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Standard Guide for Sediment Corrective Action – Monitoring[1]

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1. Scope

1.1 This guide pertains to corrective action monitoring before, during and after sediment remediation activities. It does not address monitoring performed during remedial investigations, risk assessments performed before the corrective action, and pre-design investigations. This standard primarily focuses on the approach for remedial actions performed under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Thus, many of the references cited are CERCLA oriented. The standard is also applicable to remedial actions performed under state, federal and international cleanup programs, but the standard does not describe requirements for each jurisdiction. The requirements for the regulatory entity under which the cleanup is performed should be reviewed to confirm they are met.

1.2 This guide provides a framework, which includes widely accepted considerations and best practices for monitoring sediment remedy effectiveness. The monitoring sediment standard guide is intended to complement and support the selection of monitoring techniques, not supersede local, state, federal or international community regulations.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D75 Practice for Sampling Aggregates

D4823 Guide for Core Sampling Submerged, Unconsolidated Sediments

D7363 Test Method for Determination of Parent and Alkyl Polycyclic Aromatics in Sediment Pore Water Using Solid-Phase Microextraction and Gas Chromatography/Mass Spectrometry in Selected Ion Monitoring Mode

E1391 Guide for Collection, Storage, Characterization, and Manipulation of Sediments for Toxicological Testing and for Selection of Samplers Used to Collect Benthic Invertebrates

E2616 Guide for Remedy Selection Integrating Risk-Based Corrective Action and Non-Risk Considerations

2.2 *Referenced Documents:*

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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2.4 *U.S Environmental Protection Agency:*[3]

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3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *adaptive management, n*—a structured, iterative process of robust decision-making uncertainty, with an aim to reducing uncertainty over time via monitoring.

3.1.2 *backfill, n*—clean materials placed directly on the post-dredge surface to provide cover and/or bring the post-dredging surface to a targeted elevation. (Also see, *cover material*.)

3.1.3 *background conditions (aka reference conditions), n*—substances, conditions, or locations that are not influenced by releases from a site; are usually naturally occurring (consistently present in the environment, but not influenced by human activity) or anthropogenic (influenced by human activity, but not related to specific activities at the site).

3.1.4 *baseline monitoring, n*—abiotic and biotic monitoring to establish ambient concentrations prior to the commencement of remediation.

3.1.5 *benthic community, n*—assemblage of aquatic invertebrates that live/reside in the sediments.

3.1.6 *bioavailability, n*—the relationship between external (or applied) dose and internal (or resulting) dose of the chemical(s) being considered for an effect (NRC 2003).

3.1.7 *biologically active zone (aka biotic zone), n*—the zone of greatest organism-substrate interaction (Determination of the Biologically Relevant Sampling Depth for Terrestrial and Aquatic Ecological Risk Assessments, Ecological Risk Assessment Support Center [EPA], October 2015).

3.1.8 *biota, n*—the flora and fauna living in a habitat (Glossary of Bioassessment Terms, Wetland Bioassessment Fact Sheet 10 [EPA843-F-98-001e], Office of Water [EPA], July 1998)

3.1.9 *capping, n*—the process of placing a material over contaminated sediments to mitigate risk posed by those sediments.

3.1.10 *conceptual site model, n*—the integrated representation of the physical and environmental context, the complete and potentially complete exposure pathways and the potential fate and transport of chemicals(s) of concern at a site. The site conceptual model should include both the current understanding of the site and the understanding of the potential future conditions and uses for the site. It provides a method to conduct the exposure pathway evaluation, inventory the exposure pathways evaluated, and determine the status of the exposure pathways as incomplete, potentially complete, or complete. (ASTM E50.04, E2616)

3.1.11 *corrective action objectives (CAOs), n*—describes what the corrective action is expected to accomplish, based on the conceptual site model and the exposure pathways that pose an unacceptable risk as determined in a risk assessment. CAOs are specific and achievable goals for reducing risk to human health and the environment.

3.1.12 *cover material, n*—alternative term for "*backfill*".

3.1.13 *environmental dredging, n*—the removal of contaminated sediment to reduce risks to human health and the environment.

3.1.14 *enhanced monitored natural recovery (EMNR), n*—a remediation practice that applies clean material or amendments to the sediment surface to accelerate natural recovery processes.

3.1.15 *data quality objectives (DQOs), n*—the monitoring goals for collecting data. DQOs include the performance and acceptance criteria that define whether data meet the monitoring goals.

3.1.16 *fish community, n*—an assemblage or association of populations of two or more fish species occupying the same geographical area (for example, stream reach) during a particular time.

3.1.17 *freely dissolved contaminants, n*—the concentration of the chemical that is dissipated in water and bioavailable to biota, excluding the portion sorbed onto particulate and dissolved organic carbon (kg of chemical/L of water).

3.1.18 *groundwater-surface water transport, n*—process by which surface water readily exchanges with groundwater through the subsurface volume of sediment and porous space.

3.1.19 *in situ treatment, n*—application of amendment materials to the sediment intended to mix (either naturally or mechanically) into sediments and reduce the bioavailable fraction of contamination in porewater.

3.1.20 *in situ solidification, n*—a remediation approach that mixes solidification agents (for example, Portland cement) into impacted sediments that are intended to reduce sediment permeability and the mobility of contamination within the bulk sediment.

3.1.21 *monitored natural recovery (MNR), n*—a remediation practice that relies on natural processes to protect the environment and receptors from unacceptable exposures to contaminants.

3.1.22 *post remedy monitoring, (aka long-term monitoring), n*—monitoring to determine whether contaminants of potential environmental concern (COPECs) concentrations in affected media met CAOs, or continue to decrease and are expected to meet CAOs in an acceptable time frame.

3.1.22.1 *performance monitoring, n*—post remedy monitoring conducted to determine if the remedy is performing as designed. It evaluates the remedial technology.

3.1.22.2 *effectiveness monitoring, n*—post remedy monitoring to confirm the CAOs are met.

3.1.23 *porewater, n*—water located in the interstitial voids (between solid-phase particles) of bulk sediments.

3.1.24 *remedial investigation, n*—the contaminated site investigation performed prior to remedial alternative selection to determine if the nature and extent of contamination is at unacceptable levels and warrants any potential remedial action.

3.1.25 *remedy implementation monitoring, (aka construction monitoring), n*—monitoring of conditions during remediation to determine if design criteria have been achieved.

3.1.26 *representative background concentrations, n*—a chemical concentration that is inclusive of naturally occurring sources and anthropogenic sources similar to those present at a site, but not related to site releases and site-related activities.

3.1.27 *residuals, n*—untreated contamination that remains in the sediment after dredging sediment.

3.1.28 *sediment(s), n*—a matrix of pore water and particles including gravel, sand, silt, clay and other natural and anthropogenic substances that have settled at the bottom of a tidal or non-tidal body of water.

4. Significance and Use

Note 1—This standard should be used in conjunction with other reference material to guide the user in developing and implementing sediment corrective action monitoring programs.

4.1 Activities described in this guide should be conducted by persons familiar with current sediment site characterization and remediation techniques.

4.2 This guide may be used by various parties involved in sediment corrective action programs, including regulatory agencies, project sponsors, environmental consultants, toxicologists, risk assessors, site remediation professionals, environmental contractors, analytical testing laboratories, data validators, data reviewers and users, and other stakeholders, which may include, but are not limited to, owners, buyers, developers, lenders, insurers, government agencies, and community members and groups.

4.3 This guide is not intended to supplant applicable regulations. Instead this guide may be used to complement and support such regulatory requirements.

4.4 This guide provides a decision framework based on over-arching features and elements that should be customized by the user based on site-specific conditions, regulatory context, and sediment corrective action objectives. This guide should not be used alone as a prescriptive checklist.

4.5 This guide provides a systematic, but flexible decision framework to accommodate variations in approaches by regulatory agency and by the user based on project objectives, site complexity, unique site features, regulatory requirements, newly developed guidance, newly published scientific research, changes in regulatory criteria, advances in scientific knowledge and technical capability, and unforeseen circumstances.

4.6 Implementation of the guide is site-specific. The user may choose to customize the implementation of the guide for particular types of sites, especially smaller, less complex sites.

4.7 When applying this guide, the user should undertake a systematic project planning and scoping process to collect information to assist in making site-specific, user-defined decisions for a particular project. Planning activities should include the following factors: *(a)* Assemble an experienced team of project professionals; *(b)* Identify the applicable regulatory program(s); *(c)* Engage stakeholders early and often in the planning process; *(d)* Define, agree on, and document clearly stated project objectives and intended outcomes; *(e)* Recognize that sediment programs are complex, uncertainty is high, that an appropriate project-specific approach may be developed with the investment of time and effort, and that compromise and uncertainty are inherent in the process; *(f)* Compile existing site data; and *(g)* Establish a plan for documenting and reporting key decisions and results. These project planning and scoping activities should be carried forward as the project progresses.

4.8 The users of this guide should consider assembling a team of experienced project professionals with appropriate expertise to scope, plan and execute a sediment data acquisition program. The team may include: regulatory agencies, project sponsors, environmental consultants, toxicologists, risk assessors, site remediation professionals, environmental contractors, analytical testing laboratories, and data reviewers, data validators, data users, and other stakeholders.

4.9 The users of this guide are encouraged to engage key stakeholders early and often in the project planning and scoping process, especially regulators, project sponsors, and service providers. A concerted ongoing effort should be made by the user to continuously engage stakeholders as the project progresses in order to gain insight, technical support and input for resolving technical issues and challenges that may arise during project implementation.

4.10 The users of this guide should establish a plan for documenting and reporting the results of the project planning process, including: key challenges, options considered, decisions taken, analytical approach details, data acquisition results, and project outcomes relative to project objectives.

4.11 The users of this guide are encouraged to continuously update and refine the conceptual site model and Project Work Plans and Reports used to describe the physical properties, chemical composition and occurrence, biologic features, and environmental conditions of the sediment corrective action project.

4.12 This guide supports users in the identification of key considerations for designing and implementing sediment program data acquisition plans, including the applicability and use limitations and considerations that may be necessary to achieve project data usability objectives.

5. Components of a Monitoring Program

5.1 This section discusses developing data quality objectives (DQOs), decision rules, and monitoring plans and the stages of sediment remediation monitoring. United States Environmental Protection Agency (USEPA; 2004a, 2005b) presents six key steps in developing a monitoring plan, including how to identify the monitoring objectives, develop the monitoring hypothesis, formulate the decision rules, design the monitoring plan, conduct the monitoring analysis and characterize the results, and establish management decisions. The monitoring plan development process described in this section follows the USEPA guidance.

5.2 *DQO Development*—The first step in developing a monitoring plan is to define the DQOs, which describe the questions being answered by the monitoring, and the performance and acceptance criteria for the data collected. DQOs are established for each type of monitoring conducted. The monitoring DQOs are usually based on the corrective action objectives (CAOs) for the remedial action. Typically, the monitoring DQOs serve to confirm that the CAOs are met. There may be additional monitoring DQOs beyond the CAOs. USEPA has a systematic process for developing DQOs (USEPA, 2006). Interstate Technology & Regulatory Council (ITRC, 2014) and USEPA (2001c, 2005b) discuss applying the USEPA DQO process to sediment monitoring. USEPA (2004a) describes how the DQO development process fits in the monitoring plan development process. Once the DQOs are developed, then the monitoring hypothesis is developed, which states the problem that has initiated the need for monitoring.

5.3 *Decision Rule Development:*

5.3.1 When the monitoring hypothesis is developed, then the data evaluation approach and decision-making process are defined. The decision rule describes how the data will be evaluated and how decisions will be made. The decision rules describe what action will be taken for a given monitoring result. Decision rules are often expressed as if, then statements. An initial step in the data evaluation is to confirm the appropriate data were collected and that the data are acceptable for use. USEPA has guidance on performing data verification and validation (USEPA, 1999, 2002a, 2004c).

5.3.2 Decision rules form the basis for decisions to continue, modify, or stop the monitoring, or recommend taking additional corrective action. The main elements of a decision rule are the parameter of interest; the expected outcome; an action level; the basis on which a monitoring decision will be made; and monitoring decision choices (USEPA, 2004a). The decision rule describes how the data will be evaluated, either on a data point by data point basis, or grouped together as a data set (for example, surface weighted average concentration). If a data set grouping will be used, the decision rule describes how the data will be grouped (for example, temporally, spatially, etc.). The decision rule describes which statistics will be used and how it will be confirmed that the data have the appropriate distribution for the statistical evaluation. The decision rule also describes the criteria the data will be compared to. For example, the decision rules describe whether data will be used to estimate a mean value for a spatial extent or time period, a trigger concentration (that is, a condition necessitating immediate action), or if the data set will be used as one line of evidence in a multiple line of evidence approach. The decision rule describes what decision will be made for each potential outcome of the criteria comparison.

5.3.3 USEPA has guidance for monitoring data evaluation based on years of environmental data collection and evaluation (USEPA 2000):

5.3.3.1 *Review the DQOs and Sampling Design*—Review the DQO outputs to confirm that they are still applicable. Review the sampling design and data collection documentation for consistency with the DQOs.

5.3.3.2 *Conduct a Preliminary Data Review*—Review quality assurance reports, calculate basic statistics, and generate graphs of the data. Use this information to learn about the structure of the data and identify patterns, relationships, or potential anomalies.

5.3.3.3 *Select the Statistical Test*—Select the most appropriate procedure for summarizing and analyzing the data, based on the review of the DQOs, the sampling design, and the preliminary data review. Identify the key underlying assumptions that must hold true for the statistical procedures to be valid.

5.3.3.4 *Verify the Assumptions of the Statistical Test*—Evaluate whether the underlying assumptions hold, or whether departures are acceptable, given the data.

5.3.3.5 *Draw Conclusions from the Data*—Perform the calculations required for the statistical test(s) and document the inferences drawn as a result of these calculations. If the sampling design is to be used again, evaluate the performance of the sampling design, and make adjustments to improve performance (as necessary).

5.3.4 The data evaluation should be presented in a transparent format that allows duplication of the evaluation and decision rules. The results of the data evaluation should clearly inform the cause for additional monitoring actions, for modification to the monitoring plan, or to exit part (or all) of the monitoring program.

5.4 *Monitoring Plan Development:*

5.4.1 The monitoring plan presents the DQOs, monitoring hypothesis, decision rules, what monitoring will be performed, how it will be performed, and the schedule for monitoring. Battelle (2003), Electric Power Research Institute (EPRI; 2008), ITRC (2014), ESTCP (2009), National Research Council (2007), Space and Naval Warfare Systems Center Pacific (2010), US Army Corps of Engineers (USACE; 1998, 2008), and USEPA (2001c, 2004b, 2005, 2014b) provide examples of sediment remediation monitoring plans.

5.4.2 Sediment monitoring often includes three types of measurements:

5.4.2.1 Physical measurements (that is, physical properties of sediment and surface water).

5.4.2.2 Chemical measurements (that is, chemical properties of sediment, porewater, surface water, and biota).

5.4.2.3 Biological measurements (that is, biological characteristics).

5.4.3 Methods for collecting physical, chemical, and biological measurements are described in Battelle (2003), EPRI (2008), ITRC (2014), National Research Council (2007), Space and Naval Warfare Systems Center Pacific (2010), USACE (1998, 2008, 2015), and USEPA (2001a, 2005, 2014b). Table 1 presents common monitoring methods and provides references to guidance documents on how to perform various physical, chemical, and biological measurements.

5.4.4 All data collection efforts need to adhere to the data quality objectives. Quality assurance, preparation of field sampling plans (FSPs), standard operating procedures (SOPs) and appropriate statistical procedures, including data analysis, need to consider the merits of baseline sampling for evaluating various aspects (for example achieving CAOs, trend analysis) of remedial activities (USEPA 2002c, 2006).

5.4.5 Strategic review of the monitoring program is an important aspect of the program. For example, at CERCLA sites USEPA performs formal reviews every 5 years. This can be a convenient frequency to review the monitoring program and then coordinate decision making with the regulator. Modifications to the monitoring plan (for example, reduced frequency of monitoring) may be appropriate to optimize the monitoring plan, based on the data collected. The monitoring frequency will depend on the remedy or remedies selected and the specifics of the regulatory program.

5.5 *Stages of Monitoring*—Monitoring associated with sediment remediation is divided into three stages: baseline, remedy implementation, and post remedy (Fig. 1).

5.5.1 *Baseline Monitoring*—Baseline monitoring is performed prior to implementation of an active remedy, or prior to the commencement of a compliance monitoring program, for the purpose of obtaining data prior to future data acquisition efforts. Data collected during remedial investigation, risk assessment, and pre-design investigation may have different DQOs than baseline monitoring and may not be adequate for characterizing baseline conditions. These data also may have been collected a long time ago and may not represent current site conditions. Therefore, monitoring may be warranted to define baseline conditions, prior to remedy implementation. Baseline monitoring may include evaluating background conditions, which is discussed in section 6.1.3. Remedy implementation monitoring data are compared to baseline data to evaluate if construction is modifying baseline conditions to an unacceptable level. The post remedy monitoring results are compared to the baseline conditions to evaluate if the completed remedy is performing as designed and meeting the CAOs. Baseline monitoring and determination of background conditions are discussed in more detail in Section 6.

5.5.2 *Remedy Implementation Monitoring*—Remedy implementation monitoring (also referred to as construction monitoring) takes place during construction of the remedy. Remedy implementation monitoring is performed to determine if design criteria (as defined in the drawings and specifications) and the permit requirements (or substantive permit requirements) were achieved. Remedy implementation monitoring is discussed in more detail in Section 7.

5.5.3 *Post Remedy Monitoring*—Post remedy monitoring (also known as long term monitoring), takes place after remedy implementation is completed. When construction is considered complete, the post remedy monitoring period begins. Post remedy monitoring includes performance monitoring and effectiveness monitoring. Performance monitoring is conducted to determine if the remedy is performing as designed. It evaluates the remedial technology (for example, isolation for capping and natural recovery for MNR). Effectiveness monitoring is conducted to confirm the CAOs are met. Post remedy monitoring is described in more detail in Section 8.

6. Baseline Sampling to Support Long Term Monitoring Efforts

6.1 *Baseline Sampling Program*—The baseline sampling is an essential component of a long term monitoring program that evaluates the long-term success of a sediment remediation project. Typically, the baseline sampling is conducted during the site characterization or remedial investigation phase of a project. However, the scope of the baseline sampling effort could change during the investigation phase and into the pre-design and pre-construction phases of the project, as additional data are collected to support pre-design. Once the CAOs for the site are defined, the baseline sampling program may be modified to ensure appropriate data are collected to meet long term monitoring objectives. Appendix X1 provides a simplistic case study example demonstrating how baseline monitoring can be designed and executed.

6.1.1 *Importance of Baseline Data*—The data collected during the baseline sampling program need to be sufficient to allow comparison to post-remedy monitoring data to determine if the remedy was a success, whether the CAOs will be met within an acceptable timeframe and if additional adaptive management actions are warranted. In addition, baseline data need to reflect the variability, uncertainty, and complexity of the system being remediated. The baseline data should be consistent with the conceptual site model and risk assessments, including documentation of media concentrations (for example, sediment, surface water, porewater, biota) and other measures of environmental quality (for example, ecotoxicity, habitat structure and function, etc.) that will be affected by the site remedy. Insufficient baseline sampling data may limit the ability of decision makers to determine if post-remedy issues

TABLE 1 Sampling Methods

Reference	Bathymetric Survey	Side Scan Sonar	Acoustic Subbottom Profiling	Current Velocity	Hydrodynamic Analysis	Sediment Settlement Plate	Sediment Trap	Sediment Profile Imaging	Sediment Profile Photography	Sediment Shear Stress	Sediment Erosion	Suspended Sediment Monitoring	Surface Water Samples	Semi-Permeable Membrane Device	Core Samples	Grab Samples	Rapid Sediment Characterization Tools	Seepage Meter/Flux Sampler	Porewater Sampling	Benthic Surveys/Community Analysis	Caged Organisms	Artificial Substrate Samplers	Drift Net Sampling	Fish Community Census/Terrestial Wildlife Census	Vegetation Survey	Tissue Sampling	Toxicity	Capping	Air Sampling
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