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Riverbank Stabilization of Lead Contaminated Soils Using Native Plant Vegetative Caps

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Hamburg is a small borough located in Berks County, Pennsylvania. During the 1940s and 1950s, crushed automobile battery casings, containing high levels of lead, were used as fill in and around Hamburg. Several of the fill areas were along the eastern bank of the Schuylkill River and the Schuylkill River Canal. To reduce exposure to human and ecological receptors, the United States Environmental Protection Agency (U.S. EPA) initiated actions at several of the fill areas. Remediation actions at three of these fill areas, the Berry Property, the Hamburg Playground City Playground, and the Port Clinton Avenue site, utilized native plants, slope stabilization, and soil caps.

The Berry Property consisted of a flat, wooded area adjacent to the river. The Hamburg Playground consisted of a steep wooded slope between the river and the parking lot for the municipal park. The Port Clinton Avenue site consisted of flat and sloped, wooded, and old-field areas between the canal and Port Clinton Avenue. At each of the three sites, some of the contaminated soils were excavated and the remainder was graded and capped. The clean soil cap was then covered with an erosion control mat, seeded with native grasses, and planted with native shrubs. At the Hamburg Playground and Port Clinton Avenue site, the existing trees and much of the existing vegetation were maintained to preserve the slope stability and the natural environment. Great care was taken to ensure community access to the municipal park. Some of the important considerations included retaining the existing trees, dealing with invasive species, maintaining the plants during a drought, and channeling storm-water runoff. The work was coordinated with the Hamburg Borough Council, the Schuylkill River Greenway Association, and the Pennsylvania Department of Environmental Protection (PADEP).

The actions resulted in a stabillized slope with channelized storm water to control erosion and protect the river, a clean soil and plant cover that eliminates exposure to human and animal receptors, and an aesthetically pleasing and usable area that meets the needs of the community and the local conservation/environmental organization.

Keywords Lead, restoration, stabilization, capping, revegetation

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Introduction

The Price Battery Plant operated in Hamburg, Pennsylvania (PA), (Figure 1), from 1918 to the mid-1990s. While in operation, lead-acid battery casings were broken open and the lead plates inside the batteries were removed for re-smelting. The casing material was given away free to the public. Because this material was free, it was used throughout the Borough of Hamburg and surrounding areas as fill. The fill areas range from small residential lots to a large municipal park, many of them in low areas along the banks of the Schuylkill River and the Schuylkill River Canal. Often, the fill material contained residual pieces of the battery casings and lead plates, and in some areas these pieces are readily observed at the ground surface. The lead concentration in the fill material has been recorded as high as 7% (70,600 milligrams per kilogram (mg/kg)) and consistently ranges from 3,000–10,000 mg/kg (U.S. EPA, 1995).

Several previous studies and U.S. EPA actions have been conducted at the Hamburg sites under the Removal Branch of the Superfund Program. In 1992, the U.S. EPA Assessment Section measured high levels of lead (over 1,000 mg/kg) while conducting a Screening Site Inspection (SSI). In December 1992, the U.S. EPA Region III Site Assessment Section completed an SSI of the Hamburg Playground and, in April 1993, completed an SSI for the Hamburg Fieldhouse. During August 1993, the Removal Branch performed additional assessments of both the Hamburg Playground and the Hamburg Fieldhouse. Broken battery casings were observed at the ground surface in both areas. These areas were unfenced and readily accessible to the public. The U.S. EPA then conducted soil sampling activities, and lead was detected above health-based risk levels in the surface soils, presenting an imminent and substantial threat to human health. At that time, the U.S. EPA action level for lead in surface soils was 500 mg/kg in residential areas, and the levels found in Hamburg were several orders of magnitude above this level (U.S. EPA, 1995).

During the U.S. EPA actions conducted from September 1993 through October 1995, approximately 1,450 tons of excavated contaminated soil and debris, along with used personal protective equipment, were collected and disposed of at a landfill. In addition to excavation and disposal, capping was employed in several of the areas. Then, in September 1999, broken battery casings were discovered in areas adjacent to the sites previously addressed. Therefore, in March 2000, a screening-level ecological risk assessment (SLERA) was conducted (U.S. EPA, 2000a) that indicated a potential ecological risk from exposure to high levels of lead in soil and sediment. In June 2000, a baseline ecological risk assessment (BERA) was prepared (U.S. EPA, 2000b). Based on the results of the ecological risk assessments, and in consultation with the Agency for Toxic Substances and Disease Registry (ATSDR), an action level of 400 mg/kg was determined sufficient to protect both human health and the environment. In consultation with private land owners, several fill areas with soil lead levels above the action level were identified throughout the borough.

Study Goals

Due to the large amount of material that was excavated and disposed of during the previous operations, alternative remediation methods were evaluated and employed at three of the newly identified fill areas. The objective of this evaluation and action was to identify and implement an alternative to excavation and offsite disposal, which would stabilize the slopes, prevent surface run-off, reduce human and ecological exposure to lead-contaminated

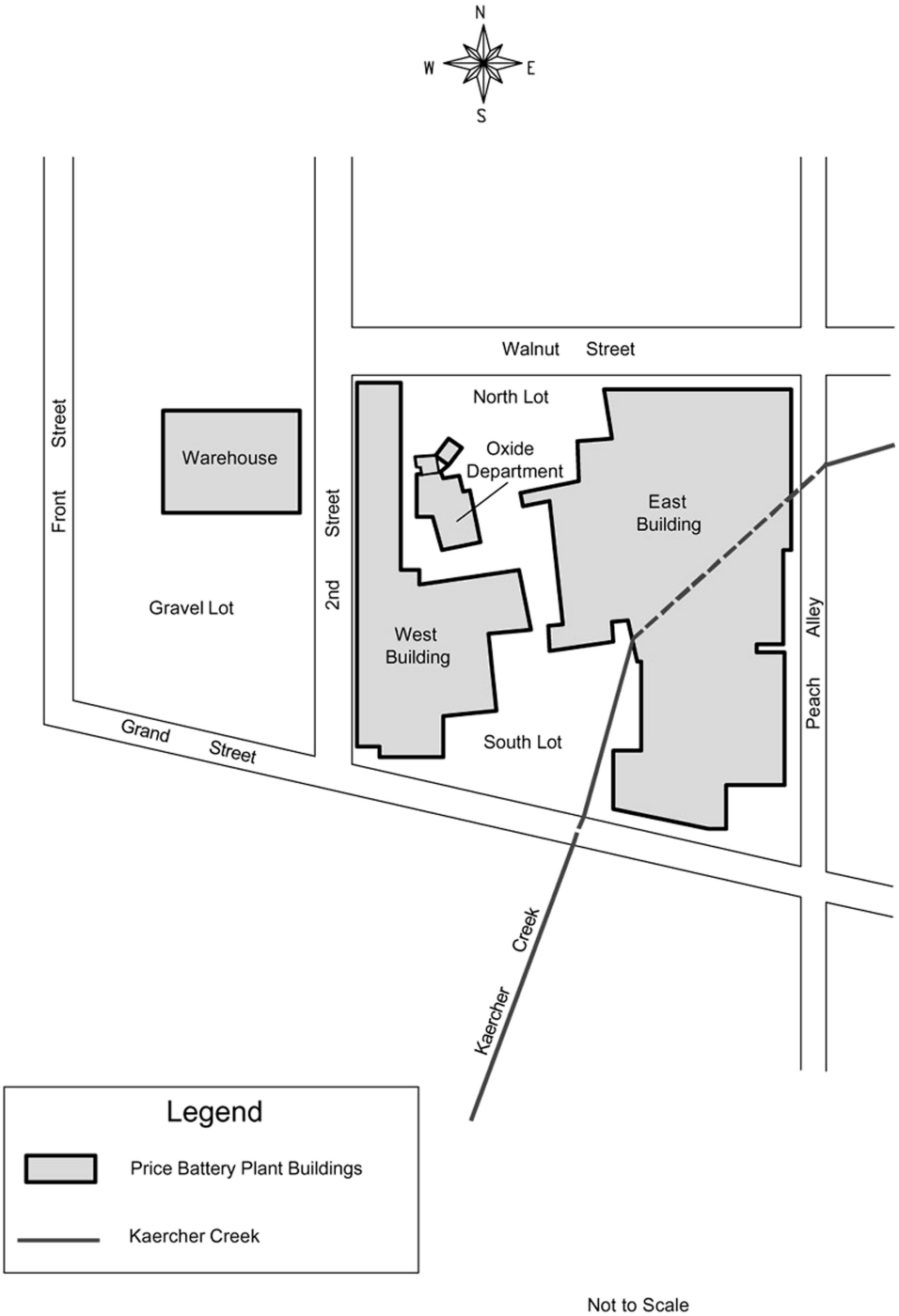

Figure 1. The Price Battery Plant in Hamburg, PA.

fill material, be cost-effective, be consistent with the plans of the Schuylkill Greenway Association, and meet the needs of the local community.

Site Description

The three fill areas of concern are the Berry Property site, the Hamburg Playground site, and the Port Clinton Avenue site (Figure 2). Due to decades of improper use of waste battery casings as fill material, these sites were confirmed to contain many areas of lead contamination above the established action level concentration of 400 mg/kg.

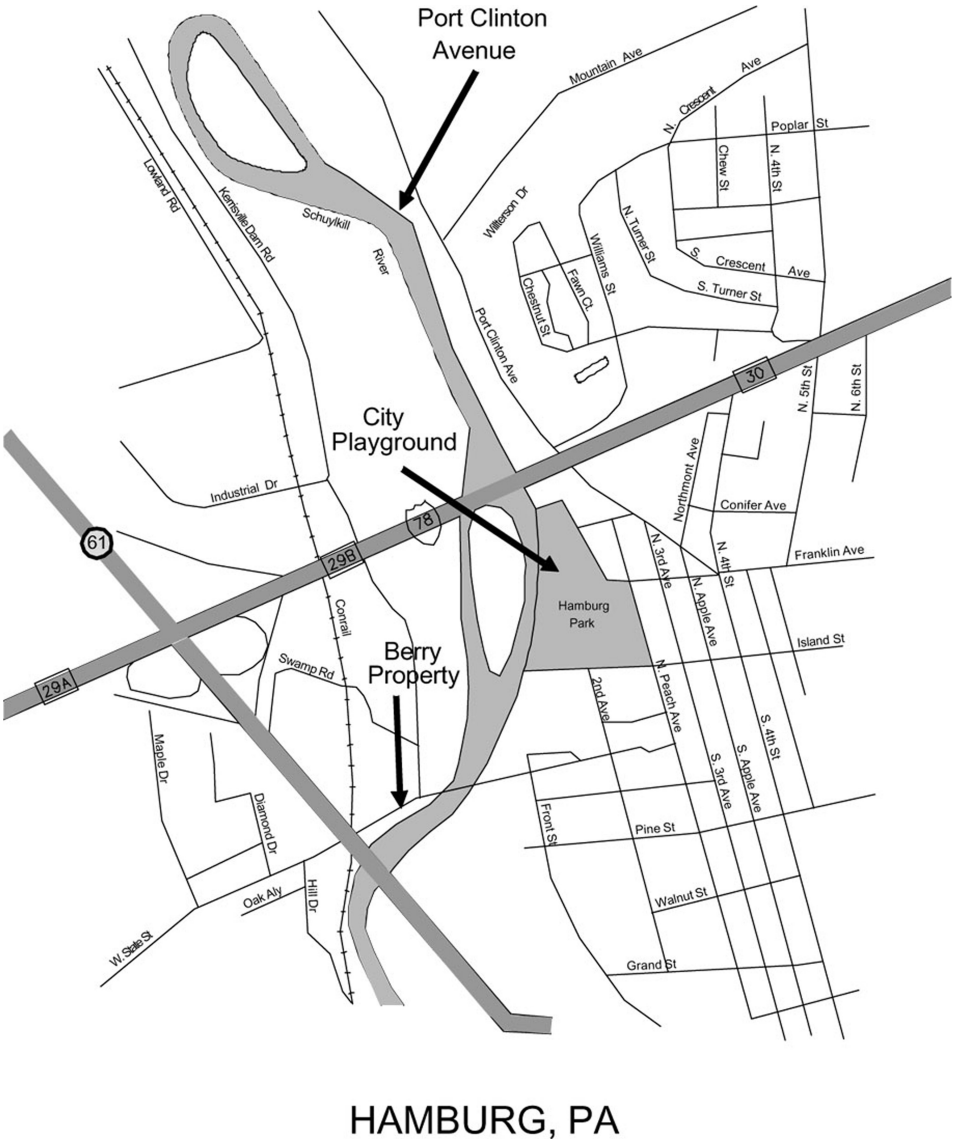

Figure 2. Relative locations of the three fill areas of concern.

The Hamburg Playground Site was a steep wooded embankment visually contaminated with battery casings and battery chips, along a 185-meter section of the Schuylkill River and adjacent to the parking lot for the community park. The Port Clinton Avenue site was an overgrown, vegetated area, which varied in topography and was contaminated with small amounts of battery casings and battery chips, along a 170-meter section between the Schuylkill River Canal and Port Clinton Avenue. The Berry Property was a fairly flat, wooded area that contained battery casings to a depth of greater than 1 meter along a 275-meter stretch of the river.

The Hamburg Playground and Port Clinton Avenue site were dominated by large, established trees and are within view of the general Hamburg population, who utilize adjacent areas for recreation. Of note were several yellow poplars (*Liriodendron tulipifera*), sycamore (*Plantanus occidentalis*), and a black oak (*Quercus velutina*) that ranged from 91 to 122 cm in diameter. These trees were naturally helping to stabilize the stream bank.

Agencies and Parties Involved

U.S. EPA Region III had authority for the remediation actions, and they were supported by two of their contractors: the Emergency Rapid and Response Services contractor, Earth Tech, Inc., who implemented the remedy, and the Superfund Technical Assistance and Response Team contractor, Tetra Tech, (EMI), who provided technical and oversight support. Region III turned to the U.S. EPA Environmental Response Team (ERT) to provide technical support to the revegetation plan, including the selection of appropriate native shrubs and native seed mixtures, deciding which particular trees should be left in place, and advising on strategies for surface grading and storm water runoff. ERT was supported in all of these activities by Lockheed Martin, under the Response, Engineering, and Analytical Contract (REAC). The U.S. EPA also requested the assistance of the United States Fish and Wildlife Service (USFWS) to help ensure that the actions implemented resulted in minimal ecological impact.

The U.S. EPA consulted with several other agencies prior to and during the activities at the sites. The Berks County Conservation Service was consulted about the seed mixture composition and dates of seeding for the Berry Property. The Borough of Hamburg was consulted, as was the owner of the Hamburg Playground and Port Clinton Avenue site. Regular meetings were held with members of the Hamburg Borough Council and the mayor. At these meetings, proposed remediation plans were presented and the council was allowed to comment. These comments were incorporated into the final remediation work plans. Representatives of the Pennsylvania State Department of Natural Resources were also contacted and included in decisions on the work plans. These regular meetings and the ability to comment allowed all appropriate agencies and representatives of the public to agree on the final outcome.

Consultation with the Schuylkill River Greenway Association

The Schuylkill River Valley has been designated as a National Heritage Area (SRVNHA). This river valley is one of only 24 areas in the United States to receive this designation. A National Heritage Area is defined as an area where the environment has shaped human traditions and values, and in turn the use of the land has created a landscape that reflects their cultures (NPS, 2004). The SRVNHA is managed by the Schulkill River Greenway Association (SRGA). One goal of the SRGA is to link a series of trails together to form

Figure 3. Wildflowers along the path at Hamburg Playground.

a complete system of greenways and trails from Philadelphia to Pottsville, PA. As part of this greenway expansion, in 1997, the Hamburg Area Inter-Club Council (HAICC) and the SRGA prepared a plan for the creation of the Hamburg River Park (HAICC, 1997). The River Park would create an extension of the already established Bicentennial Walkway (Figure 3) that is located to the north of the Hamburg Playground. The park would be used for recreational activities such as walking, hiking, jogging, and fishing. In addition, this section of the river would contain a pullout area for car-top boats (e.g., canoes, rafts, and tubes).

This River Park plan calls for the park to be further developed as a naturalized environment. In addition, the plan calls for the removal of fill (i.e., battery casings and other debris) along the bank. Besides the ecological components of the park, this plan also describes the physical parameters that should be used in any construction activities (i.e., walkway construction or river access points). Therefore, in order to comply with the guidelines set forth in the River Park plan, a representative of the Schuylkill River Greenway Association was contacted and participated in the development of several aspects of the work plan, specifically those sections within the Hamburg Playground.

Materials and Methods

Physical Delineation

Visual observation of battery casings along with the chemical results of lead analysis in soil were used to delineate fill areas of concern. At each site, an initial series of transects was established based on the visual presence of battery casings. Surface soil (0–15 cm in depth) samples were collected from nodes at 15-meter intervals along the transects. These

samples were analyzed for lead, and the results were then reviewed to determine if there were wastes present at levels of concern (lead concentrations greater than 400 mg/kg). Transects were added and/or extended based on the results, to ensure a complete delineation of each site.

Samples collected from the river or canal were not usually collected along a predetermined transect, but rather their locations were based on the visual observation of battery casings. Biased samples were also collected in depositional areas, obvious run off pathways, or in locations needed to further refine a fill area.

Lead Analysis

Lead was the contaminant of concern at all of the Hamburg sites. For all soil and sediment samples, a Niton 700® X-Ray Fluorescence (XRF) Spectrometer was used to measure lead concentrations. Soil and sediment samples were collected from the top layer (0–15 cm depth) and homogenized in disposable aluminum pans. The samples were then taken back to a laboratory trailer where they were dried in an oven at 100°C for approximately 1–2 hours. Following the sample drying, the samples were sieved through a 10-mesh (<2 mm) stainless steel sieve to remove rocks and large pieces of organic debris. Next, samples were placed in a labeled 31-millimeter (mm) polyethylene X-ray cup and sealed with 0.2 mil thick polypropylene X-ray window film. The sample cup was placed directly on the aperture window of the XRF spectrometer for the measurement of lead concentration. The method detection limit was generally around 50 mg/kg lead.

The XRF spectrometer was checked daily using National Institute of Standards and Technology (NIST) reference materials. Sample duplicates were also measured, and 10% of the samples were analyzed for either total lead or target analyte list (TAL) metals using a U.S. EPA Contract Laboratory Program (CLP) facility.

Remediation Method Evaluation

Four remediation technologies and strategies were evaluated: limited excavation with a vegetative cap; excavation and disposal; impermeable cap; and chemical stabilization. Each technology was evaluated based on cost, effectiveness of reducing exposure risk, and public acceptance.

Work Plan/Section Design

At the Hamburg Playground and Port Clinton Avenue site, the areas of concern were separated into segments for delineation and remediation. This delineation was done in part because of variations in the slope of the river bank, and also so that a large area was never stripped of its native vegetation for a long time period before the clean soil cap was installed. At the Hamburg Playground, there were large variations in the slope and amount of existing vegetation on the bank. Therefore, 33 individual segments were established, with each segment consisting of a 4-meter stretch of river bank. At the Port Clinton Avenue site, the segments were based on size and physical features, rather than on a strict size measurement like those at the Hamburg Playground. The banks of the canal were not as steep or large as those at the Hamburg Playground. Therefore, it was determined that larger sections would be practical for the remediation. In addition, a drainage swale and an access road served as natural delineations for the sections, resulting in five individual segments.

Within each segment, the vegetation species, the percent cover, the presence of battery casings, and the topographical details were noted and recorded. Then, based on these observations, along with the analytical results, a work plan (WP) was written for each segment. The existing slopes of the river embankment were determined, and a cross-section (Figure 4) of each segment was developed. Finally, a 2-meter horizontal to 1-meter vertical slope (2 to1) was laid out, and the amount of contaminated material to be excavated to achieve this slope was calculated.

The Berry Property was not separated into segments, but rather addressed as a whole. The boundaries were defined as beginning at the western bank of the Schuylkill River and extending west to the boundary of the existing cap (approximately 50 ft.).

Excavation/Regrading Technique

The first step of the remdiation actions was to clear the existing understory vegetation. For the Hamburg Playground and Port Clinton Avenue site, larger trees (greater than 15 cm diameter at breast height [dbh]) were flagged. Then, trees, shrubs, and vines smaller than this were cut down to ground level. An attempt was made at the Hamburg Playground to leave approximately 15–30 cm stumps of the smaller shrubs in place to maintain bank stability and to promote regrowth following the remediation action. However, these stumps became a tripping hazard, and it was subsequently decided that all small vegetation should be cut down to the ground surface. The flagged trees were left standing unless it was absolutely necessary to remove them to allow for the regrading to achieve the 2 to 1 slope required for a stable bank. Extreme care was used to protect all tree roots and branches from damage during the removal activities.

The Berry Property was handled differently for two reasons: first, a flood during the fall of 1999 knocked over many of the trees and shrubs along this section of the river; and second, this section of the river bank was fairly flat, thus the stability of the bank was not a significant issue. Therefore, the vegetation was removed by grubbing, and the larger trees were cut up and removed in pieces.

Next, several types of equipment were used to either excavate material or to pull back the banks so that they were not as steep (to prevent erosion). At the Hamburg Playground, a medium-sized excavator and backhoe were used to regrade the slopes of the river embankment to as close to 2 to 1 as possible. At the Port Clinton Avenue site, a zero-clearance excavator and a small Bobcat™ were used whenever possible. Great care was taken when working around the large trees that were left standing to avoid damaging the bark or the root structures. Soil excavated in the process of regrading was stockpiled and later sent to a certified landfill. Since there were no standing trees at the Berry Property, a large excavator and front end loader were used to excavate and directly load dump trailers for hauling the contaminated material to a certified landfill.

Once the desired river bank angle was achieved, a layer of high-visibility, orange erosion fence was laid over the ground surface. This material was put in place as a marker for any future activities. Approximately 15–25 cm of clean topsoil was then placed over the erosion fence and compacted using a vibratory-plate compactor. Because it was desired to preserve the mature trees at the Hamburg Playground and Port Clinton Avenue site, there was a large amount of manual handwork required. This did not affect the quality of the cap, but did make the work labor-and time-intensive. For example, it took approximately one full 12-hour day to clear and cap a 4-meter section at the Hamburg Playground. For the next step, a 1-inch mesh jute mat was placed over the soil and pinned in place. Seeds were

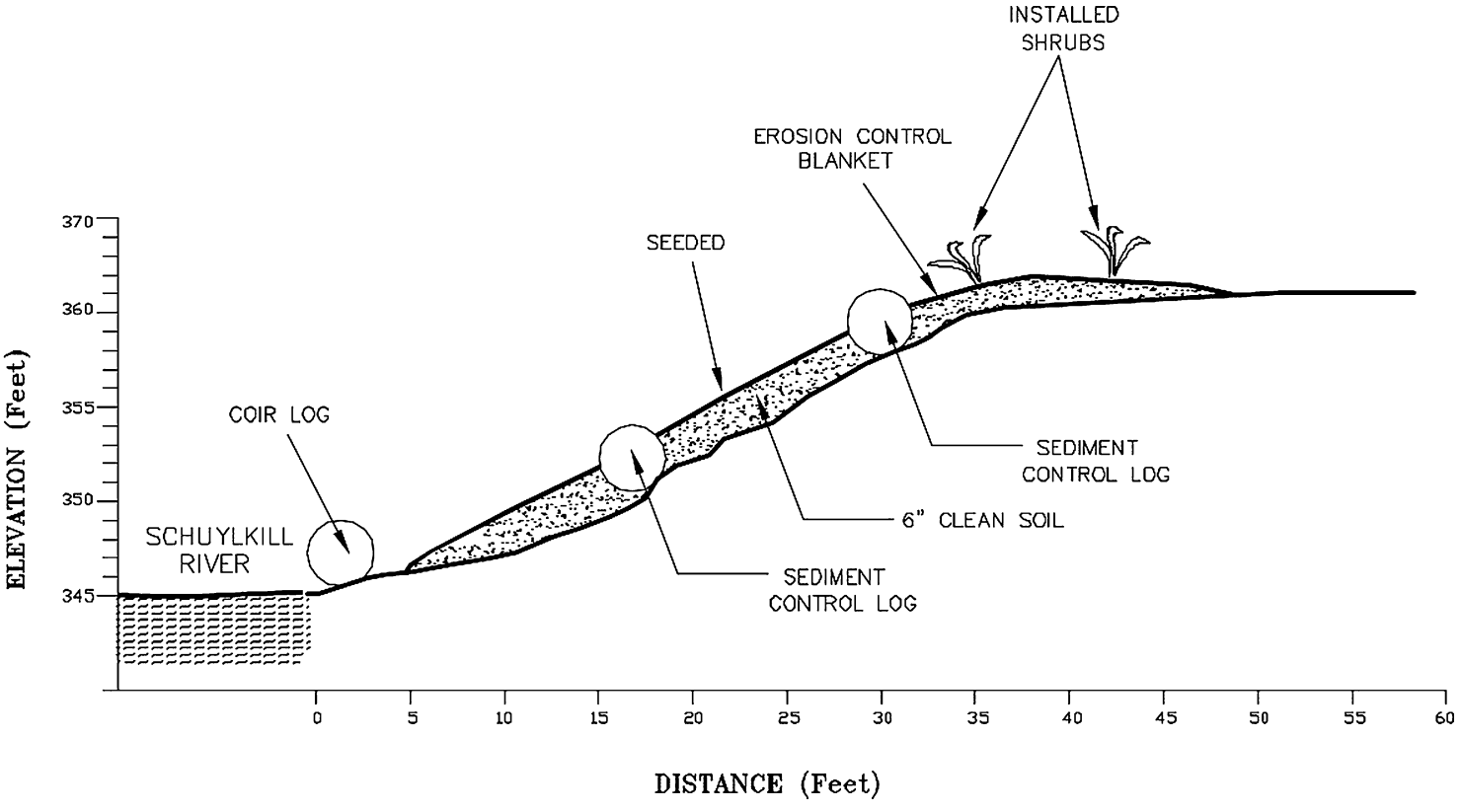

Figure 4. Cross-section of riverbank at the Hamburg Playground.

broadcast directly over the mat. For shrubs, holes were cut in the mat and the shrubs planted in the clean fill. Once all remediation steps were completed for a section, the operators moved on to the next section. During dry periods, the segments were watered to promote seed germination and plant growth.

Revegetation Design and Methods

Many revegetation designs utilize mixtures of lawn grasses or quick growing species suitable for erosion control. Although this is standard practice, the U.S. EPA is now trying to utilize suitable native species wherever possible. Because much of the contaminated streambanks were in public areas and had a dense cover of trees and existing vegetation, it was desired to blend remediated areas with the surrounding landscape and to save the large existing trees at the Hamburg Park and Port Clinton Avenue site.

Woody material. Use of native species for site restoration is part of Superfund's Redevelopment Initiative. Native species are adapted to local conditions and provide food and habitat for wildlife. In addition, revegetating an area helps to prevent colonization of disturbed soil by invasive "weeds." Criteria for native plant species selection included adaptability to site conditions, species diversity, and wildlife value. At the Hamburg Playground property, a mixture of several species was used to provide four-season interest, as the shrubs were planted adjacent to a well-used path. Woody species selected included Winterberry Holly (*Ilex verticillata*), Red-twig Dogwood (*Cornus sericea*), Red and Black Chokeberry (*Aronia arbutifolia* and *A. melanocarpa*), Inkberry Holly (*Ilex glabra*), Summersweet (*Clethra alnifolia*), and Arrowwood Viburnum (*Viburnum dentatum*). At the Berry Property, three shrub species—Winterberry Holly (*Ilex verticillata*), Red-twig Dogwood (*Cornus sericea*), and Red Chokeberry (*Aronia arbutifolia)*—were utilized close to the stream bank. It was anticipated that these would help stabilize this area during occasional flooding and also provide bright red stems and berries for autumn/winter interest to the local people. In total, 30 native shrubs were planted at the Hamburg Playground site and 155 native shrubs at the Berry Property site. The shrubs were generally purchased in 2-liter (L) pots and had to be carefully planted by hand to ensure that the cap was not breached during installation. No shrubs or trees were planted at the Port Clinton Avenue site.

Seed mixtures. A shade-tolerant seed mix was used at the Hamburg Playground and the Port Clinton Avenue site, while the Berks County standard seed mix was used at the Berry Property. Annual Ryegrass (*Lolium multiflorum*) was seeded over most of the area as a temporary cover along the banks at the Hamburg Playground and the Port Clinton Avenue site, as it was anticipated that the existing vegetation would soon reestablish. Special attention was given to the Bicentennial Greenway path, which ran along the upper slope at the Hamburg Playground. Since this path is utilized by the public for recreational activities, wildflower plugs and seeds were planted along a split rail fence that was installed parallel to the path. The seed mixture was a combination of a native Eastern Wildflower and native meadow seed mixture purchased from a producer/supplier of native seed, which is locally adapted. Many "wildflower" mixtures on the market contain showy but nonnative, and sometimes invasive, alien plant species. An effort was made to utilize seeds and plants native to this particular part of Pennsylvania and appropriate for site conditions. The seed mix included species such as Black Eyed Susan (*Rudbeckia hirta*), Ox Eye Sunflower

(*Heliopsis helianthoides*), and Pale Purple Coneflower (*Echinacea pallida*). As some of the native species are slow to establish from seed, plugs of native New England Aster (*Aster novae-angliae*) were also planted along the fence to provide showy blooms during the first growing season.

Watering schedule. For the fall planting at the City Playground, it was assumed that an initial watering for six weeks would be sufficient to establish the plants. For the spring plantings at the Port Clinton Avenue and Berry Property sites, it was assumed that a watering schedule through August would be sufficient to establish the plants. These sites were generally watered daily throughout the period using water pumped directly from the river.

Results

Remediation Method Evaluation

Installation of a vegetative cap was selected as the remediation method. This consisted of limited excavation, physical stabilization by grading to a 2 to 1 slope, installation of a clean soil cap, and planting with a covering of native shrubs and/or grasses for erosion control.

Remediation Action Implementation

The initial cap installation was completed at the Berry Property site in the spring of 2001, the Hamburg Playground in the fall of 2001, and at the Port Clinton Avenue site in the fall of 2002. However, several problems were encountered at the Hamburg Playground and Berry property sites that required maintenance to continue through to the fall of 2002. Problems involved a drought, destruction of plants by geese, and invasive plants. Despite these setbacks, the vegatative caps at all three sites were well established by the end of the fall of 2002.

Discussion of Results

Remediation Method Evaluation

Before deciding on the vegetative cap that was employed at these sites, other remediation technologies and strategies were also investigated. The other primary technologies investigated included excavation and offsite disposal, a traditional impermeable cap, and chemical stabilization techniques.

Excavation and disposal. Excavation and disposal in a secure hazardous waste landfill is a known and proven method to remove lead-contaminated soils. Although it was used as part of the treatment strategy at all three of the sites it was deemed to be inappropriate as the primary treatment for several reasons. First, at both the Hamburg Playground and Berry Property, adjacent areas had been previously capped and considered safe and stable. Excavating near these previously capped areas may have damaged the previously existing cap. Also, excavation and disposal were inconsistent with the previous choice, a vegetative cap, which was still deemed appropriate and protective. At the Hamburg Playground and Port Clinton Avenue site, it was decided that since there were several large trees stabilizing the river embankment, excavation would do more harm than good. There was also a cost

consideration since there was a high potential for the contamination to be several feet deep at all of the sites. At $100.00/ton (actual site incurred cost) for transportation and disposal (not accounting for excavation, backfilling, and grading), the cost would have escalated quickly.

Impermeable cap. A standard impermeable cap usually consists of a low permeability layer (usually clay) to prevent water from infiltrating into the covered matrix, and sometimes includes a drainage layer to collect leachate. At both the Hamburg Playground and Port Clinton Avenue site, it was not feasible to attempt to install an impermeable cap around the existing trees. Also, for all three of the sites, the two major routes of exposure were direct contact for humans and erosion into the river for the ecosystem. Based on these exposure concerns, it was not deemed necessary to install an impermeable cap.

Chemical stabilization. Chemical stabilization in many forms was considered for the sites. A large-scale excavation, chemical stabilization, and replacement scheme was developed for the Berry Property. A bench-scale treatability study utilizing biosolids and phosphoric acid determined that the soils could be sufficiently treated to a point where the lead concentration in the leachate was below the regulatory limit. The realities of accomplishing this at full-scale, however, were less promising. Due to the nature of the waste and the tight site conditions, it was doubtful that the mixing could be done thoroughly enough to treat all of the soil. Also, due to the site being on a riverbank, there were concerns about using biosolids or vendor supplied proprietary ingredients that might adversely impact the aquatic ecosystem. At the other two sites, *in-situ* chemical stabilization was considered, where phosphorus, in the form of diammonium phosphate, would be mixed into the top few inches of the soil. Again there was concern about being able to adequately mix the chemical into the soil, since in this case it would be done with hand tools around trees and roots. U.S. EPA decided that the additional time and money required to stabilize the soil were not feasible, since complete soil stabilization was uncertain.

Remediation Action Implementation

Due to the severe drought in 2002 and destruction by geese at the Berry Property, a large portion of the vegetation cap was damaged and required re-seeding. Attempts to reseed the area were once again thwarted by geese eating the seed. After many unsuccessful attempts to scare away the geese (i.e., balloons) the area was re-seeded, and covered until germination was achieved. Therefore, watering continued from the spring through the end of September 2002.

The drought killed a large section of the grass at the Hamburg Playground site as well, which required re-seeding and continuous watering throughout the next summer. At the Hamburg Playground, the geese were sitting on the shrubs and pulling them out of the ground. Where necessary, the shrubs were replanted and barriers were installed for protection. The native wildflower mixture established very well in 2002; however, it had the benefit of frequent watering during this dry summer. It should be noted that many native wildflowers and grasses are slow to initially establish, and may not show final height or bloom until the second or third season. Annual ryegrass, although nonnative, was used as quick cover and for erosion control in some of the wooded areas. Because of the surrounding mature trees, it was anticipated that these areas would quickly revegetate on their own from the expansion of surrounding vegetation and its seedbank. Although annual ryegrass may

persist for a season or two, it generally will be eventually outcompeted and replaced by other vegetation.

At the Port Clinton Avenue site, the grass was watered continuously throughout the summer and became well established by the end of the growing season. Invasive plant species can cause havoc on a revegetation effort. Many invasive species take advantage of disturbed soils and, for this reason, it is especially important to seed or plant a vegetative cover of more desirable species.

The invasive species Japanese Knotweed (*Polygonum cuspidatum*) became a troublesome issue at the Hamburg Playground. Initial attempts to control Japanese Knotweed included cutting, application of herbicide, and building a root barrier (trench, stone) to prevent further spreading. Several more attempts were made in the spring, and each time the Knotweed was cut back and then sprayed with herbicide at the first sign of regrowth. Crown Vetch (*Coronilla* sp.), Dock (*Rumex* sp.), and other invasive plant species also began to appear in the wildflower and shrub areas. Where possible, some of these were pulled by hand.

Despite the challenges, all of the plants were well established by the fall of 2002, and continued to thrive through the 2003 growing season. The wildflower mixture began to bloom late in 2002 and has continued through the seasons in 2003 in full view of the community. Despite the extensive remediation efforts, the area appeared relatively undisturbed within a short time after its completion. This is especially important in areas used by the community for recreation.

Reduction in Exposure—Human Health

One priority of the removal activities at the Hamburg Lead sites was to limit the exposure of lead to humans. In a memo written by ATSDR (U.S. DHHS, 1993), the recommendations included the prevention of exposure to areas of soil contamination at levels greater than 500 to 1,000 mg/kg. The results of soil sampling at several of the waste sites indicated that lead concentrations were almost always greater than this range. For example, a recent survey of samples collected along a section of Kaercher Creek (another site in the Hamburg area) indicated lead concentrations along the bank ranged from 430 to 45,184 mg/kg, with 25 out of 33 of the samples containing greater than 1,000 mg/kg lead. Therefore, the remediation action completed at the Hamburg Playground (limited excavation and bank stabilization followed by capping) blocked the exposure pathway to humans and effectively reduced the risk of lead contamination.

Reduction in Exposure—Ecological

Another priority at the Hamburg Lead sites was to limit the exposure of lead to ecological resources and reduce the source of contaminated material from upland areas to the surrounding creeks and river. An ecological risk assessment (U.S. EPA, 2000b) indicated risk to ecological resources above 400 mg/kg lead in soil and sediment. For example, sediment toxicity tests of the waste material indicated that it was acutely toxic to benthic invertebrates following 10 days of exposure (U.S. EPA, 2000b). The sample was collected in an area where waste material had sloughed off the bank and had settled in the creek sediment. The successful bank stabilization efforts should prevent the run-off of waste material from the bank into the Schuylkill River and reduce exposure to ecological receptors.

Additional Benefits

Upon completion of the remediation activities, several added benefits were gained by the SRGA at little or no additional cost to the U.S. EPA. For example, the trail from the Bicentennial Walkway was extended south approximately for 125 meters. The trail was designed using the criteria in the Park Plan (i.e., 2.5 meters wide, with a surface slightly higher than the surrounding areas). This trail benefitted the remediation action in that it effectively stopped surface water runoff from an adjacent parking lot from flowing over the cap and causing an erosion problem. A second benefit was that unsightly rip rap was removed from one section of the bank (due to high lead contamination) and the vegetative cap was extended to cover this area. These plants added to the aesthetic appeal of the walking trail and followed the guidelines that the park be developed as a natural environment.

Conclusions

At all three sites, the remediation action accomplished the goals of both the U.S. EPA and the local community. Human and ecological risks were abated by eliminating routes of exposure, and the public was left with a pleasing and natural environment. For the Hamburg Playground and Port Clinton Avenue site, there was minimal habitat destruction by leaving the larger trees and the existing root mat in place. In addition, this allowed for the bank to remain stabilized in the event of a flood. The use of a native seed mixture and the planting of indigenous shrubs at all three sites increased the habitat value along the banks of the river. The addition of flowering plants also created pleasing aesthetic value, which was important to the Borough and the SRGA. Although native seed mixtures may take as much or more attention to prepare an area and seed as standard "contract mix" or lawn grass, they will ultimately require less maintenance (cost reduction) and provide much higher benefit to local wildlife. This will allow increased recreational use of this park while maintaining the protective nature of the cap. Controlled access to the river along the pathway via a stairway that was built from the walkway to the river's edge and a fence along the top of the river will hopefully discourage disturbing the remediated bank.

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