Executive Summary

In 2001, the U.S. Environmental Protection Agency (EPA) released for comment a draft report, *The Incidence and Severity of Sediment Contamination in Surface Waters of the United States*, identifying locations in all regions of the country where sediment contamination could be associated with probable or possible adverse effects to aquatic life and/or human health (U.S. EPA 2001a). In addition, contaminated sediment has significantly impaired the navigational and recreational uses of rivers and harbors in the U.S. (NRC 1997 and 2001). As of 2001, EPA had decided to take an action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to clean up sediment at approximately 140 sites (U.S. EPA 2001a) and additional sites under the Resource Conservation and Recovery Act (RCRA). The remedies for 66 sites are large enough that they are being tracked at the national level. Many other sites are being cleaned up under state authorities, other federal authorities, or as voluntary actions.

This document provides technical and policy guidance for project managers and management teams making risk management decisions for contaminated sediment sites. It is primarily intended for project managers considering actions under CERCLA, although technical aspects of the guidance are also intended to assist project managers addressing sediment contamination under RCRA. However, many aspects of this guidance will be useful to other governmental organizations and potentially responsible parties (PRPs) that may be conducting a sediment cleanup. Provided below is a short summary of each of the eight chapters. Sediment cleanup is a complex issue, and as new techniques evolve, EPA will issue new or updated guidance.

Chapter 1, Introduction, describes the general backdrop for sediment remediation and reiterates EPA's previously issued OSWER Directive 9285.6-08, *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (U.S. EPA 2002a). Other issues addressed here include the role of the natural resource trustees, states, tribes, and the community at sediment sites. Where there are natural resource damages associated with sediment sites, coordination between the remedial and trusteeship roles at the federal, state, and tribal levels is especially important. In addition to their role as natural resource trustees, certain state cleanup agencies and certain Indian tribes or nations have an important role as co-regulators and/or affected parties and as sources of essential information. Communities of people who live and work adjacent to waterbodies containing contaminated sediment should be given understandable information about the safety of their activities, and be provided opportunities for involvement in the EPA's decision-making process for sediment cleanup. Social and cultural practices should also be considered in evaluating the impacts associated with contaminated sediment and sediment cleanup.

Chapter 2, Remedy Investigation Considerations, introduces investigation issues unique to the sediment environment, including those related to characterizing the site, developing conceptual site models, understanding current and future watershed conditions, controlling sources, and developing cleanup goals. Especially important at sediment sites is an accurate conceptual site model that identifies contaminant sources, transport mechanisms, exposure pathways, and receptors at various levels of the food chain. Project managers should consider the role of a sediment site in the watershed context, including other potential contaminant sources, key issues within the watershed, and current and reasonably anticipated or desired future uses of the waterbody and adjacent land. Essential parts of good site characterization and remedy selection include the identification and control of continuing sources of contamination and an accurate understanding of their contribution to site risk and potential for recontamination. It is also very important that remedial action objectives, remediation goals, and cleanup levels are based on site-specific data and are clearly defined. At most Superfund sites, chemical-specific remediation goals should be developed into final sediment cleanup levels by weighing the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) balancing and modifying criteria and other factors relating to uncertainty, exposure, and technical feasibility.

Chapter 2 also introduces issues relating to sediment bed stability and modeling at sediment sites. An important part of the remedial investigation at many sediment sites is a site-specific assessment of the extent of sediment disturbance in the past, and a prediction about whether there is likely to be significant disturbance in the foreseeable future. An accurate assessment of sediment stability (e.g., erosion and deposition rates) can be one of the most important factors in identifying areas suitable for monitored natural recovery (MNR), in-situ caps or near-water confined disposal facilities. Evaluation of alternatives should include consideration of disruption from human and natural causes, including at a minimum, the 100-year flood and other events with a similar probability of occurrence. Project managers should make use of the variety of empirical field methods available for evaluating sediment stability and, where appropriate, also use numerical models for evaluating events for which there is no field record and for predicting future stability. There is a wide range of empirical models and more robust computer models that can be applied to contaminated sediment sites. Models are useful tools, but they can be very time consuming and expensive to apply at complex sediment sites. Nevertheless, models are helpful in that, when properly applied, they provide a more complete understanding of the future transport and fate of contaminants. When using models, project managers should be aware of the uncertainties and variability of model predictions and, where possible, quantify these using sensitivity analysis or other evaluation methods. Project managers should, where possible, use validated and verified models that are in the public domain and calibrate them to site-specific conditions.

Chapter 3, Feasibility Study Considerations, supplements existing EPA guidance by offering sediment-specific guidance about developing alternatives, applying the NCP remedy selection criteria, identifying applicable or relevant and appropriate requirements (ARARs), estimating cost, and using institutional controls. Major cleanup methods include dredging and excavation, in-situ capping, and MNR. Innovative pilot and lab testing of in-situ treatment in the form of reactive caps or sediment additives are underway and may be useful in the future. Due to the limited number of cleanup methods available for contaminated sediment, generally project managers should evaluate both in-situ and ex-situ methods at every site where they may be appropriate. At large or complex sites, project managers have found that alternatives that combine a variety of cleanup methods are frequently cost effective. All final remedial actions at CERCLA sites must be protective of human health and the environment, and must comply with ARARs unless a waiver is justified. Developing accurate cost estimates is an essential part of evaluating sediment alternatives. Project managers should evaluate capital costs, operation and maintenance costs (including long-term monitoring), and net present value. Institutional controls are frequently evaluated as part of sediment alternatives to prevent or reduce human exposure to contaminants. Common types of institutional controls at sediment sites include fish consumption advisories, commercial fishing bans, and waterway use restrictions. In some cases, land use restrictions or structure maintenance requirements have also been important elements of an alternative.

Chapter 4, Monitored Natural Recovery, summarizes the natural processes that should be considered when evaluating MNR as a cleanup method, and briefly discusses enhanced natural recovery through thin-layer placement. The chapter defines MNR as a sediment cleanup method that uses known, ongoing, naturally occurring processes to contain, destroy, or otherwise reduce the bioavailability or toxicity of contaminants in sediment. Although "natural recovery" may be ongoing at many sites, the key factors that distinguish use of MNR as a remedy are the presence of unacceptable risk (i.e., the need for action), the ongoing burial or degradation/transformation of contaminants, and the establishment of a cleanup level that is expected to be met in a particular time frame. Although burial by clean sediment is often the dominant process relied upon for natural recovery, multiple physical, biological, and chemical mechanisms frequently act together to reduce risk. MNR should be evaluated based on site-specific data collected over a number of years, including an assessment of seasonal variation. Project managers should evaluate the long-term stability of the sediment bed and the likely ecological and human health impacts of sediment movement. Contingency measures should be included as part of a MNR remedy when there is significant uncertainty that the remedial action objectives will be achieved within the predicted time frame. MNR should generally be used as one component of an overall site remedy, and cautiously as the sole cleanup method.

Chapter 4 also discusses the major advantages and disadvantages of MNR. The major advantages of MNR are its relatively low cost and its non-invasive nature which involves minimal disruption to the existing biological community. In addition, because no construction or infrastructure is needed, it is generally much less disruptive to communities than active cleanup methods. Major disadvantages of MNR are that it generally leaves contaminants in place without engineered containment; it can be slow to reach cleanup levels in comparison to active cleanup methods; its effectiveness may be more uncertain than active cleanup methods; and it frequently relies upon institutional controls, such as fish consumption advisories, which may have limited effectiveness to control human exposure during the recovery period.

Chapter 5, In-Situ Capping, summarizes the major capping technologies and describes the site conditions that are critical to understand in evaluating the feasibility and effectiveness of in-situ capping. In-situ capping refers to placement of a subaqueous covering or cap of clean material over contaminated sediment. A cap reduces risk through three primary functions: 1) physical isolation of the contaminated sediment from the aquatic environment; 2) stabilization of contaminated sediment, preventing resuspension and transport to other sites; and 3) reduction of the movement of dissolved and colloidally transported contaminants. Backfill of clean material designed to mix with dredging or excavation residuals or to fill post-dredging depressions, rather than act as a engineered cap to isolate buried contaminants, is not considered in-situ capping in this guidance.

Chapter 5 also discusses the major advantages and disadvantages of in-situ capping. The major advantage of in-situ capping is that it can quickly reduce exposure to contaminants. Compared to dredging and excavation, less infrastructure is needed (e.g., materials handling, treatment, disposal), and the potential for contaminant resuspension and the risks associated with dispersion of contaminated materials during construction is typically lower. In-situ capping may also be less disruptive to communities than dredging or excavation. The major disadvantage of in-situ capping is that the contaminated sediment is left in place in the aquatic environment where contaminants may be exposed or dispersed if the cap is significantly disturbed or not properly maintained. Another potential disadvantage to in-situ capping may be that in some situations usable habitat may not be provided by the cap materials.

Chapter 6, Dredging and Excavation, summarizes excavation (conducted in the dry) and dredging (conducted under water) technologies; the components involved in transport, treatment, storage, and disposal of dredged or excavated sediment; and describes the importance of evaluating site conditions that are critical to the feasibility and effectiveness of dredging and excavation. A dredging or excavation alternative should include a thorough evaluation of the details concerning all phases of the project, including removal, transport and storage, treatment (pretreatment, treatment of decant and/or dewatering effluents and sediment, if necessary), and disposal (liquids and solids). When conducted, environmental dredging should use equipment and methods of operation which minimize resuspension. In some environments, excavation may lead to lower levels of residual contamination than dredging, although site preparation for excavation can be more lengthy and costly than for a dredging project due to the need for re-routing or draining the waterbody. Dredging projects should make realistic assumptions regarding residual contamination. Where over-dredging is possible, residual contamination is generally lower than where this practice is not possible. When predicting the effects on risk reduction of a dredging or excavation remedy which includes removal of deeply buried contaminants, it is important that project managers recognize that contaminant levels in fish tissue or other biota will only respond to removal of contaminants that are bioavailable.

Chapter 6 also discusses the major advantages and disadvantages of sediment removal by dredging and excavation. One of the principal advantages of removing contaminated sediment from the aquatic environment is that, if residuals are low, it results in the least uncertainty regarding future environmental exposure to contaminants because they are removed from the aquatic ecosystem and treated and/or disposed in a controlled environment. Sediment removal is currently the only cleanup method that allows for treatment and/or beneficial reuse of previously contaminated material. Sediment removal also allows maximum flexibility regarding future use of a waterbody. The principal disadvantages of sediment removal are that it is usually more complex and costly than in-situ cleanup methods, and that there is frequently significant uncertainty concerning the extent of residual contamination. The need for transport, storage, treatment (where applicable), and disposal facilities may lead to increased social or risk impacts on communities. In particular, disposal capacity may be limited in existing municipal or hazardous waste landfills and it may be difficult to site new local disposal facilities. Another disadvantage includes the potential for contaminant losses during dredging through resuspension, and to a generally lesser extent, through other processes during transport, treatment, or disposal. Finally, short-term disruption of the benthic environment is unavoidable during sediment removal, as it is for a capping remedy.

Chapter 7, Remedy Selection Considerations, discusses applying the NCP expectations (NCP §300.430(a)(1)(iii)) to CERCLA sediment remedies, considering a no-action alternative, choosing among sediment cleanup methods, and considering alternatives that include institutional controls. Generally, selecting a “no-action” remedy may be appropriate when: 1) the site poses no current or potential threat to human health or the environment; 2) CERCLA or RCRA do not provide the authority to take action; or 3) a previous action has eliminated the need for further action. Where a remedy is necessary, the best route to overall risk reduction depends on a large number of site-specific considerations, some of which may be subject to significant uncertainty. Any decision regarding the specific choice of a risk management strategy for contaminated sediment should be based on careful consideration of the advantages and disadvantages of each available option and a comparison among them. Documenting and communicating how and why remedy decisions were made are especially important at complex sediment sites. When considering remedies that include institutional controls, project managers should determine what entities possess the legal authority, capability and willingness to implement, and where applicable, monitor, enforce and report on the status of the control. When evaluating cleanup alternatives, project managers should include realistic assumptions concerning residuals and contaminant releases from in-situ and ex-situ remedies, the potential effects of those residuals and releases, and the length of time over which a risk may persist. In addition to considering the impacts of each alternative on human health and ecological systems, the social and cultural impacts of each alternative on the community and the opportunities for site reuse and redevelopment should be assessed.

At many sites, but especially at large sites, a combination of sediment cleanup methods may be the most appropriate way to manage the risk. The remedy selection process for sediment sites should include a clear understanding of the uncertainties involved, including uncertainties concerning the predicted effectiveness of various alternatives and the time frames for achieving remedial goals. The uncertainty of factors very important to the remedy decision should be quantified, so far as this is possible. Where it is not possible to quantify uncertainty, sensitivity analysis may be helpful to determine which apparent differences between alternatives are most likely to be significant.

Chapter 8, Remedial Action and Long-Term Monitoring, provides an approach to developing an effective remedial action and long-term monitoring program at contaminated sediment sites. It presents the key elements of a contaminated sediment site monitoring program, introduces some of the monitoring techniques available for physical, chemical, and biological measurements, and summarizes some of the factors to consider when monitoring remedies which include natural recovery, in-situ capping, or dredging/excavation. A monitoring program is important for all types of sediment remedies, both during the remedial action and over the long-term to ensure that sediment risks and exposure pathways at a site have been adequately managed and the remedy remains protective. The development of monitoring plans should follow a systematic planning process that identifies monitoring objectives, decision criteria, endpoints, and data collection and analysis methods. Remedial action monitoring includes both construction/operational monitoring and monitoring intended to measure whether cleanup levels and remedial action objectives have been met. After completion of the remedial action, long-term monitoring is important to assess potential re-contamination, to evaluate continued containment of buried or capped contaminants, and to monitor dredging residuals and on-site disposal facilities. Additional monitoring data will help not only to answer site-specific questions but will also contribute to better understanding of technology performance at the national level.