TETRA TECH

January 4, 2018

Mr. Todd Davis
EPA Site Assessment Manager
U.S. Environmental Protection Agency, Region 7
11201 Renner Boulevard
Lenexa, Kansas 66219

Subject: Green Infrastructure and Habitat Restoration Plan
Kansas City Municipal Farms Site, Kansas City, Missouri
U.S. EPA Region 7, START 4, Contract No. EP-S7-13-06, Task Order No. 0167
Task Monitor: Todd Davis, EPA Site Assessment Manager

Dear Mr. Davis:

Tetra Tech, Inc. (Tetra Tech) is submitting the attached Green Infrastructure and Habitat Restoration Plan report regarding the Kansas City Municipal Farms in Kansas City, Missouri. This report provides an optimal course of action for developing green infrastructure and habitat restoration plans for the site.

If you have any questions or comments, please contact the Project Manager at (816) 412-1745.

Sincerely,

Kirk Mammoliti
START Project Manager

Ted Faile, PG, CHMM
START Program Manager

Enclosures

cc: Debra Dorsey, START Project Officer (cover letter only)

X9025.17.0167.000

415 Oak Street, Kansas City, MO 64106
Tel 816.412.1741 Fax 816.410.1748 www.tetratech.com

GREEN INFRASTRUCTURE AND HABITAT RESTORATION PLAN

KANSAS CITY MUNICIPAL FARMS SITE, KANSAS CITY, MISSOURI

Superfund Technical Assessment and Response Team (START) 4 Contract

Contract No. EP-S7-13-06, Task Order No. 0167.000

Prepared For:

U.S. Environmental Protection Agency
Region 7
11201 Renner Boulevard
Lenexa, Kansas 66219

January 4, 2018

Prepared By:

Tetra Tech, Inc.
415 Oak Street
Kansas City, Missouri 64106
(816) 412-1741

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) tasked Tetra Tech Inc. (Tetra Tech) to conduct planning for green infrastructure and habitat restoration at the Municipal Farms site (the site). The site is within an urban area in Kansas City, Missouri, with surrounding property use a mixture of residential, commercial, and industrial. An approximately 1,536-acre sub-watershed drains to the Municipal Farms property. Water on the site eventually flows to the Blue River, which runs along the western and northern boundaries of the site. Some water flows through Round Grove Creek before reaching the Blue River, while other water flows through unnamed surface waters on the site.

The site is currently in the EPA Brownfields program, with the City of Kansas City (City) considering several conceptual plans for redevelopment of the property. The site has undergone a wide range of historical uses, ranging from agriculture to police bomb disposal and prisons. Multiple facilities currently operate at the site, including a National Guard facility, city public works facilities, a police firing range and bomb disposal area, an animal shelter, and a radio tower area. Also, large portions of the site are currently inactive. The City is planning for redevelopment of the property, with multiple possible end uses. Several conceptual designs for the site have been completed, with recommended end uses ranging from residential and commercial development to urban agriculture and outdoor recreation/education. The current redevelopment plan for the site focuses primarily on urban agriculture and outdoor recreation/education, but is subject to change.

Given the wide-ranging historical and current uses of the site, several environmental investigations have been completed. These investigations have included detailed desktop review of available data in the form of an area-wide Brownfields plan similar in scope to a Phase I Environmental Site Assessment (ESA), as well as acquisition of field data during several Phase II ESAs.

Review of Existing Information

Tetra Tech initiated the green infrastructure and habitat restoration process by compiling and reviewing available historical data and possible redevelopment plans. Based on conversations with EPA and the City during this process, it was determined that no central location currently housed all relevant project data and plans. This was identified as a key need for the project moving forward so that all stakeholders would have all relevant project information readily available to inform planning, and to aid establishment of a consensus understanding of the status of the site. Tetra Tech compiled all available project analytical data into a secure database system, and created an interactive web mapping application to display project data, including previous conceptual designs. The web mapping application is housed on the project's EPA webpage, and can be accessed by any project stakeholders granted access by EPA.

After compiling relevant project data, Tetra Tech performed a limited review of available analytical data from previous site investigations to identify areas hosting contamination that could impact future planning and redevelopment, including planning for green infrastructure and habitat restoration. Tetra Tech identified two primary areas of concern based on existing data: (1) arsenic contamination in surface soil at the former LaFarge Concrete Batch Plant; and (2) pesticide contamination in surface soil at the former Health Emergency Hazmat Site (HEHS). Consideration of these areas of contamination is important for green infrastructure and habitat planning to avoid spread of contamination to new locations, and potential exposure of new receptors to contamination.

Hydrologic and Hydraulic Modeling

After completing the compilation and review of available site data, Tetra Tech created a hydrologic and hydraulic (H&H) model to analyze stormwater and surface water conditions at the site. Tetra Tech developed the model using PCSWMM 2017 software developed by Computational Hydraulics International (CHI). PCSWMM provides a user interface based on a geographic information system (GIS), and integrates seamlessly with the EPA Storm Water Management Model (SWMM5) engine. It allows for integration of H&H modeling into a single model, so that runoff and overland flow conditions and in-stream surface water conditions can be analyzed concurrently. Tetra Tech referenced results of the H&H models and the evaluation of available data to create conceptual habitat and green infrastructure plans for the site.

Habitat Restoration Planning

To create the habitat restoration plan, Tetra Tech performed a desktop review of available information, including soil types, wetland locations, and flood plains. This desktop review was combined with results of historical data compilation and H&H modeling to create a recommended habitat restoration plan for the site. The habitat plan offers recommendations for restoration of the following habitat areas at the site (with expected consideration of site-specific conditions as redevelopment plans are finalized): bottomland woodland, riparian/wetland and open water areas, wet-mesic prairie, early successional habitat, upland savannah and woodlands, ravines, native plantings on the former landfill, the former Botsford mine area, no work zones, and developed and recreation areas. The habitat restoration plan also suggests restoration methods, as well as potential native plant and seed mixes for specific habitat areas.

Green Infrastructure Planning

Tetra Tech also used results of historical data compilation and H&H modeling to create a conceptual green infrastructure plan for the site. Because future redevelopment plans for the site have not been finalized, the green infrastructure plan provides broad guiding concepts for implementation of green infrastructure at the site. This includes a review of green infrastructure technology that could be implemented at the site, and recommendations for best practices that can be implemented during redevelopment activities.

Based on available data regarding the site, the green infrastructure plan also determined that the West Subarea appears well-suited for a stormwater capture and reuse system, with captured runoff used for irrigation at future urban agriculture facilities. Tetra Tech outlined two possible methods for implementing a capture and reuse system in this area: (1) a naturalized approach that uses existing drainage channels for capture and conveyance, and uses existing ponds as storage nodes; and (2) a traditional gray infrastructure capture, conveyance, and storage system, which would depend highly on the layout of final redevelopment plans for further evaluation and design. The green infrastructure plan also identifies several subwatersheds on the site that should be targeted for green infrastructure based on volume of runoff they generate per unit area. Finally, the green infrastructure plan identified four high-priority areas that should be targeted for filtering and infiltrative technologies, based on three characteristics: (1) high proportion of impervious surfaces, (2) proximity to potentially sensitive surface waters, and (3) potential for runoff to have elevated levels of suspended solids and pollutants. The four high-priority areas are: (1) areas surrounding the former LaFarge Concrete Batch Plant, (2) the area between the City Services Facility and existing surface waters, (3) the area between the Animal Shelter and Round Grove Creek, and (4) areas north and east of the National Guard Facility.

Recommended Next Steps

Throughout the data compilation, modeling, and planning process, Tetra Tech identified key data gaps that should be filled as the redevelopment process progresses. These data gaps are listed below. Recommendations are offered for additional environmental investigations to ensure safety of future site users and success of habitat restoration and implementation of green infrastructure. Recommendations are also to acquire key datasets as habitat restoration and the green infrastructure planning process transition from planning to design, in order to update existing H&H models and refine both habitat restoration and green infrastructure plans.

DATA GAPS AND RECOMMENDATIONS	
Environmental Investigation Data Gaps	**Green Infrastructure and Habitat Planning Recommendations**
1. pH Levels at the LaFarge Concrete Batch Plant Site 2. Unexploded Ordinance (UXO) at the Kansas City Police Department (KCPD) Bomb Detonation Area 3. Former Botsford Mine Area Stability 4. Former Building Sites 5. Pesticide Contamination at the HEHS Site 6. Gasoline/Diesel Generators Throughout the Site 7. Comprehensive Contamination Screening	1. Acquisition of Bathymetric Survey Data from Major Waterbodies 2. Culvert Invert Elevations 3. Details on the Stormwater Sewer System in the Contributing Watershed 4. Acquisition of Calibration Data 5. Development of Site Water Balance 6. Wetland Delineation 7. Shoreline Survey and Sediment Sampling of Open Water Areas 8. Vegetation Survey 9. Existing Trail Survey

1.0 INTRODUCTION

The Tetra Tech, Inc. (Tetra Tech) Superfund Technical Assessment and Response Team (START) was tasked by the U.S. Environmental Protection Agency (EPA) Region 7 Superfund Division to prepare a green infrastructure and habitat restoration plan for the Kansas City Municipal Farms site (the site) in Kansas City, Jackson County, Missouri. The City of Kansas City, Missouri (City) requested planning assistance under the Targeted Brownfields Assessment (TBA) program. Specifically, the City requested assistance in developing plans for incorporation of green infrastructure and habitat restoration into site redevelopment plans.

Tetra Tech determined an optimal course of action for developing green infrastructure and habitat restoration plans for the site. This course of action included four primary elements: (1) attain thorough understanding of available information related to the site; (2) develop a site-specific hydrologic and hydraulic (H&H) model to guide spatial distribution of green infrastructure and habitat restoration elements; (3) develop plans for green infrastructure and habitat restoration in lockstep, as these share several design considerations; and (4) offer recommendations for next steps to refine and further develop the plans. Tetra Tech's project approach sought to accomplish each primary element in a manner that would maximize value for EPA, and allow easy dissemination of information to key project stakeholders.

This green infrastructure and habitat restoration plan describes planning background, presents methodology, and addresses results. Section 2.0 describes the site and recounts its history; Section 3.0 presents Tetra Tech's review of existing data; Section 4.0 describes development of the site-specific H&H model used as a primary planning tool, as well as outputs and results from application of the model; Section 5.0 summarizes green infrastructure alternatives and recommendations for the site; Section 6.0 summarizes habitat restoration options for the site; and Section 7.0 offers recommendations for next steps to further development of green infrastructure and habitat restoration plans, and to continue progress toward general redevelopment of the site. References cited are listed in Section 8.0. Selected figures are in Appendix A; selected tables are in Appendix B.

2.0 SITE DESCRIPTION AND HISTORY

The Municipal Farms site is in the Eastwood Hills neighborhood of Kansas City, Jackson County, Missouri. The site encompasses approximately 441 acres, and is divided by interstate highway I-435 into the East Subarea and West Subarea (see Appendix A, Figure A-1). Surrounding property uses are a mixture of residential, industrial, and commercial. The East Subarea is surrounded by Raytown Road and Eastern Avenue, with industrial facilities and the Kansas City Chiefs and Kansas City Royals stadium complex beyond to the north, Raytown Road and Ozarks road with multi-tenant residential facilities and vacant land beyond to the east, Ozark Road with residential and commercial properties beyond to the south, and Eastern Avenue with I-435 beyond to the west. The West Subarea is surrounded by East Coal Mine Road, with the Blue River and a large industrial complex beyond to the north, a KCS railroad line with I-435 beyond to the east, a KCS railroad line with residential properties beyond to the south, and East Coal Mine Road with the Blue River beyond to the west. The Blue River is approximately 150 feet from the site at minimum separation, and runs from southwest to northeast along the western and northern boundary of the site. Surface waters from several portions of the site discharge directly to the Blue River via culverts. Round Grove Creek passes through the East Subarea, running generally from southeast to northwest, and discharges to the Blue River just north of the site.

The City began acquiring the land that comprises the site in 1907, and continued its land holding through the 1950s. The original farm consisted of approximately 252 acres. Part of the site is currently used, with several tenants and land uses as follows:

- **Kansas City Department of Public Works:** Mixed use facility houses an office building, as well as staging and storage for construction materials, debris, and equipment.
- **KCCV Radio Broadcast Tower:** Occupies a large field with a small office, four radio broadcast towers, and high-voltage equipment. Within most of the field, wiring has been installed approximately 6 inches below ground surface (bgs) to facilitate radio transmission.
- **Kansas City Police Department (KCPD) Firing Range:** Occupies northern-most section of the West Subarea. Currently operational firing range.
- **KCPD Bomb Disposal Facility:** Adjacent to and south of the firing range, across East Coal Mine Road. During past investigation activities, START personnel have observed unexploded ordinance (UXO) on the grounds.
- **Round Grove Pumping Station:** Provides pumping capacity to limit combined-sewer overflows along Round Grove Creek.
- **KCPD Patrol Support Unit:** Includes a helicopter hangar and landing pad, as well as canine unit training facility.

- **Kansas City Pet Project Adoption Center:** Active pet shelter and adoption facility.
- **Missouri National Guard Armory Facility:** Active national guard armory with large storage and office facilities.

Based on discussions with the City, START understands that several of these facilities may be moving from the site in the relatively near future, which would both open additional land for redevelopment and eliminate land uses with potential to cause contamination issues. However, these changes to site uses have not been formally confirmed, and were not considered for the current iteration of the green infrastructure and habitat restoration plan.

In addition to current site uses cited above, the site has a long history of numerous and highly varied historical land uses. Tetra Tech gathered information on both current and historical site uses from a previously prepared Area-Wide Brownfields Plan (EAE 2012). Section 2.0 of this report provides a comprehensive table and maps summarizing present and past land uses. Key past land uses from a green infrastructure and habitat restoration planning perspective include:

- Pesticide manufacturing facility
- Abandoned mine
- Batch concrete plant
- Tuberculosis hospital
- Correctional facilities
- Municipal cemeteries
- Health Emergency Hazmat Site (HEHS) (hazardous materials storage site)
- Round Grove Creek Landfill
- Canning factory
- Agricultural areas

Visual representations of current and past land uses on the West and East Subareas are presented in Appendix A in Figures A-2 and A-3, respectively. For additional details on current and past land uses, refer to the Area-Wide Brownfields Plan.

Since the City began efforts to redevelop the site, several projects have been undertaken in addition to the Area-Wide Brownfields plan, including three Phase II Environmental Site Assessments (ESA) under the Targeted Brownfields Assessment (TBA) program, with a fourth ongoing during 2017. Phase II ESAs have occurred at the LaFarge Concrete Batch Plant area, the Municipal Correctional Institute area, the Animal Shelter Area, and the former pesticide manufacturing area/hazardous material storage area. These assessments are discussed in more detail in Section 3.0. The City also completed or obtained results from several planning projects intended to define anticipated future uses and layouts of the site. These planning projects included a Sustainable Reuse Plan/Conceptual Land Use Plan developed by a design consortium led by BNIM (BNIM 2012); the Sustainable Cities Design Academy (SCDA, which is part of the American Architectural Foundation) (SCDA 2015) plan; and a USACE Section 206 Preliminary Habitat Restoration Plan for the western portion of the site (USACE plan) (USACE 2015) that was developed for the West Subarea, but was never funded for implementation.

Currently, the City continues to work with stakeholders and prospective tenants to identify, evaluate, and plan for various future land uses at the site. Based on conversations with the City, Tetra Tech understands that the SCDA plan is considered the most current redevelopment plan for the site, but is considered a rough guide rather than an implementable plan. As a result, future uses of the site may change, subject to results of future site assessments, funding availability, stakeholder input, and views of interested tenants.

3.0 REVIEW OF EXISTING INFORMATION

Tetra Tech initiated development of the green infrastructure and habitat restoration plan by seeking thorough understanding of available information regarding the site. Tetra Tech's review focused on (1) reviewing the narrative history of the site and current site conditions conveyed in various historical documents; (2) reviewing conclusions of past planning efforts for the site; (3) gathering site-specific data, namely analytical results from past sampling efforts; and (4) analyzing existing sampling data to anticipate effects of contaminant levels on potential green infrastructure and habitat restoration planning.

3.1 REVIEW OF HISTORICAL DOCUMENTS

Tetra Tech began its review of existing information by reviewing several documents provided by EPA and the City describing site history and current conditions. These documents included the Area-Wide Brownfields Plan, the Animal Shelter Phase II ESA Report (Tetra Tech 2013a), the LaFarge Concrete Batch Plant Phase II ESA Report (Tetra Tech 2013b), the Municipal Correctional Institute (MCI) Phase II ESA Report (Tetra Tech 2013c), the Underground Development Assessment of the Botsford Property (Woodward-Clyde 1984), and the Botsford Mine Bat Survey Memo (Missouri Department of Conservation 2015).

The Area-Wide Brownfields Plan includes a comprehensive, planning-level investigation into past and current uses of the site. It identifies specific portions of the site most likely to be contaminated based on land use, and attempts to detail types of contaminants most likely to pose issues within various sections of the site. This document is highly useful for gaining a thorough understanding of the site history, but is similar to a Phase I ESA in that it bases its findings solely on historical research, rather than acquisition of physical data.

Guided by findings of the Area-Wide Brownfields Plan, the City and EPA have completed Phase II ESAs in three areas of the site, and sampling in a fourth area of the site during summer 2017. Tetra Tech reviewed the findings of these reports to identify any major concerns or evidence of serious contamination. A more detailed analysis of analytical data generated during these Phase II ESAs appears in Section 3.4.

Tetra Tech also reviewed two documents related to the condition of the Botsford mine within the western-most portion of the west side of the site. The geotechnical assessment by Woodward-Clyde Consultants (1984) identified structural issues with the abandoned mine that preclude most future development options. The structural issues include evidence of unstable roof structures—sink holes, support columns within the mine that did not meet the criteria to support the roof in a structurally stable manner, and flooding of large portions of the mine that could render attempts to stabilize the structure of the mine prohibitively expensive. Based on conversations with the City, Tetra Tech also understands that since the mine was abandoned, it has become an active hibernacula site for multiple species of bats. The City provided Tetra Tech with a memo prepared by the Missouri Department of Conservation (MDC) that documents a bat population survey on December 22, 2015 (during the hibernation season). During this single-day survey, MDC documented 2,399 tri-colored bats (*Perimyotis subflavus*) and 298 big brown bats (*Eptesicus fuscus*). These survey results indicate that the on-site Botsford mine may host the largest single hibernacula for tri-colored bats in the State of Missouri. The survey memo also documents presence of white-nose syndrome, caused by the fungus *Pseudogymnoascus destructans,* in the mine system. During the 2015 survey, MDC observed at least 25 tri-colored bats with visual evidence of white-nose syndrome. Both the size of the bat population that hibernates within the mine and documented presence of white-nose syndrome indicate that the mine acts as a valuable but fragile habitat site. Use of the mine as a hibernacula, in concert with the mine's documented structural issues, indicate that the mine would be best utilized in the future as a protected habitat site for tri-colored bats. The area surrounding the mine (and on top of the mine) could also be targeted for bat-specific habitat restoration.

3.2 REVIEW OF PAST PLANNING EFFORTS

In addition to the documents discussed above, which provided information on past and present conditions at the site, Tetra Tech also reviewed several planning documents that describe potential future uses of the site. The City provided Tetra Tech with several past planning documents, including the Municipal Farm Sustainable Reuse Plan (including the Conceptual Land Use Plan) (BNIM 2012), the SCDA plan (SCDA 2015), and the USACE plan (USACE 2015). In addition to these plans, specifically intended to evaluate future land uses at the site, Tetra Tech also reviewed planning documents with less formal intent, including the 2016 Heartland Conservation Alliance Natural Resource Damage Groundwater Restoration grant application, and the East Side Municipal Farms Evaluation (City undated). A brief summary of key takeaways from each of these planning documents is provided below.

3.2.1 Municipal Farm Sustainable Reuse Plan

The Sustainable Reuse Plan includes a Conceptual Land Use Plan (CLUP) that lays out recommended future uses for the entire Municipal Farms site. The CLUP divides the site into 21 subareas, recounts historical land uses, recommends future land use within each subarea, and describes potential environmental issues. Recommended land uses include habitat restoration, residential development, green industrial development, commercial development, agricultural development, and green energy implementation. Tetra Tech evaluated each recommended land use, and identified potential issues that could hinder implementation of these intended land uses. Importantly, while the CLUP provides a useful large-scale accounting of assets of the site and a context for sustainable and comprehensive redevelopment of the site, the plan is conceptual. The CLUP's recommendations are not always realistic or technically sound based on site constraints identified in other reviewed documents. For example, the CLUP recommends residential or commercial development on the land directly above the abandoned Botsford mine, which is known to have structural stability issues. Based on conversations with the City, Tetra Tech understands that the CLUP represents one of several plans for the site, and is not intended to be implementable or a final plan. As a result, Tetra Tech drew from the CLUP general guiding principles for identifying areas attractive for redevelopment, and areas possibly best suited for habitat restoration due to their limited utility for redevelopment.

3.2.2 SCDA Plan

The SCDA plan was the result of a short-term, intensive evaluation of the Municipal Farms site. Similar to the CLUP, the SCDA plan divides the site into subareas and recommends future uses for each subarea. The SCDA divides the site into 24 subareas, with 14 subareas in the West Subarea of the site, and 10 subareas in the East Subarea. The SCDA plan abandons some of the large-scale residential and commercial development envisioned in the CLUP, and focuses on a mixture of environmentally friendly land uses in a park-like setting. These proposed land uses include substantial agricultural practices, habitat restoration, outdoor recreation, an outdoor classroom, a restaurant, and multiple green-energy usages, including solar and wind energy. Based on conversations with the City, Tetra Tech understands that the SCDA plan, although conceptual, is considered the most current plan for the site. The SCDA plan's approach to site redevelopment considers past land uses and possible hindrances of these to redevelopment. The SCDA plan also attempts to minimize large-scale conversions of natural areas to developed areas. As a result, on the whole it is environmentally friendly and encourages future use of the site for agriculture/produce, outdoor recreation, and environmental education.

3.2.3 USACE Plan

The USACE plan focuses primarily on possible habitat restoration actions in the West Subarea. The plan was developed as part of a habitat restoration assessment of the confluence of the Blue River and Brush Creek. The site was identified as a primary component of this larger habitat restoration plan for several reasons, including its proximity to the Blue River, Brush Creek, and Round Grove Creek; its underutilized open spaces; and existing waterbodies in need of restoration. The USACE plan is a fine-resolution plan for habitat restoration that focuses on the eastern portion of the West Subarea, and divides this portion into 23 subareas. The plan indicates where specific habitat types would be best suited for restoration, and designates areas for agriculture, an outdoor classroom, and implementation of green infrastructure. The

USACE plan has not obtained the necessary funding to move forward into engineering and implementation project phases. Although funding of the USACE plan is not expected (according to the City), it can serve as a useful starting point for planning habitat restoration and land use in the West Subarea.

3.2.4 2016 Heartland Conservation Alliance Natural Resource Damage Groundwater Restoration

The City acquired funding for the "Heartland Conservation Alliance (HCA) plan" entailing habitat restoration work in the West Subarea with the goal of restoring groundwater quality; this funding came via successful application for the 2016 Natural Resource Damage Groundwater Restoration grant (HCA 2016). The project involves selective implementation of portions of the USACE plan. The HCA plan addresses a 15- to 18-acre area in the West Subarea that includes significant areas of direct groundwater-surface water interface, particularly in existing wetlands; the plan envisions use of quality native habitat and vegetative communities to restore groundwater at the site. Habitat types to be restored include shallow marsh, riparian buffer, scrub-shrub wetland, and bottomland hardwood forest. Implementation of the HCA plan began in the summer of 2017, with a focus on removing invasive plant species from the project area. The project will continue in 2018 and 2019, with seeding and planting of native species to improve habitat quality, and ongoing maintenance to prevent reestablishment of invasive species. Because the HCA plan has been funded and implementation is under way, it is considered a final plan for habitat restoration within the portion of the site that it covers. This renders it highly useful as a basis for habitat restoration planning in the remaining areas of the West Subarea.

3.2.5 East Side Municipal Farms Evaluation

The East Side Municipal Farms evaluation is an informal, internal document generated by an employee of the City after conducting a limited visual assessment of the East Subarea. The purpose of the assessment was to evaluate current conditions in the East Subarea, and to gather information on topography, vegetation density, and soil to aid in identifying potential future land uses. The assessment focused on agricultural and recreational future land uses, and identified seven zones within the East Subarea differentiated by current conditions and potential future land uses. Recommended land uses include several styles of agricultural development, outdoor recreation (including hiking and mountain biking), and outdoor education. The evaluation describes each of the seven zones, but does not include a map with clear demarcation of the boundaries of each zone.

3.3 DATA AND PLAN CONSOLIDATION

Based on the review of historical documents and prior planning efforts described above, as well as conversations with the City, it became apparent that different stakeholders had different understandings of the most current plan for future land use, and a comprehensive accounting of past sampling efforts at the site did not exist. Therefore, the City suggested that establishing a central clearinghouse for project-related data and information would be an especially helpful subtask of the green infrastructure and habitat restoration planning project—given that consideration of historical data and future site plans is essential to develop a useful green infrastructure and habitat restoration plan. This subtask was included in the project's scope of work.

Based on the types of site data available, Tetra Tech determined that an interactive web map would be an ideal end product of the data consolidation task. An interactive web map would allow multiple stakeholders to access and review key site information, EPA to maintain security and access control of the data, and users to interact with and analyze useful datasets. Development of the interactive web map was accomplished via the three-step process described as follows:

3.3.1 Identification of Useful Datasets

The first step in development of the web map was to determine which datasets should be included on the map, namely datasets that could significantly affect future development plans for the site. Tetra Tech reviewed numerous data sources in addition to the historical and planning documents cited above, including the KCMO Open Data Portal, H&H modeling information from the Federal Emergency Management Agency (FEMA) and the City, and wetlands and watershed information from multiple sources. After reviewing and compiling data sources, Tetra Tech identified for inclusion on the web map six data categories especially useful for future site plans. Table 1 below lists these six data categories, primary sources referenced for each category, and data layers identified for inclusion in the web map.

TABLE 1

DATA CATEGORIES AND LAYERS FOR INTERACTIVE WEB MAP

Data Category	Primary Data Source	Data Layer(s) to Include
City Information	KCMO Open Data Portal	Rivers and Lakes
		Parks
		Neighborhood Organizations
		Land Use Planning Areas
		Area Plan Boundaries
		City Limits
		County Boundary
		Annexation Areas
		Watershed Boundaries
		Zoning
Cadastral Information	KCMO Open Data Portal	Utility Easements
		Sewer Easements
		Water Easements
		Parcels
		PLSS Sections
H&H Modeling	Provided by City	FEMA Model Flow Change Locations
		FEMA Model Cross Sections
		FEMA Model River Line
		FEMA Base Flood Elevations
		Stream Reaches Modeled
		Subwatersheds
		Land Use/Land Cover
Proposed Designs	Provided by City	Conceptual Land Use Plan
		SCDA Plan
		USACE Section 206 Plan
Wetlands Information	Various	National Wetlands Inventory
		HUC 8 Watershed Boundaries
		HUC 8 Watershed Wetland Boundaries
		Blue River Wetland Restoration Suitability Index
Sampling Information	Phase II ESA Reports	Sample Locations

Notes:

ESA Environmental Site Assessment
FEMA Federal Emergency Management Agency
H&H Hydrologic and hydraulic
HUC 8 Eight digit hydrologic unit code
KCMO Kansas City, Missouri
PLSS Public Land Survey System
SCDA Sustainable Cities Design Academy
USACE U.S. Army Corps of Engineers

Summaries of the utility of each data category and key data layers are as follows:

- **City Information:** Information about key city assets (including nearby parks) useful for planning trail connections. Also information on planning areas and organizations, allowing quick identification of key stakeholder groups.

- **Cadastral Information:** Practical legal, zoning, and related information that could significantly affect implementation of redevelopment plans. Key data layers include parcel information that would facilitate identification of key legal information about areas of the site; and easement locations, permitting site planners to avoid or account for impacts on existing utilities.

- **H&H Modeling:** Provides key information on existing FEMA and City models. The land use/land cover data layer provides useful information on existing land uses and generalized habitat types.

- **Proposed Designs:** The three major existing proposed designs for the site. This dataset allows easy comparisons among the plans, and integrated assessment of existing plans with other key information, such as sampling results, utility locations, and existing land uses.

- **Wetlands Information:** General background information on likely locations of wetlands on the site. This information is important for many aspects of planning for future site usage. Redevelopment plans should avoid impacts on existing wetlands to preclude permitting issues and potential need to account for impacts via mitigation. Current wetland locations can also guide habitat restoration and green infrastructure planning, as wetlands are valuable habitat that already perform many tasks typically performed by green infrastructure, including water storage, water quality improvement, and a location for settlement of excess suspended solids from the water column via deposition.

- **Comprehensive Sampling Information:** This is crucial for redevelopment of Brownfields properties. Compiling all available sampling data in one display allows quick visual assessment of geospatial resolution and coverage of the data. Locations of exceedances of relevant risk screening levels can be quickly pinpointed to identify areas that may need remediation, and to selectively guide land use planning to avoid siting sensitive land uses at contaminated locations.

In addition to these primary data categories, Tetra Tech created two site-specific data layers and included these on the web map. These data layers consist of (1) the boundary and key features of the abandoned Botsford Mine, based on the 1984 geotechnical assessment of the mine; and (2) the overall project area boundary.

3.3.2 Data Preparation and Management

After identifying the data layers for inclusion on the interactive web map, it was necessary to organize and prepare the data for display on the web map. The level of effort required for this task varied by original data source for each data layer. The process for preparing each major data category was as follows:

- **City Information:** All data layers included in the City Information data category were originally housed on the KCMO Open Data Portal. Tetra Tech accessed the data on the portal, downloaded those data, and implemented a project-specific geodatabase to allow for customized organization of the data layers. This dataset required minimal effort and reorganization for inclusion on the web map.

- **Cadastral Information:** Similar to the City Information data category, data layers included in the Cadastral Information data category were downloaded directly from the KCMO Open Data Portal. Tetra Tech then incorporated the data into the project-specific geodatabase for customized organization and display. This dataset required minimal effort and reorganization for inclusion on the web map.

- **H&H Modeling:** Most data layers included in the H&H Modeling data category were provided by the City in Geographic Information System (GIS) shapefile format. These data layers were included in the project-specific geodatabase. The land use/land cover dataset was obtained from the Mid-America Regional Council's (MARC) data portal. These data were originally stored in raster format. Tetra Tech determined that a polygon data format would be more useful for the project because (1) smaller file size would reduce loading/processing time for the web map, (2) polygon format would allow the user to interact with specific areas of the data by clicking and viewing information specific to that location, and (3) polygon format would allow spatial analysis and calculations important to the H&H modeling portion of the project. Tetra Tech converted the original raster format to a polygon format using GIS software, and included the resulting layer in the project-specific database. This dataset, including the MARC dataset conversion, did not require extensive effort for inclusion on the web map.

- **Proposed Designs:** No geospatial data were available for any of the three proposed designs included on the web map. To create geospatial data for each design, Tetra Tech georeferenced images of the designs, and created polygon data layers to represent each design area. Descriptions of each area's intended land use were included in geospatial data. For the CLUP, a brief summary of technical issues that could prevent implementation of the recommended land use were also included. Once the geospatial data were completely populated, those data were included in the site-specific geodatabase. Development of geospatial datasets for designs proposed for inclusion on the web map required a moderate amount of effort because of need to create new datasets based on georeferenced images.

- **Wetlands Information:** Data layers related to wetland locations were compiled from several sources. Locations of wetlands included in the National Wetlands Inventory were downloaded directly from the U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI) Mapper website (USFWS 2017). This data layer includes information on spatial extents and types of wetlands on or near the site, and provides a good starting point for evaluating impacts on wetlands from redevelopment of the site. This dataset includes additional information on the original source of information that led to inclusion of specific areas in the NWI. Eventually, this dataset should be supplemented with a site-specific wetland delineation. Tetra Tech also included the Blue River Wetland Restoration Suitability Index data layer, produced by the U.S. Geological Survey (USGS) (USGS 2012). This layer was developed to identify locations along the Blue River with appropriate characteristics for wetland restoration, considering criteria such as inundation, slope, and soil type. The raster dataset was clipped to the portion of the Blue River near the site, and included in the project-specific geodatabase.

- **Sampling Information:** Sampling data and analytical results from past site investigations were widely scattered, and no comprehensive database of sampling results existed for the site. Tetra Tech evaluated the types of available data to determine the best methodology for consolidating and easily integrating analytical and spatial data into a single database. Based on this evaluation, Tetra Tech decided to use EPA's Scribe database system. Scribe is built on a Microsoft Access database platform, and has been specifically tailored to integrate sampling information, analytical data, and geospatial data. It also has an established data architecture for integration with interactive web maps via Scribe.net. This data architecture allows management of Scribe databases by a single user, but publication to Scribe.net, where any users with project-specific login information can subscribe to the database to view and download data, without ability to manipulate the source data. Data from Scribe.net can also be directly published to the EPA Environmental Sciences Research Institute (ESRI) Geoplatform, which houses the project-specific interactive web map.

After determining that a Scribe database would house site data, Tetra Tech gathered all available sampling data pertaining to the site. Data were obtained from multiple sources, and were stored in multiple formats, including PDF laboratory reports and electronic data deliverables. Specific data fields and formats are required for accurate data upload to a Scribe database. For data in PDF format, Tetra Tech transferred the data into a comma-separated value (CSV) format with the required format for upload to Scribe. For data in electronic data deliverable format, Tetra Tech performed the necessary manipulations to format the data for upload to Scribe. Once analytical data were correctly formatted, those data were uploaded to Scribe. Sampling information (including geospatial sample locations) was also obtained from numerous sources, including GIS shapefiles and PDF maps indicating sample locations. If only PDF maps were available, Tetra Tech georeferenced the map images and created geospatial data layers. Sampling information was manipulated to proper format and uploaded to Scribe. Once all relevant sampling and analytical data were successfully housed in a Scribe database, the database was published to Scribe.net and included on the interactive web map.

3.4 EVALUATION OF EXISTING SAMPLING DATA

After compiling all relevant sampling information, Tetra Tech performed a detailed review of analytical results. Compilation of data into a single comprehensive database facilitated this process by providing a uniform data format, and correlating analytical data with geospatial data. Uniform data formatting allowed Tetra Tech to use automated scripts to perform basic data analysis. Correlation of analytical and geospatial data allowed quick and easy display of sample locations, as well as isolation of specific subsets of samples to analyze relationships between analytical results and spatial distributions.

3.4.1 Purpose of Data Evaluation

Thorough understanding of contamination issues at a site is crucial for developing green infrastructure and habitat restoration plans. This understanding is especially important at a site like Municipal Farms that has undergone a wide array of historical land uses, including uses that frequently have resulted in contamination at the site.

Two primary characteristics of green infrastructure constructed within an area hosting soil contamination that could spread contamination are: (1) a large portion of green infrastructure technologies rely on and promote infiltration of surface runoff to groundwater, and (2) green infrastructure systems often include capture and reuse of surface runoff. As captured runoff infiltrates through soil, it can transport contamination to groundwater. Contaminants can typically move more freely via groundwater than via soil, which can spread contamination to locations previously not impacted. Green infrastructure systems that include capture and reuse of runoff can also inadvertently spread contamination or expose new receptors if implemented within an area hosting existing contamination. In this case, surface runoff that travels through contaminated areas can transport contamination via overland flow, until reaching a collection point. If the captured runoff is then used for irrigation without any treatment, the contaminants can be spread, and new receptors can be exposed to contaminants via multiple exposure pathways, including direct contact and consumption via produce irrigated with contaminated water.

From a habitat restoration perspective, it is important to understand contamination conditions to avoid exposing biological communities to potentially toxic conditions. Successful habitat restorations should take into account not only physical characteristics of the intended habitat, but also biochemical conditions that best support organisms dwelling in that habitat. Special care should be taken to avoid creating habitats apparently beneficial from a visual standpoint (for example, a wetland with an appropriate hydrologic regime and widespread vegetation), but harmful to organisms due to contamination. This circumstance is typically referred to as an attractive nuisance issue, whereby organisms are attracted by physical characteristics of a habitat, but harmed by contaminants there. This situation can result in cascading effects throughout the ecosystem due to bioaccumulation and biomagnification.

Understanding contaminant levels is important for other practical reasons. Two of the most common practical tasks in redeveloping a Brownfields site are evaluating health risks to site workers and future users, and properly characterizing material removed from the site for disposal. Sampling data acquired in the past at the Municipal Farms site can be utilized for both of these purposes, thus further necessitating compilation of site data into a secure, comprehensive database as a priority for this project.

3.4.2 Preliminary Review of Past Sampling Effort and Spatial Dispersion

Tetra Tech’s evaluation of available sampling data first focused on understanding the total amount of sampling at the site to date. Figure A-4 in Appendix A shows locations of all known samples collected and analyzed for chemical contamination—92 investigative samples collected at 68 discrete sampling locations from various media, including soil, sediment, surface water, and groundwater. As shown on Figure A-4, sampling completed to date has occurred within relatively limited areas of the site, clustered where Phase II ESAs have been completed.

The southeastern corner of the East Subarea has undergone relatively widespread sampling during past investigations to support the existing community garden and potential greenhouse installation. A second cluster of samples has been collected at the center of the East Subarea, near the former HEHS facility. A smaller third cluster of samples has been collected farther north, immediately adjacent to the current animal shelter. The cluster-based locational pattern of previous sampling has left large swathes of the East Subarea unassessed for chemical contamination. This limited dataset has hindered green infrastructure and habitat restoration planning in the East Subarea, and should be enlarged via additional sampling before finalization of plans for green infrastructure and habitat restoration.

Sampling in the West Subarea has focused solely on the former LaFarge Concrete Batch plant and associated waste piles, resulted in relatively densely spaced sampling clusters in the western-most portion of this area, and no sampling data from most of the West Subarea. Similar to the East Subarea, this limited dataset restricts green infrastructure and habitat restoration planning, and should be enlarged via additional sampling before finalization of plans for green infrastructure and habitat restoration.

Importantly, no sampling has occurred in any waterbody on the site. All existing plans for the site target existing waterbodies for habitat restoration, outdoor recreation, and outdoor education. Acquiring data on current conditions of the waterbodies is recommended to guide planning for future uses. Habitat restoration planning will require information on water quality and chemical contamination levels in surface water and sediment. Planning for outdoor recreation and education will also necessitate information on chemical contamination in surface water and sediment to evaluate potential risks posed to future site users.

3.4.3 Detailed Review of Past Sampling Results

Tetra Tech performed a detailed review of available sampling results to (1) help guide habitat restoration and green infrastructure planning, and (2) provide a comprehensive assessment of known conditions at the site. The first step in evaluating available analytical data was to identify appropriate and useful risk-based screening levels to which the data would be compared. Screening levels were selected individually for each sample medium from which analytical results had been acquired.

The following four screening levels were used to evaluate analytical results from soil:

- **EPA Regional Screening Level (RSL) for Residential Soil, Target Cancer Risk = 1E-6; Target Hazard Quotient = 1:** The default RSL for residential soil was used as a highly conservative screening level to identify basic exceedances. The residential soil RSL was developed to be protective of individuals living in the area under evaluation—entailing highly conservative exposure assumptions such as exposure duration of 30 years and exposure frequency of 350 days per year (EPA 1991). Based on these exposure assumptions, the Residential Soil RSL is likely overly conservative for the site; but it is commonly used as a baseline screening level to identify contaminants of concern (COC).

- **EPA RSL for Industrial Soil, Target Cancer Risk = 1E-6; Target Hazard Quotient = 1:** The default RSL for industrial soil was used as a less conservative measure to identify soil with more significant contamination. The industrial soil RSL is designed to be protective of workers. As a result, it entails exposure assumptions more in line with anticipated site usage, such as an exposure duration of 25 years and an exposure frequency of 250 days per year. However, because this RSL is designed to evaluate soil in industrial settings, it does not take into account exposure to children. Because the final use of the site includes outdoor recreation and education, the industrial soil RSL can serve better than the residential RSL as a generic means of identifying areas with more significant contamination, but should not be used as a prescriptive cleanup level because it is not designed to protect children.

- **EPA RSL for Outdoor Workers, Target Cancer Risk = 1E-6; Target Hazard Quotient = 1:** The default RSL for outdoor workers was used as a preliminary measure to evaluate safety for future site workers, such as maintenance workers or urban farmers. This screening level is based on exposure assumptions similar to those of the industrial soil RSL, with an exposure duration of 25 years and an exposure frequency of 225 days per year. However, other exposure assumptions are adjusted to account for greater likelihood of an outdoor worker coming in direct contact with soil during activities like digging or landscaping. The outdoor worker RSL is a useful starting point for identifying areas of concern for future adult workers at the site. However, as the industrial RSL, it is not designed to protect children, so it is not appropriate for use as a site-wide, comprehensive screening level.

- **EPA RSL for Recreators, Target Cancer Risk = 1E-6; Target Hazard Quotient = 1:** The RSL for recreators is designed to evaluate safety for future recreators. Exposure assumptions must be defined on a site-specific basis, depending on anticipated site usage. Tetra Tech populated key exposure assumptions based on anticipated site usage. Specifically, an exposure duration of 2 hours per visit was selected as reasonable for exposure of a recreator to site soils. An exposure frequency of 56 days per year was selected, assuming one visit per week in April, May, September, and October; and three visits per week during the 13 weeks of summer. This calculated RSL for recreators should be considered a preliminary screening level to evaluate safety of future visitors to the site. A detailed risk assessment by a qualified human health risk assessor would be required to fully characterize risk to future recreators at the site.

For water samples, two screening levels were evaluated because to date only groundwater samples have been collected at the site. Limited screening levels are available to evaluate groundwater, as typically the only exposure pathway is via direct ingestion through drinking. Other exposure routes for both humans and the ecosystem are typically not considered because groundwater is isolated from direct contact. In Tetra Tech's baseline screening for potential contamination, Tetra Tech compared analytical results from groundwater samples to:

- **EPA Maximum Contaminant Levels (MCL) for Drinking Water:** MCLs are legal standards for drinking water quality as defined by the Safe Drinking Water Act. Standards are developed considering both potential impacts on receptors and practical capabilities of water treatment facilities. For the site, MCLs are overly conservative and thus not ideal screening levels for groundwater at the site because groundwater is not used for drinking water there.

- **EPA RSL for Tapwater, Target Cancer Risk = 1E-6; Target Hazard Quotient = 1:** RSLs for tapwater constitute a risk-based set of screening levels similar to the RSLs used to screen soil sample results. Like MCLs, RSLs for tapwater are designed to evaluate safety of drinking water. Thus these also are likely overly conservative and not ideal screening levels for groundwater at the site.

After selecting screening levels, Tetra Tech compared all available analytical results to the relevant screening levels. A summary of exceedances of screening levels is in Table B-1 in Appendix B. A visual display of locations of samples exceeding relevant screening levels appears on Figure A-5 in Appendix A.

Based on available sample analytical results and anticipated future land uses at the site, which include urban agriculture, recreation, and habitat restoration, and the available dataset, soil contamination is of greater concern than groundwater contamination. As displayed on Figure A-5 in Appendix A, current exceedances of relevant screening levels are primarily limited to the LaFarge Concrete Batch Plant site and the HEHS site. Notably, while the total number and spatial distribution of exceedances is relatively limited, this can be attributed in large part to collection of samples in only four focused areas at the site.

Soil contamination exceeding relevant screening levels at the site occurs at two surface soil sample locations, with arsenic concentrations exceeding all relevant screening levels, as well as the Jackson County background level for arsenic as determined by USGS. These contamination levels present potential risks to future site users, and care should be taken to avoid spreading existing contamination to new locations via habitat restoration or implementation of green infrastructure.

Soil contamination exceeding relevant screening levels at the HEHS site consists primarily of pesticide contamination in surface soil. Concentrations of dichlorodiphenyldichloroethane (DDD), dichlorodiphenyldichloroethene (DDE), dichlorodiphenyltrichloroethane (DDT), and dieldrin were detected in surface soil samples at five different locations. This pesticide contamination in surface soils is of particular concern for future plans for habitat restoration. Each pesticide that exceeded relevant screening levels was commonly used during historical agricultural activities (or was a breakdown product of the original pesticide). These also tend to persist in the environment for long periods of time, do not easily dissolve in water, and typically sorb to soil particles. If they are transported into surface water bodies via overland flow and erosion, they typically persist in sediment for long periods of time, where benthic organisms and fish are exposed. Pesticides present at the site are also known to bioaccumulate in tissues of organisms exposed to them. DDT is particularly well-known for its propensity for biomagnification, whereby concentrations of the contaminant in tissue increase upward through the trophic system, resulting in more acute exposures to higher-level consumer organisms such as predatory fish and birds. One sample at the HEHS site contained mercury concentration exceeding the EPA RSL Target Cancer Risk = 1E-6; Target Hazard Quotient = 0.1. That this concentration exceeded only the EPA RSL with a Target Hazard Quotient of 0.1 (and not the RSL with a Target Hazard Quotient of 1) indicates mercury could be a COC at the site, but this result is not of great concern for future site users.

In addition to soil contamination at the LaFarge Concrete Batch Plant and HEHS sites, two soil sample locations at the MCI site hosted concentrations of polycyclic aromatic hydrocarbons (PAH) exceeding relevant screening levels. One sample location was within 11 to 13 feet bgs, below where future site users and organisms are likely to come into contact with the contamination. The second sample location was in surface soil. While PAH concentrations exceeded all relevant screening levels there, these exceedances were isolated, and thus probably not a major concern for planners of future site usage.

3.4.4 Past Sampling Results Conclusions

The following three key conclusions resulted from the review of past sampling efforts and available data at the site:

- Spatial resolution and dispersion of past sampling efforts were insufficient to fully characterize contaminant levels across the entire site. Sampling was clustered relatively densely in four portions of the site, with large swaths of the site never having been investigated.
- Sampling must occur within surface waters at the site to fully evaluate the impact of past site usages on aquatic and wetland habitat, and to accurately plan for habitat restoration.
- Contamination that could directly impact green infrastructure/habitat restoration and future site usage exists at the LaFarge Concrete Batch Plant and HEHS sites. The pesticide contamination at the HEHS site is of particular concern, given its known impact on ecosystems.

More in-depth recommendations for supplementing the available sampling dataset are recommended in Section 7.1.

4.0 HYDROLOGIC & HYDRAULIC MODEL

Tetra Tech developed an H&H model of the site and its contributing watershed to gain understanding of H&H conditions at the site. The model provides information on flow conditions within waterbodies at the site that can guide habitat restoration planning, and also provides information on the spatial extent and relative depth of surface water inundation. Inundation modeling is extremely useful for both habitat restoration and green infrastructure design. For habitat restoration design, areas with consistent inundation can be identified and evaluated for wetland habitat restoration. Expected inundation depths can guide plant selection and placement. For green infrastructure design, key overland flow routes can be identified and targeted with green infrastructure to maximize runoff capture or infiltration. This model will also be valuable during future planning and engineering and design phases, as the model can be updated as future site uses become more concrete, and green infrastructure and habitat restoration elements can be modeled and evaluated for their efficacy and impact on the site. The H&H model was created by use of PCSWMM 2017 software developed by Computational Hydraulics International (CHI). PCSWMM provides a user interface based on a GIS and integrates seamlessly with the EPA Storm Water Management Model (SWMM5) engine. It can simulate a single rain event or a long-term, continuous simulation of runoff—modeling runoff and routing flows through a series of pipes, channels, and storage nodes such as detention ponds, and thus rendering the program ideal for use in both rural and urban areas. Tetra Tech selected this software based on its ability to integrate flow through a storm sewer network and an open channel in a single model. An additional factor in selecting PCSWMM was its ability to integrate 1-D and 2-D modeling. 2-D modeling allows for creation of a mesh that covers a land surface and models flow of water over a two-dimensional area, incorporating elements such as elevation, obstacles, and flow constrictions, thus accurately modeling flood conditions. 2-D modeling also allows creation of visual representations of flow and inundation conditions in real time.

The four primary components of the Municipal Farms PCSWMM model are as follows:

1. **Subcatchments:** Subcatchments are used to delineate subwatersheds and route overland flow in the model. Rain data are distributed across subcatchments, and land use and soil characteristics influence behavior of overland runoff through the subcatchment.

2. **Conduits:** Conduits represent flow conveyances. Conduits can be used to represent storm sewer systems, natural channels, culverts, bridges, and other structures that convey water. Size, slope, configuration, and roughness of conduits significantly affect hydraulic conditions within the model.

3. **Junctions:** A junction acts as a single point where changes to flow and conduit characteristics can occur. For the model and the downstream conduit to account for all flow (including overland and hydraulic), all flow must be routed to a junction. Junctions also allow for changes in physical characteristics within a network of conduits, so that the model can account for all changes to a

hydraulic flow path (such as changes in channel size, slope, bed material, etc.). Junctions can also be used to model single-point elements of an H&H system, such as catch basins and manholes.

4. **Outlets:** An outlet functions as the most-downstream point of the model, and allows implementation of boundary conditions that impact hydraulic conditions throughout the model.

To set up the base for a successful model, PCSWMM requires three primary forms of data: (1) topographic data, (2) watershed characteristics, and (3) precipitation data. Incorporation of each of these data types is discussed in the following sections.

4.1 TOPOGRAPHIC DATA

Tetra Tech used one primary data source to create a digital elevation model (DEM) of the Municipal Farms property and its contributing watershed. The DEM provides elevation data to the model, allowing it to accurately model land surface conditions. Inclusion of surface conditions and elevations allows the model to determine overland flow paths and directions. Tetra Tech initiated creation of the Municipal Farms DEM by reviewing numerous available elevation data sources, and identified two data sets that could be used for this project: (1) County LiDAR-based DEM Mosaic dataset provided by the Missouri Spatial Data Information Service (MSDIS), and (2) National Elevation Dataset provided by USGS.

The County LiDAR DEM data provided by MSDIS consists of raster DEM datasets with 1-meter resolution. The DEM is a bare-earth model, meaning that natural features such as vegetation have been removed from the dataset to provide a model of actual ground elevations. This model also includes hydro-flattening, which means that visible waterbodies have an interpolated bed elevation, rather than being represented in the model by the water surface elevation at the time of the LiDAR survey.

The National Elevation Dataset consists of raster DEM datasets with spatial resolution varying from approximately 3 to 10 meters. This dataset covers the entire continental United States. For most locations, bare-earth models are available, but do not include hydro-flattening.

After reviewing the two datasets discussed above, Tetra Tech decided to utilize the MSDIS County LiDAR DEM data because these data (1) had finer spatial resolution than the National Elevation Dataset, and (2) included hydro-flattening that provided approximate bed elevations of surface water features. Hydro-flattening is especially useful for the waterbodies on the Municipal Farms property, as no bathymetric survey data are available regarding any of these waterbodies. Importantly, hydro-flattening produces a rough approximation of actual bed elevations, and if possible should be supplemented with actual bathymetric survey data in future iterations of the model.

Tetra Tech performed basic manipulations of the MSDIS DEM to allow its accurate incorporation in the H&H model. This consisted of two steps: (1) converting projection and elevation data from meters to feet, to allow the DEM to interact accurately with existing GIS data for the project; and (2) clipping the DEM to a more reasonable spatial extent to allow a preliminary analysis of conditions at the site. These manipulations were performed by use of GIS software.

Once the DEM was incorporated into the PCSWMM model, Tetra Tech evaluated existing HEC-RAS models of nearby rivers for inclusion in the Municipal Farms model. The HEC-RAS models—provided by the City and produced by both FEMA and the City—covered a very large geographic extent, well beyond the boundaries of the site. Tetra Tech performed a limited review of the HEC-RAS models to determine which models were likely to significantly influence H&H conditions at the site. Based on this review, Tetra Tech determined that models of the Blue River and Round Grove Creek should be included in the site-specific model. The Blue River is a relatively large river that flows adjacent to the site to the north and west. Most water that enters the site eventually discharges to the Blue River, which means that the Blue River has a direct hydraulic connection with the waterbodies on the site. The HEC-RAS model of the Blue River also indicated that during large flow events, the Blue River can flood small portions of the site, thus influencing hydrologic conditions at the site. Round Grove Creek flows through the eastern section of the site and the northern portion of the western section of the site before discharging to the Blue River, rendering its inclusion in the site-specific model crucial. Most water from the eastern section of the site discharges to Round Grove Creek, and large flow events cause Round Grove Creek to flood directly onto the site, indicating its influence on H&H conditions at the site.

After identifying the Blue River and Round Grove Creek HEC-RAS models for inclusion in the site-specific model, Tetra Tech performed a more detailed review of each to determine the most efficient means of incorporating each model into the site-specific model. The Blue River and Round Grove Creek models cover a relatively vast geographic extent. Including the entire HEC-RAS models would be extremely burdensome for the PCSWMM model, as inclusion of the entire contributing watershed would be necessary to account for overland runoff contributions to the Blue River and Round Grove Creek. To avoid creating a model with a huge spatial extent and poor resolution, Tetra Tech identified both upstream and downstream locations where the Blue River and Round Grove Creek models could be truncated. Tetra Tech chose the truncation locations based on proximity to the site, flow conditions, and physical channel attributes. Flow conditions at the upstream truncation locations were maintained as a baseline flow for the PCSWMM model, allowing for accurate representation of flow conditions throughout the reaches of the Blue River and Round Grove Creek that were included in the model.

After identifying truncation locations, Tetra Tech imported the entire Blue River and Round Grove Creek HEC-RAS models into PCSWMM to define appropriate subwatershed boundaries in order to allow determination of a final spatial extent of the PCSWMM model. The HEC-RAS models were first shortened to be longer than the final truncated versions, so that subwatersheds that discharge to locations beyond the intended model extent could be distinguished from subwatersheds that discharge to locations within the intended model extent. The models with preliminary shortening and the DEM were used in conjunction with aerial photographs to define key hydraulic features at the site, including flowpaths for visible waterbodies. This information was utilized to perform a preliminary subwatershed delineation of the site. Tetra Tech utilized PCSWMM's Watershed Delineation Tool to automatically delineate subwatersheds, using flowpaths as a burn-in layer, and a target subwatershed size of 20 acres. This broad watershed delineation was used to identify major subwatersheds. Each subwatershed was delineated based on topographic conditions, and water from each subcatchment was routed to the nearest downgradient conduit. The Watershed Delineation Tool created a conduit-network based on the flowpath burn-in, as well as overland flow conditions. Upon completion of the subwatershed delineation, Tetra Tech reviewed the discharge location for each subwatershed. Subwatersheds that discharged within the site or within the intended truncated extent of the Blue River and Round Grove Creek were identified as contributing watersheds that directly impact the site. Subwatersheds that discharged to locations beyond the intended truncated extent of the Blue River and Round Grove Creek, or to other locations not directly connected to the site, were deleted, as these would not affect on-site conditions. The spatial extent of contributing watersheds was used as the final spatial extent of the PCSWMM model. The DEM was clipped to these spatial extents, and the Blue River and Round Grove Creek models were truncated to their final extents.

After determining the final spatial extent of the PCSWMM model, Tetra Tech utilized both aerial photographs and the DEM to create a conduit network to represent visible waterbodies on the site. Junctions were included only at key locations such as the upstream and downstream extents of each conduit, and at locations where two or more conduits converged. Once this basic construction of the conduit network at the site was complete, Tetra Tech performed a second, more detailed subwatershed delineation. Tetra Tech again utilized the built-in PCSWMM Watershed Delineation Tool. For this delineation, Tetra Tech used the conduit network for a burn-in path, and used a target subwatershed size of 10 acres to maintain a reasonable level of detail within the model without creating unnaturally small subwatersheds. The resulting network of subwatersheds was used as the final subcatchment layer for the model. Each subcatchment is defined by characteristics including size, flow length, percent impervious, storage depth, and soil characteristics. Inclusion of these characteristics in the model is discussed in the following section.

4.2 WATERSHED CHARACTERISTICS

The second critical data source for the H&H model was characteristics of the contributing watershed, including amount of impervious area, soil types, and runoff conditions. These characteristics significantly influence the amount of water that flows out of each subcatchment to the waterbodies on the site during rain events. Tetra Tech reviewed several sources of land use data, including the City’s Zoning data, and the Mid-America Regional Council’s (MARC) Land Use/Land Cover dataset. Tetra Tech’s evaluation indicated that the MARC dataset would be more useful because of its greater level of detail in the area near the site, as well as its land use classification system, which differentiated among different types of undeveloped land such as deciduous forest, herbaceous, and cultivated.

Tetra Tech reviewed the MARC dataset by comparing it with recent aerial photographs. The contributing watershed to the site is comprised of a mixture of undeveloped land, residential areas, and some commercial, industrial, and open space areas. Figure A-6 in Appendix A shows land uses within the site’s contributing watershed.

Land uses derived from the MARC dataset were included in calculations of the percent impervious, impervious and pervious Manning’s N roughness coefficient, and impervious and pervious depression storage for each subcatchment. These watershed characteristics influence the hydrologic behavior of each subcatchment in the model. In particular:

- The percent impervious defines the portion of the subcatchment where impervious surfaces prevent any infiltration of precipitation.
- The impervious and pervious Manning’s N value is a dimensionless representation of roughness of land surface within the subcatchment. Roughness is a key factor in evaluating overland flow speed and energy, as more rough surfaces can significantly impede overland flow.
- The impervious and pervious depression storage is a measure of amount of precipitation stored in micro-depressions typical of land use. For example, concrete has very little depression storage capacity due its typically uniform surface, while a land use such as a forest has a much greater depression storage due to common irregularities in ground surface that can trap water.

The percent impervious, impervious and pervious Manning’s N roughness coefficient, and impervious and pervious depression storage for each land use type were based on several sources, including the EPA SWMM5 User’s Manual (EPA 2015), and the Urban Storm Drainage Criteria Manual: Volume I, published by Colorado’s Urban Drainage and Flood Control District (Colorado UDFCD) (UDFCD 2017). Values for land uses in the Municipal Farms’ watershed are listed below in Table 2.

TABLE 2

LAND USE CHARACTERISTICS

Land Use	Percent Impervious (%)	Impervious Manning's N	Pervious Manning's N	Impervious Depression Storage (inches)	Pervious Depression Storage (inches)
Barren	10	0.011	0.13	0.1	0.2
Cultivated	10	0.011	0.17	0.1	0.35
Herbaceous	10	0.011	0.15	0.1	0.35
Impervious Buildings	95	0.011	0.41	0.1	0.15
Impervious Other	95	0.011	0.41	0.1	0.1
Lowland Deciduous Forest	0	0.011	0.6	0.1	0.4
Lowland Herbaceous/Cultivated	10	0.011	0.16	0.1	0.35
Mixed Forest	0	0.011	0.6	0.1	0.4
Pavement	100	0.011	0	0.1	0.1
Scrub-Shrub	0	0.011	0.15	0.1	0.4
Upland Deciduous Forest	0	0.011	0.6	0.1	0.4
Upland Herbaceous/Cultivated	10	0.011	0.16	0.1	0.35
Water	100	0.011	0	0.1	0.01

Notes:

% Percent

Once these values had been assigned to each land use type, the area weighting method was applied to calculate percent impervious, impervious and pervious Manning's N roughness coefficient, and impervious and pervious depression storage for each subcatchment in the PCSWMM model.

Necessary as well was inclusion of soil characteristics in the model to accurately model infiltration and runoff. Tetra Tech used the Green-Ampt infiltration method in the PCSWMM model, which requires input of three primary soil characteristics: (1) initial moisture deficit, (2) hydraulic conductivity, and (3) suction head at the wetting front. Soil type data regarding the Municipal Farms' contributing watershed were obtained from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Geospatial Data Gateway (USDA NRCS 2017). Tetra Tech obtained GIS shapefiles with soil type data pertaining to the project area. Figure A-7 in Appendix A shows general soil types in Municipal Farms' contributing watershed. Input values for the required soil characteristics (listed in Table 3 below) were based on the SWMM5 User's Manual.

TABLE 3

SOIL CHARACTERISTICS

Soil Type	Saturated Hydraulic Conductivity (inches/hour)	Suction Head (inches)	Initial Deficit (fraction)
Sand	4.74	1.93	0.024
Loamy Sand	1.18	2.4	0.047
Sandy Loam	0.43	4.33	0.085
Loam	0.13	3.5	0.116
Silt Loam	0.26	6.69	0.135
Sandy Clay Loam	0.06	8.66	0.136
Clay Loam	0.04	8.27	0.187
Silty Clay Loam	0.04	10.63	0.21
Sandy Clay	0.02	9.45	0.221
Silty Clay	0.02	11.42	0.251
Clay	0.01	12.6	0.265

Once these values had been assigned to each soil type, the area-weighting method was applied to calculate overall characteristics of each subcatchment.

Inclusion of these data, coupled with characteristics determined by PCSWMM's watershed delineation tool (including subcatchment area, width, flow length, and slope), resulted in an accurate base model of physical characteristics of the site's contributing watershed. Some characteristics, such as Manning's N values and subcatchment width, are considered calibration terms. Therefore, these can be adjusted within the model to attempt to calibrate the model with known flow data. Because calibration data regarding Municipal Farms are not currently available, typical values were used for these characteristics. These characteristics can be revisited if calibration data are acquired during future design and engineering project phases.

4.3 PRECIPITATION AND STORM EVENTS

Input of precipitation into the H&H model also was necessary. PCSWMM can simulate multiple types of precipitation, including design storms, actual events based on rain gauge data, and long-term simulations of weather patterns. Tetra Tech analyzed multiple precipitation data sources for the Municipal Farms H&H model, including local rain gauge data and relevant guidance documents. Tetra Tech reviewed stormwater BMP guidance from the Kansas City MARC (MARC 2012) for design and implementation of BMPs in Kansas City. This guidance provided multiple approaches to model rainfall data. The first approach consists of a statistically-derived "Water Quality Storm," defined as the 24-hour storm that produces < 90% of all 24-hour storms on an annual basis. This means that in a given year, 90% of 24-hour storms would produce the same amount or less runoff than the water quality storm. The designated water quality storm precipitation depth for Kansas City is 1.37 inches. MARC guidance also suggests use of USDA NRCS Technical Release 55, "Urban Hydrology for Small Watersheds," which provides general ranges of precipitation amounts for varied storm durations and recurrence intervals. Tetra Tech referenced the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 Point Precipitation Frequency Estimates (NOAA 2013) to obtain more accurate estimates of precipitation patterns. NOAA has compiled weather data throughout the country, and has statistically analyzed those data sets to generate estimates of precipitation on multiple scales—at point-locations, regionally, and statewide. Tetra Tech obtained the NOAA Point Precipitation Frequency Estimates for the centroid of the site. The NOAA Point Precipitation Frequency estimation tool calculates precipitation depths and intensities of rain events ranging in duration from 5 minutes to 60 days, and ranging in recurrence interval from 1 to 1,000 years. These rainfall estimates are calculated in accordance with methods detailed in NOAA Atlas 14. Table 4 below lists precipitation estimates for the centroid of the site.

TABLE 4

PRECIPITATION AMOUNTS (INCHES) BASED ON DURATION AND RECURRENCE INTERVAL

Duration	Average recurrence interval (years)									
	1	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**	**1000**
5-min	0.407	0.474	0.589	0.687	0.827	0.939	1.06	1.18	1.34	1.47
10-min	0.596	0.695	0.862	1.01	1.21	1.38	1.55	1.72	1.96	2.15
15-min	0.726	0.847	1.05	1.23	1.48	1.68	1.88	2.10	2.40	2.63
30-min	1.02	1.19	1.48	1.73	2.08	2.37	2.66	2.96	3.38	3.70
60-min	1.33	1.56	1.96	2.30	2.79	3.18	3.59	4.02	4.60	5.06
2-hr	1.64	1.94	2.43	2.87	3.49	4.00	4.52	5.07	5.83	6.42
3-hr	1.85	2.19	2.77	3.28	4.01	4.61	5.23	5.88	6.79	7.50
6-hr	2.23	2.66	3.39	4.03	4.97	5.73	6.52	7.37	8.54	9.47
12-hr	2.63	3.15	4.05	4.83	5.97	6.90	7.87	8.90	10.3	11.5
24-hr	3.08	3.68	4.70	5.60	6.90	7.96	9.07	10.2	11.9	13.2
2-day	3.62	4.24	5.31	6.25	7.63	8.76	9.94	11.2	12.9	14.3
3-day	4.00	4.61	5.67	6.61	8.00	9.13	10.3	11.6	13.4	14.8
4-day	4.31	4.92	5.97	6.91	8.28	9.41	10.6	11.9	13.7	15.1
7-day	5.10	5.73	6.81	7.75	9.12	10.2	11.4	12.6	14.3	15.6
10-day	5.78	6.47	7.64	8.64	10.1	11.2	12.4	13.6	15.2	16.5
20-day	7.70	8.67	10.2	11.5	13.3	14.6	15.9	17.2	18.9	20.2
30-day	9.31	10.5	12.4	13.9	15.9	17.4	18.8	20.2	22	23.3
45-day	11.4	12.8	15	16.8	19.1	20.7	22.3	23.8	25.6	26.8
60-day	13.2	14.7	17.2	19.1	21.6	23.3	25	26.5	28.3	29.5

Tetra Tech modeled the 24-hour duration precipitation events with 2-, 10-, 25-, 50-, and 100-year recurrence intervals for this project. For 24-hour duration precipitation events, Tetra Tech entered the corresponding rainfall depth into the U.S. Soil Conservation Service (SCS) Type II 24-hour design storm, in accordance with the Kansas City construction and material specifications for storm drainage systems and facilities (American Public Works Association [APWA] 2006).

Tetra Tech also manipulated rainfall data from the Kansas City International Airport rain gauge (NOAA Station ID 72446003947) to be readily imported into PCSWMM. This manipulation allows for the modeling of actual precipitation conditions at the site. Tetra Tech utilized this historic climate data to model conditions at the site from March 2010 through October 2010. The results of this long-term modeling are presented in Section 4.7.

4.4 1-D PCSWMM MODEL SETUP

Once all relevant data had been acquired, the full PCSWMM model was created. The final watershed delineation discussed in Section 3.3.1 provided the model's subcatchment layer, and also created conduits to route overland flow in areas where the model determined overland sheet flow would transform to shallow hydraulic flow. This determination was completed internally by the Watershed Delineation Tool and reviewed by Tetra Tech. Conduits are created based primarily on terrain and overland flow length. Conduits created by the Watershed Delineation Tool terminate at junctions along the conduits defined by Tetra Tech based on visible waterbodies. This resulted in eventual routing of all overland flow to conduits representing visible, existing waterbodies on or near the site.

The combination of user-defined conduits placed to capture visible waterbodies and shallow hydraulic flow conduits created by PCSWMM constitute the basic schematic for hydraulic flow within the model. This initial schematic consists of generic conduits, with no defined physical attributes. Tetra Tech identified conduits that represent culverts at the site, and populated their physical attributes with the general characteristics of each culvert, which had been recorded during a site visit. Tetra Tech was able to define the shapes, diameters, construction materials, and inlet/outlet characteristics of most culverts at the site. However, no elevation data were available to determine culvert invert elevations. As a result, culvert invert elevations were initially derived from the DEM, and eventually adjusted based on results of initial model runs to eliminate flow conditions not likely to exist in reality. Acquisition of survey-grade data regarding all culverts on the site would be highly useful for refining the model in the future. Invert elevations of culverts at downstream extents of waterbodies at the site would be especially useful, as these culverts control ponding elevations at the site.

After defining the physical characteristics of the culverts, it was necessary to define the physical attributes of the irregular natural channels that constitute most of the drainage system at the site. Tetra Tech completed population of the attributes via a two-phased approach—first defining attributes of the shallow hydraulic flow conduits defined by the Watershed Delineation Tool, and then defining attributes of user-defined conduits representing major visible waterbodies at the site. Tetra Tech used PCSWMM's built-in Transect Creator tool to create transects for shallow hydraulic flow conduits based on the DEM. The Transect Creator tool allows generation of transects of selected length and selected interval along each conduit. For the shallow hydraulic conduits, Tetra Tech created transects spaced at 100-foot intervals, with maximum length of 250 feet. The layout of transects was then reviewed and adjusted to ensure that the transects captured major changes in physical characteristics of the DEM, and that transects did not overlap or represent unlikely flow cross-sections. After completion of this review, the transects were assigned to the conduits by creating a new junction at each transect location, with each transect representing the cross-section of the conduit immediately downstream of its location. Once the transects had been assigned to their respective conduits, each conduit was reviewed in order to assign Manning's N roughness values. PCSWMM allows definition of left and right bank stations with intent to differentiate between in-channel and overbanks flow. The program also allows for three separate Manning's N roughness values: one for in-channel flow, one for left overbank flow, and one for right overbank flow. Tetra Tech assigned left and right bank stations for each conduit based on reviews of the DEM and aerial photographs. Manning's N roughness coefficients were then assigned for each portion of the cross-section. Manning's N values, derived from multiple sources (Chow 1959, McCuen and others 1996), were primarily based on aerial imagery, which served as evidence of bed/ground surface over which flow would pass. Manning's N values for shallow hydraulic flow conduits varied from 0.011 to 0.8. In many cases, the entire cross-section (including in-channel and overbanks areas) was assigned the same Manning's N value because of (1) lack of a distinct channel, and (2) evidence from aerial photographs that all flow would likely encounter similar conditions throughout the cross-section.

Generation of user-defined conduits that represent visible waterbodies on the site involved a similar process, with two key differences: (1) different spacing interval of transects, and (2) inclusion of a separate overbanks layer to define left and right bank stations. These differences are discussed in more detail below.

Tetra Tech once again utilized PCSWMM's built-in Transect Creator tool to create transects along user-defined conduits based on the DEM. Because the user-defined conduits consist of major waterbodies at the site that will exert the most impact on site conditions, Tetra Tech created transects at a finer resolution than that for shallow hydraulic flow transects. For the user-defined conduits, Tetra Tech opted to space transects at 50-foot intervals, with maximum length of 500 feet. Closer spacing of these transects allowed more detailed representation of physical characteristics of waterbodies at the site, while still maintaining a conduit length large enough to avoid model inconsistencies that often arise from designations of short (less than approximately 30-foot) conduit lengths. After creation of the transects, Tetra Tech performed a similar review process, ensuring that transects did not overlap, and that major changes in physical structure of channels were captured. Where necessary, transects were altered or deleted, with focus on truncating or extending transects to attempt to ensure that flow would be bound within each transect. Once this review was complete, Tetra Tech created a layer to define overbanks locations for the natural waterbodies on the site. To create the overbanks layer, Tetra Tech reviewed aerial photographs and the DEM, and used GIS mapping tools to create a layer defining left and right boundaries of visible channels. Tetra Tech then assigned the transects to their respective conduits by creating a junction at each conduit location, with the transect at each junction representing the cross-section of the conduit immediately downstream. Left and right bank stations were automatically assigned to each conduit segment based on the user-defined overbanks layer. Tetra Tech then reviewed each conduit segment, focusing on confirming locations of left and right bank stations and adjusting as needed, and assigning Manning's N values. Separate Manning's N values were used for in-channel flow based on existence of distinct channels for this portion of conduits. In-channel Manning's N values varied from 0.035 to 0.045, based on configuration of the channels, amount of change in bed elevation in the channels, and suspected bed material. Overbanks Manning's N values varied from 0.011 to 0.8 based on nearby land uses. Finally, Tetra Tech reviewed historical aerial photos and elevations of water surfaces using Google Earth software. This review was necessary due to presence of surface waters with consistently pooled water on the site. PCSWMM allows assignment of an initial depth to each conduit in order to avoid modeling areas with standing water as dry depressions. Tetra Tech utilized the initial depth capacity of the two surface water bodies that consistently hold ponded water in the West Subarea.

The final component of the PCSWMM model setup process was defining boundary conditions for the model. Tetra Tech's site-specific model encompassed an area that eventually drains to the Blue River, with most water routed either through Round Grove Creek or unnamed waterbodies on the site. Because the City provided an approved FEMA HEC-RAS model of the Blue River and Round Grove Creek, Tetra Tech utilized conditions of the FEMA model to define boundary conditions for the PCSWMM model. Specifically, Tetra Tech selected from the HEC-RAS model a specific cross-section immediately downstream of portions of the Blue River hydraulically connected to the site, and converted that cross-section to an outfall within the PCSWMM model. Tetra Tech ran the approved HEC-RAS model, and determined anticipated flow and stream stage at this outfall location for all modeled recurrence intervals. Stream stages for each recurrence interval were then used to define fixed boundary conditions for the PCSWMM outfall. The fixed boundary condition maintains the selected stream stage at the outfall. For the purposes of the PCSWMM model, this means that conditions within the Blue River were relatively fixed to match the approved HEC-RAS model. This allowed modeling efforts to focus on evaluating impacts of the Blue River on the site, rather than expending a large effort to model the entire Blue River itself. A similar approach was applied to assign initial flow conditions at the upstream extents of the Blue

River and Round Grove Creek within the PCSWMM model. The approved HEC-RAS models for both water courses were analyzed to determine anticipated discharges at the most upstream cross-sections included in the PCSWMM model. These discharges were then assigned to the respective upstream junctions as base flows.

Figure A-8 in Appendix A shows the PCSWMM schematic for the site and its contributing watershed. The dynamic wave method was applied to route runoff through the model. The dynamic wave routing method solves all terms of the one-dimensional Saint Venant flow equations and therefore produces the most theoretically accurate results (EPA 2015). After preliminary results of the Municipal Farms H&H model had been analyzed, Tetra Tech concluded that it would be necessary to use the option to "Ignore" the inertial component of the Saint Venant equation to minimize inaccurate flow oscillations. By ignoring the inertial term, the model effectively operates as a diffusive wave model, giving precedence to acceleration caused by gravity, friction, and pressure.

4.5 1-D MODEL RESULTS

Tetra Tech used the 1-D Municipal Farms H&H model to simulate the 24-hour duration rain events with 1-, 10-, 25-, 50-, and 100-year recurrence intervals. For the purposes of green infrastructure and habitat restoration planning, Tetra Tech focused on analyzing results of two portions of the model. First, the maximum water surface elevations along the Blue River were compared to outputs from the approved HEC-RAS model of the Blue River to evaluate accuracy of the 1-D PCSWMM model. Second, the runoff characteristics of each subcatchment on the site were evaluated to determine optimal areas of the site to target for green infrastructure implementation. Tetra Tech also reviewed in-channel flow rates and flow velocity throughout the site. For current planning purposes, in-channel flow rate and velocity will not significantly affect plan development. However, as the redevelopment project progresses, and specific waterbodies are targeted for restoration or nearby development, these characteristics will be valuable for designing restoration, and avoiding in-channel erosion and downcutting. Each of these categories of results is discussed below.

4.5.1 Blue River Maximum Water Surface Elevation Analysis

Tetra Tech used the approved HEC-RAS model of the Blue River as a check to evaluate accuracy of the PCSWMM model. Tetra Tech also evaluated use of the HEC-RAS model of Round Grove Creek to evaluate accuracy of the PCSWMM model, but a review of the HEC-RAS model of Round Grove Creek revealed that the model did not appear to take into account backwater effects from the Blue River. For example, for the 100-year recurrence interval, 24-hour duration rain event, the Round Grove Creek HEC-RAS model indicated that at the cross-section nearest the confluence with the Blue River, the maximum surface water elevation was 739.61 feet above mean sea level (AMSL). However, for the 100-year recurrence interval, 24-hour duration rain event, the Blue River HEC-RAS model indicated that the cross-section at the confluence with Round Grove Creek was 764.03 feet AMSL. This disparity in maximum water surface elevation for the same rain event indicated that the Round Grove Creek HEC-RAS model did not consider backwater effects from the Blue River. Because the PCSWMM model was a comprehensive model of the full hydraulic system of the area near the Municipal Farms site, it did consider all backwater effects. As a result, Tetra Tech determined that the Round Grove Creek HEC-RAS model did not yield appropriate water surface elevation data to use for evaluation of accuracy of the PCSWMM model, and proceeded to use data only from the Blue River HEC-RAS model.

Comparisons of maximum water surface elevations from the approved HEC-RAS model of the Blue River and the PCSWMM model developed for this project are in Table B-2 in Appendix B. Average difference in surface water elevation between the models for all simulated rain events was 0.5795 feet, indicating that the PCSWMM model is a relatively accurate approximation of the approved HEC-RAS model of the Blue River. Backwater effects of the Blue River on the site are well represented in the PCSWMM model, but could be more accurately modeled if calibration data are acquired for the model in the future (for additional details, see Section 7.2).

4.5.2 Subcatchment Runoff Analysis

Amount of surface runoff exiting each subcatchment is a highly useful parameter for determining which areas of the site should be targeted for green infrastructure implementation. The PCSWMM model takes into account numerous characteristics of each subcatchment to determine overland flow parameters, including soil type, land use type, size, and slope. Subcatchments that yield large volumes of surface runoff are typically targeted for green infrastructure. Because volume of runoff depends highly on size of the subcatchment, Tetra Tech controlled for subcatchment size by calculating the volume of runoff generated per acre of subcatchment area for each subcatchment. This calculated parameter acts as a measure of how much runoff a subcatchment produces per unit area, which is impacted by land use, soil type, and slope. Figure A-9 in Appendix A shows volume of runoff generated per unit area for each subcatchment on the site.

4.5.3 Review of Flow Rate and Velocity Results

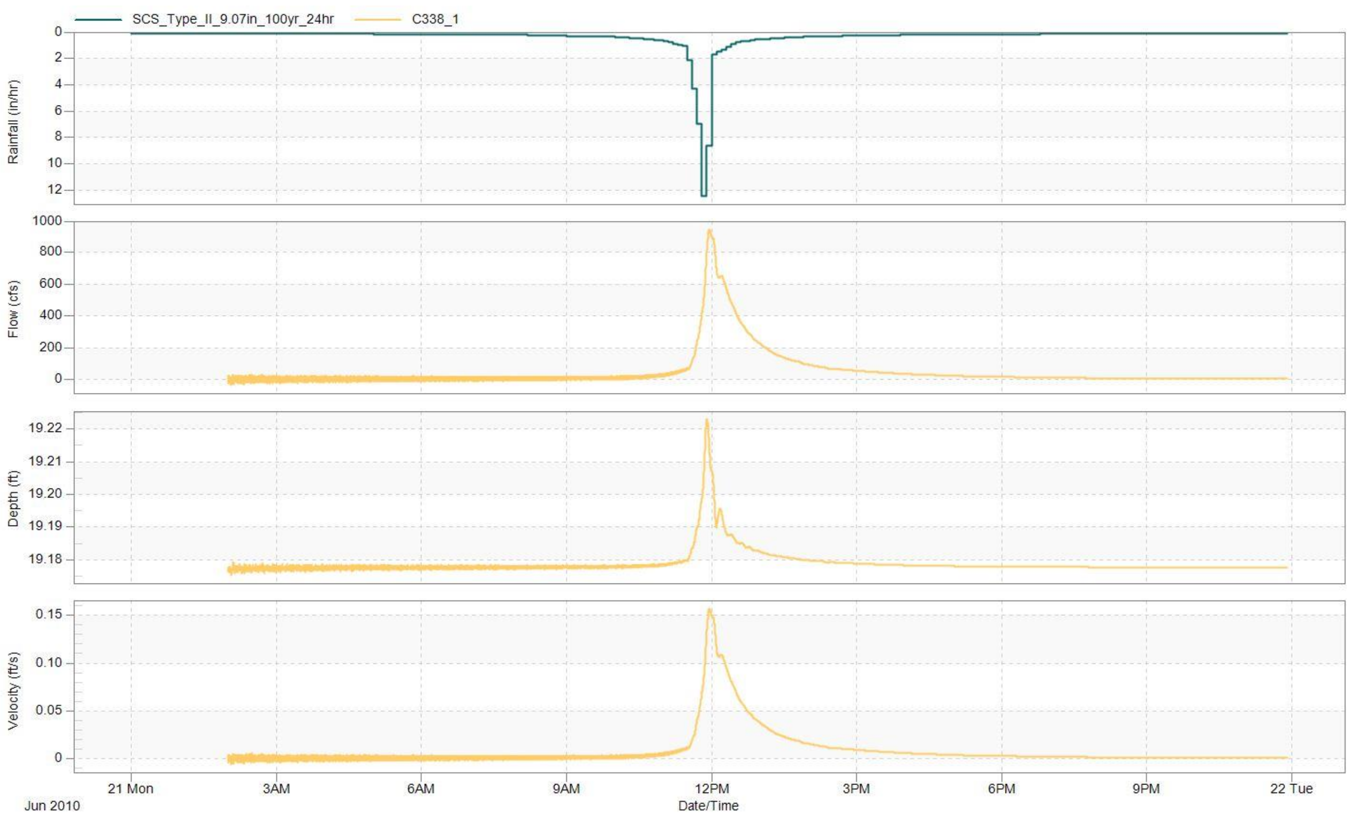
While in-channel flow rates and velocities will not directly impact the current green infrastructure and habitat restoration planning process, these are key to the H&H model, and will likely be very useful in future project phases. Tetra Tech conducted a detailed review of discharge and velocity for each surface water body on the site. While not directly relevant to the current project phase, a brief summary of representative flow conditions within surface water bodies at the site appears below. Figure A-10 in Appendix A depicts locations of the five surface water bodies discussed below. Results were gaged against visual observations of site conditions and professional judgement. Future acquisition of model calibration data would allow for a more robust analysis of in-channel flow conditions at the site.

Surface Water Body 1:

Surface Water Body 1 is the westernmost pond in the West Subarea. It is relatively flat, has well-defined banks, and is consistently ponded due to presence of a culvert connecting it to the Blue River. The inlet invert elevation of this culvert acts as the primary water surface elevation control for Surface Water Body 1. The contributing watershed to this waterbody is relatively large, and includes wooded areas and the Public Works facility. Figure 1 below compares flow rate, depth, and velocity in a representative segment of Surface Water Body 1 with the 100-year recurrence interval, 24-hour duration rain event.

FIGURE 1

SURFACE WATER BODY 1 FLOW CHARACTERISTICS



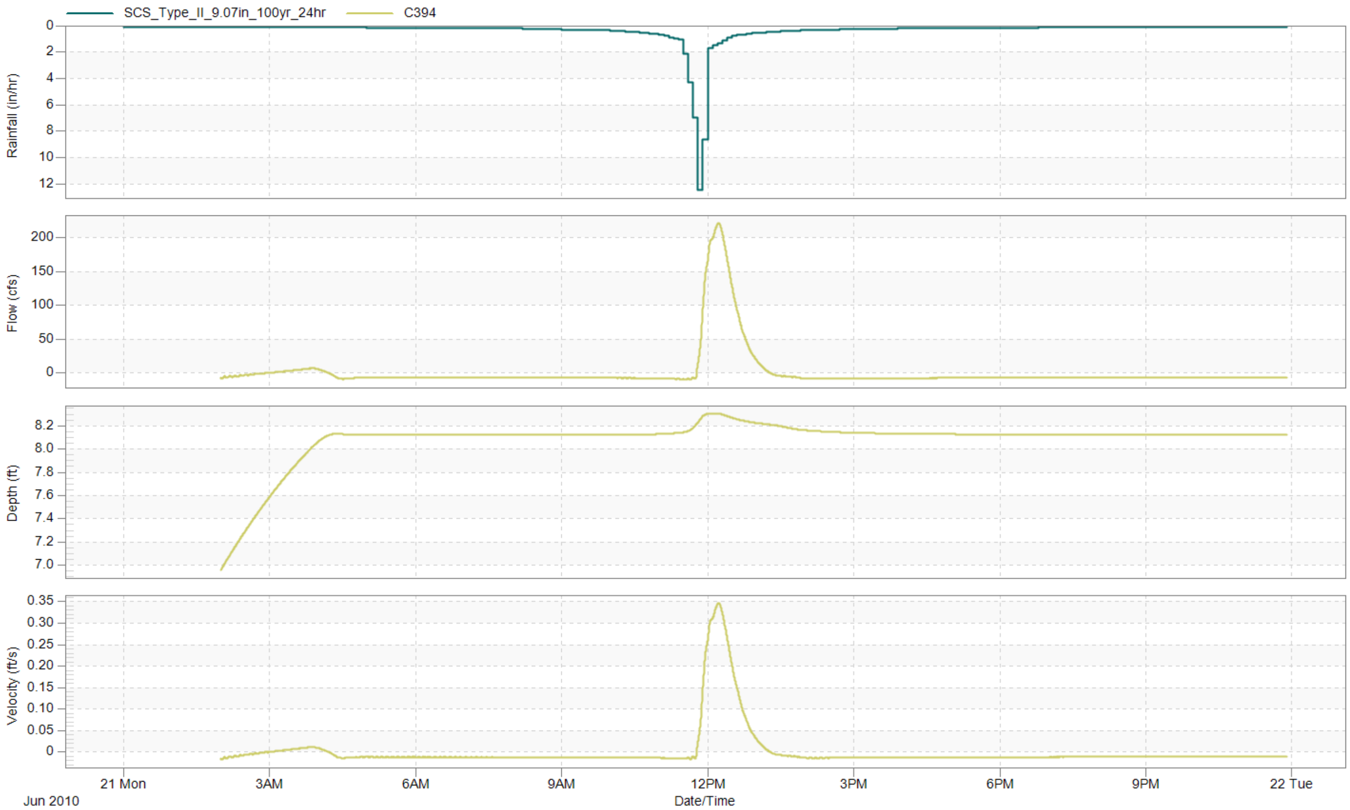
The above pattern is expected for a pond with a flow control device that connects it to a larger water body with significant backwater effects. At the beginning of this simulation, backwater effects from the Blue River have already caused reverse flow through the culvert connecting Surface Water Body 1 to the Blue River. The culvert is surcharged, and remains surcharged due to the water surface elevation of the Blue River. Once rainfall begins, there is a short period of attenuation between the start of rainfall and observed increased in flow. As expected for a pond with significant backwater impacts, a large flow profile, and a wide, well-connected flood plain, increase in flow does not cause a very large increase in depth of flow velocity. For example, the 100-year recurrence interval storm yields only an approximately 0.05-foot increase in depth, because the water surface elevation has already equilibrated with the water surface elevation of the Blue River. There is greater attenuation for depth than flow and velocity because the stream does not have particularly steep banks, allowing flow to spread out over a larger area. This relatively wide flow area coupled with backwater effects also keeps flow velocities relatively low, with a maximum velocity below 5 feet per second. This water body demonstrates the exceedingly significant impact that conditions in the Blue River have on water bodies at the site during significant rain events.

Surface Water Body 2:

Surface Water Body 2 is the central linear ponded area in the West Subarea. Similar to Surface Water Body 1, it is relatively flat, has well-defined banks, and is consistently ponded due to presence of a culvert connecting it to the Blue River. The inlet invert elevation of this culvert acts as the primary water surface elevation control for Surface Water Body 2. The contributing watershed to this waterbody is relatively large, and includes wooded areas and most of the Radio Tower area. Figure 2 below compares flow rate, depth, and velocity in a representative segment of Surface Water Body 2 with the 100-year recurrence interval, 24-hour duration rain event.

FIGURE 2

SURFACE WATER BODY 2 FLOW CHARACTERISTICS



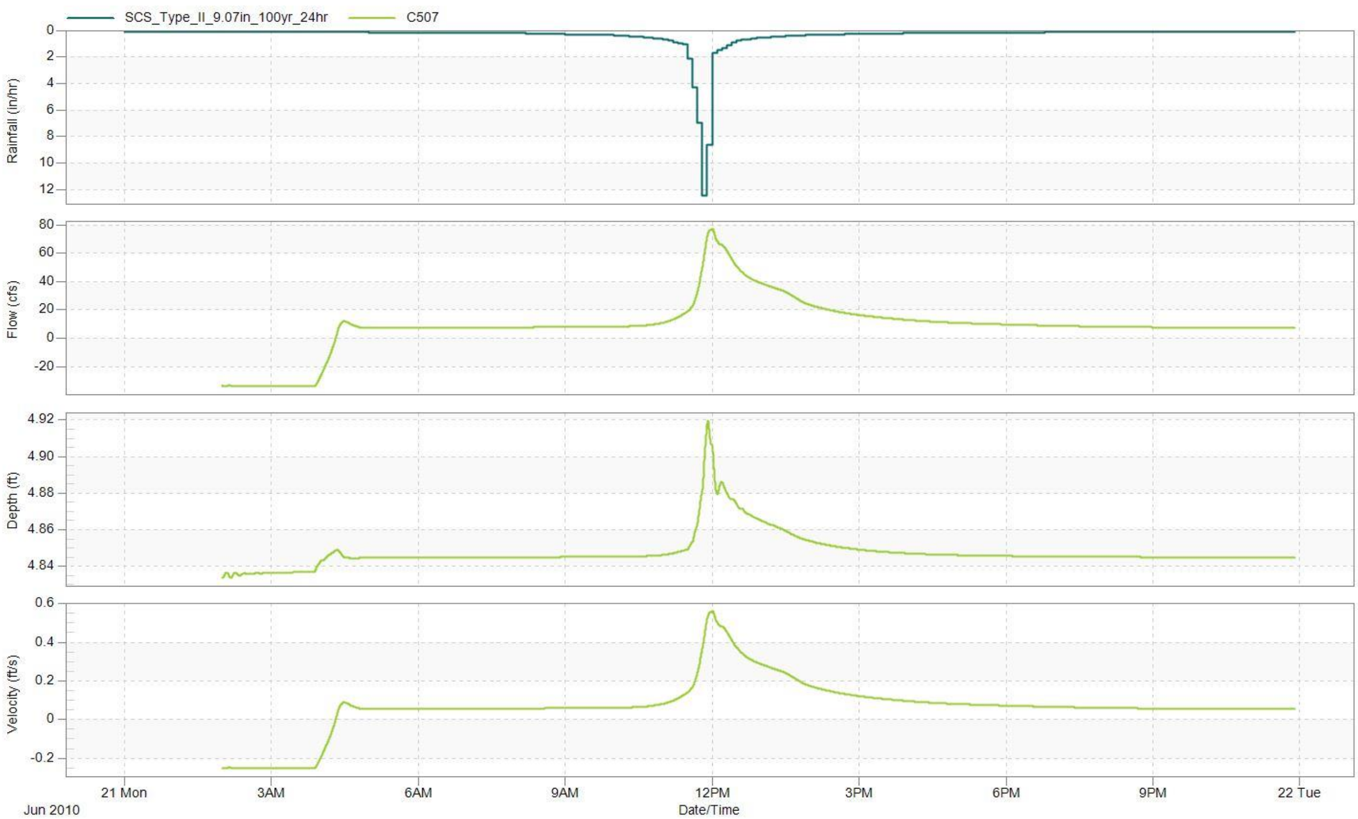
The above pattern is expected for a pond with a flow control device that connects it to a larger water body with significant backwater effects. At the beginning of this simulation, backwater effects from the Blue River have already caused reverse flow through the culvert connecting Surface Water Body 2 to the Blue River, but have not impacted the full length of the water body. This is demonstrated by increase in depth in the water body that occurs before rainfall occurs. The depth equivalates over time to reflect backwater impacts from the Blue River, and then increases a small amount once rainfall begins. Similar to Surface Water Body 1, flow velocities are slow, reflecting the flat, relatively wide flow area, and impact of backwater effects. There is greater attenuation of depth than flow and velocity because the water body does not have particularly steep banks, allowing flow to spread out over a larger area. This water body also demonstrates the significant impact that conditions in the Blue River have on water bodies at the site during significant rain events.

<u>Surface Water Body 3:</u>

Surface Water Body 3 is the easternmost stream in the West Subarea. It is a relatively flat stream that flows a large portion of the West Subarea before eventually discharging to Round Grove Creek near its confluence with the Blue River. The stream has relatively well-defined banks, and in most areas a well-connected flood plain. This water body is connected to Surface Water Body 2, with flow divided between the two. The contributing watershed to this waterbody is comprised of a mixture of open space and the National Guard facility, as well as wooded areas in the easternmost portion of the West Subarea. Figure 3 below compares flow rate, depth, and velocity in a representative segment of Surface Water Body 3 with the 100-year recurrence interval, 24-hour duration rain event.

FIGURE 3

SURFACE WATER BODY 3 FLOW CHARACTERISTICS



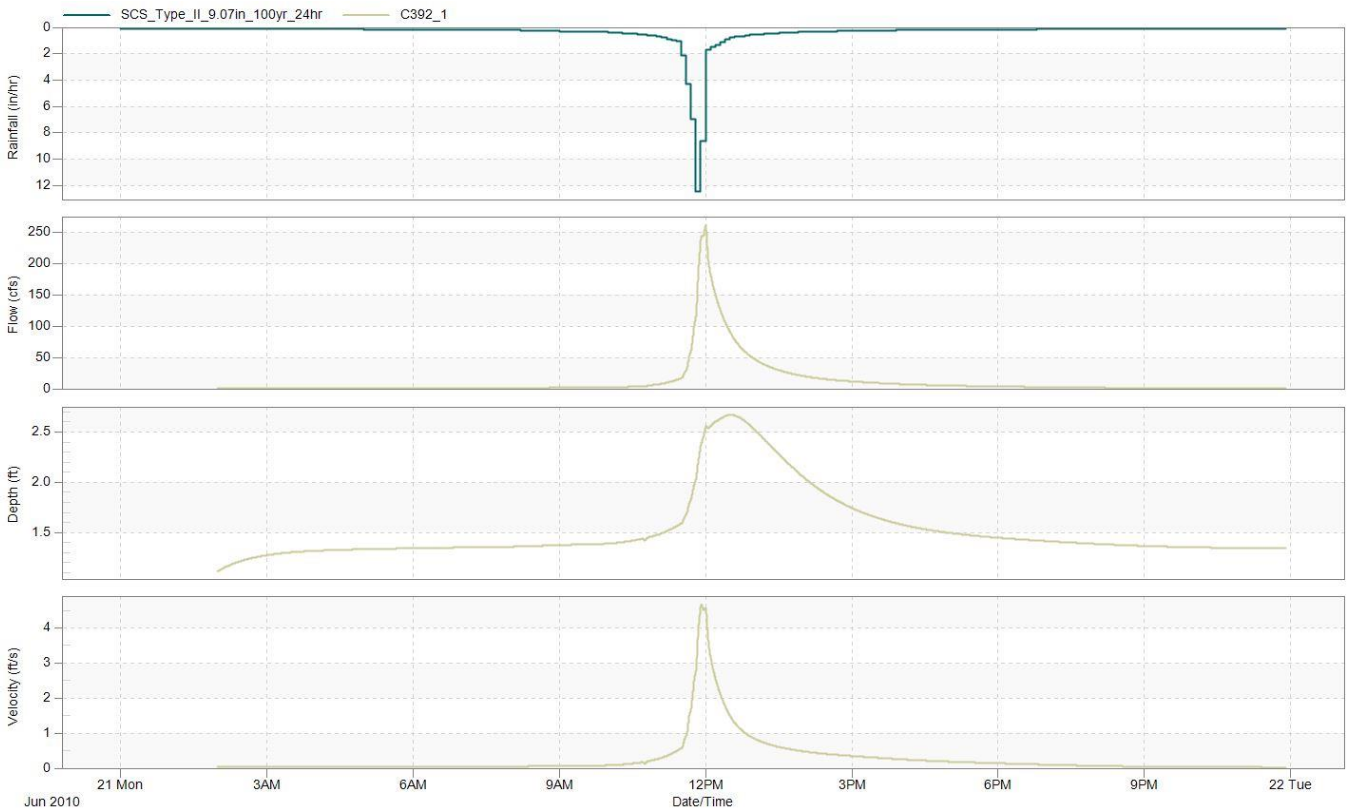
The above pattern is expected for a stream that connects to a larger water body with significant backwater effects. At the beginning of this simulation, backwater effects from the Blue River transmitted through Round Grove Creek and the length of Surface Water Body 3 caused a short duration reverse flow and small increase in depth before beginning of rainfall. Flow, depth, and velocity are all fairly well-attenuated, in part because water flowing toward the split between Surface Water Body 2 and Surface Water Body 3 will initially travel to Surface Water Body 2, until the water surface elevation reaches the invert elevation of Surface Water Body 3, which is approximately 1.5-feet higher than that of Surface Water Body 2. Like Surface Water Bodies 1 and 2, this water body demonstrates the significant impact of conditions in the Blue River on water bodies at the site during significant rain events.

Surface Water Body 4:

Surface Water Body 4 is the westernmost stream in the East Subarea. It is a relatively steep stream that flows through a ravine area. The contributing watershed to this waterbody is comprised of a mixture of open space and the National Guard facility. Its banks are not particularly steep. Figure 4 below compares flow rate, depth, and velocity in a representative segment of Surface Water Body 4 with the 100-year recurrence interval, 24-hour duration rain event.

FIGURE 4

SURFACE WATER BODY 4 FLOW CHARACTERISTICS



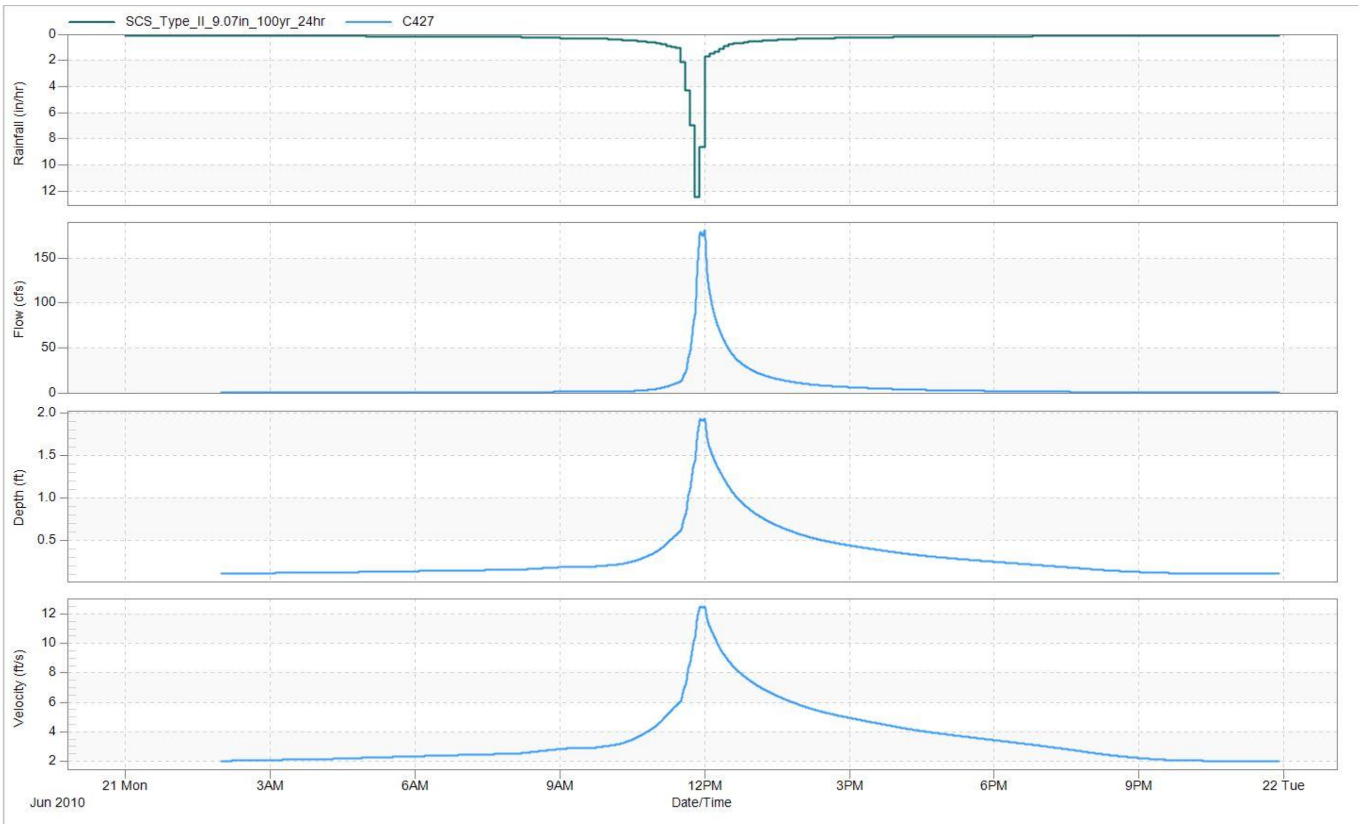
The above pattern is expected for a relatively steep stream with a relatively small watershed that is a mixture of pervious and impervious surfaces. There is a short period of attenuation between the start of rainfall and observed increased in flow, velocity, and depth. There is greater attenuation of depth than flow and velocity because the stream does not have particularly steep banks, allowing flow to spread out over a larger area. This relatively wide flow area also keeps flow velocities relatively low, with a maximum velocity below 5 feet per second. The initial pulse flow passes through the stream quickly, with a relatively rapid drawdown to baseflow conditions. This stream is likely ephemeral, with zero flow during dry weather.

Surface Water Body 5:

Surface Water Body 5 is the easternmost stream in the East Subarea. Similar to Surface Water Body 4, it is a relatively steeply-banked stream that flows through a ravine area. The contributing watershed to this waterbody is primarily comprised of open space and the easternmost portion of the National Guard facility. Figure 5 below compares flow rate, depth, and velocity in a representative segment of Surface Water Body 5 with the 100-year recurrence interval, 24-hour duration rain event.

FIGURE 5

SURFACE WATER BODY 5 FLOW CHARACTERISTICS



The above pattern is expected for a relatively steep, embanked stream with a relatively small watershed. There is a short period of attenuation between start of rainfall and observed increased in flow, velocity, and depth. Unlike Surface Water Body 4, there is little difference in attenuation rates of flow, depth, and velocity. This is caused by the steeply embanked physical profile of the stream. Due to the constrained flow profile, flow velocities are relatively high, with a maximum flow rate of approximately 12 feet per second. The initial pulse flow passes through the stream quickly, with a relatively rapid drawdown to baseflow conditions. This stream is likely ephemeral, with zero flow during dry weather.

4.6 2-D PCSWMM MODEL SETUP

After completing the creating of the 1-D PCSWMM model and analyzing its results to confirm its accuracy, Tetra Tech created an integrated 1-D/2-D PCSWMM model to allow for the modeling of spatial inundation at the site. The 2-D portion of the model consists of a 2-dimensional mesh that is created to cover overland portions of the site. The 2-D mesh uses the DEM to include elevation attributes in the mesh. Within PCSWMM, the mesh is modeled as a network of conduits and junctions. Once the overland mesh is created, it can be linked to the existing 1-D model. As a result, the 1-D model is used to model in-channel hydraulics, but when flow overtops the banks of channels, it is conveyed into the 2-D mesh and accurately distributed based on the DEM elevation. This allows for the modeling of flow, water surface elevation, and depth for each cell within the 2-D mesh. Depth is particularly useful for analyzing inundation conditions and patterns at the site that can be used to guide green infrastructure and habitat restoration planning.

The creation of the integrated 1-D/2-D model for Municipal Farms proceeded in four steps after the 1-D model was completed. The steps are summarized below.

Step 1: Creation of 2-D Input Data

Within PCSWMM, the creation of a 2-D model requires a minimum of three base layers, including (1) the spatial bounds of the overland mesh; (2) a 2-D node layer that represents the junctions for the mesh; and (3) a source for elevation data. Tetra Tech defined the spatial bounds of the 2-D mesh to encompass the entire site, and minimize areas outside of site boundaries. This approach allows for the analysis of inundation over the entire site, while minimizing the area modeled since 2-D modeling typically requires a large amount of computer processing power. Tetra Tech created a 2-D node layer based on the spatial bounds layer, with a target resolution of 50-feet, with nodes placed in a regular hexagonal pattern. There are also several additional layers that can be included to fine-tune the creation of the overland mesh. For the Municipal Farms site, Tetra Tech included an obstructions layer, which is a spatial representation of areas where flow is physically blocked. For Municipal Farms, this primarily consisted of buildings located on the site. Tetra Tech also included a centerline layer, which is used to indicate the locations of channelized flow.

Step 2: Conduit Truncation

Since the 1-D model was included in the integrated 1-D/2-D model, the conduits included in the model for natural channels are defined by transects, which cover both in-channel and overland flow outside of channel banks to allow for the accurate conveyance of floods. Since the 2-D mesh will cover all overland portions of the site, it is important to eliminate the overland portions of the transects assigned to conduits to avoid double-counting flow in these areas. To accomplish this, all conduits within the spatial bounds of the 2-D mesh were truncated at their bank stations. This allows base flow to be transmitted via the conduits, with any bank overtopping introduced to the 2-D mesh.

Step 3: 2-D Mesh Creation

Once the 2-D nodes were created and conduit transects were truncated at bank stations in steps 1 and 2, it was possible to create the overland 2-D mesh. PCSWMM includes a tool to automatically generate the mesh based on 2-D node locations and the DEM. Once the mesh was created, there are several options for rendering the visual style of the mesh, including displaying mesh cell elevation, depth, and water surface elevation.

Step 4: Connect 2-D Mesh to 1-D Junctions

After creating the 2-D mesh, it is necessary to connect the mesh to the 1-D conduits in order to link the two portions of the integrated model, and allow water to flow between them. PCSWMM includes a tool to automatically link the 2-D mesh to selected 1-D junctions. Tetra Tech ensured that all 1-D junctions located within the spatial bounds of the 2-D mesh were linked to the mesh.

Long-Term Simulation Preparation

One purpose of the integrated 1-D/2-D model was to evaluate runoff and inundation conditions over a relatively long period of time using actual precipitation data. As discussed in Section 4.3, hourly precipitation data were obtained from NOAA Climate Data records of the Kansas City International Airport rain gauge. Tetra Tech chose to model actual conditions at the site from March 2010 through October 2010. This time period was selected due to its alignment with the typical growing season for vegetation, and its relatively frequent rain events. Simulations covering longer timespans could be completed using the current model, but would require intensive computer processing and very long runtimes. Once the rain gage data were incorporated into the model, it was also necessary to base upstream and downstream boundary conditions on actual recorded data. Upstream boundary conditions consisted of discharge for the Blue River and Round Grove Creek. Downstream boundary conditions consisted of stream gage elevations of the Blue River. Tetra Tech reviewed available stream gage and discharge data from the USGS National Water Information System (USGS 2017). Tetra Tech obtained stream gage and discharge data regarding downstream boundary conditions from the USGS Stream Gage historical data for the Stadium Drive monitoring location (USGS Site 06893578). No historical discharge datasets were available regarding upstream boundary conditions for the Blue River and Round Grove Creek. Given this lack of recorded data, Tetra Tech determined that an appropriate method for populating upstream discharge conditions within the PCSWMM model would focus on evaluating relationships in the approved

Hydrologic Engineering Centers – River Analysis System (HEC-RAS) model between the downstream discharge in the Blue River and (1) upstream discharge in the Blue River, and (2) upstream discharge in Round Grove Creek. Tetra Tech performed two linear regression analyses between downstream and upstream discharges in an effort to identify a consistent relationship between upstream and downstream discharge rates. Results of these regression analyses are shown below on Figures 6 and 7.

FIGURE 6

BLUE RIVER UPSTREAM DISCHARGE REGRESSION ANALYSIS

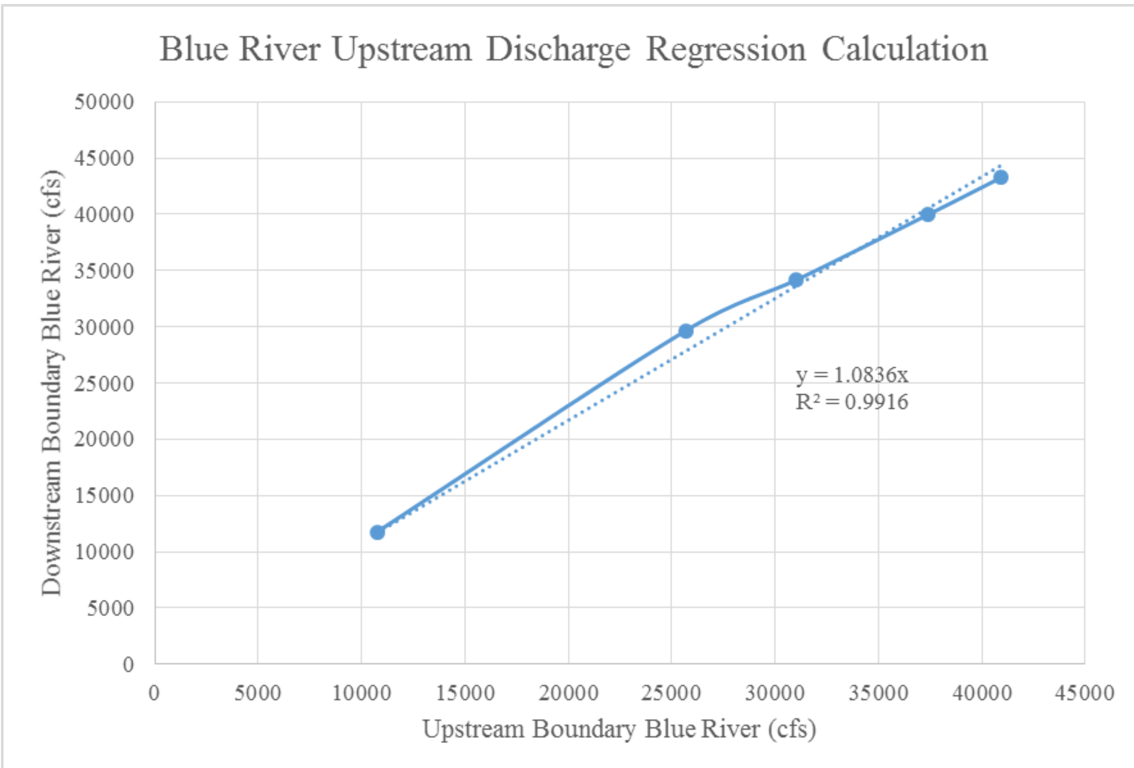
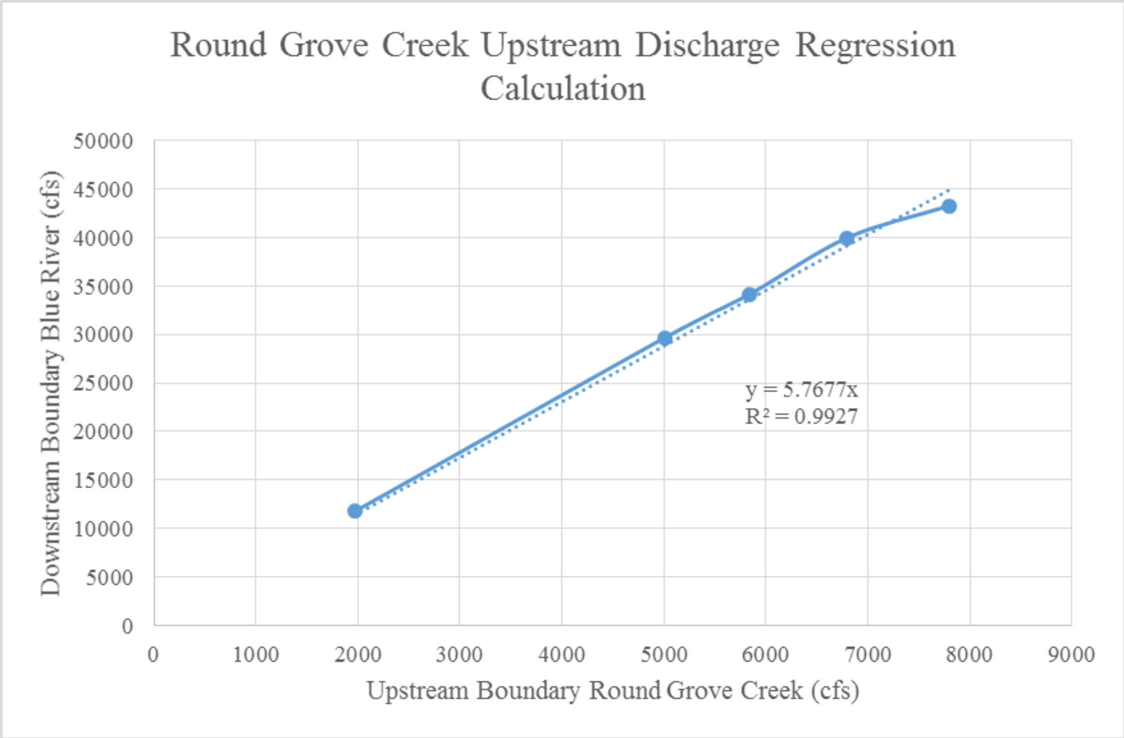


FIGURE 7

ROUND GROVE CREEK UPSTREAM DISCHARGE REGRESSION ANALYSIS



While the HEC-RAS models provided limited datasets for the regression analyses, the results indicate strong linear correlation between downstream discharge rates for the Blue River and upstream discharge rates for both the Blue River and Round Grove Creek. Because historical discharge data are available regarding downstream conditions on the Blue River, the linear regression equations generated during this analysis were used to calculate estimated upstream discharge rates for the Blue River and Round Grove Creek. This is a relatively simplified but appropriate approach for estimating upstream discharge within the current planning-level analysis for which the PCSWMM model is intended.

The calculated upstream discharge rates were then included in the PCSWMM model as time series, and the integrated 1-D/2-D model was applied to simulate real-world data, as well as multiple design storms. Results of these simulations are discussed in Section 4.7.

4.7 2-D PCSWMM MODEL RESULTS

Tetra Tech used the integrated 1-D/2-D Municipal Farms H&H model to simulate the 24-hour duration rain events with 1-, 10-, and 100-year recurrence intervals. Tetra Tech also performed a long-term simulation using real-world data for precipitation boundary conditions. The results from these simulations were used for two primary purposes: (1) the results of the 100-year, 24-hour precipitation event were compared to the FEMA 1% annual flood boundary to evaluate the accuracy of the model, and (2) results of all simulations were used to evaluate inundation patterns at the site.

FEMA 1% Annual Flood Boundary Comparison

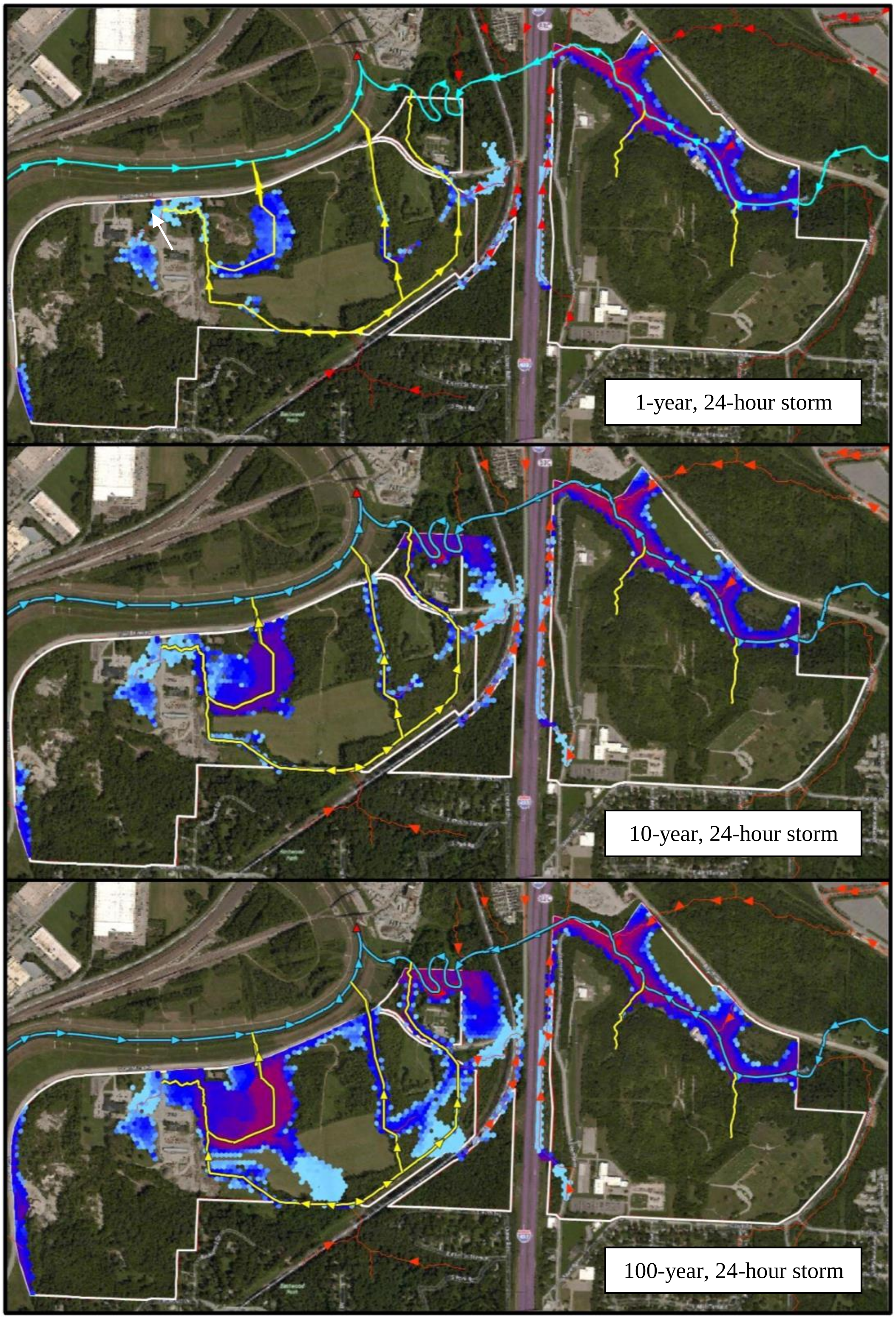
The primary means of evaluating the accuracy of the 2-D model of the Municipal Farms site consisted of comparing the spatial extent of inundation predicted by the model with the FEMA 1% annual flood boundary. Figure A-11 in Appendix A includes a visual display of this comparison. As displayed in this figure, the 2-D model of the site very closely matches the FEMA 1% annual flood boundary in the majority of the site. There are some spatial differences between the model and the FEMA boundary in the eastern portion of the West Subarea. This is likely caused by the fact that measured inlet elevations for the culvert beneath Coal Mine Road were not available, and the PCSWMM model uses assumed invert elevations based on the DEM and site observations. As a result, the 2-D model was considered an accurate representation of site conditions, with an understanding that additional refinement is possible based on the collection of more accurate elevation data for key site features.

Inundation Analysis

The primary utility of the 2-D PCSWMM model is that it allows for the analysis of inundation throughout overland areas at the site. This information is useful for the targeted implementation of green infrastructure, and for guiding habitat restoration plans based on hydrologic regimes. Tetra Tech analyzed inundation patterns for the 1-, 10-, and 100-year recurrence interval, 24-hour duration rain events. The spatial inundation patterns for each of these recurrence intervals is presented below in Figure 8. Within this figure, inundation depth varies from blue to red, with blue representing shallow inundation, and red representing deeper inundation. A more detailed comparison of the results of each storm event is presented in Figure A-12 in Appendix A.

FIGURE 8

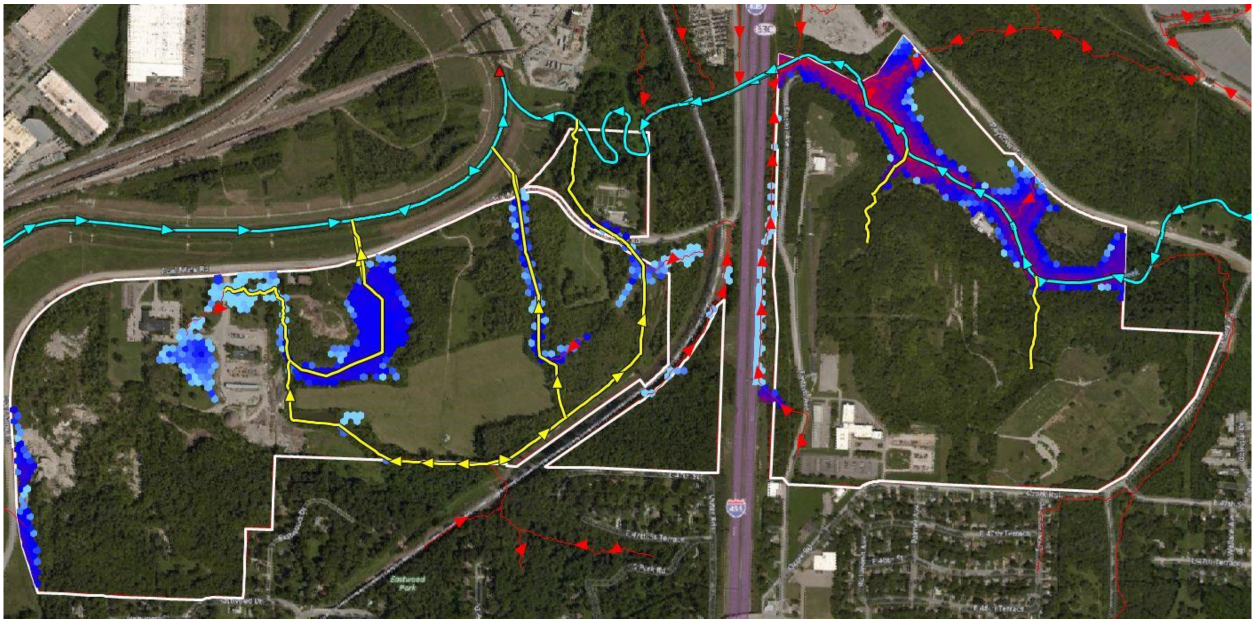
1-, 10-, AND 100-YEAR RECURRENCE INTERVAL INUNDATION RESULTS



These results indicate particular areas of inundation that can be targeted for green infrastructure and habitat restoration. From a broad perspective, it is clear that inundation is limited in the East Subarea, with inundated areas limited to the floodplain of Round Grove Creek. This lack of standing water is expected, and explained by the steep slopes present through much of the East Subarea, which allow overland flow to be quickly transmitted to Round Grove Creek. The West Subarea is more frequently inundated, with relatively large portions of the central and eastern areas inundated by 10-year and 100-year recurrence interval rain events. These model results are borne out by on-site observations, with ponding predicted at each of the water bodies visible in aerial photos, as well as ponding in the potential wetland area near the eastern boundary of the East Subarea. In addition to the design storm simulations discussed in the previous section, Tetra Tech also performed a long-term simulation using actual rain data from March 2010 through October 2010. This simulation also used actual stream gage records for the downstream boundary conditions, and calculated discharges for upstream boundary conditions. The maximum spatial extent of inundation for this real-world simulation is shown on Figure 9 below.

FIGURE 9

LONG-TERM RAIN INUNDATION RESULTS



Results of the long-term simulation are also available in a video format that allows a visual analysis of trends and patterns in inundation over time throughout the growing season. These inundation trends were considered during development of green infrastructure and habitat restoration plans, as discussed in Sections 5 and 6. Capability to conduct long-term simulations also will be highly useful for determining volume of water expectedly available for potential stormwater capture and reuse alternatives that could be implemented at the site. Long-term simulations of weather conditions can guide sizing of capture, conveyance, and storage components of potential reuse systems, and can be used to evaluate the balance between volume of captured stormwater and future irrigation demands. Before completion of these detailed analyses, to ensure accurate representations by the model of final discharge locations of each subcatchment that contributes to the site, an evaluation of the existing stormwater sewer system in areas surrounding the site should occur, as well as incorporation of that system into the PCSWMM model where necessary.

5.0 GREEN INFRASTRUCTURE PLANNING

Green infrastructure best management practices (BMP) encompass a wide range of technologies aimed at developing "green" stormwater strategies that contribute to watershed-wide sustainability. Each BMP should be carefully selected based on the unique conditions of the site and surroundings. This section reviews green infrastructure technologies best suited for implementation at the site in Section 5.1, and summarizes potential implementations of green infrastructure in Section 5.2. Because siting and selection of green infrastructure elements depend greatly on future iterations of site development plans, a broad conceptual plan is presented. This plan should be revisited and refined as site uses are finalized and locations of key site elements are determined.

5.1 REVIEW OF GREEN INFRASTRUCTURE TECHNOLOGY

This section summarizes commonly implemented green infrastructure technologies. For each technology, the following information is provided: (1) a brief description, (2) a list of benefits and limitations, and (3) a discussion of potential applications of the technology at the site, including site-specific constraints on implementation of that technology.

5.1.1 Bioretention/Rain Gardens

Bioretention involves presence of a shallow stormwater basin or landscaped area that utilizes engineered soils and vegetation to capture and treat stormwater runoff primarily via infiltration. Bioretention areas are also referred to as rain gardens. Plants are selected that can tolerate both drought and flood conditions.

<u>Benefits and Limitations</u>

- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate flow and reduce volume of stormwater runoff
- Good retrofit capability
- Applicable to small drainage areas
- Good for highly impervious areas
- Relatively low maintenance requirements
- Can serve as a four-season landscape feature
- Difficult to implement in areas with steep slopes
- Difficult to implement in areas with high water tables
- As an infiltrative technology, should not be installed in areas with existing soil contamination.

Implementation at Municipal Farms

Implementation of bioretention/rain gardens at Municipal Farms will be driven by future site usage. Rain gardens are typically relatively small structures targeting impervious areas that would produce large amounts of runoff. As a result, locations of rain gardens are best determined based on final development plans. At Municipal Farms, rain gardens would be especially useful if targeting runoff from roofs and parking areas. Rain gardens could also be used in conjunction with bioswales as part of a naturalized surface drainage network to slow down flows and allow for settling of suspended solids.

Primary constraints on implementation of rain gardens at the site are: (1) areas of the site have steep slopes and (2) large portions of the site have not been investigated for contamination. Steep slopes can render implementation of rain gardens logistically difficult, as locations of these must be on ground that is flat or has a shallow slope. However, bioretention can also be applied to address issues associated with runoff from steep slopes by siting rain gardens at transitions from steep to shallow slopes, providing a much-needed means to slow down overland flow and remove suspended solids as the flow exits steep slopes. Lack of information about large portions of the site is a serious constraint to proper siting and implementation. Because rain gardens function as an infiltrative technology, it is important to determine whether soil contamination is present that could be transmitted to groundwater via infiltration, or spread to other areas of the site during overflow events. To address this constraint, collection of soil samples for laboratory analysis should occur in areas where rain gardens may be installed, or rain gardens should be implemented in portions of the site where historical land uses were unlikely to result in contamination.

5.1.2 Bioswales

A bioswale is a modified swale that uses bioretention media—engineered soils and vegetation—to improve water quality, reduce runoff volume, and modulate peak runoff rate while also allowing conveyance of excess runoff through a linear system.

Benefits and Limitations

- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate flow, reduce volume of stormwater runoff
- Good retrofit capability
- Provides stormwater treatment and conveyance
- Can be part of infrastructure within transportation rights-of-way
- Can serve as a four-season landscape feature

- Check dams, weirs, or stepped cells must be installed in areas with steep slopes
- As an infiltrative technology, should not be installed in areas with existing soil contamination. Infiltration can be avoided by lining bioswales with an impermeable barrier

Implementation at Municipal Farms

Implementation of bioswales at Municipal Farms will be driven by future site usage. Bioswales are well-suited for use within the rights-of-way of linear transportation corridors. They perform similar functions as grassed swales by serving as a conveyance structure, and filtering and infiltrating runoff, but use of bioretention media enhances infiltration, water retention, and pollutant removal. Bioswales can supplement or even replace traditional gray infrastructure elements such as subsurface stormwater conveyance sewer systems. Runoff is reduced via infiltration and retention in soils, and interception, uptake, and evapotranspiration by plants. Bioswales may be used in conjunction with pretreatment BMPs such as filter strips, vegetated filters, or other sediment capturing devices to prevent sediments from accumulating in the swale. The enhanced properties of bioswales do not preclude need for discharge to another BMP such as a bioretention cell or a detention basin during a large storm event.

Constraints on implementation at the site are: (1) areas of the site have steep slopes, (2) large portions of the site have not been investigated for contamination, and (3) well-defined transportation (or stormwater conveyance) corridors are not present in many portions of the site. Bioswales can be costly to implement in areas with steep slopes, as installation of engineered weirs or stepped cells is typically necessary to maintain appropriate flow rates in order to avoid extreme erosion. Similar to rain gardens, bioswales should not be installed in areas not previously investigated for contamination. Bioswales are an infiltrative technology, meaning that soil contamination present in areas where they are installed could be transmitted to groundwater, further spreading contaminants. It is possible to avoid infiltration by overdigging bioswales and installing an impermeable barrier beneath bioretention media, but this approach is more costly than traditional installation. Finally, bioswales are typically implemented as linear conveyance features, but the current layout of the Municipal Farms site lacks clearly defined linear corridors for installation of bioswales. As future site plans are more fully developed, streets, driveways, and paved trails all could function as linear corridors along which bioswales could be implemented. Bioswales could then act as the primary means of stormwater conveyance at the site, as well as a means to capture runoff directly from adjacent infrastructure elements.

5.1.3 Permeable Pavement

Permeable pavements contain small voids that allow stormwater to drain through the pavement to an aggregate reservoir and then infiltrate into soil. They may be a modular paving system (concrete pavers, grass-pave, or gravel-pave) or poured in place solutions (pervious concrete, pervious asphalt).

Benefits and Limitations

- Alternative to impervious hardscapes
- Reduces impervious area of a site
- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate flow and reduce volume of stormwater runoff
- Pavement layer and aggregate subbase provide rapid infiltration; total volume retention depends on properties of native soils
- Only practical in areas that would otherwise be impervious surfaces, such as parking areas and driveways
- Difficult to implement in areas with high water tables
- As an infiltrative technology, should not be installed in areas with existing soil contamination.

Implementation at Municipal Farms

Permeable pavement is typically used to replace traditional impervious pavement for most pedestrian and vehicular applications except high-volume/high-speed roadways. Permeable pavements have been used successfully in pedestrian walkways, sidewalks, driveways, parking lots, and low-volume roadways. Several design options are available for using permeable pavements to intercept, contain, filter, and infiltrate stormwater on site. Permeable pavements can be installed across an entire street width or an entire parking area. Alternatively, they can be installed in combination with impermeable pavements to infiltrate runoff; several applications use permeable pavement in parking lot lanes or parking stalls to treat runoff from adjacent impermeable pavements. Permeable pavements are used to reduce volume of stormwater runoff by converting an impervious area to a treatment unit. The aggregate subbase provides water quality improvements through filtering and chemical and biological processes. Volume reduction and water treatment capabilities of permeable pavements are effective at reducing pollutant loads.

Constraints on implementation at the site primarily involve lack of data on soil contamination within large portions of the site. Because permeable pavement is an infiltrative technology, avoiding installation in areas with contaminated soil is important to preclude transport of contamination to groundwater. Other than contamination issues, constraints on implementation of permeable pavement are minimal, as permeable paving can be implemented at most locations where a roadway or parking area would be installed, based on future site plans. More detailed planning will be required to ensure that soils beneath possible locations for permeable pavement have sufficient infiltration capacity to provide storage of water that permeates the pavement. In areas with insufficient infiltration capacity, supportive infrastructure such as linear cisterns can be installed below permeable pavement to provide increased storage capacity, and allow stored stormwater to infiltrate slowly based on infiltrative capacity of surrounding soils. Permeable pavement is more costly than traditional impervious paving.

5.1.4 Tree Box

Tree boxes are urban applications of high-rate bioretention systems with vegetation and bioretention media contained in a precast concrete box designed for installation similar to that for a standard curb inlet.

Benefits and Limitations

- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate peak flow rates
- Good retrofit option to use with existing infrastructure
- Can be used in streetscape applications
- Primarily a water quality improvement device with limited volume retention.

Implementation at Municipal Farms

Utility of tree boxes at Municipal Farms depends on future development plans. If relatively large areas are developed with gray infrastructure, tree boxes would be a useful tool for intercepting and filtering stormwater as it enters the conventional stormwater conveyance system. However, if sizeable installations of gray infrastructure do not occur at the site, implementation of tree boxes would not be necessary, as these are best suited to treat relatively small areas with extremely high percentages of impervious area. Tree boxes are typically installed immediately upstream of a curb cut leading to a storm sewer inlet. The vegetation sits in a box of bioretention media through which street or parking lot runoff is filtered prior to entering the collection system. During low to moderate flows, stormwater enters through the tree box inlet, filters through the soil, and exits through an underdrain into the storm sewer system. During high flows, stormwater bypasses the tree box if it is full, and flows directly to the downstream curb inlet. Small trees and shrubs up to 15 or 20 feet tall that are tolerant of tree box conditions are suitable vegetation choices. Typically, tree boxes measure 6 by 6 feet, and treat runoff from 0.25 acre of impervious surface. Larger and smaller sized tree boxes are available, including double tree boxes that may accommodate canopy trees. A constraint on implementation at the site is that tree box utility depends on whether future site uses will include sizeable areas of gray infrastructure.

5.1.5 Vegetated Roofs

Vegetated roofs are used to introduce vegetation onto sections of roof to reduce imperviousness and absorb and filter rainfall. They are typically categorized as either extensive- or intensive-type vegetated roofs.

Benefits and Limitations

- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate flow and reduce volume of stormwater runoff
- Good retrofit capability as long as the existing roof is structurally able to support the vegetation and sub-layers
- Reduces impervious area
- Wood frame and unreinforced masonry buildings generally unable to bear additional load of a vegetated roof
- Design modifications required to install vegetated roofs on sloped roofs.

Implementation at Municipal Farms

A vegetated roof consists of a layer of soil media and vegetation that filters, absorbs, and retains/detains rain falling upon it. Rainfall that infiltrates into the vegetated roof is lost to evaporation or transpiration by plants, or, once the soil has become saturated, percolates through to the drainage layer and is discharged through roof downspouts. Under unsaturated conditions, vegetated roofs provide high rates of rainfall retention during small storm events. Lower rates of retention occur during larger storm events, but runoff volume and peak flow rate are reduced because of temporary storage in the soil. Vegetated roofs may cover large sections of a roof while maintaining access for utilities, maintenance, or recreation. Vegetated roofs are most often applied to buildings with flat roofs, but can be installed on roofs with slopes up to 30 degrees by use of mesh, stabilization panels, or battens. Slopes exceeding 30 degrees require special design considerations.

Constraints on implementation of vegetated roofs at the site are primarily uncertainty of future site uses and additional costs of green roof installation. While green roofs could be implemented on any new structures at the site, their impact would be larger with increased amount of impervious roof space added to the site—green roofs on multiple buildings or large buildings would exert a correspondingly larger impact than green roofs on smaller structures. Moreover, installation of a green roof is more expensive than a traditional roof, as a green roof requires additional structural support. Green roofs also require additional up-front cost of media and plant installation, and ongoing maintenance costs.

5.1.6 Tree Canopy

A tree canopy both intercepts rainfall and transpires water back into the air, thereby reducing stormwater runoff volume. In addition, tree roots improve infiltration capacity of soil, further reducing runoff potential. Trees may be placed strategically as a buffer, or in flow paths and depressions to adsorb runoff. Trees can also be introduced in urban areas as street trees, which can improve urban aesthetics, provide shade and cooling, and improve air quality in addition to providing stormwater benefits.

Benefits and Limitations

- Able to attenuate flow and reduce volume
- Provides shading and cooling, and improves air quality
- Cost-effective method of improving environmental conditions
- Requires adequate space for roots to allow for tree development and prevent root damage to structures in urban areas
- In the fall, deciduous trees produce leaf litter that may require management.

Implementation at Municipal Farms

Municipal Farms is in an advantageous position for this green infrastructure practice because much of the site is already covered by an established tree cover. Most green infrastructure practices aim to replicate effects of an established tree cover, and numerous studies have found that established tree cover is the most effective means of reducing stormwater runoff and mitigating pulse flows. Established root systems also reduce erosion caused by overland flow, reducing suspended solids and nutrient loads. Mulch resulting from leaf loss and natural tree stock loss can increase water retention, decrease erosion, improve soil stability, and insulate seeds and tree stock from temperature extremes. As a result, maintaining the existing tree cover at the site should be a top priority during redevelopment planning.

Two primary constraints on utilizing the existing tree canopy at the site for green infrastructure are: (1) future site development may necessitate removal of some tree canopy, and (2) portions of the tree canopy may be composed of invasive species. Future site development plans can be tailored to avoid unnecessary impacts on the existing tree canopy via careful planning. Where impacts are unavoidable, the tree canopy should be replenished in equal measure via required tree replacement plantings. This process may slightly shift portions of the site with tree canopy cover, but should not result in significant reductions in total area covered by tree canopy. Based on lack of active management of the forest community at the site in the past, portions of the tree canopy likely are composed of invasive tree species such as buckthorn. It is advisable to remove invasive species to prevent further encroachment on native species, which tend to provide more valuable habitat for the forest community. However, sudden, large-scale removal of invasive trees can negatively impact the tree canopy and green infrastructure services it provides. As a result, removal of invasive trees should not proceed until completion of a survey of the tree canopy, and then under management to prevent large-scale eliminations of canopy coverage.

5.1.7 Stormwater Wetland

Stormwater wetlands are constructed wetlands designed to mimic physical, chemical, and biological processes in natural wetlands. Constructed wetlands combine engineered flow regimes with vegetative habitat to promote settling of suspended solids, uptake of excess nutrients, and mitigation and storage of large-pulse flows. Constructed wetlands are typically sized based on site-specific physical limitations, as well as stormwater volumes.

Benefits and Limitations

- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate flow, reduce volume
- Can be designed to fit a large range of site conditions and flow volumes
- Provides valuable and visually appealing habitat
- Can be combined with other treatment practices to target water quality impairments
- Requires ongoing maintenance to maintain proper flow conditions and avoid establishment of invasive species.
- Can act as a trap for sediment-bound contaminants, presenting regulatory and disposal challenges during maintenance
- May require impermeable liner in areas with inadequate soils
- Can be difficult to maintain adequate storage capacity in areas with high water tables
- As a semi-infiltrative technology, should not be installed in areas with existing soil contamination.

Implementation at Municipal Farms

Constructed stormwater wetlands could be a useful application at the site. Existing pond and wetland areas demonstrate that soils in portions of the site are conducive to establishment of aquatic/wetland features and communities. Stormwater wetlands are particularly useful when sited near areas that generate a large amount of runoff, as their relatively large storage capacity is especially efficient at mitigating pulse flows. Stormwater wetlands are useful tools for improving water quality, and when well-designed, can function as natural filters for suspended solids, excess nutrients, and some contaminants that readily sorb to sediment or vegetation. This propensity for improving water quality would allow use of stormwater wetlands as a source of protection for existing surface water bodies at the site. Constructed wetlands could be used as a focal point of a naturalized treatment train that would aim to improve quality of water before it enters the large pond features at the site. Additional investigation of surface waters at the site would provide useful information about current impairments to the surface waters, so that treatment trains could be designed to target key sources of impairment. Stormwater wetlands could also be utilized as a treatment alternative for stormwater that is then captured and used for irrigation at the site.

Two primary constraints on implementing constructed stormwater wetlands at the site are: (1) need to avoid constructing wetlands in contaminated areas, and (2) ongoing maintenance requirements and potential regulatory requirements. First, a full evaluation of whether constructed wetlands will be built in contaminated areas is important because these act as a centralized capture location for water before it travels to other locations, and also function as an attractive habitat feature. Intentional implementation of stormwater wetlands in contaminated soils is appropriate under the following conditions: (1) contaminants present can be reduced via phytoremediation, and (2) contamination levels are appropriate for an attenuated natural mitigation approach. Under this scenario, the stormwater wetland can be used both to improve stormwater conditions at the site and to aid in natural remediation of contaminated soils. However, if a stormwater wetland is built in heavily contaminated soils, stormwater passing through the wetland could transmit contamination farther downstream, exacerbating contamination issues by spreading contaminants to a larger area. Additionally, if built in a heavily contaminated area, stormwater wetlands can act as an attractive nuisance, by visually appearing as a quality habitat area to organisms. As organisms populate the wetland, they would be exposed to contamination, potentially triggering bioaccumulation and biomagnification processes, spreading contaminants throughout the local ecosystem, and causing cascading impacts up the trophic system.

The second constraint to implementing stormwater wetlands at the site involves ongoing maintenance requirements typically associated with constructed wetlands. Ongoing maintenance requirements include invasive species control and native plant maintenance/replacement. If engineered flow controls are used, these also typically require ongoing maintenance to ensure proper function. Type of maintenance depends on specific flow control technology utilized. A less frequent but more labor-intensive maintenance requirement includes removal of excess sediments deposited in the wetland over time. Stormwater wetlands are often designed with a sedimentation forebay to limit the amount of sediment deposited throughout the wetland. This allows for targeted sediment removal in a small portion of the feature, and avoids disturbing the benthic community throughout the wetland following removal of sediment. Reuse or disposal of removed sediment must also be considered. The sediment must be sampled for chemical contamination prior to reuse or disposal. If contamination is present, cost of disposal in compliance with regulatory requirements can be high.

5.1.8 Stormwater Capture and Reuse

Stormwater capture and reuse can involve several other green infrastructure technologies discussed in this section with an end goal of capturing stormwater runoff and using it for another purpose. Captured stormwater is often stored in a large cistern, storage tank, or storage pond, and used for purposes such as irrigation or interior and exterior gray water applications.

Benefits and Limitations

- Uses physical processes to remove a variety of pollutants
- Able to attenuate flow, reduce volume
- Can be designed to fit a large range of site conditions and flow volumes
- Provides usable water at low cost
- Can be combined with other treatment practices to target water quality impairments
- Requires widespread infrastructure development to capture water from large areas
- Water should be tested prior to reuse to ensure it meets appropriate water quality standards based on intended final use.

Implementation at Municipal Farms

Stormwater capture and reuse could be a highly useful technology at the site, given the intended urban agriculture practices there. Stormwater runoff from areas of the site not used for agriculture could be routed to a central location for storage and eventual distribution to agricultural areas via an irrigation system.

The stormwater capture system could be integrated with other green infrastructure technologies to provide water quality improvement before the water is stored and distributed for reuse. Smaller, more localized capture and reuse systems such as rain barrels and small cisterns could also be established in portions of the site where connection to a central system is impractical. These systems would have smaller capacity based on a limited drainage area, but would require less intensive infrastructure installation.

Two primary constraints to implementation of stormwater capture and reuse technologies at the site are: (1) relatively intensive infrastructure development would be required to capture runoff from large portions of the site and direct it to a central location for reuse and redistribution, and (2) contamination concerns must be further evaluated and addressed prior to reuse of captured runoff. First, for stormwater reuse to be implementable on a relatively large scale for a purpose such as agricultural irrigation, a large amount of water is required. To meet this need, it would be necessary to capture runoff from large areas and then transport it to a centralized storage location.

This transmittal of runoff can be accomplished via (1) traditional gray infrastructure or (2) a network of other green infrastructure technologies, such as bioswales or rain gardens. The site poses advantages and disadvantages to both approaches. Utilizing traditional gray infrastructure would limit the amount of time that runoff is in direct contact with site soils. This is a benefit at the site, where past site uses may have contaminated site soils, and widespread investigations of soil contamination have not been completed. However, installation of a traditional gray storm sewer system is costly and labor intensive, and would not provide water quality improvements as runoff is transmitted from source to destination. Alternatively, use of green infrastructure for runoff conveyance would maximize contact between runoff and site soils. Given past site uses, this is a concern at the site, and would require additional sampling to ensure that soils along the conveyance route would not contaminate runoff coming into contact with them. Benefits of implementing green infrastructure for runoff conveyance include water quality improvement as suspended solids settle out while passing through bioswales/rain gardens, habitat creation, and less intrusive installation activities than those necessary during gray infrastructure installation.

It is also important to consider possible impacts of contamination on water reuse applications at the site. Two primary concerns relate to capturing contaminated water and redistributing it via irrigation at the site: (1) physically spreading contamination to new locations that previously may not have been impacted, and (2) exposing new receptors to contamination, including agricultural workers and potentially consumers via uptake into produce. To avoid exacerbating existing contamination issues, testing of water to ensure it meets relevant standards prior to reuse likely would be necessary, and if required as well, providing some form of water treatment prior to reuse. Water treatment could take many forms depending on results of additional site investigations. Green infrastructure technologies such as stormwater wetlands and bioswales may provide sufficient treatment, but inclusion of additional treatment options, such as activated carbon chambers, may also be necessary.

5.1.9 Infiltration Trench

An infiltration trench is an excavated trench lined with filter fabric and backfilled with stone to allow stormwater to infiltrate into subsurface soils.

Benefits and Limitations

- Uses biological, chemical, and physical processes to remove a variety of pollutants
- Able to attenuate flow, reduce volume
- Useful for space-limited applications
- Can be used within transportation rights-of-way
- Needs appropriate pretreatment for optimal effectiveness.

Implementation at Municipal Farms

Infiltration trenches are well suited for roadway medians and shoulders, and applications with limited available space. These allow reduction in volume of stormwater discharges by promoting infiltration and allowing runoff to percolate into native soils through sides and bottom of the trench. Infiltration trenches are designed to reduce volume of runoff while providing water quality improvements through pollutant removal mechanisms such as filtration, sorption, and chemical and biological degradation. They also allow for groundwater recharge. Infiltration trenches are typically used in conjunction with pretreatment BMPs such as filter strips or other sediment capturing devices to prevent sediments from clogging the trench. At the site, infiltration trenches could be used to capture runoff from permanent impermeable structures such as roadways and buildings. Under this scenario, runoff from more permanent installations would be routed through a pretreatment technology such as a bioswale or filter strip, and then directed to an infiltration trench to promote groundwater recharge and reduce pulse flows.

The primary constraint on implementing infiltration trenches at the site is potential to infiltrate stormwater through contaminated soil. As discussed for several other green infrastructure technologies, this could transmit contamination to groundwater and increase the spatial footprint of contamination. As a result, sampling should occur at locations that may be targeted for infiltration trenches to ensure that trenches are not placed in contaminated soils.

5.1.10 Dry Wells

Dry wells are similar to infiltration trenches, but are better suited to areas with extremely limited space. Dry wells are typically gravel or stone filled pits located to catch stormwater from roof downspouts or paved areas.

Benefits and Limitations

- Able to attenuate flow, reduce volume
- Useful for space limited applications
- Promotes infiltration
- Not appropriate for treating runoff from large impervious areas

Implementation at Municipal Farms

A dry well typically consists of a pit filled with large aggregate such as gravel or stone. Dry wells may also be constructed with a perforated drum placed in a pit and surrounded with stone. These dry well structures are available as commercial products. Dry wells capture and infiltrate water from roof downspouts or paved areas. The surface of the dry well is typically at or just below existing grade, and it may be covered by grass or another surface. Dry wells are suitable for treating small impervious areas and may be useful on steeper slopes where infiltration trenches or other facilities cannot be installed. At the site, dry wells could be installed to capture runoff from small structures such as equipment sheds, garages, or portions of greenhouses.

The primary constraint on implementing dry wells at the site is potential to infiltrate stormwater through contaminated soil. As discussed for several other green infrastructure technologies, this could transmit contamination to groundwater and increase the spatial footprint of contamination. As a result, sampling should occur at locations that may be targeted for dry wells to ensure that these are not placed in contaminated soils.

5.1.11 Sand Filter

A sand filter is a treatment system used to remove particulates and solids from stormwater runoff through filtering and physical pollutant removal.

Benefits and Limitations

- Uses physical processes to remove pollutants
- Occupies a small footprint relative to drainage area treated
- Good retrofit capability
- Cannot attenuate volume if stormwater is unable to infiltrate into the native soils

Implementation at Municipal Farms

A pocket sand filter is designed to improve water quality from impervious drainage areas by filtering runoff through sand. It is primarily used at small sites to treat water quality volume of runoff. Pollutant removal in pocket sand filters occurs primarily through straining and sedimentation. Pocket sand filters are designed slightly differently than conventional flow-through systems. Stormwater diverted to the system travels through a flow spreader, across a grass filter strip, and into a plunge pool. From the plunge pool, the stormwater flows into the sand filter, which is covered with a soil layer and grass cover or stone. Often the water quality volume of runoff is temporarily stored above the filter bed. Once the stormwater flows through the pocket sand filter, it can infiltrate into native soils or be collected in an underdrain.

Pocket sand filters are well suited to treat runoff from small impervious drainage areas. At the site, sand filters could function in a variety of ways. These could be deployed in conjunction with infiltration trenches or dry wells in areas with limited space to prevent clogging of trenches or wells. They could also be deployed as pretreatment elements in a larger treatment train, such as a stormwater wetland to remove large suspended particles before these are deposited within the wetland.

The primary constraint on implementing sand filters at the site relates to the eventual destination of water passing through the filter. In most cases, this water is either infiltrated or conveyed to another element in a treatment train. As discussed above, it is important to avoid infiltrating water through contaminated soils, and to prevent spread of contamination to new locations via conveyance of contaminated water without proper treatment.

5.2 CONCEPTUAL GREEN INFRASTRUCTURE PLAN

Tetra Tech has created a conceptual green infrastructure plan that would implement several green infrastructure technologies outlined in Section 5.1. Importantly, this plan is conceptual, and undoubtedly would be revised as additional data are acquired, and as final uses for the site are determined. Intent is to avoid contaminated areas and to target new impervious surfaces created by redevelopment.

In developing the green infrastructure plan, Tetra Tech referenced information acquired from an examination of site history, environmental investigations, and application of H&H modeling. The following three categories of goals for green infrastructure development at the site are conveyed within the plan: (1) Redevelopment Best Practices, (2) Capture and Reuse, and (3) Targeted Infiltration/Runoff Mitigation. Each of these categories is discussed in detail in the following sections, and applications of these to the site are depicted on Figure A-13 in Appendix A. This figure shows a tentative layout for implementation of a naturalized stormwater capture and reuse system; identifies high-runoff subcatchments within site boundaries that should be targeted with infiltrative green infrastructure technologies where possible; and focuses on four key priority treatment areas where site conditions merit focused actions to mitigate pulse flows and reduce stormwater pollutant loads.

5.2.1 Redevelopment Best Practices

During refinement and finalization of redevelopment plans for the site, several green infrastructure technologies merit attention. Although many green infrastructure technologies can be implemented as retrofits to traditional development approaches, cost savings can be realized by planning for green infrastructure implementation early in the redevelopment process. Based on anticipated future site uses, the following three best practices should be implemented where possible:

1. **Maintenance of Existing Tree Canopy:** An established tree canopy and associated leaf litter and soil conditions are among the most effective means of reducing pulse flows, minimizing runoff volume, and reducing erosive overland runoff. A large, well-established tree canopy well suited to regulate overland flow conditions is present at the site. As redevelopment plans are finalized, care should be taken to minimize removal, and especially clear-cutting, of the established tree canopy. Where clearing of the tree canopy is unavoidable, native landscaping practices should be implemented, including replanting of native trees where possible.
2. **Minimization of New Impervious Surfaces:** Redevelopment plans likely will include new impervious surfaces at the site (at access roads, parking areas, and new structures). Recommendation is to minimize new impervious structures via a multi-faceted approach.
    - <u>Access Roads</u>. Along access roads, bioswales and rain gardens could be implemented in tandem as roadside green infrastructure to capture and infiltrate runoff from impervious road surfaces. It may also be possible to utilize a bioswale network to transport runoff to central stormwater capture locations for reuse, depending on the layout of future access roads. Importantly, before implementation of infiltrative technologies such as rain gardens and bioswales, the area where they will be installed should be investigated for contamination to avoid transporting contamination to groundwater or new areas of the site.
    - <u>Parking Areas</u>. Parking areas can be designed to implement pervious pavement technology to avoid introducing new impervious surfaces to the site. In areas where introduction of pervious pavement would be impractical or cost prohibitive, infrastructure and landscaping plans can be tailored to capture runoff from parking areas to mitigate large pulse flows. In particular, implementation of rain gardens and sand filters adjacent to parking areas would be effective in removing pollutants and suspended solids from parking area runoff, and mitigating large pulse flows. If soil conditions (inadequate infiltration capacity or contamination) render implementation of infiltrative technologies impractical, traditional gray stormwater infrastructure can be introduced with adequate storage capacity to reduce pulse flows.
    - <u>New Structures</u>. Two primary approaches to introduction of new structures can minimize effects of impervious roof surfaces. The first—green roof technology—must be considered early in the planning process because the additional weight of a green roof would necessitate adjustments to the structural engineering of a building. Costs of green roofs likely render them impractical on numerous structures. These are often best suited to large, high-visibility structures. The second approach would be suitable at other, lower-

profile structures, where landscaping plans can be tailored to improve water quality and mitigate pulse flows from runoff from impervious roofs. Moreover, in planning for roof runoff capture early in the development process, roof slope, gutter system design, and stormwater capture or infiltration technologies can all be designed and implemented to best suit site-specific conditions.

3. **Maintenance of Site-Wide Water Balance:** Tetra Tech recommends developing and maintaining site-wide water balance during all phases of redevelopment planning and implementation (see Section 7.1 for additional details). Maintenance of a site-wide water balance will allow analyses of wide-ranging conditions and effects of development actions. Smaller, development-specific water balances can be used to more directly gauge results of specific actions. These small-scale water balances will be highly useful for ensuring that sufficient green infrastructure capacity is included in redevelopment plans. PCSWMM models developed for the site are useful for developing and tracking water balances. As development plans are finalized, the models can be revised and updated to focus on small portions of the site that would be impacted by specific redevelopment plans. Ensuring that discharge locations for all subcatchments are accurate in the model will require acquisition of additional information regarding storm sewer systems in the areas surrounding the site.

5.2.2 Capture and Reuse

Based on current conceptual redevelopment plans for the site and discussions with the City, Tetra Tech understands that all current plans for future site use include a focus on urban agriculture. This intended site use presents an ideal opportunity for implementing a stormwater capture and reuse system, with captured stormwater to be used for irrigation by urban agriculture facilities. As described in Section 5.1, large stormwater capture and reuse systems typically convey stormwater from a relatively wide area to a central storage location—most frequently a via traditional gray infrastructure storm sewer system or systems of trenches and swales. Depending on intended end use of captured stormwater, the storage location often includes some means for water quality treatment.

Tetra Tech utilized the results of the H&H model and information gathered during a site visit to evaluate the site for implementation of a stormwater capture and reuse system. To begin this evaluation, Tetra Tech analyzed general flow and inundation conditions in both the East and West Subareas. The following discusses potential viability of capture and reuse systems in the East and West Subareas, followed by two general approaches to develop such a system.

<u>East Subarea</u>

Utilizing both the 1-D and integrated 1-D/2-D PCSWMM models, Tetra Tech determined that runoff in the East Subarea typically is conveyed rapidly into steep, embanked streams that discharge to Round Grove Creek. Areas with inundation in the East Subarea are minimal, with most inundation limited to Round Grove Creek’s floodplain.

The DEM provides additional information on the cause of these flow conditions: large portions of the East Subarea are relatively steeply sloped, with two notable ravine areas that channel most runoff to Round Grove Creek. Implementation of a stormwater capture and reuse system in the East Subarea would be difficult because of large differences in elevation, flashy flow conditions, and lack of consistent inundation. While the ravines in the East Subarea conveniently concentrate runoff into relatively small channels that could be captured, this concentration of runoff occurs rapidly over steeply-sloped flow courses. By the time runoff has been concentrated within the ravines and reaches an area with a gentle enough slope for central storage, it has reached the floodplain of Round Grove Creek in the northernmost portion of the East Subarea, with elevations ranging from 752 to 760 feet AMSL. By comparison, the areas of the East Subarea currently targeted for agricultural development are on a plateau in the southeastern portion of the East Subarea. Elevations in this targeted agricultural area range from 880 to 925 feet AMSL. This would result in a central capture and storage location widely separated both spatially and vertically from areas where captured stormwater would be reused. In particular, the vertical pump head required to pump water from the Round Grove Creek flood plain to the plateau in the southeast portion of the East Subarea is impractical. For these reasons, a large stormwater capture and reuse system was discarded as a viable green infrastructure approach for the East Subarea. It would be possible to implement smaller, more localized stormwater capture and reuse technologies in the southeastern area where agricultural activities are planned. In this scenario, new structures and impervious surfaces such as greenhouses and storage facilities could be planned to route roof runoff to rain barrels and cisterns for reuse in their immediate vicinity.

West Subarea

Conditions for capture and reuse in the West Subarea differ significantly from those in the East Subarea. Outside of the southwestern corner, the West Subarea is relatively flat. An analysis of flow conditions based on both the 1-D and integrated 1-D/2-D PCSWMM models indicated that most runoff in the West Subarea is eventually routed to two central locations: (1) the large pond in the central portion of the subarea (Surface Water Body 1) and (2) the linear pond in the eastern portion of the subarea (Surface Water Body 2). Within each of these two water bodies, flow conditions are relatively stable, with low-velocity flow conditions even during 100-year recurrence interval rain events. Inundation is also relatively widespread in the West Subarea, as depicted on Figure A-12 in Appendix A.

Both surface water bodies are also fed by an interconnected network of existing channels that gather overland runoff from the site and subwatersheds contributing to the site from outside site boundaries to the south, and concentrate the runoff into Surface Water Body 1 and Surface Water Body 2. Because of differences in elevation at key junctions in this network of contributing channels, most runoff is routed to

Surface Water Body 1. Based on the DEM and H&H model results, large rain events (approximately 10-year recurrence interval or larger) are required for water elevations in the channel network to rise high enough to induce water within the network to flow to Surface Water Body 2. As a result, water in Surface Water Body 1 likely circulates better and stagnates less than water in Surface Water Body 2. This model result is supported by on-site observations and historical aerial photo review, which indicate that Surface Water Body 2 is much more prone to algal blooms and pond scum than Surface Water Body 1.

The West Subarea is well suited for a large, centralized stormwater capture and reuse system because the existing network of channels concentrates stormwater runoff into two central locations with ponded waterbodies that act as storage nodes—in fact, to a significant extent, the West Subarea already operates as an effective stormwater capture system.

Approaches to Implement Capture and Reuse

After determining that the West Subarea is well-suited for implementation of a stormwater capture and reuse system, Tetra Tech identified two general approaches to develop this system at the site, each with unique advantages and constraints.

Because no site water quality data are available, Tetra Tech assumes necessity for a method to treat and improve stormwater water quality prior to reuse as irrigation water. Results of future investigations could eliminate need to treat this water, but for now, an assessment of water quality on the site and presentation of treatment options for proposed capture and reuse systems seem prudent.

5.2.2.1 Approach 1: Conversion of Existing Ponds to Naturalized Storage Systems

This approach to stormwater capture and reuse focuses on exploiting current conditions at the site in a manner allowing existing stormwater conveyance networks to concentrate runoff in Surface Water Body 1 and Surface Water Body 2, thus converting these water bodies to naturalized stormwater storage locations. A pumping system would be installed to transport captured water for reuse as irrigation water in urban agriculture areas.

Capture Method: The current natural drainage system in the West Subarea would be used to capture and convey runoff to central storage locations.

> <u>*Advantages:*</u> Three key advantages of using the natural drainage system for capture and conveyance of stormwater are: (1) cost savings, (2) technical implementability, and (3) improvements of habitat and water quality.
>
> Cost savings are readily apparent and significant—installation of a new conveyance system that could utilize gray or green infrastructure would not be necessary, precluding costs of detailed engineering and intensive earthmoving.
>
> This approach is also readily implementable because the site's natural features already adequately capture and convey stormwater to central storage locations (Surface Water Bodies 1 and 2). Rerouting natural runoff patterns could be difficult to implement, requiring careful design and perhaps regrading of large portions of the site. At a heavily wooded site like Municipal Farms, any large-scale regrading activities likely would be difficult to implement, would be costly, and would necessitate clear-cutting of swaths of established canopy, affecting the amount of runoff generated at the site and eliminating potentially valuable habitat.
>
> Finally, utilizing the natural drainage network could improve water quality and habitat within the natural drainage channels on the site. Transmitting stormwater via natural channels would offer greater opportunity for water quality improvement during conveyance than would use of traditional gray infrastructure; for example, during conveyance within naturalized channels, vegetation would filter out and thus decrease suspended solids, and suspended solids would settle out within pooled areas. These same features could also function as valuable aquatic habitat at the site, and could be attractive visually for future recreators. Based on visual observations, the drainage channels are not currently high-quality aquatic habitat. However, over time, habitat restoration projects along the drainage channels could introduce and maintain more natural stream flow conditions. These restoration projects should focus on implementing natural stream structures and flow conditions, which would provide varied habitat and opportunities for water quality improvement.
>
> <u>*Constraints:*</u> Two primary constraints to use of the natural drainage system in the West Subarea for capture and conveyance of stormwater are: (1) permitting requirements and (2) lack of data regarding conditions within the drainage channels. Permitting may be required if construction is necessary within/near the existing channels, as portions of the channels are currently listed as wetlands within the USFWS NWI (see Figure A-14 in Appendix A). As a result, channel realignment, capacity expansion, or habitat improvement projects within portions of the natural drainage system would necessitate a more intensive permitting process. Lack of data regarding current conditions in the drainage channels is also a key constraint. As discussed in Section 5.1, it is important to recognize whether contamination issues are present in any areas where stormwater will be conveyed or infiltrated. Currently, no information is available regarding sediment and surface water conditions within the natural drainage channels in the West Subarea. Before these channels are used as a primary conveyance route for a capture and reuse system, they should be investigated to determine whether they would introduce stormwater containing elevated levels of contamination, and whether flow conditions could cause resuspension of sediments and any associated contaminants.

Storage Method: Existing ponded surface water bodies (Surface Water Bodies 1 and 2) would be used as naturalized storage ponds. Surface Water Body 1 would act as the primary storage node, with the option to link Surface Water Bodies 1 and 2 to provide additional storage capacity and flow circulation.

Advantages: The primary advantages of using the existing ponds as storage nodes for capture and reuse system are: (1) potential cost savings, (2) utilization of natural runoff conditions, and (3) location.

First, significant cost savings would result if installing a new large storage pond or gray infrastructure storage system (e.g., storage tanks) proves unnecessary.

Advantages 2 and 3 are interrelated, because natural runoff conditions and topography of the West Subarea indicate the optimal location for storing water in this area. Because runoff will naturally run to low points on the site, use of existing ponds at those low points avoids need for comprehensive regrading, or installation of complex infrastructure systems to reroute water to a new location. Locations of existing ponds are also conducive to use of these as storage nodes. Based on existing plans for redevelopment, the area between Surface Water Bodies 1 and 2, as well as the area east of Surface Water Body 2, would be the primary locations for urban agriculture in the West Subarea. Both of these areas are adjacent to existing ponds, and could be serviced with irrigation water, given relatively limited pumping distances and vertical head requirements.

Surface Water Bodies 1 and 2 are also relatively near each other, with similar bank elevations. A possible option for expanding storage capacity would be to link the two water bodies via either a surface channel or subsurface piping, and to establish a small pumping system for circulation of water between the two ponds. This would also help maintain adequate storage reserves in both ponds and improve circulation in both ponds. Improved circulation would improve water quality in both ponds, but most notably in Surface Water Body 2, by reducing stagnant conditions and helping to prevent large algal blooms.

Constraints: Three primary constraints to use of existing ponds in the West Subarea as storage for a capture and reuse system are: (1) permitting requirements, (2) lack of information on current conditions in the ponds, and (3) maintenance requirements. The first constraint is practical. A preliminary review of available information indicated likely inclusion of portions of both ponds in the USFWS NWI, meaning that activities impacting conditions in the ponds would fall under the purview of USACE Section 401 for impacts on wetlands, and possibly USACE Section 404 on placement of fill in a jurisdictional wetland. The capture and reuse system may also fall under municipal separate storm sewer system (MS4) regulation administered by the City under direction from EPA. Before pursuing this storage option, consultations should occur with each potential permitting agency to identify and devise methods for addressing obstacles to implementation.

Regarding the second constraint, because of intended reuse of captured stormwater for irrigation of urban agriculture, water stored in the ponds likely will directly contact workers and produce grown at the site eventually to be consumed. Thus, determination is necessary as to whether water stored in the ponds is exposed to elevated levels of contamination that then could be transported to new areas and cause new exposure via irrigation. A comprehensive assessment of sediment and surface water conditions would be necessary to evaluate potential for transporting contamination via irrigation. Depending on sediment contaminant levels, remediation may be necessary to allow use of the ponds as storage nodes. Remediation would likely consist of sediment removal and disposal, which could be costly. Remediation may also provide the opportunity for tailoring physical layouts of the ponds to meet a target storage capacity based on expected irrigation use. Pump systems could also be installed during remediation activities. Based on results of pond assessments, regular sampling of irrigation water may be advisable to ensure safety of agricultural workers and consumers; that leads to the final constraint of ongoing maintenance requirements.

Use of the ponds as storage facilities would require maintenance considerations unnecessary for a more traditional storage system. Maintenance of vegetation in and around the pond would be required to prevent fouling of any pipe/pump intakes. Inclusion of a pump intake designed to avoid impact on aquatic organisms and to prevent pump fouling would be necessary.

Treatment Method: Stormwater wetlands could be constructed near the upstream terminus of storage nodes to provide natural treatment of stormwater. While an assessment of runoff water quality would be necessary to determine potential effectiveness and develop a site-specific treatment approach, Tetra Tech anticipates that reductions in typically regulated total maximum daily load (TMDL) parameters will help improve quality of water within the storage nodes and any water discharging to the Blue River.

Advantages: Two primary advantages to use of stormwater wetlands for water quality treatment are: (1) natural treatment capacity and (2) attractive habitat creation. Stormwater wetlands utilize natural physical and biochemical processes to improve quality of water that passes through them. These processes include filtering and settling of suspended solids, uptake and deposition of nutrients, and ability to target other contaminants of concern. At the site, these natural treatments could be sufficient to allow direct reuse of runoff for irrigation. The second advantage, relating to habitat, involves active promotion within stormwater wetlands of native vegetation and use of the area by local fauna for habitat. Thus, this naturalized treatment process can result in visually appealing areas that offer opportunities for recreation and education.

Constraints: Three primary constraints to implementation of stormwater wetlands for water treatment at the site are: (1) permitting requirements, (2) lack of information on current conditions in areas possible for wetlands, and (3) ongoing maintenance requirements. Permitting requirements for conversion of portions of the existing ponds to stormwater wetlands could be substantial, and would require close coordination with permitting agencies. Optimal locations of stormwater wetlands in the West Subarea are currently designated as wetlands in the USFWS NWI, and are hydraulically connected to the Blue River—indicating likely inclusion of wetland creation under USACE Section 404 and 401 authority. The USACE Kansas City district does maintain two Nationwide permits that could be relevant to stormwater wetland creation, including Nationwide Permit 27 and Nationwide Permit 43. These permits specify streamlined permitting processes for ecological restoration and stormwater management/green infrastructure projects, respectively. Stormwater wetland creation under either of these Nationwide permits would significantly simplify the permitting process. The second constraint again involves lack of data regarding current conditions at potential locations of stormwater wetlands. Installations of stormwater wetlands should generally not occur within contaminated areas to avoid creation of an attractive nuisance issue. Also important is to identify contaminants that runoff from other portions of the site could introduce to the wetlands, in order to reduce contaminant levels where possible in those wetlands. Finally, stormwater wetlands require ongoing maintenance to maintain flow control structures, prevent establishment of invasive plant species, and maintain cultivated native plant species.

5.2.2.2 Approach 2: Installation of Conventional Storage Systems

This approach is far more conceptual, as implementation of it would depend heavily on future layout of the West Subarea. As a result, analysis of advantages and constraints of each key element of the capture and storage system is broader, and should be refined as site redevelopment plans are finalized.

Capture Method: For a conventional storage system, traditional gray infrastructure storm sewer systems likely would be used to capture and convey water to a central storage location. The layout of the storm sewer system would depend greatly on the final redevelopment plan, as significant cost and time savings can be realized by installing storm sewers at the same time and at the same locations as other infrastructure (typically roadways). As a general rule, where possible, the storm sewer system should follow the natural topography of a site to avoid extensive regrading and pumping requirements.

> *Advantages:* The primary advantage of a gray infrastructure storm sewer system is possibility of isolating stormwater from contact with site soils once the water enters the sewer system. Given current ignorance of potential contamination in soils in large portions of the site, utilization of a storm sewer system would limit need for environmental investigations and sampling.
>
> *Constraints:* Three primary constraints to implementation of a traditional storm sewer system for capture and conveyance of runoff are: (1) cost, (2) intrusive installation, and (3) lack of green infrastructure benefits. Cost of installing a storm sewer system would be substantial compared to that of utilizing pre-existing natural channels at the site. Moreover, installation of a storm sewer system is a relatively intrusive process, requiring disturbances within surrounding areas to allow access by heavy machinery, and often requiring trenching along the length of the storm sewer system. This intrusiveness could damage current habitats on site, which may trigger extensive permitting requirements. In addition, if infeasible to install the storm sewer system in a manner closely following existing site topography, large portions of the West Subarea could require regrading to ensure that stormwater eventually reaches the storm sewer system and can be captured for reuse. Wide-scale regrading would be highly intrusive, as well as costly. Finally, use of a traditional storm sewer system would limit any water quality improvement and pulse flow mitigation that could occur within a more naturalized system. Runoff would quickly be conveyed to a central storage location, but may require additional treatment prior to reuse for irrigation, because rapid flows typical of storm sewer systems would not allow settlement of suspended solids and other pollutants out of the water column.

Storage Method: Traditional storage vessels would be implemented at a central, low-elevation location on the site. Storage vessels could include aboveground or belowground storage tanks, or cisterns. Calibration of sizing to expected irrigation demand would be necessary. The most likely location of storage vessels would be between Surface Water Body 1 and Surface Water Body 2, based on existing topography and flow patterns; but the final location would depend on finalized site plans. A pumping system would be necessary to transport captured water to urban agriculture areas for irrigation.

> *Advantages:* Two primary advantages to use of traditional storage vessels are: (1) avoidance of contamination issues and (2) relatively simple ongoing maintenance. Storing captured stormwater in a pre-fabricated storage vessel avoids direct contact with potentially contaminated site media for long periods of time—thus precluding need to conduct extensive environmental investigations driven by concerns over contact between sediment in the ponds and stored water. Ongoing maintenance requirements for pre-fabricated storage vessels would also be more simple than those for naturalized pond storage nodes. Notwithstanding a recommendation for regular sampling of irrigation water, given that stormwater will be in contact with site soils prior to entry into the storm sewer system, other maintenance concerns would be simplified, such as little or no need for controls of vegetation or animals. Helpful as well would be installation of a water level gauge within the vessels to track water usage and monitor for leaks, and visual inspections for obvious signs of damage. Regular maintenance of the pumping system would be necessary.

<u>Constraints:</u> Primary constraints to use of a traditional storage vessel are: (1) cost, (2) potential permitting requirements, and (3) lack of habitat or visual appeal. Installation of a large storage vessel could necessitate a relatively substantial cost. This process also would require either excavation or installation of a foundation that could support the weight of the filled vessel. Permitting requirements also may loom because water diverted from the natural drainage system to a storage tank would affect water levels in the existing ponds in the West Subarea, which would impact wetlands areas. Preliminary consultations with USACE and MDNR likely would be necessary to determine whether effects of stormwater diversion on wetlands would require permits. Finally, presence of large storage tanks would not provide wildlife habitat or be visually attractive at the site. Subsurface storage tanks likely would not negatively impact site aesthetics, but would also be more difficult to maintain or repair than aboveground alternatives. Lowering of water levels in West Subarea ponds could also negatively affect the aesthetics and habitat quality of the site, with shallower conditions dissipating open water views and potentially allowing invasive vegetative species such as *Phragmites australis* to dominate the water bodies.

Treatment Method: Necessity for water treatment prior to reuse is less certain under a traditional gray infrastructure approach. Opportunity for contamination would lessen with shorter time of stormwater contact with potentially contaminated site media before entry into prefabricated storm sewer and storage systems. Depending on the source of stormwater, some contamination issues may still be present, but additional investigations of site conditions would be required to make a final determination. Many treatment options are available for insertion into the flow system prior to reuse of water for irrigation. Extensive usage of traditional infrastructure systems has resulted in a multitude of predeveloped treatment options available for relatively easy insertion at different points within the capture and conveyance system. Final plans for site layout will greatly influence selection of viable alternatives for treatment based on availability of space. Given the large influence of the final site layout on selection(s) among potential treatment alternatives, specific advantages and constraints are not presented here.

5.2.3 Targeted Infiltration/Runoff Mitigation

The final component of the conceptual green infrastructure plan focuses on targeted infiltration and runoff mitigation in specific areas of the site that meet at least one of two criteria: (1) largest production of stormwater runoff per unit acre and (2) high-priority treatment area. Areas identified based on these criteria would be well-suited for intensive stormwater capture to mitigate pulse flows and remove pollutants from runoff. In each area, a wide variety of green infrastructure technologies could be implemented, with focus on infiltrative and filtration-based systems. Importantly, before installation of any infiltrative technology, areas of installation should be investigated for possible contamination, and to determine infiltration capacities of local soils.

To satisfy the first criterion, production of stormwater runoff or volume of stormwater produced per acre was evaluated by application of the 1-D PCSWMM model. For each design storm simulated via the 1-D model (1-, 10-, 25-, 50-, and 100-year recurrence interval, 24-hour-duration design storms), Tetra Tech tracked volume of runoff generated by each subcatchment located at least partially on the site. Because volume of runoff can depend significantly on size of subcatchment, Tetra Tech controlled subcatchment size by calculating volume of runoff per acre for each subcatchment. Factors influencing this metric include land uses within the subcatchment, impervious surfaces, and slope. Results of this analysis appear on Figure A-9 in Appendix A, with runoff volume per unit acre increasing from light to dark blue. This analysis allowed Tetra Tech to select key subcatchments to target for runoff reduction.

Tetra Tech dealt with the second criterion, high-priority treatments areas, via a review of the DEM, historical aerial photography, and visual observations during Tetra Tech's site visit. High-priority areas were identified according to three characteristics: (1) high proportion of impervious surfaces, (2) proximity to potentially sensitive surface waters, and (3) potential for runoff to contain elevated levels of suspended solids and pollutants. Based on these characteristics, Tetra Tech identified the following four high-priority treatment areas:

1. **Areas surrounding the former LaFarge Concrete Batch Plant:** Within this area of the West Subarea is an abandoned industrial facility and waste piles associated with the former concrete production facility. Runoff in this portion of the West Subarea tends to flow north and west, and eventually discharges to the Blue River. The area is characterized by low permeability and impermeable surfaces that may be highly alkaline given the chemical constitution of concrete. Areas north of the abandoned facility and waste piles should be targeted for capture and infiltration, if site conditions allow. If conditions are extremely alkaline, remediation or other source control methods may be necessary prior to implementation of green infrastructure. Green infrastructure technologies in this area should focus on capturing the first flush of runoff to mitigate pulse flows to the Blue River and to allow some settlement of suspended solids. Rain gardens planted with native species that prefer alkaline soil conditions could help attain these goals and provide a visually attractive site feature.

2. **Area between the City Services Facility and existing surface waters:** This is an area of distinct change in elevation, with the City Services facility on a plateau with a steep decline to existing surface water bodies to the immediate east. The City Services facility is composed of a large amount of low permeability and impervious substances, and likely generates elevated levels of suspended solids and pollutants in runoff based on current site uses, which include staging for sand, gravel, and other construction materials, and storage of equipment and vehicles. Very limited space is available between the City Services facility and existing surface waters, with the distance between City Services facilities and open surface waters less than approximately 100 feet in some places. As a result, implementation of linear green infrastructure technologies should be considered in this area, including sand filters and infiltration trenches. A bioswale could also be used to route runoff to a portion of the site with more space available for implementation of non-linear technologies.

3. **Area between the Animal Shelter and Round Grove Creek:** The Animal Shelter is composed of a large area of impervious surfaces, with Round Grove Creek flowing immediately to the north. Pulse flows from the impervious surfaces are introduced directly to Round Grove Creek, with minimal attenuation. The narrow strip of space between the Animal Shelter and Round Grove Creek should be maintained as a riparian buffer, with possible installations of (1) a bioswale to capture runoff and transport it north (through natural topography) to an area currently hosting an

abandoned and degraded road, and (2) a system of infiltrative green infrastructure technologies to provide increased storage capacity that would attenuate pulse flows before these are discharged to Round Grove Creek.

4. **Areas north and east of the National Guard Facility:** The National Guard facility includes a very large area of impervious surfaces in the southwestern portion of the East Subarea. Based on the DEM, a hydrologic divide appears to run through the facility, with approximately one-third of the facility's area generating runoff that travels to the west, and the remaining area generating runoff that runs to the north and east. Runoff that travels to the west quickly enters a ravine area along I-435, and would be difficult to capture without encroaching on the footprint of the National Guard facility. Runoff that travels to the north and east encounters a well-established wooded area. Based on this current site configuration, the existing tree canopy provides natural green infrastructure benefits. However, depending on future site redevelopment, this area north and east of the National Guard facility should be targeted for large-scale infiltrative practices to mitigate the large pulse flows generated by the extensive area of impervious surfaces at the National Guard Facility, and potential stormwater pollutant sources resulting from large-scale vehicle storage.

6.0 HABITAT RESTORATION PLANNING

As discussed in Section 3.0, a variety of planning documents have been prepared related to habitat restoration and redevelopment opportunities at portions of the site, primarily in the West Subarea. However, a comprehensive plan for habitat restoration opportunities throughout the site is needed, particularly for the East Subarea of the site. Purposes of habitat restoration planning activities for this project were to: (1) review and integrate the diverse array of data, planning efforts, and reports completed to date; and (2) develop a comprehensive conceptual habitat restoration plan that will (a) increase public interest in using the site as an outdoor resource and improve wildlife habitat, and (b) be flexible enough to adapt as site development continues and additional information regarding the site becomes available.

A description of the site and its historical uses is in Section 2.0. Past historical uses have led to contamination in areas of the site, and lack of a comprehensive management plan has led to degraded habitat in some areas of the site. A description of current habitat conditions over the entire site was not available. However, previous planning documents addressing portions of the site did convey some general information and observations of habitat conditions. The site was described as one of the largest contiguous open spaces south of the Missouri River in Kansas City (USACE 2015). At the West Subarea, large portions of the site were observed to host areas of managed turf grass, commercial use, and unmanaged vegetation of low quality and diversity. However, wetland hydrology was present and could be enhanced relatively easily (Vireo 2012). According to the Blue River Greenways Preliminary Restoration Plan, areas in the West Subarea were described as highly disturbed with evidence of active dumping, all-terrain vehicle (ATV) use, and historical fill. Vegetation observed consisted mainly of cool season turf grasses with dense stands of woody vegetation surrounding the ponds adjacent to Coal Mine Road (see Figure A-2 in Appendix A). Dominant invasive species observed included shrub honeysuckle (*Lonicera* sp.), Tree of Heaven (*Ailanthus altissima*), Johnsongrass (*Sorghum halepense*), and fescue (*Festuca* sp.) (Vireo 2012). An additional Preliminary Conservation Management Plan indicated that short prairie and riparian habitats were dominated by invasive and undesirable species, including fescue. However, early successional habitat and lowland forest were near their desired state and required only periodic invasive species management to maintain presence (MDC 2016).

Regarding the East Subarea, the East Side Municipal Farms Evaluation (City undated) described the site as containing steep sloped valleys and naturally exposed cliffs and boulders. The upland woodland areas contained a variety of trees, including American sycamore (*Platanus occidentalis*), while the ravine included wet prairie and bottomland forest containing ash trees (*Fraxinus* sp). Some upland areas at the east end also appeared to contain “fill dirt.”

Based on available information, the site has incredible potential to become a hub for urban agriculture, outdoor recreation, and education activities, as well as to provide much needed quality habitat for wildlife. Despite conceptual plans for and observations of portions of the site, a comprehensive plan is needed to ensure consideration of open space and habitat to benefit wildlife and to meet the needs of the community as development of the site continues. Section 6.1 describes habitat restoration planning considerations. Section 6.2 summarizes findings of a desktop review of the site. Section 6.3 presents proposed restoration activities.

6.1 HABITAT RESTORATION PLANNING CONSIDERATIONS

The first step in developing this plan was to review available site background and planning information to determine important historical features and current conditions at the site that should be considered during the planning process. This plan builds on previous efforts directed at portions of the site, and data sources are described in Section 3.0. In addition, discussions with stakeholders, aerial photographs, and observations from a brief site visit were referenced to identify project opportunities and constraints. However, based on review of available information, a wetland delineation and vegetation survey are also needed to document current baseline habitat conditions and to define the most effective site-specific restoration activities. During development of the conceptual plan, Tetra Tech considered the following factors:

- **Current Habitat Conditions:** As described in Section 6.0, a description of existing conditions over the entire site was not available, but general observations of portions of the site indicated some areas dominated by invasive species and other areas near their desired state of habitat quality. This large contiguous open space in an urban setting provides a rare opportunity for outdoor recreation for residents, as well as an oasis for local wildlife and migratory birds.

- **Historical Uses:** Past historical uses of the site have resulted in known contamination in some portions of the site, and pose possibility of contamination in portions of the site not yet sampled, as discussed in Section 3.4.

- **Current Uses:** The following current uses of the site may not be compatible with restoration or recreation activities, or should otherwise be considered:

  - KCCV Radio leases a large portion of the site for communication towers. This portion of the site hosts a mixture of cool season grasses and wetland vegetation regularly mowed by KCCV Radio. Radio broadcast towers, high-voltage equipment, and presence of wiring installed approximately 6 inches bgs throughout the leased area is not compatible with restoration activities, including use of herbicides or planting of native vegetation (Vireo 2012).

  - The KCPD firing range is currently operational, and START personnel have observed UXO at the bomb disposal facility. Restoration activities in these areas could pose safety concerns.

  - The abandoned Botsford mine exhibits structural issues, resulting in sink holes that preclude most future development or recreation options. However, the mine may act as the largest single hibernacula for tri-colored bats in the State of Missouri, thus possibly warranting protection (MDC 2015).

- Tetra Tech understands that currently used agricultural areas on the West Subarea will remain agricultural in the future. Therefore, no restoration activities are proposed within these areas.

- **Future Uses:** Several current facilities may be moving from the site in the future, which could open additional land for redevelopment and eliminate incompatible land uses. However, these changes at the site have not been formally confirmed, and future development at the site in these areas is currently unknown. Habitat restoration options and recommendations consider current uses of the site. The conceptual habitat restoration plan will be a general plan for the site, including those areas, but must be refined in the future as portions of the site are developed.

The goal of the conceptual habitat restoration plan is to consider these factors and build on existing information and planning efforts to maximize potential for restoring ecosystem health by preserving and improving existing habitats in a manner that will balance needs of the community with those of natural resources at the site.

6.2 DESKTOP REVIEW

In addition to the data sources described in Section 3.0, Tetra Tech conducted a desktop review of the site to identify general soil types, wetlands, and areas in the floodplain. Maps reviewed include the USDA Soil Survey map of Jackson County, Missouri; the USFWS NWI map of the site; and the FEMA Flood Insurance Rate Map (FIRM) of the site. A summary of findings is as follows:

Jackson County Soil Survey Review

Tetra Tech reviewed the Jackson County Soil Survey map (see Figure A-15 in Appendix A), which indicated presence of several soil types within the site. In the West Subarea, the former Botsford mine area hosts a mixture of Snead-Rock outcrop complex, Menfro silty clay loam (severely eroded), Urban land-Harvester complex, and Harvester-Urban land complex; northwest corner soil is Pits-quarry; north area soil is Uradents-Urban land complex; south area soil is Colo silty clay loam; Boys Grow area soil is Bremer silt loam; soil in the agricultural area to the east is Wiota silt loam; soil at the cemetery to the north is a mixture of Uradents-Urban land complex and Colo silty clay loam; and soil in the triangular area at the southeast corner is primarily Snead-Rock outcrop complex with a small area of Knox-Urban land complex.

In the East Subarea, soils at Round Grove Creek Landfill areas at the east end are primarily Uradents-Urban land complex; soil at Round Grove Creek is Kennebec silt loam; soil within the steeply sloped areas leading to the creek are Snead-Rock outcrop complex; soils at the center of the site are primarily Knox silty clay loam (severely eroded) and Knox-Urban land complex; and soil along the west end is primarily Snead-Urban land complex.

NWI Map Review

The NWI map identified four types of water and wetlands within the West Subarea of the site. The area around the pond and stream that run through the center of the site hosts riverine (R2UBG), freshwater pond (PUBGh), freshwater emergent wetland (PEM1C), and freshwater forested/shrub wetland (PFO1A). East of the Boy's Grow area and around the cemetery are freshwater pond (PUBGh), freshwater emergent wetland (PEM1C), and freshwater forested/shrub wetland (PFO1A). At the east end of the site, Round Grove Creek is listed as riverine (R2UBG). Wetland classifications and locations on the NWI map appear on Figure A-14 in Appendix A.

FEMA FIRM Review

Tetra Tech's review of the FEMA FIRM indicated that at the West Subarea of the site, the area around the pond, east of the Boy's Grow area, and cemetery are special flood hazard areas (Zone AE) with a 1% annual chance of flood hazard; and a small area at the cemetery is floodway (Zone AE). Within the east end of the site, the area around Round Grove Creek is in the floodway (Zone AE), with additional areas in the ravine designated special flood hazard areas (Zone AE). Floodway boundaries are shown on Figure A-16 in Appendix A.

6.3 PROPOSED RESTORATION ACTIVITIES

This section proposes restoration activities based on available information, including recommendations in available planning documents to preserve and enhance existing resources. Primarily, the following planning documents were reviewed: (1) the CLUP, (2) the Municipal Farm Concept Plan from the SCDA Charette (SCDA plan), and (3) the Preliminary Conservation Management Plan (MDC 2016). Information conveyed in these plans was compiled and considered along with additional information summarized in Section 3.0 to determine proposed restoration activities throughout the site. A brief discussion of the various land uses and habitat types, as well as proposed restoration activities, are in Section 6.3.1, and proposed restoration methods are described in Section 6.3.2.

Proposed restoration activities and methods discussed below can serve as guides for preparing detailed habitat restoration design plans and specifications after further assessment and evaluation of current site conditions and final determination of uses of the site. Prior to restoration activities, early coordination with regulatory agencies is recommended to ensure acquisition of any required permits. Figures A-17 and A-18 in Appendix A show layouts of proposed uses of and habitat types within the West Subarea and East Subarea, respectively.

6.3.1 Land Uses and Habitat Types

This section briefly discusses land uses and habitat types shown on Figures A-17 and A-18 in Appendix A, as well as restoration activities proposed for each area.

No Work Zone

The area leased by KCCV Radio includes radio broadcast towers, high-voltage equipment, and wiring installed approximately 6 inches bgs throughout the area (Vireo 2012). This precludes potential recreation or restoration activities, including use of herbicides, which could damage the wiring. Therefore, no activities are proposed, and this area is designated on Figure XX as a no work zone. Given the size of the area and presence of mowed grasses and wetland vegetation, if KCCV Radio moves from the site, this area could be converted to wet-mesic prairie until a site use is determined. A discussion of wet-mesic prairie areas appears below.

Developed and Recreational Areas

Developed and recreational areas are at the northwest and northeast corners of the West Subarea and along the south and west sides of the East Subarea. At the West Subarea, the CLUP includes a mix of areas of habitat restoration or recreation, productive landscapes, institutional/civic uses, and sustainable industrial uses. The SCDA plan and Section 206 Preliminary Restoration Plan include a variety of potential uses, including a recreational climbing wall and skate park in the recreational area, as well as a nursery, BMP maintenance training facility, inland water research institute, restaurant, and event space in the developed area. Within the East Subarea, the CLUP noted presence of the National Guard facility and Potters Field cemetery, and recommended mixed-use residential or institutional/civic uses in this area.

As future development of these sites and planned uses progress, native plantings and landscaping can be implemented to reduce long-term maintenance and introduce pockets of habitat for wildlife. However, contamination at the LaFarge site at the West Subarea and contamination at the HEHS site at the East Subarea should be considered prior to development or habitat restoration activities to avoid spreading contaminated soil or exposing construction or restoration workers or site visitors to contaminated soil. Section 3.4.3 includes a discussion of sampling efforts at the LaFarge site. In addition, possibly present contamination and UXO at the KCPD firing range and bomb detonation facility should be considered prior to any restoration activities there.

Invasive species management would consist of removal of large woody vegetation and herbiciding of fescue or other invasive or undesirable vegetation with glyphosate followed by native seeding. Wet-mesic prairie seeding would be appropriate in areas surrounding recreational features and developed areas. A mix of native prairie wildflowers would provide aesthetic appeal and wildlife habitat while eliminating need to mow these areas. See Table 1 in Section 6.3.2 for the MDC recommended wet-mesic prairie seed mix. A pollinator mix could also be applied in these areas, such as CP42 Pollinator Mix 3 (MDC 2016).

Former Botsford Mine

The former Botsford Mine is in the southwest portion of the West Subarea. The CLUP designated the former mine for mixed-use residential, while the SCDA plan recommended converting most of the area to agriculture. Documented structural issues and presence of sinkholes poses a safety issue that could limit redevelopment potential of the area without further assessment of the structural integrity of the mine. The mine also provides valuable bat habitat, as documented in a memo prepared by MDC (2015). Therefore, as indicated in the Section 206 Preliminary Restoration Plan, minimal activities are recommended in this area, including (1) invasive species removal through cutting and treating stumps of large woody invasive species and herbiciding herbaceous species, and (2) selective tree removal to open the canopy to improve bat habitat. A vegetation survey would be beneficial in this area to determine the amount of additional selective tree removal necessary to further improve the area as bat habitat once large woody invasive species have been removed. In addition, hibernacula gates or other appropriate protective measures could be installed in coordination with MDC to restrict public access to the mine.

Bottomland Woodland

The CLUP and SCDA plan designated these areas for wetland and habitat restoration. These areas currently surround the former Botsford Mine, the KCCV Radio area, and KCPD firing range and bomb detonation area, all of which were listed in Section 6.1 as current uses potentially incompatible with recreation and some restoration activities. These areas could remain as densely wooded areas to act as buffers limiting access to incompatible or no work zone areas. To improve habitat in these areas, invasive species management and supplemental planting activities could occur. Trails in these areas should be limited and should be directed away from or around the incompatible or no work zone areas. Additional details on invasive species management are in Section 6.3.2.

Riparian/Wetland and Open Water Areas

The CLUP and SCDA plan designated riparian and open water areas in Figure A-17 in Appendix A for wetland and habitat restoration. The Preliminary Conceptual Restoration Plan also indicated that riparian areas host invasive Amur honeysuckle (*Lonicera maackii*) and fescue. Aggressive treatment using herbicides approved for application near water was recommended followed by planting native trees and shrubs and seeding or planting herbaceous species, along with monitoring for natural regeneration of native species. These areas would also benefit from continued invasive species control via spot spraying with herbicide and prescribed burning (MDC 2016). Section 6.3.2 includes additional details on invasive species management and seeding and planting.

Restoration of the surrounding wetland and riparian areas would likely lead to improvement of open water habitat as well. Planting of submergent and emergent wetland plugs in open water areas would further improve fish and wildlife habitat, act as a food source for aquatic animals, absorb excess nutrients in the waterbody, and help stabilize the shoreline and sediment. Additional information, including water depth and sediment composition, is needed to identify appropriate site-specific submergent vegetation for planting. Determining water depth along the shoreline would help identify optimal areas for planting submergent and emergent vegetation. In addition, prior to planting activities, samples should be collected of surface water and sediment to determine if the sediment type is suitable for planting, and to determine if contamination is present to avoid exposure of restoration workers and attractive nuisance issues.

Wet-Mesic Prairie

The CLUP combines the wet-mesic prairie habitat type shown on Figure A-17 in Appendix A with the Boys Grow and KCCV Radio areas, and recommends a productive landscape with green infrastructure features directing stormwater to the surrounding wetland and open water areas. The Preliminary Conservation Management Plan describes the wet-mesic prairie as dominated by fescue and other undesirable species. The wet-mesic prairie habitat quality could be improved through a combination of invasive species management and native seeding. First would be removal of large woody vegetation and treatment with appropriate herbicide. Then repeatedly spraying fescue with an appropriate herbicide is recommended prior to seeding with native species. Periodic mowing and spot spraying with herbicide might be necessary in the first year after seeding, but ongoing maintenance would likely be limited to periodic spot spraying with herbicide and prescribed burning (MDC 2016). Section 6.3.2 includes additional details on invasive species management and seeding and planting.

Early Successional Habitat

The CLUP designated the early successional habitat type shown on Figure A-17 in Appendix A for wetland and habitat restoration, and the SCDA plan recommended edible forest landscaping or inclusion of edible fruit and nut trees in an open canopy forest setting in this area. If edible forest landscaping is incorporated, prior to site preparation for an edible forest, the current early successional habitat could be maintained through invasive species management, selective tree removal, and periodic prescribed burning. Early successional habitat generally consists of a highly productive habitat with well-developed ground cover, shrubs, or young trees, and an open canopy. This habitat type is maintained by recurring disturbances necessary to maintain species diversity, and is an important habitat type for a variety of wildlife species (Greenberg and others 2011). According to the Preliminary Conservation Management Plan, this habitat type is already in its desired state of habitat quality and would be maintained through removal of large woody invasive species, periodic disturbance through prescribed burning, and possible introduction of specific desirable species. Additional information on invasive species control is in Section 6.3.2. A vegetative survey in this area would be beneficial to determine appropriate desirable species for seeding or planting.

Upland Savannah and Woodlands

The CLUP recommended mixed-use residential and habitat restoration/productive landscapes with trail connections off site for the upland woodland at the southeast corner of the West Subarea. The SCDA plan recommended forested habitat and bike trails. This area includes a relatively flat upland area in the southeast corner, and then steep slopes north and west to the railroad tracks. In addition, upland woodlands north and west of the Boys Grow area include an area of eastern red cedar (*Juniperus virginana*) to the north and additional woodlands to the west. The Preliminary Conservation Management Plan recommended maintenance of the eastern red cedar area as a natural fence, and indicated that the woodland to the west would be eventually cleared and grubbed, with final habitat to be determined. Prior to any potential future development, these woodland areas would be improved through invasive species management. A vegetation survey would help identify invasive species to target for removal, and determine if supplemental seeding and planting is necessary to maintain desired canopy cover. Section 6.3.2 includes additional details on potential invasive species control activities and seeding and planting activities. For woodlands with steep slopes, erosion control measures should be considered when implementing invasive species control or seeding and planting. Section 6.3.2 includes additional details on bank stabilization and erosion control. A survey of existing trails and their condition would be beneficial before determination of trail locations.

At the East Subarea, upland savannah and woodland habitat include the former HEHS site and quarry. The CLUP recommended a combination of mix-use residential, institutional/civic, and commercial space. The SCDA plan designated this area as the Urban Agricultural Hub, which would include an administrative headquarters building, post-harvest processing, grower support, demonstration plots, and space for classes, youth camps, and retreats. Similar to the West Subarea, prior to development, these areas would be improved through invasive species management, but a vegetative survey would be required to determine specific restoration activities. Prior to development, agricultural, or habitat restoration activities, contamination at the HEHS site should be considered to avoid spreading contaminated soil or exposing construction or restoration workers or site visitors to contaminated soil. Section 3.4.3 includes additional details on sampling activities in this area.

Native Plantings on Landfill

The Round Grove Creek landfill areas are along the eastern boundary of the East Subarea of the site. The CLUP and SCDA plan recommended renewable energy, possibly solar, in this area. Based on a review of aerial photographs, the northern landfill area appears to consist of mowed grass, while the southern landfill area contains some open areas but is largely dominated by trees, particularly around the borders of the landfill. With proper planning, these mowed areas can likely be converted to a native landscape that would provide greater aesthetic value, require less maintenance, and furnish habitat for wildlife. A concern about planting on landfill surfaces is ensuring that the integrity of the containment system is not damaged by roots penetrating the cap. However, research and case studies have shown that, if properly designed and implemented, a landfill surface can support a variety of native plants without compromise of integrity of the system. Soil depth on the landfill surface is important in determining whether and what type of native species would be appropriate for planting (EPA 2006).

A variety of groups can help determine appropriate native plant species, including EPA's Biological Technical Assistance Groups, EPA's Environmental Response Team, NRCS, and local native plant societies. Additional information about native planting on landfills is in EPA's "Revegetating Landfills and Waste Containment Areas Fact Sheet" (EPA 2006).

Once appropriate native plant species have been determined, the site can be prepared for native seeding or planting by prescribed burning, herbiciding, or removal of a thin layer of soil with the current grass. Prior to any prescribed burning on a landfill area, potential safety concerns related to landfill gas should be considered. Depending on the appropriate species chosen, native plants could also be seeded through the current grass by use of a no-till drill (EPA 2006). Section 6.3.2 includes additional details on potential invasive species control activities and seeding and planting activities.

Ravine

The CLUP describes this area as very steep slopes leading down to Round Grove Creek, with dense vegetation and a closed tree canopy. Both this plan and the SCDA plan recommend habitat restoration and a trail network in this area. Sampling activities at the adjacent HEHS site indicated presence of mercury contamination (see Section 3.4.3), and additional sampling in this area is recommended prior to creation of any trails or habitat restoration activities to avoid spreading contaminated soil or exposing construction and restoration workers or site visitors to contaminated soil.

A vegetation survey would help identify invasive species to target for removal and determine if supplemental seeding and planting would be necessary to maintain desired canopy cover. Section 6.3.2 includes additional details on potential invasive species control activities and seeding and planting activities. Because of presence of steep slopes, erosion control measures should be considered when implementing invasive species control, seeding and planting, or installing trails. Section 6.3.2 includes additional details on bank stabilization and erosion control. Whenever possible, existing trails should be used to minimize habitat disturbance. A survey of existing trails and their condition would be beneficial before determination of trail locations.

6.3.2 Proposed Restoration Methods

A variety of proposed methods were recommended in Section 6.3.1 to maintain or enhance habitat at the site. This section summarizes invasive species control options, seeding and planting, and bank stabilization and erosion control.

Invasive Species Control Options

Most areas recommended for potential habitat restoration would be improved through continued invasive species control activities. Goals of invasive species control are to remove invasive trees, herbs, and shrubs, and achieve a reduced relative cover of invasive herbaceous species. Depending on the amount of invasive species present in a given area, different invasive species control methods are available. A vegetative survey is recommended to determine the most appropriate methods of invasive species control and maintenance.

Areas dominated by invasive species could be treated with broad application of non-selective herbicide in conjunction with mechanical brush-hogging, and cutting of invasive species. Selective spot herbiciding or removal would be more appropriate in areas hosting a mixture of native and invasive species. Prescribed burning would also be an effective invasive species control measure for portions of the site, particularly for the riparian, wet-mesic prairie, and early successional habitat types. Burning should accord with an approved site-specific burn plan with specified appropriate burning conditions and notifications. For example, burning should occur during daylight hours only, and under appropriate wind, temperature, and other conditions that will limit impacts of smoke on neighbors and roadways. In addition, fire breaks should be mowed prior to burning to ensure burning will remain within project boundaries.

Seeding and Planting

Following invasive species control measures, seeding and planting with native species would further improve the habitat. The following tables include seeding and planting lists for select habitat types that were recommended by MDC in the Preliminary Conservation Management Plan (MDC 2016). Local nurseries also have standard seed mixes for a wide variety of habitat types. Early coordination with the nursery is recommended to ensure availability of native seed or plugs of local genotype. In addition, coordination with regulatory agencies and stakeholders, including MDC, is recommended during preparation of final seeding and planting lists for areas that may require federal, state, or local permits.

TABLE 5

SEED MIX FOR WET-MESIC PRAIRIE

Scientific Name	**Common Name**	**Seeding Rate** (ounces per acre)
	Grasses	
Bouteloua curtipendula	Sideoats grama	48
Schizachyrium scoparium	Little bluestem	48
Sporobolus asper	Tall dropseed	16
	Flowers	
Asclepias sullivantii	Prairie milkweed	5
Asclepias syriaca	Common milkweed	5
Coreopsis lanceolata	Lance-leaved coreopsis	4
Coreopsis tinctoria	Plains coreopsis	8
Dalea candidum	White prairie clover	2
Dalea purpurea	Purple prairie clover	4
Echinacea purpurea	Purple cone flower	8
Rudbeckia hirta	Black-eyed Susan	12
TOTAL		**160 ounces per acre**
		10 pounds per acre

TABLE 6

SEED MIX FOR BOTTOMLAND FOREST

Scientific Name	Common Name	Seeding Rate (ounces per acre)
Grasses		
Andropogon gerardii	Big bluestem	16
Panicum virgatum	Switchgrass	16
Sorghastrum nutans	Indian grass	16
Spartina pectinata	Prairie cordgrass	32
Tripsacum dactyloides	Eastern gamagrass	32
Flowers		
Amsonia illustris	Shining blue star	5
Asclepias incarnata	Swamp milkweed	5
Aster novae-angliae	New England aster	5
Baptisia australis	Blue false indigo	5
Baptisia luecantha	White wild indigo	5
Eupatorium purpureum	Joe-Pye weed	5
Hibiscus lasiocarpos	Rose mallow	5
Helenium autumnale	Sneeze weed	5
Rudbeckia fulgida	Orange cone flower	5
Solidago rigida	Riddell's goldenrod	5
TOTAL		**162 ounces per acre**
		10 pounds per acre

TABLE 7

TREE AND SHRUB PLANTING LIST

Scientific Name	**Common Name**	**Habitat**
	Shrubs	
Aesculus pavia	Red buckeye	Upland woodlands and mesic areas of bottomland woodlands.
Amelanchier arborea	Downy serviceberry	A late successional species that grows in a variety of habitats.
Aronia melanocarpa	Black chokeberry	Grows in a variety of habitats.
Asimina triloba	Paw	Grows in a variety of habitats.
Cercis Canadensis	Red bud	Grows in a variety of habitats.
Cephalanthus occidentalis	Button bush	Bottomland woodland, riparian, and wetland areas.
Lindera benzoin	Spice bush	Bottomland woodland, riparian, and wetland areas.
Physocarpus opulifolius	Ninebark	Bluffs, wooded hillsides, cliffs, and rocky banks of streams.
Sambucus canadensis	Elderberry	Riparian and wetland areas, bottomland woodland, and wet meadows.
	Trees	
Acer saccharum	Sugar maple	Well-drained soils, upland woodland.
Carya laciniosa	Shagbark hickory	Well-drained soils, upland woodland.
Gymnocladus dioicus	Kentucky coffee tree	Bottomland woodland or rocky hillsides.
Juglans nigra	Black walnut	Bottomland woodland.
Platanus occidentalis	American sycamore	Bottomland woodland and along riverbanks.
Populus deltoids	Eastern cottonwood	Bottomland woodland and along riverbanks.
Quercus alba	White oak	Well-drained soils, upland woodlands, and savannahs.
Quercus bicolor	Swamp white oak	Bottomland woodland, wetlands, and along riverbanks.
Quercus macrocarpa	Bur oak	Grows in a variety of habitats.
Quercus palustris Muenchh	Pin oak	Bottomland woodland.

TABLE 8

RIPARIAN/WETLAND PLANTING LIST

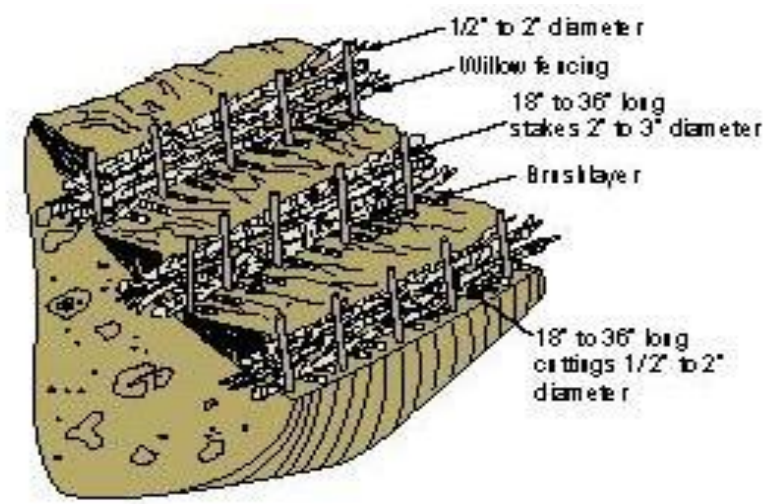
Scientific Name	**Common Name**
Asclepias incarnata	Marsh milkweed
Carex stricta	Tussock sedge
Chelone obliqua	Rose turtlehead
Eloecharis palustris	Spike rush
Iris versicolor	Blue flag iris
Juncus effusus	Soft rush
Lobelia cardinalis	Cardinal flower
Pontedaria cordata	Pickerel weed
Sagittaria latifolia	Common Arrowhead

6.3.3 Bank Stabilization and Erosion Control

Planting for erosion control may be necessary on steep slopes and exposed surfaces that will not be immediately seeded. Erosion control measures in areas cleared for seeding would include seeding of annual grass for temporary coverage to inhibit growth of invasive species during establishment of native seeding. Common annual grass species for temporary coverage include common oat (*Avena sativa*) and annual ryegrass (*Lolium multiflorum*).

FIGURE 10

DETAIL FOR WILLOW FENCING AND BRUSH LAYERING



A recommended strategy for stabilizing steep slopes with vegetation is to plant a mixture of trees, shrubs, and herbaceous species because a multi-level canopy will more effectively slow precipitation before it hits the ground, and will reduce surface erosion. In areas with steep slopes and significant woody invasive species removal or grading activities, soil bioengineering techniques might be necessary to prevent erosion, which could include brush layering and willow fencing. Brush layering would consist of inserting live, cut branches or brush between successive lifts or layers of compacted soil, perpendicular to slope contours. A willow fence may be used to support a short brush layer. The willow fence would act as a short retaining wall built of live cuttings with a brush layer base. The figure above shows additional detail on installation of willow fencing and brush layering. These structures would reduce slope angle and provide a stable platform for establishment of vegetation.

7.0 RECOMMENDED NEXT STEPS

As discussed earlier in this plan, the redevelopment project is currently in an early phase without committed end uses for the site. Therefore, it is important to treat both the green infrastructure and habitat restoration plans as living documents, with updates and refinements implemented as redevelopment plans for the site are finalized. Green infrastructure in particular depends on final site uses, as well as the specific layout of the site and locations of key site infrastructure and other elements. As a result, these plans are conceptual. In an effort to further help lay out a path forward for a successful redevelopment project with associated green infrastructure and habitat restoration, Tetra Tech has compiled two sets of recommendations for next steps. The first set of recommendations encompasses key environmental concerns that should be addressed before final planning for site redevelopment can be completed. The second set of recommendations focuses on green infrastructure and habitat restoration planning, as well as information needed to refine the existing plans and model and eventually move into a design phase.

7.1 NEXT STEPS FOR ENVIRONMENTAL INVESTIGATION

As discussed in Section 3.0, Tetra Tech reviewed available environmental investigation and other information about the site as part of the habitat restoration and green infrastructure planning process. While conducting the review, Tetra Tech also identified seven primary data gaps regarding potential environmental concerns that should be further evaluated as redevelopment moves forward, and before formal plans for the site are finalized. Tetra Tech understands that some data gaps will persist for some time due to existing leases and active usage of some portions of the site, but these data gaps are called out regardless for the sake of completeness. Each of the seven primary data gaps is summarized below.

1. **pH Levels at the LaFarge Concrete Batch Plant Site:** Tetra Tech reviewed available data from a Phase II ESA at the LaFarge Concrete Batch Plant site, which apparently did not include analytical data documenting pH levels in soils at that site. Cement used in the concrete manufacturing process is a highly alkaline substance, often with pH greater than 12.5. There was also no information in the Phase II ESA report related to the pHs measured at groundwater sampling locations. Based on past use of this portion of the Municipal Farms site, as well as an aerial photo review that indicated areas near the LaFarge Concrete Batch Plant with limited or no vegetation, it is possible that soils and/or groundwater are highly alkaline. These highly alkaline materials would present a direct contact hazard to future users of the site, and could also create inhospitable or even toxic conditions for local flora and fauna. If possible, groundwater sample collection data sheets from sampling during the Phase II ESA should be obtained and reviewed for pH levels. In addition, soil samples should be collected, with measurements of pH.

2. **UXO at KCPD Bomb Detonation Area:** Tetra Tech understands that the KCPD bomb detonation area is still actively in use, and that during a previous attempt at collecting samples in this area, a Tetra Tech employee visually identified UXO. Before this area can be converted into

any future uses, it will require a thorough investigation that should address both UXO and common associated derivatives, including VOCs, PAHs, and metals.

3. **Former Botsford Mine Area Stability:** Tetra Tech reviewed the Botsford Mine structural investigation report completed in 1984, which documented significant structural issues with the abandoned mine. This investigation should be updated prior to allowing any access to this portion of the site. Based on previous reports reviewed, the former mine area is currently structurally sensitive, with documented sinkholes. The mine also represents valuable habitat, as home to possibly the largest bat hibernacula in the State of Missouri. The structural integrity of the mine area should be assessed for safety of visitors and habitat inside the mine. The structural assessment could be completed with appropriate safety precautions via visual inspection, or more advanced technological means, such as an electromagnetic survey.

4. **Former Building Sites:** At numerous locations throughout the site, historic buildings have been demolished. A brief list of buildings that appear to have been demolished at the site include the former men's reformatory, the former Municipal Corrections Institution, the former women's reformatory, the former City Workhouse (including vehicle storage house, stable, garage, and feed house), the former tuberculosis hospital, and various agricultural buildings (canning warehouse, machine shops, poultry houses, etc.). Based on the timeframe during which these facilities were constructed, operated, and demolished, it is possible that their demolition resulted in release of asbestos-containing materials (ACM) or lead-based paint (LBP). Soils in areas near footprints of historic buildings that have been demolished at the site should be sampled for contaminants including ACM and lead prior to releasing these areas for public use.

5. **Pesticide Contamination at the HEHS Site:** Tetra Tech reviewed available information about the HEHS site, including a Phase II ESA report. Based on this report, the HEHS site has apparently received a certificate of closure in the past, but that closure appears to be limited to a very small area of that site, and does not appear to address pesticide contamination discovered during the Phase II ESA. Tetra Tech also understands that additional assessment activities were planned at this site during summer 2017. Pending results of the summer 2017 investigation, additional assessment activities should occur at this site to fully delineate pesticide contamination. Once fully delineated, the contamination should be appropriately addressed (via remediation, excavation, installation of a barrier to contact, etc.) prior to releasing the area for public use.

6. **Gasoline/Diesel Generators Throughout the Site:** Multiple facilities currently operating at the site may utilize backup electrical generators that require on-site storage of gasoline or diesel. If these operating facilities are near areas open to public use, or eventually are to be converted to public use, the areas near generators and associated fuel storage tanks should be investigated to determine whether leaks or spills have occurred that would contaminate soils and possibly groundwater.

7. **Comprehensive Contamination Screening:** As discussed elsewhere in this document, assessment activities to date have focused on evaluating contamination in a few relatively small areas within the Municipal Farms site. Because current conceptual plans involve converting large portions of the site to public and agricultural use, it will be important to perform a more comprehensive assessment of contamination throughout the site. Specifically, any areas that will allow direct contact of the public or workers with site soil or groundwater should be further evaluated and sampled as needed for a broad range of contaminants. A common rule of thumb to evaluate large sites with a wide range of potential contaminants for planning purposes is to collect one soil sample per 0.5-acre area, and analyze all samples for VOCs, semivolatile organic compounds (SVOC), PCBs, metals, herbicides, pesticides, and pH. If this broad assessment

reveals contamination at concentrations exceeding relevant screening levels, additional investigations could occur to fully delineate contamination, and to provide the necessary information for determining appropriate remediation actions.

7.2 NEXT STEPS FOR GREEN INFRASTRUCTURE AND HABITAT RESTORATION PLANNING

Tetra Tech has developed the preliminary green infrastructure and habitat restoration plans laid out in Sections 5 and 6 based on available information about the site. During preparation of these plans and creation of the H&H model upon which the plans are built, Tetra Tech identified data gaps important for future phases of planning. A summary of nine key data gaps and their purposes in refining the green infrastructure and habitat restoration plans are as follows:

1. **Bathymetric Survey Data for Major Waterbodies:** As discussed in Section 4.1, the current iteration of the H&H model uses a hydro-flattened digital elevation model (DEM) to represent bed elevations of ponds and streams at the site. The hydro-flattened DEM does not represent actual bed elevations. Accurate bathymetric survey data are necessary to render the model more accurate, as well as to facilitate planning for any possible habitat restoration within the waterbodies on the site. The two larger surface water bodies on the west side of the site could likely be surveyed by use of survey-grade equipment with real-time kinematic (RTK) geospatial corrections. An RTK-enabled laser total station could be set up on the banks of each of the waterbodies, and a small john-boat could be deployed with the laser prism mounted on a sediment probing pole. Tetra Tech recommends also incorporating an assessment of sediment depth into the bathymetric survey, as it requires identical equipment and can be completed with minimal additional effort while in the field. The sediment depth assessment would provide useful information in case sediment removal is considered as a method for remediation or habitat restoration, and could also aid in evaluating current habitat conditions. Acquiring bathymetric survey data at streams in the eastern portion of the site would likely require more intensive effort due to the density of vegetative cover in these areas. A more traditional survey approach would likely be required, with necessity for establishment of line-of-site backsights to an established benchmark.

2. **Culvert Invert Elevations:** Similar to the bathymetric survey data mentioned above, invert elevations of culverts at the site were estimated for the current iteration of the model based on the DEM and in-field observations. It is extremely important to obtain accurate inlet and outlet elevations for each culvert at the site, as these elevations play a significant role in controlling pooling of water in surface water bodies, and flooding in upland areas. Culvert invert elevations could be measured by use of the same equipment and application of the same methodology recommended for bathymetric surveying. Tetra Tech recommends acquiring all relevant survey data (bathymetric, culvert inverts, other key site features as desired by KCMO) during a single effort to minimize field deployment costs.

3. **Details on the Stormwater Sewer System in the Contributing Watershed:** Part of the process of creating the site-specific H&H model involved delineating the subwatershed that contributes to the site. This delineation was based primarily on visible surface water features and topography. Results of the delineation indicated that several areas outside of the site boundaries are part of the site's contributing watershed. Based on observed land uses in many of these areas outside of the site boundaries (commercial, industrial, professional sports venues), Tetra Tech assumes presence of stormwater infrastructure in these areas. Tetra Tech requested any existing design or geospatial

information related to storm sewers in the contributing watershed, but did not receive any information. In future iterations of the model, it will be important to incorporate any available information on storm sewer infrastructure within the contributing watershed. An existing storm sewer network may route stormwater around the site and directly to the Blue River or Round Grove Creek, or may collect water from specific areas and discharge it to particular locations within or outside of site boundaries. This could affect the amount of stormwater entering and passing through the site, rendering it an important component in the design of green infrastructure.

4. **H&H Model Calibration Data:** An important part of evaluating results of an H&H model is comparing model results to actual flow data from the area included in the model. Actual flow measurements are used to adjust calibration parameters within the model until it can accurately produce flow conditions similar to those measured in the field for a given rain event. This type of data is not currently available for the site. Tetra Tech recommends installation of flow meters and a rain gauge during future project phases. Based on results of the current H&H model, it appears that approximately four flow meters would be necessary (depending on deployment strategy), with flow meters installed at each major outfall from the site. This would include three flow meters installed on the west side of the site, and one flow meter installed on the east side of the site. A single rain gauge could be installed at any open location on the site where vegetation or structures would not impact acquisition of precipitation data. These instruments could be deployed for a relatively short time frame (2 to 3 months), or could be made permanent installations. A shorter deployment may result in cost savings. However, given the nature of the intended redevelopment at the site, which includes a focus on green infrastructure and sustainable redevelopment, permanent installation would provide a more robust dataset to evaluate impacts of various redevelopment activities.

5. **Development of Site Water Balance:** Data acquired via the rain gauge and flow meters discussed above can be combined with the H&H model to develop a detailed water balance for the site. Development of a detailed site water balance is especially important for the site, as one recommended green infrastructure use revolves around capture and reuse of stormwater for agricultural irrigation. The water balance will first be used to evaluate practical implementation of a stormwater capture and reuse system. Based on expected volume of water captured from different portions of the site, decisions can be made as to whether to implement central or localized capture and reuse, and whether the system could provide enough water to act as a practical water source for agriculture. Second, the water balance would provide information crucial for sizing elements of this system, including storage tanks, stormwater wetlands, and elements of the irrigation system such as pumps and piping.

6. **Wetland Delineation:** Wetland information was obtained from a USFWS NWI map of the site. Although NWI mapping provides valuable indicators, field verification is always necessary to confirm extents of wetland areas, particularly to determine potential permitting or mitigation requirements. Grading or filling in a jurisdictional wetland or water of the U.S. would require a Section 404 permit from USACE. Therefore, a wetland delineation would be needed prior to conducting restoration work in potential wetland areas.

7. **Shoreline Survey and Sediment Sampling of Open Water Areas:** Open water areas would be improved by planting native submergent and emergent wetland vegetation along the shoreline and in shallow open water areas. Species selection and placement depend highly on water level and sediment composition. Needed to develop a site-specific planting plan are a shoreline survey that would determine current shoreline plant species composition and the extent of shallow open water areas, and sediment sampling to determine composition of sediment.

8. **Vegetation Survey:** General information about and observations of habitat conditions in portions of the site were referenced to determine proposed restoration activities at the site. A survey of existing habitat conditions including dominant vegetation species present is needed to determine appropriate site-specific restoration activities.

9. **Existing Trail Survey:** If possible, use of existing trails is recommended to minimize impacts on habitat areas. In addition, site-specific conditions, including inundation in wetland areas and steepness of slopes, should be evaluated to determine suitability and type of trails appropriate for each area. Therefore, an evaluation of existing trails should occur prior to determination of trail placement at the site.

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APPENDIX A

FIGURES

Legend

Project Boundary

Source: Bing Maps Hybrid, 2016

N

1,000 0 1,000

Feet

KCMO Municipal Farms
Kansas City, Missouri

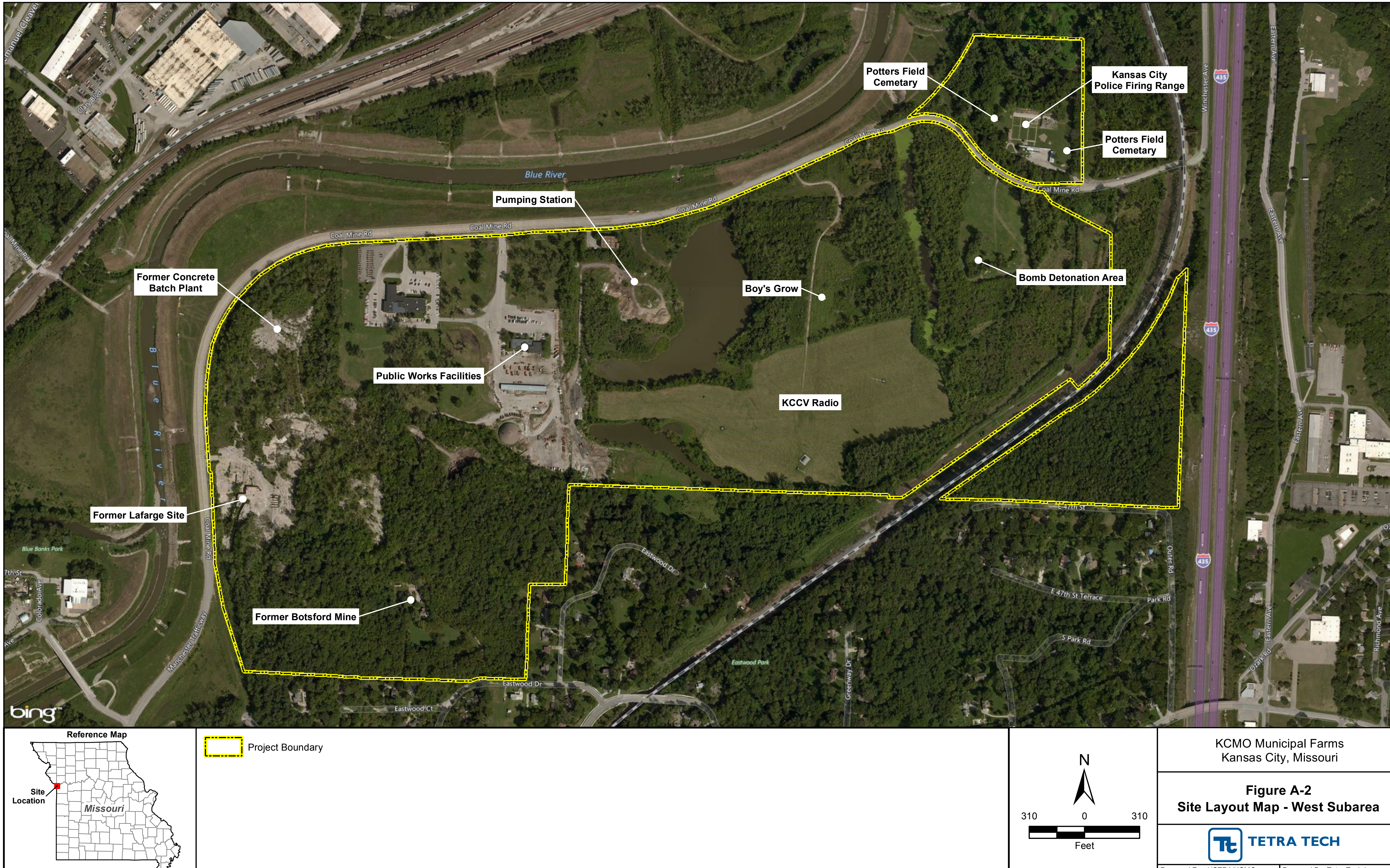
Figure A-1
Site Location Map

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-1_SiteLocationMap.mxd

Date Saved: 12/29/2017



KCMO Municipal Farms
Kansas City, Missouri

Figure A-2
Site Layout Map - West Subarea

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-2-SiteLayout-West.mxd

Date Saved: 12/29/2017

Legend

Project Boundary

Notes:
HEHS - Health Emergency Hazmat Site

N

300 0 300

Feet

KCMO Municipal Farms
Kansas City, Missouri

Figure A-3
Site Layout Map - East Subarea

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-3-SiteLayout-East.mxd

Date Saved: 1/2/2018

Site Location

Legend

- Ground Water Sample Location
- Sediment Sample Location
- Soil Sample Location
- Surface Water Sample Location
- Project Boundary
- Mine Boundary
- Known Sinkhole
- Probable Sinkhole

Source: Bing Maps Hybrid, 2016

N

400 0 400

Feet

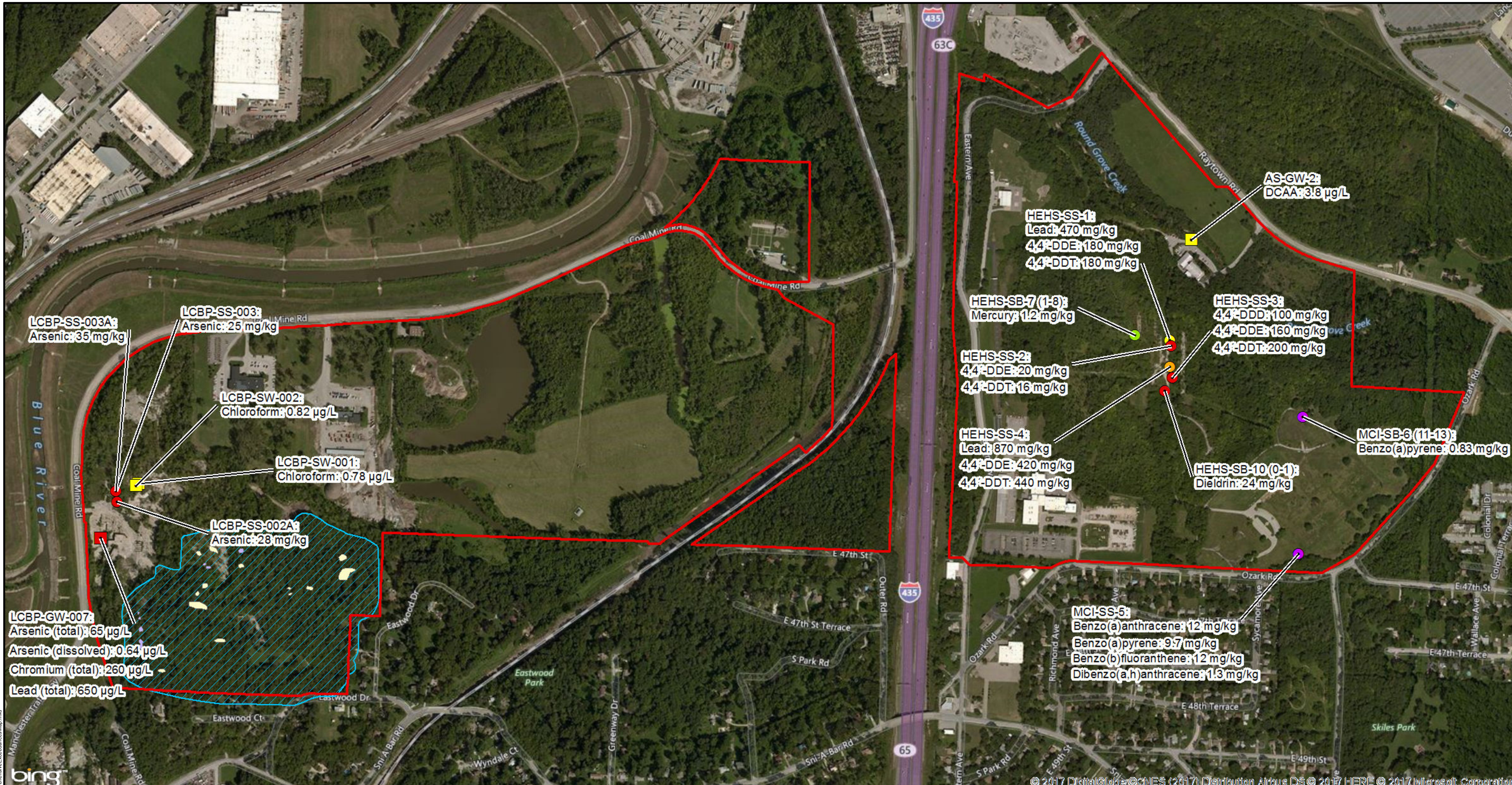
KCMO Municipal Farms
Kansas City, Missouri

Figure A-4
Existing Investigation Data Map

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

Date Saved: 1/2/2018



Site Location

Legend

- Water Sample w/ MCL Exceedance
- Water Sample w/ Tapwater RSL Exceedance
- Water Sample w/ Tapwater RSL and MCL Exceedance
- Soil Sample w/ Residential Soil RSL Exceedance
- Soil Sample w/ Residential Soil RSL (HQ=0.1) Exceedance
- Soil Sample w/ Residential and Industrial Soil RSL Exceedance
- Soil Sample w/ Residential, Industrial, Outdoor Worker, and Recreator Soil RSL Exceedance
- Soil Sample w/ Residential and Recreator RSL Exceedance
- Project Boundary
- Mine Boundary
- Known Sinkhole
- Probable Sinkhole

Notes:
mg/kg - milligrams per kilogram
µg/L - micrograms per liter

Source: Bing Maps Hybrid, 2016

N

400 0 400
Feet

KCMO Municipal Farms
Kansas City, Missouri

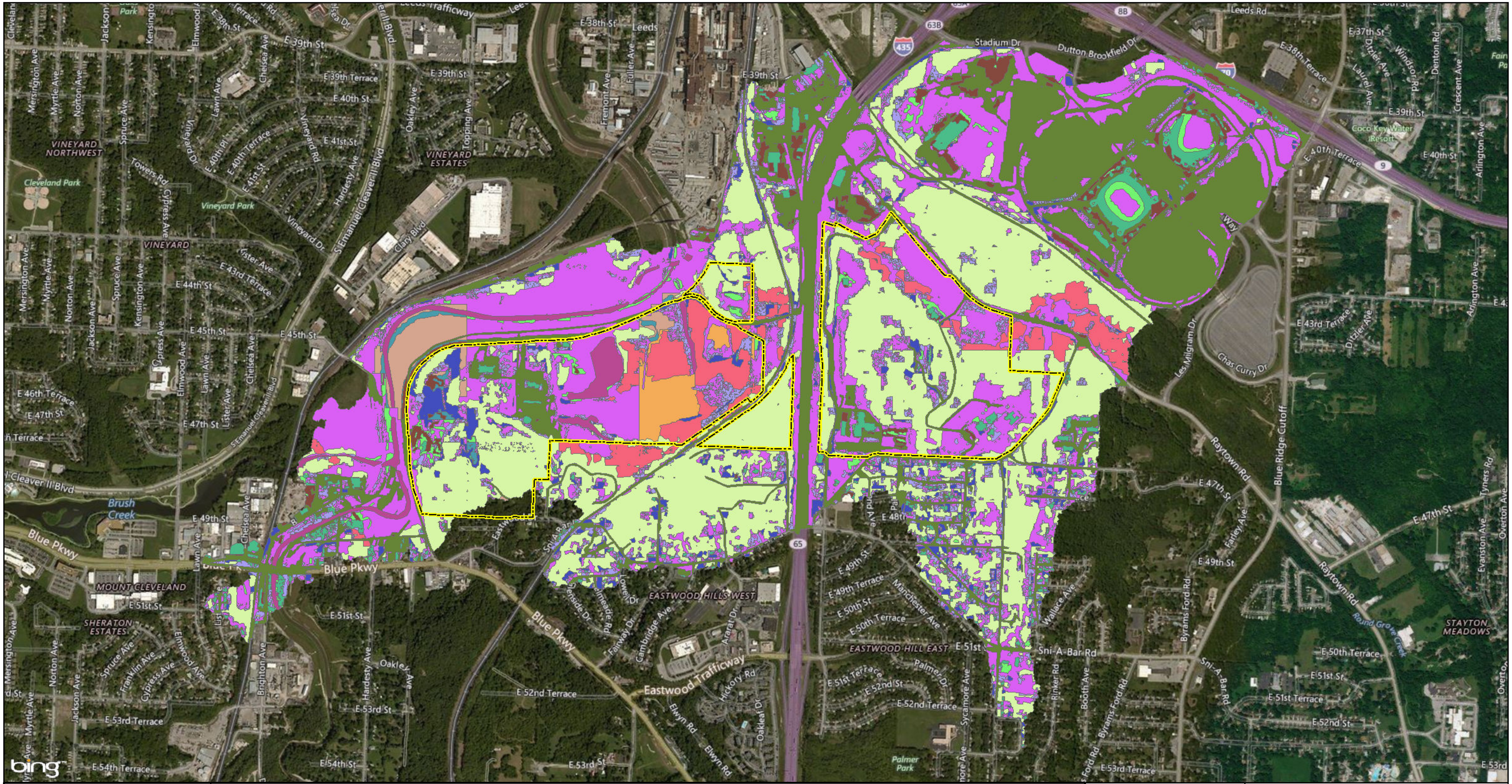
Figure A-5
Comprehensive Analytical Exceedance Map

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-5_ComprehensiveExceedancesMap.mxd

Date Saved: 1/2/2018



Legend

- Project Boundary

Land Use

- Barren
- Cultivated
- Herbaceous
- Impervious Buildings
- Impervious Other
- Lowland Deciduous Forest
- Lowland Herbaceous/Cultivated
- Mixed Forest
- Pavement
- Scrub-Shrub
- Upland Deciduous Forest
- Upland Herbaceous/Cultivated
- Water

Source:
Mid-America Regional Council's Land Use/Land Cover Dataset

N

840 0 840
Feet

KCMO Municipal Farms
Kansas City, Missouri

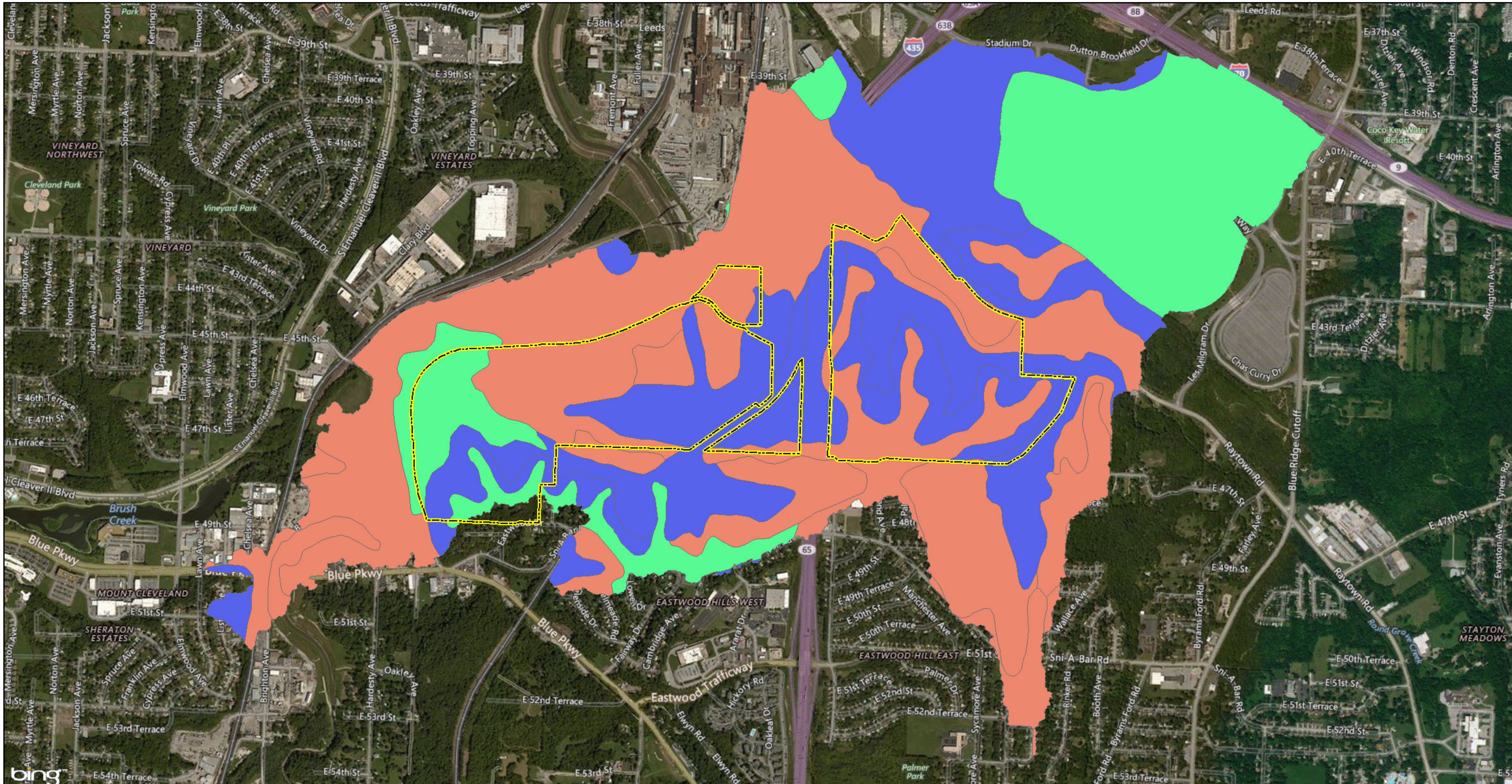
Figure A-6
Land Use Map

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-6_LandUseMap.mxd

Date Saved: 12/29/2017



Legend

Project Boundary

General Soil Type

- Silt loam
- Silty clay loam
- Urban Land

Source: USGS Web Soil Survey

N

840 0 840

Feet

KCMO Municipal Farms
Kansas City, Missouri

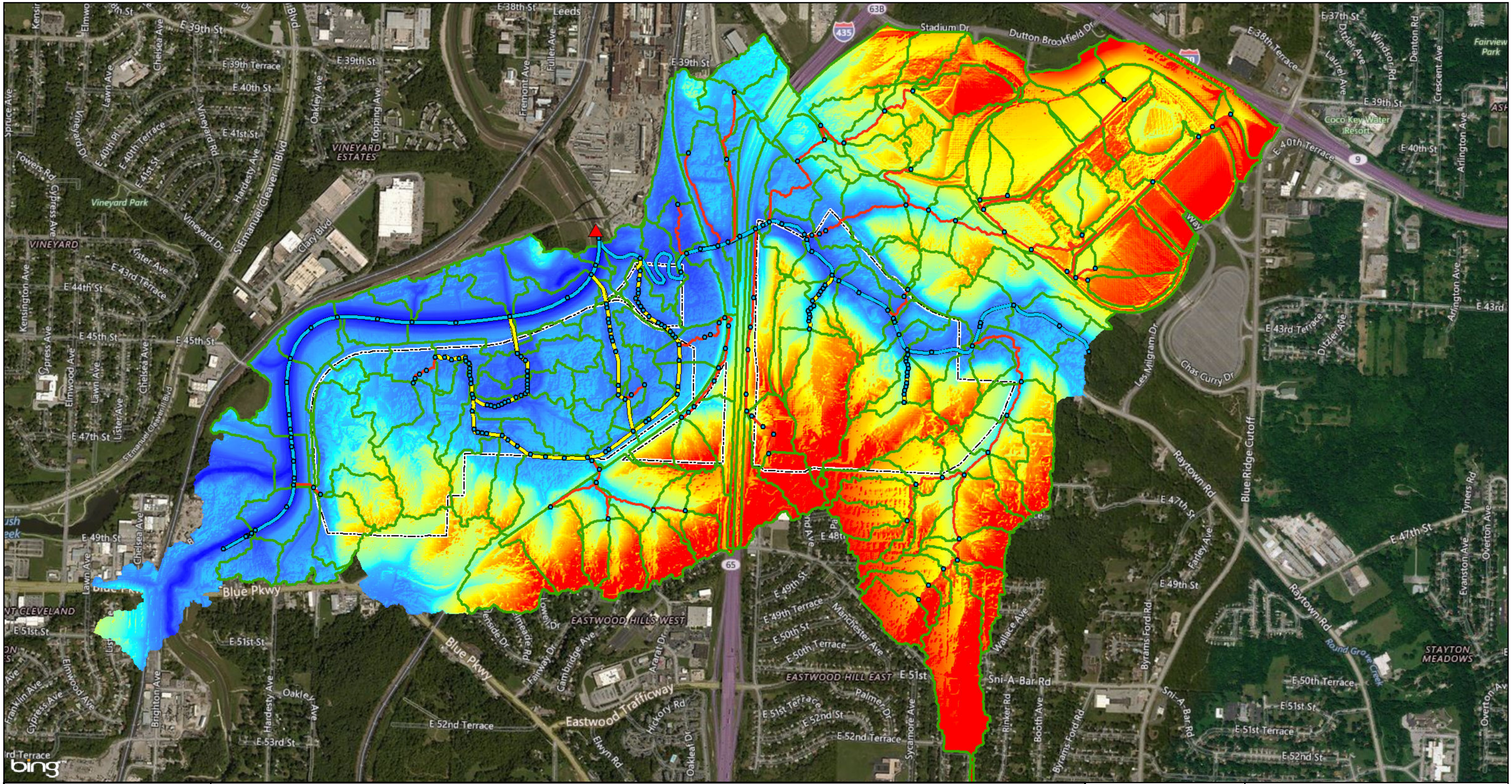
Figure A-7
General Soil Type Map

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-7_GeneralSoilTypeMap.mxd

Date Saved: 12/29/2017



Legend

- Outfalls
- Junctions
- Subcatchments

Conduits

- HEC-RAS Model
- On-Site Waterbodies
- Overland Flow

Digital Elevation Model

Elevation (feet above mean sea level)

High : 992.073

Low : 721.882

Project Boundary

Notes:
HEC-RAS - Hydrologic Engineering Center River Analysis System

Source: Bing Maps Hybrid, 2016

N

800 0 800

Feet

KCMO Municipal Farms
Kansas City, Missouri

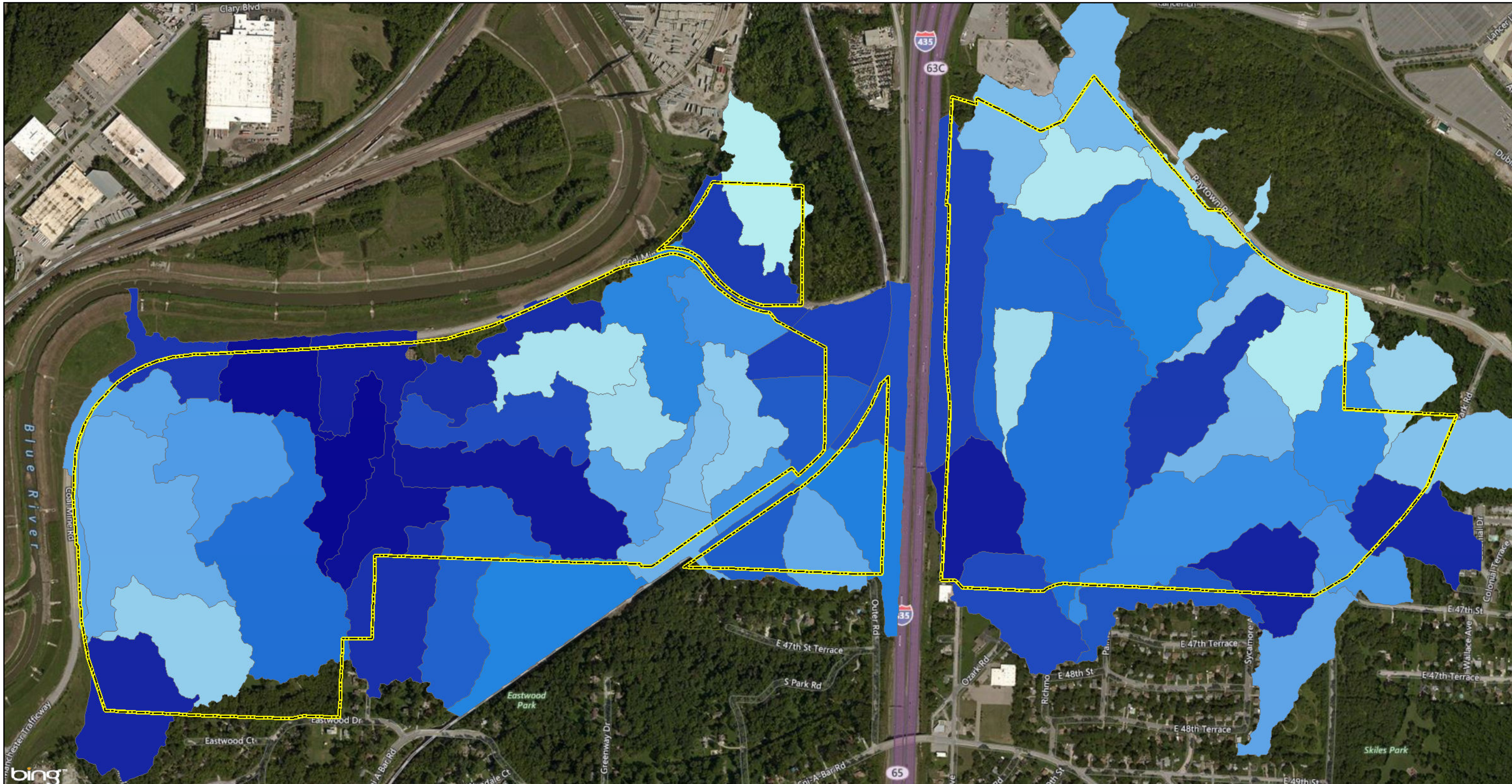
Figure A-8
PCSWMM Model Layout

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-8_PCSWMM_ModelLayout.mxd

Date Saved: 1/2/2018



Legend

Project Boundary

Subcatchments Runoff Volume per Unit Area

High : 115,000 gal/acre

Low : 59,000 gal/acre

Note: Volume of runoff per acre calculation based on 10-year recurrence interval, 24-hour duration rain event

Source: Bing Maps Hybrid, 2016

N

410 0 410

Feet

KCMO Municipal Farms
Kansas City, Missouri

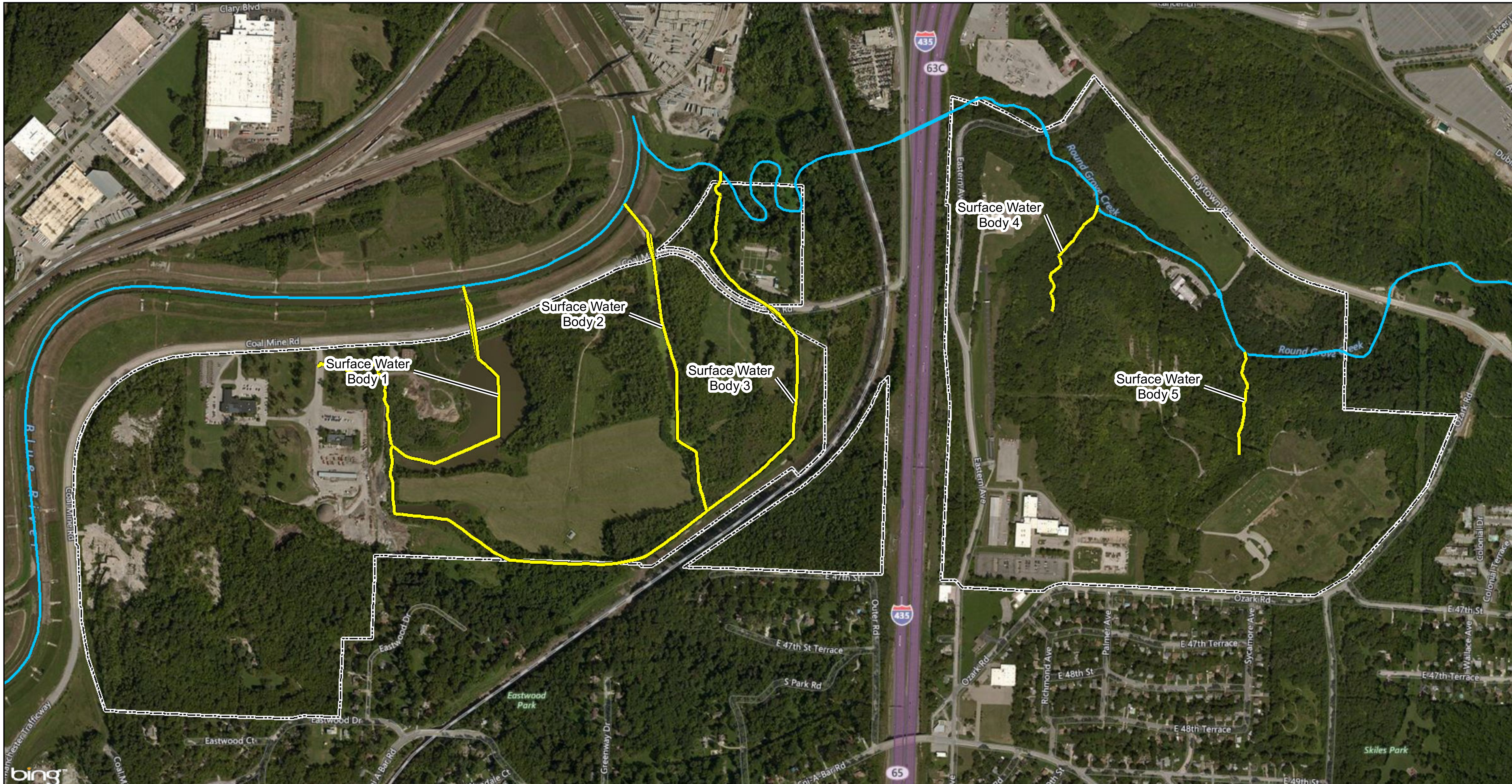
Figure A-9
Subcatchment Runoff Volume Per Unit Area

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-9_Subcatchment_RunoffPerAcre.mxd

Date Saved: 12/29/2017



Legend

PCSWMM Conduits

- HEC-RAS Model
- On-Site Waterbodies
- Project Boundary

Notes:
HEC-RAS - Hydrologic Engineering Center River Analysis Center
PCSWMM - Computational Hydraulics International PCSWMM Software

Source: Bing Maps Hybrid, 2016

N

410 0 410
Feet

KCMO Municipal Farms
Kansas City, Missouri

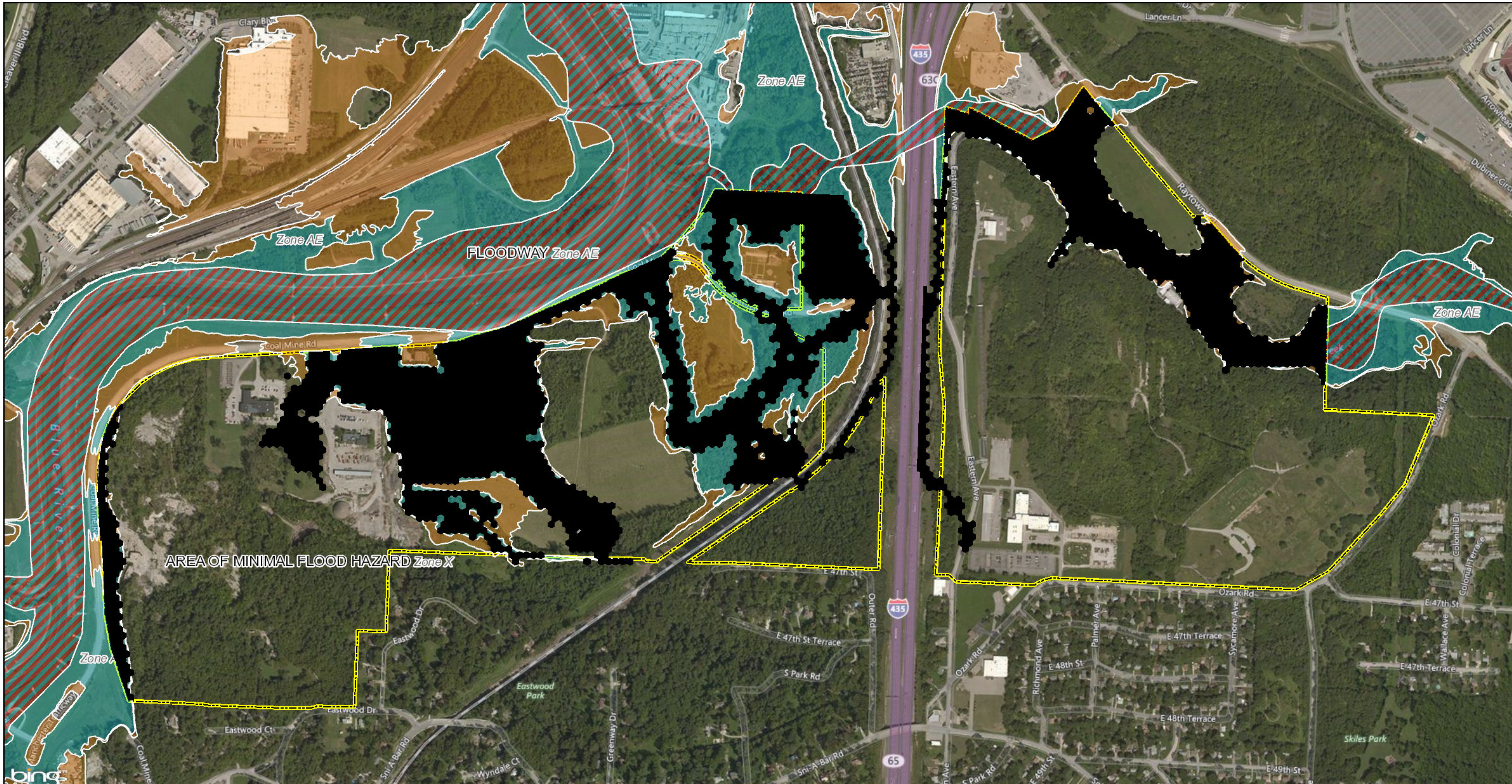
Figure A-10
Primary Site Surface Waters Map

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-10_PrimarySiteSurfaceWaters.mxd

Date Saved: 1/2/2018



Legend

- PCSWMM 2-D Model Predicted 1% Annual Chance Flood Hazard
- 1% Annual Chance Flood Hazard
- Regulatory Floodway
- Special Floodway
- 0.2% Annual Chance Flood Hazard
- Future Conditions 1% Annual Chance Flood Hazard
- Area with Reduced Risk Due to Levee
- Area of Undetermined Flood Hazard
- Project Boundary

Notes:
PCSWMM - Computational Hydraulics International PCSWMM Software

Source:
GIS Web Services for the FEMA National Flood Hazard Layer (NFHL)
On-Line Address: https://hazards.fema.gov/gis/nfhl/services

N
420 0 420
Feet

KCMO Municipal Farms
Kansas City, Missouri

Figure A-11
PCSWMM 2-D Model
Results Evaluation

TETRA TECH

Prepared For: USEPA/KCMO
Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA11_PCSWMM2DvsFEMA100yr.mxd

Date Saved: 12/29/2017

Legend

Predicted 1-Year Flood
Depth
30 ft
0.1 ft

Predicted 10-Year Flood
Depth
30 ft
0.1 ft

Predicted 100-Year Flood
Depth
30 ft
0.1 ft

Project Boundary

Notes:
PCSWMM - Computational Hydraulics International PCSWMM Software

Source: Bing maps Hybrid, 2016

N
420 0 420
Feet

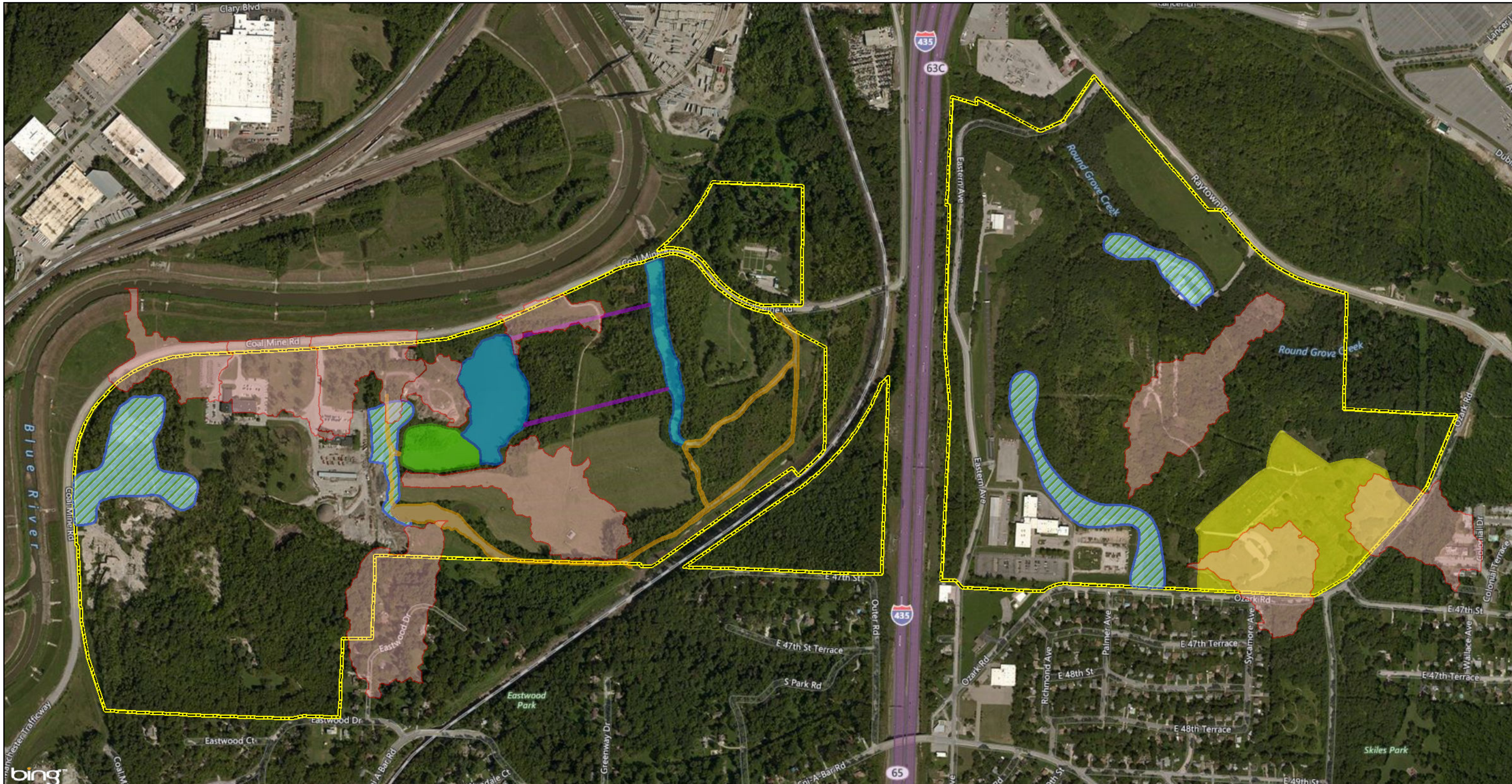
KCMO Municipal Farms
Kansas City, Missouri

Figure A-12
PCSWMM 2-D Model
Recurrence Interval Comparison

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA12_PCSWMM2D_RecurrenceIntervalComparison.mxd
Date Saved: 1/2/2018



Legend

Targeted Infiltration Area

High Runoff Subcatchments

Project Boundary

Conceptual Naturalized Capture/Reuse System

Natural Capture/Conveyance System

Potential Stormwater Wetland Location

Potential Storage Pond 1

Optional Storage Pond 2

Potential Circulation System

Potential Small-Scale Capture and Reuse Area

Source: Bing Maps Hybrid, 2016

N

410 0 410

Feet

KCMO Municipal Farms
Kansas City, Missouri

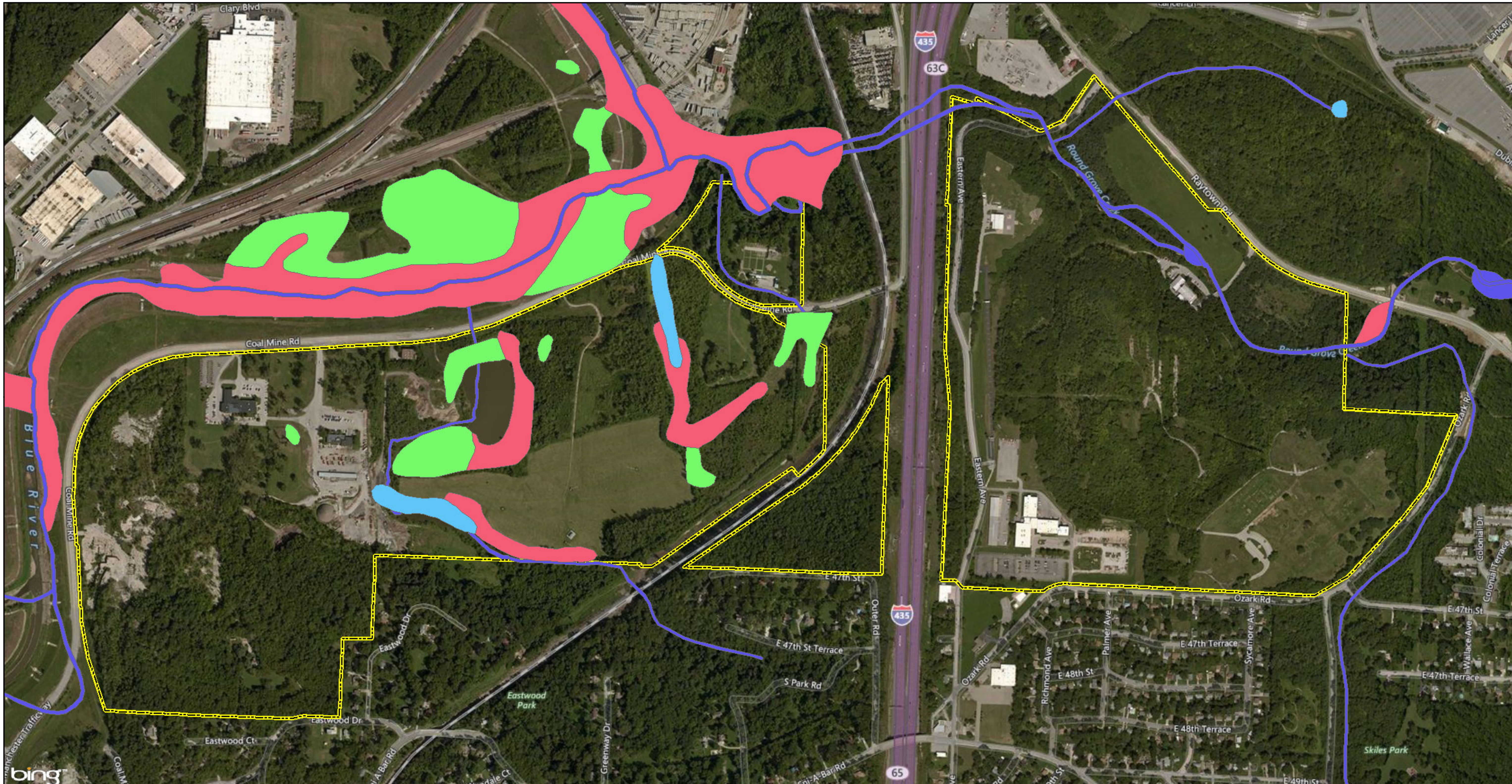
Figure A-13
Preliminary Comprehensive Green Infrastructure Plan

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA13_PrelimComprehensiveGreenInfrastructurePlan.mxd

Date Saved: 12/29/2017



Legend

Project Boundary

National Wetland Inventory

Wetland Type

- Freshwater Emergent Wetland
- Freshwater Forested/Shrub Wetland
- Freshwater Pond
- Riverine

Source: Bing Maps Hybrid, 2016

N

410 0 410

Feet

KCMO Municipal Farms
Kansas City, Missouri

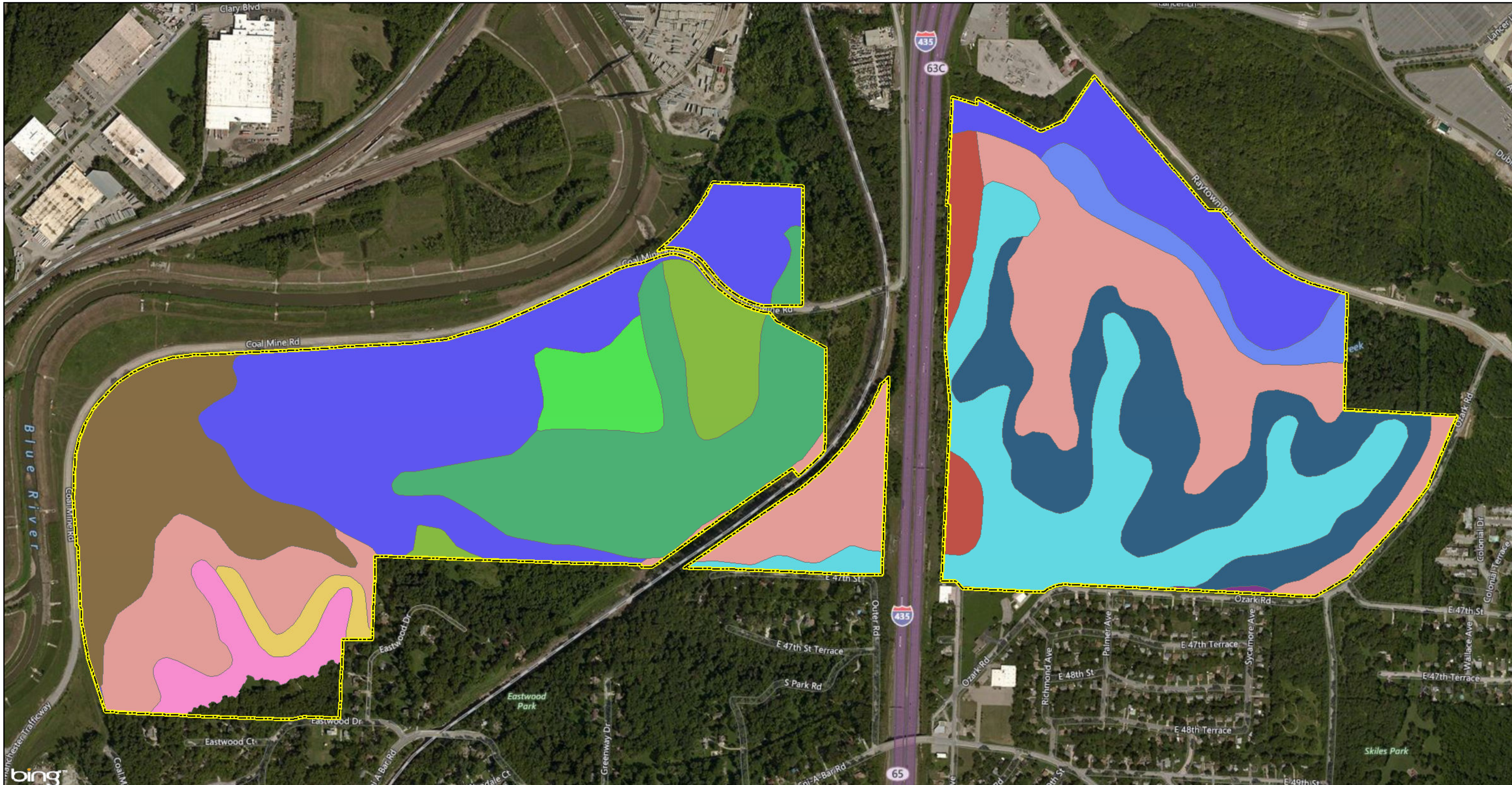
Figure A-14
US Fish & Wildlife Service
National Wetlands Inventory Map

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-14_NationalWetlandsInventory.mxd

Date Saved: 12/29/2017



Reference Map

Legend

Project Boundary

Detailed Site Soil Types

- Bremer silt loam, 0 to 2 percent slopes, occasionally flooded
- Colo silty clay loam, heavy till, 0 to 2 percent slopes, occasionally flooded
- Kennebec silt loam, 1 to 4 percent slopes, occasionally flooded
- Knox silty clay loam, 9 to 14 percent slopes, severely eroded
- Knox-Urban land complex, 5 to 9 percent slopes
- Knox-Urban land complex, 9 to 14 percent slopes
- Menfro silty clay loam, 9 to 14 percent slopes, severely eroded
- Pits, quarry
- Snead-Rock outcrop complex, 14 to 30 percent slopes
- Snead-Urban land complex, 9 to 30 percent slopes
- Udarents-Urban land complex, 2 to 9 percent slopes
- Urban land-Harvester complex, 2 to 9 percent slopes
- Wiota silt loam, 0 to 2 percent slopes, rarely flooded

Source: USGS Web Soil Survey

N

400 0 400

Feet

KCMO Municipal Farms
Kansas City, Missouri

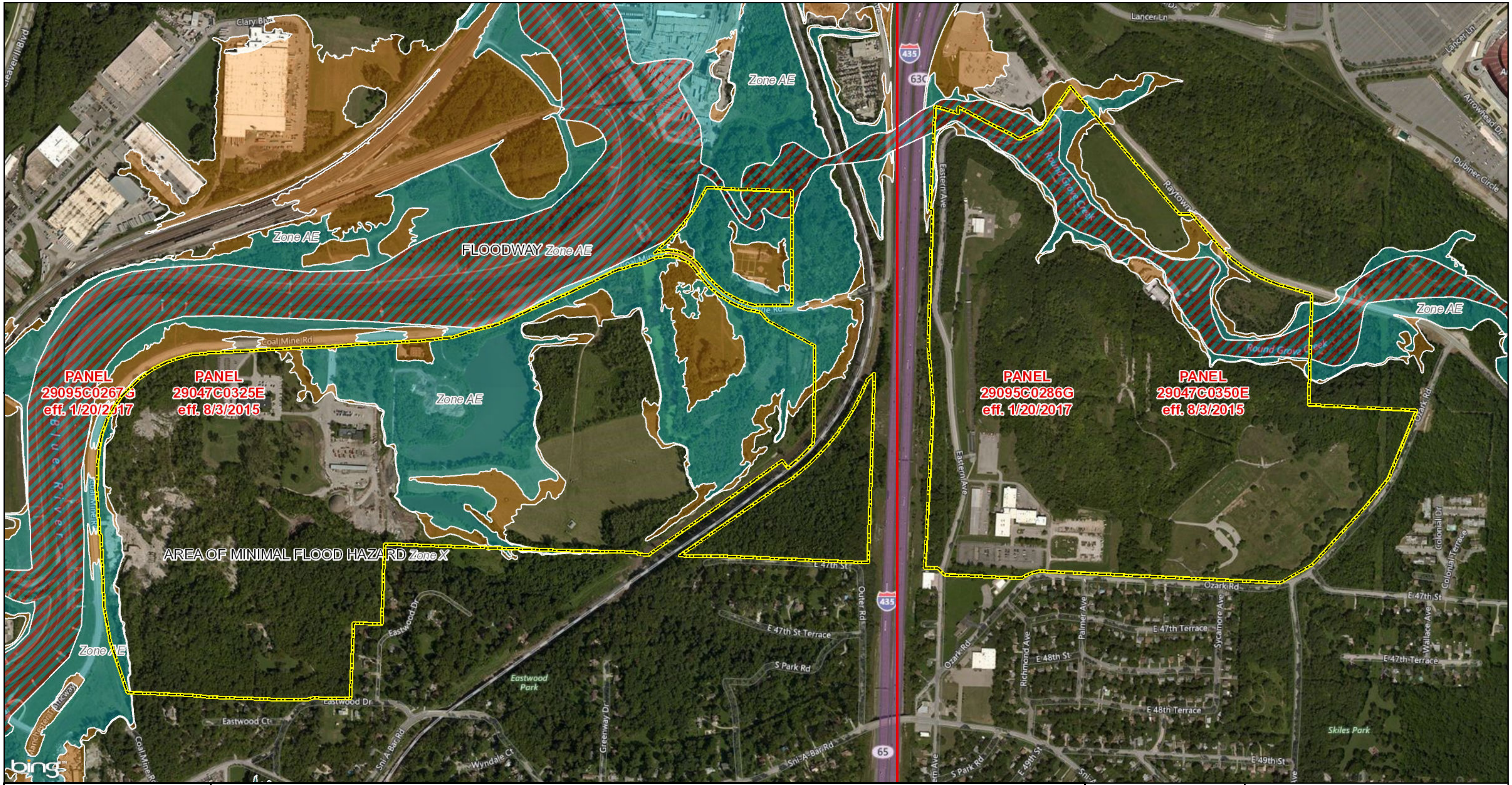
Figure A-15
Detailed Soil Type Map

TETRA TECH

Prepared By: Tetra Tech Inc.
Prepared For: USEPA/KCMO

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-15_DetailedSoilTypeMap.mxd

Date Saved: 1/2/2018



Reference Map

Legend

- FIRM Panels
- 1% Annual Chance Flood Hazard
- Regulatory Floodway
- Special Floodway
- Area of Undetermined Flood Hazard
- 0.2% Annual Chance Flood Hazard
- Future Conditions 1% Annual Chance Flood Hazard
- Area with Reduced Risk Due to Levee
- Project Boundary

Source:
GIS Web Services for the FEMA National Flood Hazard Layer (NFHL)
On-Line Address: https://hazards.fema.gov/gis/nfhl/services

N

420 0 420
Feet

KCMO Municipal Farms
Kansas City, Missouri

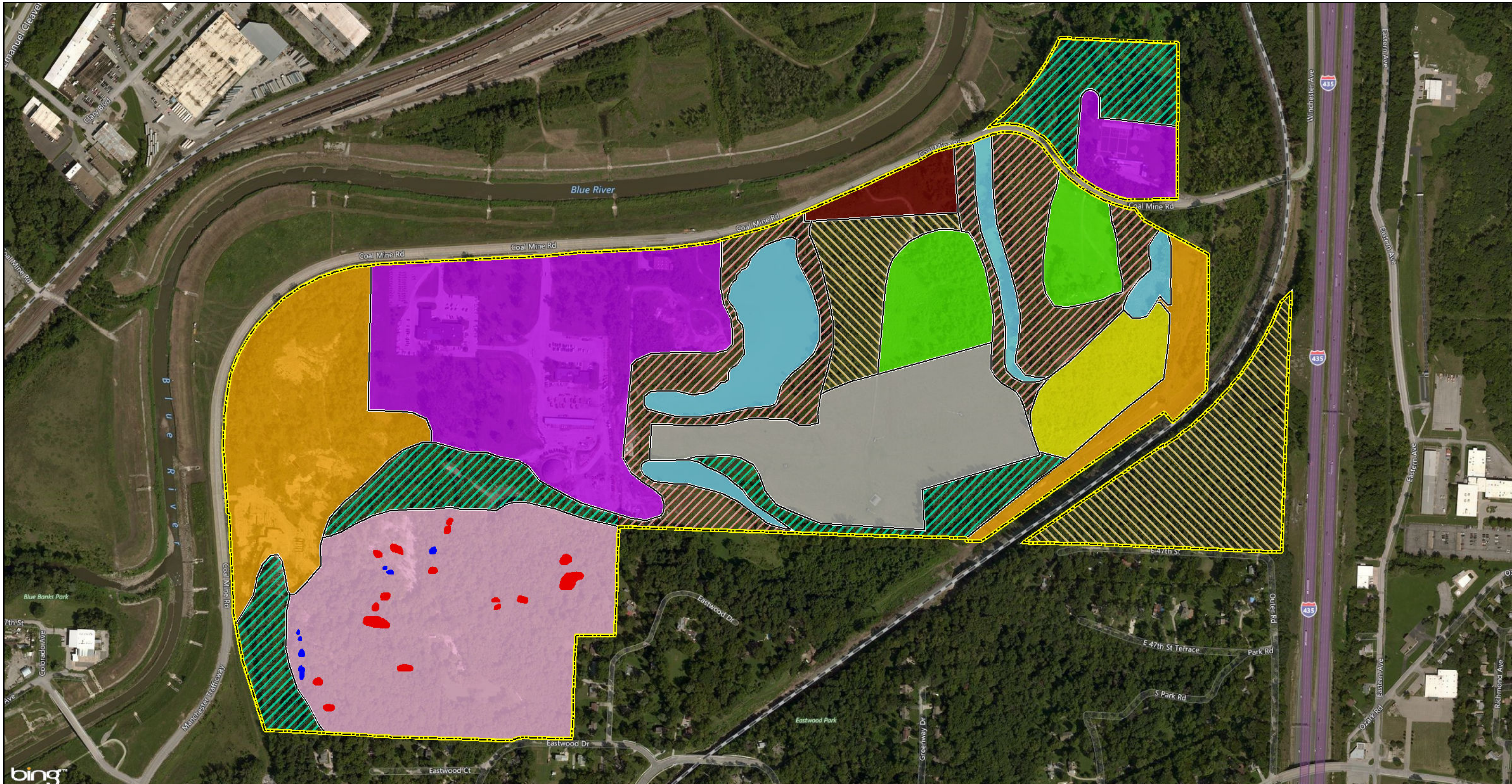
Figure A-16
FEMA 100 Year Floodplain Map

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-16_FloodplainBoundaryMap.mxd

Date Saved: 12/29/2017



Project Boundary
Known Sinkhole
Probable Sinkhole
Agriculture
Bottomland Woodland
Developed Area
Early Successional Habitat
Former Mine
No Work Zone
Open Water
Recreational Area
Riparian Area
Upland Woodland
Wet-mesic Prairie

N

300 0 300

Feet

KCMO Municipal Farms
Kansas City, Missouri

Figure A-17
Preliminary Habitat Restoration Plan
West End

TETRA TECH

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File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-17_HabitatRestoration-West.mxd

Date Saved: 12/29/2017

Legend

- Project Boundary
- Agriculture
- Developed Area
- Landfill
- Ravine
- Upland Savana/Woodland
- Upland Woodland

N

310 0 310

Feet

KCMO Municipal Farms
Kansas City, Missouri

Figure A-18
Preliminary Habitat Restoration Plan
East End

TETRA TECH

Prepared For: USEPA/KCMO | Prepared By: Tetra Tech Inc.

File Path: G:\MISC\KCMO Municipal Farms\mxd\2017-12\FigA-18_HabitatRestoration-East.mxd

Date Saved: 12/29/2017

APPENDIX B

TABLES

TABLE B-1

SUMMARY OF SCREENING LEVEL EXCEEDANCES

Sample Number	Lab Matrix	Analyte	CAS Number	RSL: Residential Soil Cancer Risk: $1x10^{-6}$ HQ = 1	RSL: Industrial Soil Cancer Risk: $1x10^{-6}$ HQ = 1	RSL: Residential Soil Cancer Risk: $1x10^{-6}$ HQ = 0.1	RSL: Industrial Soil Cancer Risk: $1x10^{-6}$ HQ = 0.1	RSL: Outdoor Worker Soil Cancer Risk: $1x10^{-6}$ HQ = 1	RSL: Recreator Soil Cancer Risk: $1x10^{-6}$ HQ = 1	USGS Background Level for Jackson County, Missouri	RSL: Tapwater Cancer Risk: $1x10^{-6}$ HQ = 1	MCL	Result	Qualifier	Result Units	Total/ Dissolved	Type of Exceedance
LCBP-SS-002A	Soil	Arsenic	7440-38-2	0.68	3	0.68	3	3.33	4.23	16.603	NA	NA	28		mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
LCBP-SS-003	Soil	Arsenic	7440-38-2	0.68	3	0.68	3	3.33	4.23	16.603	NA	NA	25		mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
LCBP-SS-003A	Soil	Arsenic	7440-38-2	0.68	3	0.68	3	3.33	4.23	16.603	NA	NA	35		mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
MCI-SB-6 (11-13)	Soil	Benzo(a)pyrene	50-32-8	0.11	2.1	0.11	2.1	2.34	0.718	NA	NA	NA	0.83		mg/kg	NA	Residential, Recreator RSLs
MCI-SS-5	Soil	Benzo(a)anthracene	56-55-3	1.1	21	1.1	21	22.9	7.17	NA	NA	NA	12		mg/kg	NA	Residential, Recreator RSLs
MCI-SS-5	Soil	Benzo(a)pyrene	50-32-8	0.11	2.1	0.11	2.1	2.34	0.718	NA	NA	NA	9.7		mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
MCI-SS-5	Soil	Benzo(b)fluoranthene	205-99-2	1.1	21	1.1	21	23.4	7.18	NA	NA	NA	12		mg/kg	NA	Residential, Recreator RSLs
MCI-SS-5	Soil	Dibenzo(a,h)anthracene	53-70-3	0.11	2.1	0.11	2.1	2.34	0.718	NA	NA	NA	1.3		mg/kg	NA	Residential, Recreator RSLs
LCBP-GW-007	Water	Arsenic	7440-38-2	NA	NA	NA	NA	NA	NA	NA	0.052	10	0.64	J	µg/L	Dissolved	Tapwater RSL
LCBP-GW-007	Water	Arsenic	7440-38-2	NA	NA	NA	NA	NA	NA	NA	0.052	10	65		µg/L	Total	Tapwater RSL, MCL
LCBP-GW-007	Water	Chromium	7440-47-3	NA	NA	NA	NA	NA	NA	NA	NA	100	260		µg/L	Total	MCL
LCBP-GW-007	Water	Lead	7439-92-1	NA	NA	NA	NA	NA	NA	NA	15	15	650		µg/L	Total	Tapwater RSL, MCL
AS-GW-2	Water	DCAA	79-43-6	NA	NA	NA	NA	NA	NA	NA	1.5	60	3.8		µg/L	NA	Tapwater RSL
LCBP-SW-001	Water	Chloroform	67-66-3	NA	NA	NA	NA	NA	NA	NA	0.22	80	0.78	J	µg/L	NA	Tapwater RSL
LCBP-SW-002	Water	Chloroform	67-66-3	NA	NA	NA	NA	NA	NA	NA	0.22	80	0.82	J	µg/L	NA	Tapwater RSL
HEHS-SB-7 (1-8)	Soil	Mercury	7439-97-6	11	46	1.1	4.6	50.7	814	NA	NA	NA	1.2		mg/kg	NA	Residential RSL (HQ=0.1)
HEHS-SB-10 (0-1)	Soil	Dieldrin	60-57-1	0.034	0.14	0.034	0.14	0.16	0.212	NA	NA	NA	24	J	mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
HEHS-SS-1	Soil	4,4´-DDE	72-55-9	2	9.3	2	9.3	10.3	12.7	NA	NA	NA	180	J	mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
HEHS-SS-1	Soil	4,4´-DDT	50-29-3	1.9	8.5	1.9	8.5	9.48	11.8	NA	NA	NA	180	J	mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
HEHS-SS-1	Soil	Lead	7439-92-1	400	800	400	800	NA	NA	NA	NA	NA	470		mg/kg	NA	Residential RSL
HEHS-SS-2	Soil	4,4´-DDE	72-55-9	2	9.3	2	9.3	10.3	12.7	NA	NA	NA	20	J	mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
HEHS-SS-2	Soil	4,4´-DDT	50-29-3	1.9	8.5	1.9	8.5	9.48	11.8	NA	NA	NA	16	J	mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
HEHS-SS-3	Soil	4,4´-DDD	72-54-8	2.3	9.6	2.3	9.6	10.6	14.1	NA	NA	NA	100	J	mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
HEHS-SS-3	Soil	4,4´-DDE	72-55-9	2	9.3	2	9.3	10.3	12.7	NA	NA	NA	160		mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
HEHS-SS-3	Soil	4,4´-DDT	50-29-3	1.9	8.5	1.9	8.5	9.48	11.8	NA	NA	NA	200		mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
HEHS-SS-4	Soil	4,4´-DDE	72-55-9	2	9.3	2	9.3	10.3	12.7	NA	NA	NA	420	J	mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
HEHS-SS-4	Soil	4,4´-DDT	50-29-3	1.9	8.5	1.9	8.5	9.48	11.8	NA	NA	NA	440	J	mg/kg	NA	Residential, Industrial, Outdoor Worker, Recreator RSLs
HEHS-SS-4	Soil	Lead	7439-92-1	400	800	400	800	NA	NA	NA	NA	NA	870		mg/kg	NA	Residential, Industrial RSLs

Notes:

CAS	Chemical Abstracts Service
DCAA	Dichloroacetic acid
DDE	Dichlorodiphenyldichloroethene
DDT	Dichlorodiphenyltrichloroethane
HQ	Hazard quotient
MCL	Maximum Contaminant Level
mg/kg	Milligrams per kilogram
NA	Not applicable
RSL	EPA Regional Screening Level
USGS	U.S. Geological Survey
µg/L	Micrograms per liter

TABLE B-2

SUMMARY OF MAXIMUM WATER SURFACE ELEVATIONS PREDICTED BY HYDROLOGIC AND HYDRAULIC MODELS

River Mile	100-Year, 24-Hour Rain Event			50-Year, 24-Hour Rain Event			25-Year, 24-Hour Rain Event			10-Year, 24-Hour Rain Event			1-Year, 24-Hour Rain Event		
	PCSWMM	HEC-RAS	Difference	PCSWMM	HEC-RAS	Difference	PCSWMM	HEC-RAS	Difference	PCSWMM	HEC-RAS	Difference	PCSWMM	HEC-RAS	Difference
Blue_J48234	763.9	764.03	-0.13	763.16	763.27	-0.11	760.37	760.47	-0.1	756.35	756.32	0.03	744.38	744.4	-0.02
Blue_J48730	763.99	764.08	-0.09	763.24	763.32	-0.08	760.47	760.52	-0.05	756.5	756.38	0.12	744.52	744.5	0.02
Blue_J49176.8	764.08	764.15	-0.07	763.33	763.39	-0.06	760.55	760.6	-0.05	756.59	756.5	0.09	744.61	744.66	-0.05
Blue_J49995	764.13	764.17	-0.04	763.38	763.4	-0.02	760.6	760.57	0.03	756.69	756.49	0.2	744.83	744.73	0.1
Blue_J50716	764.3	764.18	0.12	763.54	763.42	0.12	760.79	760.66	0.13	756.95	756.62	0.33	745.04	744.9	0.14
Blue_J51753.7	764.62	764.32	0.3	763.85	763.56	0.29	761.14	760.81	0.33	757.39	756.82	0.57	745.39	745.15	0.24
Blue_J52673.7	764.98	764.44	0.54	764.19	763.67	0.52	761.48	760.94	0.54	757.8	757.01	0.79	745.73	745.38	0.35
Blue_J53503.7	765.32	764.56	0.76	764.51	763.78	0.73	761.82	761.06	0.76	758.2	757.17	1.03	746.05	745.61	0.44
Blue_J53938.5	765.51	764.63	0.88	764.7	763.85	0.85	762.02	761.13	0.89	758.42	757.26	1.16	746.23	745.73	0.5
Blue_J54131.1	765.65	764.66	0.99	764.84	763.88	0.96	762.16	761.17	0.99	758.59	757.31	1.28	746.36	745.79	0.57
Blue_J54359.9	765.79	764.72	1.07	764.97	763.93	1.04	762.32	761.22	1.1	758.8	757.37	1.43	746.57	745.87	0.7
Blue_J55187.7	765.92	764.82	1.1	765.1	764.04	1.06	762.45	761.35	1.1	758.97	757.54	1.43	746.84	746.15	0.69
Blue_J55777.6	766.02	765.1	0.92	765.19	764.3	0.89	762.56	761.64	0.92	759.11	757.92	1.19	747.04	746.52	0.52
Blue_J55840.4	766.08	765.26	0.82	765.25	764.44	0.81	762.63	761.75	0.88	759.2	758.03	1.17	747.12	746.58	0.54
Blue_J55858.4	766.11	765.26	0.85	765.28	764.44	0.84	762.65	761.74	0.91	759.24	758.01	1.23	747.15	746.57	0.58
Blue_J56201.5	766.18	765.22	0.96	765.35	764.41	0.94	762.73	761.74	0.99	759.35	758.04	1.31	747.28	746.72	0.56

Notes:

All elevations reported in feet above mean sea level; NAVD88 datum

HEC-RAS Hydrologic Engineering Centers River Analysis System
PCSWMM PC Storm Water Management Model