Riverfront Remediation:
Redevelopment for Human Access and Wildlife Health

by

Tyler Swehla

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture, Regional & Community Planning
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Abstract

Historically, industrial riverfronts often polluted waters and sites with chemicals, leading to degraded ecosystem health and reduced numbers of aquatic wildlife downstream. These sites currently pollute the environment through residual chemicals and waste left behind by industrial-era production factories. Urban riverfront redevelopment offers many possibilities to restore wetland ecosystems and reestablish site connections to surroundings through human access. By redeveloping urban rivers for wetland protection and stormwater management, cities can begin to regain their connections with the landscape while providing resilient ecosystems through restoration. This proposal identifies possibilities for riverfront redevelopment as wetlands and tools for restorative action aiding increased human access and wildlife health. A stormwater management plan utilizing phytotechnology is proposed for the ARMCO Site at 7000 Winner Rd. Kansas City, MO, a former steel manufacturing site, adjacent to the Missouri River and Blue River waterways. Using plant material and landscape design, the ARMCO riverfront has been redesigned to unlock the full potential of treatment wetlands and showcase emerging treatment methods that could soon become typical cleanup procedure. A template for remediation design has been created with the techniques identified for remediation, stormwater treatment, and habitat creation outlined in the master plan proposal. Nine precedent studies have been used to identify key concepts for design phasing aimed at human accessibility and modifications of restorative tools. Careful deliberation of stormwater containment and flood plain levels define site layout while contributing design responses adaptable for year-round functionality coupled with landscape interest for each season. The techniques and planting palette have been tailored to address the specific site contaminants for the Missouri River riverfront but are adaptable for various contaminants and ecosystems.

RIVERFRONT REMEDIATION

Redevelopment for Human Access and Wildlife Health

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A master plan proposal for the former ARMCO Steel manufacturing site in Kansas City, Missouri to control and remove pollutants contributing to ground and water contamination.

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ABSTRACT

Historically, industrial riverfronts often polluted waters and sites with chemicals, leading to degraded ecosystem health and reduced numbers of aquatic wildlife downstream. These sites currently pollute the environment through residual chemicals and waste left behind by industrial-era production factories. Urban riverfront redevelopment offers many possibilities to restore wetland ecosystems and reestablish site connections to surroundings through human access. By redeveloping urban rivers for wetland protection and stormwater management, cities can begin to regain their connections with the landscape while providing resilient ecosystems through restoration. This proposal identifies possibilities for riverfront redevelopment as wetlands and tools for restorative action aiding increased human access and wildlife health. A stormwater management plan utilizing phytotechnology is proposed for the ARMCO Site at 7000 Winner Rd. Kansas City, MO, a former steel manufacturing site, adjacent to the Missouri River and Blue River waterways. Using plant material and landscape design, the ARMCO riverfront has been redesigned to unlock the full potential of treatment wetlands and showcase emerging treatment methods that could soon become typical cleanup procedure. A template for remediation design has been created with the techniques identified for remediation, stormwater treatment, and habitat creation outlined in the master plan proposal. Nine precedent studies have been used to identify key concepts for design phasing aimed at human accessibility and modifications of restorative tools. Careful deliberation of stormwater containment and flood plain levels define site layout while contributing design responses adaptable for year-round functionality coupled with landscape interest for each season. The techniques and planting palette have been tailored to address the specific site contaminants for the Missouri River riverfront but are adaptable for various contaminants and ecosystems.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

Industrial riverfront sites have been regarded as sources of contamination for years. Post-industrial areas within cities are often places of neglect as their uses and functions became obsolete with new age development. Leftover pollutants and degrading infrastructure places a heavy burden on downtown development as economic, social, and environmental conditions are negatively impacted by these effects. These areas are commonly located along waterfronts since construction, transportation, and industry often relied on convenient access to water. Contamination spreads easily from these sites because of their proximity to the ground water table. "Many people are now realizing the potentially catastrophic results which can occur from the abuse that man has inflicted upon the natural environment for decades" (Brooker and Corder 115). The natural environment, which can provide many benefits to residents of urban areas, have been widely underutilized, or neglected.

People were once able to use and swim in urban rivers openly, without fear of coming into contact with a poisonous chemical or untreated waste. Perhaps one day, this will be possible again. For this to happen however, a significant adjustment must be made to the way we see our rivers. Rather than viewing our riverfronts as points of exclusive access for industry, we must begin to see riverfronts as areas of interest for public use and environmental development. The environmental contamination of our urban waterways is a concern because of its impact on the environment as an operating system and its impacts on human access. Three important aspects to consider when restoring a landscape's ecological health are the removal of site contaminants, stormwater management, and habitat creation for wildlife.

A city's physical environment also has great impacts on individual and community development in the form of social and environmental capital. "Local environmental capital provides important functions to communities. Undeveloped lands, especially wetlands, act as flood control and part of a system of water storage" (Green and Haines 215). Social networks and community relationships can be fostered through communal outdoor spaces designed for recreation and leisure, while environmental capital in the form of clean parkland can add value to local real estate.

Natural areas provide aesthetically pleasing environments, and if large enough, provide plant and animal diversity (Green and Haines). Natural areas also provide opportunities for economic development, education, and spiritual enrichment. It is important to keep these areas clean of pollution for both human and wildlife engagement so that they may continue to provide areas of refuge and stimulation. "Proper waterfront design has measurable economic benefits related to climate mitigation, biodiversity, resource management and the extraordinary forgotten value of immediate human contact with nature" ("The Nature of Cities"). Maintaining access to these areas of environmental and social capital during phases of pollution removal should be carefully monitored. "Waterfronts must also be realized and developed as a part of public open space plans and firmly placed in public realm. Active engagement of public on the waterfronts will ensure public vigilance and its protection from abuse and misuse. This will not only ensure the democratization of the waterfronts and public spaces, but also lead to the achievement of a sustainable and resilient ecology of cities" ("The Nature of Cities"). Urban riverfronts can play an important ecological role, but they must work together to create a healthy, constructive place of activity for both wildlife and humans.

This master plan proposal is intended to be a demonstration of decontamination tailored for the ARMCO Site, not a comprehensive river cleanup project. This plan proposal focuses on improving the downstream ecosystem health of the Missouri River using the implementation of stormwater management practices that control runoff pollution, phytotechnology techniques that capture and remove contaminants from the water and soil, growth of natural habitat areas for urban and aquatic wildlife, and the development of parts of the site to become safe for human use as public space. It is important to understand that the proposal is not intended to treat the entire river but rather a portion of its riverfront. Urban riverfronts are the primary focus of this study, analyzing contamination, post-industrial riverfront conditions, and their transformation into urban public spaces. How can phytotechnology be applied to the ARMCO Site along the Missouri River riverfront in Kansas City to reduce land contaminates, improve stormwater runoff quality, and promote human access and wildlife health?

01 LITERATURE REVIEW

THE RIVERFRONT

The importance of urban riverfronts is apparent when discussing redevelopment because these areas are no longer used as industrial sites, are frequently vacant, and often heavily polluted. These pollutants come from caustic soda, cement dust, smoke, distilleries, fertilizers, dye, iron and steel, pesticides, oils, tanneries and countless others. Protecting waterfront corridors is critical for preserving the water quality of our rivers. Thoughtful processes can help cities consider the needs of the people and the environment first, and the growth of infrastructure second. The health of our waterways can be measured by the capacity of its systems, which can be biological, or mechanical, to perform normal functions (“Ecosystem Health”).

Urban riverfronts need to be maintained, and restored, because they have typically been sites of “heavy development and are often sites of pollution or exclusive access.” (“Nature of Cities”). These sites along riverfronts provide prime opportunities for redevelopment as ecological corridors and points of recreation for human use. Through natural landscape techniques (non-mechanical), riverfronts can absorb environmental impacts and help aid the cleanup of our waterways which would significantly support reduction of ocean dead zones where, “over 1 million seabirds and 100,000 sea mammals are killed by pollution every year” (“Pollution L Blacksmith Institute”). The significance of this problem is growing, as our cities become more populated and more developed, more evolved stormwater management systems are required to maintain and restore our waterways to their former glory. Instead of focusing efforts on obtaining new land for future development, recovering unused land already owned by the city offers many potential benefits. Urban waterfront restoration offers great potential development opportunities by utilizing the waterfront location as well as the historic tradition of the old ports and its architecture (“Vita Water Technologies”).

To restore natural chemical balances to these areas, the primary concern must be to remove site contaminants. Along with the removal of buried contaminants existing within soil surrounding the river, the removal of pollutants from surface flow is paramount as, “some redevelopment sites are under the direct influences of up-gradient sites so that run-on stormwater may contain contaminants that have direct impacts on the environmental quality” of the river in question (Russ 83). Improper stormwater management can lead to erosion

Fig. 1.1: Missouri River (Swehla, 2017)

and increased sedimentation downstream, a reduction of groundwater recharge, observable degradation of the ecosystem and environmental quality, reduced base flow stream, and loss of riparian zone quality (Russ). Redevelopment of underutilized post-industrial sites as treatment wetlands restores environmental quality and economic value to the area. Natural riparian corridors include grass, trees, shrubs, and a combination of natural features along the banks of rivers and streams (Sipes). These features are what give natural riverfronts the ability to clean and treat water entering its flow. Urban riverfronts often lack these features because they are encroached upon by modern development. Riverfronts must be designed to handle stresses of pollution and flooding through wetland treatment methods to regain these abilities. The remediation process is difficult to achieve because these locations are constantly changing with season and weather; however, waterfronts play an important role connecting the city to their riparian ecologies. These riverfront areas were previously flexible spaces, able to adjust and move as needed with added water; today they are constricted by rigid boundaries.

The opportunities and implications of land development in urban areas extends to neighborhoods and communities and the people who live there, influencing their mental/physical health and quality of life. “Site designs must account for the mitigation of contamination to protect the users and the environment” (Russ 2). For example, the Ohio River “topped the nation’s waterways for pollution discharges from industry at 24,180,821 pounds in 2013 ... The amount is more than double what industries pour into the Mississippi River, which ranked second” (Bruggers). Concentrations of toxins in the Ohio River are diluted to a point of tolerance for human use, however the high concentrations of nitrate-nitrogen are detrimental to aquatic organism and vegetation along the river. These situations can be reversed however. In Cincinnati, the southern portion of the Ohio River was cleared of industrial type contaminates using a mechanized filtration system processing out gasoline, herbicides, and pesticides (Schack). This method can be costly to maintain and operate; for many cities, this is not an option. Luckily, carefully selected plant types have the ability to extract contaminates free of charge, this process is named phytoremediation.

In Allentown, Pennsylvania a remediation project was implemented along the Lehigh River as the floodplain along its banks washed harmful chemicals into the river. Instead of installing a mechanized filtration system, the EPA provided assistance to Allentown with stormwater management implementations, sediment control, riverfront features in the form of low-impact-development (LID), and site redevelopment features in the attempt to regain control over the natural ecosystem of the riverfront (“Brownfields Sustainability Pilots”). Features included naturalized detention areas with wetland vegetation, reinforced bank slopes, bio retention areas, rain gardens, and cisterns. Methods of collecting and controlling water were highly effective in mitigating pollutants and extracting excess nutrients that can be harmful to the environment in large quantities. If similar habitats utilizing phytotechnology and stormwater management techniques were implemented along the Ohio River riverfront, downstream conditions of ecosystem health may have been improved much more cheaply since, “wetlands play a role in reducing pollution levels in inflowing water” (NCSU Group).

A wetland treatment method was put into action at the Houtan Park along the Huangpu River in Shanghai. “The park’s constructed wetland, ecological flood control, reclaimed industrial structures and materials, and urban agriculture are integral components of an overall restorative design strategy to treat polluted river water and recover the degraded waterfront in an aesthetically pleasing way” (“Shanghai Houtan Park/Turenscape”). This project is an influential example of a restored riverfront maximizing cleaning potential. The center of the park is a linear wetland designed to create a reinvigorated waterfront as a living machine to treat contaminated water from the Huangpu River. “Cascades and terraces are used to oxygenate the nutrient rich water, remove and retain nutrients and reduce suspended sediments while creating pleasant water features” (“Shanghai Houtan Park/Turenscape”). Water quality improvements happen at each terrace level, cleaned by plant composition.

A proposal for redevelopment will be presented for the ARMCO Site along the Missouri River riverfront in Kansas City, identifying sources of contamination and a consequent cleanup strategy.

DESIGNING FOR HUMAN ACCESS

The importance of human access to natural landscapes is evident through examples of increased physical and social health. "Access to nature has been related to lower levels of mortality and illness, higher levels of outdoor physical activity, restoration from stress, a greater sense of well-being, and greater social capital" ("Improving Health and Wellness"). Well-designed greenways and trails encourage walking and active recreation. Many studies associate access to nature through trees, water features, neighborhood parks, or forested areas with reduced levels of stress, whether stress is measured physiologically or by self-report ("Improving Health and Wellness"). Protecting and restoring access to nature in different spheres of people's lives, among those of all ages, social groups, and abilities, can alleviate some of the most important problems in public health, including obesity, stress, social isolation, injury, and violence.

Increased social health was measured in urban areas, where higher levels of nearby vegetation and vacant lot greening were associated with fewer aggressive acts against partners and lower rates of crime, including gun assaults, robbery, and burglary ("Improving Health and Wellness"). "People of all ages are more likely to use open spaces with trees, increasing opportunities for social interaction and for children's supervised play. Teenagers value natural areas as places for adventurous play and hanging out with friends, younger children value them for exploration and creative social play, and older adults value these areas for walking, enjoying scenery, and meeting friends" as well as many other social engagements. Having vegetated views has been linked to an increased perception of safety, enhanced feeling of neighborhood togetherness, and less crime ("Improving Health and Wellness"). Understanding neighborhood social contexts where people live is critical to promoting safe outdoor play and positive and lasting engagement with natural environments.

Access Limitations on Polluted Sites

River corridors and corresponding greenways are special types of landscape elements that are found as part of the natural infrastructure of regions, cities, and local landscapes with value to the residents (Kennen and Kirkwood). The goal of remediating the ARMCO Site is to return the land use back to the people of Kansas City. Pollution exposure must be evaluated to reduce human contact with contaminants for health and safety reasons. Topographic surfaces, roads, pathways, planting areas, storage areas, and water bodies all contribute varying levels of protection and contact with ground materials. "Paved areas, dense vegetative mats, and thickly mulched beds prevent direct exposure to users" (Kennen and Kirkwood 252).

The design process considered phasing and limited access areas to mitigate exposure risks. Site restrictions, site circulation, and permeability dictated access to the site and conversely the pollution points. Limiting access can be achieved by raised walkways or incorporating landscape barriers. Analyzing acceptable degrees of human access also influenced the design expectations and allowances. In order to study the above-mentioned limitations of access on polluted sites, precedent studies were investigated the impacts of phyto-design on human access in the methodology portion of this proposal.

Post-Construction Completion

Institutional controls are a viable risk management tool for clean ups when they are durable, enforceable and run with the land. The durability of institutional controls is a concern given that they may be forgotten, regulatory agencies may fail to monitor property use effectively, or property users simply may ignore restrictions. Engineered controls are a common remediation tool, but require maintenance in order to remain effective over time.

Post-construction engineering and institutional controls ensure that cleanups provide for the long-term protection of human health and the environment. Ongoing ctivities after construction include operating and maintaining long-term cleanup technologies, regularly reviewing the site to be sure that the cleanup continues to be effective, and enforcing any necessary restrictions to minimize the potential for human exposure to contamination ("About the Superfund Cleanup Process").

TOOLS FOR RESTORATIVE ACTION

Since waterfronts were often the first areas to be developed in cities, they are often the first to decay, sometimes becoming unusable. Typical regulatory requirements include shoreline stabilization and protection from incoming chemical runoff, prevention of incoming pollutants, and the restoration of ecosystem health after contamination (Kennen and Kirkwood). Post-industrial sites are often considered brownfields, which means they are "abandoned, idled, or underused industrial and commercial property that has been taken out of productive use because of actual or perceived risks from environmental contamination" (Dennison 362). Common hazardous substances found in brownfields are: arsenic, lead, mercury, vinyl chloride, and benzene (Russ). Materials are considered hazardous if they are ignitable or corrosive in liquid form, normally unstable and reactant to water, capable of leaching hazardous constituents, or are listed as hazardous waste by The Resource Conservation and Recovery Act (Russ). "Until the 1990's the challenge to redevelop contaminated properties was restrained by problematic public policy, reluctant lenders, and significant financial risk. Since then, however, the opportunities for redevelopment have improved dramatically" (Russ 2). Waterfront developers should be aware of the potential waterfronts have to restore natural processes; "redevelopment of environmentally impacted or contaminated properties is still very much an emerging area of professional practice" (Russ 2).

Contaminant Removal through Phytotechnology

When designing a response plan, designers must consider costs of the redevelopment strategy. An important factor to consider during redevelopment stages is cost of implementation. The cost of remediation should be viewed as both initial costs and lifecycle costs. Initial costs include the costs of environmental site assessment, site design, site acquisition, construction, and start-up, while life cycle costs include the operation and maintenance of the design (Russ). The redevelopment plan and environmental action plan should be all-inclusive. Life-cycle costs of phytotechnologies are relatively cheap compared to alternative cleaning techniques, however one disadvantage of using plants to extract contaminants is the elongated time period required for bioremediation to be completed. Each of phytotechnology mechanisms discussed in this chapter addresses pollution in the designed landscape directly. By addressing these contaminants on site, pollutants can be prevented from migrating to larger water bodies.

During clean up planning, decision-makers should weigh the full costs of this option, including capital costs, costs of long-term sampling and analysis, and costs of replacing equipment. Concerns about the potential long-term risks associated with the contaminants left in place versus the costs of options that would remove the contaminants permanently should be considered before developing a remediation plan.

Phytotechnology Mechanisms

Phytotechnology is the process of using vegetation to remove contaminants in soil, sediment, surface water, and groundwater ("Phytotechnologies"). The following phytotechnologies shown in Figure 2.2 are not a comprehensive list of all available techniques, but rather a variety of mechanisms capable of addressing the ARMCO Site pollutants. Each mechanism describes certain processes that allow the plant to modify or react with a pollutant. It is important to remember that multiple mechanisms can be at work simultaneously.

Phytotechnology Planting Types

Ways of implementing phytotechnology mechanisms differ depending on the conditions of the site. Cases of multiple contaminate sources require a combination of design solutions to address concerns. Potential strategies may involve a hierarchy of responses, determining which of the contaminants presents the greatest risk (Russ). Some examples of phytotechnology planting types, shown in Figure 2.3, include extraction plots, constructed treatment wetlands, stormwater filters, interception hedgerows, and groundwater migration tree stands ("Phytotechnologies"). Here, it is important to remember that different typologies can be combined into a cohesive planting arrangement in order to acquire multiple remediation goals. Likewise, remediation typologies can also be combined with non-remediation planting methods for a variety of landscape preferences.

Phytotechnology Mechanisms

I. Phytoextraction

Phytoextraction is the plants ability to take up pollutants from the soils and water and move it into the plant parts. Inorganic contaminants are not capable of being broken down into smaller parts, and therefore must be stored in the plants shoots and leaves. For the pollutant to be removed from the site, the plant must be harvested before the leaves drop. Harvested biomass may be disposed of in landfills, burned, reused for biomass, or smelted into ore to collect valuable metals (Kennen and Kirkwood).

II. Phytostabilization

Phytostabilization is the plants ability to hold the contaminant in place so that it does not move off site. This happens because the plant is physically covering the pollutants releasing phytochemicals into the soil that can bind it in place, making them less bioavailable. In addition, phytoaccumulation (a form of phytostabilization) can collect airborne pollutants on leaf surfaces, physically filtering the air and holding them in place (Kennen and Kirkwood).

III. Rhizofiltration

Rhizofiltration is the plants ability to filter out pollutants from the water. Rhizofiltration is unique to this mechanism palette because it is a process that requires the symbiotic relationship that occurs between root and water. The roots of plants filter out pollutants in water bodies such as constructed wetlands or stormwater filters. “The plants add oxygen and organic matter to the soil to maintain binding sites for contaminant filtration and storage” (Kennen and Kirkwood 41).

IV. Phytohydraulics

Plants create a subsurface hydraulic pull towards their root systems as they attract water in the soil. Phytohydraulics is the plants ability to capture and evaporate water off the plant, take up and transpire water through the plant, and the plant’s ability to pull water into the roots. The pull of water can be so great that groundwater can be drawn towards the plant. Massing large vegetation can actually stop, or change the direction of, groundwater plume migration (Kennen and Kirkwood).

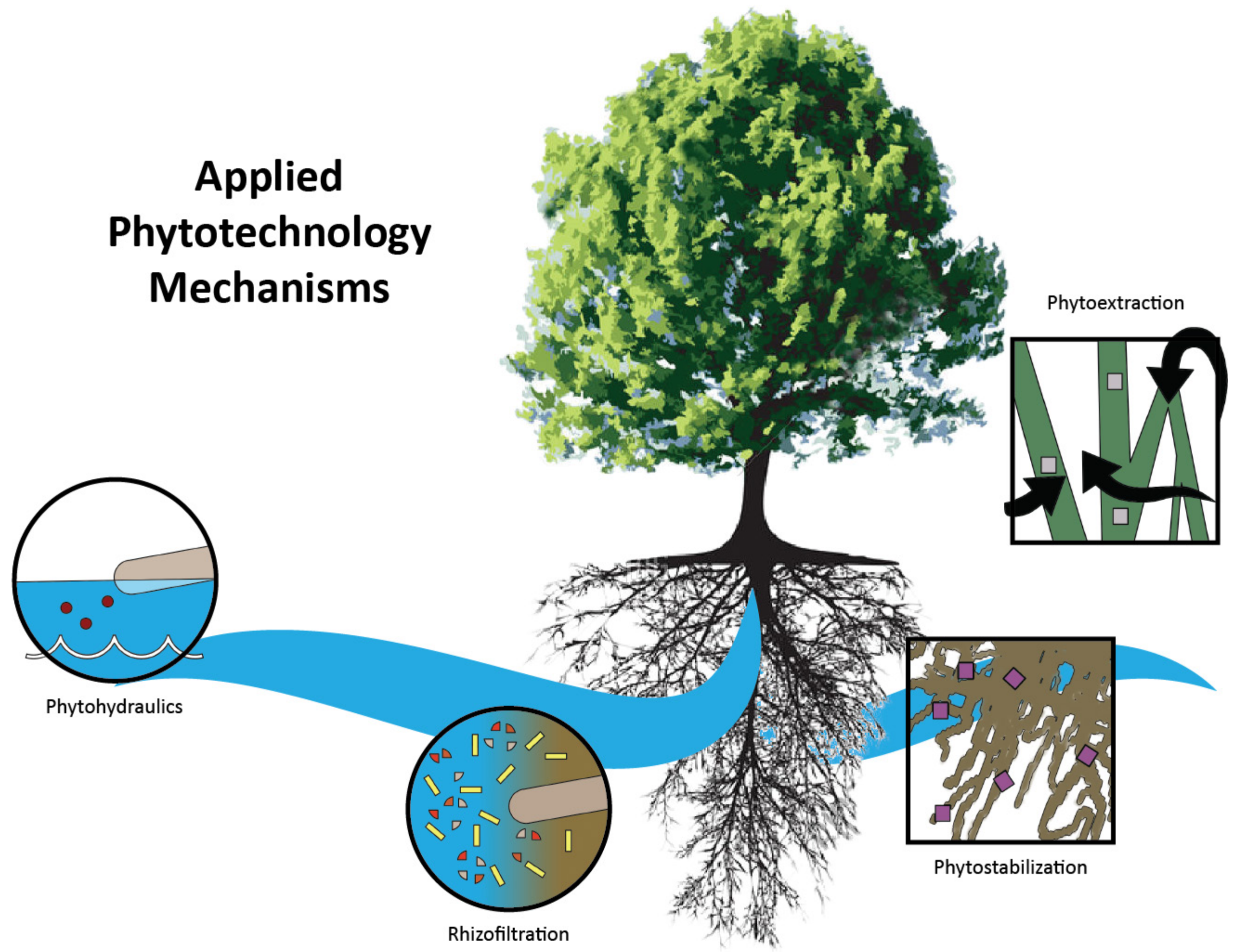


Fig. 1.2: Applied Phytotechnology Mechanisms (Swehla, 2017)

Phytotechnology Planting Types

I. Extraction Plots

Hyperaccumulator plants or high-biomass crop species are used to extract inorganic pollutants or recalcitrant organic pollutants from the soil. The plants must be harvested to remove the contaminants from the site. Extraction plots have been most effectively used for low levels of arsenic or selenium contamination on a site, or to remove nickel from the soil for phytomining. For slightly elevated levels of metal in soil, such as cadmium and zinc combinations, extraction plots can be grown and harvested over decades to remove the bioavailable fraction of the pollutants (Kennen and Kirkwood). This planting type provides dense vegetation and therefore provides a great opportunity for wildlife habitat. Extraction plots can be planted in high concentrations to offer cover and niche communities for native wildlife during grow season. Design considerations for extraction plots include bioavalaibility, harvesting, and bioaccumulation. The primary phytotechnology mechanisms at work in this planting type are phytoextraction and phytostabilization.

II. Stormwater Filter

Plants and soil remove or trap contaminants found in stormwater. The objective is to remove stormwater contaminants at the source, before they spread to groundwater or other water bodies. Contaminated stormwater is most often generated by rainfall on impervious surfaces. Stormwater filters can capture these contaminants from surface run-off. Stormwater filters can be implemented into landscape design through bio-swales, vegetated swales, vegetated filter straps, rain gardens, and detention basins (Kennen and Kirkwood). It is important to integrate swale catchments and stormwater filters to trap solid pollutants from entering and contaminating the site further. Solid objects, such as litter and trash, can be removed from the stormwater runoff and thus be kept from degrading site aesthetic values. Organic pollutants can be degraded, while nitrogen contamination in water may be converted into gas and returned to the atmosphere. Inorganic contaminants may be immobilized and remain in soils on site. Design considerations for stormwater filters include evapotranspiration and debris material accumulation. The primary phytotechnology mechanism at work in this planting type is rhizofiltration.

Applied Phytotechnology Planting Types

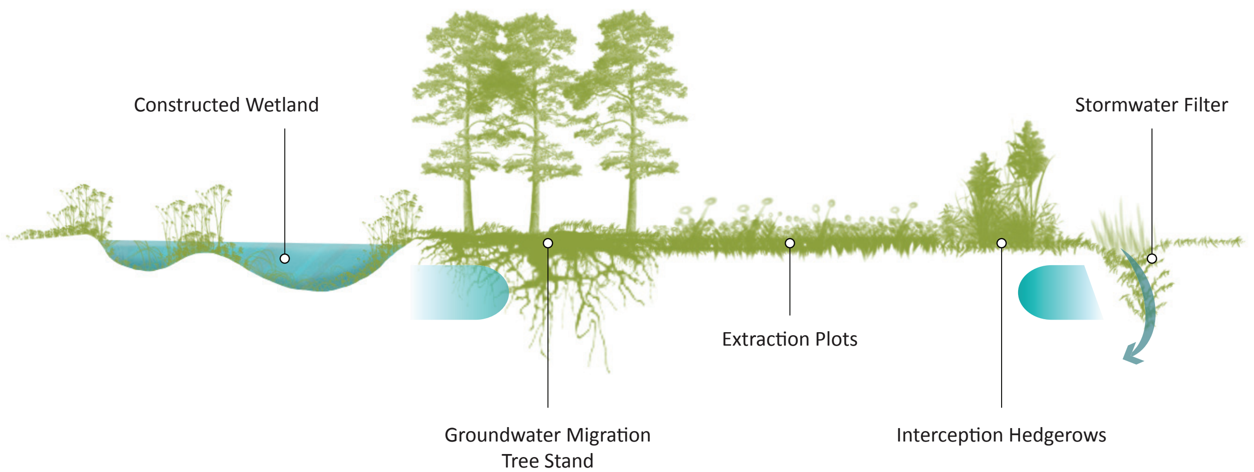


Fig. 1.3: Applied Phytotechnology Planting Types (Swehla, 2017)

III. Constructed Wetland

In this planting type, water is guided through a series of planted marshes and engineered soil media at various depths to remove pollutants. The objective is to clean water as it moves across the landscape. Surface-flow constructed wetlands closely mimic the ecosystem of a natural wetland by using plants to filter water through root zones, planting medium, and open water zones. Most of the treatment does not occur within the plants themselves, but in biofilm on the roots of the plants and within the biology and chemistry of the water and planted media. Implementations of treatment wetlands have led to further investigations of applied phytotechnology (Kennen and Kirkwood). Constructed wetlands should be implemented at the ARMCO site because they provide opportunities for stormwater infiltration and reduced surface runoff, habitat creation for native wildlife, and vegetation growth. Design considerations for surface flow constructed wetlands include the pairing of constructed wetlands with upland groundwater migration tree stands or phytoirrigation. The primary phytotechnology mechanism at work in this planting type is rhizofiltration.

IV A. Interception Hedgerow

A row of trees taps groundwater supply, assisting contamination degradation. The objective of the vegetation hedge is to remove contaminants from the groundwater below the surface. Hedgerows can be used in place of groundwater migration tree stands, or in conjunction, to remove some contaminants in the space available. Interception hedgerows are typically planted along the edges of polluted sites to aesthetically buffer adjacent properties while helping to degrade contaminants at the same time (Kennen and Kirkwood). This mechanism can also be applied on site near rivers or creek systems to draw water into the site for treatment by other phytotechnology mechanisms. The implementation of interception hedgerows will allow the design to include a variety of vegetation types provided by various shrub species. Interception hedgerows can be placed alongside circulation routes and trail heads to draw water away from the paths, keeping them dry and reducing erosion impact. Design considerations for interception hedgerows include phytotoxicity. The primary phytotechnology mechanism at work in this planting type is phytohydraulics.

IV B. Groundwater Migration Tree Stand

Trees with deep tap roots and high evapotranspiration rates are planted to modify hydrology and keep contaminants from migrating throughout the site. The trees pull water through transpiration, which slows groundwater plume migration, or changes plume direction towards the trees. The objective is to guide groundwater contamination plumes towards the site to reduce outflow of pollution (Kennen and Kirkwood). This planting type can be applied on site near rivers or creek systems to draw water into the site for treatment by other phytotechnology mechanisms. The implementation of groundwater migration tree stands will allow the design to include a variety of canopy types provided by various tree species. Design considerations for groundwater migration tree stand implementations include depth to water table, plant species variability and dormancy, and vaporation climate factors. The primary phytotechnology mechanism at work in this planting type is phytohydraulics.

Stormwater Management Plan

Riverfront designs must always take into consideration flooding and water related hazards. "Development of land results in increased runoff from impermeable surfaces because of the change in the equilibrium between precipitation and the infiltration capacity of the site" (Russ 97). "In contrast to traditional stormwater practices, which are designed to direct water away from where it falls, sustainable approaches to site and regional water resource management strive to treat water as a resource, not a waste product" (Farr 175).

A criterion for resilient design of ecosystem health depends on a mix of strategies for flood resistance and pollutant control. Among the most common water quality problems are: eutrophication (enrichment of an ecosystem from chemical nutrients), trash and debris, high bacteria levels, aquatic life toxicity, and sediment and fish tissue contamination (Sipes 53). Ecosystem health is an integrative concept, which includes biological philosophies for "preserving the functions of ecosystems, even though the system may be considerably altered because of human domination" ("Ecosystem Health").

Stabilization of Pollutants

"The level of biological activity, or biological productivity, in ponds, and especially wetlands, is thought to be among the highest of any natural system" (Russ 136). These areas are important for treating and stabilizing toxic material concentrations. "While brownfield water quality issues may be complicated by the presence of toxins, the use of bioremediation technologies in conjunction with storm water management design may represent an important element of brownfield site design" (Russ 137).

The creation of flat areas to intercept runoff and encourage infiltration might be developed to function as wetlands; these pockets prove to be important storm water quality features, but also contribute to aesthetic interest and habitat creation. Factors to consider while developing management strategies for wetlands include: wetland type, surrounding land use, vegetation quality, the presence of rare/endangered species, surface water quality, and wildlife habitat. Sediment removal, erosion control, nutrient transformation, metals reduction, and the reduction of water temperature are also important contributors to ecosystem health that need to be regulated before entering river systems (NCSU Group). The regulations may be made on-site, or off-site through comprehensive concepts integrating street scale projects that pre-treat water prior to its arrival in the wetland treatment process.

Watershed Storm Capacity

It is important for stormwater management plans to incorporate design considerations for storm frequency and the site's water carrying capacities. Stormwater management policies encourage maximizing the infiltration of stormwater so that the volume of runoff discharging to surface waters is decreased. The available capacity for stormwater infiltration is influenced by many different factors. Some of the site characteristics that may influence the ability to hold water include soil type and depth, depth to water table, surface type, and antecedent soil moisture conditions, which is the moisture condition of the soil prior to the storm event ("Overview Of Stormwater Infiltration").

Modern stormwater infiltration techniques often mimic natural landscapes such as wetlands and swales. By incorporating a stormwater management plan into the landscape, a number of benefits can be achieved; some of these benefits are, decreased peak runoff flow rates, decreased volume of stormwater runoff, reduced stormwater pollutant loading to surface waters, the retention and breakdown of contaminants in soil, increased groundwater recharge, the preservation of baseflow in streams, and the reduction of thermal impacts of stormwater runoff ("Overview Of Stormwater Infiltration").

Ecosystem Restoration

Urban wild space is important for wildlife growth but should be managed for the role it can play in more sustainable environmental protection. "Riparian corridors harbor a disproportionately high number of wildlife species and perform a disparate number of ecological functions compared to most plant habitats" (Sipes 5). These natural habitats, and aquatic ecology are important elements to riverfronts because they provide for native and migratory species of the area. Comprehensive habitat management programs provide environmental protection and monitoring to assure that habitats are protected and preserved. It is important to replace riverfront habitats that have been destroyed by development because biodiversity of wildlife would be scarce otherwise. "Ecological designs have been implemented, particularly by projects adding microhabitat, creating more shallow water habitat, and reconstructing missing or altered rocky benthic habitats" (Dyson and Yocom).

Native vegetation restoration is important because the use of indigenous grasses, shrubs, and trees provide habitat to the local wildlife and historically present species in the area. Consequently, the use of native plants contributes to the stabilization of natural ecosystems. In remediation design, built infrastructure can create a balance between its environmental impact and the needs of human access to promote the restoration of natural riverfronts through boardwalks and active spaces which utilize native vegetation, improve water quality, and revive wildlife habitat (Project for Public Spaces).

Fig. 1.4: Habitat disruption by human activity (Swehla, 2017)

2 PROCESS

PROCESS

This Chapter explains in further detail the specific methods used to answer the research question previously stated in Chapter 1. The process involved qualitative and quantitative measures covering site selection, site inventory and analysis, plant palette selection, as well as precedent studies.

The Chapter is organized by method, beginning with the site selection process which outlines the search criteria for choosing a project location, the site's context, and it's demographic profile. Second, the process of conducting a site inventory is described, cataloging the project's current state, showcasing a variety of site characteristics, through photographs. A site analysis was conducted in order to interpret conditions affecting redevelopment and phytoremediation applications. Third, A plant palette was created through a process of cross referencing native Missouri species with known phytoremediating plants.

Lastly, nine riverfront reclamation projects were studied for their public integration and remediation applications. The precedents were grouped based on their abilities to enhance systems for human access, promote wildlife health, and increase stormwater management. The groups are identifiable throughout the remaining document with the use of icons symbolizing the above abilities (shown below). From these precedent studies, a master plan was developed for the cleanup of the ARMCO Site using techniques taken from authors on stormwater management, habitat and public space creation, and phytotechnology.

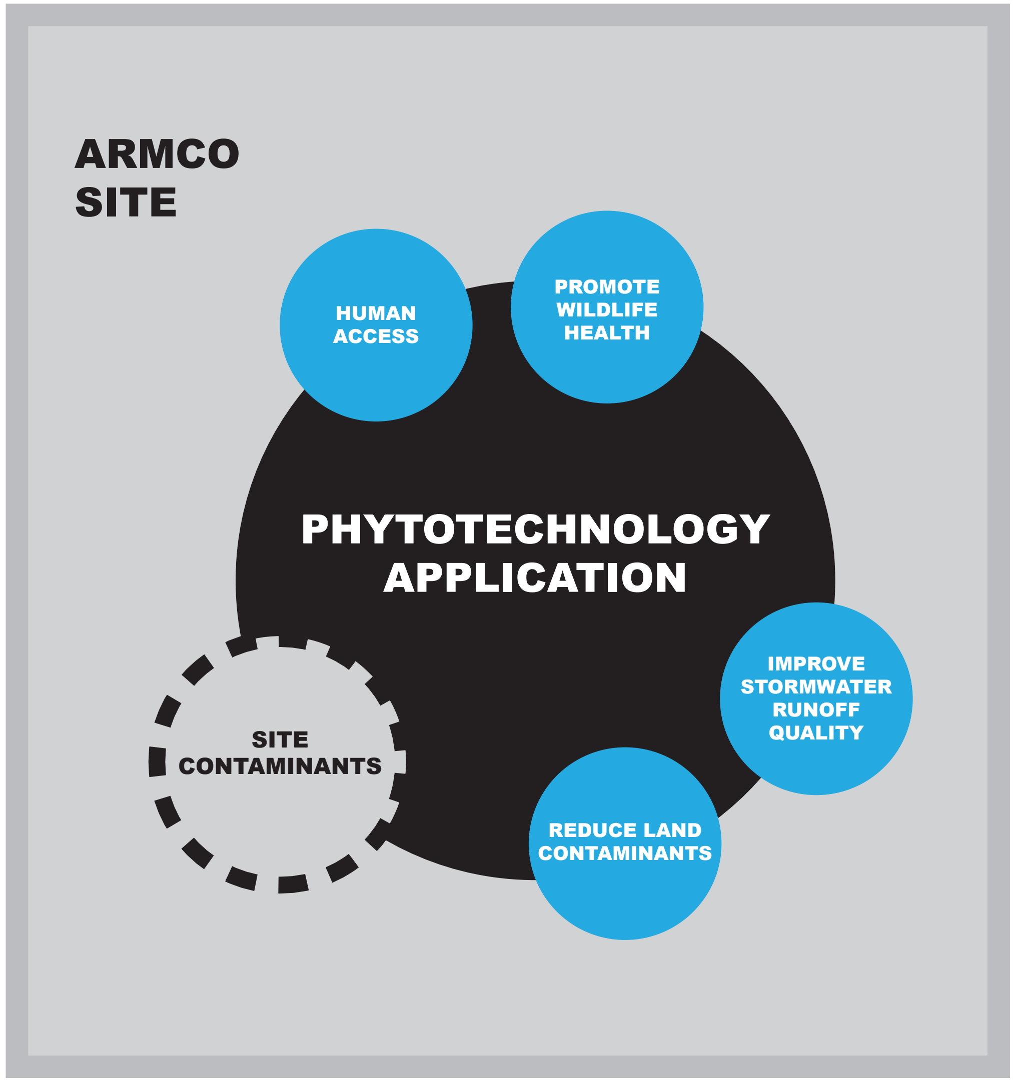


Fig. 2.1: Methodology Framework (Swehla, 2017)

SITE SELECTION

The process of selecting a site was influenced by many factors, which included location accessibility, type of contamination found on site, the level of contamination, contextual impacts of site development, and relevance to community development. Preliminary investigations included sites abroad as well as regional locations. Sites were inevitably eliminated due to ease of accessibility. Kansas City, Missouri fell within this proposal's search criteria because of its proximity and contamination data available online through city planning offices.

The prospective site list was narrowed down by process of elimination after reviewing contamination data. The project timeline required data to be readily available and accessible. The Missouri Department of Natural Resources provided data for all hazardous waste sites within the state. This registry includes significant site data including: a site location map, address, waste type, site description, present property owner, environmental problems related to the site, remedial actions at the site, geologic and hydrogeologic description, public drinking water advisory and health assessment, National Priorities List (NPL) sites in Missouri, a link to the Environmental Protection Agency's site summary about each NPL site, registry cleanup list, consent agreement site list, health assessment chemical table, and glossary of health terms.

The Missouri Department of Natural Resources' Hazardous Waste Program regulates the management of hazardous waste, oversees the cleanup of contamination, regulates the operation of underground tanks, and oversees removal and cleanup of petroleum storage tanks. A weblink to the Environmental Site Tracking and Research Tool (E-START) used to identify the focus area of this report is provided below:

http://www.dnr.mo.gov/ESTARTMAP/map/init_map.action

Fig. 2.2: ARMCO Site in Kansas City (Swehla, 2017)

ARMCO Stewardship Site

Located in Jackson County at 7000 Winner Rd. Kansas City MO 64125-1416, the ARMCO complex is an inactive steel manufacturing plant. From 1962 to 1980, ARMCO disposed of electric furnace baghouse dust generated from steel production processes in two landfills located on its property. Baghouse dust generated by ARMCO contained leachable quantities of lead and cadmium and a high concentration of zinc (10-12 percent). After 1980, these waste by-products became regulated by the Resource Conservation and Recovery Act (RCRA) that now requires alternative means of disposal.

During site cleanup, the property owners decided to cap the landfills with three feet of clean soil and vegetative cover rather than remove contaminants from the site. Since the cleanup procedure predates the 1980 RCRA, the landfills were not capped with impermeable plastic liners. This allows for non-point source pollution to flow downstream during heavy rainfalls and flooding as the ARMCO site is near the Missouri River and Blue River floodplains. Site-wide corrective actions need to be addressed pursuant to an Environmental Protection Agency (EPA) issued Hazardous Waste and Soil Waste Amendments (HSWA) permit. Thirty-Nine Solid Waste Management units (SWMU) and eight Areas of Concern (AOC) were identified as part of the RCRA Facility Assessment conducted on the behalf of EPA. Conclusive site assessment revealed air contaminants including cadmium, lead, metals, and zinc; soil contaminants including arsenic, cadmium, lead, metals, SVOC's (semi volatile organic compounds), VOC's (volatile organic compounds), and zinc; ground water contaminants including cadmium, lead, and zinc; and surface water contaminants including cadmium, lead, and zinc ("Modnr Estart").

The ARMCO Site is located adjacent to the Missouri River, Blue River, and Rock Creek waterways. The site's adjacency to 3 different waterways provides a unique natural junction. The site's relationship with these waterways is important to note because the master plan proposal intends to intercept and clean a large amount of the site's runoff stormwater before it reaches the Missouri River. Across the Blue River to the North, Bayer Corporation holds private land which restricts public access to the riverfront. Views into the site are offered from 435 Highway to the West, which services the community's transit needs, connecting the neighborhood to the broader Kansas City region. Along the site's southern boundary, the Union Pacific

Fig. 2.3: Remnant platforms from ARMCO facility (Swehla, 2017)

Fig. 2.4: Former steel unloading area; visible pollutants (Swehla, 2017)

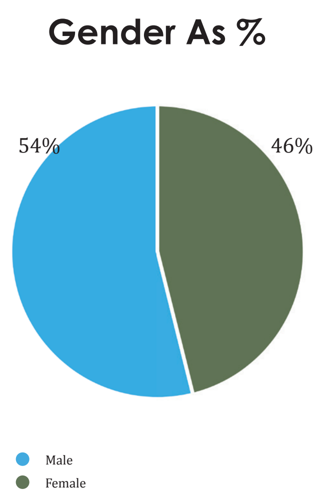
Railroad owns an active rail corridor which creates a barrier between the site and it's surrounding context, while also creating an auditory reaction when trains move through the area. To the East, Fairmount Park is situated inside the Sugar Creek neighborhood. The park is topographically separated by a steep hillside, disallowing any connectivity between the two areas, however, proximity to the Sugar Creek neighborhood ensures site usage.

To understand the community characteristics that will be associated with the site's redevelopment, statistical data was collected for the adjacent zip code, 64053. This data was collected in order to better design the park with programmable areas and amenities that would most benefit the 64053 community.

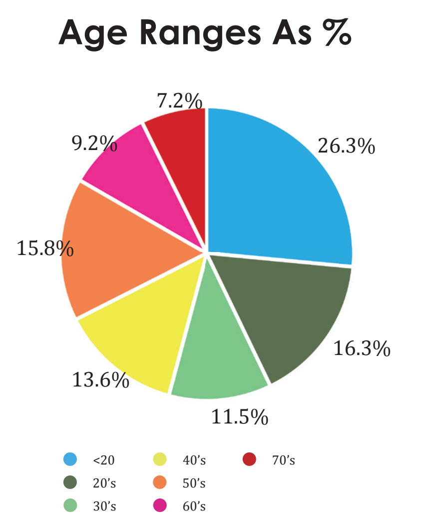
Zip code 64053 is located in northeast Kansas City and has a slightly higher than average population density. The people living here are primarily white with a large number of people in their late 20's to early 40's. The age ranges of this community suggest that there is a large portion of young, active residents. The communities diversity also suggests that this redevelopment site could serve as an important cultural gathering place for community members to bond. There is also a small number of families but a large number of single parents. The percentage of residents under the age of eighteen living in the 64053 zip code is slightly higher than the country's average.

The income statistics, demographic data and crime stats shown in the figures to the right were collected from the online sources at www.incomebyzipcode.com and www.towncharts.com.

Fig. 2.5: ARMCO Site Context (Swehla, 2017)



2.1



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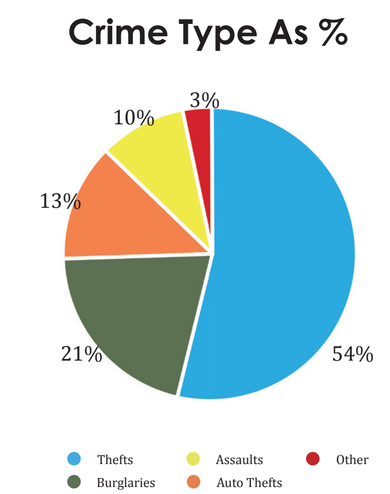

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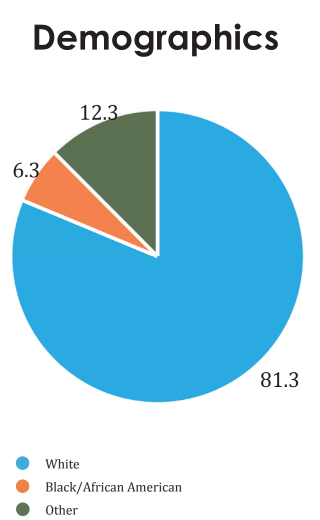

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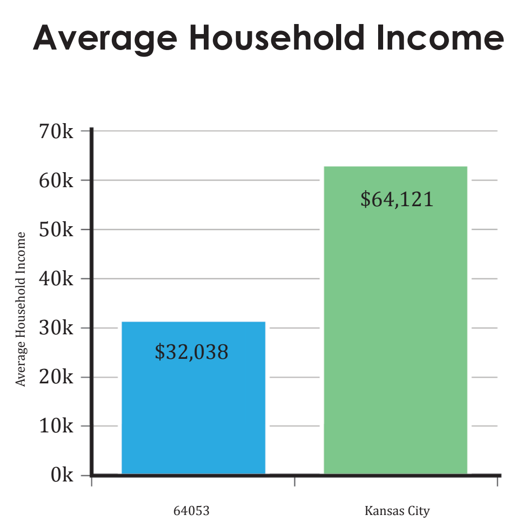

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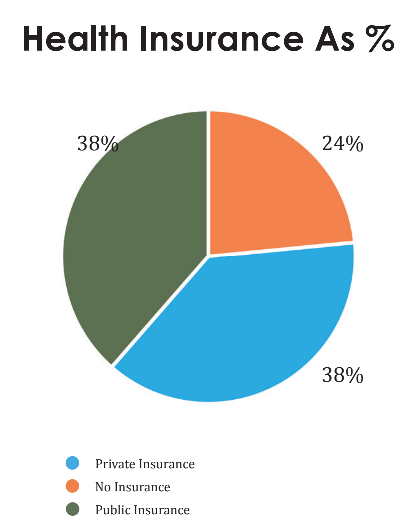


2.6

Table 2.1 - 2.6: 64053 Statistics
(Swehla, 2017)

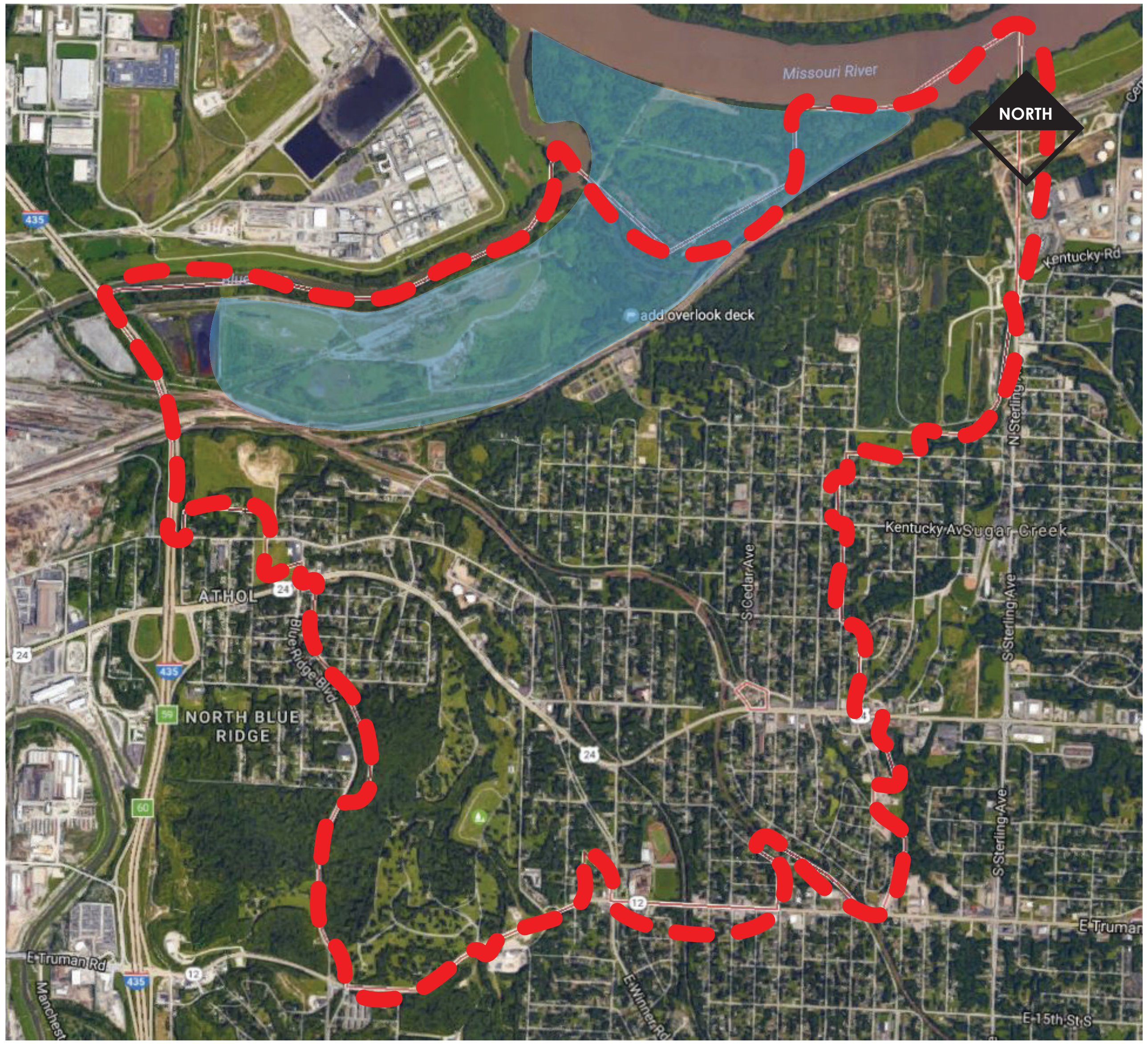


Fig. 2.6: 64053 Zip Code Boundary
(Swehla, 2017)

SITE INVENTORY AND ANALYSIS

Site Inventory

The site was photographed to help determine where programmable features and areas occur within the current site context. A fully documented site inventory was established after multiple site visits and spatial mapping to help the implementation of a landscape plan. The organization of this method is shown using images labeled along portions of the existing trail network, with corresponding trail descriptions. Results of these analyses are shown in the following Chapter.

Site Analysis

A site analysis was conducted in order to interpret conditions affecting redevelopment and phytoremediation applications. Opportunities and constraints were listed for each analyzed condition and assessed based on their ability to enhance/hinder human access, increase/inhibit vegetative growth, and improve stormwater infiltration. These conditions were assessed by the author and are categorized using qualitative and quantitative measures.

Geospatial data was collected from http://maps.kcmo.org/apps/parcelviewer/ online to conduct ArcMap analysis. This data contained site topography, road center lines, and surface type. With this information base maps for schematic design were created. Site mapping included documentation of existing pathways, existing vegetation, hydrologic mapping, pollution zone identification, contaminant identification, soil characteristics, site connections, boundaries, and adjacent assets. Accompanying site maps are listed opportunities and constraints that may help identify design elements or opportunities moving forward in the design process. Soil data was collected for the ARMCO Site using the U.S. Department of Agriculture Web Soil Survey online database. A link to the online website has been provided below:

https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

Data used for calculating the site's stormwater carrying capacity was obtained through The Precipitation Frequency Data Server (PFDS) found at the Hydrometeorological Design Studies Center website provided below:

http://hdsc.nws.noaa.gov/hdsc/pfds/

Site pollution data detailing contaminants within the soil was collected from the Missouri Department of Natural Resources online website, http://dnr.mo.gov/. This data is also obtainable through correspondence with the property owners or the city planning office.

Results of this inventory is shown in the following Chapter.

PLANT PALETTE SELECTION

The planting palette for the ARMCO Site redevelopment plan was created to combat specific contaminants and their concentration levels, as well as provide habitat structure for native wildlife. When considering plants for selection, plants were chosen based on their capability to perform required phytotechnology mechanisms, their ability to enhance wildlife health, and their non-invasive qualities. The phytotechnology mechanisms made possible by the planting palette aid pollution extraction and water movement within the soil. Plant material in the constructed wetland stormwater management area is composed of phytoremediating plants that extract lead, arsenic, cadmium, and zinc. Outside of the phytoremediation zones there are no residual chemicals that need to be treated at the ARMCO Site, allowing a more diverse, native palette to be used. The native plants chosen for the redevelopment plan provide food, habitat, and security to desired and endangered wildlife. Missouri native plants were chosen from the following environmental communities: wetland, forest, and prairie.

The native plants chosen for landscape features and elements were chosen using *The Terrestrail Natural Communities of Missouri* (Nelson). Phytoremediating plants were identified through the use of *Phyto: Principles and Resources for Site Remediation* (Kennen and Kirkwood). These plants were cross referenced with lists of invasive species to ensure that they would not dominate or encroach upon the native habitats.

Further documentation of plant characteristics included their individual hardiness zones, water and sun requirements, plant descriptions, seasonal interests, and landscape uses.

PRECEDENT STUDIES

Effects of Phytoremediation Design on Human Access

One of the most important methods of remediation design is to control the source of pollution, as land-use challenges arise from the smallest amount uncontrolled. Phytoremediation offers many solutions for pollution control and habitat protection but is often a combating force against human access in landscaped environments. Large sites with extreme pollution may not be suitable for human contact and therefore require limited design or prevention tactics to restrain people's interaction with the land. Sites with low pollution content may allow higher levels of human access since there is less risk, conversely, sites with low levels of human access, or a degree of separation, may correlate with sites of high pollution and dangerous chemical content (Kennen and Kirkwood).

A series of precedent studies was conducted on three different sites examining phytoremediation applications and designed impacts on human access on the site. One driving idea behind the remediation of a polluted site is to return the land to the people; these precedent studies were carefully selected to provide information on a variety of remediation designs allowing for a variety of human access. Methods for on-site treatment, buffer zones, and stormwater filters preventing the flow of contaminants are extracted from these precedents and implemented in this master plan proposal.

The following three precedents have been examined to answer the question, what has previously been done with human access on contaminated sites? Findings from these examinations are shown in the following Chapter.

Ningbo Eco-Corridor | Zhejiang, China

Houtan Park | Shanghai, China

Fresh Kills Park | New York, USA

Further questions that may help divulge design intentions for areas of human access are: How did the phasing of these projects develop as construction and phytoremediation occurred? What was accessible during each phase? How were accessibility restrictions enforced? Was the program for each site influenced by the site contaminants? What functions were impacted by the installation of phytotechnology implementation? How was human interaction with the site mediated? What design elements aided the separation of people and pollutants?

The varying methods used across the spectrum affect human access in different ways, but ultimately correspond with the unique level of contamination on each site. In some cases, human access may be restricted during initial phases of design implementation, only to be opened at later times after remediation has occurred.

Effects of Phytoremediation Implementation on Wildlife Habitat Restoration

The effects of vegetation as a natural remedy technique can help increase the amount and variety of habitat on a formerly polluted and abandoned site. If this is carefully considered during the design process, phytotechnology can increase the canopy cover, nesting sites and potential food available to wildlife without exposing animals to toxicity (Kennen and Kirkwood). By using the many different phytotechnology planting types a range of vegetated conditions can be established, leading to a diversity of plants, in turn increasing food and shelter opportunities for wildlife.

The following three precedents have been examined to answer the question, what kinds of habitats have been restored through phytoremediation projects? Findings from these examinations are shown in the following Chapter.

The Corktown Common | Toronto, Canada

Brooklyn Bridge Park | New York, USA

Woodbridge Waterfront Restoration | NJ, USA

Further questions that may help divulge design intentions are: What phytotechnology planting types were utilized in these precedents? How did these planting types contribute to native wildlife habitat? How did the planting palette provide nourishment to wildlife? Was the plant's food production impacted by pollutants? Or did it affect the wildlife?

Effects of Phytoremediation Implementation on Stormwater Management

Unlike many other stormwater treatment methods, plant based systems are natural, passive, solar energy-driven methods of addressing the remediation and regeneration of several types of pollution-impacted landscapes. Pollution prevention can be integrated into the landscape to stop the spread of future pollution releases and the further environmental degradation of urban land and waterways (Kennen and Kirkwood). The plant process is not as invasive as removal/disposal or soil washing. Another designed benefit is a reduction of water temperature for the river system.

The following three precedents have been examined to answer the question, what kinds of stormwater management have been done for brownfield remediation? Findings from these examinations are shown in the following Chapter.

Landschaftspark | Duisburg, Germany

Viet Village Urban Farm | New Orleans, USA

Minghu Wetland Park | Liupanshui, China

Further questions that may help divulge design intentions are: How does stormwater management integrate with phytoremediation layout and programming? Does the accumulation of pollutant stormwater affect aesthetic design? What stormwater filter/holding precedents are applicable to the ARMCO Site? How does the implementation of stormwater management benefit these landscapes?

3 FINDINGS

SITE INVENTORY

Site Inventory

An informal entry point from underneath the southern rail corridor provides access to the site. A long stretch of raised earth contains remnants of a gravel path which is visible in some areas where grass has not completely covered it. This area is mowed. Midway down this section there is a short peninsula branch that allows you to enter a seasonal wetland area to the North. This area is seasonally moist, retaining water after floods and rainstorms.

There are remnants of industrial usage along this section of the pathway, including concrete culverts, pre-cast concrete barriers, and metal gas piping. Dense vegetation lines both edges of the pathway.

Fig. 3.1: Path Section 1
(Swehla, 2017)

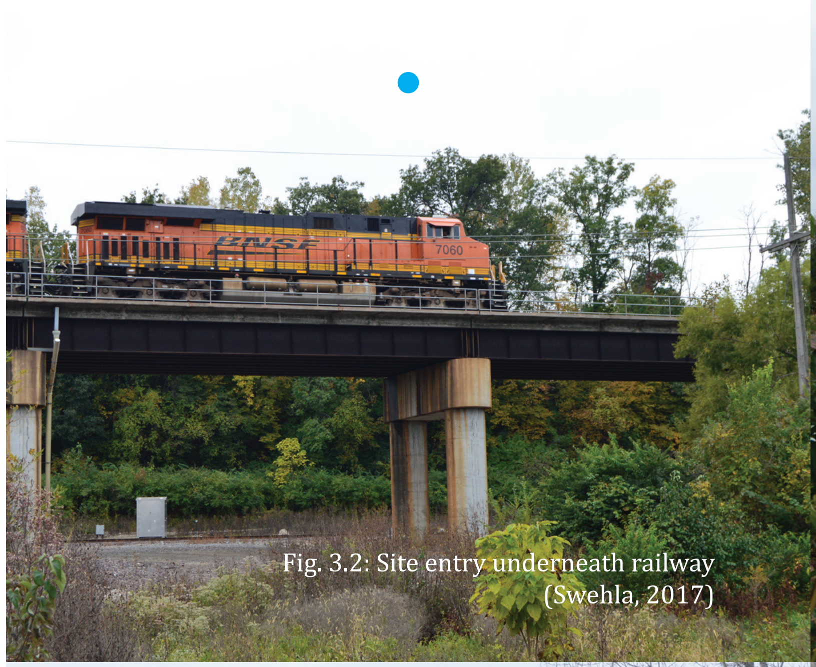


Fig. 3.2: Site entry underneath railway
(Swehla, 2017)

Fig. 3.3: Seasonally wet lowland
(Swehla, 2017)

Fig. 3.4: Mowed path looking West
(Swehla, 2017)

Fig. 3.5: Industrial remnants West
(Swehla, 2017)

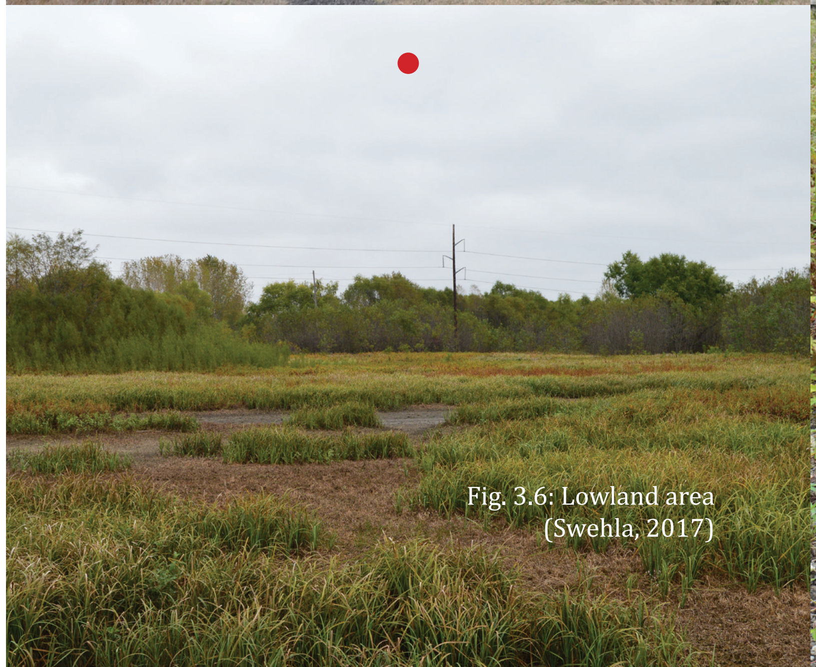


Fig. 3.6: Lowland area
(Swehla, 2017)

Fig. 3.7: Industrial remnants peninsula
(Swehla, 2017)

This area of the pathway is similar to the previous section. The path is gravel, partially overgrown with short grass. Further down the trail, however, the grass pathway turns entirely to gravel. In the gravel paved sections of this path there were sightings of snimal tracks, like deer, goose, and turkey. There are telephone lines crossing the path midway which continue into the site. On the southern boundary, there is a channel collecting water that feeds Rock Creek, and a steep incline which services the rail corridor. The vegetation lining the edges of this section vary from tall grasses to shrubs, eventually giving way to forest. The path narrows as it progresses East, funneling into the next section of trail head.

Fig. 3.8: Path Section 2
(Swehla, 2017)

Fig. 3.9: Telephone line
(Swehla, 2017)

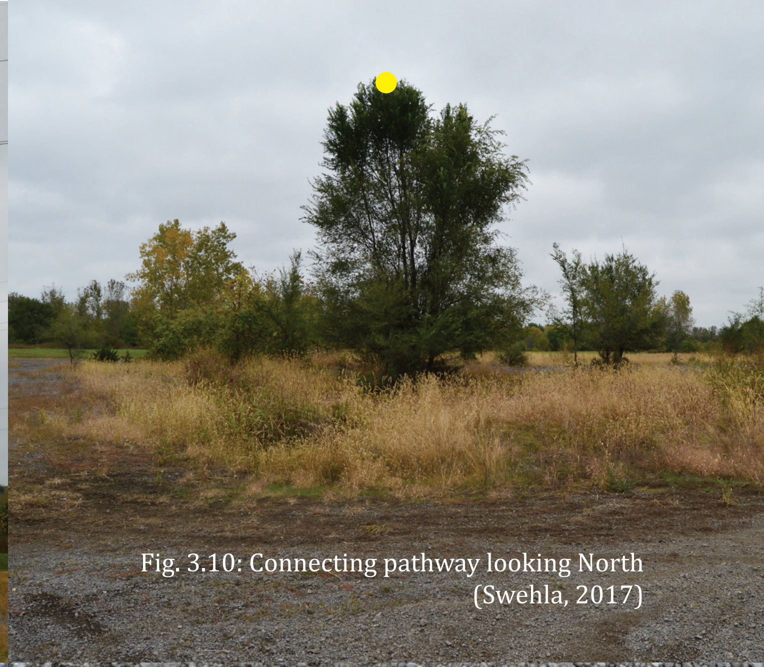


Fig. 3.10: Connecting pathway looking North
(Swehla, 2017)

Fig. 3.11: Mowed path looking East
(Swehla, 2017)

Fig. 3.12: Deer track
(Swehla, 2017)

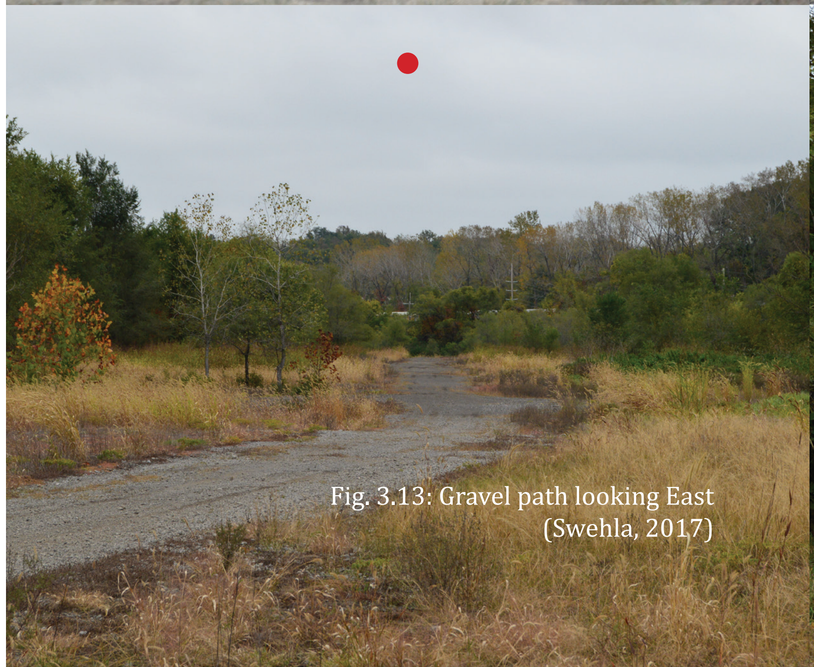


Fig. 3.13: Gravel path looking East
(Swehla, 2017)

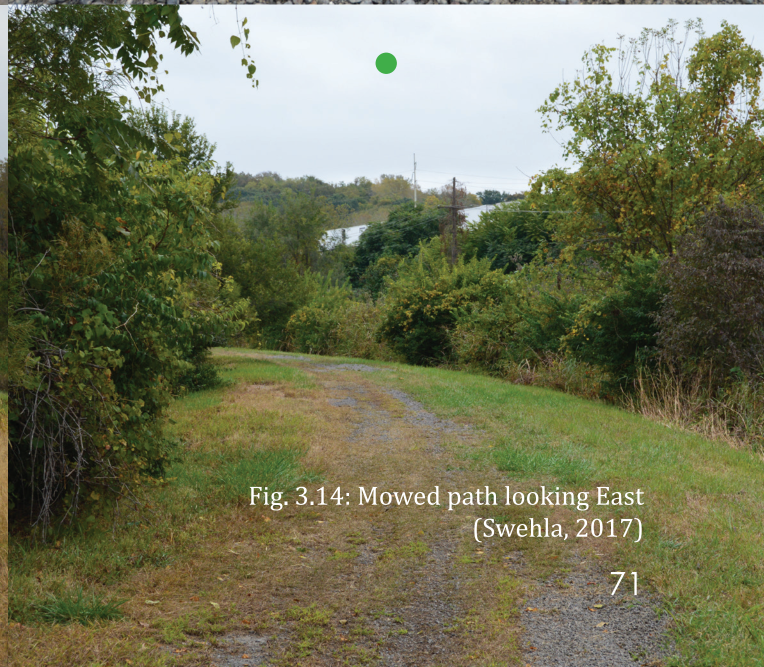


Fig. 3.14: Mowed path looking East
(Swehla, 2017)

The looping section of trail highlighted below is heavily vegetated. Areas of this trail require you to duck beneath tree limbs and step over fallen debris. The beginning leg of this trail is sparsely paved with loose gravel, quickly transitioning to overgrown grass. It is obvious that this beginning section is unmowed and unmaintained. The path crosses a steeply sloped, dried ox bow section of Rock Creek. Near the ox bow, warning signs are found marking half buried pipelines. Evidence of recreational vehicle use was also found in some places. The Rock Creek Treatment Plant releases water within sight of the southern trail. The northern section leading out of the loop is more clearly defined, with a wide path and mowed grass. Vegetation in this section is heavy forest.

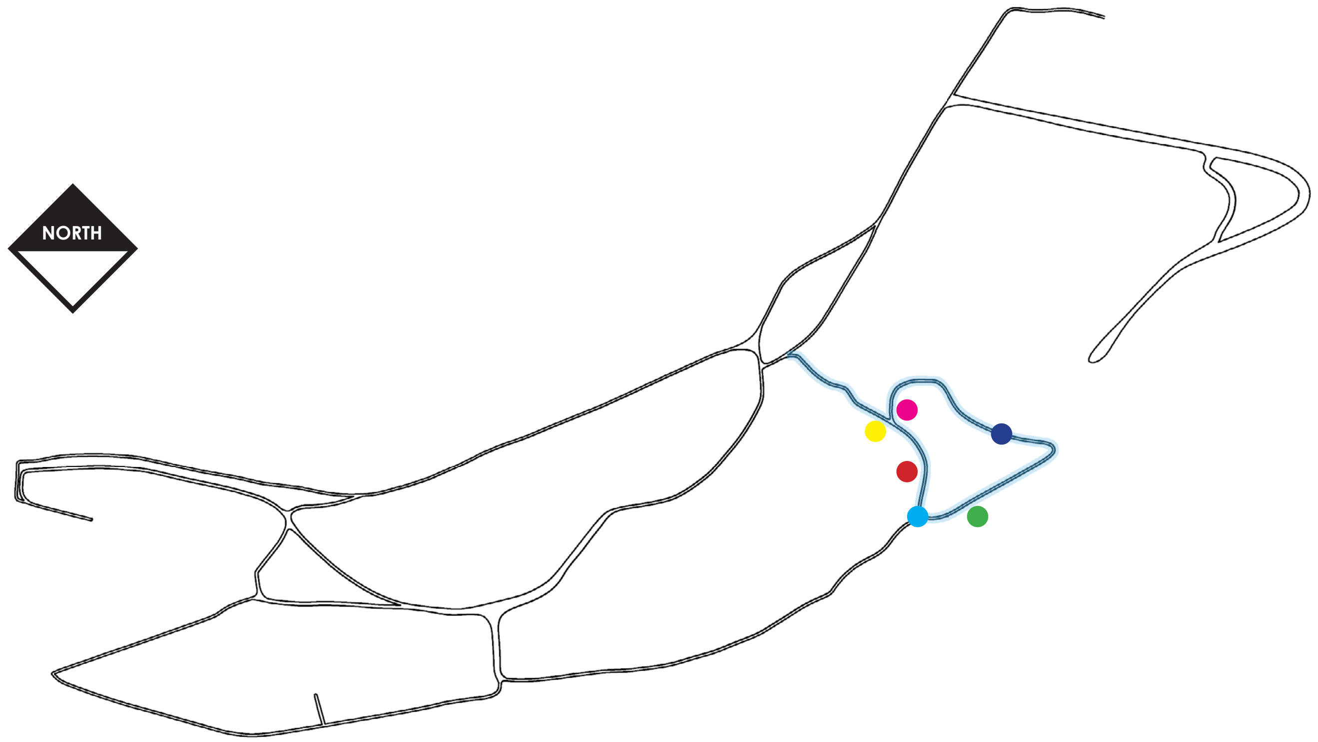


Fig. 3.15: Path Section 3
(Swehla, 2017)


Fig. 3.16: Forested entry
(Swehla, 2017)

Fig. 3.17: Industrial remnants
(Swehla, 2017)


Fig. 3.18: Mowed path looking East
(Swehla, 2017)


Fig. 3.19: Dirt pathway looking North
(Swehla, 2017)


Fig. 3.20: Rock Creek ox bow
(Swehla, 2017)


Fig. 3.21: Water treatment facility run off
(Swehla, 2017)

One of the two landfills located at the ARMCO Site is directly adjacent to the highlighted section of gravel path below. The landfill sits slightly elevated above the pathway. North of this landfill is the former rail corridor where the ARMCO Steel Co. would import and unload their steel for manufacturing. This process left large amounts of surface debris. The soil that was excavated to cap the waste by-products left behind a shallow depression on the North side of the landfill that collects water during flooding and rainstorms. This collection of water attracts frogs and turtles from Rock Creek and the Blue River. Vegetation near and around this path is primarily low growing, grass and shrubs.

Fig. 3.22: Path Section 4
(Swehla, 2017)

Fig. 3.23: Surface contaminants
(Swehla, 2017)

Fig. 3.24: East landfill
(Swehla, 2017)

Fig. 3.25: Turtle
(Image by Swehla)

Fig. 3.26: Landfill cap and warning sign
(Swehla, 2017)

Fig. 3.27: Deer tracks
(Swehla, 2017)

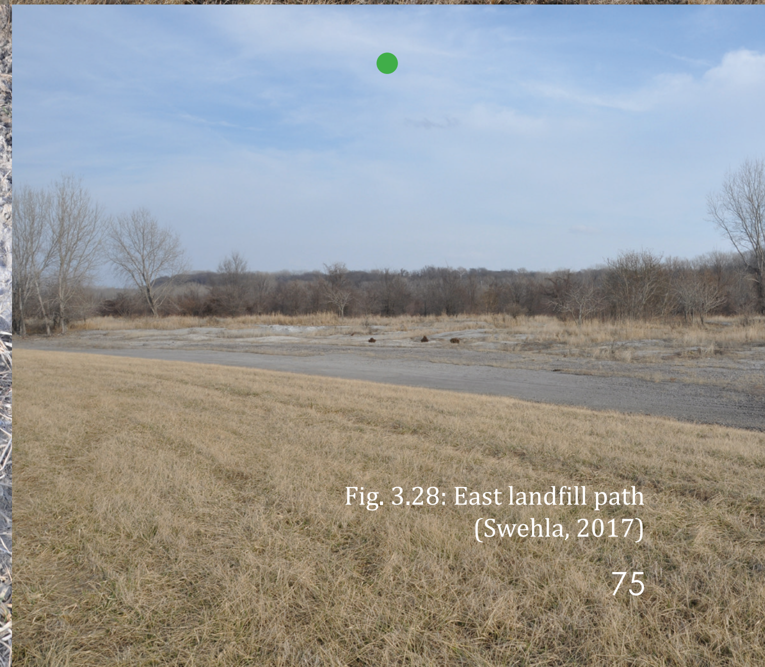


Fig. 3.28: East landfill path
(Swehla, 2017)

This highlighted pathway provides access from the lowland area to the two landfills. The former rail corridor running through the site left a trail of metal debris on the north edge. Rainfall on the western side of the trail's fork runs west towards the existing railroad corridor, and eventually the Blue River, while rainfall on the eastern side of the trail fork deposits into Rock Creek. The area of land located inside the connected pathway shown below is heavily vegetated, containing indiscernible concrete forms and metal debris. From this path you see the first glimpse of the West landfill and can walk along it's East edge.

Fig. 3.29: Path Section 5
(Swehla, 2017)

Fig. 3.30: West landfill
(Swehla, 2017)

Fig. 3.31: West landfill
(Swehla, 2017)

Fig. 3.32: Electrical lines
(Swehla, 2017)

Fig. 3.33: Overgrown rail corridor
(Swehla, 2017)

Fig. 3.34: Former rail corridor
(Swehla, 2017)

Fig. 3.35: View North down rail corridor
(Swehla, 2017)

The West landfill located at the ARMCO Site is much taller than the East landfill. The West landfill is steeply sloped on the North, East, and South sides. From the top of the landfill mound you can clearly see above the canopy of any surrounding trees. The landfill has air release valves to help relieve gaseous buildup underground. Access to the landfill mound is provided by a gravel trail running along the North and West sides. The West side trail is shallowly sloped, allowing a gradual summit to the top. The trail ends but transitions to short grass which is pleasant to walk upon. The size of the mound is large enough to imagine an entire soccer field utop it. Vegetation along the trail is planted short grass with very little tree growth.

Fig. 3.36: Path Section 6
(Swehla, 2017)

Fig. 3.37: Landfill warning sign and gas release
(Swehla, 2017)

Fig. 3.38: View towards downtown KC
(Swehla, 2017)

Fig. 3.39: Landfill view East
(Swehla, 2017)

Fig. 3.40: Landfill view East
(Swehla, 2017)

Fig. 3.41: Landfill slope South-West
(Swehla, 2017)

Fig. 3.42: Landfill terrace view West
(Swehla, 2017)

The trail section highlighted below is slightly raised above the surrounding ARMCO Site because it is on top of the flood dyke built by ARMCO Steel Co. to prevent the Blue River floodplain from expanding. Across the open area to the South of this section, the ground is littered with remnants from the ARMCO Steel Co. manufacturing business. It is clear to see where the old railroad lines came onto the site. The slab of concrete where the company building was located is still visible. Vegetation along the flood dyke trail is lowland forests to the North. To the South, vegetation is sparse and scattered, containing grasses, shrubs, and some trees. The majority of the ground cover in the former rail corridor is not vegetative, but gravel.

Fig. 3.43: Path Section 7
(Swehla, 2017)

Fig. 3.44: View towards East landfill
(Swehla, 2017)

Fig. 3.45: View towards East landfill
(Swehla, 2017)

Fig. 3.46: Former rail corridor
(Swehla, 2017)

Fig. 3.47: Former rail corridor
(Swehla, 2017)

Fig. 3.48: ARMCO Steel Co. pollution
(Swehla, 2017)

Fig. 3.49: ARMCO Steel Co. building pad
(Swehla, 2017)

The path shown below leads towards the Missouri River. On the Southeast edge of the trail there is an accumulation of stagnant water from flooding. The depression that retains water here is a portion of the dried Rock Creek ox bow. The northwest edge of the trail is steeply sloped towards the Blue River, vegetated with lowland forest. The East side of the trail is grown over with a mixture of tall grasses and shrubs.

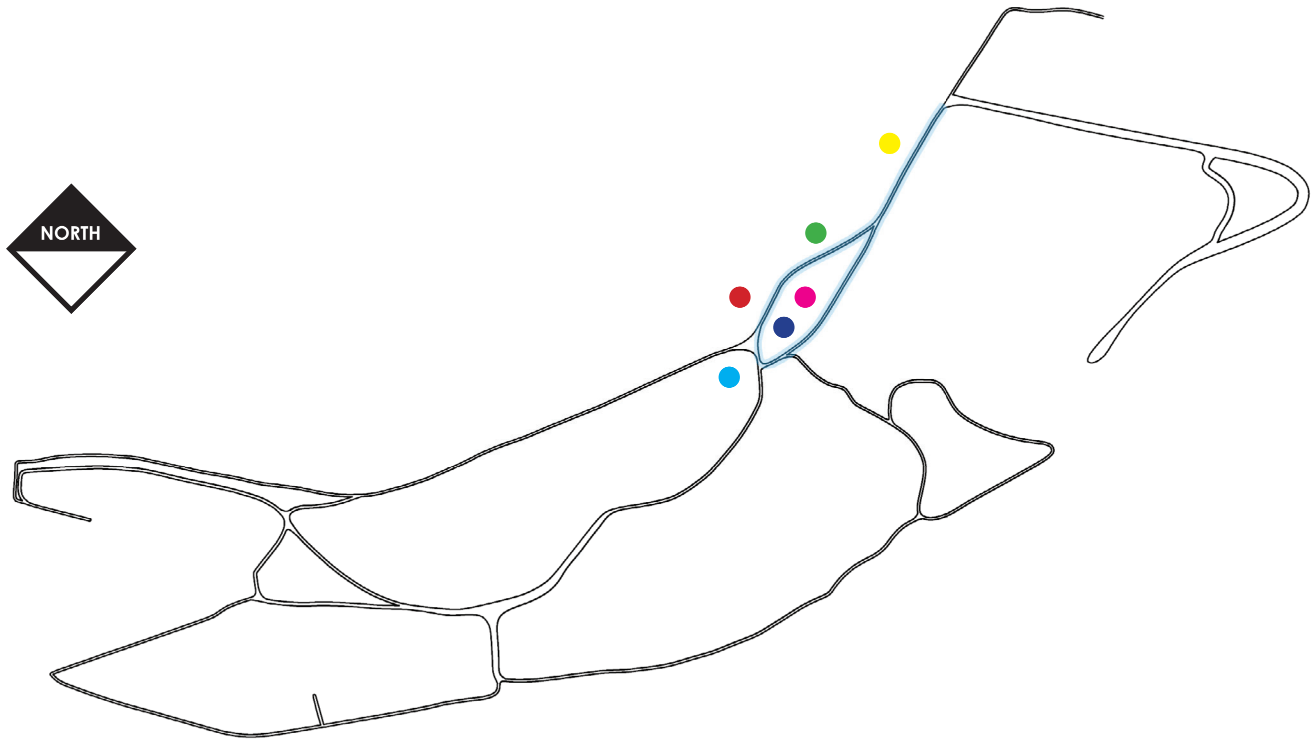


Fig. 3.50: Path Section 8
(Swehla, 2017)

Fig. 3.51: View towards east landfill
(Swehla, 2017)

Fig. 3.52: Gravel pathway looking East
(Swehla, 2017)

Fig. 3.53: Stagnant pond
(Swehla, 2017)

Fig. 3.54: Stagnant pond
(Swehla, 2017)

Fig. 3.55: Blue River
(Swehla, 2017)

Fig. 3.56: Flood dyke
(Swehla, 2017)

Branching off of the last trail section is a gravel pathway leading further into the back reaches of the site. The highlighted trail splits midway. The North trail continues on to a cliff side overlook. A drop of about 30 feet makes this overlook unscalable to the lower portion of trail. The rock at the cliff side seems to have been excavated for use in other areas of the site. Following the South fork brings you to the bottom of the cliff and allows you to traverse the remaining section. The trail is littered with bricks and trash along it's entire length. Portions of the gravel path are barren, exposing rough concrete underneath. At the end of the trail you can see Rock Creek from another overlook. Vegetation along the path is dense on either side with trees and shrubs.

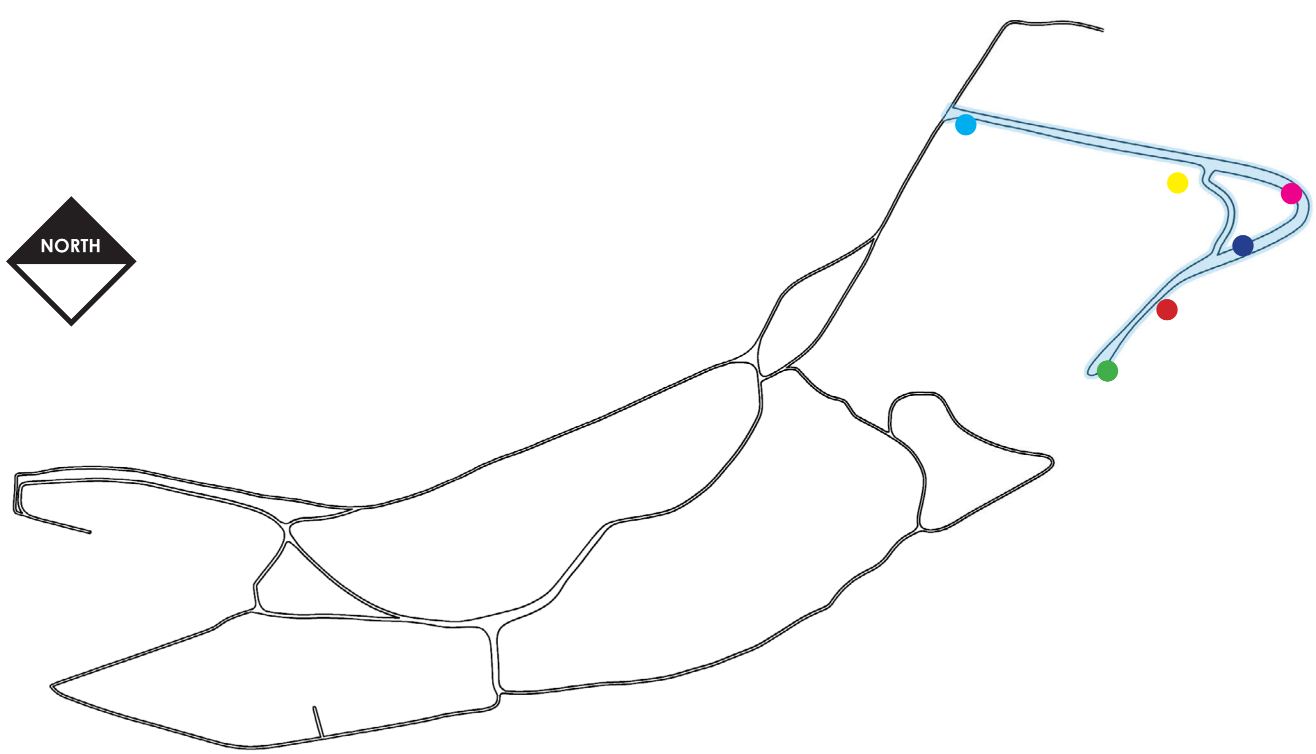


Fig. 3.57: Path Section 9
(Swehla, 2017)

Fig. 3.58: Gravel pathway looking East
(Swehla, 2017)

Fig. 3.59: Telephone lines
(Swehla, 2017)

Fig. 3.60: Cliff side looking South
(Swehla, 2017)

Fig. 3.61: View of cliff side looking North
(Swehla, 2017)

Fig. 3.62: End of pathway, looking North
(Swehla, 2017)

Fig. 3.63: View of Creek Creek from pathway
(Swehla, 2017)

The farthest trail section is gravel paved and lined along the sides with tall grasses. The area at the end of the trail is a large prairie style opening with tall light poles illuminating the space at night. The river edge is a steep drop off into the Missouri River. At the water's edge, there is an old shipping dock. The dock is a metal structure with timber topping which has rotted through in some areas.

Fig. 3.64: Path Section 10
(Swehla, 2017)

Fig. 3.65: Lightpoles and prairie
(Swehla, 2017)

Fig. 3.66: Industrial remnants
(Swehla, 2017)

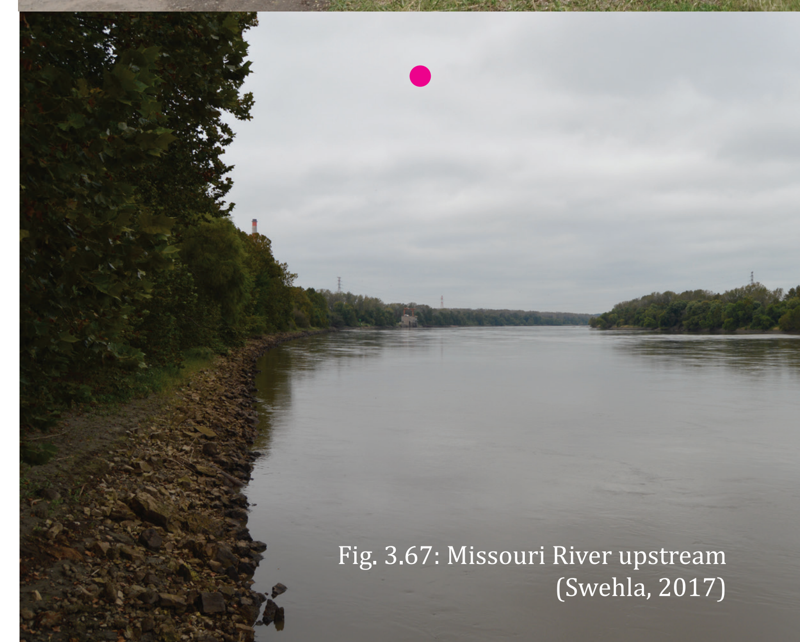


Fig. 3.67: Missouri River upstream
(Swehla, 2017)

Fig. 3.68: Old dock landing
(Swehla, 2017)

Fig. 3.69: Exposed flood wall
(Swehla, 2017)

Fig. 3.70: Old dock landing
(Swehla, 2017)

SITE ANALYSIS

Land Cover and Pathways

In order to develop site circulation, mapping was done to determine where trail infrastructure exists. A combination of paved, semi-paved, and grassy pathways currently exist on site. The pathways demarcated in the figure to the right differ in width, ranging from 10 feet to 25 feet wide. The site vegetation was massed using aerial photography and site images. This helps to reveal where conservation areas and views through the park could be placed.

The site's pathways are leftover trucking roads used by ARMCO to move industrial material. Remnant material and construction are seen throughout the site. It is also apparent that the site is used for unsanctioned activities because there are alcohol bottles and other unwanted litter found in almost every area of the site.

Opportunities

- Using the former trucking roads to build a trail system within the site allows for minimal habitat disturbance.
- Some of these areas are already paved or semi-paved, creating a solid foundation for new infrastructure.
- The existing paths already connect a high percentage of the site, creating unique and distinctly different pockets.
- Trail widths are wide enough to accommodate multiple forms of movement.

Constraints

- Many portions of the pathways are grass or bare soil, which would become unusable during wet conditions without further modification.
- Pathway construction over landfills is restrictive.
- Dense vegetation restricts views on some sections of the pathway.

Fig. 3.71: Existing Paths and Vegetation (Swehla, 2017)

Site Contaminates

There are two landfills located to the West and center of the site. These landfills have been capped with 3 feet of clean top soil. The site cleanup was done before modern regulations requiring that landfills be capped with a plastic liner to remove risk of pollution spread. Baghouse dust generated by ARMCO contained leachable quantities of lead and cadmium and a high concentration of zinc. The absence of this plastic liner indicates that pollution is migrating from the landfills to other areas of the site. The orange zone highlighted on the map to the right is extremely contaminated with surface debris. The surface debris in this area is a mixture of metal and plastics, mainly foam material. The soil here is contaminated with arsenic, which is a common chemical pollutant found where treated timber logs are used for rail road construction.

The West landfill is nearly 10 acres, the East landfill is 5 acres, and the polluted rail corridor is almost 21 acres. Combined, the ARMCO Site has 36 acres of contaminated soil.

Opportunities

- Landfill mounds isolate large areas that cannot be structurally developed, leaving these spaces for flexible programming.
- The historic rail corridor provides inspiration for design elements.
- The West landfill mound offers an elevated position to view the site from.

Constraints

- Landfill mounds will require plastic liners to prevent pollution migration and human access without contamination.
- The east landfill is adjacent to a low spot that routinely collects water runoff.
- The polluted rail corridor will require phytoremediation and a stormwater management plan.
- Management plans are required in order to remove chemicals and reduce their spread.

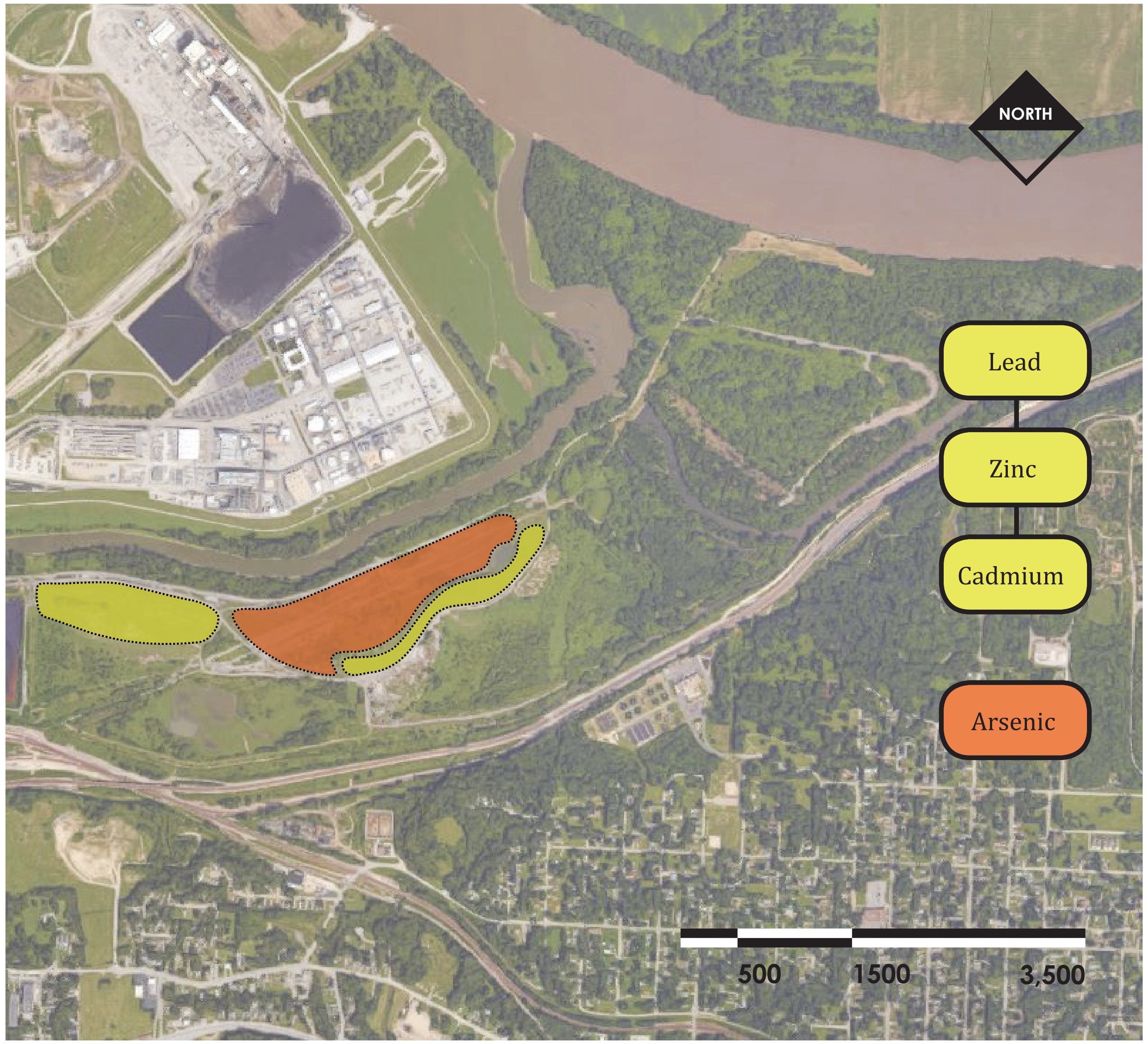


Fig. 3.72: Site Contaminants
(Swehla, 2017)

Pollutant Identification

High Bioavailability

I. Arsenic

Arsenic is a widespread pollutant in both urban and rural areas. At the ARMCO Site, arsenic is found in the soil. Arsenic pollution on the ARMCO Site most likely came as a result from industrial metal processing and mining byproducts. Arsenic kills organisms such as fungi, insects, and bacteria that can encourage beneficial environmental properties. There are opportunities for arsenic to be phytoextracted by hyperaccumulator plants. Phytoextraction of arsenic can be integrated into landscape design through the utilization of extraction plots, constructed wetlands, stormwater filters, interception hedgerows, and groundwater migration tree stands (Kennen and Kirkwood).

Long-term exposure to arsenic in drinking water can cause cancer in the skin, lungs, bladder and kidney. It can also cause other skin changes such as thickening and pigmentation. Arsenic-contaminated environments are characterized by limited species abundance and diversity (“Arsenic: 6”).

II. Cadmium

Cadmium and zinc are compounds that are usually found together on contaminated sites, often with 100-200 times more zinc contamination than cadmium. Cadmium is listed among the top twenty environmental toxins. Cadmium has a high level of bioavailability and therefore is capable of slow extraction. There are opportunities for cadmium to be phytoextracted and phytostabilized. Phytoextraction and phytostabilization can be applied to the landscape design through extraction plots, constructed wetlands, stormwater filters, interception hedgerows, and groundwater migration tree stands (Kennen and Kirkwood).

Cadmium contamination is a potential danger to animals that are dependent upon the plants for survival since cadmium can accumulate in their bodies. Earthworms and other essential soil organisms are extremely susceptive to cadmium poisoning. They can die at very low concentrations and this has consequences for the soil structure (“Cadmium”).

III. Zinc

Zinc contamination can be found in industrial sites where metals were processed and urban soils often have high levels from smoke stack and vehicle emissions, paint residue, and applications of phosphorous fertilizers. At the ARMCO Site, zinc contamination is found in the air, soil, and water. Like cadmium, zinc has a high level of bioavailability and can be extracted over long periods of time. There are opportunities for zinc to be phytoextracted and phytostabilized. Phytoextraction and phytostabilization can be applied to the landscape design through extraction plots, constructed wetlands, stormwater filters, interception hedgerows, and groundwater migration tree stands (Kennen and Kirkwood).

Zinc located in soils can contaminate groundwater. A limited number of plants have a chance of survival on zinc-rich soils. Fish absorb zinc when they live in zinc-contaminated waterways, which transfers up the food chain. Although humans can handle some concentrations of zinc, too much zinc can damage the pancreas, disturb protein metabolism, and cause arteriosclerosis (“Zinc”).

Difficult to Extract

IV. Lead

Lead contamination is one of the most common widespread contaminants in U.S. urban areas. Lead poisoning is also the leading environmentally induced illness in children. At the ARMCO site, lead can be found in the air, soil, and water. There are opportunities for lead to be phytostabilized. Phytostabilization of lead can be integrated into natural landscapes by the utilization of extraction plots, interception hedgerows, and groundwater migration tree stands (Kennen and Kirkwood).

Lead is a particularly dangerous chemical, as it can accumulate in individual organisms, but also in entire food chains. Lead accumulates in the bodies of water organisms and soil organisms. These organisms will experience lead poisoning. Phytoplankton is an important source of oxygen production in seas and many larger sea-animals eat it. That is why we now begin to wonder whether lead pollution can influence global balances (“Lead”).

Soil Type

Soil mapping allows for more detailed design of the site because soil characteristics of the site have implications on the types of plants that can grow in certain areas and requirements for design elements. The differing soils are telling signs of flood zones and stormwater infiltration abilities.

Mapping the ARMCO site's soil helps identify the infiltration and runoff amounts, water storage and filtering abilities, and the physical and chemical support for vegetation. Site soils are described using descriptors based on their soil horizons and distinct horizon characteristics. The descriptors used to explain the soil characteristics, shown below, were taken from *Soil Science Simplified* (Kohnke an Franzmeier).

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Parkville silty clay	0 to 2 percent slopes, occasionally flooded	73.2	15.7
Bremer silt loam	0 to 2 percent slopes, occasionally flooded	5.3	1.1
Zook silty clay loam	0 to 2 percent slopes, occasionally flooded	24.8	5.3
Leta silty clay	0 to 2 percent slopes, occasionally flooded	5.3	1.1
Haynie silt loam	0 to 2 percent slopes, occasionally flooded	275.1	59.1
Sarpy fine sand	0 to 2 percent slopes, frequently flooded	54.9	11.8
Water		12.4	2.7
Udarents-Urban land complex	2 to 9 percent slopes	14.3	3.1

Table 3.7: Soil Type
(Swehla, 2017)

Master Soil Horizon Designations

A - Uppermost horizon, which is composed mostly of mineral material but is rich in organic matter

B - Subsurface horizon that has an accumulation of clay, organic matter, and shows other evidence of alteration, such as distinctive color or structure.

C - Geologic materials, including partially weathered bedrock, that show little change sue to soil formation

Subordinate Horizon Distinctions

gl - Soil that is saturated with groundwater

p - An A horizon that has been plowed or otherwise tilled

- Indicates changing characteristics within same horizon

= Parkville silty clay
= Zook silt clay laom
= Haynie silt loam
= Udarents-urban
= Bremer silt loam
= Leta silty clay
= Sarpy fine sand
= Water

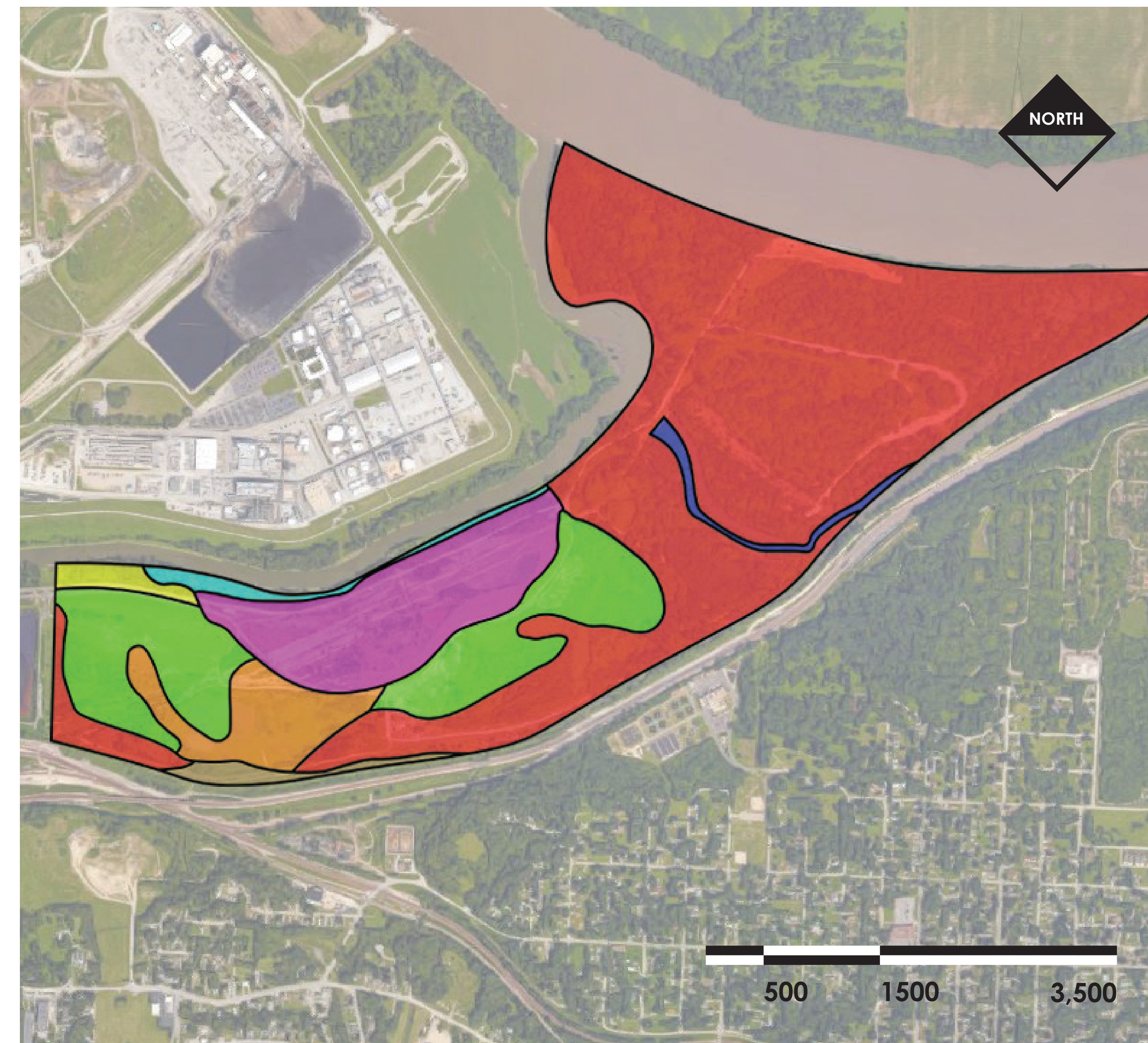


Fig. 3.73: Soil Map
(Swehla, 2017)

I. Parkville Silty Clay

The Parkville Silty Clay series consists of deep, calcareous, somewhat poorly drained soils formed in clayey over loamy alluvium on flood plains of major streams. Permeability is slow or very slow in the upper part and moderate in the lower part of the soil. Parkville soils are typically accepting of farmland crops such as corn, soybeans, wheat, alfalfa, and pasture with native vegetation consisting of willows and cottonwoods.

The Ap horizon of the Parkville Silty Clay series is 0" - 8" deep, with strong fine granular structure in the upper part and strong very fine subangular blocky structure in the lower part. Texture is silty clay loam, silty clay, or clay. Reaction is neutral to moderately alkaline. The A horizon (8" - 16") is a moderate medium angular blocky structure, while the 2Cgl horizon consists of weak horizontal bedding planes and a pronounced bedding plane at the horizontal break 16" - 32" below the surface. 2C horizon ranges from mildly to moderately alkaline ("USDA-NRCS Official). This soil series is categorized as 'very limited' for path and trail construction due to its depth to saturation zone (.44/1.0), clayey soil structure (1.0/1.0), and dusty conditions (.09/1.0).

II. Bremer Silt Loam

The Bremer Silt Loam series consists of very deep, poorly drained soils formed in alluvium. These soils are on stream terraces of floodplains. The soil is poorly drained with saturation occurring within a 1 foot depth during March to June and saturated hydraulic conductivity as moderately high. Surface runoff potential is negligible or low. Most Bremer soils are cultivated, with principal crops being corn and soybeans. The soils natural vegetation is big bluestem, indiangrass, switchgrass, and other grasses of the tall grass prairie.

The Ap horizon of the Bremer Silt Loam series is 0" - 19" deep, with weak very fine subangular blocky structure. Texture is silty clay loam. Reaction is moderately acid to neutral. The B horizon consists of a weak medium prismatic structure parting to weak very fine and fine subangular blocky particles. The B horizon ranges from moderately acidic to neutral ("USDA-NRCS Official). Engineering constraints include: a 'very limited' rating for shallow excavation due to its depth to saturation zone (1.0/1.0), flooding (.60/1.0), dusty conditions, and unstable excavation walls; 'very limited' rating for camp areas due to its depth to saturation zone (1.0/1.0), flooding (1.0/1.0), slow water movement (.96/1.0), and dusty conditions; 'very limited' rating for picnic areas due to its depth to saturation zone (1.0/1.0), slow water movement (.96/1.0), and dusty conditions; 'very limited' rating for paths/trails due to its depth to saturation zone (1.0/1.0) and dusty conditions; 'very limited' rating for playgrounds due to its depth to saturation zone (1.0/1.0), slow water movement (.96/1.0), flooding (.60/1.0), and dusty conditions; and 'slight' erosion hazards for roads/trails due to slope erodibility (.05/1.0).

III. Zook Silt Clay Loam

The Zook Silt Clay Loam series consists of very deep, poorly drained soils formed in alluvium. These soils are on flood plains and stream terraces in river valleys and in drainage ways on uplands. Where drained, most areas are cultivated. The principal crops are corn and soybeans. The native vegetation is big bluestem, western wheatgrass, sedges, blue grama and other species of the tall grass prairie that are tolerant of excessive wetness.

The Ap and A1 horizons of the Zook Silt Clay Loam series are 0" - 7" deep, and 7" - 14" respectively, with weak fine subangular blocky structure parting to weak fine granular structure. Texture is silty clay loam or silty clay. The Ap and A horizons react moderately acidic to slightly alkaline. The A2 horizon makes up 14" - 20" below the surface, with a moderate fine prismatic structure parting to moderate fine subangular blocky structure. The A3 and A4 horizons create depths 20" - 31" , and 31" - 38", with moderate medium prismatic structure parting to a moderate fine subangular blocky structure ("USDA-NRCS Official). Engineering constraints for include ratings of: 'well suited', for hand planting suitability; 'very limited' for shallow excavations due to its depth to saturation zone (1.0/1.0), flooding (.60/1.0), dusty conditions, and unstable excavation walls; and 'slight' erosion hazards for roads/trails due to slope erodibility (.05/1.0).

IV. Leta Silty Clay

The Leta Silty Clay series consists of very deep, somewhat poorly drained soils that formed in alluvium. These soils are on flood plains along major streams. Permeability is slow in the upper part and moderate or rapid in the lower part. Runoff is low, however these soils are subject to rare or frequent flooding. Most Leta soils are cropped to corn, soybeans, and wheat. Native vegetation is mostly willows and cottonwoods.

The Ap horizon of the Leta Silty Clay series are 0" - 8" deep and have a weak fine granular structure. The A horizon consists of depths between 8" - 13" with a moderate medium subangular blocky structure. The B horizon (13" - 25") is a moderate medium subangular blocky structure. The Ap, A, and B horizons react slightly alkaline ("USDA-NRCS Official). The engineering constraints include ratings of: 'unsuited' for agricultural use due to soils not suited to forage crops; poorly suited' for road suitability due to its depth to saturation zone (1.0/1.0); 'fair' in construction material reclamation due to its low water erosion potential (.06/1.0) and clayey soil structure(.54/1.0); 'fair' for topsoil material due to its wetness (.02/1.0) and clay soil structure (.53/1.0); 'very limited' for shallow excavations due to its depth to saturation zone (1.0/1.0), flooding (.60/1.0), dusty conditions, and unstable excavation walls; 'very limited' for camp areas due to its depth to saturation zone (1.0/1.0), flooding (1.0/1.0), clayey soil structure (1.0/1.0), slow water movement (.94/1.0), and dusty conditions; 'very limited' for picnic areas due to its depth to saturation zone (.96/1.0), slow water movement (.94/1.0), clayey soil structure (1.0/1.0), and dusty conditions; 'very limited' for paths/trails due to its depth to saturation zone (.92/1.0), clayey soil structure (1.0/1.0), and dusty conditions; and 'very limited' for playgrounds due to its depth to saturation zone (1.0/1.0), flooding (.60/1.0), slow water movement (.94/1.0), clayey soil structure (1.0/1.0), and dusty conditions.

V. Haynie Silt Loam

The Haynie Silt Loam series consists of very deep, moderately well drained soils on flood plains. These soils formed in calcareous alluvium. Surface runoff potential is low. Most areas are cultivated. The principal crops are corn, soybeans, small grain, and hay. Some areas are land-leveled and irrigated. The native vegetation is big bluestem, indiangrass, switchgrass, and other grasses of the tall grass prairie.

The Ap horizon of the Haynie Silt Loam series is 0 - 7" deep, with small clods parting to weak fine subangular blocky and weak fine granular structure. The Ap horizon reacts neutral or slightly alkaline. The C horizon makes up depths between 7" - 60", with weak thin alluvial stratification. This horizon reacts slightly alkaline or moderately alkaline ("USDA-NRCS Official). The engineering constraints include ratings of: 'unsuited' for agricultural use due to soils not suited to forage crops; 'well suited' for hand planting suitability; 'slight' for roads/ trails due to slope erodibility (.05/1.0); 'fair' for topsoil material due to its wetness (.14/1.0) and exchange capacity (.83/1.0); 'fair' for construction material reclamation due to its low water erosion potential (.06/1.0) and low content of organic matter; 'somewhat limited' for shallow excavation due to flooding (.6/1.0), dusty conditions, and unstable excavation walls.

VI. Sarpy Fine Sand

The Sarpy Fine Sand series consists of very deep, excessively drained soils on flood plains. These soils formed in sandy alluvium. Surface runoff potential is negligible or low. Cleared areas are in pasture or cultivated. Common crops include alfalfa, oats, soybeans, and wheat. The native vegetation commonly is a thin stand of native grasses and sandburrs or cottonwood and willow trees.

The Ap horizon of the Sarpy Fine Sand horizon is 0" - 6", with a weak fine granular structure. The Ap horizon reacts neutral to moderately alkaline. The C horizon consists of soil depths between 6" - 60", with a single grain structure. The C horizon reacts neutral to strongly alkaline ("USDA-NRCS Official). The engineering constraints include ratings of: 'high' for pesticide leaching; 'medium' for pesticide runoff potential; 'moderately well suited' for hand planting potential; 'very low' for potential water erosion, 'high' potential fire damage hazard due to its texture/surface layer thickness (1.0/1.0), 'poor' for topsoil material due to its exchange capacity (.71/1.0); 'very limited' for shallow excavations due to flooding (.8/1.0) and unstable excavation walls; and 'slight' for roads/trails due to slope erodibility (.05/1.0).

VII. Udarents-Urban Land Complex

The Udarents-Urban Land Complex series consists of silt loam fill that is somewhat poorly drained. Surface runoff potential is very high. The native vegetation is commonly a mix of native tallgrass species.

The C1 horizon of the Udarents-Urban Land Complex series is 0" - 5" inches, reacting nonsaline to very slightly saline. The C2 horizon is 5" - 80" inches, composed of silty clay loam ("USDA-NRCS Official). The Engineering constraints include: 'unsuited' for agricultural use due to soils not suited to forage crops; 'generally not suited' for pasture hayland due to stony surfaces that limit the adaptability and productivity of forage harvesting; 'somewhat limited' for shallow excavations due to its dusty conditions and unstable excavation walls; 'somewhat limited' for paths and trails due to its dusty conditions; 'well suited' for hand planting suitability; 'very limited' for construction of paved and unpaved roads due to its depth to saturation zone (1.0/1.0); and 'moderate' for roads/trails due to slope erodibility (.50/1.0).

Opportunities

- The polluted rail corridor where phytoremediation will be implemented frequently floods, which is beneficial to the design of a constructed wetland. Also suggesting a planting scheme tolerant of wet conditions. Sarpy fine sand commonly hosts native grasses and cottonwoods.
- 59% of the site's soil aids growth of native big bluestem, indiangrass, switchgrass, and other grasses of the tall grass prairie.
- The majority of the site is under 2% slope with haynie silt loam.
- The eastern side of the site is a uniform soil type.

Constraints

- The East landfill is within a soil zone that floods occasionally. This will require thoughtful design to ensure the landfill does not leach more pollutants.
- The sarpy fine sand soil is well drained, which is not conducive for constructing wetland areas, thus requiring a synthetic bed liner to retain water.
- The site's soil characteristics offer no unique, natural formations.

Hydrologic Soil Group

To assist runoff calculations, this map was created to label the hydrologic soil groups (HSG). ARMCO Site soils are assigned to groups, A, B, C, or D, according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

For the soils that are assigned to a dual hydrologic group (C/D), the first letter is for drained areas and the second is for undrained areas. Soil data was collected for the ARMCO Site using the U.S. Department of Agriculture Web Soil Survey online database ("Web Soil Survey"). The groups are defined as follows:

Map Unit Name	Description	Rating
Parkville silty clay	0 to 2 percent slopes, occasionally flooded	D
Bremer silt loam	0 to 2 percent slopes, occasionally flooded	C/D
Zook silty clay loam	0 to 2 percent slopes, occasionally flooded	D
Leta silty clay	0 to 2 percent slopes, occasionally flooded	C/D
Haynie silt loam	0 to 2 percent slopes, occasionally flooded	B
Sarpy fine sand	0 to 2 percent slopes, frequently flooded	A
Water		
Udarents-Urban land complex	2 to 9 percent slopes	C

Table 3.8: Hydrologic Soil Group (Swehla, 2017)

I. Group A

Sand, loamy sand, or sandy loam. Soils having a high infiltration rate when thoroughly wet. Water is transmitted freely through the soil. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. Group A soils typically have less than 10 percent clay and more than 90 percent sand or gravel and have gravel or sand textures. Some soils having loamy sand, sandy loam, loam or silt loam textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments ("Hydrologic Soil Groups").

II. Group B

Silt loam or loam. Soils having a moderate infiltration rate when thoroughly wet. Water transmission through the soil is unimpeded. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. Group B soils typically have between 10 percent and 20 percent clay and 50 percent to 90 percent sand. Some soils having loam, silt loam, silt, or sandy clay loam textures may be placed in this

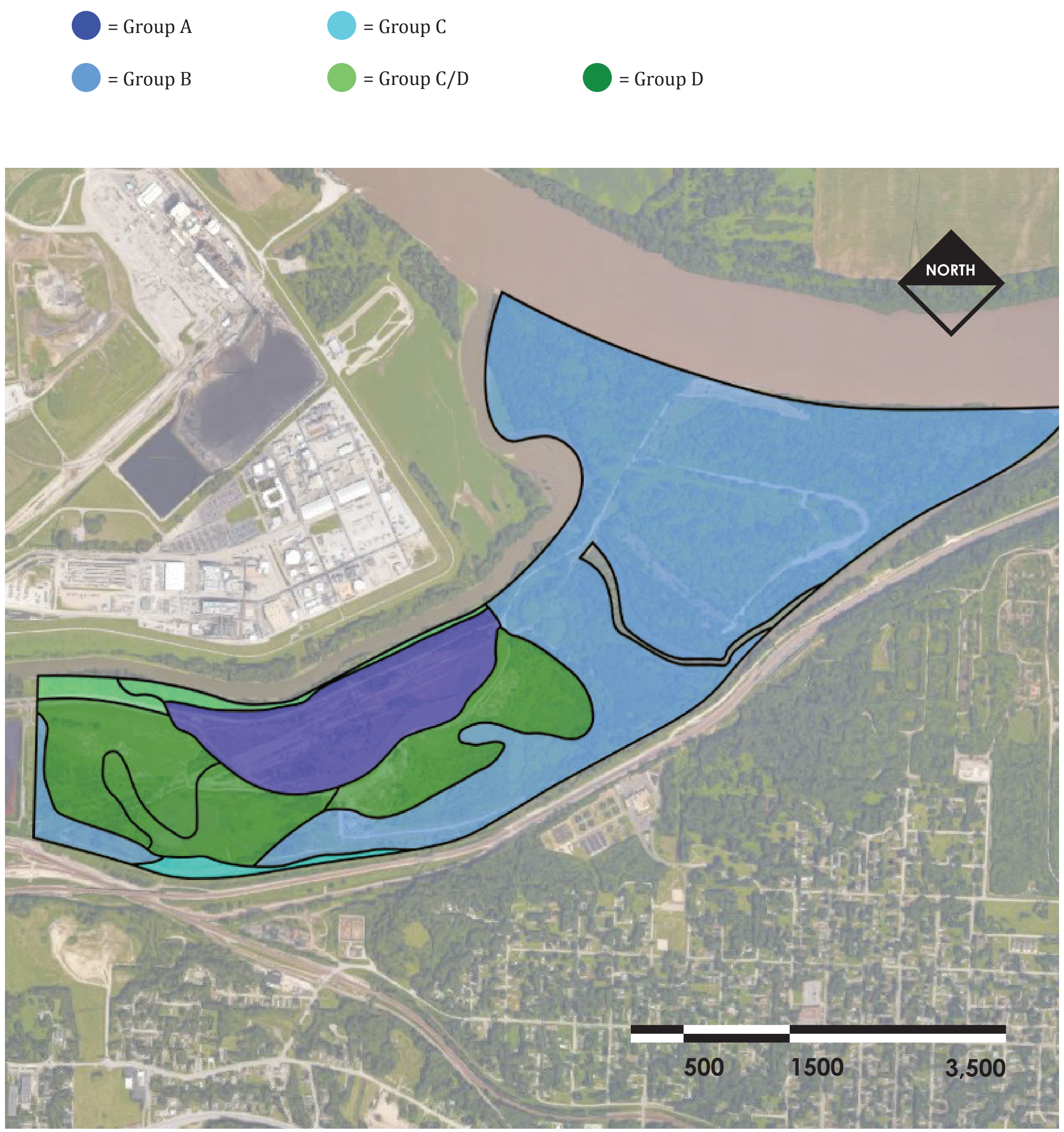


Fig. 3.74: Hydrologic Soil Group (Swehla, 2017)

group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments (“Hydrologic Soil Groups”).

III. Group C

Sandy clay loam. Soils having a slow infiltration rate when thoroughly wet. Water transmission through the soil is somewhat restricted. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. Group C soils typically have between 20 percent and 40 percent clay and less than 50 percent sand. Some soils having clay, silty clay, or sandy clay textures may be placed in this group if they are well aggregated, of low bulk density, or contain greater than 35 percent rock fragments (“Hydrologic Soil Groups”).

IV. Group D

Clay loam, silty clay loam, sandy clay, silty clay, or clay. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. Water movement through the soil is restricted or very restricted. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. Group D soils typically have greater than 40 percent clay, less than 50 percent sand (“Hydrologic Soil Groups”).

It should be understood that as a result of urbanization, the soil profiles may be considerably altered and the listed group classification may no longer apply.

Opportunities

- The West landfill is covered with Group D soils. This means that the runoff potential is high and stormwater infiltration to polluted soils will be low.
- The seasonally wet lowland is also within Group D soils, meaning that it’s ability to withhold water can be leveraged for a wetland design.
- Group A soils cover the old rail corridor where surface pollution was found. Infiltration of stormwater will allow soils and plant roots to filter and clean out unwanted chemicals.

Constraints

- The area of the site with surface pollutants is classified as Group A. Pollutants may infiltrate the soils and reach the water table without succumbing to phytoremediation.
- The East landfill is partially located within Group A and Group D soils. This means that the landfill is susceptible to stormwater infiltrating its soil cap and leaching more pollutants into the site.

Soil Percent Clay

After reviewing the infiltration rates of each soil type, further investigation was needed in order to assess the amount of clay particulate in the soil. This may give a better understanding of where chemical pollutants may be absorbed by more solid soil structures.

The amount and kind of clay affect the fertility, physical condition of the soil, tillage and earth-moving operations. They influence shrink-swell potential, saturated hydraulic conductivity (Ksat), plasticity, and the ease of soil dispersion. The estimated clay content of each soil layer is given as a percentage. Typically, soil that consists of over 50% clay particles is referred to as “heavy clay”, but they are not prevalent at the ARMCO Site (“A Gardener’s Guide”).

Map Unit Name	Description	Rating (percent)
Parkville silty clay	0 to 2 percent slopes, occasionally flooded	26.5
Bremer silt loam	0 to 2 percent slopes, occasionally flooded	31.5
Zook silty clay loam	0 to 2 percent slopes, occasionally flooded	38.6
Leta silty clay	0 to 2 percent slopes, occasionally flooded	37
Haynie silt loam	0 to 2 percent slopes, occasionally flooded	8.2
Sarpy fine sand	0 to 2 percent slopes, frequently flooded	2
Water		
Udarents-Urban land complex	2 to 9 percent slopes	26.5

Table 3.9: Soil Percent Clay
(Swehla, 2017)

I. High Clay Percent

Soil with higher clay percentages will naturally absorb and retain chemicals in its soil structure better than those with low clay percentage. This ability is due to the size of pores provided for the passage and retention of gasses and moisture within the soil profile. The soil’s ability to retain water molecules is held more tightly by the fine particles of a clay soil than to coarser particles of a sandy soil (“Soils And Drainage”).

The amount of clay within a soil zone also affects the type of vegetation that may be grown there. Clay retains moisture well and tends to be more nutrient-rich than other soil types. The reason for this is that the particles that make up clay soil are negatively charged. They attract and pick up positively charged particles, such as calcium, potassium, and magnesium. This means that trees and shrubs grow well in clay, however, the roots of most annuals, perennials, and vegetables

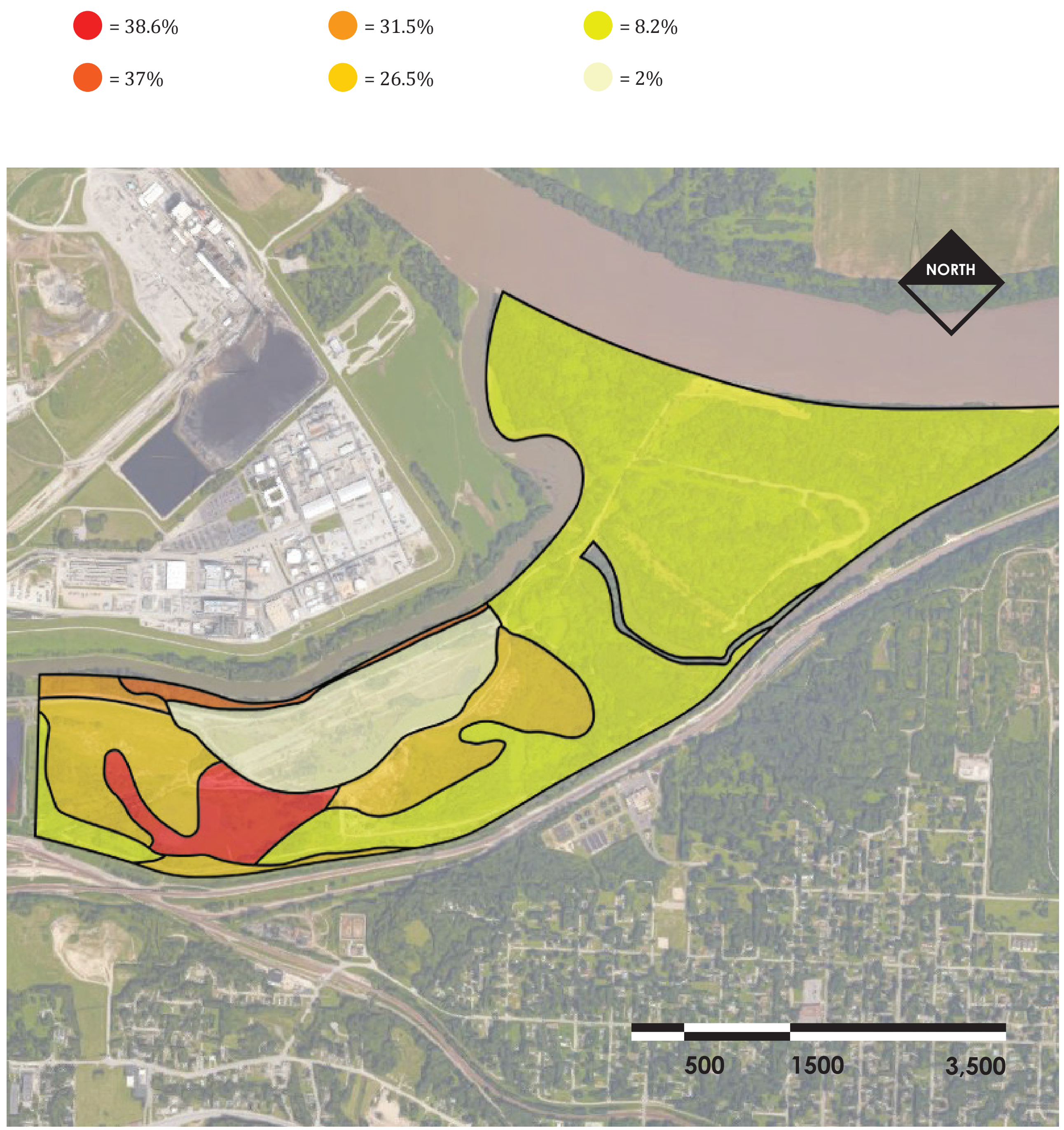


Fig. 3.75: Soil percent Clay
(Swehla, 2017)

are not strong enough to make their way through clayey soil.

II. Low Clay Percent

In the assessment of clay percentages, stormwater runoff potential is a major concern. High clay percentages result is high runoff potential and low infiltration capacities, while low clay percentages result in low runoff potential and high infiltration capacities. Sites with low infiltration capacity soils may limit the type, location, number and/or sizing of infiltration best management practices (BPMs) that can be used for stormwater management. Soils with lower clay percentages may not retain many nutrients that are required for most plants to grow to their desired size.

Opportunities

- The areas with less clay will effectively percolate water through the site's soil layers, increasing the site's stormwater carrying capacity.
- The area of the site with surface pollutants is low percent clay, which means that contaminants will move through the soil columns more easily, allowing it to be more bioavailable for phytoremediation.
- The area of the site where phytoremediation will be implemented has low clay percentages. The soil here may not be nutrient dense, making it more difficult for some plants to grow.

Constraints

- The areas of the site with high soil percent clay will absorb and hold contaminants on site.
- More stormwater will runoff from the areas of the site with high soil percent clay.
- Low clay percentage soils will require plastic liners to help capture and hold stormwater.
- The area of the site with surface pollutants is low percent clay, which means that contaminants will move through the soil columns more easily,

Site Hydrology

The site's stormwater is collected in 11 existing sub-watersheds. Each watershed eventually connects to the Missouri River. Conditions within the ARMCO Site's watersheds are important to investigate because they ultimately determine the health and quality of water in the Blue River, Rock Creek, and Missouri River waterways.

This watershed map can help identify areas of the site that experience large amounts of stormwater runoff. The watershed's drainage divides show where ridge lines direct water towards different areas of the site. At the ARMCO Site, the ridge lines are commonly located along existing pathways.

I. Watershed 1

Along the North side of the site a ridge line separates Watersheds 1 and 5 from Watershed 2. This ridge line sends stormwater off site, towards the Blue River (unpolluted), or into Watershed 2, where it mixes with chemical pollution within the soils.

Soil within Watershed 1 is composed of Bremer Silt Loam. The Bremer Silt Loam series is very deep, poorly drained with saturation occurring within a 1 foot depth during March to June. Surface runoff potential is negligible or low. Texture is silty clay loam.

II. Watershed 2

Watersheds 2 and 3 receive stormwater flowing off a portion of the West landfill that is most likely contaminated with lead, zinc, and cadmium. This stormwater in Watershed 2 then runs through the polluted rail corridor where it absorbs arsenic. Contaminated stormwater that does not percolate through the soils or get absorbed by vegetation is then carried into Watershed 6.

Soil within Watershed 2 is composed of Parkville Silty Clay and Sarpy Fine Sand. The Parkville Silty Clay series is a deep, calcareous, somewhat poorly drained soil. Permeability is slow or very slow in the upper part and moderate in the lower part of the soil. Texture is silty clay loam, silty clay, or clay. The Sarpy Fine Sand series is a very deep, excessively drained soil with negligible or low surface runoff potential.

III. Watershed 3

Polluted stormwater from the West landfill flowing into Watershed 3 is outlet to the Blue River waterway via a storm drain running off site.

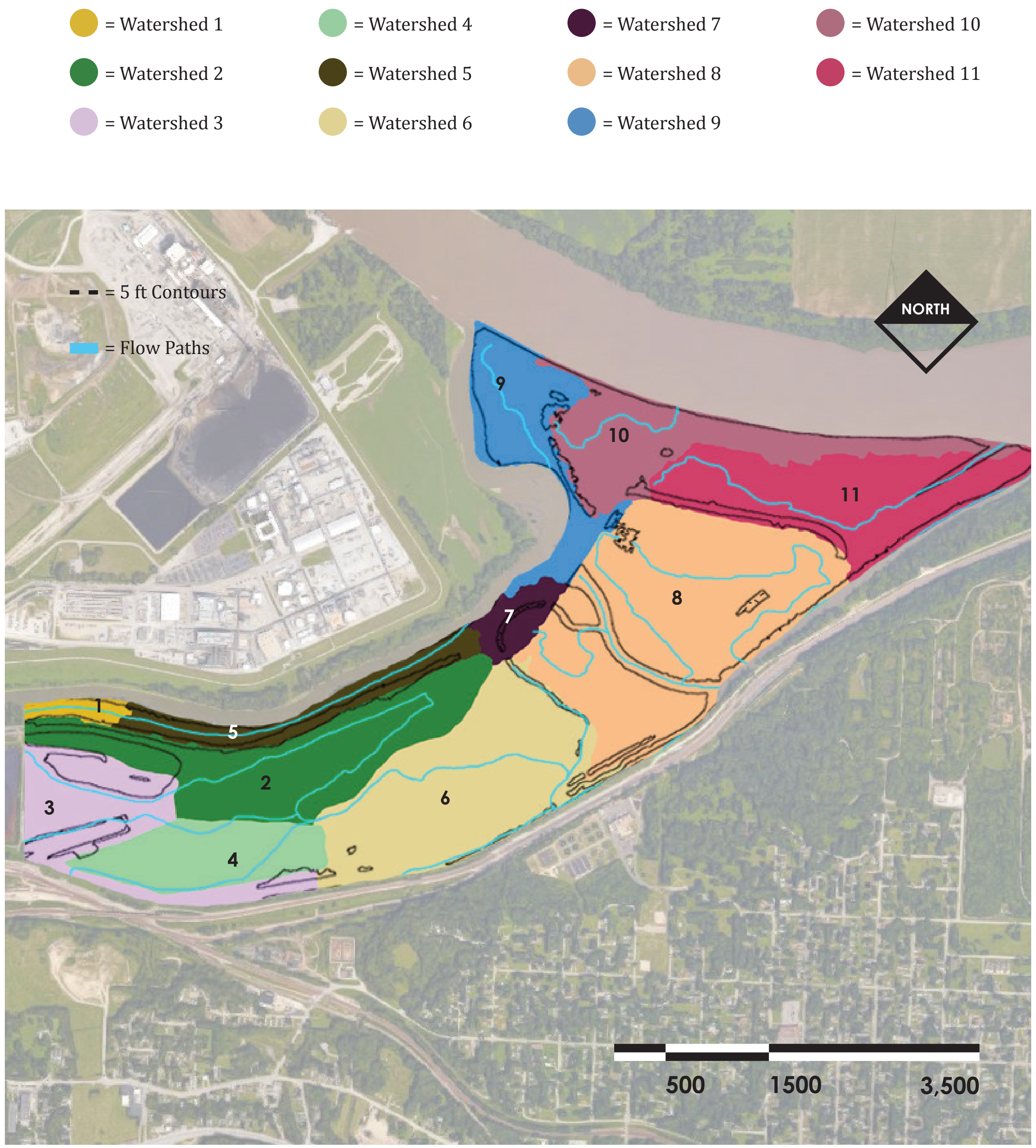


Fig. 3.76: Existing Watershed Map (Swehla, 2017)

Soil within Watershed 3 is composed of Parkville Silty Clay, Zook Silty Clay Loam, and Haynie Silt Loam. The Parkville Silty Clay series is a deep, calcareous, somewhat poorly drained soil. Permeability is slow or very slow in the upper part and moderate in the lower part of the soil. Texture is silty clay loam, silty clay, or clay. The Zook Silt Clay Loam series is a very deep, poorly drained soil. Texture is silty clay loam or silty clay. The Haynie Silt Loam series is a very deep, moderately well drained soil with low surface runoff potential.

IV. Watershed 4

There is a slight depression in Watershed 4 that collects water seasonally. The low point of this watershed is located above the water table and is not polluted by site contaminates.

Soil within Watershed 4 is composed of Parkville Silty Clay, Zook Silty Clay Loam, Haynie Silt Loam, and Udarents-Urban Land Complex. The Parkville Silty Clay series is a deep, calcareous, somewhat poorly drained soil. Permeability is slow or very slow in the upper part and moderate in the lower part of the soil. Texture is silty clay loam, silty clay, or clay. The Zook Silt Clay Loam series is a very deep, poorly drained soil. Texture is silty clay loam or silty clay. The Haynie Silt Loam series is a very deep, moderately well drained soil with low surface runoff potential. The Udarents-Urban Land Complex series is a silt loam fill that is somewhat poorly drained with very high surface runoff potential.

V. Watershed 5

Stormwater falling on Watershed 5 is either guided North to the Blue River, or South into Watershed 2.

Soil within Watershed 5 is composed of Leta Silty Clay and Haynie Silt Loam. The Leta Silty Clay series is a very deep, somewhat poorly drained soil. Runoff is low, however these soils are subject to rare or frequent flooding. The Haynie Silt Loam series is a very deep, moderately well drained soil with low surface runoff potential.

VI. Watershed 6

Watershed 6 accepts polluted stormwater from Watershed 2, as well as from the East landfill. Stormwater draining from the East landfill is most likely polluted with lead, zinc, and cadmium. This water is connected with Rock Creek through a dried up ox bow.

Soil within Watershed 6 is composed of Parkville Silty Clay and Haynie Silt Loam.

The Parkville Silty Clay series is a deep, calcareous, somewhat poorly drained soil. Permeability is slow or very slow in the upper part and moderate in the lower part of the soil. Texture is silty clay loam, silty clay, or clay. The Haynie Silt Loam series is a very deep, moderately well drained soil with low surface runoff potential.

VII. Watershed 7

The section of the dried ox bow located within Watershed 7 has been disconnected from the rest by the paving of an existing pathway. Stormwater collected hear is held stagnant within the isolated ox bow section, avoiding contamination from polluted soils.

Soil within Watershed 7 is composed of Haynie Silt Loam. The Haynie Silt Loam series is a very deep, moderately well drained soil with low surface runoff potential.

VIII. Watershed 8

The flood dyke built by ARMCO along the North edge of the site seems to have blocked a section of the Missouri River’s flow through Watersheds 8 and 9. The dried ox bow running through Watersheds 6 and 8 creates a low point that channels water toward Rock Creek.

Soil within Watershed 8 is composed of Haynie Silt Loam. The Haynie Silt Loam series is a very deep, moderately well drained soil with low surface runoff potential.

IX. Watershed 9

Stormwater falling within Watershed 9 flows unpolluted into the Blue River and Missouri River waterways.

Soil within Watershed 9 is composed of Haynie Silt Loam. The Haynie Silt Loam series is a very deep, moderately well drained soil with low surface runoff potential.

X. Watershed 10

Watershed 10 empties stormwater directly into the Missouri River. Stormwater within this watershed has not been mixed with site contaminates and does not impose immediate threat to the natural balance of the river.

Soil within Watershed 10 is composed of Haynie Silt Loam. The Haynie Silt Loam series is a very deep, moderately well drained soil with low surface runoff potential.

XI. Watershed 11

Watershed 11 acts similarly to Watershed 10, emptying its unpolluted stormwater into Rock Creek.

Soil within Watershed 11 is composed of Haynie Silt Loam. The Haynie Silt Loam series is a very deep, moderately well drained soil with low surface runoff potential.

Opportunities

- The naturally occurring sub-watersheds are characteristically different, creating ponding areas and lowlands.
- The northern boundary of the site is topographically elevated, creating a flood wall.
- The Rock Creek ox box creates a low, serpentine channel that collects surface runoff from a majority of the west site.
- Most pathways act as high points within the topography.

Constraints

- A large portion of stormwater runs through the contaminated rail corridor, flushing contaminants into the river.
- The site sits above the water table, making it difficult to hold water year-round.

PLANT PALETTE SELECTION

The following plant list was chosen to combat site pollutants and provide native habitat.

= extracts lead = extracts arsenic = extracts cadmium = extracts zinc

Fig. 3.77 - 3.108: Plant Palette (Swehla, 2017)

Grass Palette

Scientific Name	Common Name	Extracts Lead	Extracts Arsenic	Extracts Cadmium	Extracts Zinc	Native?	Water Needs	Sun Needs	Description	Seasonal Interest	Landscape Uses
Andropogon gerardii	Big Bluestem					x	dry/ mod	full sun	Tall, perennial, warm season grass	Nov - Feb	Best massed in meadows or prairies. Effective in borders.
Agrostis delicatula	Bentgrass		x				mod	full sun	Dense carpet typically grows to 3-6" tall	non flowering	Uniformity and manicured lawn appearance.
Leersia oryzoides	Rice Cutgrass		x				mod/ high	full sun/ med	Tall grass ~ 3 ft	June - Oct	Wetlands including floodplains and pond margins.
Panicum virgatum	Switchgrass	x		x	x	x	mod/ high	full sun/ med	High biomass. Thick growing tall clump grass.	July - Feb	Effective as a screen, prairie, water gardens, and along ponds.
Scirpus cyperinus	Woolgrass					x	wet	full sun/ med	Grass-like, rhizomatous, aquatic perennial	June - July	Wet meadows, bottomland prairies, stream/ pond margins.
Spartina perctinata	Cordgrass					x	mod/ wet	full sun/ med	Coarse, tough, grass that grows in a clump to 4-7'	July - Aug	Ponds/water gardens. Erosion control along slopes/streams.
Tripsacum dactyloides	Eastern Gammagrass					x	mod	full sun/ med	Robust, clump-forming, grass that grows from 4-8' tall	May - Sep	Borders, meadows, prairies, along ponds and streams.
Typha angustifolio	Narrowleaf Cattail					x	wet	full sun/ med	Aquatic cattail forms densely in shallow water	June - July	Water gardens, and ponds.

Table 3.10: Grass Palette
(Swehla, 2017)

Shrub Palette

Scientific Name	Common Name	Extracts Lead	Extracts Arsenic	Extracts Cadmium	Extracts Zinc	Native?	Water Needs	Sun Needs	Description	Seasonal Interest	Landscape Uses
Hyndrangea arborescens	Wild Hydrangea					x	mod/ high	med	3-6' tall shrub, native to moist streambanks.	May - Frost	Mass or group in shaded area of shrub border/ woodland garden.
Onoclea sensibilis	Sensitive Fern		x			x	mod/ wet	med/ full sun	Large fern that grows 4' tall in moist soils along streams.	non flowering	Plantings along streams and ponds/shaded areas.
Polystichum acrostichoides	Christmas Fern		x			x	dry/ mod	med/ full sun	Typically grows in a fountain-like clump to 2' tall.	non flowering	Shaded areas along walls, good for erosion control.
Impatiens capensis	Jewelweed					x	mod/ wet	med/ full sun	Grows along stream banks, 2-5' tall on watery stems.	June - Sep	Planted in bog gardens, along streams and ponds. Low spots.
Physocarpus opulifolius	Ninebark					x	mod/ high	med/ full sun	Grows upright along streams, gravel bars, and moist soils.	May - Frost	Wetlands,stream edges, shrub borders, and erosion control.
Lindera benzoin	Spicebush					x	mod/ high	full sun	Grows 6-12' high in moist soils and along streams.	May - Frost	Fragrant shrub borders, moist areas, and naturalized areas.
Cornus sericea	Red Twig Dogwood	x				x	mod/ wet	med/ full sun	Grows upright, 6-9' tall with a larger spread.	May - June	Specimen tree. Perform well in wet locations along ponds.
Cephalanthrus occidentalis	Buttonbush					x	mod/ wet	ful sun/ med/ full shade	6-12' tall, occuring in wet open areas, and pond margins.	June	May be grown in shallow water at the edge of ponds.

Table 3.11: Shrub Palette
(Swehla, 2017)

Tree Palette

Scientific Name	Common Name	Extracts Lead	Extracts Arsenic	Extracts Cadmium	Extracts Zinc	Native?	Water Needs	Sun Needs	Description	Seasonal Interest	Landscape Uses
Carya cordiformis	Bitternut Hickory					x	mod/ wet	full sun/ med	Tree that grows 50-80' tall with oval-rounded crown.	April - May	A tall ornamental shade tree for large properties and parks.
Platanus occidentalis	American Sycamore					x	mod/ wet	full sun	Grows 75-100', along streams, rivers and flood plains.	April	A large tree for a large space.
Quercus bicolor	Swamp White Oak					x	mod/ wet	full sun	Medium size, rounded crown and short trunk which grows to 50-60'.	April	Specimen tree. A good tree for wet ground and low spots.
Populous deltoides	Cottonwood					x	mod/ high	full sun	Fast-growing, tree that grows 50-80'. High biomass.	May - April	Shade tree and rain gardens.
Carya ovata	Shagbark Hickory					x	mod	full sun/ med/ full shade	Large tree that grows 70-90' tall with oval-rounded crown.	May - Frost	Ornamental shade tree. Cover and nesting for birds, small animals, and other insects.

Table 3.12: Tree Palette
(Swehla, 2017)

Scientific Name	Common Name	Extracts Lead	Extracts Arsenic	Extracts Cadmium	Extracts Zinc	Native?	Water Needs	Sun Needs	Description	Seasonal Interest	Landscape Uses
Juniperus virginia	Red Cedar					x	dry/ mod	full sun	Grows 30-65', in a wide range of soils conditions.	non flowering	Landscape specimen. Large screens.
Acer saccharinum	Silver Maple					x	mod/ wet	full sun/ med	Grows 50-80', in moist soils on floodplains.	March	A beautiful large landscape tree. Shade tree.
Rhus glabra	Smooth Sumac					x	mod	full sun	A large, open, shrub which typically grows 8-15' tall.	July - Frost	Hedgerows or screens. Used along woodland edges. Berries attract birds.
Quercus rubra	Northern Red Oak					x	dry/ mod	full sun	Grows to 50-75' with rounded, crown.	May	Generally a durable and long-lived tree.
Cornus racemosa	Gray Dogwood					x	mod	full sun/ med	Grows 10-15' tall, in moist ground along streams, ponds, wet meadows.	May - June	Shrub borders, along streams, ponds, or as a screen. Ability to grow in poor soils.

Forbs Palette

Scientific Name	Common Name	Extracts Lead	Extracts Arsenic	Extracts Cadmium	Extracts Zinc	Native?	Water Needs	Sun Needs	Description	Seasonal Interest	Landscape Uses
Liatris pycnostachya	Prairie Blazing Star					x	dry/ mod	full sun	Grows 2-4’ tall in prairies, meadows and railroad tracks.	July - Aug	Borders, wild gardens, native plant gardens, or prairies.
Tagetes patula	French Marigold			x		x	mod	full sun	Compact annual that typically grow 6-12” tall.	June - Frost	Used mainly as an edging plant in butterfly gardens.
Helianthus doronicoides	Perennial Sunflower	x	x	x	x	x	mod	full sun	High biomass, good cover for wildlife.	July - Oct	Spreads rapidly by seed, especially in disturbed sites.
Penstemon digitalis	Beardtongue					x	dry/ mod	full sun	Grows 3-5’ tall in prairies, meadows and railroad tracks.	April - June	Mass in sunny borders, wild gardens, native plant gardens.
Physostegia virginiana	False Dragonhead					x	mod	full sun	Perennial found in meadows, and along railroads.	June - Sep	Borders, cottage gardens, wild gardens, prairies or meadows.
Potentilla simplex	Common Cinquefoil					x	mod	full sun/ med	Typically grows in a mound 2-4’ tall.	June - Sep	Low hedge, mixed or shrub borders. Sunny parts of the landscape.

Table 3.13: Flower Palette
(Swehla, 2017)

Native Habitat Encourages Missouri Wildlife

A wide range of wildlife species may be attracted to the native planting palette chosen for the ARMCO redevelopment site. The native plants may create habitat for a number of animals and insects, including some endangered wildlife species originating from this region ("Missouri Department Of Conservation"). This list of species should be read as a list of potential site wildlife, not a guaranteed, or targeted, list.

! = endangered species

Fig. 3.109 - 3.132: Native Wildlife (Swehla, 2017)

PRECEDENT STUDIES

Ningbo Eco-Corridor | Zheijang, China

The Ningbo Eco-Corridor is a 2 mile long living filter built atop a previously existing brownfield. The intent of the project was to build synergy between human activity and the wildlife habitat, while serving as a valuable teaching tool to Zheijang's urban population. The linear network services the city's 3.5 million residents, as well as the native wildlife and plant communities. The Eco-Corridor provides a central location for the city's open space system, creating and connecting a variety of demographics and land uses back to their ecologies.

Using excavation from nearby development projects, the designers created hills and valleys that merge with the urban fabric. These valleys act as water catchment areas for wetland ecosystems, while the hills provide buffer from the urban environment, frame views, provide vista points for visitors, and increase habitat diversity. The connected network of hills restricts visitor access to waters but also allows recreational and educational opportunities. The site is undergoing phytoremediation and therefore must restrict pedestrian access by utilizing a combination of raised pathways, railings, and bridges.

The key elements influencing human access were: the integration of the environment within the urban fabric; balance between environmental processes and human habitation; and the creation of positive open spaces, spatial character, and park identity.

Ningbo's Eco-Corridor balances the impact of new development and revitalizes the natural environment by offering opportunities for education, creating spaces for recreation and adaptive reuse, and providing cultural facilities to connect different land uses in a common space. The Corridor merges seamlessly, creating a symbiotic relationship between the greenway and surrounding landscape ("Ningbo Eco-Corridor").

Precedent Lessons

- Build synergy between human activity and the wildlife habitat, while serving as a valuable teaching tool.
- Connect a variety of demographics and land uses back to their ecologies.
- Valleys act as water catchment areas for wetland ecosystems, while hills provide buffer from the urban environment, frame views, provide vista points for visitors, and increase habitat diversity.
- Restrict pedestrian access by utilizing a combination of raised pathways, railings, and bridges.
- Provides cultural facilities to connect different land uses in a common space.

Fig. 3.133: Ningbo Eco-Corridor restricted access pathways (Fox, 2016)

Houtan Constructed Wetland | Shanghai, China

The Houtan Constructed Wetland is a regenerative living landscape built across a site measuring nearly 35 acres long. The parks objective was to create a green Expo, with the ability to accommodate a large influx of visitors during the months or May and October, demonstrate green technologies, and transition the riverfront into a permanent park after the Expo. The park's location, adjacent to the Huangpu riverfront, transforms a previously unsafe industrial landscape, devoid of aquatic life, into an educational aesthetic.

Native agricultural crops were planted to create an urban farm allowing people to witness the seasonal changes. Filtration terraces with elevated walkways separate visitors from the polluted waters upstream while enhancing the landscape along the wetland. The terraces encourage visitors to enter the living system through the field's corridors and experience the wetland firsthand.

In order to preserve connections to the waterfront, traditional retaining wall practices were excluded from the design proposal. Rather, the designers opted to include the people in the landscape, allowing human access to the riverfront. The terraced wetland lets visitors enter the inner spaces of the living landscape, increasing the capacity of the park without sacrificing experience.

The paths, designed like capillaries of a sponge, absorb and pull people to circulate the park. Benches along the walkways urge people to linger, with raised platforms, bridges, and railings providing pre-chosen pathways so that visitors do not deviate to a restricted area undergoing phytoremediation. The former industrialization of the site remains visible through the reclamation of old structures and materials.

The boardwalks through the wetland allow visitors to become submerged within the landscape. The wetland provides a refuge from the city, recreation areas, and education and research opportunities. A series of vantage points, built between the elevation of the water's edge and the elevation of the city road 10 feet above the terraces, connect the people back to the river ("Shanghai Houtan Park").

Precedent Lessons

- A native plant palette allows visitors to witness the seasonal changes of their regional ecologies.
- Filtration terraces with elevated walkways separate visitors from the polluted waters upstream.
- Visitors enter the inner spaces of the living landscape, increasing the capacity of the park without sacrificing experience.
- Raised platforms, bridges, and railings provide pre-chosen pathways so that visitors do not deviate to a restricted area undergoing phytoremediation.
- Vantage points connect the people back to the river.

Fig. 3.134: Houtan Park's elevated, wetland pathways (Yu, 2010)

Freshkills Park | New York, USA

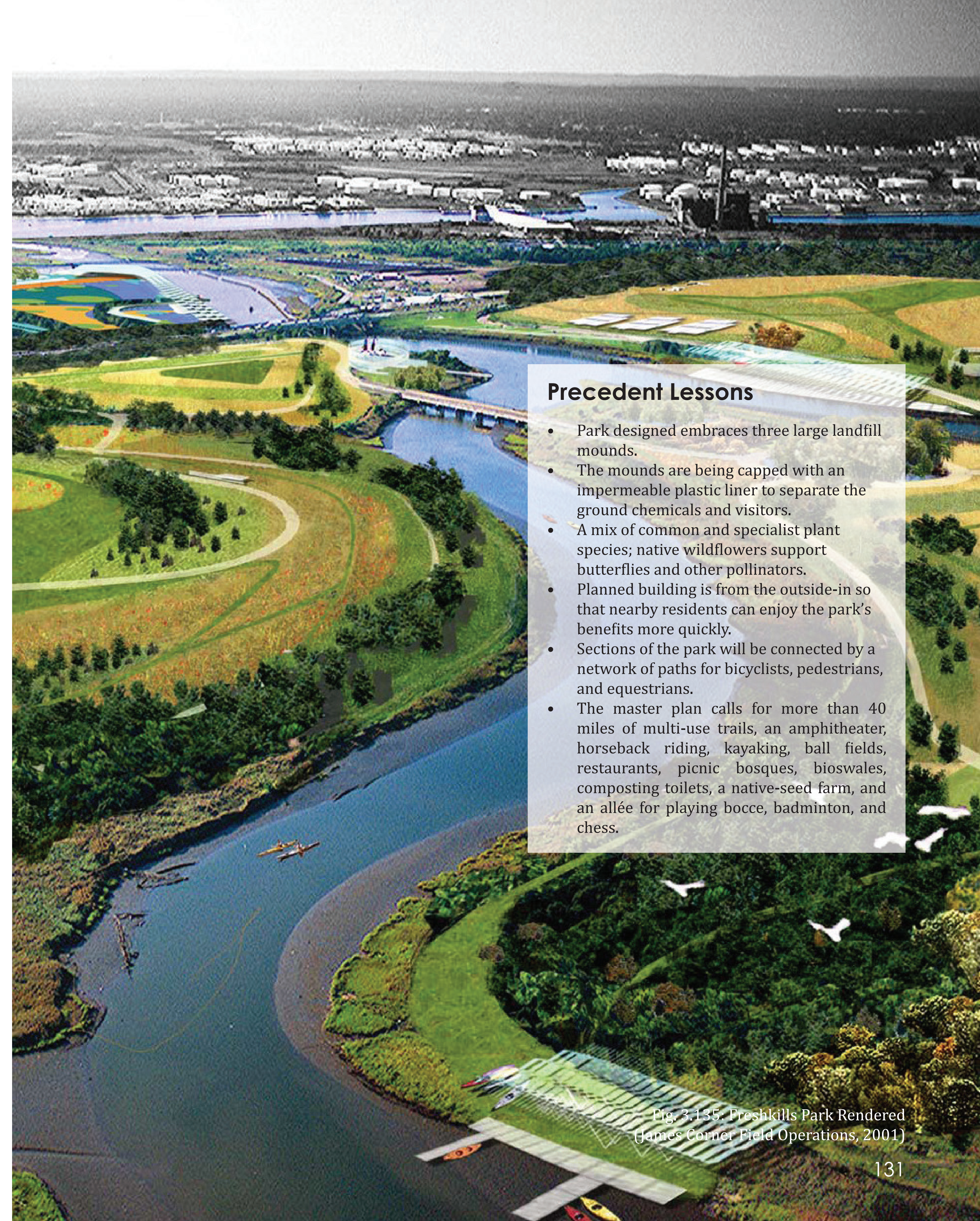
Formerly the world's largest landfill, Fresh Kills Landfill has been re-imagined as a two-thousand-acre public amenity featuring playgrounds, athletic fields, kayak launches, and trails for running, horseback riding, and large-scale art installations.

This park is being opened in phases with completion slated for 2036. The Department of Sanitation has established state-of-the-art environmental controls to provide public safety while the park undergoes phytoremediation processes. The design proposal divides the park into three areas designed around three large landfill mounds. The mounds are being capped with an impermeable plastic liner and eight additional layers of barrier material to separate the ground chemicals and visitors.

The park design celebrates the ecology of the city, creating unique habitats, like marshes, woodlands, and prairies. The plantings are a mix of common and specialist plant species; native wildflowers support butterflies and other pollinators. A combination of soil managements techniques were used to increase soil quantity and quality, maintain soil stability, and increase soil depth. The park phasing timeline spans roughly thirty years; planned building is from the outside-in so that nearby residents can enjoy the park's benefits more quickly. Public access will be restricted on pathways leading into the park during phytoremediation phases on the mounds until reclamation and capping is finalized.

Sections of the park will be connected by a circulation system for vehicles and a network of paths for bicyclists, pedestrians, and equestrians. During programming phases of the design process, the project hosted a 'Sneak Peak' where visitors had the opportunity to kayak, bike, hike, and fly kites on a closed section of the park.

Once the planet's largest dump, Freshkills park will morph into New York City's largest and most biologically diverse urban oasis, at nearly 2.5 times bigger than Central Park. In addition to esplanades, promenades, and panoramic viewpoints, the master plan calls for more than 40 miles of multi-use trails, an amphitheater, horseback riding, kayaking, ball fields, restaurants, picnic bosques, bioswales, composting toilets, a native-seed farm, and an allée for playing bocce, badminton, and chess ("Freshkills Park Alliance").



Precedent Lessons

- Park designed embraces three large landfill mounds.
- The mounds are being capped with an impermeable plastic liner to separate the ground chemicals and visitors.
- A mix of common and specialist plant species; native wildflowers support butterflies and other pollinators.
- Planned building is from the outside-in so that nearby residents can enjoy the park's benefits more quickly.
- Sections of the park will be connected by a network of paths for bicyclists, pedestrians, and equestrians.
- The master plan calls for more than 40 miles of multi-use trails, an amphitheater, horseback riding, kayaking, ball fields, restaurants, picnic bosques, bioswales, composting toilets, a native-seed farm, and an allée for playing bocce, badminton, and chess.

Fig. 3.135: Freshkills Park Rendered (James Corner Field Operations, 2001)

The Corktown Commons | Toronto, Canada

The Corktown Commons was redeveloped with a new design, showcasing thoughtful topography and a rich planting palette. From post-industrial to park, this sixteen-acre project creates unique habitats using a planting palette mix between common and specialist plants species. The native wildflowers were chosen specifically to support butterflies and other pollinators. The park celebrates the ecology of the cities, making it an important crossroads connecting the heart of the city to the landscape.

Different soil types and depths were designed to support marsh, edge woodlands, and prairie, the range of which provides for experiential variety and wildlife habitat. The variety of soil depths also create various microclimatic plant zones, which attract people and fauna throughout the year. Migratory birds can utilize this green space within the urban hardscape.

The wide range of habitats create great living environments for the growing number of birds and amphibians; a great testimony to the parks success. The park was designed with organic maintenance in mind; meaning that sustainable care practices will contribute to the preservation of the ecological integrity of this greenspace. The park was planted with over seven hundred trees and one hundred twenty species of plants. Native wildflowers known to self-seed now grow throughout the park.

A hilly park, with pathways and prairie grasses, overlooks the mouth of the Don River, which doubles as a 28 foot-high berm designed to protect the eastern downtown from a major flood. On the river side of the park, there is an additional 7.9 acre prairie.

The park's topography redirects rainwater and city water used at the rubberized pad to the marsh, where it is bio-treated and redirected to be stored in a cistern for later irrigation. This movement of grey water into the marsh prevents eutrophication and algal blooms in the summertime ("Michael Van Valkenburgh Associates, Inc.").

Precedent Lessons

- Topography creates a unique habitat using a planting palette mix between common and specialist plants species.
- The park was designed with organic maintenance in mind.
- The park's topography redirects rainwater and city water where it is bio-treated and redirected to be stored in a cistern for later irrigation.

Fig. 3.136: Corktown Commons Marsh (Arup, 2014)

Brooklyn Bridge Park | New York, USA

Situated in the shadow of the iconic bridge, Brooklyn Bridge Park recreates shoreline ecologies that mimic real life conditions, built to evolve over time. At 1.3 miles long, the park provides plenty of space for visitors to interact with their environment. The native vegetation, rebuilt salt marches, and meadows require less intensive maintenance than many other implementation options. Birds and marine habitats are positioned to minimize their visibility within the park, allowing security for native wildlife.

Brooklyn Bridge park is sub-divided into 6 piers, each with their own unique theme and application. Pier 1 contains water gardens displaying water-loving plants, while Pier 4's beach is planted with natives assisting in an ongoing evolution as a protected habitat preserve. The beach design incorporates ECOncrete that mimics tidal pools. Only some of these pools are accessible to the public, reserving some areas for undisturbed wildlife growth. These public areas provide an interactive demonstration of the park's diverse habitats for marine and plant life. Located offshore, an inaccessible island, named 'Bird Island', acts as a nature preserve planted with the intent to foster a diverse ecology. Here, there are platforms designed for Osprey and other avifauna.

The park's lawns, plant beds, and soil are treated organically, meaning that no chemicals are used to deter weeds and invasive species. The grass lawn areas are cut taller than traditional practice dictates, reincorporating clippings to promote deep toot growth. This practice also helps attract and establish birds, butterflies, and other insects. Historically, this area had a bountiful oyster population which lead to the designer's reinstatement of the oyster reefs. Reviving the oyster's habitat contributes to water filtration, wave attenuation, and diverse habitat health ("Brooklyn Bridge Park").

Precedent Lessons

- Native vegetation requires less intensive maintenance than many other implementation options.
- Birds and marine habitats are positioned to minimize their visibility within the park, allowing security for native wildlife.
- Only some areas are accessible to the public, reserving some areas for undisturbed wildlife growth.
- The park's lawns, plant beds, and soil are treated organically.

Fig. 3.137: Brooklyn Bridge Park Beach (Schaer, 2014)

Woodbridge Waterfront Restoration | New Jersey, USA

At 185 acres, this brownfield to greenfield project plans to enhance wetland environments with an interconnected system of trails and boardwalks providing the Woodbridge Township with public access to nature for the first time in over a decade. The initial project timeline was set to be completed by the end of 2016, with additional funding supplementing ongoing projects within the park.

Restoration of the natural wetlands habitat has been intensive, including more than 2,000,000 native plantings among the tidal wetlands, freshwater wetlands, and enhanced upland areas. The planting of 500,000 herbaceous, and 12,000 trees/shrubs ensure that this park offers a variety of spaces and wildlife habitat. The park features include 30 acres of nature area, seven thousand feet of walking trails, 800 feet of boardwalk, and wildlife blinds for visitors to birdwatch. The removal of invasive phragmites, is a multi-year process.

Within the design process, a framework was used to analyze the amount of pre-restoration acreage of habitat versus designed and actually created space. This process allowed the design team to assess the effective area of habitat space required to maintain existing wildlife health conditions. Other ecological restorations underway include the creation of a 6 acre lined pond. Here, and along the riverfront, islands for waterbirds will provide habitat security and nesting places ("Construction Starts At Woodbridge").

Precedent Lessons

- Park design enhances wetland environments with an interconnected system of trails and boardwalks.
- Native plantings ensure that this park offers a variety of spaces and wildlife habitat.
- Park design incorporates wildlife blinds for visitors to engage and learn.
- The amount of habitat acreage was analyzed to maintain space specifically for wildlife.
- Along the riverfront, islands for waterbirds provide habitat security and nesting places.

Fig. 3.138: Woodbridge Watefront (Great Ecology, 2009)

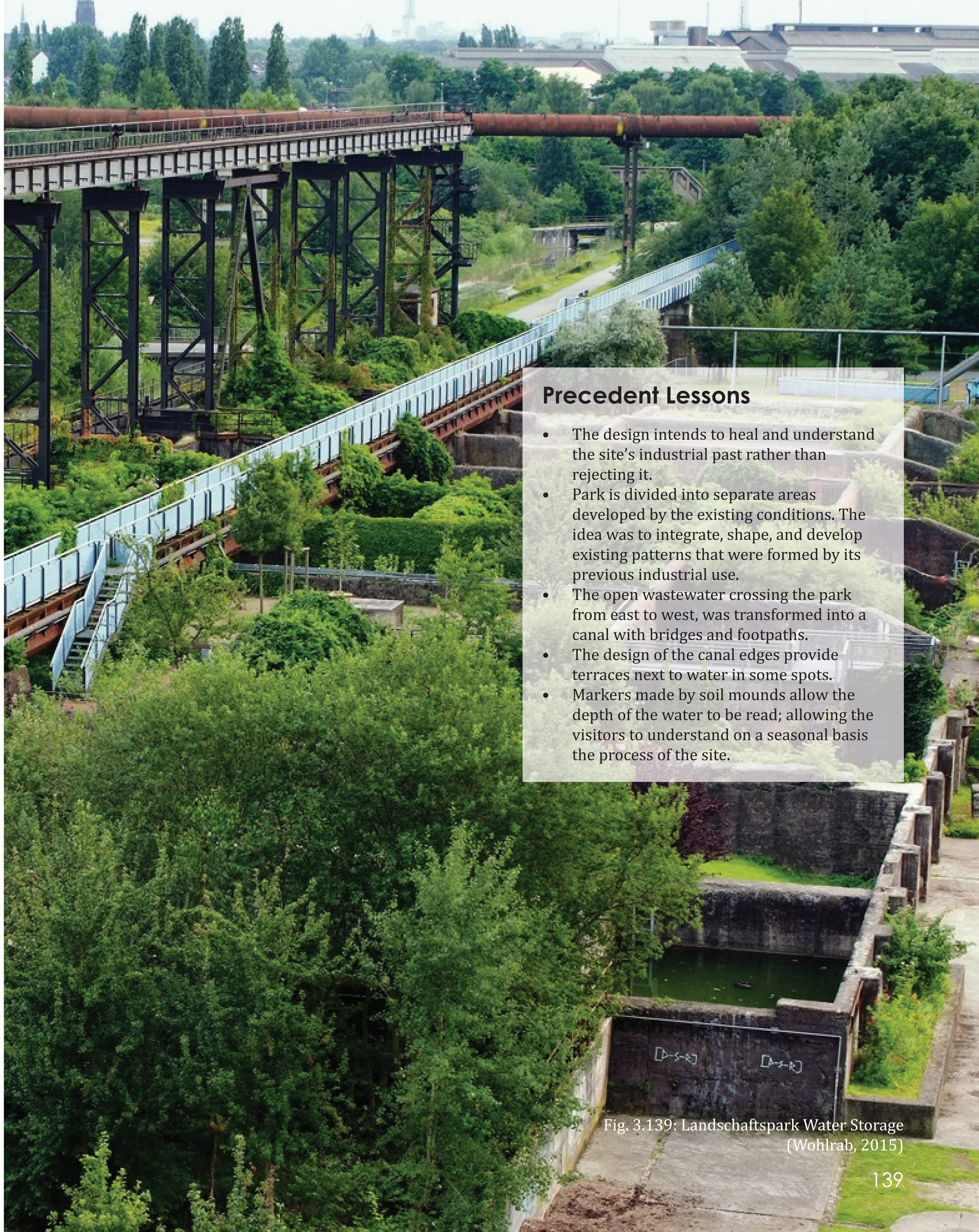
Landschaftspark | Duisburg, Germany

Historically, Landscaftspark was transformed from agricultural land to an industrial steel production plant. Presently, a public park resides here, built to heal and understand the site's industrial past rather than rejecting it. The sequestered soils with high toxicity were treated on site using phytoremediation.

The park is divided into separate areas developed by the existing conditions. The design was influenced by the roads and railways left from the industrial factory. The idea was to integrate, shape, and develop existing patterns that were formed by its previous industrial use, and to find a new interpretation.

Existing sewage canals were repurposed as a method of cleansing the site. Stormwater is captured and channeled to the three gardens within the park. The waste water is moved underground in a clay sealed pipe which collects run off from the site's buildings, bunkers, and former cooling ponds. A wind-powered installation was set up in the mill tower of the former sintering plant to power the cleaning and transportation of the stormwater.

The open wastewater crossing the park from east to west, was transformed into a clearwater canal with bridges and footpaths. The design of the canal edges provide terraces next to water in some spots. The canals are built with deep and shallow sections to allow sedimentation and habitat growth. The canals on site help visitors understand the water management happening here. Markers made by soil mounds allow the depth of the water to be read; here the visitors are able to understand on a seasonal basis the process of the site. The water channels and the connected water systems aim to restore natural processes in a previously abused environment ("Landschaftspark Duisburg-Nord").



Precedent Lessons

- The design intends to heal and understand the site's industrial past rather than rejecting it.
- Park is divided into separate areas developed by the existing conditions. The idea was to integrate, shape, and develop existing patterns that were formed by its previous industrial use.
- The open wastewater crossing the park from east to west, was transformed into a canal with bridges and footpaths.
- The design of the canal edges provide terraces next to water in some spots.
- Markers made by soil mounds allow the depth of the water to be read; allowing the visitors to understand on a seasonal basis the process of the site.

Fig. 3.139: Landschaftspark Water Storage (Wohlrab, 2015)

Viet Village Urban Farm | New Orleans, USA

This urban farm is built upon an abandoned lot in the heart of a downtown New Orleans neighborhood. Environmental infrastructure systems were designed to support an organic urban farming operation. Site pollutants came from car chemicals and debris accumulation following Hurricane Katrina.

The farm is located in an area of frequent flooding where drainage is difficult. To solve this, water movement across the site was controlled using a series of sub-watersheds that can be expanded as the site grows. Irrigation and post-irrigation water will be returned to a central reservoir through a series of bioswales designed to naturally filter the water through soil and plants as it heads back towards the reservoir for reuse A secondary system for stormwater runoff was established to prevent the farm sites from flooding.

The design team and the engineering firm assisted the community with the design of the environmental infrastructural systems supporting an organic urban-farming operation. Standing as an example for sustainable site development by using biofiltration of water and alternative energy sources such as wind and solar power. The park employs a windmill energy system in order to circulate this recycled water.

The site's main canal is designed to hold standing water at depths of 4 to 5 feet year round. The side slopes are planned to grow vegetation, mainly water hyacinth, however the center channel should remain clear. The side canals will be outfitted with a sluice gate in order to isolate each channel if needed. This allows for the channels to be drained and cleaned out. The canals and reservoirs will distribute water to the farm plots, but will also detain stormwater. The proposed design of the site will accommodate a 10 year storm event ("Viet Village Urban Farm").

Precedent Lessons

- Water movement is controlled using a series of sub-watersheds that can be expanded as the site grows.
- The canals and reservoirs distribute water, but also detain stormwater.
- Designed to support an organic urban farming operation.
- Biofiltration of water and alternative energy sources such as wind and solar power were used.

Fig. 3.140: Viet Village Urban Farm (Mossop + Michaels, 2008)

Minghu Wetland Park | Liupanshui, China

The park's pre-development condition was dominated by garbage dumps and polluted water. This previously channelized concrete river and deteriorated urban site have been transformed into a wetland park functioning as a major part of the city-wide ecological infrastructure planned to provide multiple ecosystem services. A series of regenerative design techniques to slow down the flow of storm-water, manage water cleansing, and recover native habitats develop a holistic strategy to address problems with water pollution, flood inundation, and creation of public space.

The strategy is to slow the flow of water from the hillside slopes and create a water-based ecological infrastructure that will retain and remediate the storm-water, and make water the active agent in regenerating a healthy ecosystem to provide natural and cultural services that transform the industrial city into a livable human habitat. Existing streams, wetlands, and low-lying land are all integrated into a storm-water management and ecological purification system linked by the river, forming a series of water retention ponds and purification wetlands with different capacities. This approach not only minimizes urban flooding but also increases the base flow to sustain river water flow after the rainy season. A natural riverbank was restored to revitalize the riparian ecology and maximize the river's self-purification capacity.

The concrete river embankment was removed to create two ecological zones. One encourages native vegetation to grow within the flood zone and the other establishes conditions for emergent vegetation in the riverbed. Aerating cascades were created along the river to add oxygen that fosters bioremediation of the nutrient-rich water. Terraced wetlands and retention ponds were created to reduce peak water flow and regulate the seasonal rainwater. These terraced habitats slow the flow of water and speed nutrient removal from the water by microorganism and plant species that use excess nutrients as resources for rapid growth ("Minghu Wetland Park/Turenscape").

Precedent Lessons

- The park was designed as ecological infrastructure to provide multiple ecosystem services.
- Design techniques slow down the flow of stormwater, manage water cleansing, and recover native habitats. Developing a holistic strategy to address problems with water pollution, flood inundation, and creation of public space.
- Existing streams, wetlands, and low-lying land are all integrated into a storm-water management system.
- Terraced wetlands and retention ponds reduce peak water flow and regulate the seasonal rainwater.

Fig. 3.141: Minghu Wetland Park (Turenscape, 2014)

SUMMARY OF FINDINGS

Site Inventory

The site inventory revealed many aspects of the site used to develop the master plan proposal. Existing pathways and their conditions were documented, as well as areas of the site that contain surface contamination. Photographs of the trail conditions, vegetation cover, infrastructure, and remnant material provide useful information for the designer and readers understanding the context of the current site.

Site Analysis

Mapping site conditions provided further understanding of the spatial characteristics affecting redevelopment processes on site. Existing site watershed were mapping to understand where areas of accumulation occur and where chemical contamination might spread. Areas that require remediation considerations were identified through mapping of site contaminates. Soil characteristics affecting vegetation growth, stormwater runoff, pollution migration, and engineering capabilities were mapped so that master planning could coordinate remediation designs with human access opportunities. Vegetation massing and existing trail networks were mapped to show where previous disturbance has occurred and where opportunities for wildlife conservation might be applicable.

In order to synthesize the opportunities and constraints found through the site analysis process, two composition maps have been created. These maps, shown on the following pages, visually showcase the opportunities and constraints listed for the design of the site, habitat restoration within the site, and remediation concerns within the site.

Site Opportunities

Design

- The historic rail corridor provides inspiration for design elements.
- The northern boundary of the site is topographically elevated, creating a flood wall.
- The Rock Creek ox box creates a low, serpentine channel that collects surface runoff from a majority of the west site.
- Landfill mounds isolate large areas that cannot be structurally developed, leaving these spaces for flexible programming.
- Most pathways act as high points within the topography.
- Trail widths are wide enough to accommodate multiple forms of movement.
- The existing paths already connect a high percentage of the site, creating unique and distinctly different pockets.

Habitat

- 59% of the site's soil aids growth of native big bluestem, indiangrass, switchgrass, and other grasses of the tall grass prairie
- Using the former trucking roads to build a trail system within the site allows for minimal habitat disturbance.
- A large majority of the East site has been unaffected by previous development.

Remediation

- The polluted rail corridor where phytoremediation will be implemented frequently floods, which is beneficial to the design of a constructed wetland.
- The West landfill is covered with Group D soils. This means that the runoff potential is high and stormwater infiltration to polluted soils with be low.
- Group A soils cover the old rail corridor where surface pollution was found. Infiltration of stormwater will allow soils and plant roots to filter and clean out unwanted chemicals.

= Design Opportunities = Habitat Opportunities = Remediation Opportunities

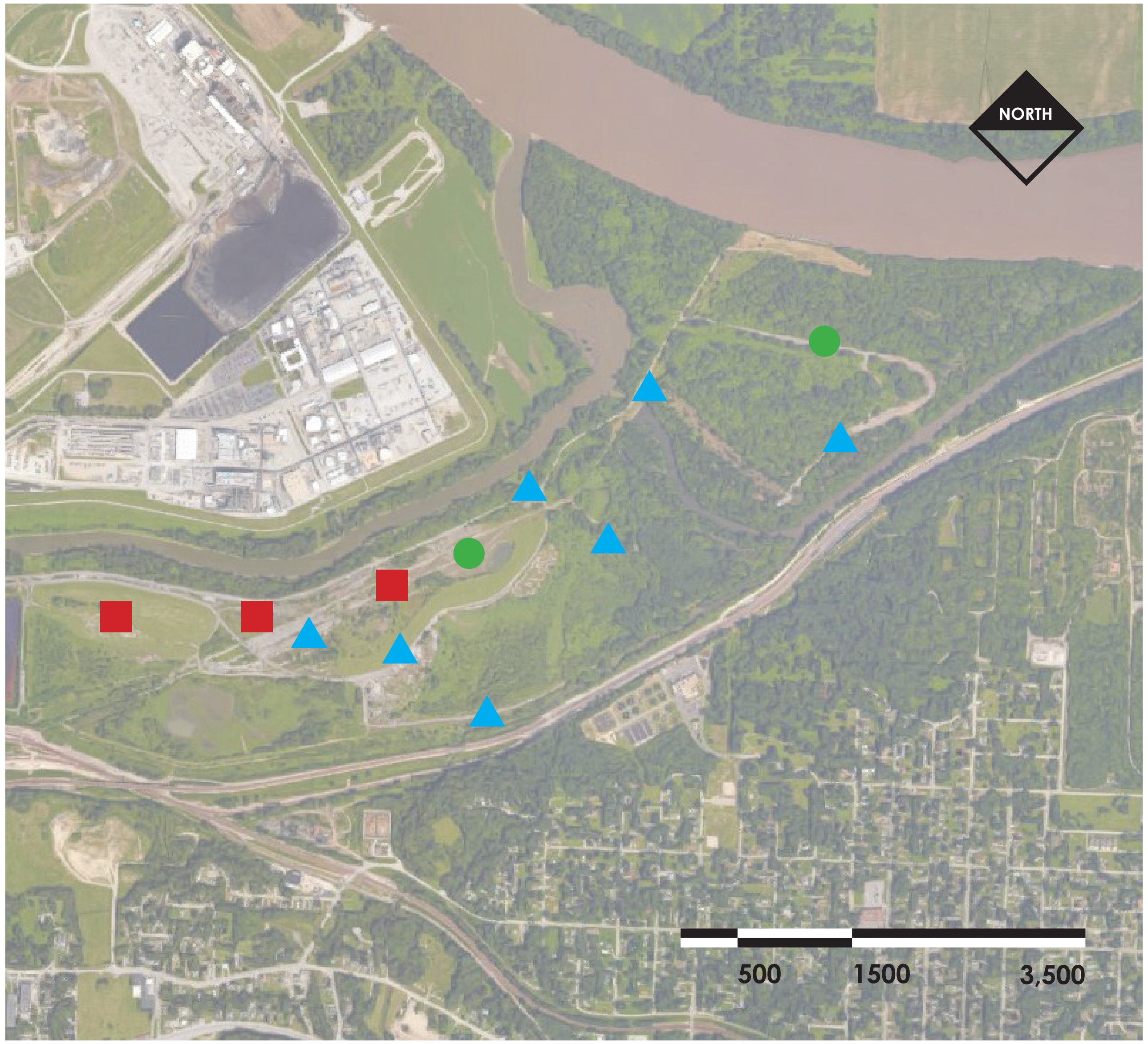


Fig. 3.142: Opportunities Map (Swehla, 2017)

Site Constraints

Design

- The polluted rail corridor will require phytoremediation and stormwater.
- Landfill mounds will require plastic liners to prevent pollution migration and human access without contamination.
- The sarpy fine sand soil is well drained, which is not conducive for constructing wetland areas, thus requiring a plastic bed liner to retain water.
- Dense vegetation restricts views on some sections of the pathway.
- Pathway construction over landfills is restrictive.
- Many portions of the pathways are grass or bare soil, which would become unusable during wet conditions without further modification.
- The east landfill is adjacent to a low spot that routinely collects water runoff.
- Management plans are required in order to remove chemicals and reduce their spread.

Habitat

- The site sits above the water table, making it difficult to hold water year-round.
- Pollutants within the soil and stormwater are detrimental to local wildlife and vegetative growth.

Remediation

- The polluted rail corridor will require phytoremediation and stormwater.
- The East landfill is within a soil zone that floods occasionally. This will require thoughtful design to ensure the landfill does not leach more pollutants.
- The area of the site with surface pollutants is classified as Group A. Pollutants may infiltrate the soils and reach the water table without succumbing to phytoremediation.
- The East landfill is partially located within Group A and Group D soils. This means that the landfill is susceptible to stormwater infiltrating its soil cap and leaching more pollutants into the site.
- A large portion of stormwater runs through the contaminated rail corridor, flushing contaminants into the river.
- The areas of the site with high soil percent clay will absorb and hold contaminants on site.

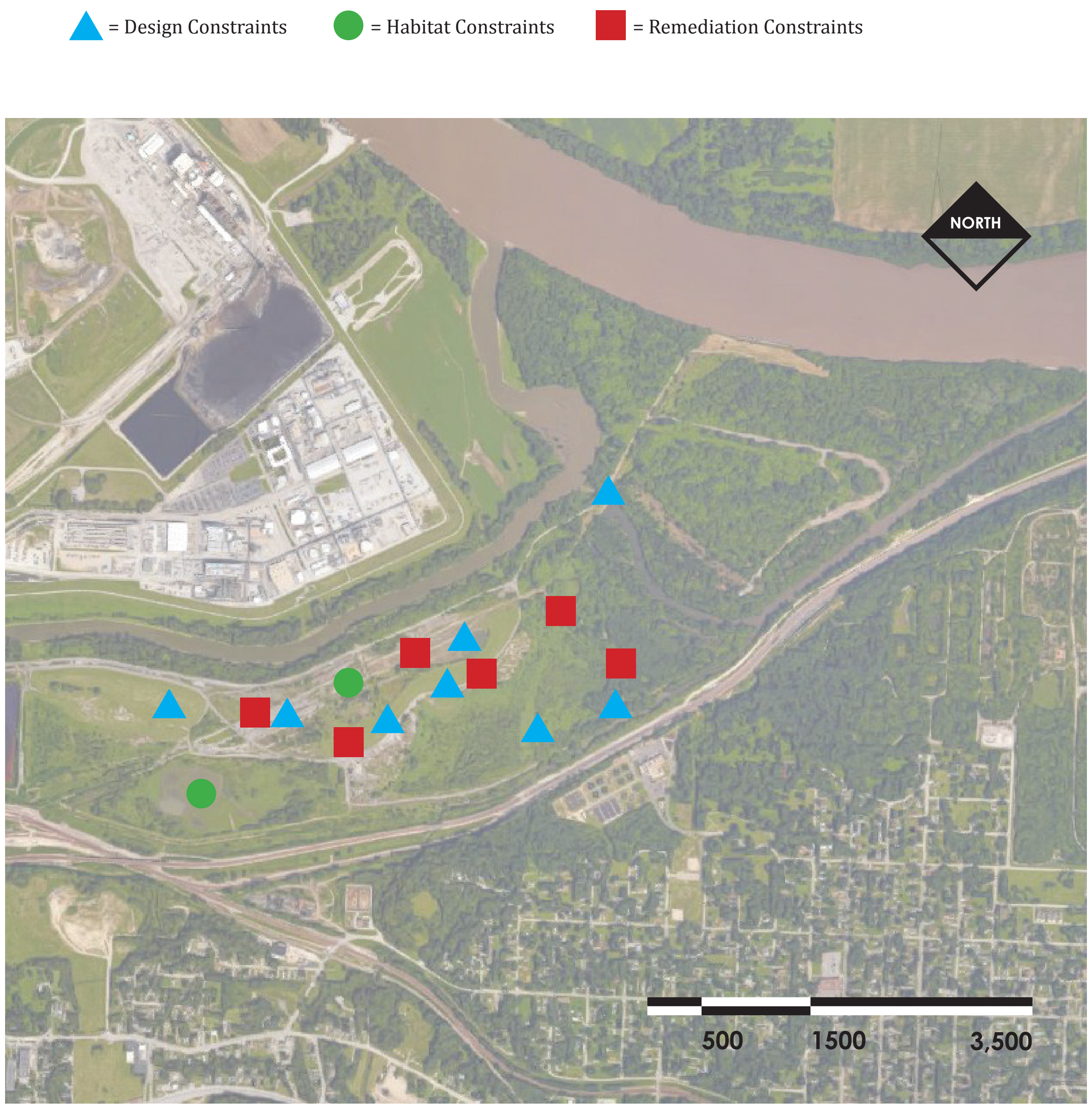


Fig. 3.143: Constraints Map (Swehla, 2017)

Plant Palette Selection

The process of selecting a plant palette revealed the challenges designers are faced with when designing on contaminated sites. Choosing plants capable of extracting chemical pollution while also remaining healthy was an important aspect realized through many iterations of planting palettes. In the end, an overall understanding of resiliency and sustainability led to the creation of a majorally native planting palette capable of withstanding a variety of climactic conditions. The selection of native vegetation ensured plant diversity and encourages colonization by indigenous wildlife.

Precedent Studies

The precedent study analyses showed applications of phytotechnology mechanisms and planting types performing in the field. These precedents provided examples for the master plans design implementation of phytoremediation.

The precedent studies showcasing human access on contaminated sites provided examples of how designed topography can create a separation between visitors and an pollution. Restricting pedestrian access by using raised platforms, railings, and bridges were specifically replicated in the ARMCO redevelopment plan.

Design elements for wildlife habitat restoration were extracted from precedents paying particular attention to the enhancement of their natural environments. From minimal maintenance designs to the introduction of exclusive wildlife zones, these precedents helped develop the landscape qualities and conservation properties of the ARMCO Site for native wildlife and vegetation.

Stormwater management techniques utilizing extraction plots, constructed wetlands, and stormwater filters were taken from the precedent studies. The concept of designing the park as a piece of ecological infrastructure that provides ecosystem services to the city was recreated at the ARMCO Site. The precedent study analyses showed many variations of wetland systems that reduce stormwater runoff and regulate seasonal rainwater that were emulated in this proposal. Designing techniques that slow down the flow of stormwater, manage water cleansing, and recover native habitats was a concept found in the literature review and echoed in each precedent study.

When these analyses was being conducted many questions were answered and even more were left unaddressed. The question about the exact contamination level of the ARMCO Site soils for each chemical compound were never revealed. The exact reason for contamination is speculative.

4 MASTER PLAN

PLAN INTENT

The master plan proposal for the redevelopment of the ARMCO Site intends to provide a non-mechanical, plant based system for pollution extraction. Ultimately, this master plan is one component of a larger system feeding the Missouri River, and attempts to clean only a portion of the stormwater entering its flow. To accomplish this goal, the site has been redesigned with accommodations for phytoremediation, stormwater management, return of human access to the site, and restored wildlife habitat.

Plan Description

In order to develop the site conscientiously, the plan program has been divided into 2 distinct areas for phytoremediation and conservation. Respectively named as the Phytoremediation and Conservation Areas, the site programs have been designed to provide human access throughout the site with the use of existing pathways leftover from the site's industrial use.

The Phytoremediation Area has been designed to clean and remove chemical pollution in the site's soils and stormwater runoff. The phytoremediating components are described in more detail within this chapter.

The Conservation Area has been designed using minimal impact strategies to reduce the amount of vegetation and wildlife habitat disturbance with the development of the site.. This strategy is a large component of the plans focus to increase wildlife habitat. An overall explanation of the site's active design elements and layout is given. Here, the design of the phytotechnology mechanisms are described.

Plan Components

Further details regarding the implementation of phytotechnology mechanisms and their corresponding planting types are shown in this section. Diagrams show the placement of the extraction plots, the constructed wetland, stormwater filter, interception hedgerows, and groundwater migration tree stands. Accompanying the diagrams are a selection of plants chosen from the planting palette that may be used for phytoremediation, stormwater runoff interception, and the creation of native habitat for wildlife.

A watershed map has been created to show the design influence on stormwater runoff collection.

For ongoing research applications or site redevelopment, a maintenance and monitoring plan has been laid out for site developers and community organizations to adhere to.

Design Elements

The last section of this chapter is designated for the design elements chosen to populate the park for further development of human access and wildlife habitat growth. The list of design elements was developed using the information gathered from precedent studies, site mapping, and site inventory.

PLAN DESCRIPTION

Phytoremediation Area

This document provides a redevelopment proposal for the contaminated ARMCO Site. The site has been redesigned as a 465 acre public park. The target for redevelopment is the cleanup of residual chemical waste leftover from the previous site usage with the implementation of a remediation plan.

The ARMCO Site has been redesigned using a theme that showcases conservation and phytoremediation. The desire to separate the site into two distinctly themed areas came from the recognition that a large portion of the eastern site was undisturbed by previous site development. The two areas are more easily distinguished based on whether or not they contained documented levels of residual pollution from the ARMCO Steel factory. Portions of the site containing documented pollution, or within proximity of polluted areas, were considered to be in the phytoremediation area, while portions of the site containing no documentation of residual pollution were considered to be in the conservation area. This documentation was acquired using the Missouri Department of Natural Resources' Hazardous Waste Site Locator Map ("Modnr Estart").

A specially selected plant palette has been implemented in the phytoremediation area to stabilize and extract arsenic, cadmium, zinc, and lead within the treatment field. Site features adjacent to elevated topography and river edges were regraded to include stormwater collection areas. These stormwater management areas will treat water and perform three steps: collect stormwater for settlement in pools, disperse storm flow across broad, shallow wetland meadows for infiltration, and infiltrate storm flows through ground water recharge and plant material. A constructed wetland, occupying a stretch of the riverfront site, will take stormwater from the swales and subject the contaminated water to cleaning by phytoremediation, before discharging it to Rock Creek. The primary purpose of the swale is to removal of suspended solids, trash, and heavy oils. The constructed wetland was designed with vegetation capable of removing excess nutrients from the wastewater before release. Both landfills on the site have been capped with plastic liners and covered with clean topsoil to deter leachable quantities of lead, zinc, and cadmium from moving through runoff stormwater.

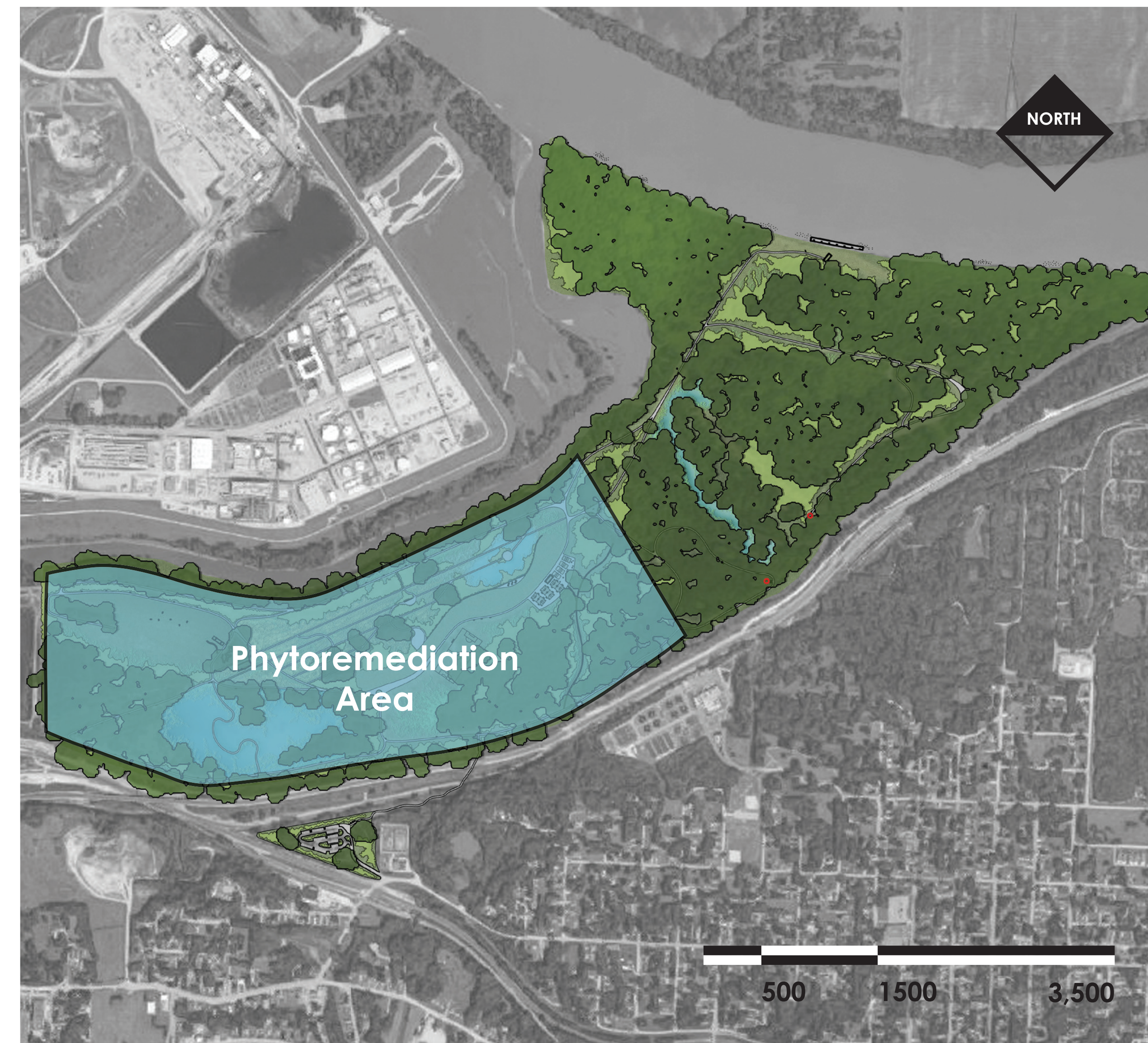


Fig. 4.1: Phytoremediation Area (Swehla, 2017)

A proposed cleanup procedure for the contaminated rail corridor has been provided using phytotechnology. Contaminated stormwater flowing through the park is temporarily stored. Plants in the park absorb some of this water and the rest infiltrates into the soils. The park has a phytoremediation field which is planted with more deeply rooted grasses and flowers so that water is able to drain more deeply into the soil and begin the remediation process. This vegetative layer removes some of the nutrients and pollutants from the stormwater flow.

Designated as the 'phytoremediation treatment field', the former rail corridor has been planted with chemical extracting vegetation that is landscaped for aesthetic enhancement, habitat enrichment, and stormwater management. The treatment field was planted with extraction plots to intercept and remove migrating pollutants. These extraction plots are removing chemicals from the soils as well as water running through their root structures.

The treatment field channels water as sheet flow (<2% grade) towards a constructed treatment wetland. Here, rhizofiltration is undergone, further remediating chemical pollutants in stormwater. To control the movement of stormwater through the treatment field, two phytohydraulic planting types were used along the edges to trap water (interception hedgerows and groundwater migration tree stands). These planting types also control stormwater from infiltrating into the East landfill. The constructed wetland is designed to hold a water volume equal to a 10 year/24 hour storm typical of the Kansas City region. At capacity, the wetland will discharge overflow into a stormwater filter built inside the Rock Creek ox box for further treatment.

Unlike traditional conveyance systems that hide water beneath the surface and work independently of site topography, this proposed remediation plan works with the natural land forms to become a major site design element. The drainage patterns help generate a more aesthetically pleasing relationship with the site. The plan improves water quality by filtering runoff and providing interesting planting opportunities.

The former rail road lines that transported metal to the ARMCO facility have been reconstructed as raised decking, running parallel through the treatment field. These raised pathways separate the park visitors from soil and water undergoing remediation. Viewing areas are proposed throughout the phytoremediation field to spawn opportunities to educate park visitors of the remediation process. All areas of the treatment field are proposed to be planted with native Kansas City plant communities, which by design offer habitat to native Kansas City wildlife. The natural habitats created for local wildlife provide visitors with the opportunity to engage and observe plants and animals throughout multiple seasons. Witnessing this change is intended to connect the community with their larger regional environment, showcasing the ecologies of this area prior to it's development.

The new ARMCO Park features interactive elements for all ages, including a playground, river viewing platforms, nature conservation areas, running and biking trails, sports fields, a prairie hilltop, and an educational pollutant extraction demonstration.

The four fundamental aspects to the redevelopment of the ARMCO Site are to remove site contaminants from the existing soils, give the land back to the people of Sugar Creek, create natural and healthy habitat for local wildlife, and implement stormwater management practices that reduce runoff and increase infiltration.

Readers and potential developers should be aware that further investigations and design iterations should be considered before site construction begins.

Conservation Area

The Conservation Area of the ARMCO redevelopment plan creates a 235 acre nature sanctuary. The goal of this design decision is to create habitat for wildlife and maximize the amount of undisturbed site vegetation. Existing vegetation cover has been undisturbed to preserve natural habitats already developed on site.

Site development within the Conservation Area has been limited to trail improvements and the erection of two separate viewing platforms. The old shipping dock located along the Missouri River has been rebuilt as a pedestrian viewing platform. The dock allows visitors to glimpse riparian wildlife and connect themselves with the river. A viewing tower, located along the pathway, elevates visitors above the tree canopies. This tower is meant to provide wildlife encounter opportunities for bird watchers. The proximity of this viewing platform to the adjacent rail road corridor creates an opportunity for visitors to experience the powerful engine noise trains passing by the park.

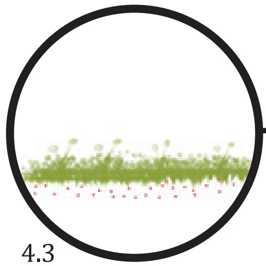
Pilings have been installed along the ARMCO Site riverbank for aquatic habitat creation and bird nesting spots. A majority of these pilings have been placed outside the reach of visitors to provide habitat security for the wildlife. A handful of pilings have been placed near the pedestrian viewing platform along the Missouri River to encourage an engaging experience between visitor and wildlife.

This area of the ARMCO Site does have any documented pollution and therefore does not require phytoremediation design.

Fig. 4.2: Conservation Area (Swehla, 2017)

PLAN COMPONENTS

Phytoremediation Treatment Field

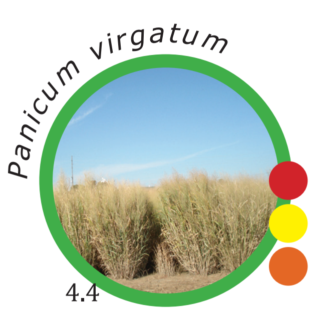


4.3

Extraction Plots

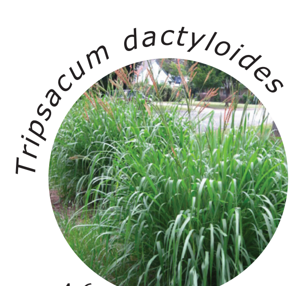
Extraction plots are placed at the top of the phytoremediation treatment field in order to phytostabilize and phytoextract chemical pollutants moving in the surface and sub surface stormwater.

- Phytostabilization
- Phytoextraction



4.4

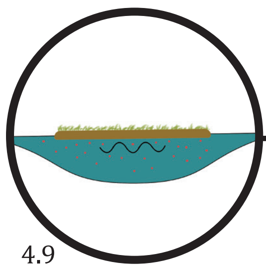
4.5



4.6

4.7

Fig. 4.8: Extraction Plots
(Swehla, 2017)



4.9

Constructed Wetland

A constructed wetland catches stormwater runoff escaping the extraction plots, creating opportunity for rhizofiltration to occur within the aquatic root system.

- Rhizofiltration

4.10

4.11

4.12

4.13

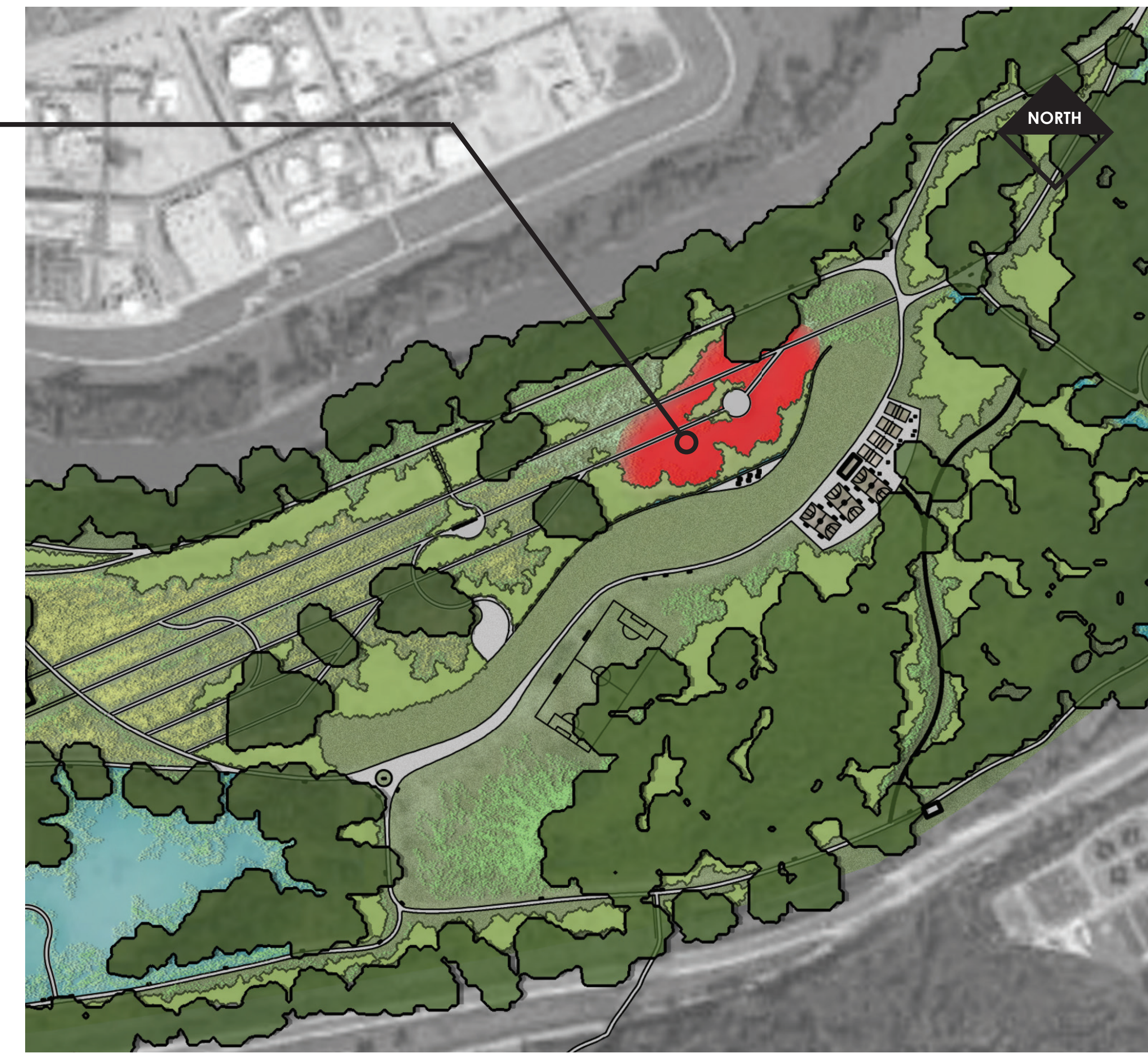
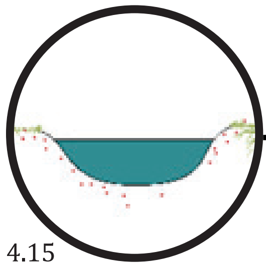


Fig. 4.14: Constructed Wetland (Swehla, 2017)



4.15

Stormwater Filter

During rain events exceeding 5”, the constructed wetland will discharge stormwater to a stormwater filter created within the Rock Creek ox bow. The stormwater filter will trap surface debris and allow further rhizofiltration to occur before discharging the runoff to Rock Creek.

- Rhizofiltration

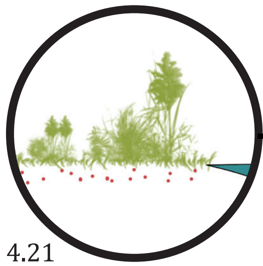
4.16

4.17

4.18

4.19

Fig. 4.20: Stormwater Filter
(Swehla, 2017)



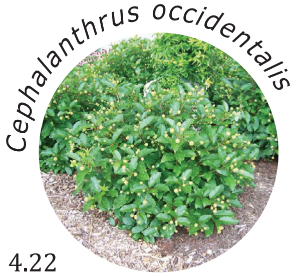
4.21

Interception Hedgerow

In order to prevent polluted stormwater from escaping the phytoremediation treatment field, interception hedgerows have been planted along the east landfill. The interception hedgerows will pull water into their roots, hydraulically trapping contaminated water in place.

- Phytohydraulics

Cephalanthrus occidentalis



4.22

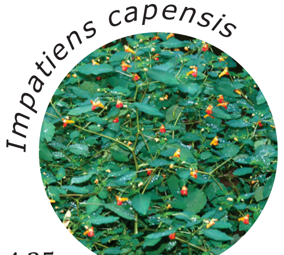
Hydrangea arborescens

4.23

Cornus sericea

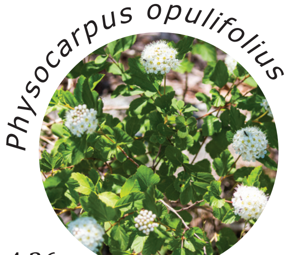
4.24

Impatiens capensis



4.25

Physocarpus opulifolius

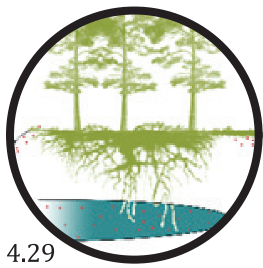


4.26

Lindera benzoin

4.27

Fig. 4.28: Interception Hedgerows (Swehla, 2017)



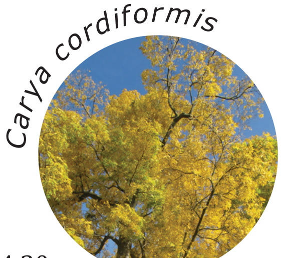
4.29

Groundwater Migration Tree Stand

For habitat and wildlife diversity, groundwater migration tree stands have also been planted along the phytoremediation treatment field in order to assist phytohydraulic performance. The groundwater migration tree stands also assist in decreased stormwater flow during rain events.

- Phytohydraulics

Carya cordiformis



4.30

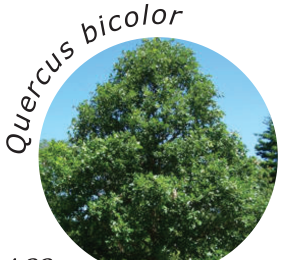
Ulmus americana

4.31

Rhus glabra

4.32

Quercus bicolor



4.33

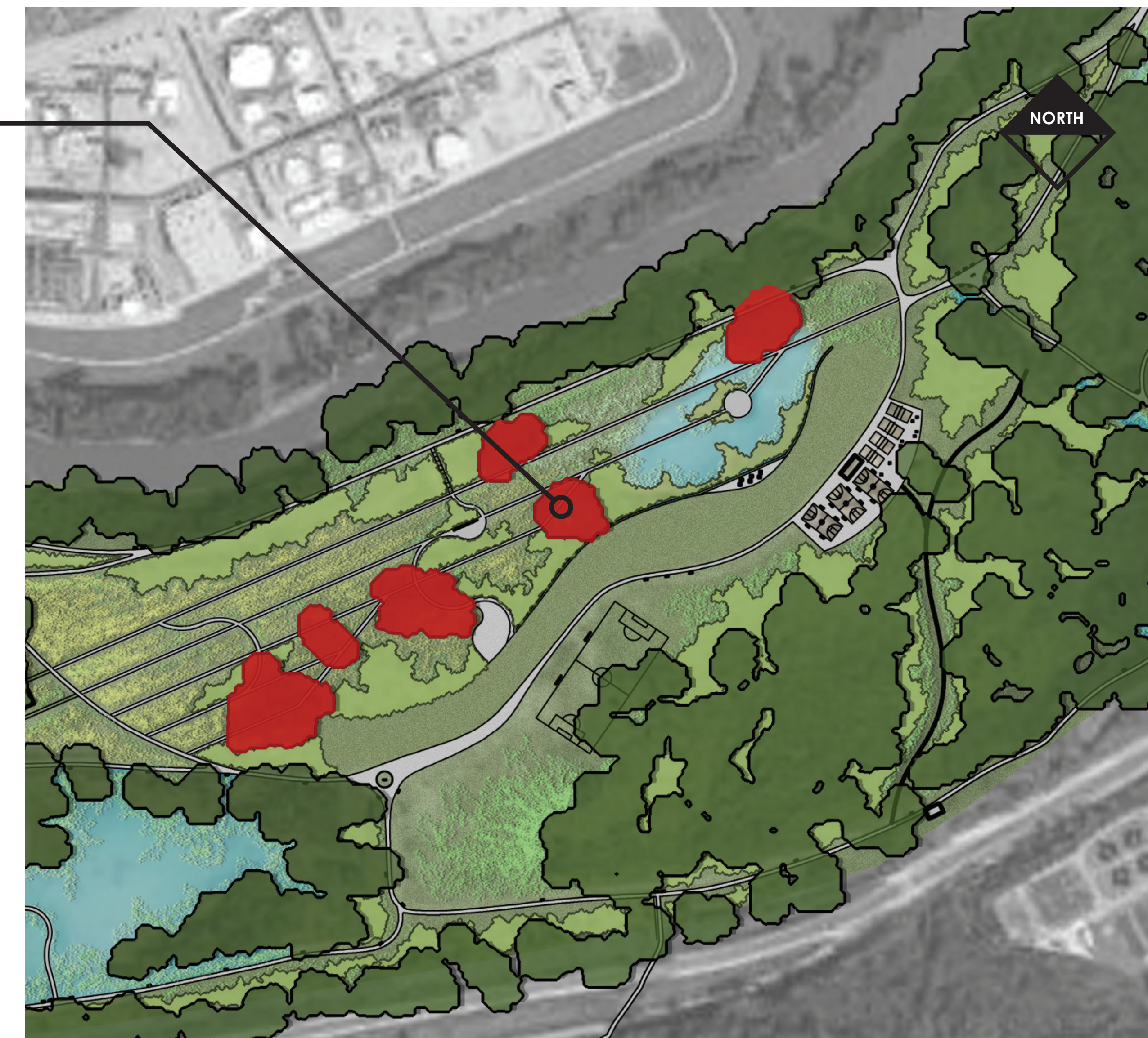


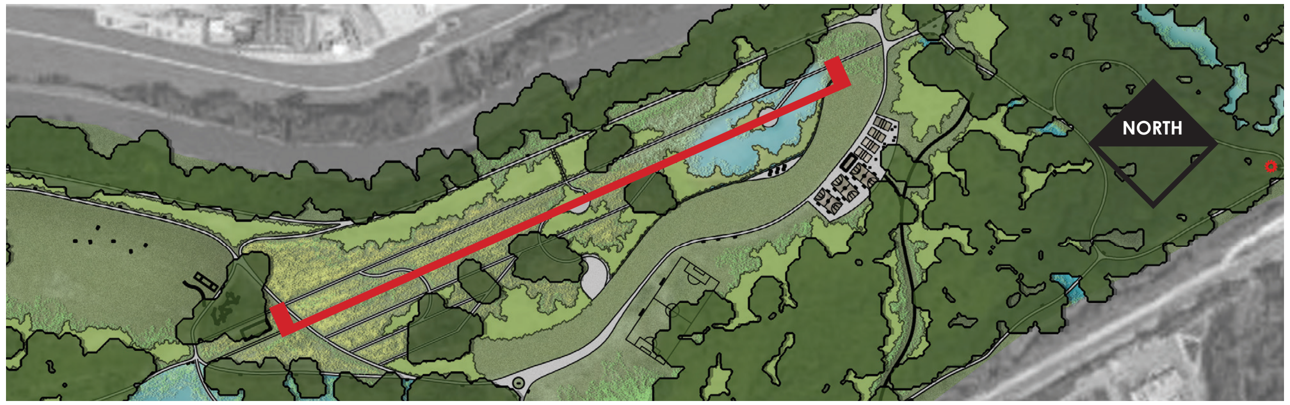
Fig. 4.34: Ground Water Migration Tree Stand (Swehla, 2017)

Treatment Field Habitat Creation

The length of the phytoremediation treatment field is measured at .4 miles long. This section is vertically exaggerated by a factor of 4 in order to more easily visualize the sloped environment of the treatment field.

Stormwater begins the treatment process by moving from the West edge of the field towards the lower, East edge. The highest portions of the treatment field are planted with extraction plots which remove chemical pollutants from the soil and stormwater for storage within the plants biomass.

Extraction plots provide habitat for birds, insects, and ground mammals such as deer, squirrels, voles, rabbits, mice, and fox. The extraction plots require frequent harvesting to remove the chemical pollutants being stored in the biomass. An insufficient



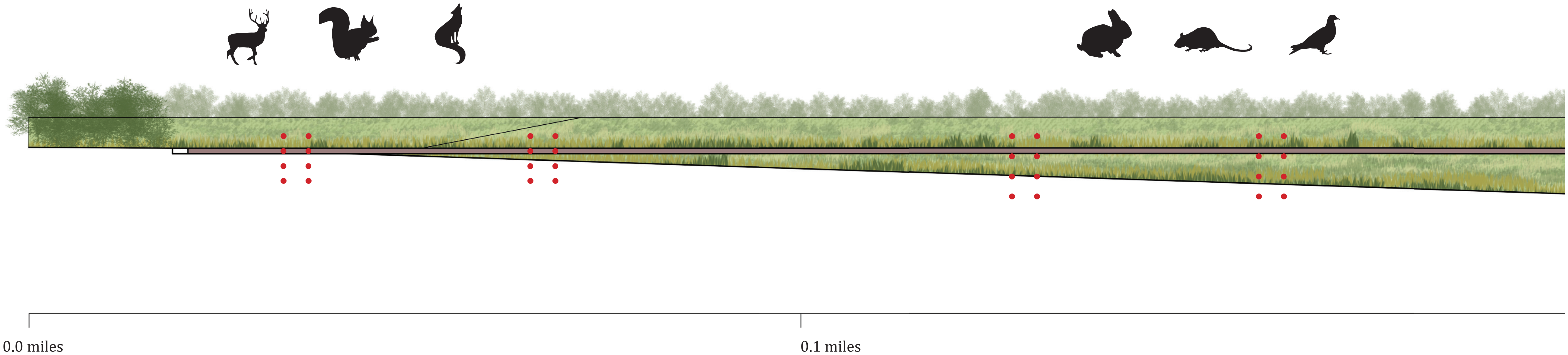


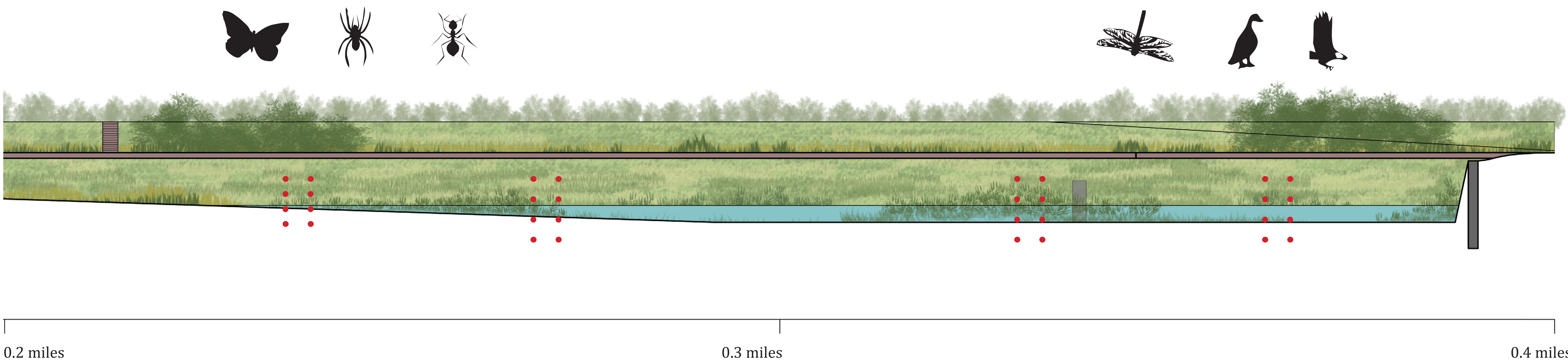
Fig. 4.35:Treatment Field Habitat Creation (Swehla, 2017)

harvesting schedule could result in damaging levels of chemical uptake within the plants, oversaturation of chemicals within plant biomass hindering the phytoremediation process, or biomagnification transferring into wildlife species that feed upon the plants.

The pedestrian paths that extend into the treatment field are placed on top of the former railroad corridor and gradually become an elevated boardwalks as the ground plane falls away. These boardwalks provide an area of separation between park visitors and collected stormwater. This separation also allows for the wildlife habitat underneath to be undisturbed from human foot traffic.

Stormwater flowing through the treatment field is slowed downhill by the implementation of interception hedgerows and groundwater migration tree stands. These two phytomechanism planting types provide a different variety of habitat for the park's wildlife. Blooming bushes and fragrant trees attract birds and insects.

Stormwater is collected along the East edge of the treatment field where chemicals are broken down through rhizofiltration in the constructed wetland. At capacity, the wetland is outlet through an overflow drain hidden beneath the elevated boardwalk. The constructed wetland creates another habitat variation for amphibious animals, insects, birds, and mammals.



Post-Design Hydrology Map

Alterations to the site's sub-watersheds were kept to a minimum. This was done to prevent the spread of chemical pollutants entering areas of the site that are not already contaminated. Site grading was primarily focused within Watershed 2 to create a constructed wetland environment along the East edge.

Watershed 2 contained chemical pollutants and therefore required designed hydrologic alterations. A constructed treatment wetland was created down gradient to collect polluted stormwater runoff and perform phytoremediation. Stormwater runoff from the West and East landfills are collected for treatment within the constructed wetland. Contaminated stormwater flowing over the rail corridor picks up chemical pollution for deposition into the wetland. This stormwater is cleaned in route to the wetland through extraction plot phytomechanisms.

The sizing of this treatment wetland area corresponds with the calculated watershed's average rainfall catchment. These calculations can be found in Appendix A. The rainfall event used to calculate the runoff estimate was taken from a 10 year, 24 hour storm. The wetland was designed to hold 6.42 acre/ft of runoff stormwater. At capacity, the constructed wetland will outlet to a stormwater filter placed in the dried Rock Creek ox bow.

When estimating the runoff coefficient for the phytoremediation field area, conservative calculations were used to ensure that the designed wetland area could accommodate maximum runoff capacity. The runoff coefficient for each surface material was taken from the Grade D column of the hydrologic soil grade chart. All calculations for estimated stormwater runoff can be found in Appendix A.

A section of the dried ox bow in Watershed 6 has been regraded to help stormwater runoff dispelled from the constructed wetland reach Rock Creek. The regraded portion of the ox bow has been planted with phytoremediating plants to remove further contaminates from the runoff. To help understand stormwater volume dispelling through Watershed 6, calculations in Appendix B show further estimations regarding volume carrying capacity.

Existing site hydrology was preserved for all areas of the site not undergoing phytotechnology.

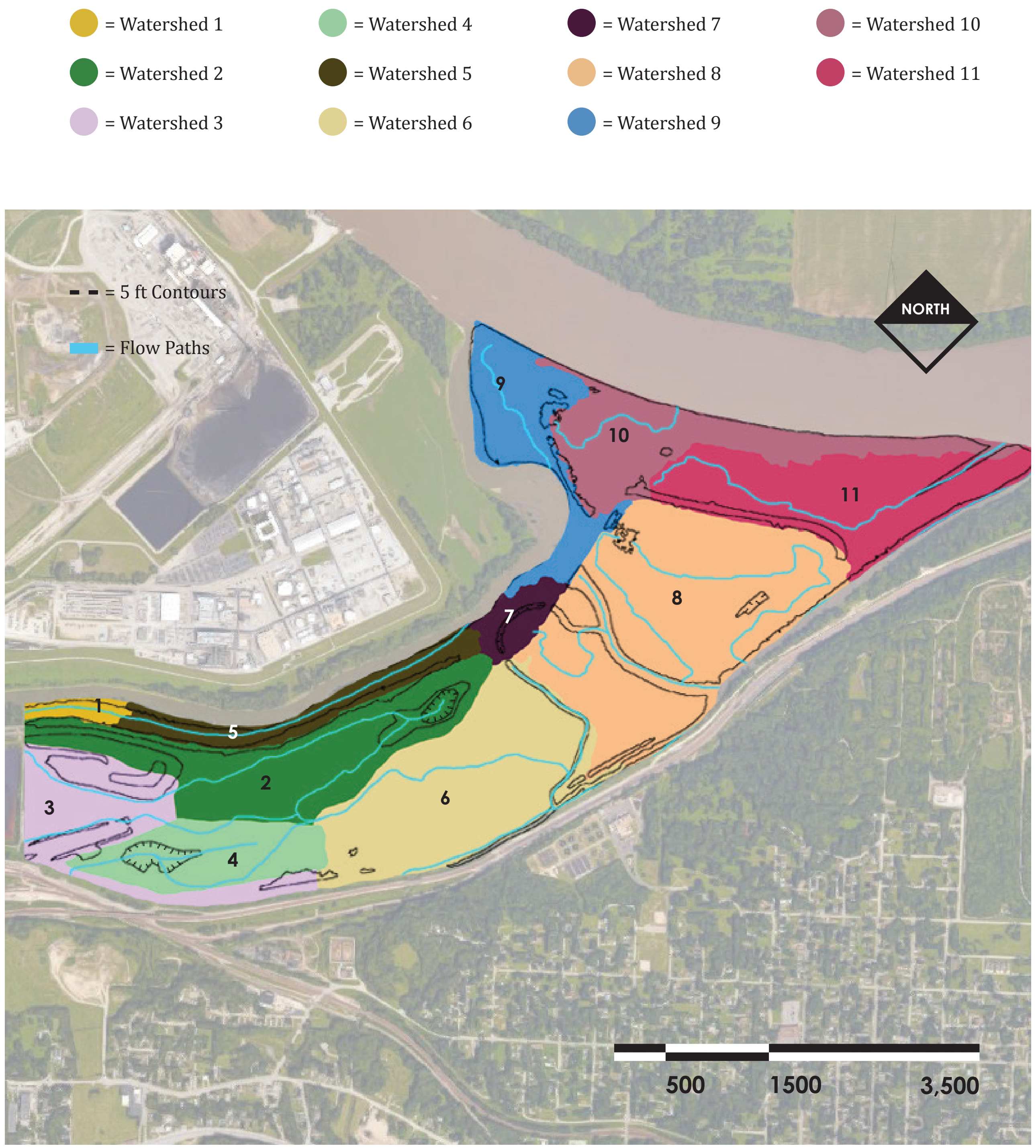


Fig. 4.36: Post-Design Hydrology Map (Swehla, 2017)

Maintenance and Monitoring

Maintenance is an important component of a response plan to ensure that the remedy performs as intended and may be required indefinitely for remedies that contain waste on-site or include institutional controls. Property owners, business operators, or prospective buyers want their prospective property cleaned up to standards acceptable to the state. This can greatly reduce the environmental liability associated their site. In regards to the ARMCO Site, former rail road right of ways are common areas to find elevated arsenic levels due to historic arsenical herbicide use. 'Rails-to-trails' conversions and other projects typically must demonstrate that risks are limited based on planned use and engineering controls. Engineering controls are physical controls put into place at a site to prevent human and ecological exposure to contamination by limiting direct contact with contaminated areas, reducing contamination levels or controlling the spread of contaminants through the environment ("Superfund: Post Construction Completion").

This proposal recommends that ground water monitoring wells be placed throughout the phytoremediation field to track pollution migration across the extraction plots and into the constructed wetland. Ground water monitoring wells should also be placed along the stormwater filter strip channeling runoff water towards Rock Creek. Further studies of contaminant migration and removal will need to be done in accordance with EPA's guidelines and requirements for remediation ("Superfund: Post Construction Completion").

Other engineering controls that should be implemented and monitored for the ARMCO redevelopment include the maintenance of the landfill caps, mowing, reseeding, ensuring appropriate controls for run off, repairing cracks, animal burrow damage, and areas of settlement and erosion.

Institutional controls are administrative or legal instruments intended to minimize the potential for human exposure to contamination by limiting land or resource use. Determined on a site-specific basis; site managers should work closely with the state/federal agencies, and local governments as appropriate and seek advance written agreements on who will implement, maintain, and enforce institutional controls ("Superfund: Post Construction Completion").

Fig. 4.37: Maintenance and Monitoring (Swehla, 2017)

This redevelopment plan incorporates an extraction plot phytomechanism which requires frequent harvesting to remove bioaccumulated contaminants. The contaminant concentrations in the harvested biomass can be tested to determine chemical uptake. It should be noted that if extremely high levels of arsenic are found to be accumulating in the biomass, disposal in a hazardous waste facility should be anticipated (Kennen and Kirkwood).

The site's monitoring plan is intended to comply with the requirements for certification for Missouri's Voluntary Cleanup Program administered by the Hazardous Waste Program's Brownfields/Voluntary Cleanup Program Section which provides state oversight for voluntary cleanups of properties contaminated with hazardous substances ("Missouri Department Of Natural Resources").

The constructed wetland should receive annual inspections for clogging, debris build up, and sediment accumulation. Any sediment removal should take place when the basin in thoroughly dry.

This proposal suggests that a review be conducted five years after the remediation plan has been implemented. The purpose of the review is to evaluate the implementation and performance of the remediation plan to determine the systems compliance with human health and environmental protection goals. A five-year review will provide an opportunity to identify any problems with the remediation plan and adjust monitoring and maintenance where necessary. It is likely that the remediation plan will require more than five years to reach the cleanup goal. In this case, another review should be conducted at the ten year mark.

Site reviews can be determined through visual observation during site visits, interviews with site stakeholders, and local citizens and officials, review/evaluation of existing monitoring information, and collection of new data ("Superfund: Post Construction Completion").

DESIGN ELEMENTS

The design elements chosen for the ARMCO Site redevelopment were taken from the precedents examined for the impact of phytoremediation design on human access, wildlife habitat restoration, and stormwater management. As the impacts of phytoremediation design on stormwater management have been discussed in previous sections, the designed elements chosen for increased human access and habitat restoration will be explained here.

Phytoremediation Area Design Elements

The design elements for the Phytoremediation Area include a star gazing hill, sports fields, a youth playground, a pavilion, a wetland walk, a timber walk, and a raised network of pathways reconstructed on the site's former railroad lines.

The West landfill has been capped with a plastic liner and resurfaced with clean topsoil. The plastic liner protects visitors from the underground pollution allowing the hill to be programmed for star gazing or any number of activities requesting a large open space, such as festival events.

The southeast face of this landfill has taken shape as a youth playground. The playground utilizes the landfills topography to incorporate slides into the hillside.

A pavilion is proposed for construction at the northeast corner of the East landfill. The pavilion is meant to service the East landfill's sport facilities. These facilities include 2 basketball courts, 4 sand volleyball courts, 1 full size soccer field, and a large, multi-use, recreation lawn. The sports fields are intended to provide free recreation opportunities for the Sugar Creek neighborhood and increase the 64053 zip code acces to healthy, outdoor recreation.

Raised walkways through the seasonal wetland create an interactive element for visitors experiencing the park during spring and fall months. The walkway elevates the visitor above native wetland vegetation and reptilian wildlife in a shallow pond. Similarly, the timber walk creates a curvilinear trail through a tall grass prairie, flanked on either side with dense forest. These two walkways attempt to reconnect the park visitors with the experience of two iconic natural environments, the river wetland and the tall grass prairie.

The design of the phytoremediation treatment field trail network is a tribute to the ARMCO Site's industrial past. Reconstructing the former rail corridor into a series of raised pathways provides the necessary physical separation of human and pollution seen throughout the precedent studies. By creating a pathway that repurposes the rail corridor for pedestrian use, a connection is made between the historic actions of the ARMCO Steel Co. that led to the site's contamination, and the healing process now being implemented. Creating a link between the cleanup process, and the lack of compassion for our environment shown in the site's previous ownership, helps educate a larger audience on the necessity of environmental protection.

Conservation Area Design Elements

The design elements for the Conservation Area include river pilings, a river viewing platform, a pavilion, and a viewing tower. These elements are intentionally low impact on the environment and have small physical footprints.

A majority of the Conservation Area is dedicated to protecting existing forest habitat. The areas alongside the park trails have been planted with native vegetation to create interesting trail characteristics and increase diversity of wildlife habitats.

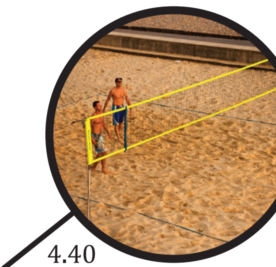
Pilings along the river are intended to build wildlife habitat and create points of visually contact between visitors and the native species within the park. Some of these pilings are placed away from park pathways to create areas of habitat that will undisturbed by human presence.

Phytoremediation Area Design Elements

Fig. 4.38: Phytoremediation Area Design Elements
(Swehla, 2017)


4.39

Star Gazing
An open hill to view the night sky.


4.40

Ball Fields
Sports facilities for young adults.


4.41

Playground
Youth playground with hill slides.


4.42

Pavilion
Covered patio near sports amenities.


4.43

Wetland Walk
An elevated walkway above the seasonal wetland.


4.44

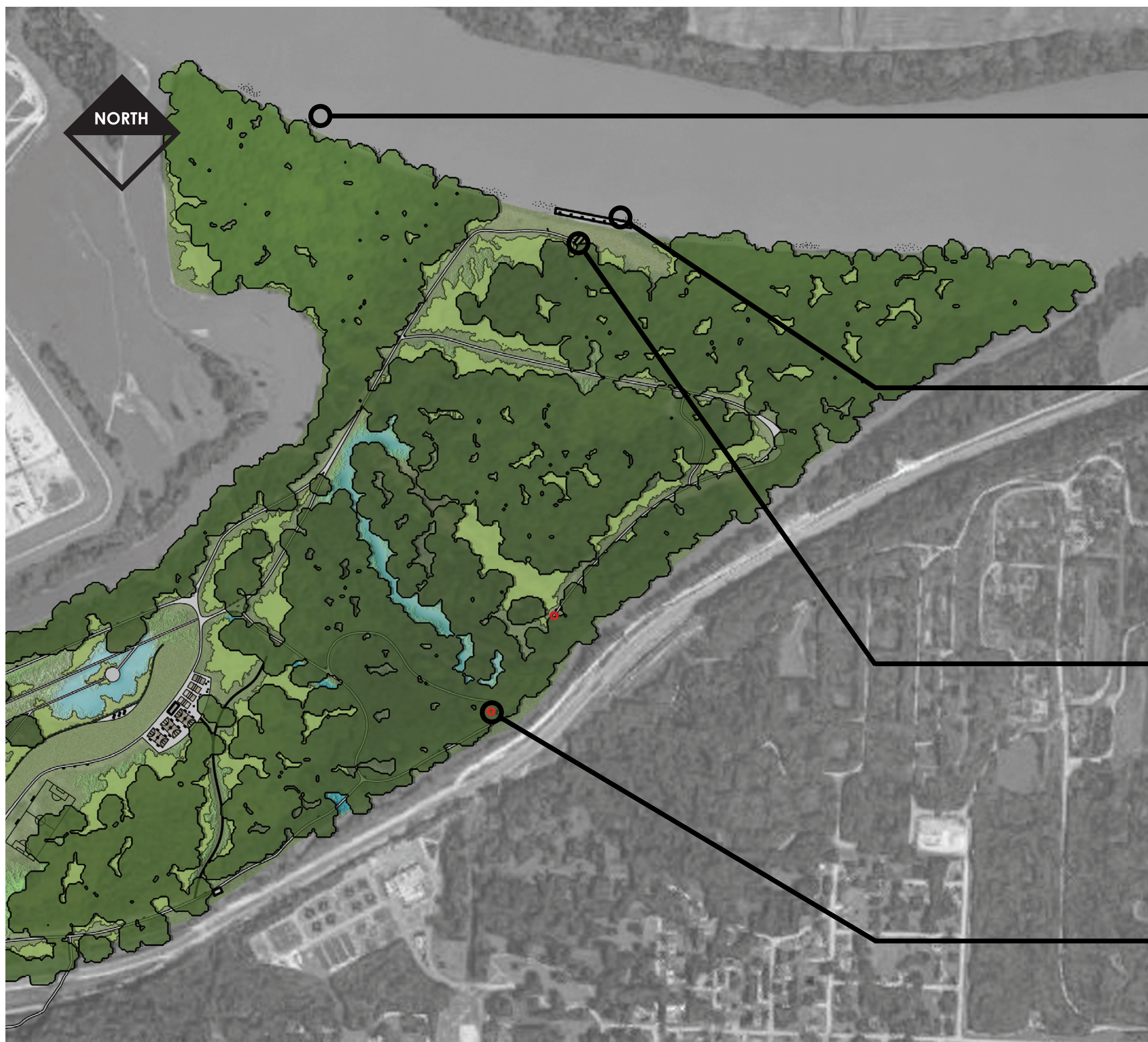
Timber Walk
Rail timbers create pathway through tall grass prairie.


4.45

Railroad Pathway
Historic rail corridor creates walking path.

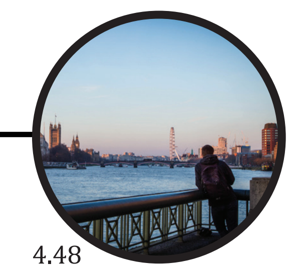
Fig. 4.39 - 4.45: Phytoremediation Area Design Elements
(Swehla, 2017)

Conservation Area Design Elements



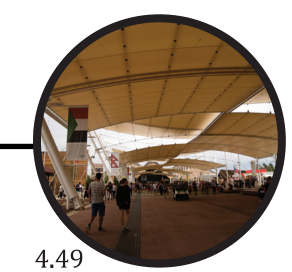
4.47

Pilings
Wooden pilings for avian and aquatic habitat development.



4.48

River Platform
A docking platform converted for visitor viewing to the Missouri River.



4.49

Pavilion
Shelter structure for weather security and leisure provides covered seating space.

4.50

Viewing Tower
Elevated platforms above the tree canopy offer views the surrounding environment.

Fig. 4.46: Conservation Area Design Elements
(Swehla, 2017)

Fig. 4.47 - 4.50: Phytoremediation Area Design Elements
(Swehla, 2017)

5 CONCLUSIONS

PROJECT RESULTS AND DISCUSSION

Research Findings

The aesthetic qualities of phytoremediation design offer many more benefits to the public than most mechanized methods of pollutant removal. Phytotechnology application allows for the natural enhancement of local environmental assets while providing needed chemical and pollutant removal on contaminated sites. Phytotechnology planting types utilized in this proposal provide native habitats for local plant and animal communities. A native planting palette aids adequate water absorption and proper water management principles while providing food, resting, mating, and shelter areas for wildlife.

Design Outcomes

Applying the research findings in the form of a design solution created a much higher degree of understanding of the requirements for phytoremediation, stormwater management, and habitat creation. Understanding that the design considerations for phytoremediation are affected by not only the type of contaminant, but also the site topography, soil characteristics, human access, and design intentions is paramount to application of the phytotechnologies.

Understanding the environmental needs of a remediation project is critically important to the successful reintroduction of the site's vegetation and wildlife. By applying the research findings for native plantings and local wildlife, the master plan solution provides a plan for recovering a healthy landscape.

The redevelopment of the ARMCO Site may have far reaching implications for the neighboring communities. The new park will be able to service a large variety of activities that will be offered free of admission. The poor economic situation of the nearby 64053 zip code implies that the residents have a need for free amenities.

Project Limitations

Time was an important limiting factor of this project. Despite the constraints provided by time, the project was successful in providing meaningful answers to its original research questions.

There are many disadvantages of phytotechnologies. Many contaminants cannot be remediated with phytotechnologies. Soil/climate conditions are not favorable for their application. Extraction processes are limited to shallow contamination and dependent on adaptability of plants to various climate zones. In some cases plants may need to be harvested in order to remove and dispose of waste. Contained contaminants in plant matter may be unintentionally released through transpiration or uncontrolled incineration. Ongoing maintenance costs, site monitoring requirements and ground water testing, an elongated timeline of phytotechnology installation, natural system intervention by wildlife or weather patterns may interrupt or alter anticipated results. Suitable plant palettes may not be available regionally or provided by local growers (Kennen and Kirkwood).

Rebuttals to this proposal may argue that: riverfront land could be repurposed for better uses, the land here may be more valuable for development, redevelopment of land using phytotechnology is a waste of resources while producing unattractive landscapes. However, implementations of phytotechnology can be elegant. With design features, such as urban parkland and recreational fields, redevelopment of this land could be designed differently to achieve better results while also adding aesthetic value.

Arguments may arise regarding the scale of cleaning required; stating, site scale design improvements will have no effect on overall river pollution levels. While this may be true with just one riverfront redevelopment project, a new trend would emerge if multiple riverfront properties were redeveloped as treatment wetlands.

Future Research

Future research opportunities include applying phytoremediation to other ecosystem types, examining results after implementation of the design proposal, further studies to identify alternative ways to remove contaminates from riverfront ecosystems, and tests of downstream water quality and ecosystem health post-implementation. Observations of wildlife populations could be monitored to record any increases in wildlife health. Wildlife health monitoring could incorporate the testing of plant material to determine levels of phytotoxicity and bioaccumulation within wildlife. These tests could help determine the biomagnification within the site's wildlife. A more detailed site design could be achieved with an extended report.

Soil tests to determine the infiltration capacity of soil should be performed at all proposed stormwater facilities that have a recharge or infiltration components to their design. The purpose of the testing is to identify and confirm the soil characteristics and determine suitability for infiltration components.

Project and Process Reflection

The methodology executed over the course of this project has informed the creation of a successful design solution to promote phytoremediation, human access and wildlife health at the ARMCO Site. The methods chosen to arrive at this solution are grounded in research investigation through literature review, site inventory and analysis, extraction suitability analysis, precedent study analysis, and design. The project shows that the ARMCO Site redevelopment opportunity can contribute many environmental and public amenities.

As many city's remodel their waterfronts, this project creates an argument to reimagine the urban riverfront as an ecosystem working to reverse the damage left behind after the industrial era. By redeveloping urban rivers for wetland protection and stormwater management, cities can begin to regain their connections with the landscape while providing resilient ecosystems through restoration. This proposal identifies possibilities for riverfront redevelopment as wetlands and tools for restorative action aiding increased human access and wildlife health.

The ARCMO Site has the potential to play an important role in the local image and quality of life for the Sugar Creek neighborhood. This community's environmental capital is important to protect because it comprises the entire range of natural resources within the community. By emphasizing redevelopment tools that enhance the natural environment I learned many ways that the built environment can intermingle with natural landscapes.

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Figure 1.3
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Figure 1.4
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Figure 2.1
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Figure 2.2
Swehla, Tyler. "ARMCO Site in Kansas City". 2017. Adapted from Google Earth imagery. Adobe Illustrator.

Figure 2.3
Swehla, Tyler. "Remnant platforms from ARMCO facility." 2017. Photograph.

Figure 2.4
Swehla, Tyler. "Former steel unloading area; visible pollutants." 2017. Photograph.

Figure 2.5
Swehla, Tyler. "ARMCO Site Context". 2017. Adapted from Google Earth imagery. Adobe Illustrator.

Figure 2.6
Swehla, Tyler. "64053 Zip Code Boundary". 2017. Adapted from Google Earth imagery. Adobe Illustrator.

Figure 3.1
Swehla, Tyler. "Path Section 1". 2017. Civil 3D, Adobe Illustrator.

Figure 3.2
Swehla, Tyler. "Site entry underneath railway." 2017. Photograph.

Figure 3.3
Swehla, Tyler. "Seasonally wet lowland." 2017. Photograph.

Figure 3.4
Swehla, Tyler. "Mowed path looking West." 2017. Photograph.

Figure 3.5
Swehla, Tyler. "Industrial remnants West." 2017. Photograph.

Figure 3.6
Swehla, Tyler. "Lowland area." 2017. Photograph.

Figure 3.7
Swehla, Tyler. "Industrial remnants at peninsula." 2017. Photograph.

Figure 3.8
Swehla, Tyler. "Path Section 2". 2017. Civil 3D, Adobe Illustrator.

Figure 3.9
Swehla, Tyler. "Telephone line." 2017. Photograph.

Figure 3.10
Swehla, Tyler. "Connecting pathway looking North." 2017. Photograph.

Figure 3.11
Swehla, Tyler. "Mowed path looking East." 2017. Photograph.

Figure 3.12
Swehla, Tyler. "Deer track." 2017. Photograph.

Figure 3.13
Swehla, Tyler. "Gravel path looking East." 2017. Photograph.

Figure 3.14
Swehla, Tyler. "Mowed path looking East." 2017. Photograph.

Figure 3.15
Swehla, Tyler. "Path Section 3". 2017. Civil 3D, Adobe Illustrator.

Figure 3.16
Swehla, Tyler. "Forested entry." 2017. Photograph.

Figure 3.17
Swehla, Tyler. "Industrial remnants." 2017. Photograph.

Figure 3.18
Swehla, Tyler. "Mowed path looking East." 2017. Photograph.

Figure 4.48
Swehla, Tyler. "ARMCO Steel Co. pollution." 2017. Photograph.

Figure 3.49
Swehla, Tyler. "ARMCO Steel Co. building pad." 2017. Photograph.

Figure 3.50
Swehla, Tyler. "Path Section 8". 2017. Civil 3D, Adobe Illustrator.

Figure 3.51
Swehla, Tyler. "View towards east landfill." 2017. Photograph.

Figure 3.52
Swehla, Tyler. "Gravel pathway looking East." 2017. Photograph.

Figure 3.53
Swehla, Tyler. "Stagnant pond." 2017. Photograph.

Figure 3.54
Swehla, Tyler. "Stagnant pond." 2017. Photograph.

Figure 3.55
Swehla, Tyler. "Blue River." 2017. Photograph.

Figure 3.56
Swehla, Tyler. "Flood dyke." 2017. Photograph.

Figure 3.57
Swehla, Tyler. "Path Section 9". 2017. Civil 3D, Adobe Illustrator.

Figure 3.58
Swehla, Tyler. "Gravel pathway looking East." 2017. Photograph.

Figure 3.59
Swehla, Tyler. "Telephone lines." 2017. Photograph.

Figure 3.60
Swehla, Tyler. "Cliff side looking South." 2017. Photograph.

Figure 3.61
Swehla, Tyler. "View of cliff side looking North." 2017. Photograph.

Figure 3.62
Swehla, Tyler. "End of pathway, looking North." 2017. Photograph.

Figure 3.63
Swehla, Tyler. "View of Creek Creek from pathway. 2017. Photograph.

Figure 3.64
Swehla, Tyler. "Path Section 10". 2017. Civil 3D, Adobe Illustrator.

Figure 3.65
Swehla, Tyler. "Light poles and prairie." 2017. Photograph.

Figure 3.66
Swehla, Tyler. "Industrial remnants." 2017. Photograph.

Figure 3.67
Swehla, Tyler. "Missouri River upstream." 2017. Photograph.

Figure 3.68
Swehla, Tyler. "Old dock landing." 2017. Photograph.

Figure 3.69
Swehla, Tyler. "Exposed flood wall." 2017. Photograph.

Figure 3.70
Swehla, Tyler. "Old dock landing." 2017. Photograph.

Figure 3.71
Swehla, Tyler. "Existing Paths and Vegetation". 2017. Adapted from Google Earth imagery. Adobe Photoshop.

Figure 3.72
Swehla, Tyler. "Site Contaminants". 2017. Adapted from Google Earth imagery. Adobe Illustrator.

Figure 3.73
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Figure 3.74
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Murphy, Dennis. Gray Fox. 2016. Photograph. Flickr. Web. 20 April 2017.

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Drescher-Lehman, Jonathan. Eastern Musk Turtle and Leech. 2014. Photograph. Flickr. Web. 20 April 2017.

Figure 3.125
San Martin, Gilles. Myotis myotis. 2011. Photograph. Flickr. Web. 20 April 2017.

Figure 3.126
Gunn, Mark. Springtime colors!. 2017. Photograph. Flickr. Web. 20 April 2017.

Figure 3.127
Kynd, Fyn. Eastern Gray Squirrel. 2014. Photograph. Flickr. Web. 20 April 2017.

Figure 3.128
Petrie, Todd. CVNP MarshFrog. 2013. Photograph. Flickr. Web. 20 April 2017.

Figure 3.129
Short, David. Gypsy moth (NH266). 2016. Photograph. Flickr. Web. 20 April 2017.

Figure 3.130
Hicks, Kathy. Swamp Rabbit. 2013. Photograph. Flickr. Web. 20 April 2017.

Figure 3.131
U.S. Department of Agriculture. k5437-1. 2010. Photograph. Flickr. Web. 20 April 2017.

Figure 3.132
Adams, Susan E. Bullfrog. 2009. Photograph. Flickr. Web. 20 April 2017.

Figure 3.133
Fox, Tom. Elevated walkways allow urban runoff to be filtered without interruption. 2016. Photograph. Asla.org. Web. 1 April 2017.

Figure 3.134
Yu, Kongjian. 006. 2010. Photograph. Asla.org. Web. 1 April 2017.

Figure 3.135
James Corner Field Operations. Freshkills Park. 2001. Illustration. ArchDaily. Web. 1 April 2017.

Figure 3.136
Arup. The Marsh. 2014. Photograph. The Architect's Newspaper. Web. 1 April 2017.

Figure 3.137
Schaer, Julienne. The beach at Brooklyn Bridge's Pier 4. 2014. Photograph. nypost.com. Web. 1 April 2017.

Figure 3.138
Great Ecology. EL-PASO-SEWER-BERM-RENDERING. 2009. Illustration. greatecology.com. Web. 1 April 2017.

Figure 3.139
Wohlrab, Mark. Duisburg-Nord Industrial Landscape Park. 2015. Photograph. germany.travel. Web. 1 April 2017.

Figure 3.140
Mossop + Michaels. Viet Village Urban Farm. 2008. Illustration. Asla.org. Web. 1 April 2017.

Figure 3.141
Turenscape. Liupanshui Minghu Wetland Park. 2014. Photograph. www.archilovers.com. Web. 1 April 2017.

Figure 3.142
Swehla, Tyler. "Opportunities Map". 2017. Adapted from Google Earth imagery. Adobe Illustrator.

Figure 3.143
Swehla, Tyler. "Constraints Map". 2017. Adapted from Google Earth imagery. Adobe Illustrator.

Figure 4.1
Swehla, Tyler. "Phytoremediation Area". 2017. Adapted from Google Earth imagery. Adobe Photoshop.

Figure 4.2
Swehla, Tyler. "Conservation Area". 2017. Adapted from Google Earth imagery. Adobe Photoshop.

Figure 4.3
Swehla, Tyler. "Extraction Plot Call Out". 2017. Adobe Photoshop.

Figure 4.4
Hilkerbäumer, Christoph. Switchgrass. 2008. Photograph. Flickr. Web. 20 April 2017.

Figure 4.5
USFWS Mountain-Prairie. Ross' bentgrass. 2009. Photograph. Flickr. Web. 20 April 2017.

Figure 4.6
Jeff Quayle. Tripsacum dactyloides08. 2012. Photograph. Flickr. Web. 20 April 2017.

Figure 4.7
OakleyOriginals. Big Blue Stem Grass. 2010. Photograph. Flickr. Web. 20 April 2017.

Figure 4.8
Swehla, Tyler. "Extraction Plot". 2017. Adapted from Google Earth imagery. Adobe Photoshop.

Figure 4.9
Swehla, Tyler. "Constructed Wetland Call Out". 2017. Adobe Photoshop.

Figure 4.10
Lavin, Matt. Leersia oryzoides. 2007. Photograph. Flickr. Web. 20 April 2017.

Figure 4.11
bobistraveling. Woolgrass Brumley Forest TLC Chapel Hill NC 8223. 2015. Photograph. Flickr. Web. 20 April 2017.

Figure 4.12
Wigham, Akuppa J. Cordgrass. 2007. Photograph. Flickr. Web. 20 April 2017.

Figure 4.13
West, Liz. Typha angustifolio. 2005. Photograph. Flickr. Web. 20 April 2017.

Figure 4.14
Swehla, Tyler. “Constructed Wetland”. 2017. Adapted from Google Earth imagery. Adobe Photoshop.

Figure 4.15
Swehla, Tyler. “Stormwater Filter Call Out”. 2017. Adobe Photoshop.

Figure 4.16
Lavin, Matt. Leersia oryzoides. 2007. Photograph. Flickr. Web. 20 April 2017.

Figure 4.17
bobistraveling. Woolgrass Brumley Forest TLC Chapel Hill NC 8223. 2015. Photograph. Flickr. Web. 20 April 2017.

Figure 4.18
Wigham, Akuppa J. Cordgrass. 2007. Photograph. Flickr. Web. 20 April 2017.

Figure 4.19
West, Liz. Typha angustifolio. 2005. Photograph. Flickr. Web. 20 April 2017.

Figure 4.20
Swehla, Tyler. “Stormwater Filter”. 2017. Adapted from Google Earth imagery. Adobe Photoshop.

Figure 4.21
Swehla, Tyler. “Interception Hedgerow Call Out”. 2017. Adobe Photoshop.

Figure 4.22
BotBln. Cephalanthus occidentalis BotGardBln07122011A.JPG. 2011. Photograph. Wikipedia Commons. Web. 20 April 2017.

Figure 4.23
glacierheart. wild hydrangeas. 2012. Photograph. Flickr. Web. 20 April 2017.

Figure 4.24
Reis, Larry. redosier dogwood (Cornus sericea) at Lake Meyer Park IA IMG_7892. 2015. Photograph. Flickr. Web. 20 April 2017.

Figure 4.25
dbarronoss. Impatiens capensis. 2014. Photograph. Flickr. Web. 20 April 2017.

Figure 4.26
McMasters, Melissa. Common ninebark. 2016. Photograph. Flickr. Web. 20 April 2017.

Figure 4.27
Keck, Dan. Spicebush. 2017. Photograph. Flickr. Web. 20 April 2017.

Figure 4.28
Swehla, Tyler. “Interception Hedgerow Call Out”. 2017. Adapted from Google Earth imagery. Adobe Photoshop.

Figure 4.29
Swehla, Tyler. “Groundwater Migration Tree Stand Call Out”. 2017. Adobe Photoshop.

Figure 4.30
Enking, Leonora (Ellie). Carya cordiformis (Bitter Nut). 2013. Photograph. Google. Web. 20 April 2017

Figure 4.31
Msact. American Elm Tree at Spring Grove Cemetery, Hartford, CT - May 26, 2012.JPG. 2012. Photograph. Wikipedia Commons. Web. 20 April 2017.

Figure 4.32
K M. 150823 96 High Line - Rhus glabra Smooth Sumac. 2015. Photograph. Flickr. Web. 20 April 2017.

Figure 4.33
Grandmont, Jean-Pol. Quercus bicolor JPG1. jpg. 2007. Photograph. Wikipedia Commons. Web. 20 April 2017.

Figure 4.34
Swehla, Tyler. “Interception Hedgerow”. 2017. Adapted from Google Earth imagery. Adobe Photoshop.

Figure 4.35
Swehla, Tyler. “Phytoremediation Field Habitat Creation”. 2017. Autodesk Civil 3D, Adobe Photoshop, Adobe Illustrator.

Figure 4.36
Swehla, Tyler. “Post-Design Hydrology Map”. 2017. Adapted from Google Earth imagery. ArcGIS.

Figure 4.37
Swehla, Tyler. “Maintenance and Monitoring”. 2017. Adapted from Google Earth imagery. Adobe Photoshop, ADobe Illustrator.

Figure 4.38
Swehla, Tyler. “Phytoremediation Area Design Elements”. 2017. Adapted from Google Earth imagery. Adobe Photoshop, ADobe Illustrator.

Figure 4.39
Dischner, Zach. Stargazin. 2014. Photograph. Flickr. Web. 30 April 2017.

Figure 4.40
Knight, Garry. Beach Volleyball. 2011. Photograph. Flickr. Web. 30 April 2017.

Figure 4.41
Silla, Jaanus. Stroomi beech kids playground at night, Estonia. 2009. Photograph. Flickr. Web. 30 April 2017.

Figure 4.42
Daveynin. Alumni Pavilion. 2012. Photograph. Flickr. Web. 30 April 2017.

Figure 4.43
Tonehill, Nicholas A. Swamp Walk. 2013. Photograph. Flickr. Web. 30 April 2017.

Figure 4.44
Benson, John. Sunflowers. 2012. Photograph. Flickr. Web. 30 April 2017.

Figure 4.45
Coursey, Lee. Tracks. 2014. Photograph. Flickr. Web. 30 April 2017.

Figure 4.46
Swehla, Tyler. “Conservation Area Design Elements”. 2017. Adapted from Google Earth imagery. Adobe Photoshop, ADobe Illustrator.

Figure 4.47
Venditti, Phil. Birds on pilings. 2017. Photograph. Flickr. Web. 30 April 2017.

Figure 4.48
Scottow, Adrian. View over the Thames towards the Houses of Parliament. 2017. Photograph. Flickr. Web. 30 April 2017.

Figure 4.49
Nakayama, Norio. EXPO Milano 2015. 2015. Photograph. Flickr. Web. 30 April 2017.

Figure 4.50
BumFluff2009. Lookout. 2015. Photograph. Flickr. Web. 30 April 2017.

LIST OF TABLES CITATIONS

Table 2.1
Swehla, Tyler. “Gender As %.” 2017. Adapted from www.towncharts.com. 1 April 2017.

Table 2.2
Swehla, Tyler. “Age Ranges As %.” 2017. Adapted from www.towncharts.com. 1 April 2017.

Table 2.3
Swehla, Tyler. “Crime Type As %.” 2017. Adapted from www.towncharts.com. 1 April 2017.

Table 2.4
Swehla, Tyler. “Demographics.” 2017. Adapted from www.towncharts.com. 1 April 2017.

Table 2.5
Swehla, Tyler. “Average Household Income.” 2017. Adapted from www.incomebyzipcode.com. 1 April 2017.

Table 2.6
Swehla, Tyler. “Health Insurance As %.” 2017. Adapted from www.towncharts.com. 1 April 2017.

Table 3.7
Swehla, Tyler. “Soil Type.” 2017. Adapted from Websoilsurvey.sc.egov. 1 April 2017.

Table 3.8
Swehla, Tyler. “Hydrologic Soil Group.” 2017. Adapted from Websoilsurvey.sc.egov. 1 April 2017.

Table 3.9
Swehla, Tyler. “Soil Percent Clay.” 2017. Adapted from Websoilsurvey.sc.egov. 1 April 2017.

Table 3.10
Swehla, Tyler. “Grass Palette.” 2017.

Table 3.11
Swehla, Tyler. “Shrub Palette.” 2017.

Table 3.12
Swehla, Tyler. “Tree Palette.” 2017.

Table 3.13
Swehla, Tyler. “Flowers Palette.” 2017.

7

PROJECT GLOSSARY

PROJECT GLOSSARY

(* = definition from ***Phyto***, 2015)

bioaccumulation*

Intracellular accumulation of environmental pollutants such as heavy metals by living organisms.

bioavailability*

The proportion of a containment that is available for uptake by a plant.

bioremediation*

The process by which living organisms are used to degrade or transform hazardous organic contaminants.

brownfield*

An abandoned, idled, or underused industrial or commercial facility where expansion or redevelopment is complicated by a real or perceived environmental contamination.

environmental capital

Characteristics of the ecosystems, or natural capital, are environmental functions, defined as 'the capacity of natural processes and components to provide goods and services that satisfy human needs (directly and/or indirectly).

evapotranspiration*

Water lost to the atmosphere from the ground surface, evaporation from the capillary fringe of the groundwater table, and the transpiration of groundwater by plants whose roots tap the capillary fringe of the groundwater table.

greenway

A strip of undeveloped land near an urban area, set aside for recreational use or environmental protection.

herbicide

A substance that is toxic to plants and is used to destroy unwanted vegetation.

hyperaccumulator

A plant that absorbs toxins, such as heavy metals, to a greater concentration than that in the soil in which it is growing.

inorganic compounds*

Inorganic pollutants are naturally occurring elements on the periodic table such as lead and arsenic. Human activities such as industry production and extraction mining create a release of inorganic pollutants into the environment, causing toxicity. These are elements, so they cannot be degraded and destroyed; instead they can sometimes be taken up and extracted by plants. If extraction is possible, the plants must be cut down and harvested to remove the pollutants from a site.

organic compounds*

Components that typically contain bonds of carbon, nitrogen, and oxygen. Many organic contaminants can be degraded with phytotechnologies, breaking them down into smaller, less toxic components. Organic contaminants may be degraded outside the plant in the root zone, taken into a plant, bound to the plant tissues, degraded to form non-toxic metabolites, or released to the atmosphere. If persistent, organic contaminants may not be able to be degraded by plants.

pesticide

A substance used for destroying insects or other organisms harmful to cultivated plants or to animals.

phytochemicals

Any of various biologically active compounds found in plants.

phytodegradation*

The process whereby plant-produced enzymes break down dissolved organic contaminants that are in the plant through the uptake of water.

phytoextraction*

The uptake and accumulation of inorganic elements into the plant tissues.

phytohydraulics

The ability of plants to capture, transport and transpire water from the environment. This action in turn contains pollutants and controls the hydrology of the environment. This mechanism does not degrade the contaminant.

phytoirrigation*

Polluted water is irrigated onto plantings. Removal of the polluting compounds is provided by the plants; the objective is to completely degrade and remove the contaminants being irrigated onto the plants.

phytomining

Some plants absorb copper compounds through their roots. They concentrate these compounds because of this. The plants can be burned to produce an ash that contains the copper compounds. This method of extraction is called phytomining. Some bacteria absorb copper compounds.

phytoremediation*

Use of plants to remediate contaminated soil, sediments, surface water, or groundwater.

phytostabilization*

The ability of plants to hold and stabilize certain inorganic elements in the plant and the root zone.

phytotechnology

Implementation of solutions to scientific and engineering problems in the form of plants.

phytotoxicity

A toxic effect by a compound on plant growth. Such damage may be caused by a wide variety of compounds, including trace metals, salinity, pesticides, phytotoxins or allelochemicals.

phytovolatilization*

The uptake and subsequent transpiration of volatile contaminants through the plant leaves.

rhizodegradation*

Biodegradation of organics by the soil organisms. Exuded plant products through phytosequestration can lead to enhanced biodegradation in the rhizosphere.

rhizofiltration*

Trapping of contaminants by the roots of plants immersed in water and soil.

social capital

The networks of relationships among people who live and work in a particular society, enabling that society to function effectively.

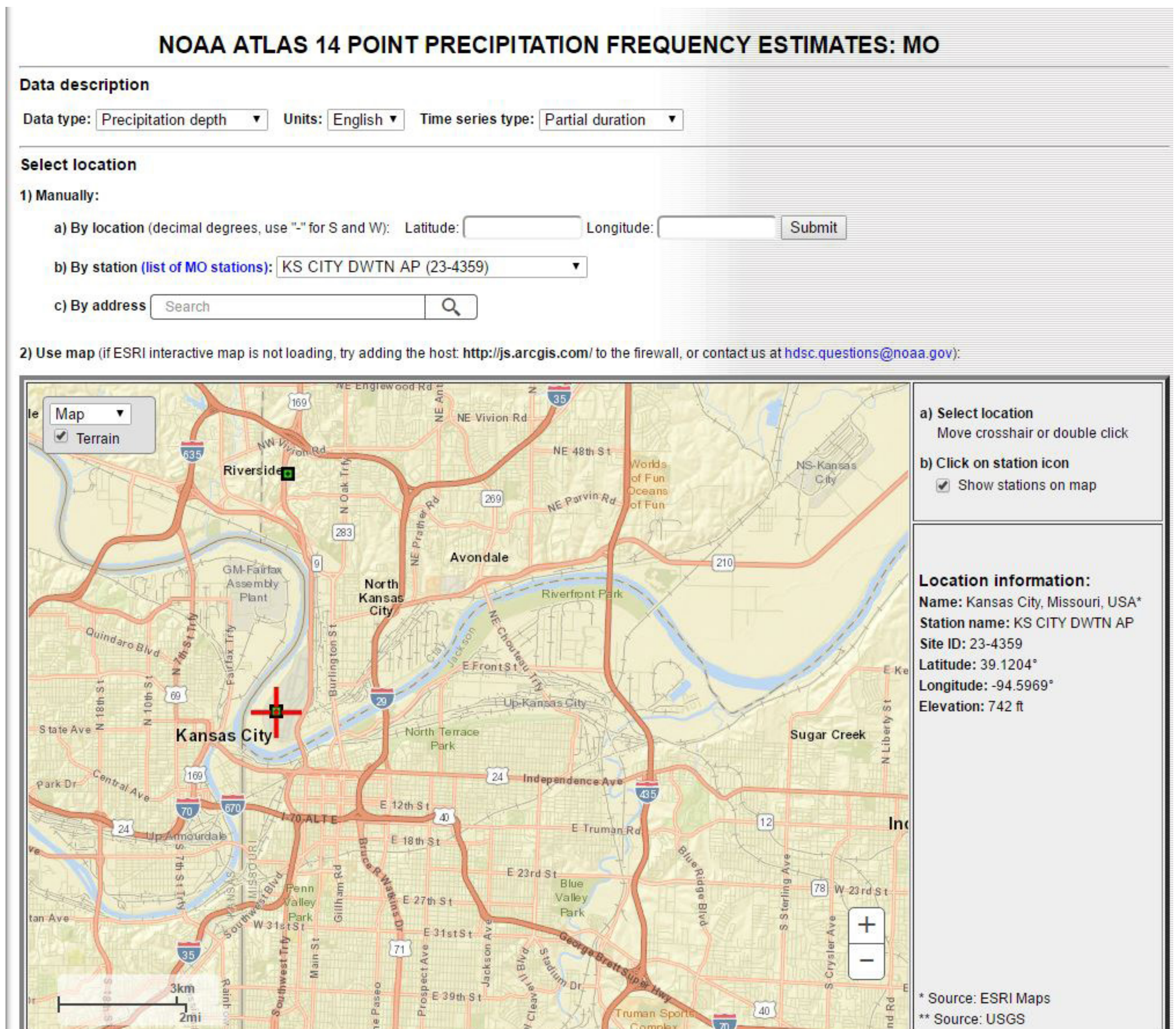
volatile organic compounds (VOC's)*

Synthetic organic chemical capable of becoming vapor at relatively low temperatures.

APPENDIX 8

APPENDIX A - ESTIMATING RUNOFF

The following documents used for estimating runoff were taken from the Hydrometeorological Design Studies Center, Precipitation Frequency Data Server.



PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.401** (0.317-0.515)	**0.469** (0.370-0.603)	**0.585** (0.460-0.752)	**0.684** (0.535-0.883)	**0.828** (0.628-1.10)	**0.943** (0.698-1.26)	**1.06** (0.759-1.44)	**1.19** (0.813-1.64)	**1.36** (0.895-1.91)	**1.50** (0.957-2.11)
10-min	**0.587** (0.464-0.754)	**0.687** (0.542-0.882)	**0.856** (0.673-1.10)	**1.00** (0.784-1.29)	**1.21** (0.919-1.61)	**1.38** (1.02-1.84)	**1.56** (1.11-2.11)	**1.74** (1.19-2.40)	**1.99** (1.31-2.79)	**2.19** (1.40-3.09)
15-min	**0.716** (0.566-0.920)	**0.838** (0.661-1.08)	**1.04** (0.821-1.34)	**1.22** (0.956-1.58)	**1.48** (1.12-1.96)	**1.68** (1.25-2.25)	**1.90** (1.35-2.57)	**2.12** (1.45-2.92)	**2.43** (1.60-3.41)	**2.67** (1.71-3.77)
30-min	**1.01** (0.795-1.29)	**1.18** (0.931-1.52)	**1.48** (1.16-1.90)	**1.73** (1.35-2.23)	**2.10** (1.59-2.78)	**2.39** (1.77-3.19)	**2.70** (1.93-3.65)	**3.02** (2.07-4.16)	**3.46** (2.27-4.85)	**3.80** (2.43-5.37)
60-min	**1.32** (1.04-1.69)	**1.56** (1.23-2.00)	**1.97** (1.55-2.53)	**2.32** (1.81-2.99)	**2.83** (2.15-3.75)	**3.24** (2.40-4.32)	**3.66** (2.62-4.97)	**4.11** (2.81-5.67)	**4.72** (3.11-6.63)	**5.21** (3.33-7.35)
2-hr	**1.63** (1.30-2.06)	**1.93** (1.54-2.46)	**2.46** (1.95-3.12)	**2.91** (2.30-3.71)	**3.56** (2.73-4.67)	**4.08** (3.05-5.39)	**4.63** (3.34-6.21)	**5.20** (3.60-7.10)	**5.99** (3.98-8.32)	**6.61** (4.27-9.24)
3-hr	**1.83** (1.47-2.31)	**2.19** (1.76-2.76)	**2.80** (2.24-3.54)	**3.33** (2.65-4.21)	**4.09** (3.16-5.33)	**4.71** (3.54-6.17)	**5.35** (3.88-7.13)	**6.02** (4.19-8.16)	**6.95** (4.65-9.59)	**7.68** (4.99-10.7)
6-hr	**2.21** (1.79-2.75)	**2.65** (2.15-3.31)	**3.42** (2.76-4.26)	**4.08** (3.28-5.10)	**5.03** (3.92-6.48)	**5.80** (4.41-7.53)	**6.61** (4.85-8.71)	**7.45** (5.24-10.0)	**8.62** (5.83-11.8)	**9.54** (6.27-13.1)
12-hr	**2.61** (2.15-3.21)	**3.14** (2.58-3.86)	**4.04** (3.30-4.98)	**4.82** (3.92-5.96)	**5.96** (4.70-7.59)	**6.87** (5.28-8.81)	**7.83** (5.81-10.2)	**8.83** (6.28-11.7)	**10.2** (6.98-13.8)	**11.3** (7.51-15.4)
24-hr	**3.06** (2.54-3.71)	**3.64** (3.02-4.43)	**4.64** (3.84-5.65)	[illegible] (4.53-6.73)	**6.78** (5.40-8.53)	**7.80** (6.06-9.89)	**8.87** (6.65-11.4)	**9.99** (7.18-13.1)	**11.5** (7.97-15.5)	**12.8** (8.57-17.2)
2-day	**3.58** (3.00-4.29)	**4.18** (3.51-5.01)	**5.21** (4.36-6.26)	**6.12** (5.09-7.37)	**7.44** (6.00-9.24)	**8.51** (6.69-10.7)	**9.63** (7.31-12.3)	**10.8** (7.86-14.1)	**12.5** (8.70-16.5)	**13.8** (9.33-18.4)
3-day	**3.94** (3.33-4.68)	**4.53** (3.83-5.40)	**5.56** (4.68-6.64)	**6.47** (5.42-7.74)	**7.79** (6.33-9.62)	**8.87** (7.03-11.0)	**10.0** (7.65-12.7)	**11.2** (8.20-14.5)	**12.9** (9.05-17.0)	**14.2** (9.69-18.8)
4-day	**4.24** (3.60-5.02)	**4.84** (4.11-5.73)	**5.86** (4.96-6.95)	**6.76** (5.69-8.05)	**8.08** (6.60-9.92)	**9.16** (7.29-11.3)	**10.3** (7.90-13.0)	**11.5** (8.45-14.8)	**13.2** (9.29-17.2)	**14.5** (9.93-19.1)
7-day	**5.02** (4.31-5.88)	**5.63** (4.83-6.60)	**6.69** (5.71-7.85)	**7.60** (6.46-8.96)	**8.93** (7.35-10.8)	**10.0** (8.03-12.2)	**11.1** (8.61-13.8)	**12.3** (9.11-15.6)	**13.9** (9.90-18.0)	**15.2** (10.5-19.9)
10-day	**5.69** (4.91-6.62)	**6.37** (5.49-7.42)	**7.52** (6.46-8.77)	**8.50** (7.26-9.94)	**9.89** (8.18-11.9)	**11.0** (8.87-13.3)	**12.1** (9.44-15.0)	**13.3** (9.92-16.8)	**14.9** (10.7-19.2)	**16.2** (11.3-21.1)
20-day	**7.57** (6.62-8.69)	**8.54** (7.45-9.81)	**10.1** (8.78-11.6)	**11.4** (9.84-13.1)	**13.1** (10.9-15.5)	**14.5** (11.8-17.3)	**15.8** (12.4-19.2)	**17.1** (12.9-21.3)	**18.9** (13.6-24.0)	**20.2** (14.2-26.0)
30-day	**9.16** (8.06-10.4)	**10.3** (9.09-11.8)	**12.2** (10.7-14.0)	**13.8** (12.0-15.8)	**15.8** (13.2-18.4)	**17.3** (14.2-20.4)	**18.8** (14.8-22.6)	**20.2** (15.3-24.9)	**22.0** (16.0-27.8)	**23.4** (16.5-29.9)
45-day	**11.2** (9.93-12.7)	**12.6** (11.2-14.3)	**14.8** (13.1-16.8)	**16.6** (14.5-18.9)	**18.9** (15.9-21.8)	**20.6** (16.9-24.1)	**22.1** (17.6-26.4)	**23.7** (18.0-28.9)	**25.5** (18.6-31.9)	**26.9** (19.1-34.2)
60-day	**13.0** (11.6-14.6)	**14.5** (12.9-16.4)	**17.0** (15.0-19.1)	**18.9** (16.6-21.3)	**21.3** (18.0-24.5)	**23.1** (19.1-26.8)	**24.7** (19.7-29.3)	**26.2** (20.0-31.8)	**28.1** (20.6-34.8)	**29.3** (21.0-37.1)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

The following documents used for estimating runoff were taken from the United States Department of Agriculture 'Urban Hydrology for Small Watersheds' - TR-55

SCS runoff curve number method

The SCS Runoff Curve Number (CN) method is described in detail in NEH-4 (SCS 1985). The SCS runoff equation is

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad \text{[eq. 2-1]}$$

where

- Q = runoff (in)
- P = rainfall (in)
- S = potential maximum retention after runoff begins (in) and
- I_a = initial abstraction (in)

Initial abstraction (I_a) is all losses before runoff begins. It includes water retained in surface depres-sions, water intercepted by vegetation, evaporation, and infiltration. I_a is highly variable but generally is correlated with soil and cover parameters. Through studies of many small agricultural watersheds, I_a was found to be approximated by the following empirical equation:

$$I_a = 0.2S \qquad \text{[eq. 2-2]}$$

By removing I_a as an independent parameter, this approximation allows use of a combination of S and P to produce a unique runoff amount. Substituting equation 2-2 into equation 2-1 gives:

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad \text{[eq. 2-3]}$$

S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by:

$$S = \frac{1000}{CN} - 10 \qquad \text{[eq. 2-4]}$$

Figure 2-1 and table 2-1 solve equations 2-3 and 2-4 for a range of CN's and rainfall.

Factors considered in determining runoff curve numbers

The major factors that determine CN are the hydro-logic soil group (HSG), cover type, treatment, hydro-logic condition, and antecedent runoff condition (ARC). Another factor considered is whether impervious areas outlet directly to the drainage system (connected) or whether the flow spreads over pervious areas before entering the drainage system (unconnected). Figure 2-2 is provided to aid in selecting the appropriate figure or table for determining curve numbers.

CN's in table 2-2 (*a* to *d*) represent average antecedent runoff condition for urban, cultivated agricultural, other agricultural, and arid and semiarid rangeland uses. Table 2-2 assumes impervious areas are directly connected. The following sections explain how to determine CN's and how to modify them for urban conditions.

Hydrologic soil groups

Infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. Soils are classified into four HSG's (A, B, C, and D) according to their minimum infiltration rate, which is obtained for bare soil after prolonged wetting. Appendix A defines the four groups and provides a list of most of the soils in the United States and their group classification. The soils in the area of interest may be identified from a soil survey report, which can be obtained from local SCS offices or soil and water conservation district offices.

Most urban areas are only partially covered by impervious surfaces: the soil remains an important factor in runoff estimates. Urbanization has a greater effect on runoff in watersheds with soils having high infiltration rates (sands and gravels) than in watersheds predominantly of silts and clays, which generally have low infiltration rates.

Any disturbance of a soil profile can significantly change its infiltration characteristics. With urbaniza-tion, native soil profiles may be mixed or removed or fill material from other areas may be introduced. Therefore, a method based on soil texture is given in appendix A for determining the HSG classification for disturbed soils.

Cover description		Curve numbers for hydrologic soil group			
Cover type and hydrologic condition	Average percent impervious area 2/	A	B	C	D
Fully developed urban areas (vegetation established) Open					
space (lawns, parks, golf courses, cemeteries, etc.) 3/:					
Poor condition (grass cover < 50%)		68	79	86	89
Fair condition (grass cover 50% to 75%)		49	69	79	84
Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:					
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:					
Paved; curbs and storm sewers (excluding right-of-way)		98	98	98	98
Paved; open ditches (including right-of-way)		83	89	92	93
Gravel (including right-of-way)		76	85	89	91
Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:					
Natural desert landscaping (pervious areas only) 4/		63	77	85	88
Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)		96	96	96	96
Urban districts:					
Commercial and business	85	89	92	94	95
Industrial	72	81	88	91	93
Residential districts by average lot size:					
1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
2 acres	12	46	65	77	82

Cover description		Curve numbers for hydrologic soil group			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range—continuous forage for grazing.[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	—	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element.[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 [4]	48	65	73
Woods—grass combination (orchard or tree farm).[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods.[6]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 [4]	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

ARMCO Watershed 2

Step 1: Substitute

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

substitute:

$I_a = 0.2S$

$$S = \frac{1000}{CN} - 10$$

Step 2: Substitute

$$Q = \frac{\left(P - 0.2\left(\frac{1000}{CN} - 10\right)\right)^2}{\left(P + 0.8\left(\frac{1000}{CN} - 10\right)\right)}$$

substitute:

CN = 74.6

P = 4.82 in.

Step 3: Solve

$$Q = \frac{\left(4.82 - 0.2\left(\frac{1000}{74.6} - 10\right)\right)^2}{\left(4.82 + 0.8\left(\frac{1000}{74.6} - 10\right)\right)}$$

Q = 2.27 in.

The following document used for estimating runoff was taken from the United States Department of Agriculture 'Urban Hydrology for Small Watersheds' - TR-55

Project ARMCO Site Redevelopment	By TJS	Date 4/25/2017
Location Kansas City, Missouri	Checked SH	Date 4/27/2017

Check one: ☒ Present ☐ Developed

1. Runoff curve number

Soil name and hydrologic group	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Figure 2-3	CN 1/ Figure 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
66010, D	Paved Area	98			1.2	113.7
66010, D	Short Grass	80			9.3	746.4
66010, D	Tall Grass	73			21.8	1,592.9
66010, D	Gravel	50			1.7	83
				Totals	34	2,536

1/ Use only one CN source per line

CN (weighted) = total product / total area = 2,536 / 34 ; 74.6 Use CN 74.6

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ... yr	10		
Rainfall, P (24-hour) ... in	4.82		
Runoff, Q ... in (Use P and CN with table 2-1, figure 2-1, or equations 2-3 and 2-4)	2.77		

Step 4: Extrapolate

$$\text{Total Watershed Runoff} = \frac{Q \times A \text{ (area of watershed)} \times 43{,}560 \text{ sq./ft per acre}}{12 \text{ in.}}$$

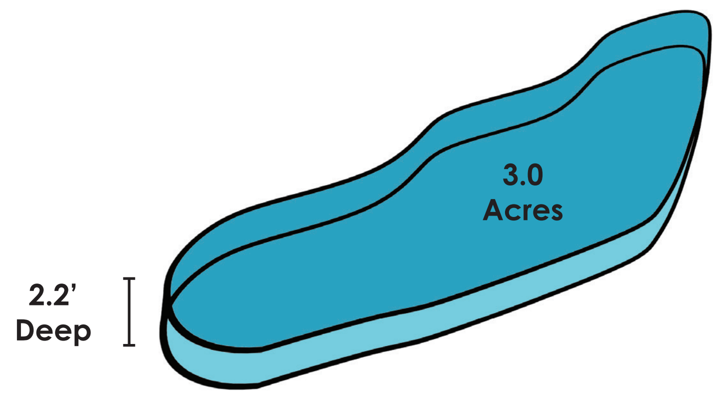
Q = 2.27 in.

A = 34 acres

$$= \frac{2.27 \text{ in.} \times 34 \text{ acres} \times 43{,}560 \text{ sq./ft.}}{12 \text{ in.}}$$

$$\boxed{= 6.43 \text{ acre/ft}}$$

$$\frac{6.43 \text{ acre/ft}}{\boxed{2.2' \text{ deep}}} \boxed{= 3.0 \text{ acre wetland}}$$



ARMCO Watershed 6

Step 1: Substitute

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where

Q = runoff (in)
P = rainfall (in)
S = potential maximum retention after runoff begins (in) and
I_a = initial abstraction (in)

substitute:

$I_a = 0.2S$

$$S = \frac{1000}{CN} - 10$$

Step 2: Substitute

$$Q = \frac{\left(P - 0.2\left(\frac{1000}{CN} - 10\right)\right)^2}{\left(P + 0.8\left(\frac{1000}{CN} - 10\right)\right)}$$

substitute:

CN = 74.6

P = 4.82 in.

Step 3: Solve

$$Q = \frac{\left(4.82 - 0.2\left(\frac{1000}{77.45} - 10\right)\right)^2}{\left(4.82 + 0.8\left(\frac{1000}{77.45} - 10\right)\right)}$$

Q = 2.51 in.

The following document used for estimating runoff was taken from the United States Department of Agriculture 'Urban Hydrology for Small Watersheds' - TR-55

Project: ARMCO Site Redevelopment	By: TJS	Date: 5/22/2017
Location: Kansas City, Missouri	Checked: SH	Date: 5/22/2017

Check one: ☒ Present ☐ Developed

1. Runoff curve number

Soil name and hydrologic group	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN [1/] Table 2-2	CN Figure 2-3	CN Figure 2-4	Area ☒ acres ☐ mi² ☐ %	Product of CN x area
66010, D	Paved Area	98			2.0	196
66010, D	Short Grass	80			8.4	672
66010, D	Tall Grass	73			5.6	408.8
66010, D	Gravel	50			1.0	50
66010, D	Woods	77			23.0	1,771
1/ Use only one CN source per line				Totals ➡	40	3,097.8

CN (weighted) = total product / total area = 3,097.8 / 40 ; 77.45 Use CN ➡ 77.45

2. Runoff

	Storm #1	Storm #2	Storm #3
Frequency ... yr	10		
Rainfall, P (24-hour) ... in	4.82		
Runoff, Q ... in (Use P and CN with table 2-1, figure 2-1, or equations 2-3 and 2-4)	2.77		

Step 4: Extrapolate

$$\text{Total Watershed Runoff} = \frac{Q \times A \text{ (area of watershed)} \times 43{,}560 \text{ sq./ft per acre}}{12 \text{ in.}}$$

Q = 2.51 in.

A = 40 acres

$$= \frac{2.51 \text{ in.} \times 40 \text{ acres} \times 43{,}560 \text{ sq./ft.}}{12 \text{ in.}}$$

$$\boxed{= 8.37 \text{ acre/ft}}$$

$$\frac{8.37 \text{ acre/ft}}{\boxed{\text{depth}}} \boxed{= \text{area}}$$

*Calculations for Watershed 6's holding capacity were intentionally left blank. Watershed 6 was not designed in this cleanup proposal. Further design considerations for the ARMCO Site's remediation capabilities can be modeled using the above equation.