



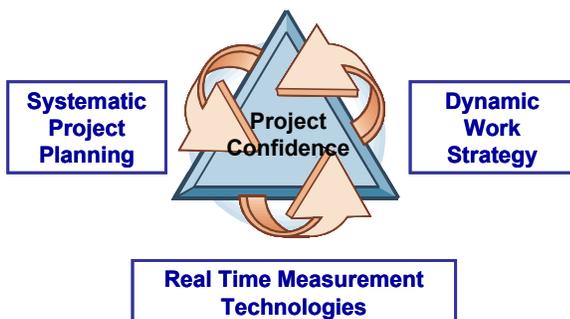
# Demonstrations of Method Applicability under a Triad Approach for Site Assessment and Cleanup — Technology Bulletin

## August 2008



Since its inception in 1995, the U.S. Environmental Protection Agency's (EPA) Brownfields Initiative and other revitalization efforts have grown into major national programs that have changed the way contaminated property is perceived, addressed, and managed in the United States. In addition, there has been a shift within EPA and other environmental organizations in the way hazardous waste sites are cleaned up. Increasingly, project managers, regulators, technology providers, and other stakeholders are recognizing the value of implementing a more dynamic and flexible approach to site cleanup that focuses on real-time decision-making in the field to reduce costs, improve decision certainty, and expedite site closeout. The approach, known as Triad, uses (1) systematic project planning, (2) dynamic work strategies, and (3) real-time measurement technologies designed to increase confidence in the project (Figure 1).

Figure 1. The Triad Approach



Triad's best management and technical practices have been successfully implemented in a variety of regulatory frameworks, including Brownfields, Superfund, the Resource Conservation and Recovery Act (RCRA), management of underground storage tanks (UST), and voluntary cleanup programs. As a result, the EPA Brownfields and Land Revitalization Technology Support Center (BTSC) is preparing a series of technical bulletins to provide additional information on implementing specific aspects of the Triad approach. These bulletins are intended for technical project managers and team members. Non-technical managers or stakeholders may also present these bulletins to consultants and service providers to ensure Triad best management and technical practices are implemented appropriately at their sites. These bulletins provide sufficient information for less technical project managers and team members to request

that critical Triad project elements be included in scope of work and planning documents.

Demonstrations of Method Applicability (DMA) are a key component of using real-time measurement technologies and are presented in this bulletin through:

1. Answers to frequently asked questions on key aspects of DMAs
2. Examples of DMAs performed at hazardous waste sites:
  - Wenatchee Tree Fruit, Wenatchee, Washington
  - Poudre River, Fort Collins, Colorado
  - Fort Lewis Small Arms Firing Range, Fort Lewis, Washington
3. Sources of additional information for communities and project teams that desire to implement DMAs and the Triad approach.

### About the Brownfields and Land Revitalization Technology Support Center (BTSC)

EPA established the BTSC (see [www.brownfieldstsc.org](http://www.brownfieldstsc.org)) to ensure that brownfields and other land revitalization decision-makers are aware of the full range of technologies and technical support services available for site assessments and cleanups and to help them make informed decisions about their sites. The center can help federal, state, local, and tribal officials evaluate strategies to streamline the site assessment and cleanup process at specific sites; identify, review, and communicate information about complex technology options; evaluate contractor capabilities and recommendations; and plan technology demonstrations. BTSC is coordinated through EPA's Office of Superfund Remediation and Technology Innovation (OSRTI) and works through EPA's Office of Research and Development (ORD) laboratories. The center also works closely with EPA's Office of Brownfields Cleanup and Redevelopment and in partnership with the U.S. Army Corps of Engineers (USACE) and Argonne National Laboratory.

Localities can submit requests for assistance through the EPA Regional Brownfields Coordinators, online, or by calling 1-877-838-7220 toll free. For more information about the BTSC, contact Carlos Pachon at (703) 603-9904 or [pachon.carlos@epa.gov](mailto:pachon.carlos@epa.gov).

## What is a DMA?

A DMA is an initial site-specific performance evaluation for a wide range of sampling, testing, and data management tools. It is a concept founded in EPA SW-846 guidance ([www.epa.gov/epaoswer/hazwaste/test/sw846.html](http://www.epa.gov/epaoswer/hazwaste/test/sw846.html)) and is based on the principles of EPA's performance-based measurement system (PBMS) initiative ([www.epa.gov/SW-846/pbms.htm](http://www.epa.gov/SW-846/pbms.htm)). A DMA usually falls into one of two categories: (1) a comparison of a field-based method with a more established laboratory-based method to demonstrate the usefulness of the field-based method, or (2) a test to evaluate whether a particular tool will work on a specific site. Both types of DMAs may be needed at a single site, and the exact format of the DMA will depend heavily on the site characteristics, the history of investigations at the site, and the intended use of the data.

The DMA serves several different purposes for many applications, including showing whether a technology will be effective at the intended site, but also to optimize how it will be used collaboratively with other information sources at the site. DMA data are of particular importance relative to understanding the potential effects of matrix heterogeneity and sample support on data quality. During the DMA, the types and frequency of quality assurance and quality control (QA/QC) procedures are often tested for adequacy, and preliminary field-based action levels are developed for comparison with site decision criteria. Methods for data sharing and management are also tested to assure a project can proceed in real-time.

In addition, a DMA can be used to evaluate technologies for generating analytical data (or other information) both in the field and in an off-site location that will provide information appropriate for meeting project decision criteria. The ability of technologies such as X-ray fluorescence (XRF), immunoassay (IA), ultraviolet (UV) fluorescence, and direct sensing tools such as the membrane interface probe (MIP) and laser induced fluorescence (LIF) to produce decision quality data has been well documented ([www.epa.gov/ORD/SITE](http://www.epa.gov/ORD/SITE) and [www.epa.gov/etv](http://www.epa.gov/etv)) and their suitability to a site can be evaluated through a DMA. Extensive literature and performance data are available for some technologies, and these data should be reviewed by project teams before a DMA is designed.

A DMA can also provide information on cost and performance that can be used to optimize collaborative data collection using technologies for generating analytical data (or other information) both in the field and in an off-

site location. Additionally, a DMA can offer stakeholders an understanding of the site-specific performance of a technology while at the same time it provides the basis to optimize standard operating procedures (SOPs) for deployment.

DMAs are performed easily and affordably before mobilization, or as an early component of a field program. Advice on the specific technology and assistance to set up a DMA sometimes are available from equipment vendors or service providers.

The question often arises: "How do DMAs fit into the data quality objective (DQO) process?" Various aspects of DMA planning and implementation fall under a number of DQO steps, but the most important one is Step 7: Select the most resource-effective sampling and analysis strategy that meets the performance criteria.

## When is it necessary to perform a DMA?

DMAs may be used when the project team works with a technique that previously has not been used at the site. Site-specific factors often may render an otherwise useful technique unsuitable and can result in high and unnecessary project costs if they are not discovered early in the project. A DMA can quickly ascertain whether the new technique is suitable for use at the site, allowing the project team to identify an alternative if the proposed technique is not suitable. Conversely, the project team can proceed with confidence, realizing the benefits offered by the technique, if the DMA suggests that it will be effective.

A DMA may be necessary when:

- A project will depend heavily on field-based results to make real-time decisions.
- Experience indicates a technology's performance is variable from site to site.
- Heterogeneity and the cost of cleanup are high.
- The chemistry of contaminants is complex.
- A specific relationship is needed between collaborative forms of data sets to support decision-making.
- Stakeholder acceptance requires that the utility of a technology or approach be evaluated.

## What are the benefits of performing a DMA?

A well-planned DMA can simultaneously test, refine, and coordinate many project design parameters before full-

scale project activities are under way. Project design parameters often evaluated during a DMA include sampling and analytical methods, QA/QC procedures, data management, communication and data sharing strategies, collaborative or comparative data needs (for example, technologies matched with other field tools or standard fixed-laboratory analytical methods), project staffing, and the overall flow or sequencing of field activities. A carefully considered DMA can help an entire project run faster and more smoothly, resulting in lower costs, and assuring that the data collected will be adequate for the intended end use. Both field-based and fixed laboratory methods have limitations, and the project team should verify their performance during project startup to avoid generating data or using equipment that does not meet project requirements for precision, accuracy, representativeness, completeness, comparability, specificity, sensitivity, ruggedness, and reliability.

Project-specific DMAs guide the project team in selecting and optimizing collaborative methods and assuring adequate method performance for site conditions and decision criteria. DMA results can be used to develop project-specific action levels; analytical, sampling, and data analysis procedures; QA/QC requirements; and additional data requirements to assure the quality of the

decision. Furthermore, A DMA can help set acceptable levels of uncertainty relative to decision thresholds used in the field as part of a dynamic field decision strategy. The fast pace of real-time cleanup projects makes DMAs essential to avoid down time related to problems that arise from inadequate planning for sampling and analysis.

As noted earlier, DMAs can be used to test the suitability of technologies for generating any data, whether the analysis occurs in the field or in a traditional laboratory. Chemical data-oriented DMA tasks involve collecting, preparing, and analyzing samples from a site-specific matrix (soil, water, air, and tissue, for example).

DMAs also serve important non-analytical functions and can help evaluate whether a project is ready to proceed. DMAs can be used to test the preparedness of field personnel and service providers, as well as to evaluate the adequacy of logistical and data management plans. For example, sample throughput and analysis times can be more accurately estimated. Likewise, materials and personnel needs can be balanced and documentation procedures clarified. In addition, instrument compatibility and data exchange or upload protocols can be verified and debugged as necessary. Assessing logistical feasibility in this manner is especially important when the project team uses dynamic work strategies. This aspect of a DMA can help evaluate practical constraints for work at the site in relation to the timing of sample collection and analytical throughput, including field analytical equipment, labor, sample storage, and the cost and supply of consumables.

The DMA can also be used to “test-drive” real-time decision support tools (DSTs). These tools include electronic data management procedures, global positioning system (GPS) and surveying equipment, and modeling, mapping, and data display software. This aspect of a DMA will improve the ease of use during full-scale field mobilization by ensuring operators can do the job and identifying those aspects of a DST that can be improved. In some cases, the project team may decide a different DST is more appropriate for one particular portion of a project versus another.

Finally, the DMA can be used to assess the appropriateness and performance of proposed generation techniques for data other than chemical, such as geophysical, geotechnical, or direct sensing or probing methods. The presence of site-specific interferences that could compromise the performance of these tools can be tested as a result. Interferences for geophysical techniques could include tree leaf cover, seasonal wetland

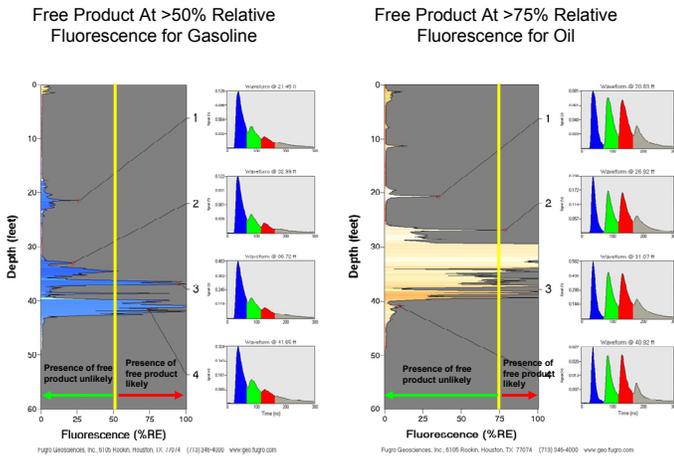
**Important functions of a DMA include:**

- Providing assurance that the proposed site characterization methods are suitable for the specific project.
- Generating data of known quality.
- Developing initial relationships between field methods or tools and other collaborative methods such as fixed laboratory. These relationships are used to design and focus the QC program.
- Testing a preliminary CSM to refine sampling protocols if assumptions are found to be incorrect.
- Setting preliminary field-based action levels to be used for real-time decision-making.
- Establishing the readiness of field personnel, equipment, and procedures before full-scale work begins at a site.
- Assessing alternative strategies as contingencies should the performance of the intended methods be compromised by unanticipated problems.

areas, low power lines, fences, shallow bedrock, salts, and interlocking sands. Mineralogical interferences or other geological conditions can also affect the performance of direct-sensing equipment such as LIF probes. The presence of some forms of calcite or specific clay materials also can impair the utility of LIF. If interferences are identified during the DMA, alternative strategies for dealing with them can be developed before full-scale work is undertaken at the site.

DMA's for direct-sensing tools include many of the same techniques used for evaluating other field analytical tools. They can involve building relationships between sensor response and analytical data or other forms of comparable information such as visible staining, free product, soil saturation, or physical characteristics of the matrix. Figure 2 provides an example of developing relationships between LIF response and visual core observations. At this site, relative fluorescence for various product types such as gasoline, diesel, and oil were used to estimate the presence or absence of free product. When used with LIF logs to estimate product thickness, these values allowed members of the technical project team to estimate contaminant mass and optimize locations and depths for a product removal system.

**Figure 2: Correlations of LIF response and presence of free product.**



**What are key concerns to address in designing a DMA?**

At least four aspects of a data-focused DMA should be considered during its design, including the following:

- What are critical aspects of the preliminary conceptual site model (CSM) that should be tested to assure project success? These aspects may include assumptions about the locations and nature of

suspected releases, the degree of matrix heterogeneity, and the impact of sample processing bias. Understanding matrix heterogeneity is critical in evaluating the number of samples required for statistically based sampling designs. Without some information about the specific site and performance of the analytical method, the appropriate number of samples needed to achieve a desired level of decision confidence cannot be correctly identified.

- Is it important to evaluate the cost-effectiveness and bias of multi-increment sampling? It may be important to compare the cost-effectiveness and bias of traditional grab sample collection and mathematical averaging procedures against a multi-increment (physical averaging) sampling strategy.
- Do changes in sample support (the size, shape, and orientation of a sample) dramatically affect analytical data results? Is the level of effort associated with various sample preparation and analysis techniques worth the benefit of higher precision, accuracy, or control of bias?
- Are project decisions of a qualitative or quantitative nature? In some cases, a “yes or no” answer is all that is needed, while for others a more quantitative result is needed. For example, in some cases the decision is only whether free product is present or absent in the subsurface. In contrast, risk estimation often requires data in the form of quantitative concentration results.

DMA's should be designed to address those issues that most often provide the greatest source of uncertainty: sample heterogeneity and short-scale spatial variability. The resulting mismatch between the volume of the sample analyzed and where it is collected versus the data result that will be extrapolated to a significantly larger volume of material can be significant. Therefore, the DMA should appraise sampling designs (such as multi-increment designs), sample collection techniques (such as low-flow purging of ground water wells versus passive diffusion samplers), and sample preparation procedures (such as in situ versus ex situ readings and options for sample homogenization or fractionization based on soil properties such as particle size).

A DMA often involves “split samples” that are carefully prepared to minimize matrix heterogeneity and analyzed by two or more different techniques to establish relationships. Parametric and non-parametric techniques are commonly used to evaluate these relationships and establish decision quality for collaborative data sets.

Parametric statistical methods use assumptions about the data's underlying statistical distribution shape (normal, lognormal, or other). If those assumptions are invalid, the statistical conclusions may not be reliable. Non-parametric techniques do not require that as many assumptions be true, so they are more broadly applicable to the properties of environmental data.

Comparability is quantified by establishing the frequency that results from different techniques agree with each other with respect to a declared reference point. Different points of reference can be used, but the most common strategy in Triad projects is to establish comparability in terms of the decision being made on the data. These data may require quantitative comparability (such as if or when two data sets are combined to calculate risk assessment parameters) or qualitative comparability for agreement at the compliant or non-compliant decision threshold.

A comparability DMA can be used to demonstrate the suitability of field-based technologies or project-specific modifications to improve the performance of an established fixed-laboratory method. The techniques to be compared include sampling related methods as well as analytical methods. Understanding the effects of sample heterogeneity is extremely important when samples will be split for the different analytical methods to be evaluated. A valid comparison of data sets requires thorough homogenization of samples before they are split to ensure both methods see the same sample characteristics that will be used to make a decision. To understand method differences, known or blind QA samples (spikes, replicates, reference materials, or blanks) are also often subjected to comparative analysis to assure technical team members that both methods are providing representative results.

#### ***What data deficiencies can be addressed using a DMA?***

Site-specific method reporting limits (MRLs), precision, bias, false positive rates, and false negative rates can be assessed through the DMA process. For example, MRLs and sample reporting limits can be tested by analyzing samples spiked with known amounts of target contaminants and comparing site-specific matrices to find the lowest concentration that can be reliably detected and quantified.

Data from laboratory reference methods and from a field-based method should be compared to see whether they produce data that lead to the same project decision based on established field-based action levels or decision rules.

The ability of two methods to agree for decision-making is an important parameter to examine when comparing analytical methods, especially when methods with lower analytical performance such as immunoassay methods (which measure several closely related analytes and report a single result for the group) are being compared with methods with higher performance, such as gas chromatography (GC) and mass spectrometry (MS) (which are usually able to distinguish between closely related analytes and measure each). In this way, the DMA is a critical component in Triad's efforts to manage the analytical contribution to decision uncertainty.

#### ***How can DMA use weight of evidence and collaborative data sets?***

Terms such as "weight of evidence" or "multiple lines of evidence" and "collaborative data sets" have been developed to describe these layered data sets. From a Triad perspective, there is a distinction between the two. "Weight (or lines) of evidence" refers to combining information from various different sources into a holistic picture (that is, a CSM). For example, historical information may be used in conjunction with geological, hydrogeological, chemical, and geophysical data to predict contaminant fate and transport.

On the other hand, "collaborative data sets" or "collaborative methods" refer specifically to the strategy of using two (or more) analytical methods to measure the "same" analyte or a surrogate of an analyte. For example, total uranium can be measured by XRF, gamma spectroscopy, and alpha spectroscopy. Collaborative methods are paired so that the strengths of one method can compensate for the limitations of the other. Frequently, a field method is selected for its ability to provide a much higher density of data points than an expensive laboratory method. However, the laboratory method will generally achieve better detection limits and accuracy than the field method. A DMA should be designed to guide the "marriage" of the techniques to produce reliable information that is not biased by the effects of heterogeneity or analytical inaccuracy.

Additionally, alternative analytical methods, particularly any that provide results in "real time," can be used to optimize the decision making process. For example, the real-time decisions and high data density possible with field methods can reduce the volume of material removed during cleanup by more precisely defining and confirming the actual contamination footprint. Real-time data can in this way improve confidence in the decision and limit "surprises" after a project is complete.

### What is involved in performing a DMA?

Designing an appropriate DMA is specific to the technology or technique being employed and to the project, the site matrix or matrices, the effects of heterogeneity, sample support (the size, shape, and orientation of a sample), the expected use of the data, and a myriad of other factors. During systematic planning, the project team may evaluate potential candidate technologies or strategies for use at the site.

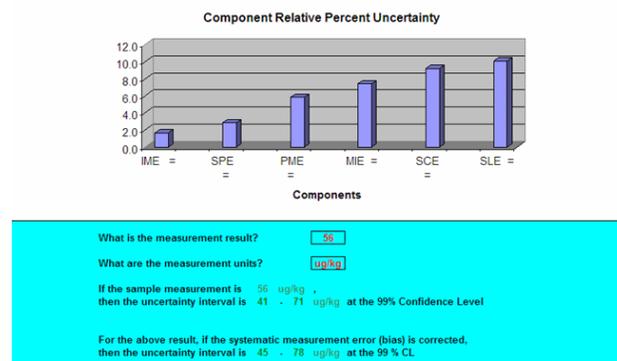
Technologies and strategies that can improve project efficiency and the CSM, increase data density, and reduce uncertainties associated with decision making are most often targeted. Project teams are encouraged to employ the services of an experienced Triad practitioner when technologies or strategies are short listed. Although there is no generic format for designing a DMA, a number of activities are often involved.

- Evaluating the strengths and limitations of technologies or techniques to be used on site samples.
- Evaluating sample support, throughput, ease of use, manipulation and storage of data, and other logistics so that the process is optimized.
- Collecting and analyzing QC samples to evaluate the uncertainties that are the largest contributors to total measurement error. Project resources can then be allocated to control for those activities with the greatest effect (Figures 3 and 4).

Figure 3. Uncertainty Sources and Associated QC Samples

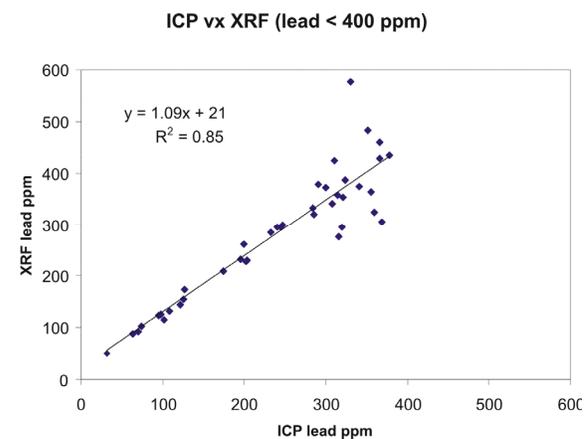
Uncertainty Sources	Source Symbol	Analytical Sample	Analytical Sample Symbol
Intrinsic (Instrumental) Measurement Effects	IME	Instrument Calibration Standard	ICS
Spike Preparation Effects	SPE	Initial Calibration Verification Standard	ICV
Preparation Method Effects	PME	Laboratory Control Sample	LCS
Matrix Interference Effects	MIE	Matrix Interference Sample Matrix Spike/ Duplicate Sample	MIS MS/MSD
Sample Collection Effects	SCE	Field Replicate (Duplicate) Sample (Collected from same location and during same sampling event time)	FSR
Sample Location Effects	SLE	Co-Located (Same Location) Sample (Collected 0.5–3 feet away from field sample)	CLR
Sampling Site Population Effects	SSE	Site field sample collected from the environmental site for the study	SFS

Figure 4. Output from an Uncertainty Evaluation



- Collecting information to establish initial relationships with data from the fixed laboratory or other collaborative information. The collaborative relationship (data comparability) can be evaluated using a variety of options.
- Completing parametric statistical techniques, such as linear regression (Figure 5). Although commonly applied, caution should be used with linear regression. The correlation coefficient ( $R^2$ ) is universally used as a measure of a good relationship between two methods, but can be misleading. Examining the slope and y-intercept can be far more informative and less distorted by isolated high values.

Figure 5. Sample Linear Regression



- Using non-parametric techniques (often more useful for establishing comparability). These techniques are “common sense,” but still powerful aids to decision making. Examples include scatter plots, calculating decision error rates and establishing investigation levels to use with the alternative technique (Figure 6).

Figure 6. Sample Investigation Levels

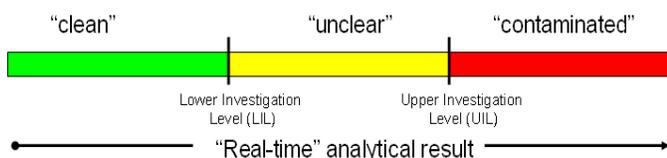
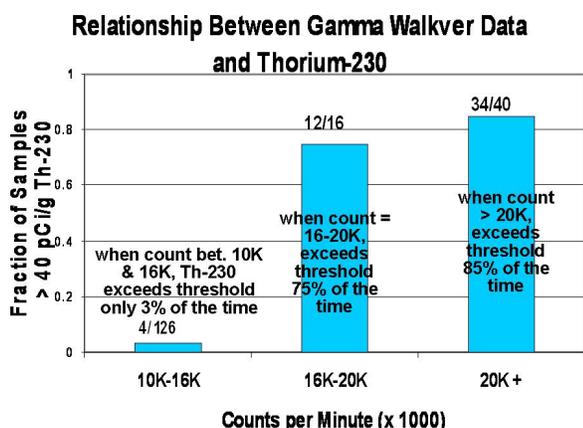


Figure 7. Typical Outputs of Investigation Levels and Decisions Bins Using Non-Parametric Methods



- Using “decision bins” to establish investigation levels can guide confident decisions made on field data. (Figure 7).
- Identifying potential interferences, bias, false positive and false negative rates, and other issues. Depending on project timelines, the Quality Assurance Project Plan (QAPP) can be formally or informally updated and optimized as a result of the DMA to manage QA issues and produce data of known quality. The plan should also identify steps to address violations of QC criteria should they occur during the full-scale field effort.
- Using data collected during the DMA as the input values to construct a statistical sampling design. One of the acknowledged pitfalls associated with using classical statistical tools in sampling design is that project teams seldom have a sound estimate of total measurement error to use in establishing sample quantities, grid sizes, and other factors. With results from a DMA, project teams can use classical statistical tools (such as the Visual Sample Plan software, <http://vsp.pnl.gov/>) more effectively in sampling design because they have generated site-specific information on method error.

- Evaluating site-specific method error helps establish initial collaborative relationships that can be refined as the program progresses. These relationships provide a framework for indicating problematic samples or “out of control” QC issues.
- Providing insight into how the full set of data may be statistically evaluated. Statistical methods such as those described in the guidance on Data Quality Assessment (EPA 2006b) may be examined for effectiveness and used to test basic project data assumptions, contaminant distributions, and sampling designs planned for use at a site.
- Testing the suitability of data visualization and management strategies.

**How are results of an analytical DMA applied?**

If the DMA is properly designed, the data can be used for the following:

- Support development or refinement of the CSM
- Estimate matrix and contaminant concentration variability at different spatial scales
- Identify potential interferences
- Ascertain whether particle size is correlated with contaminant concentrations
- Evaluate the value and effectiveness of different sample collection and processing techniques to optimize SOPs
- Establish a comparability relationship between two measurement systems
- Establish proper decision logic and sequencing of data collection

In this section, readers will be introduced to some of the basics of environmental decision making. Understanding the context in which decisions are made is essential for discerning how managing associated uncertainties affects the decisions. Managing decision uncertainties is important to developing realistic and protective field-based action levels for a site. Overly protective standards can significantly increase project costs, while less stringent standards may lead to controversy or surprises later in the project.

Under Triad, use of collaborative data becomes essential to provide sufficient density, and these data sets are then compared to improve decision certainty. A variety of methods can be used to assess the comparability between measurement systems. “Measurement system” refers to the combination of techniques used to collect and

process a sample in addition to the actual analysis. For example, analysis of split samples that have been well-homogenized (which, depending on the matrix and analyte, may require grinding to a uniform particle size), will be only part of the measurement system compared. The overall measurement system for both XRF and the compared laboratory technique must be considered for technologies such as XRF spectrometers that can be used for in situ sampling and where the effect of sample properties cannot be removed from the analytical process.

Although there are a variety of mechanisms to assess the comparability of data sets from two different measurement methods, traditional statistical techniques are widely used to begin the process of exploring the data. Traditional statistical evaluations of data sets can include summary statistics and statistical plots (box and whisker plots, histograms, and probability plots) to evaluate distributional characteristics of the sample population (normal, lognormal, or other) that decide what types of statistical manipulations are warranted.

Field-based and fixed-laboratory results can be compared by developing correlation scatter plots, or by calculating best-fit lines and correlation coefficients to describe the mathematical relationship between the data sets. If a field method is shown to be biased high uniformly across a site, the bias might be used to provide a natural safety factor when compared with regulatory limits. Alternatively, if the bias is highly consistent and predictable across samples and concentrations, adjustment for the bias is a possibility.

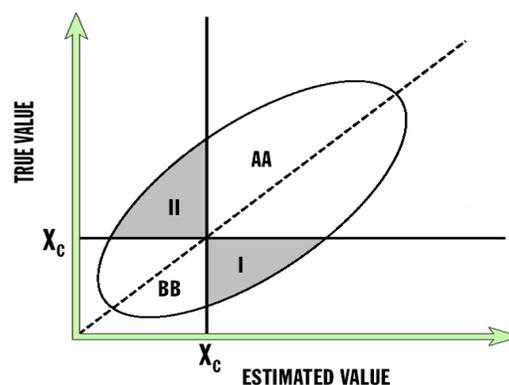
One common use of a DMA is to demonstrate that a less-rigorous analytical method correlates well with an established method. Best-fit lines and correlation coefficients may be used for this purpose. If correlation is lower than expected, a DMA may show that decision error is low enough that the less-rigorous method is still acceptable for the purpose of increasing sampling density to delineate contaminant footprints and control data variability on large and small spatial scales. This ability is valuable since matrix heterogeneity and small-scale variability are often the largest contributor to total measurement error in environmental data.

In real life, the “true value” is unknown. Any data result, no matter how good the analytical method, is an approximation of the true value. *If sample heterogeneity and interferences are controlled*, the more sophisticated analytical method will be closer to the “truth.” However, the expense of these methods can limit the number of samples that can be analyzed. Non-representative data that are biased by matrix problems can lead an unwary

decision maker into costly decision errors. Using two analytical methods helps ensure that matrix heterogeneity does not mislead the decision maker. One analytical method (usually the fixed-laboratory method) will produce more accurate measures of concentration, and that method is used as the surrogate for the “true value.” The other method (usually a field method) produces a more accurate representation of sample representativeness, but at the expense of data accuracy. Therefore, in a DMA, traditional laboratory results are assigned as the “true value” (y axis) in Figures 8 through 10. Field results are assigned as the “estimated value” (x axis). “Investigation levels” are selected through the process of comparing the two sets of data and minimizing the likelihood of decision errors. Field results that fall above and below the upper and lower investigation levels can support confident decisions. Field results that fall within the concentration range between the investigation levels require analysis by the more accurate laboratory method.

Figure 8 illustrates two types of decision errors possible when two sample analysis methods are compared. Assume all data points fall within the ellipse. “False positive” decision errors (also called “false dirty” decision errors) occur when a data result falls above an action level when the true result is below the action level, and the decision maker undertakes unnecessary remediation. “False negative” decision errors (also called “false clean” decision errors), occur when a data result is below the action level when the true result is actually above the action level. If the decision maker accepts the data at face value, erroneous decisions are possible that potentially increase risk to human or ecological receptors.

Figure 8. Misclassification Ellipse

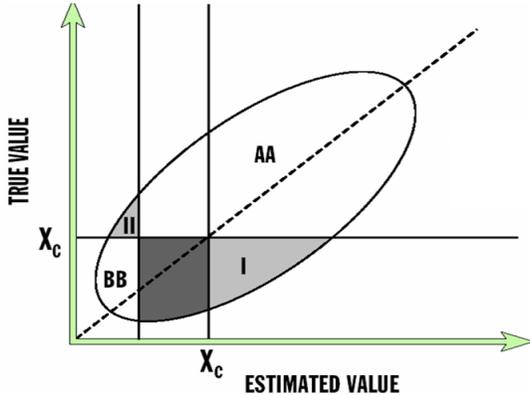


$X_c$  denotes the action level, areas I and II indicate the false positive and the false negative decision error zone, respectively. Areas AA and BB indicate zones of consistent decisions between the data results and the true values.

Figure 9 shows how using a safety factor below the action level can reduce the false clean (false negative) decision error rate.

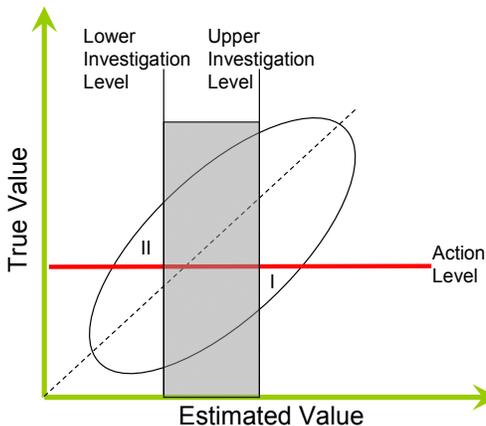
Figure 10 shows how safety factors both above and below the action level reduces both the false clean and false dirty decision errors.

**Figure 9. Misclassification Ellipse with Safety Factor.**



$X_c$  denotes the action level, area I indicates the false positive error zone, and area II indicates the false negative error zone that has been reduced by the safety factor. Areas AA and BB indicate zones of consistent decisions between the data results and the true values.

**Figure 10. Multiple Investigation Levels.**



Both types of errors are reduced. Shaded area represents data results falling between the investigation levels that require more accurate analysis.

**What else should project managers and technical staff consider when planning a DMA?**

Refining decision criteria and decision logic based on the results of a DMA can significantly improve project performance. Results from the DMA should be integrated as quickly as possible into work strategies to assure project efficiency (See EPA 542-F-05-008, “Use of Dynamic Work Strategies Under a Triad Approach for Site

Assessment and Cleanup — Technology Bulletin, [www.brownfieldstsc.org/pdfs/DWSBulletin.pdf](http://www.brownfieldstsc.org/pdfs/DWSBulletin.pdf).

Project managers must identify resource needs to support real-time decision-making during the DMA. These resources include DSTs and associated expertise. For example, a DST may be required to assist in developing and verifying field-based action levels.

Project managers and technical staff should refine the type and level of field documentation required based on the DMA. Site-specific work plans and SOPs for field methods with sufficient flexibility can be easily revised as more is learned about a site, even after the DMA is complete. Team member responsibilities should be consistent and modified as needed based on the DMA.

Creativity and flexibility in procurement and contracting is often needed for a DMA, or in response to a DMA. Review EPA’s procurement guide at [www.brownfieldstsc.org/pdfs/procurement.pdf](http://www.brownfieldstsc.org/pdfs/procurement.pdf) as a starting point for procurement and contracting strategies for Triad investigations. Unitizing or classifying costs per analytical sample or borehole, for example, is an illustration of a financial strategy that allows project planners to accurately track costs in real time as a dynamic investigation progresses. Potential vendors may provide free resources for the DMA to market and demonstrate the applicability of the technology, reducing the cost to the project — most commonly with newer and relatively unproven technologies.

Workload balancing and task sequencing are examples of strategies used to ensure that project team members are aware of the project’s time-critical tasks. Team members should work together to prioritize each task so that no task slows the entire effort while others (drillers, samplers, or analytical chemists) are idled, but still billing time. A DMA can provide important information on potential bottlenecks in data generation and flow, so that effective field coordination and sequencing strategies can be developed for the main field investigation.

**How is a DMA documented?**

A DMA is documented through a variety of formal and informal means. Project plans such as Sampling and Analysis Plans (SAPs) and QAPPs are formal documents that undergo mandatory review. When they are written for a Triad investigation, these documents outline the DMA to refine the data collection schemes and strategies to manage uncertainty. Site-specific SOPs for field methods are useful for documenting the outcome of a DMA in the

form of exact procedures to be used at a given site, especially when there are deviations from vendor-recommended procedures or published methods (such as SW-846 methods).

More informal methods, such as memoranda of understanding, meeting notes, project Web sites, E-rooms, and electronic bulletin boards, also document the DMA process. These informal methods are particularly useful to document stakeholder participation and buy-in for Triad investigations. Informal discussions with stakeholders after the DMA can also be useful to accelerate document comment, revision, and submittal.

Regardless of the method used to document a DMA, good records are essential to scientifically validating and legally defending selection and use of analytical methods and, ultimately, the conclusions based on data generated in the field. Project teams are strongly encouraged to plan for and complete DMA documentation.

#### ***Are DMAs difficult, time-consuming, or costly?***

Generally, DMAs can be completed with 20 or fewer samples, but the level of effort can be scaled to the magnitude of expected site work. However, more data can be extremely valuable in the case of many real-time technologies where costs per sample are relatively low. If linear regressions will be generated, a good rule of thumb is at least 10 paired samples; however, 20 or more can provide exceedingly robust statistical evaluations. A key concept for analytical DMAs is to focus sample pairs around action or decision points (for example, 5 low values, 5 higher values, and 10 in areas around action levels). Using real-time measurements provides a level of assurance that samples submitted for fixed-laboratory comparative analysis are in the range of interest. Data sets with high percentages of non-detected pairs are not beneficial for statistical evaluations.

Information collected during the DMA will provide a basis for establishing QA/QC protocol, sample support, preliminary relationships for collaborative data sets, load balancing, and sequencing field activities. The DMA results are a means for optimizing use of resources and become part of the final data set that will be compiled to reach project decision points.

The cost and time required for a well-designed DMA are usually a small fraction of the cost of a full-scale field program. When the project team designs a DMA, the cost and time allotted should be proportionate to the impact of

the DMA on reduction in uncertainty about a site condition. It is expected that relationships evaluated under the DMA will continue to be refined as more data become available. Another cost savings consideration is the use of archived material (where appropriate) for comparative analyses that may have already been completed. These samples provide the advantage that concentration ranges of contaminants of concern (COCs) to target samples in the primary areas of interest will be known.

In any project, the methods being used will be under scrutiny. When a DMA is not conducted on a limited number of samples, the data collected during the full site investigation must be used to demonstrate method performance. The DMA therefore provides an opportunity to change tactics affordably if a method does not perform as expected, compared with the alternative of having to change tactics after the full site investigation.

Appropriate professional expertise and good communication among team members about their data needs are critical to planning a successful DMA. The cost of a DMA is recouped many times over through cost avoidance of unusable data and recharacterization efforts.

#### **Are DMAs appropriate in all cases?**

Some investigation and cleanups may prescribe set sample numbers or recommend limited sampling through guidance. In these cases, DMAs may not be appropriate. Similarly, resources may not be adequate at some sites with limited grant funding to accommodate a DMA. Projects with adequate resources to employ established mobile or fixed-laboratory methods at sufficient density may be inappropriate, while those that require method modifications or careful examination of sampling and spatial uncertainties may benefit significantly from DMAs. Even if only fixed-laboratory methods are used, a DMA may be considered if there is any question about matrix interference effects. A relatively limited number of pilot samples can save large sums of money by detecting extraction issues and interference problems at the start of a program.

It should be noted, however, that a DMA is beneficial for most applications precisely because a particular field analytical technique, direct-sensing tool, or innovative strategy is identified as potentially applicable to cost-effectively increase data density, refine the CSM, or address small-scale variability and matrix heterogeneity. In some cases, sampling locations for an early assessment are obvious (for example, areas of visible

staining, product, lagoons, or discharge points), while other cases are more complicated, and identifying appropriate sampling locations is a problem. Depending on the nature of the suspected contamination, some sample material can be archived and potentially used later as part of a DMA for an expanded assessment or additional investigation.

Adding limited additional cost for analyzing field analytical methods, direct-sensing tools, or other innovative technologies does not significantly raise project expenses at sites with elevated expenditures associated with collecting deeper subsurface samples. In these cases, inexpensive analytics and direct sensing tools can provide greater vertical density to help target locations for more expensive traditional laboratory samples. Furthermore, the increased density can support a more efficient design of cleanup strategies when required, leading to lower project lifecycle costs.

Finally, the definition of a Brownfield — “a property, redevelopment, or reuse which may be complicated by the presence or potential presence, of a hazardous substance, pollutant, or contaminant” — underscores the need for higher data density and collaborative data sets that accompany DMAs. Regardless of whether significant contamination or just the perception of contamination is present at a property, DMAs used to optimize sampling schemes with innovative tools provide a higher data density that facilitates timely revitalization. These well-designed data sets are particularly helpful to address stakeholder concerns and provide a level of comfort that allows developers, insurance partners, risk partners, public stakeholders, state agencies, local agencies, and others to be involved, invested, and reassured with a project outcome.

## EXAMPLES OF DMA IMPLEMENTATION

### **Example #1: Immunoassay: Wenatchee Tree Fruit Test Plot Site, Wenatchee, Washington**



The Wenatchee Tree Fruit Test Plot area contained soil contaminated with pesticide compounds from agricultural research conducted from 1966 through the mid-1980s. The U.S. Public Health Service (PHS) and EPA used the

test plot area to evaluate the effectiveness of various land disposal methods for pesticides. In 1997, USACE conducted an integrated site characterization and remediation program that allowed characterization, excavation, and segregation of contaminated material in real time. Work was completed under a voluntary cleanup program with regulatory oversight of the Washington Department of Ecology.

A DMA was conducted to provide critical input to the project design because the project would use IA methods to drive the dynamic work strategy. The DMA was structured to evaluate both the utility of the IA kits and to develop field-based action levels.

#### Site Facts

- ✓ Disposal area of an agricultural research facility.
- ✓ Reuse scenarios not identified. Changing land use nearby increased concern that the area should undergo investigation and remediation.
- ✓ Principal threats included off-site migration, contamination of other media, and direct contact.
- ✓ COCs included organochlorine, organophosphorous, and other pesticide compounds.

#### Highlights of the DMA

The DMA confirmed that the IA test kits were intentionally biased 100 percent high by the manufacturer to reduce the chance of false negative results. The DMA accommodated the response of the kits to structurally similar compounds beyond the target compounds. Taking into consideration the high bias and correlations with fixed-laboratory results, the DMA showed that the DDT test kit result exceeding 5 parts per million (ppm) could indicate elevated levels of DDT, DDE, or DDD. Likewise a cyclodiene kit response of 0.1 ppm indicated the possibility that regulatory action levels for endrin or dieldrin were exceeded. Therefore, these values were selected as the investigation levels to make decisions based on the kit results.

Several modifications to the IA kit procedures were made based on DMA results. For one, pure methanol was used instead of a water-methanol mix, and extraction volumes were doubled to 20 milliliters (mL) to bracket action levels based on cross reactivity and sensitivity results. The

resulting 20-milliliter (mL) extracts were sufficient to run both the DDT and cyclodienes IA analyses.

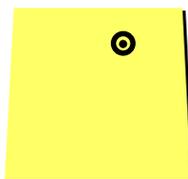
Some fixed-laboratory detection methods for collaborative data were also modified. The project team used MS detection instead of the method specified nitrogen and phosphorus detector (NPD) to improve selectivity and meet project required quantitation limits for the organophosphorus pesticides. Similarly, the team used a GC NPD method instead of high-pressure liquid chromatography (HPLC) for the carbamate pesticides to reduce interference. In addition, the surrogate compound was changed to a compound rarely used in agricultural applications. Non-target compounds and tentatively identified compounds (TICs) from fixed-laboratory methods also became crucial to understanding IA kit response from a broad range of contaminants.

During the characterization phase, the project team continued to collect a subset of samples for fixed-laboratory analysis. These results, used in conjunction with DMA data, indicated that the 5 ppm investigation level for the DDT IA kit was overly conservative. With regulator approval, the DDT IA investigation level was raised to 10 ppm to complete excavation and waste segregation.

No false negative decision errors for the action levels for individual pesticides were encountered. A low percentage of false positive errors (usually associated with the presence of endosulfans in the samples) was encountered for the cyclodiene kit. Use of the DMA and Triad principles resulted in an estimated savings of 50 percent for total project costs.

More information on the DMA and Triad work conducted for this site is available at the Triad Resource Center Web page: [www.triadcentral.org](http://www.triadcentral.org).

**Example #2: Poudre River Site, Fort Collins, Colorado**



The Poudre River Site is located in Fort Collins, Colorado, along the Cache La Poudre River. The presence of coal tar in the river and fuel-related ground water contamination prompted EPA to initiate a Targeted Brownfields Assessment in May 2003. Two DMAs were

conducted as part of the Targeted Brownfields Assessment.

**Site Facts**

- ✓ Site includes a former manufactured gas plant (MGP) that operated from approximately 1900 to 1930.
- ✓ Site includes a former municipal burn landfill that operated from the late 1930s to the early 1960s.
- ✓ Proposed reuse was recreational, commercial, and industrial.
- ✓ COCs included chlorinated solvents and petroleum-related substances.

Highlights of the DMAs

One DMA focused on demonstrating the capability of passive soil gas samplers from EMFLUX (now known as Beacon Environmental) to detect volatile organic compounds in the subsurface.

A full-scale soil gas survey was implemented using 333 devices after the passive soil gas DMA successfully demonstrated the use of the EMFLUX passive soil gas samplers. The data from the study were used to create isoconcentration maps for target analytes, helping to refine the CSM and optimize the field investigation drilling program.

A DMA was also performed for a modified EPA SW-846 Method 8260 used for the analysis of ground water samples on site via a mobile laboratory. The project team used the results from the ground water DMA to set the applicable detection and reporting limits for GC/MS results, design appropriate initial calibration and QC protocols, and evaluate the types and concentrations of contaminants expected in ground water at the site. The DMA also provided site-specific information about the accuracy and precision of the method.

Another aspect of the Poudre River Site field program that showed the usefulness of a DMA study was geophysical survey work. A ground penetrating radar (GPR) survey conducted at the site suffered from poor signal penetration because of soil conditions. However, the performance-based contract used for the work did not allow the cost of this GPR work to be billed against the program. Had the GPR vendor conducted a DMA, this problem would likely

have been discovered earlier and at significantly lower cost to the vendor.

More information on the DMA and Triad work conducted for this site is available at the Triad Resource Center Web page: [www.triadcentral.org](http://www.triadcentral.org).

**Example #3: X-ray Fluorescence: Fort Lewis Small Arms Firing Range, Fort Lewis, Washington**



In 2003, USACE used the Triad approach to expedite site characterization and remediation of contaminated soil at the former Evergreen Infiltration Training Range in Fort Lewis Washington. A dynamic sampling and analytical strategy based on rapid field-based analytical methods was used to streamline site activities and save resources while increasing confidence in remediation decisions.

Initial evaluations included a suite of metals associated with small arms firing ranges (antimony, arsenic, copper, iron, lead, tin, and zinc). The DMA indicated that lead was the primary risk driver given regulatory thresholds and site action levels. After the DMA, the remaining characterization and remediation work at the Fort Lewis site focused on lead.

**Site Facts**

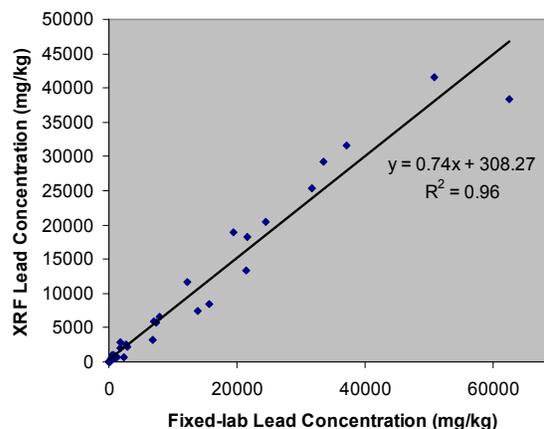
- ✓ Site is a former small arms firing range that operated over an unknown time period between 1917 and 1965.
- ✓ Proposed reuse was for military barracks.
- ✓ Principal threat is direct contact with contaminated soil.
- ✓ COCs were metals including lead and arsenic.

Highlights of the DMA

At the beginning of the field investigation, a DMA was conducted using field-portable XRF and fixed-laboratory methodologies (EPA SW-846; sections 6010 and 6020). Forty samples were collected and analyzed by both

methods. The DMA established a strong correlation between XRF and laboratory data for lead (see Figure 11), even with minimal soil sample homogenization. The measured correlation coefficient ( $R^2$ ) between the methods was 0.96; however, inspection of the slope and y-intercept indicate some loss of linearity. Examining concentrations for individual sample pairs indicates that XRF results tend to under-report concentrations as concentrations increase above percent levels (10,000 ppm). Under-reporting was not a concern for the project team, however, since various action levels for lead were all less than 1,000 ppm.

**Figure 11. Correlation Curve.**



XRF data are plotted against data from EPA methods 6010/6020 for Fort Lewis Small Arms Firing Range DMA.

A regression was also generated using results for a subset of split samples in the 0 to 1,000 ppm range for lead to evaluate XRF performance in this critical area. The DMA confirmed that the XRF reliably quantified lead concentrations down to 45 milligrams per kilogram (mg/kg), and so was accurate in locating both “clean” and “dirty” areas. Through the DMA, it was assured that data of “known and documented” quality could be produced. The level of data quality was shown to be sufficient for the project’s decisions. Although more intensive sample preparation or use of substitution methods for non-detected XRF values may have produced a better regression, the project’s data needs did not require the additional precision.

More information on the DMA and Triad work conducted for this site is available at the Triad Resource Center Web page: [www.triadcentral.org](http://www.triadcentral.org).

## SOURCES OF ADDITIONAL INFORMATION

The Triad approach is encountering ever greater acceptance by regulatory agencies, as well as by professional and industry organizations. Communities and project teams interested in implementing the Triad are encouraged to contact the BTSC for more information on these organizations and for successful examples of Triad applications. More detailed information on DMA and on the Triad approach can be found in the Brownfields Technology Primer Series document *Using the Triad Approach to Streamline Brownfields Site Assessment and Cleanup*, which is available at [www.brownfieldstsc.org](http://www.brownfieldstsc.org). Project profiles, case studies, and other information on applying the Triad approach can be found at [www.triadcentral.org](http://www.triadcentral.org). The BTSC provides other technical bulletins related to best practices embodied in the Triad approach such as "Use of Dynamic Work Strategies Under a Triad Approach for Site Assessment and Cleanup — Technology Bulletin." Additional documents providing critical information on related issues such as Green Remediation and Vapor Intrusion are also available.

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