Summary of the Triad approach

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The Purpose of the Triad Approach

Experienced practitioners from the public and private sectors have pooled their efforts to create the Triad approach. This scientific effort is supported by EPA to foster modernization of technical practices for characterizing and remediating chemically contaminated sites. The goal of the Triad approach is to **manage decision uncertainty**, that is, to increase confidence that project decisions (about contaminant presence, location, fate, exposure, and risk reduction choices and design) are made correctly and cost-effectively. ("Correct" decisions are here defined as the decisions that would be made if fully completely accurate knowledge of contamination nature and extent and receptor exposure were available to decision-makers.) The foundation for site-related decisions that are both correct and optimized (from a cost-benefit standpoint) is the **conceptual site model (CSM)**. A CSM uses all available historical and current information to estimate

- where contamination is (or might be) located,
- how much is (or might be) there,
- how variable concentrations may be and how much spatial patterning may be present,
- what is happening to contaminants as far as fate and migration,
- who might be exposed to contaminants or harmful degradation products, and
- what might be done to manage risk by mitigating exposure.

As a primary Triad product, **an accurate CSM will distinguish and delineate different contaminant populations for which decisions about risk and remediation will differ**. Distinguishing between different contaminant populations improves the quality and interpretation of data, as well as the confidence and resource-effectiveness of project decisions. Triad achieves sufficiently accurate CSMs by proactively identifying and managing decision uncertainties (i.e., those unknowns that stand in the way of making confident decisions) and data uncertainties (sources of variation in data results when decisions are based on data). These tasks are accomplished by incorporating advanced science and technology tools into the project toolbox.

The Triad approach represents an evolution and progression of technical thinking about contaminated sites. Triad serves as a platform to integrate the experiences, lessons learned, and advances in science and technical tools and know-how gained over the past 25+ years of hazardous site investigation, cleanup, and reuse. It was developed through the efforts of practitioners dedicated to perfecting the science and art of site characterization and cleanup, despite recognizing the difficulties posed by the fundamentally **heterogeneous** nature of contaminated sites. Triad supports **second-generation practices** that, although somewhat different from current practices, truly sustain all three benchmarks of "better, faster, and cheaper" projects (Crumbling, et al 2003). The Triad approach is a scientific and technical initiative, not a regulatory approach, although it is hoped that regulatory bodies will take note of advancing scientific knowledge and technical capability and integrate them into their regulatory frameworks.

The Elements of the Triad Approach

"Triad" is not an acronym, and should not be written to appear as one. The word is intended to convey that there are three elements. The most important element of the Triad, **systematic project planning** (called "strategic planning" by some), supports the ultimate Triad goal of confident decision-making. To ensure high decision confidence and stakeholder satisfaction ("better" projects) Triad encourages developing

- "social capital" (i.e., an atmosphere of trust, transparent, open communication, and cooperation between parties working toward a protective, yet cost-effective resolution of the "problem");
- consensus on the desired outcome (i.e., end goal) for the site/project;
- a preliminary CSM from existing information;

- a list of the various regulatory, scientific and engineering decisions that must be made in order to achieve the desired outcome;
- a list of the unknowns that stand in the way of making those decisions (i.e., decision uncertainties);
- strategies to eliminate, reduce, or "manage around" those unknowns; and
- proactive control over the greatest sources of uncertainty in environmental data (i.e., sampling-related variables such as sample volume and orientation, particle size, sampling density, subsampling, etc.).

The second element, **dynamic work strategies**, is the element that allows projects to be completed "faster" and "cheaper" than ever possible under traditional, static work strategies. Work planning documents written in a dynamic or flexible mode guide the course of the project to adapt in real-time (i.e., while the work crew is still in the field) as new information becomes available. This allows preliminary CSMs to be tested and evolved to maturity (i.e., sufficiently complete to support the desired level of decision confidence) in real-time, saving significant time and money while supporting better resolution of uncertainties. A valuable aspect of dynamic work strategies, focused quality control (QC) that adapt in real-time (a form of "process" QC), makes analytical QC procedures more relevant and powerful than what is possible with traditional work static strategies with the analytical operator far removed from field involvement.

Lastly, the third Triad element, **real-time measurement technologies**, makes dynamic work strategies possible by gathering, interpreting, and sharing data fast enough to support real-time decisions. The range of technologies supporting real-time measurements includes field analytical instrumentation, *in situ* sensing systems, geophysics, rapid turn-around from traditional laboratories, and computer systems that assist project planning, and store, display, map, manipulate, and share data. Although field analytical methods are usually less expensive to operate than fixed laboratory analyses, under the Triad analytic budgets will generally be the same or even higher than conventional. Sample densities are increased to manage the various factors contributing to sampling uncertainty. This allows highly accurate and detailed CSMs to be built as the foundation of confident decision-making. In the big picture, per-sample costs are much less important to the financial bottom-line than are the real-time, confident decisions that so dramatically lower the life-cycle costs of Triad projects.

An ideal Triad project would strongly rely on each element. But we do not live in an ideal world, and "the perfect should not the enemy of the good," as the saying goes. Especially when project teams are first learning Triad concepts and attempting to blend technology and strategy tools into a Triad project, it should not be expected that all Triad projects will be equally strong in every element. However, there are a few basic features that define a Triad project:

- consensus on clearly worded project goals and intended decisions (with expressions of what decision errors are tolerable and which are not) for field work before it begins,
- a CSM that anticipates site-specific heterogeneities and contaminant distributions,
- strategies to refine the CSM over the course of the project in relation to the intended decisions, and
- discussions about the mechanisms to manage sampling and analytical uncertainties in data collection.

These features are so fundamental to Triad that if they are lacking from planning or from project documents, a claim for a Triad project is suspect. The advantages offered by dynamic work strategies, high sampling densities and real-time refinement of the CSM to lower costs and increase decision confidence make them highly desirable, and Triad projects will naturally include them to the extent feasible. But the degree to which they are employed is not distinctive, since it will vary depending on many technical and logistical factors, not the least of which include regulatory, budgetary, contracting and legal constraints and the expertise of the project team.

Quality Control is Crucial to the Triad Approach

As mentioned before, QC for all data gathering and processing activities is very important to the Triad approach. Under Triad, QC is designed to aggressively address specific sampling and analytical uncertainties so that **data is of known and documented quality**. Four QC items are of particular note:

1) **Focused QC protocols** increase or decrease the frequency of targeted QC checks in response to fluctuations in the uncertainties that they manage. [Note that the decision logic laying out the rationale for altering QC frequency should be written in planning documents for approval before being implemented.]
2) Real-time evaluation of the **compatibility of incoming data against the current CSM** to detect errors either in the data results OR in the CSM. Discovering discrepancies between the data and the CSM provides valuable feedback, and resolving such discrepancies in real-time supports "better, faster, and

cheaper" projects. This incredibly powerful QC check simultaneously evaluates the reliability of both the data and the CSM, and is unique to Triad projects.

3) Split samples (often misleadingly called "confirmation samples") are used to **establish data comparability** for the performance of field methods that are less selective, more biased and/or imprecise, and/or have higher detection limits than the traditional fixed lab methods used to derive regulatory thresholds. Split samples alone, however, do not provide sufficient information to establish the reliability of field method performance. In-field QC (of a nature appropriate to both the field method and its application) is required. Split sample analysis is an adjunct that supplements, but cannot replace, fully documented in-field QC procedures.
4) **Demonstrations of method applicability** (aka, "pilot studies") are strongly suggested to establish the appropriateness of all proposed sampling and analytical methods for the actual site and application before full mobilization to the field for project implementation. A single, well-planned study can provide valuable information to guide technology selection and method modification, evaluate QC procedures, and provide initial estimates of site-specific sampling and analytical variability.

Triad embraces a **second-generation data quality model**, where sampling quality is just as important to data quality as analytical quality is. This evolution in thinking about what "data quality" truly means requires adjustment to the typical regulatory view of data produced by screening analytical methods (i.e., those field or lab methods that have higher detection limits, more bias and imprecision, or are more non-specific than available laboratory methods). The first-generation data quality model views data produced by screening <u>methods</u> as automatically of screening (i.e., inferior) <u>quality</u>. Since the term "screening" implies greater uncertainty, regulators have tended to be less accepting of data produced by screening analytical methods. What this view overlooks, however, is the all-important ability of less expensive screening methods to manage sampling variability. The lower operating costs allow sampling density to be increased, permitting tighter delineation of different populations for the purpose of building the CSM. The common phrase "screening a site" actually incorporates the underlying concept of building or testing the CSM, yet current regulatory practice seldom develops this concept to its logical conclusion. Since the CSM is THE foundation of confident project decisions, building and refining a CSM using less expensive methods to delineate populations and help manage sampling uncertainties powerfully **improves data quality**. The concept of data representativeness is meaningful only in the context of a reasonably mature CSM in the context of the intended project decisions.

Data quality for heterogeneous matrices is achieved by collaborating results between less expensive, more rapid methods (to provide cost-effective high density sampling and build the CSM) and more rigorous (but also more expensive) analyses able to manage any important analytical uncertainty "left over" from the less expensive method. Under this second-generation data quality model, samples for more expensive analyses are chosen once their sample representativeness (i.e., the contaminant population they represent) has been established through the CSM. The ability to mature the CSM to establish **data representativeness** in the context of specific project decisions is not available if expensive fixed laboratory analyses are viewed as the only reliable method options. In contrast, the Triad recognizes that high analytical quality data points are of limited utility if used alone because they are prone to erroneous interpretation if sampling variables are not controlled (Crumbling, 2002). Sampling error occurs when accurate results of tiny samples are erroneously used to represent the concentrations for much larger volumes of matrix.

A Wide Variety of Issues Are Embraced by Triad Systematic Project Planning

Triad is not a panacea or a "magic bullet." There are issues—legal, regulatory, community relations, toxicological, economic, political—that encompass concerns that Triad does not directly address as a science-based initiative. However, Triad's emphasis on face-to-face systematic planning to manage the full range of uncertainties (i.e., to clarify land use preferences, project goals and concerns through open discussion and documentation) creates an atmosphere **conducive to trust and cooperative negotiations** (i.e., the building of "social capital") among all involved parties. If the technical issues are out in the open and stakeholders are assured that resource limitations and scientific uncertainties are being fairly balanced in relation with their concerns, a strong foundation is laid for negotiating parties to balance the more thorny and value-laden social issues.

Environmental insurance and redevelopment economics provide examples of the indirect issues that Triad can impact. Insurance companies have a natural interest in the Triad approach because insurance products are designed and priced through a quantitative evaluation of uncertainty. Insurance premiums assign a dollar value to the benefits of uncertainty management. Premium pricing can help project planners quantify the benefits of investing in the Triad approach. A case of study illustrating the insurance angle was provided by Marsh, Inc. (a leading risk management and insurance services firm) on an actual Brownfields site (Woll, et al 2003). Despite spending $400,000 to characterize the site using a traditional approach, significant uncertainties remained in the conceptual site model: the actual volume of material requiring remediation and the most appropriate remedial options were still highly uncertain. As a result, the insurance model estimated that, at 98% certainty, the remedial costs could potential be less than $1 million, but could also be more than $25 million. This large uncertainty caused the Cleanup Cost Cap premium to be priced between $1.58 and $1.89 million. To resolve the lingering CSM uncertainty, an additional investigation using the Triad approach was done at a cost of $30,000. The more refined CSM delineated the contaminant populations to support a much more confident estimate of the volume to be treated and the best remedial design. It became clear that remediation could confidently be expected to cost less than $1 million. This confidence was reflected in the subsequent pricing of the insurance policy. For the $30,000 investment in a Triad investigation, the payoff was a premium reduction of $1.5 to $1.8 million! (The premium was re-priced between $80 and $100 thousand.) The decision confidence gained through the Triad approach made the feasibility of remediation more certain, the insurance more affordable, and the site more attractive to a potential buyer.

There are also instances where the Triad approach has found more contamination than initially estimated during an investigation to transfer property, but the sale and redevelopment of the property was not adversely affected. The very fact that the degree of contamination was *known* at a high degree of confidence was reassuring to investors. Triad's emphasis on the "management of decision uncertainty" casts a wide net that includes many types of issues in the systematic planning process. But the same concept simultaneously encourages planners to identify and focus on the key issues that must be resolved to have successful, cost-effective, and defensible project outcomes.

Summary

The hazardous waste cleanup arena is changing as a result of 20-30 years of scientific, engineering, and regulatory experience. There are more options for effective remediation than ever before. But a common theme is that accurate site characterization is mandatory for cleanup technologies to perform efficiently. The generation of site data must be designed to produce a CSM that reliably portrays nature and extent of contamination in relation to the intended compliance and cleanup decisions. A data set that is representative of exposure risk probably will not be representative of decisions about remedial design. A data set useful to a remedial design that functions on larger spatial scales (such as thermal oxidation) will probably not be effective for designing a remedy that functions over a smaller spatial scale (such as chemical oxidation). Designs to generate data must take these factors into account from the start, or resources are wasted gathering irrelevant information. Or worse, the non-representative data are not recognized as such and remedial design is based on faulty information, practically guaranteeing that remedial systems will be less than optimally effective. The Triad approach is but one example of the smarter work strategies now available. But coordinated effort and determination will be required to address the multitude of institutional barriers stemming from community inertia and out-of-date regulatory guidance.

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