Characterizing a Brownfields Recreational Reuse Scenario Using the Triad Approach—Assunpink Creek Greenways Project

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Since the early 1990s the U.S. government has been developing and implementing public policies that advance the redevelopment of brownfields, and the recent passage of the Small Business Liability Relief and Brownfields Revitalization Act (SBLRBRA) will significantly advance efforts to integrate environmental contamination mitigation and redevelopment. Experience has demonstrated that successful redevelopment requires the collection, analysis, and interpretation of environmental data in a timely and cost-effective manner in order to allow developers and lenders to efficiently use cleanup resources, develop response strategies that integrate cleanup with redevelopment, and support meaningful outreach to involved stakeholders. Recent advances in the science and technology of site characterization hold the promise of improved site characterization outcomes while saving time and money. One such advancement, the Triad Approach, combines systematic up-front planning with the use of a dynamic field investigation process and the generation of real time data to allow in-field decision making on sample location selection.

This article describes an application of the Triad Approach to redevelopment of an urban greenway in Trenton, New Jersey. The Triad Approach, initiated through a partnership between the City of Trenton, New Jersey Department of Environmental Protection, New Jersey Institute of Technology, and the U.S. Environmental Protection Agency, demonstrated that this approach could accelerate the characterization of the 60-acre, 11-parcel project area. Environmental issues that were solved using the Triad Approach included the delineation of the extent of historic fill, determination of no further action for several areas of concern, detailed investigation of specific impacted areas and the acquisition of sufficient data to allow the city to make important decisions regarding remediation costs and property acquisition. © 2003 Wiley Periodicals, Inc.

INTRODUCTION AND BACKGROUND

With the passage of the Small Business Liability Relief and Brownfields Revitalization Act (SBLRBRA, 2002), Congress recognized that states, through their Voluntary Cleanup Programs (VCPs), had made significant progress in tackling the perplexing issue of abandoned or underutilized commercial and industrial properties, often known as brownfields. SBLRBRA gave the U.S. Environmental Protection Agency (USEPA) the approval to institutionalize the public policies and programs that had been developing since the early 1990s to address the estimated 500,000 brownfields properties in the United States (Bartsch et al., 1991; Office of Technology Assessment, 1995; Simons, 1998, 1999). The new law not only gave support to alternatives to the one-size-fits-all philosophy that had encumbered cleanup programs, but it also took away the artificial
distinction of petroleum and non-petroleum contaminated sites. These and other
changes that sought greater alignment of federal and state policies marked a significant
departure from business as usual.

Over the past half century the U.S. population has shifted from urban areas to less
developed regions and moved into a post-industrial era that is sometimes referred to
as the service economy. The contributing drivers have been documented (Buzbee,
1999; Nivola, 1999; Orfield, 1997) and may continue to exert pressure that has led to
a general urban decline (USDHUD, 1999). In the wake of the shift are the all too
common plant downsizings and shutdowns that inevitably result in the abandonment
and underutilization of many properties. These properties fit into the SBLRBRA defi-
nition of brownfields as “real property, the expansion, redevelopment or reuse of
which may be complicated by the presence or potential presence of hazardous sub-
stance, pollutant, or contaminant” (SBLRBRA, 2002). What is clear is that these prop-
erties, when left unaddressed, continue to deteriorate, and contribute to further
neighborhood decline often creating and/or exasperating environmental problems and
negatively affecting quality of life (Greenberg et al., 1998). In addition, the economic
impact of providing city services in the face of lost revenue has been severe (Rabi-
nowitz & Page, 1993; Buzbee, 1997).

Mayors, governors, and presidents have recognized the potential that redevelopment
of brownfields represent (Bush, 2001; Clinton, 1998; National Association of Counties,
as have developers who have been stymied by the barriers, real or perceived, that dog
these properties (Alberini & Austin, 1999; Arrandale, 1997; Bartsch et al., 1991; Bartsch
& Collaton, 1997; Bartsch & Munson, 1994; Silkowski-Hackett & Schiavo, 1996; United
States Environmental Protection Agency, 1997; United States Government Accounting
Office, 1996; Van Horn et al., 1999). The obstacles, whether technical, financial, or regu-
latory, are rarely isolated from one another and they are exacerbated by the convergence
of environmental uncertainties with the redevelopment process. The most common
uncertainty, the extent of contamination, may be more simply translated as the fear that
finding contamination could lead to cleanup costs that exceed the value of the property.
For many, the decision not to proceed is made from this level of uncertainty. Beyond this
point the costs of moving through the process of identification, assessment, and remedia-
tion of contamination are of particular concern to any developer who is faced with time-
critical decision making. Lastly, contamination stemming from accidental spills,
inadequately treated discharges, leaking underground storage tanks, or other sources
could pose risks to stakeholders such as local government, investors, and nearby resi-
dents. Given these sources of uncertainty, whether they are of real or perceived contami-
nation, the complex redevelopment process, or the socioeconomic climate, is there little
wonder why brownfields properties have been left untouched?

However, one feature that distinguishes the remediation and redevelopment of
brownfields properties from other cleanups is that they are often driven by a defined
near-future land use objective. As a consequence there are two items in particular that
require certainty to achieve profitable redevelopment: time and cost.

- Time–Investors, planners, and developers generally look toward short time
  frames (two–year period) for redevelopment planning. Addressing environmen-
tal liabilities early in the redevelopment-planning time frame is critical to suc-
cessful reuse. Timely investigation programs that determine the vertical and
horizontal extent of contamination with certainty are a necessity to the redevelopment process.

• Cost—The cost for property assessment, remedy selection, and implementation is particularly critical since the redevelopment of many brownfields properties is dependent on grants and bank loans and the impact of cleanup can make or break the project. Research in brownfields redevelopment suggests that testing and remediation costs can be quadruple those of a greenfield property (Bartsch, 1999). However, experience at the New Jersey Institute of Technology has proved that systematic planning and the use of cost-saving field approaches can alter this past experience.

THE NEED FOR NEW INVESTIGATION TOOLS AND METHODS

With the advent of VCPs and now SBLRBRA, some of the uncertainty associated with acquiring and remediating a property is being addressed through a new regulatory climate and now new tools that break the traditional cleanup process mold have begun to emerge. For example, instituting a predictable and timely process for assessment and subsequent remediation process diminishes uncertainty that subsequently allows time-sensitive planning financial commitments to proceed in a predictable fashion. In this regard, prospective redevelopers can benefit from an environmental investigation process that accelerates assessment and cleanup decisions while providing a defined end-point such as regulatory finality. State VCPs have demonstrated that they can serve as an effective mechanism to meet these objectives (ELI, 1998).

Site characterization, for the most part, has followed the paradigm of manual sampling coupled with fixed laboratory analysis; whether samples were of soil, sediment, water, or air. While the fixed laboratory provided a high degree of analytical precision, experience has shown that this approach can be costly and time-consuming. Often multiple mobilizations are needed in an iterative fashion over extended periods to fulfill the minimum requirements associated with characterizing the vertical and horizontal extent of contamination for a given area of concern (AOC). As stated above, this method of site characterization is inconsistent with the realities of the redevelopment process. Thus, the cost and time associated with traditional investigation methods has led to an increased demand for faster and less costly approaches and has encouraged researchers, technology developers, and vendors to advance the state of the art for field analytical methodologies (FAMs).

A number of promising field screening and analytical technologies have emerged and several are already in widespread use and recognized by USEPA under SW-846 (USEPA, 2003). For brownfields in particular, FAMs have several important advantages:

• FAMs, which are less expensive than traditional types of analysis, offer the opportunity of providing greater density and sampling that becomes more representative of site conditions.
• Data can be captured in near “real time” to allow for on-site decision making, which allows for infield adjustment of the sampling program to account for situations where there can be a significant expansion of data associated with extent of contamination for an AOC. This will provide better representation of the site in terms of types, levels, and distribution of contaminants (definition of hot spots, exposure pathways, extent of contamination, etc).
• The integration of environmental decision making with reuse strategies can be facilitated by allowing remediation decisions and cost estimates to be moved to an earlier stage in the planning process.
• FAMs may be used, when appropriate, as a basis for concluding that a property is not contaminated, supporting a no further action determination by the regulatory agency.
• FAMs can also be used to enable area-wide or multiple property investigations that can support neighborhood redevelopment through cleanup prioritization, liability determination, and associated market-driven increases in valuation and investment risk reduction.
• Finally, rapid site characterization can enhance community involvement and reduce cynicism that can be associated with slow data development and multiple white suit events.

Advancements in field analytical and sampling technologies coupled with the need for property investigations that provide a more rapid response to the market demands of brownfields, such as better definition of the liability profile, have elevated innovative approaches that leverage the strengths of FAMs. One such innovative approach that appears promising and is being promoted by USEPA is the Triad Approach to site characterization. USEPA has also sponsored several demonstration projects to field test the approach under real-world conditions to better evaluate the cost and time advantages.

THE TRIAD APPROACH

In many states, site characterization programs rely on regulator-approved analytical methods as the basis for providing data on the distribution of contaminants. These methods have been validated and therefore are commonly assumed to be free of uncertainty. Unfortunately, that assumed analytical technique uncertainty has for the most part subsumed sampling uncertainty.

In contrast to the fixed laboratory centered site characterization approach, data produced in the field have been generalized as “screening” and thus perceived as inferior to fixed laboratory methods and not rigorous enough to support important project decisions and regulatory actions. Such generalizations are based upon 1) the current regulatory mindset that “high quality” analytical data is necessary—even sufficient—to accurately depict site conditions and 2) a near lack of understanding of the distinction between analytical method and the data sets that are produced by them. While these assumptions are inaccurate, they have been pervasive enough to inhibit widespread use of better strategies for assessing and restoring brownfields sites.

Because of the magnitude of the number of brownfields sites and the complexity of contaminated site redevelopment, alternative site characterization strategies that elevate reduction of sampling uncertainty are now undergoing field testing at NJIT. Through better sampling representativeness (data density) these approaches improve the level of confidence for site management and cleanup decisions with reduced uncertainty (Woll et al., 2003). When FAMs are used in conjunction with detailed systematic planning and dynamic work plans (DWP’s), the full promise of the Triad Approach can be realized (Robbat, 1997; Crumbling et al., 2001; United States Environmental Protection Agency, 2001).

The Triad Approach is driven by the recognition that the greatest sources of data uncertainty are issues related to sampling. The single most important component of any
sampling characterization program is the selection and collection of samples that are representative of the features being investigated. Therefore, a program that overemphasizes laboratory management at the expense of collecting representative samples can produce information that does not accurately reflect site conditions. This is particularly important when considering brownfields sites because redevelopment seeks to use the whole site and thus needs a complete understanding of site conditions.

COMPONENTS OF THE TRIAD APPROACH

Systematic Planning

Systematic planning is the critical first step for all site activities, ensuring that project end goals are clearly articulated, stakeholders have been heard, and decision makers are in agreement on the desired decisions and confidence needed to support them. A multidisciplinary technical team translates the project goals into realistic technical objectives from which the conceptual site model (CSM) is derived. The team also identifies the competency level of field staff that will be needed to fulfill the technical objectives. The CSM allows the project team to organize what is already known about the site and identify what more needs to be known to achieve the project goals. The development of the CSM strengthens communication and cooperation among stakeholders involved in the effort to redevelop the property. The systematic planning process also ties project goals to individual activities that are needed to reach these goals by identifying data gaps in the CSM. For the field components, the team uses the CSM to direct fieldwork to gather the needed information. Finally, the CSM is evergreen and evolves and matures as site work progress and data gaps are filled.

Dynamic Work Strategy or Plan

Dynamic work strategy or plan (DWP) is the element of the Triad Approach that becomes the basis for making real-time decisions in the field. It consists of stakeholder-approved decision trees and decision logic developed under the CSM. It is supported by the rapid turnaround of data collected, analyzed, and interpreted in the field so that additional sample locations can be selected “on the spot.” Success of the DWP hinges on the execution of the program by experienced staff that is empowered to “call the shots” based upon the decision logic and has the skill to cope with unanticipated conditions. Field staff must maintain close communication with stakeholders during the implementation of the DWP.

Field Analytical Methods

Field Analytical Methods (FAMs) are the final component of the Triad Approach that are used to generate real-time data for rapid team-based field decisions. Technologies include rapid sampling platforms such as direct push sampling, field GC/MS, XRF, and immunoassays as well as mobile laboratories. These methods must be appropriate to the matrix being sampled and appropriate quality assurance/quality control (QA/QC) procedures needed to achieve project goals. Methods can be integrated to control data quality, but must produce information quickly and inexpensively to support the dynamic decision-making process while maximizing data density and thus representativeness.
CASE STUDY: APPLICATION OF THE TRIAD APPROACH AT A COMPLEX BROWNFIELD PROJECT

Project Site

The city of Trenton, New Jersey, is an old industrial city of approximately 85,000 people contained within 7.5 square miles (Trenton, 2003). It has many abandoned industrial sites, which require environmental work prior to redevelopment and have become the focus of an aggressive program to investigate and remediate these sites. One of the more ambitious projects the city of Trenton is currently undertaking is the conversion of several former industrial sites, including a former wire manufacturer, former explosive plant, scrap metal recyclers, a railroad freight yard, and a refrigeration repair shop, into recreational use. These sites, which consist of over 60 acres and 11 parcels, lie in the floodplain of the Assunpink Creek that meanders through the city. Since the area has been industrialized since the late 1800s the extent of the site contamination was largely unknown at the start of the project, but preliminary assessments indicated that contamination by heavy metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and petroleum hydrocarbons could be present.

Project Objectives and Investigation Pan

The project team was faced with limited historical information for the goal of redeveloping the site into a recreational park and greenway (see Exhibit 1), which led to several objectives:

- Characterize environmental impacts in sufficient detail to allow development of remedial approach and costs.
- Delineate horizontal and vertical extent of areas of concern (AOCs) to Residential Direct Contact Soil Cleanup Standards.
- Perform characterization as cost-effectively and expeditiously as possible using FAMs and DWPs to the fullest extent allowable.
- Distinguish historic fill from site-specific AOCs.

Through systematic planning, an initial Site Conceptual Model was developed. This process served several purposes. The process:

1. created consensus among stakeholders;
2. identified important issues with regard to characterization challenges such as defining the distribution of historic fill and associated contaminants;
3. achieved agreement on potential Contaminants of Concern (COCs):
   a. Volatile Organic Compounds (VOCs)
   b. Polycyclic Aromatic Hydrocarbons (PAHs)
   c. Total Petroleum Hydrocarbons (TPH)
   d. PCBs
   e. Metals; and
4. identified multiple AOCs (drums, ASTs, distressed and discolored soil, rail yards, soil piles, and discharge pipes) within the property that would require investigation.
Thus the systematic planning process, through multiple stakeholder meetings, was critical to implementing the project because it allowed all participants to assist in defining the beneficial end uses (city of Trenton); establishing cleanup “action levels,” crystalizing project goals, and identifying key decisions needed to achieve goals such as the distribution of historic fill, the number of AOCs requiring remediation, which COCs should be targeted, the data quality requirements, field communication procedures, and the structure of the overall site investigation program.

The project approach was reduced to two phases: Phase I was designed to address critical issues associated with historic fill distribution, COCs and AOCs; and Phase II was designed to address critical issues associated with specific AOC delineation and the magnitude of remediation. Two phases were employed for reasons of funding availability, the complexity of investigating 60 acres of land with multiple potential sources of environmental impacts, the presence of an extensive amount of historic fill, and the donation of the use of EPA Region 2’s mobile laboratory.

Early in the systematic planning process it was recognized that complex site conditions warranted an innovative approach to the investigation. Thus it was agreed that, wherever possible, the Triad Approach would be used. Phase I used the Triad Approach in conjunction with traditional methods to evaluate overall site conditions (primarily mapping the extent of historic fill), investigate a large number of AOCs, eliminate certain AOCs from further investigations, and focus the additional characterization activities. Under Phase I the critical investigational issues were:

- historic fill distribution;
- whether COCs in historic fill had impacted underlying native soil;

![Exhibit 1. Assunpink Creek greenway conceptual plan](Image)
During this phase it was also determined that the action level would be driven by residential criteria. Finally, Data Quality Objectives (DQOs) pointed to a combination of FAMs, mobile laboratories, and fixed laboratory analyses.

Phase II used the Triad Approach to investigate three locations in the brownfields project study area where there was known contamination based on the investigative work completed under Phase I. The specific objective of the Triad Approach under Phase II was to enable the city of Trenton to collect environmental information about these locations in sufficient detail to make critical decisions about property acquisition and remediation requirements and costs.

RESULTS AND DISCUSSION

Phase I

The historic fill component of Phase I involved using a conductivity probe with performance verification through select borings. The use of the probe gave investigators a real-time measurement of soil of conductivity for in-field decision making such as targeting unique strata in the fill and determining the fill/native soil interface, choosing intervals for analysis (after a planning meeting), and combining the strengths of fixed base and field-based analytical methods. The findings from this component of the investigation were that the conductivity probe proved to be a quick, inexpensive, and efficient method for determining fill thickness and discovering unique zones within soil strata. For example, it was found that native soil beneath the fill had not been impacted and that targeted sampling of unique zones in the fill revealed that PAHs and metal COCs were important considerations. Additionally, it was also determined that there was a significant variability to the fill material across the project area. Mapping of the historic fill distribution over the project was accomplished in four days.

The AOC component of Phase I involved field observations and the use of preliminary assessment data to identify potential AOCs for the purpose of identifying those that would require further delineation. AOCs were categorized into different types such as point source, spills, tank releases, area wide impacts, and sediments. For this component a mix of FAMs, mobile labs, and fixed base analysis were used in conjunction with field observations. The findings for this component were that the predominant COCs were verified as PAHs, PCBs, metals, and TPH. Area-wide impacts were evident in the Rail Freight Yards. It was also determined that fuel spills in freight yards had mixed with the area-wide impacts. PCBs were identified in one area at depth and required further delineation. High levels of PAHs and metals were isolated at point locations as were sediments that were impacted at point locations. An outcome of this exercise was that some potential AOCs could be eliminated.

Data Quality Management objectives were driven by the need to maximize sampling density and minimize field time while shorting turn-around time and controlling costs. The team determined that a three-tiered approach to analysis could meet these seemingly incompatible objectives.

The foundational site analysis Tier I relied on FAMs such as: x-ray fluorescence (XRF) for metals and ultraviolet fluorescence (UVF) for PAHs and TPH. FAMs provided
semi-qualitative high sample throughput capability. Though FAMs provided high sample densities they were not always compound-specific; therefore, additional levels of analytical performance were required to meet the New Jersey Non-Residential Direct Contact Soil Cleanup Standards, which are compound-specific action criteria.

- The middle Tier II analysis utilized definitive non-certified methods to produce compound-specific PAHs and TPH results. This tier required the use of an on-site experienced analyst and offered the advantage of compound specificity and lower quantitation limits.
- The final Tier III used a combination of mobile and fixed laboratory analyses based on standard SW-846 methods.

This three-tiered collaborative analysis scheme gave the team the advantages of in-field delineation (such as real-time data and high throughput to maximize sampling density) with mobile lab and fixed laboratory SW-846 verification. Split samples were used to verify data using the mobile laboratory and a New Jersey Department of Environmental Protection (NJDEP)-certified laboratory; for example, split samples were used to confirm delineation boundaries that were detected using FAMs.

Phase II

The initial step under Phase II was to prepare and issue a Request for Proposals to hire an engineering firm to implement the Triad program to address AOC delineations based on Phase I work. The team found that the Phase I work greatly improved the quality of the bid package by focusing the Triad investigation on areas where it would be of most benefit. Because of the nature of Triad field work, unique pricing schemes were developed.

The development of location-specific conceptual models was used to guide the design of the sampling program and field decision making. The CSM for the Crescent Wire and the Rail Freight Yard sites were expanded to include a conceptualization of possible contaminant migration scenarios. These scenarios allowed field personnel conducting the investigation to compare field-generated data to potential anticipated conditions. They were used to construct decision trees that were used to guide the field decision making and manage the investigation as the work unfolded.

For example, based on site information obtained during Phase I, it was possible to speculate on potential contaminant migration scenarios that would complete the conceptual model for the Crescent Wire site. Four scenarios were developed during the systematic planning that formed the basis for developing decision logic needed to implement the investigation such that important decisions associated with the Crescent Wire site could be addressed. These were:

- Is the source(s) of the PCB/TPH impacts on-site or off-site?
- Is the source(s) of the contamination a thin floating layer of poorly soluble weathered hydrocarbons that has not produced a dissolved phase plume?
- Are subsurface impacts confined to a “hot spot” or a limited migration plume that had not reached the creek?
- Has the plume migrated to the creek, and, if so, are PCBs in creek sediments related to the plume or did they originate from sediment transport?
- What would be the design (placement and construction details) of a possible monitoring well network?
Can a monitored natural remediation approach be proposed for groundwater impacts, or is an active containment or extraction approach more appropriate?

The field implementation of the DWP involved a three-tiered collaborative data analytical program to address two seemingly incompatible needs. On the one hand, field delineation required high-density rapid throughput sampling and analysis, while on the other hand residential action criteria required compound-specific low detection limits analytical methods to verify end points. Visual observation, FAMs, modified field-based GC/MS methods, and fixed base laboratory results were integrated in a constant process such that reliable real-time information could be generated and interpreted to make daily field decisions. This enabled the field team leader to have confidence in the data when making critical field decisions, but also enabled requests for additional sample locations without being overly concerned about cost and time.

This phase of the project demonstrated the strength of the three-tiered collaborative data process, coupled with an experienced field making daily decisions about sampling to efficiently characterize targeted locations. It was observed by the field personnel that a major contributor to the successful application of the Triad Approach was the emphasis on systematic planning. The CSM scenarios allowed the field team to quickly interpret the data and communicate findings to decision makers because all stakeholders had participated in the CSM discussion and were already familiar with possible outcomes. Thus the CSM became a common framework for discussing daily findings, which led to field decisions about new sampling locations and arriving at agreement on final end points.

An example of how the CSM was used as an investigative framework was the Crescent Wire property investigation (see Exhibit 2). This portion of the Assunpink Creek project was a former manufacturing site for the production of high-tension power lines and cables. At the start of the Triad program, little was known about the site with the exception of two close-together sampling locations that indicated TPH and PCB impacts at or near the water table and one anomalous PCB data point from an Assunpink Creek sediment sample collected adjacent to the Crescent Wire property (see Exhibits 3 and 4). The team questioned if this sediment sample was linked to the PCBs identified in property groundwater. As discussed above, several CSM scenarios were developed based upon important regulatory and planning decision needs. One was ultimately selected to begin the fieldwork.

Exhibits 5 through 7 depict, in simplified fashion, the evolution of the CSM.

The field team started with resampling the original locations to confirm the previous results and calibrate the performance of the sampling and analytical methods (see Exhibit 5). Property-specific decision logic called for testing the “hot spot” CSM scenario first, so new borings were advanced in a radial pattern around the initial sampling locations. Results showed that impacts were present at all locations, requiring a shift to the next level of decision logic, which was that impacts were not an isolated “hot spot” but possibly migration of a larger plume from an off-site source.

A decision was made to go immediately to the upgradient property boundary and sample (see Exhibit 6). PCB and TPH impacts were found at the upgradient property boundary, so the next step in decision logic called for delineation of the plume dimensions as it migrated on site. This was accomplished by marching along the property boundary until edges of the plume were identified. At this point the field program was slightly more than two-and-a-half days old. Having now substantially improved the CSM by determining that the plume was originating from an upgradient source and that it was confined to a thin layer of floating weathered product, the decision logic called for a determination of whether the...
PCBs in the plume were the source of PCB impacts in the creek sediments. The Assunpink Creek is an urban stream and receives runoff from a wide variety of sources, so it would not be prudent to conclude that the PCBs in the plume were impacting the sediments.

The Triad program shifted into its final step, which was to locate the downgradient edge of the plume (see Exhibit 7). This was accomplished by establishing a pattern of borings marching in the downgradient direction and along the east edge of the Crescent Wire site, immediately upgradient from the Assunpink Creek. This program rapidly mapped the extent of the PCB/TPH smear zone, established that there was little to no dissolved phase impacts and determined that the source was upgradient and not associated with the Crescent Wire site. Thus, several important questions regarding the Crescent Wire site were quickly resolved, substantially reducing the need for further investigation work.

The approximately three-acre Crescent Wire property Triad program was accomplished in four days by using dynamic, decision logic–guided sampling and analysis to determine the characteristics of the plume and answer the questions of a possible connection between COCs in the plume and those found in Assunpink Creek sediments. The amount of data collected in the four days was sufficiently representative to allow agreement among the stakeholders for the need and design of a long-term monitoring system and the remedial approach. Coupled with the Phase I work, the Triad approach successfully investigated the environmental characteristics of the Crescent Wire site in a shorter timeframe and with greater detail and certainty that would have been possible.
Exhibit 3. Preliminary information—Crescent Wire site

Exhibit 4. Initial conceptual site model
Exhibit 5. Decision logic step 1—PCB hot spot or not?

Exhibit 6. Decision logic step 2—upgradient boundary & plume delineation
DAY 4 – Suspected downgradient source confirmed and plume extent defined.

Sampling proceeded to downgradient toward creek (4) and (5) then along the creek (6) to define leading edge of plume. Interior sampling was completed (7).

Exhibit 7. Decision logic step 3—downgradient boundary & plume delineation

Exhibit 8. Field analytics—conductivity probe
with traditional methods. The key to this accomplishment was the emphasis on systematic planning that resulted in the proper use of a range of field analytical instruments (Exhibits 8 and 9) to allow onsite decision-making.

LESSONS LEARNED

Over the course of both phases, this project tested the conventional paradigms of sampling and analysis. The project also demonstrated, during Phase II, that field investigation periods of less than one month could yield a robust data set that could support regulatory decision making and remedial approach objectives. The project also provided some valuable lessons that the authors believe will be useful to others as they implement the Triad Approach.

Municipal Planning Is Needed Early on in the Process

To bring the project to this point, municipal officials were required to determine the end land use of each portion of property at the beginning of the process. The land use was used to form the basis of the planning of the environmental work. To be useable in the CSM, these objectives must be clearly articulated and referred to regularly to avoid unnecessary sampling. In using the Triad Approach for this project, the city of Trenton had to invest additional planning time early in the process; however, the result was a more efficient, targeted, and cost-effective process.

Timeframes Are Sensitive to Complexity and Stakeholders

The complexity of the project and the number of partners caused the anticipated timeframe to be extended, and additional drafts were required before each document could be approved.
The CSM Supported Proposal Analysis.

In writing the request for proposals, the city of Trenton divided the tasks between those that were to follow a more traditional sampling approach and those for which a more creative approach was expected. The tasks in the latter category were generally those for which delineation was expected to be necessary. Despite the desire for innovation and creativity, to effectively compare proposals, the city had to provide assumptions for the consultants to follow in costing their proposals. This approach allowed the consultants to propose creative approaches, while allowing the city to determine which consultant would provide the best value for the money.

Systematic Planning Improved Communications Among Stakeholders.

The concepts embodied in the Triad Approach have been extremely useful in developing work strategies for the Assunpink Creek brownfields project. The systematic planning process successfully brought together regulators, municipal officials, academics, and practitioners in work sessions that produced clearly identified project goals and objectives, defined sampling programs, and developed a dynamic work plan that was used in field decision making and decision logic to guide the investigation.

Field Personnel Must Be Experienced Seasoned Professionals.

In some respects the Triad Approach turns the traditional model of field investigation on its head. The historical model of using junior staff in the field with senior off-site support proved antithetical to the desire to make field-based decisions using real-time analytical data. Instead, highly trained (in sampling and analytical methods), experienced field personnel must be in the field to interpret data trends. This can be addressed during the development of the DWP, which can prescribe the competencies and capabilities of field personnel.

The Comfort Level of Regulators Will Be Challenged.

When detailed data acquisition planning is performed up front and those data will be used for decision making, the traditional regulatory process of the iterative “data generation and comment” cycle is collapsed. Regulatory personnel who are unaccustomed to making such decisions may feel uncomfortable, which may signal the need to review the process and contingencies to raise the comfort level. Nevertheless, regulators must be engaged in the planning process, prepared to clearly define the “action levels” and end points, and willing to participate in the field decision making where appropriate to create a successful outcome.

A Tiered Data Process Leverages the Best of Innovative and Traditional Methods.

A three-tiered collaborative data process that leverages the strengths of field, mobile, and fixed analytical methods with a variety of compound specificity and detection limits can provide the flexibility needed to obtain high-density representative samples and verification for delineation end points. This process yielded an unexpected but important development during the investigation of the Rail Freight Yard portion of the project. A
PCB (hot spot) area of concern was discovered that could have been overlooked had it not been for the rapid and denser characterization capabilities of FAMs and experienced field personnel. The added costs were minor; however, the time saved and uncertainty reductions were significant.

ACKNOWLEDGMENTS AND DEDICATION

The Assunpink Creek Greenway project is an exemplary cooperative effort among many stakeholders including: City of Trenton Department of Housing & Development, New Jersey Institute of Technology–NHSRC Technical Assistance for Brownfields (TAB) program, USEPA Region 2, USEPA Technology Innovation Office, New Jersey Department of Environmental Protection, and the U.S. Army Corps of Engineers–Philadelphia District.

The authors wish to dedicate this paper to William Librizzi, who passed away during its preparation. We will miss his enthusiasm and leadership.

ON-LINE TRIAD APPROACH RESOURCES

U.S. Environmental Protection Agency Clu-In: http://www.clu-in/triad

REFERENCES


the concept of effective data to contaminated sites could reduce costs and improve cleanups. Environmental Science and Technology, 35(19), 405A–409A.


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