5		1.0		0.1
Di-n-butylphthalate	mg/kg		2.1		0.4		0.6		0.1

Notes: Units in mg/kg, dry weight for soil and wet weight for biota

Table 4.9. Assessment of risk to consumers of soil invertebrates: shrew and woodcock

Constituent	Toxicity Reference Value (mg/kg/day)	Feeding Rate (mg/kg/day)	Maximum Predicted Conc. In Biota	Mean Predicted Conc. In Biota	Max. Dose (mg/kg/day)	Mean Dose (mg/kg/day)	Max. SQ	Mean SQ
	Shrew							
Chromium	2740.0	0.53	13.71	0.95	9.8	0.97	0.0	0.0
Copper	11.7	0.53	6.18	2.20	19.5	2.04	**1.7**	0.2
Mercury	1.0	0.53	0.26	0.10	0.2	0.06	0.2	0.1
Nickel	40.0	0.53	50.88	4.16	29.7	2.79	0.7	0.1
Selenium	0.2	0.53	0.42	0.13	0.3	0.09	**1.3**	0.4
PCB	0.1	0.53	0.53	0.02	0.3	0.01	**4.2**	0.2
TCDD TEQ	1.0E-06	0.53	3.3E-06	3.6E-08	1.80E-06	2.2E-08	**1.8**	0.0
Benzo(a)anthracene	1.0	0.53	0.64	0.03	0.4	0.03	0.4	0.0
Benzo(a)pyrene	1.0	0.53	0.66	0.04	0.4	0.03	0.4	0.0
Benzo(b)fluoranthene	1.0	0.53	0.78	0.05	0.5	0.04	0.5	0.0
Benzo(k)fluoranthene	1.0	0.53	0.32	0.03	0.2	0.02	0.2	0.0
Chrysene	1.0	0.53	0.81	0.04	0.5	0.03	0.5	0.0
Dibenz(a,h)anthracene	1.0	0.53	0.08	0.02	0.0	0.02	0.0	0.0
Fluoranthene	13.2	0.53	0.88	0.05	0.5	0.04	0.0	0.0
Indeno(1,2,3-cd)pyrene	1.0	0.53	0.58	0.04	0.4	0.03	0.4	0.0
Pyrene	75.0	0.53	3.80	0.14	2.4	0.11	0.0	0.0
bis(2-Ethylhexyl)phthalate	18.3	0.53	0.47	0.03	0.3	0.02	0.0	0.0
Butyl benzylphthalate	159.0	0.53	0.08	0.02	0.0	0.02	0.0	0.0
Diethyl phthalate	4580.0	0.53	0.08	0.02	0.0	0.02	0.0	0.0
Di-n-butylphthalate	550.0	0.53	0.43	0.03	0.3	0.02	0.0	0.0
Di-n-octyl phthalate	13.0	0.53	0.08	0.02	0.0	0.02	0.0	0.0

Table 4.9. Assessment of risk to consumers of soil invertebrates: shrew and woodcock

Constituent	Toxicity Reference Value (mg/kg/day)	Feeding Rate (mg/kg/day)	Maximum Predicted Conc. In Biota	Mean Predicted Conc. In Biota	Max. Dose (mg/kg/day)	Mean Dose (mg/kg/day)	Max. SQ	Mean SQ
	Woodcock							
Chromium	2.7	0.77	13.7	0.9	14.2	1.20	**5.3**	0.4
Copper	47.0	0.77	6.2	2.2	28.2	2.57	0.6	0.1
Mercury	0.5	0.77	0.3	0.1	0.2	0.08	0.5	0.2
Nickel	77.4	0.77	50.9	4.2	43.1	3.79	0.6	0.0
Selenium	0.5	0.77	0.4	0.1	0.4	0.12	0.7	0.2
PCB	0.2	0.77	0.5	0.0	0.4	0.02	**2.3**	0.1
TCDD TEQ	1.4E-05	0.77	3.3E-06	3.6E-08	2.6E-06	3.1E-08	0.2	0.0
Benzo(a)anthracene	40.0	0.77	0.6	0.0	0.6	0.03	0.0	0.0
Benzo(a)pyrene	40.0	0.77	0.7	0.0	0.6	0.04	0.0	0.0
Benzo(b)fluoranthene	40.0	0.77	0.8	0.1	0.7	0.05	0.0	0.0
Benzo(k)fluoranthene	40.0	0.77	0.3	0.0	0.3	0.03	0.0	0.0
Chrysene	40.0	0.77	0.8	0.0	0.7	0.04	0.0	0.0
Dibenz(a,h)anthracene	40.0	0.77	0.1	0.0	0.1	0.02	0.0	0.0
Fluoranthene	40.0	0.77	0.9	0.0	0.8	0.05	0.0	0.0
Indeno(1,2,3-cd)pyrene	40.0	0.77	0.6	0.0	0.5	0.04	0.0	0.0
Pyrene	40.0	0.77	3.8	0.1	3.4	0.15	0.1	0.0
bis(2-Ethylhexyl)phthalate	1.1	0.77	0.5	0.0	0.4	0.03	0.4	0.0
Butyl benzylphthalate	0.1	0.77	0.1	0.0	0.1	0.02	0.7	0.2
Diethyl phthalate	0.1	0.77	0.1	0.0	0.1	0.02	0.7	0.2
Di-n-butylphthalate	0.1	0.77	0.4	0.0	0.4	0.03	**3.5**	0.3
Di-n-octyl phthalate	0.1	0.77	0.1	0.0	0.1	0.02	0.7	0.2

Table 4.10. Assessment of risk to consumers of adult aquatic insects: brown bat and tree swallow

Constituent	Toxicity Reference Value (mg/kg/day)	Feeding Rate (mg/kg/day)	Maximum Predicted Conc. in Biota	Mean Predicted Conc. in Biota	Max. Dose (mg/kg/day)	Mean Dose (mg/kg/day)	Max SQ	Mean SQ
	Brown Bat							
Chromium	2740.00	0.33	1.66	1.12	0.55	0.37	0.00	0.00
Copper	11.71	0.33	11.34	5.43	3.75	1.79	0.32	0.15
Mercury	0.15	0.33	0.06	0.03	0.02	0.01	0.12	0.06
Nickel	40.00	0.33	1.46	2.42	0.49	0.80	0.01	0.02
Endrin	0.09	0.33	5.2E-03	2.5E-03	0.00	0.00	0.02	0.01
PCB	0.07	0.33	0.06	0.03	0.02	0.01	0.31	0.15
Benzo(a)anthracene	1.00	0.33	5.80	0.42	1.91	0.14	**1.91**	0.14
Benzo(a)pyrene	1.00	0.33	7.54	0.54	2.49	0.18	**2.49**	0.18
Benzo(b)fluoranthene	1.00	0.33	13.92	0.97	4.59	0.32	**4.59**	0.32
Benzo(k)fluoranthene	1.00	0.33	4.93	0.36	1.63	0.12	**1.63**	0.12
Chrysene	1.00	0.33	7.54	0.54	2.49	0.18	**2.49**	0.18
Dibenz(a,h)anthracene	1.00	0.33	1.36	0.16	0.45	0.05	0.45	0.05
Fluoranthene	13.20	0.33	10.73	0.78	3.54	0.26	0.27	0.02
Indeno(1,2,3-cd)pyrene	1.00	0.33	4.93	0.37	1.63	0.12	**1.63**	0.12
Pyrene	75.00	0.33	29.00	1.93	9.57	0.64	0.13	0.01
bis(2-Ethylhexyl)phthalate	18.30	0.33	1.04	0.13	0.34	0.04	0.02	0.00
Di-n-butylphthalate	550.00	0.33	0.61	0.11	0.20	0.04	0.00	0.00

Table 4.10. Assessment of risk to consumers of adult aquatic insects: brown bat and tree swallow

Constituent	Toxicity Reference Value (mg/kg/day)	Feeding Rate (mg/kg/day)	Maximum Predicted Conc. in Biota	Mean Predicted Conc. in Biota	Max. Dose (mg/kg/day)	Mean Dose (mg/kg/day)	Max SQ	Mean SQ
	Tree Swallow							
Chromium	2.66	0.76	1.66	1.12	1.26	0.84	0.5	0.3
Copper	46.97	0.76	11.34	5.43	8.57	4.10	0.2	0.1
Mercury	0.02	0.76	0.06	0.03	0.04	0.02	**1.8**	0.9
Nickel	77.40	0.76	1.46	2.42	1.11	1.82	0.0	0.0
Endrin	0.01	0.76	0.01	0.00	0.00	0.00	0.4	0.2
PCB	0.18	0.76	0.06	0.03	0.05	0.02	0.3	0.1
Benzo(a)anthracene	40.00	0.76	5.80	0.42	4.38	0.32	0.1	0.0
Benzo(a)pyrene	40.00	0.76	7.54	0.54	5.69	0.41	0.1	0.0
Benzo(b)fluoranthene	40.00	0.76	13.92	0.97	10.51	0.73	0.3	0.0
Benzo(k)fluoranthene	40.00	0.76	4.93	0.36	3.72	0.27	0.1	0.0
Chrysene	40.00	0.76	7.54	0.54	5.69	0.41	0.1	0.0
Dibenz(a,h)anthracene	40.00	0.76	1.36	0.16	1.03	0.12	0.0	0.0
Fluoranthene	40.00	0.76	10.73	0.78	8.10	0.59	0.2	0.0
Indeno(1,2,3-cd)pyrene	40.00	0.76	4.93	0.37	3.72	0.28	0.1	0.0
Pyrene	40.00	0.76	29.00	1.93	21.90	1.46	0.5	0.0
bis(2-Ethylhexyl)phthalate	1.10	0.76	1.04	0.13	0.79	0.10	0.7	0.1
Butyl benzylphthalate	0.11	0.76	0.19	0.08	0.14	0.06	**1.3**	0.6
Diethyl phthalate	0.11	0.76	0.19	0.08	0.14	0.06	**1.3**	0.6
Di-n-butylphthalate	0.11	0.76	0.61	0.11	0.46	0.08	**4.2**	0.8

Table 4.11. Assessment of risk to top predators: fox and red-tailed hawk

Constituent	Toxicity Ref. Value (mg/kg/day)	Feeding Rate (mg/kg/day)	Max.Conc. Predicted in Biota	Mean Conc. Predicted In Biota	Max. Dose (mg/kg/day)	Mean Dose (mg/kg/day)	Max. SQ	Mean SQ
	Fox							
Chromium	2740.0	0.1	3.63	0.51	0.36	0.05	0.0	0.0
Copper	11.7	0.1	5.69	3.24	0.57	0.32	0.0	0.0
Mercury	1.0	0.1	0.05	0.00	0.00	0.00	0.0	0.0
Nickel	40.0	0.1	2.79	0.87	0.28	0.09	0.0	0.0
Selenium	0.2	0.1	0.28	0.15	0.03	0.02	0.1	0.1
PCB	0.1	0.1	0.09	0.01	0.01	0.00	0.1	0.0
TCDD TEQ	1.0E-06	0.1	0.00	0.00	0.00	0.00	0.1	0.0
Benzo(a)anthracene	1.0	0.1	0.06	0.00	0.01	0.00	0.0	0.0
Benzo(a)pyrene	1.0	0.1	0.07	0.00	0.01	0.00	0.0	0.0
Benzo(b)fluoranthene	1.0	0.1	0.08	0.01	0.01	0.00	0.0	0.0
Benzo(k)fluoranthene	1.0	0.1	0.03	0.00	0.00	0.00	0.0	0.0
Chrysene	1.0	0.1	0.08	0.00	0.01	0.00	0.0	0.0
Dibenz(a,h)anthracene	1.0	0.1	0.01	0.00	0.00	0.00	0.0	0.0
Fluoranthene	13.2	0.1	0.09	0.00	0.01	0.00	0.0	0.0
Indeno(1,2,3-cd)pyrene	1.0	0.1	0.06	0.00	0.01	0.00	0.0	0.0
Pyrene	75.0	0.1	0.38	0.01	0.04	0.00	0.0	0.0
bis(2-Ethylhexyl)phthalate	18.3	0.1	0.05	0.00	0.00	0.00	0.0	0.0
Butyl benzylphthalate	159.0	0.1	0.01	0.00	0.00	0.00	0.0	0.0
Diethyl phthalate	4580.0	0.1	0.01	0.00	0.00	0.00	0.0	0.0
Di-n-butylphthalate	550.0	0.1	0.04	0.00	0.00	0.00	0.0	0.0
	Redtail Hawk							
Chromium	2.7	0.1	3.6	0.5	0.36	0.05	0.1	0.0
Copper	47.0	0.1	5.7	3.2	0.57	0.32	0.0	0.0
Mercury	0.5	0.1	0.0	0.0	0.00	0.00	0.0	0.0
Nickel	77.4	0.1	2.8	0.9	0.28	0.09	0.0	0.0
Selenium	0.5	0.1	0.3	0.2	0.03	0.02	0.1	0.0
PCB	0.2	0.1	0.1	0.0	0.01	0.00	0.0	0.0
TCDD TEQ	1.4E-05	0.1	0.0	0.0	0.00	0.00	0.0	0.0
Benzo(a)anthracene	40.0	0.1	0.1	0.0	0.01	0.00	0.0	0.0
Benzo(a)pyrene	40.0	0.1	0.1	0.0	0.01	0.00	0.0	0.0
Benzo(b)fluoranthene	40.0	0.1	0.1	0.0	0.01	0.00	0.0	0.0
Benzo(k)fluoranthene	40.0	0.1	0.0	0.0	0.00	0.00	0.0	0.0
Chrysene	40.0	0.1	0.1	0.0	0.01	0.00	0.0	0.0
Dibenz(a,h)anthracene	40.0	0.1	0.0	0.0	0.00	0.00	0.0	0.0
Fluoranthene	40.0	0.1	0.1	0.0	0.01	0.00	0.0	0.0
Indeno(1,2,3-cd)pyrene	40.0	0.1	0.1	0.0	0.01	0.00	0.0	0.0
Pyrene	40.0	0.1	0.4	0.0	0.04	0.00	0.0	0.0
bis(2-Ethylhexyl)phthalate	1.1	0.1	0.0	0.0	0.00	0.00	0.0	0.0
Butyl benzylphthalate	0.1	0.1	0.0	0.0	0.00	0.00	0.0	0.0
Diethyl phthalate	0.1	0.1	0.0	0.0	0.00	0.00	0.0	0.0
Di-n-butylphthalate	0.1	0.1	0.0	0.0	0.00	0.00	0.0	0.0

Table 4.12. Assessment of risk to piscivorous wildlife: mink and Great Blue Heron

Constituent	Toxicity Reference Value, (mg/kg/day)	Feeding Rate, (mg/kg/day)	Max. Conc. Predicted in Fish	Mean Conc. Pedicted in Fish	Max. Dose, (mg/kg/day)	Mean. Dose, (mg/kg/day)	Max. SQ	Mean SQ
	Mink							
Methylmercury	0.15	0.16	0.07	0.03	0.01	0.01	0.07	0.03
Endrin	0.09	0.16	0.02	0.01	0.002	0.001	0.03	0.01
PCBs	0.07	0.16	0.19	0.09	0.030	0.014	0.45	0.21
Great Blue Heron								
Methylmercury	0.03	0.18	0.07	0.03	0.01	0.01	0.38	0.18
Endrin	0.01	0.18	0.02	0.01	0.003	0.001	0.28	0.13
PCBs	0.18	0.18	0.19	0.09	0.04	0.02	0.20	0.09

Table 4.13. Screening of Radionuclide COPCs in Aquatic Environments. All concentrations in pCi/g or pCi/L. BCG are biota concentration guides as developed by DOE (2002). Max and Mean quotients are the sum of quotients for sediment and surface water with the maximum and mean concentrations, respectively. "Est." refers to water column concentrations that were estimated with partitioning theory and measured sediment concentrations. See text.

	Sediment, pCi/g			Surface Water, pCi/L				
Parameter	Max. Detection	Mean Conc.	BCG	Max. Detection	Mean	BCG	Max Quotient	Mean Quotietn
Actinium-228	4.63	0.73	NV					
Bismuth-212	7.09	0.44	NV					
Cesium-137	0.20	0.03	3.13E+03	0.40 est.	0.06 est.	4.26E+01	0.009	0.001
Lead-212	4.89	1.03	NV					
Neptunium-237 (method 713R)	60.30	3.77	NV					
Neptunium-237 (method 714R)	38.50	9.63	NV					
Plutonium 239/240	N/A	0.00	6E+03					
Protactinium-234	95.80	12.88	NV					
Technetium-99	284.00	37.75	4.22E+04	0.00	0.47	6.67E+05	0.007	0.001
Thallium-208	1.73	0.23	NV					
Thorium-232	5.07	1.59	1E+03	0.00	0.01	2.78E+02	0.005	0.002
Thorium-234	86.90	12.03	NV	0.00	0.01			
Uranium-234	937.00	201.14	5.27E+03	1.49	1.49	2.02E+02	0.185	0.046
Uranium-235 (method 713R)	37.30	4.10	3.73E+03					
Uranium-235 (method 714R)	41.70	4.18	3.73E+03	0.14	0.07	2.18E+02	0.012	0.001
Uranium-238	84.60	10.39	2.49E+03	4.77	0.94	2.23E+02	0.055	0.008
Sum of Quotients							0.274	0.059
Screening Decision							Site Passes	Site Passes

Table 4.14. Screening of Radionuclide COPCs in Terrestrial Environments. All concentrations in pCi/g or pCi/L. BCG are biota concentration guides as developed by DOE (2002). Max and Mean quotients are the sum of quotients for sediment and surface water with the maximum and mean concentrations, respectively. "Est." refers to water column concentrations that were estimated with partitioning theory and measured sediment concentrations. See text. Quotients > 1.0 are bolded. According to DOE methods, the decision based on the mean quotient is most applicable.

	Soil, pCi/g			Surface Water, pCi/L				
Parameter	Max. Detection	Mean Conc.	BCG	Max. Detection	Mean	BCG	Max Quotient	Mean Quotient
Actinium-228	36.40	1.13	NV					
Bismuth-212	41.60	0.67	NV					
Cesium-137	1.79	0.12	2.08E+01	0.40 est.	0.06 est.	5.99E+05	0.086	0.006
Lead-212	41.20	1.33	NV					
Neptunium-237 (method 713R)	2610.00	48.50	NV					
Neptunium-237 (method 7134)	0.04	0.00	NV					
Plutonium 239/240	0.03	0.00	6.12E+03	0.00	0.00	2.00E+05	0.000	
Protactinium-234	2200.00	49.67	NV					
Technetium-99	17100.00	188.52	4.47E+03	0.00	0.47	1.55E+07	**3.826**	0.042
Thallium-208	12.10	0.38	NV					
Thorium-234	705.00	32.04	NV	0.00	0.01			
Uranium-234	604.00	261.27	5.13E+03	1.49	1.49	4.05E+05	0.118	0.051
Uranium-235 (method 713R)	308.00	11.29	2.84E+03	0.14	0.07	4.19E+05	0.109	0.004
Uranium-235 (method 714R)	23.10	2.50	2.84E+03			4.19E+05		
Uranium-238	74.30	8.55	1.58E+03	4.77	0.94	4.06E+05	0.047	0.005
Sum of Quotients							**4.18675**	0.108
Screening Decision							**Site Fails**	Site Passes

Table 5.1. Summary of Risk Screening. Listed below are COPC/Receptor combinations that could not be dismissed after initial screening. Note that no SQ values > 1.0 were obtained with surface water applied to surface water sp., sediments applied to fish-

	Surface Water COPCs/Fish		Sediment COPCs / Benthos		Sediment COPC / Insectivores		Groundwater COPCs/ Surface Water Sp.		Soil COPCs / Worm Eaters	
	Max SQ	Mean SQ	Max SQ	Mean SQ	Max SQ	Mean SQ	Max SQ	Mean SQ	Max SQ	Mean SQ
Metals										
Aluminum	**218.4**	**29.9**					**183.9**	**11.3**		
Barium	**2.9**	0.8								
Chromium			**1.1**	0.4					**5.3**	0.4
Copper	**3.4**	0.7	**3.5**	0.7					**1.7**	0.2
Iron	**23.0**	3.1								
Lead	**9.7**	1.4			**3.9**	**2.5**				
Mercury			**6.1**	0.6	0.1					
Nickel			**2.1**	0.6	0.0					
Selenium									**1.3**	0.4
Vanadium	**3.8**	0.8								
Zinc	**1.5**	0.2								
PCB/Pesticides/Dioxins										
PCB									**4.2**	0.2
TCDD TEQ									**1.8**	
SVOC										
Acenaphthene			**86.6**	**40.5**						
Anthracene			**40.0**	**6.5**						
Benzo(a)anthracene			**181.8**	**13.1**	**1.9**	0.1				
Benzo(a)pyrene			**173.3**	**12.3**	**2.5**	0.2				
Benzo(b)fluoranthene			**4.6**	0.3	**4.6**	0.3				
Benzo(k)fluoranthene			**70.8**	**5.2**	**1.6**	0.1				
bis(2-Ethylhexyl)phthalate			**19.8**	**2.5**						
Butyl benzylphthalate					**1.3**	0.6				
Chrysene			**152.9**	**11.0**	**2.5**	0.2				
Dibenz(a,h)anthracene			**142.4**	**16.4**						
Diethyl phthalate					**1.3**	0.6				
Di-n-butylphthalate			**19.0**	**3.4**	**4.2**	0.8			**3.5**	0.3
Fluoranthene			**88.1**	**6.4**						
Fluorene			**12.5**	**3.8**						
Indeno(1,2,3-cd)pyrene			**85.0**	**6.3**	**1.6**	0.1				
Naphthalene			**1.4**	**1.5**						
Pyrene			**512.8**	**34.2**						
VOC										
1,1-Dichloroethane							**13.0**	**1.6**		
1,1-Dichloroethene							**65.4**	**1.9**		
cis-1,2-Dichloroethene							**19.6**	0.6		
Tetrachloroethene							**4444.4**	**77.1**		
trans-1,2-Dichloroethene							**2.3**	0.2		
Trichloroethene							**383.0**	**20.5**		
Radionuclides										
Sum of Quotients					0.3	0.1			**4.2**	0.1

Table 5.2. Rescreening of Sediment COPCs vs. Conservative and Less Conservative ESVs. SQ values > 1.0 are bolded. Sources of Conservative ESVs are found in Table 4.2. Least Conservative ESVs are PEC values and Less Conservative ESVs are geomean of TEC and PEC values.

			Screening Against Most Conservative EVS			Screening Against Less Conservative ESV			Screeing Against Least Conservative ESV		
Parameter	95 UCL	Mean	Most Conservative ESV	Max. SQ.	Mean SQ	Less Conservative ESV	95% UCL SQ.	Mean SQ	Least Conservative ESV	95% UCL SQ.	Mean SQ
Metals, mg/kg											
Chromium Total	28	16	43	**1.1**	0.4	69.4	0.4	0.2	111	0.2	0.1
Copper	75	23	32	**3.5**	0.7	68.6	**1.1**	0.3	149	0.5	0.2
Mercury	0.4	0.1	0.2	**6.1**	0.6	0.4	0.9	0.3	1.1	0.4	0.1
Nickel	28	15	23	**2.1**	0.6	33.2	0.8	0.4	48.6	0.6	0.3
SVOC, ug/kg											
Acenaphthene	429	271	7	**86.6**	**40.5**	NA			NA		
Anthracene	986	388	60	**40.0**	**6.5**	225.2	**4.4**	**1.7**	845	**1.2**	0.5
Benzo(a)anthracene	6839	1445	110	**181.8**	**13.1**	339.9	**20.1**	**4.3**	1050	**6.5**	**1.4**
Benzo(a)pyrene	8870	1850	150	**173.3**	**12.3**	466.4	**19.0**	**4.0**	1450	**6.1**	**1.3**
Benzo(b)fluoranthene	16334	3351	10400	**4.6**	0.3	NA			NA		
Benzo(k)fluoranthene	5819	1237	240	**70.8**	**5.2**	NA			NA		
bis(2-Ethylhexyl)phthalate	1368	450	182	**19.8**	**2.5**				NA		
Carbazole	3500	423	NV								
Chrysene	8890	1876	170	**152.9**	**11.0**	468.3	**19.0**	**4.0**	1290	**6.9**	**1.5**
Dibenz(a,h)anthracene	1755	542	33	**142.4**	**16.4**	NA			NA		
Di-n-butylphthalate	892	379	111	**19.0**	**3.4**	NA			NA		
Fluoranthene	12664	2675	420	**88.1**	**6.4**	967.8	**13.1**	**2.8**	2230	**5.7**	**1.2**
Fluorene	531	296	77	**12.5**	**3.8**	203.7	**2.6**	**1.5**	536	1.0	0.6
Indeno(1,2,3-cd)pyrene	5842	1266	200	**85.0**	**6.3**	NA			NA		
Naphthalene	308	264	180	**1.4**	**1.5**	317.8	1.0	0.8	561	0.5	0.5
Pyrene	33797	6667	195	**512.8**	**34.2**	544.4	**62.1**	**12.2**	1520	**22.2**	**4.4**
Total PAH	77157	28461	1610	**47.9**	**17.7**	6058.7	**12.7**	**4.7**	22800	**3.4**	**1.2**

Table 5.3. Rescreening of COPCs in Water. Source codes for ESVs are as follows: "CSW", national chronic surface water criterion; "Missouri", chronic surface water from Missouri, "EPA V", screening values produced by EPA Region V. "Max SQ" and "Mean SQ" are maximum and mean concentrations divided by ESV. Hardness-based criteria estimated at 250 mg/l as $CaCO_3$.

Parameter	Max. wout SW-01	ESV	Source	Max SQ wout SW-01	Retained?	Rationale
Metal, ug/L						
Aluminum	980.0	87	CSW	**11.26**	No	See Text
Barium	140.0	220	EPA V	0.64	No	SQ < 1.0
Copper	10 U	16	Missouri	0.31	No	SQ < 1.0
Iron	1000.0	1000	CSW	1.00	No	SQ =< 1.0
Lead	3 U	7	CSW	0.21	No	SQ < 1.0
Vanadium	10 U	12	EPA V	0.42	No	SQ < 1.0
Zinc	17.0	233	Missouri	0.07	No	SQ < 1.0

Table 5.4. Wells with highest VOC concentrations in groundwater. Concentrations in ug/L.

Rank	cis-1,2-DCE	Well		PCE	Well		TCE	Well
1	19,000	BD-06		200,000	BD-02		18,000	BD-06
2	4,600	BD-08		14,000	FD-07		15,000	NB-72
3	3,700	NB-72		14,000	LF-09		4,000	BD-08
4	2,100	WS-30		3,300	BD-01		3,700	WS-30
5	1,400	FD-04		2,700	BD-03		3,600	NB-35
6	1,100	WS-29		2,600	NB-34		2,800	FD-04
7	920	NB-78		2,600	NB-74		1,900	FD-07
8	880	NB-64		2,500	NB-34		1,900	LF-09
9	870	NB-35		2,400	EP-20		1,900	NB-74
10	800	WS-14		2,200	WS-30		1,900	WS-31
11	770	WS-31		2,100	BD-06		1,800	FD-05
12	730	FD-05		2,100	BD-14		1,800	NB-80
13	600	BD-13		2,000	FD-01		1,400	NB-64
14	550	BP-22A		1,800	BD-08		1,100	BD-13
15	360	NB-74		1,400	BD-04		1,100	PL-04
16	340	BP-17		1,400	NB-54		1,000	BD-14
17	340	PL-04		1400	WS-14		990	BP-22A
18	290	NB-36		1200	NB-73		870	NB-78
19	280	FD-07		1100	BD-13		830	NB-31
20	280	NB-31		1000	FD-04		810	NB-36

Table 5.1. Summary of Risk Screening. Listed below are COPC/Receptor combinations that could not be dismissed after initial screening. Note that no SQ values > 1.0 were obtained with surface water applied to surface water sp., sediments applied to fish-

	Surface Water COPCs/Fish		Sediment COPCs / Benthos		Sediment COPC / Insectivores		Groundwater COPCs/ Surface Water Sp.		Soil COPCs / Worm Eaters	
	Max SQ	Mean SQ	Max SQ	Mean SQ	Max SQ	Mean SQ	Max SQ	Mean SQ	Max SQ	Mean SQ
Metals										
Aluminum	**218.4**	**29.9**					**183.9**	**11.3**		
Barium	**2.9**	0.8								
Chromium			**1.1**	0.4					**5.3**	0.4
Copper	**3.4**	0.7	**3.5**	0.7					**1.7**	0.2
Iron	**23.0**	3.1								
Lead	**9.7**	1.4			**3.9**	**2.5**				
Mercury			**6.1**	0.6	0.1					
Nickel			**2.1**	0.6	0.0					
Selenium									**1.3**	0.4
Vanadium	**3.8**	0.8								
Zinc	**1.5**	0.2								
PCB/Pesticides/Dioxins										
PCB									**4.2**	0.2
TCDD TEQ									**1.8**	
SVOC										
Acenaphthene			**86.6**	**40.5**						
Anthracene			**40.0**	**6.5**						
Benzo(a)anthracene			**181.8**	**13.1**	**1.9**	0.1				
Benzo(a)pyrene			**173.3**	**12.3**	**2.5**	0.2				
Benzo(b)fluoranthene			**4.6**	0.3	**4.6**	0.3				
Benzo(k)fluoranthene			**70.8**	**5.2**	**1.6**	0.1				
bis(2-Ethylhexyl)phthalate			**19.8**	**2.5**						
Butyl benzylphthalate					**1.3**	0.6				
Chrysene			**152.9**	**11.0**	**2.5**	0.2				
Dibenz(a,h)anthracene			**142.4**	**16.4**						
Diethyl phthalate					**1.3**	0.6				
Di-n-butylphthalate			**19.0**	**3.4**	**4.2**	0.8			**3.5**	0.3
Fluoranthene			**88.1**	**6.4**						
Fluorene			**12.5**	**3.8**						
Indeno(1,2,3-cd)pyrene			**85.0**	**6.3**	**1.6**	0.1				
Naphthalene			**1.4**	**1.5**						
Pyrene			**512.8**	**34.2**						
VOC										
1,1-Dichloroethane							**13.0**	**1.6**		
1,1-Dichloroethene							**65.4**	**1.9**		
cis-1,2-Dichloroethene							**19.6**	0.6		
Tetrachloroethene							**4444.4**	**77.1**		
trans-1,2-Dichloroethene							**2.3**	0.2		
Trichloroethene							**383.0**	**20.5**		
Radionuclides										
Sum of Quotients					0.3	0.1			**4.2**	0.1

Table 5.5. Rescreening of risk to consumers of soil invertebrates: shrew and woodcock

Constituent	Toxicity Reference Value (mg/kg/day)	Feeding Rate (mg/kg/day)	95% UCL Predicted Conc. In Biota	Mean Predicted Conc. In Biota	95% UCL Dose (mg/kg/day)	Mean Dose (mg/kg/day)	95% UCL SQ	Mean SQ
	Shrew							
Copper	11.7	0.53	2.69	2.20	2.1	2.04	0.2	0.2
Selenium	0.2	0.53	0.16	0.13	0.1	0.09	0.5	0.4
PCB	0.1	0.53	0.04	0.02	0.0	0.01	0.3	0.2
TCDD TEQ	1.0E-06	0.53	3.3E-06	3.6E-08	1.80E-06	2.2E-08	**1.8**	0.0
	Woodcock							
Chromium	2.7	0.77	1.2	0.9	1.3	1.20	0.5	0.4
PCB	0.2	0.77	0.0	0.0	0.0	0.02	0.2	0.1
Di-n-butylphthalate	0.1	0.77	0.0	0.0	0.0	0.03	0.2	0.3

Note that the 95% UCL for TCDD TEQ is the TEQ with all non-detects set equal to 1/2 the detection limit, and the mean is with NDs set to 0. See text for explantion.

Table 5.6. Rescreening of risk to consumers of adult aquatic insects: brown bat and tree swallow

Constituent	Toxicity Reference Value (mg/kg/day)	Feeding Rate (mg/kg/day)	95% UCL Predicted Conc. in Biota	Mean Predicted Conc. in Biota	95% UCL. Dose (mg/kg/day)	Mean Dose (mg/kg/day)	95% UCL SQ	Mean SQ
	Brown Bat							
Benzo(a)anthracene	1.00	0.33	1.98	0.42	0.65	0.14	0.7	0.1
Benzo(a)pyrene	1.00	0.33	2.57	0.54	0.85	0.18	0.8	0.2
Benzo(b)fluoranthene	1.00	0.33	4.74	0.97	1.56	0.32	**1.6**	0.3
Benzo(k)fluoranthene	1.00	0.33	1.69	0.36	0.56	0.12	0.6	0.1
Chrysene	1.00	0.33	2.58	0.54	0.85	0.18	0.9	0.2
Indeno(1,2,3-cd)pyrene	1.00	0.33	1.69	0.37	0.56	0.12	0.6	0.1
	Tree Swallow							
Mercury (Methyl)	0.02	0.76	0.02	0.02	0.02	0.01	0.7	0.5
Mercury (Divalent)	0.45	0.76	0.02	0.02	0.02	0.01	0.0	0.0
Di-n-butylphthalate	0.11	0.76	0.26	0.11	0.20	0.08	**1.8**	0.8

Table 5.7. Location of "Hot Spot" Soil Samples. 'Hot spots" defined as locations at which concentrations are > 10 times the mean. Note that chromium and mercury were elevated above background; risks from these metals considered directly

Sample Location	Metals at conc. > 10 * mean
BD-10	Antimony, nickel, chromium
EP-01	Mercury
EP-02	Cadmium, copper, mercury
EP-6	Arsenic
EP-04	Mercury
OA-13	Lead
OA-23	Cobalt
OA-26	Antimony

Table 5.8. Total PAH concentrations (ug/kg) in sediment samples. Total PAH equal to sum of all PAH compounds with less than detection values set equal to zero. % HMW is the proportion of high molecular weight PAH (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene). The TEC SQ, PEC SQ and Geomean SQ are the total PAH divided by the TEC (1610 ug/kg), PEC (22,800 ug/kg) and geomean of these two values (5868 ug/kg), respectively.

Sample Location	Total PAH	% HMW	TEC SQ	Geomean SQ	PEC SQ
SW-07-SS	299,900	53%	**198.6**	**51.1**	**13.2**
SW-06-SS	10,600	54%	**7.0**	**1.8**	0.5
SW-05-SS	4,090	64%	**2.7**	0.7	0.2
SW-01-SS	2,713	61%	**1.8**	0.5	0.1
SW-03-SS	1,910	56%	**1.3**	0.3	0.1
SW-12	1,344	47%	0.9	0.2	0.1
SW-10	863	70%	0.6	0.1	0.0
SW-02-SS	740	65%	0.5	0.1	0.0
SW-04-SS	729	64%	0.5	0.1	0.0
SW-15	19	0%	0.0	0.0	0.0
SW-16	0		0.0	0.0	0.0
SW-14	0		0.0	0.0	0.0
SW-13	0		0.0	0.0	0.0
SW-11	0		0.0	0.0	0.0
SW-08-SS	0		0.0	0.0	0.0
SW-08-SS	0		0.0	0.0	0.0

APPENDIX A
ESTIMATION OF WORM UPTAKE FACTORS FOR PAHS

Beyer and Stafford measured uptake of PAHs by earthworms in dredge spoils. However, use of uptake factors from Beyer and Stafford (1993) is problematic because the worms were analyzed before they had purged their guts. Thus, a considerable amount of some chemicals measured in the worms was associated with the soil in the guts. Beyer and Stafford suggest that the amount of ingested soil can be estimated by the observed uptake factor for aluminum, because they concluded that measured aluminum is almost all associated with ingested soil[10]. Based on this qualitative assessment, these authors conclude that "virtually all of the PAHs in the earthworms were in ingested soil". The UF for aluminum was 0.34, which suggests that about 1/3 of the total dry weight mass of the worm with soil gut contents was soil. Based on this assumption, the relative concentration of the worm with gut contents can be estimated as

$$33\% * [Soil] + 67\% * UF_{worm} * [Soil] = UF_{w+s} * [Soil]$$

Where [Soil] is the concentration of the compound in soil, UF worm is the uptake factor for the worm itself, and UFw+s is the observed uptake factor for the worm and unpurged soil. The equation can be simplified by dividing by [Soil] to yield

$$UF_{worm} * [Soil] = (UF_{w+s} - .33) / 0.67$$

UF_{w+s} for individual and total PAH are reported in Beyer and Stafford. Thus, the UFworm for each compound can be easily calculated, as shown in Table A1 below. Notably, the estimated UF_{worm} for total PAHs is 0, suggesting rapid metabolism of PAHs by the worms. While there were some individual PAHs with UF_{worm} values above zero, Beyer and Stafford doubt that these differences are biologically significant. There was no relationship between UF_{worm} and molecular weight of the PAHs ($r = 0.27$, $p = 0.30$, Spearman-Rank Correlation), the latter potentially an indicator of biodegradability.

[10]This supposition appears to be based on the common knowledge that aluminum if not readily incorporated into biological tissue. Data from Helmke et al. (1979) support this supposition. They estimated the bioaccumulation of a number of elements and found that several, including barium, chromium, iron, scandium, and thallium were not accumulated to any extent by earthworms. The authors note that except for barium, the elements having the lowest bioavailability "are ordinarily trivalent in soils and except for Fe, are generally biologically inert." Aluminum is also generally trivalent and also generally biologically inert.

Table A1. Observed uptake factor for PAHs and other chemicals in unpurged worms, from Beyer and Stafford, and calculated uptake factors for the worms themselves.

Compound	UF_{w+s}	UF_{worm}
Aluminum	0.34	0.01
PCB	2.70	3.54
DDE	2.70	3.54
Acenaphthene	0.30	0.0*
Acenaphthylene	0.22	0.0*
Anthracene	0.32	0.0*
Benz(a)anthracene	0.27	0.0*
Benzo(a)pyrene	0.34	0.01
Benzo(b)fluoranthene	0.21	0.0*
Benzo(g,h,i)perylene	0.15	0.0*
Benzo(k)fluoranthene	0.21	0.0*
Chrysene	0.44	0.16
Dibenz(a,h)anthracene	0.49	0.24
Fluoranthene	0.37	0.06
Fluorene	0.20	0.0*
Indeno(1,2,3-cd)pyrene	0.41	0.12
Napthalene	0.21	0.0*
Phenanthrene	0.28	0.0*
Pyrene	0.39	0.09
Total PAH	0.30	0.0*

* UF_{worm} was mathematically negative, and set to zero.

Bioaccumulation of PAHs by earthworms can also be estimated with data supplied by Talley et al. (2002), who also conducted bioaccumulation experiments with earthworms living in dried sediments. In these experiments, the worms were allowed to purge their guts for 24 hours; thus, these data provide a more direct indication of worm bioaccumulation.

As with the Beyer and Stafford data, the Talley et al. data demonstrate low rates of bioaccumulation of PAHs by worms (Table A2). On average, worms had about 7% of the PAH concentrations as soils, on a dry weight basis. Observed bioaccumulation varied by PAHs, and there was a marginally significant relationship between UF_{worm} and molecular weight of the PAHs ($r = 0.49$, $p = 0.052$, Spearman Rank Correlation). However, the UF_{worm} values estimated with these data showed no relationship with those estimated from the Beyer and Stafford data ($r = 0.27$, $p = 0.31$, Spearman Rank Correlation). On a dry weight worm to dry weight soil basis, UF_{worm} for total PAHs averaged 0.07. Worms are typically 83% water (EPA 1993), so a wet weight worm to dry weight soil UF would be approximately 0.01 on a wet weight worm to dry weight soil basis.

Table A2. PAH concentrations in soil and purged worms from Talley et al.
All concentrations as dry weight.

PAH	Soil Conc. mg/kg	Worm Conc. mg/kg	UF_{worm}
Acenaphthene	2.08	0.03	0.02
Acenaphthylene	0.28	0.01	0.04
Anthracene	3.19	0.03	0.01
Benz(a)anthracene	6.67	0.54	0.08
Benzo(a)pyrene	6.81	1.10	0.16
Benzo(b)fluoranthene	7.36	1.34	0.18
Benzo(g,h,i)perylene	5.28	0.35	0.07
Benzo(k)fluoranthene	6.11	0.63	0.10
Chrysene	9.58	1.07	0.11
Dibenz(a,h)anthracene	1.11	0.13	0.11
Fluoranthene	21.67	0.71	0.03
Fluorene	2.22	0.02	0.01
Indeno(1,2,3-cd)pyrene	5.28	0.47	0.09
Napthalene	1.39	0.03	0.02
Phenanthrene	15.28	0.10	0.01
Pyrene	17.50	1.60	0.09
Sum of PAH	111.81	8.17	0.07

A third study, for worms living in a variety of contaminated soils, was conducted by Krauss et al. (2000, 2001). These authors report Biota to Soil Accumulation Factors (BSAF) values. Most of the PAHs had BSAF values between 0.10 to 0.20, although three intermediate molecular weight PAHs (fluorene, anthracene, and phenanthrene) had BSAF values between 0.25 and about 0.5 (Table 3). These BSAF values are normalized to worm lipid, 1.2% of wet weight, and soil carbon, which averaged 3.4%. To make these values comparable to the other two analyses, these were converted to a dry weigh worm to dry weight soil UFworm. The effects of carbon and lipid were removed by multiplying by 3.4%/1.2%, and then these values were converted to dry weigh worm UF by dividing by 0.17%.

As can be seen (Table A3), values reported by Krauss et al. are considerably higher than those reported by the previous two analysts. These differences could be due to differences in texture or organic carbon. Dredged sediments might tend to be finer grained and have higher organic carbon than soils. In view of this uncertainty, the average UF_{worm} from Krauss et al. (0.47) was selected as the appropriate value to estimate earthworm concentrations. This value is equal to a wet weight worm to dry weight soil UF of 0.08. For simplicity and conservatism, a value of 0.10 was used in the food chain analyses.

Table A3. BSAF values for worms reported by Krauss et al. BSAF values are expressed on a lipid and organic carbon basis. The UF_{worm} is expressed on a dry weight worm to dry weight soil basis.

PAH	BSAF	UF_{worm}
Acenaphthene	0.23	0.29
Acenaphthylene	0.17	0.35
Anthracene	0.43	0.47
Benz(a)anthracene	0.18	1.06
Benzo(a)pyrene	0.21	0.63
Benzo(b + k)fluoranthene	0.17	0.88
Benzo(e)pyrene	0.23	0.37
Benzo(g,h,i)perylene	0.16	0.35
Chrysene	0.24	0.38
Dibenz(a,h)anthracene	0.17	0.50
Fluoranthene	0.18	0.35
Fluorene	0.51	0.43
Indeno(1,2,3-cd)pyrene	0.21	0.47
Napthalene	0.14	0.40
perylene	0.19	0.43
Phenanthrene	0.31	0.35
Pyrene	0.17	0.34
Average for all PAHs	0.23	0.47

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This report was prepared under the direction of
Westinghouse Electric Company

By

Daniel Smith
Conestoga-Rovers and Associates Inc.
559 West Uwchlan Avenue, Suite 120
Exton, Pennsylvania 19341
(773) 380-9933

and

Billy R. Thomas, CHP, CIH
Integrated Environmental Management, Inc.
2705 North Main Street, Suite 202
Findlay, Ohio 45840
(419) 423-4701