CHAPTER 2 Sediment Monitoring and Assessment Study Plans

Every study site and project are unique; therefore, sediment monitoring and assessment study plans should be carefully prepared to best meet the project objectives (MacDonald et al., 1991; see Figure 2-1).

Considerations

The initial issues that need to be considered prior to preparing study plans are...

! define the potential problem or general project objective

! determine what resources (e.g., time, money, personnel) are available for the project

! review existing information and identify specific objectives of the study

! determine what data are likely to be needed to answer project objectives, including the role of site-specific conditions and/or issues that might influence the process of data collection and analyses

Before collecting any environmental data, it is important to determine the type, quantity, and quality of data needed to meet the project objectives (e.g., specific parameters to be measured) and support a decision based on the results of data collection and observation. Not doing so creates the risk of expending too much effort on data collection (i.e., more data are collected than necessary), not expending enough effort on data collection (i.e., more data are necessary than were collected), or expending the wrong effort (i.e., the wrong data are collected).

2.1 Data Quality Objectives Process

The **Data Quality Objectives (DQO) Process** developed by EPA (GLNPO, 1994; USEPA, 2000a) is a flexible planning tool that systematically addresses the above issues in a coherent manner. The purpose of this process is to improve the effectiveness, efficiency, and defensibility of decisions made based on the data collected, and to do so in an effective manner (USEPA, 2000a). The information compiled in the DQO process is used to develop a project-specific **Quality Assurance Project Plan (QAPP)** (see Chapter 7 and USEPA, 2000a) which should be used to plan the majority of sediment quality monitoring or assessment studies. In some instances, a programmatic QAPP may be prepared, as necessary, on a project-by-project basis.

The Data Quality Objectives (DQO) process addresses the uses of the data (most importantly, the decision(s) to be made) and other factors that will influence the type and amount of data to be collected (e.g., the problem being addressed, existing information, information needed before a decision can be made, and available resources). From these factors the qualitative and quantitative data needs are determined (see Figure 2-2). DQOs are qualitative and quantitative statements that clarify the purpose of the monitoring study, define the most appropriate type of data to collect, and determine the most appropriate methods and conditions under which to collect them. The products of the DQO process are criteria for data quality and a data collection design that ensures that data will meet the criteria.

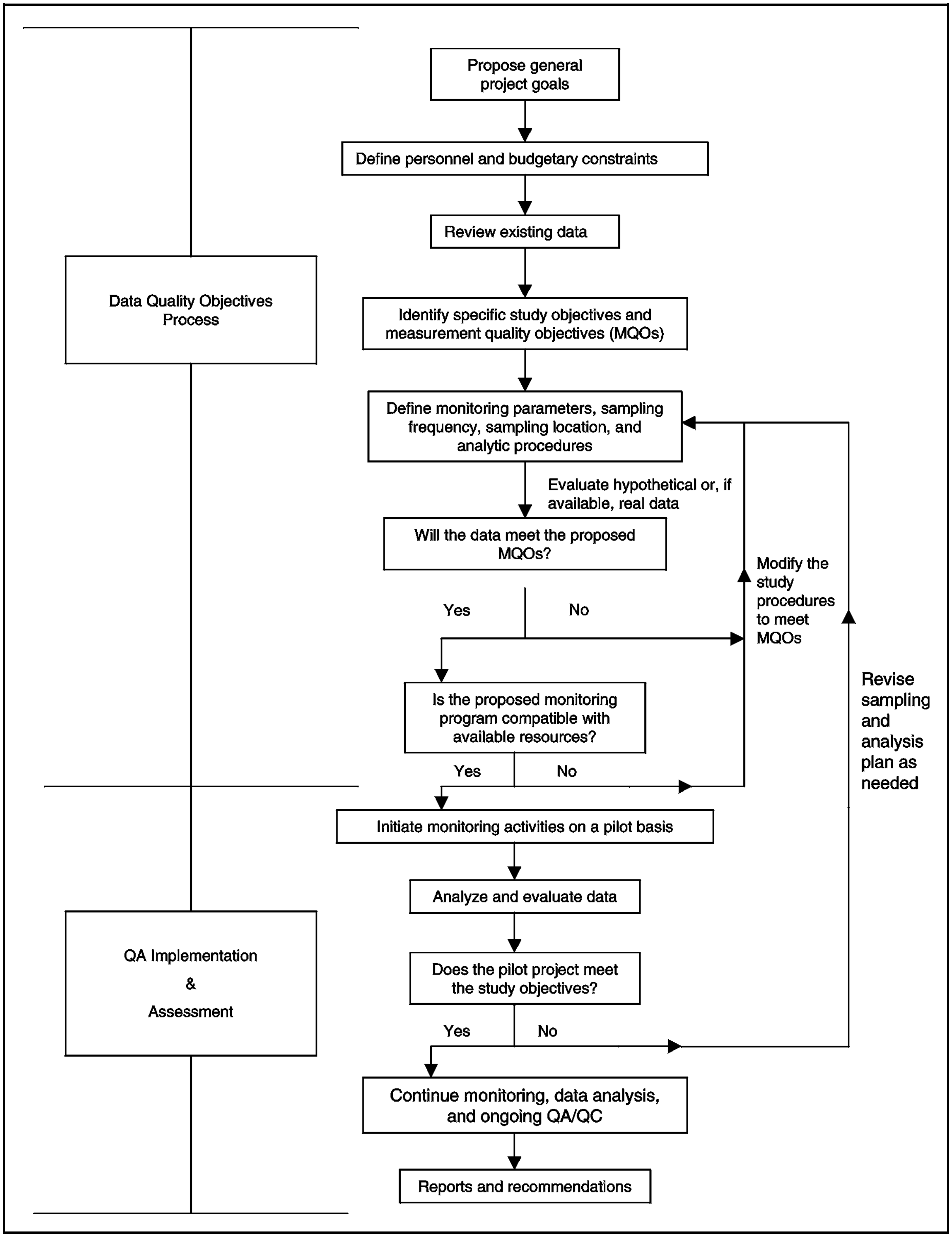


Figure 2-1. Flow chart summarizing the process that should be implemented in designing and performing a monitoring study (modified from MacDonald et al. (1991)).

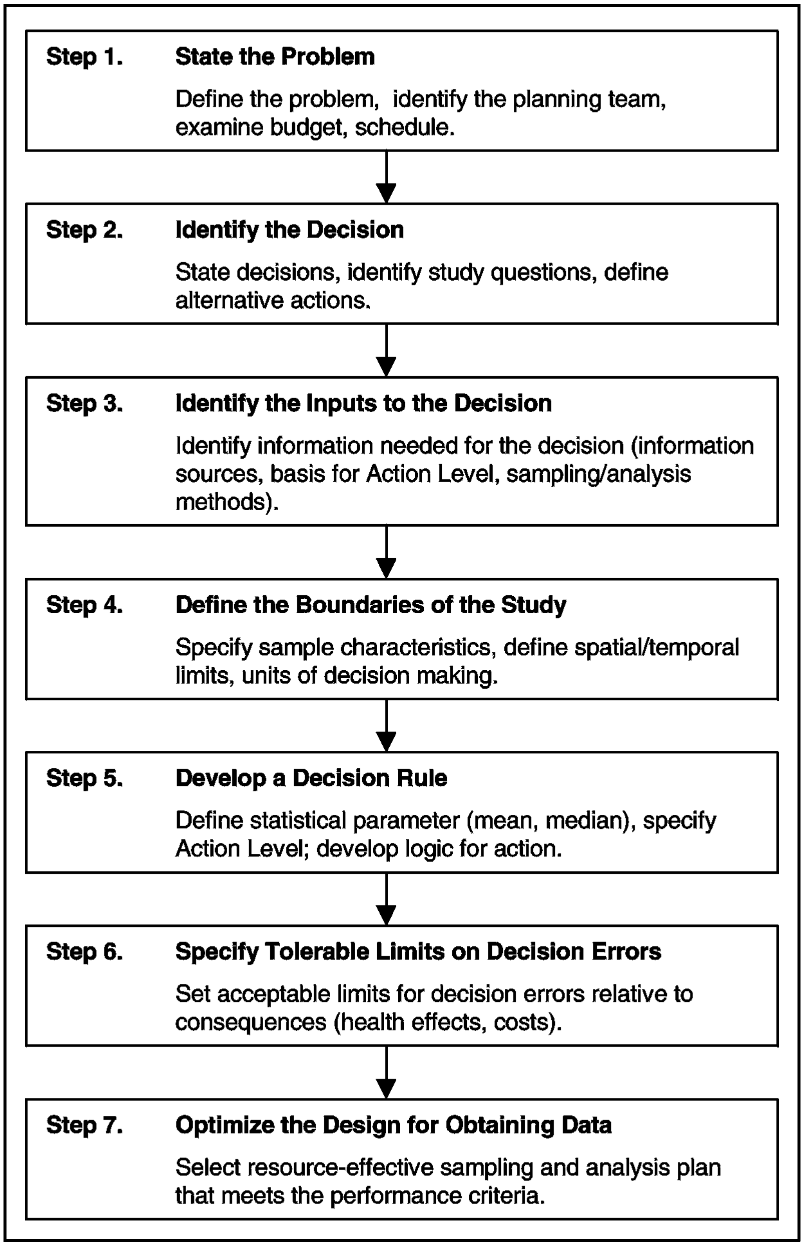


Figure 2-2. Flow chart summarizing the Data Quality Objectives Process (after USEPA, 2000a).

Checklist

In the DQO process, the following steps should be addressed:

- ✓ **Clearly state the problem: purpose and objectives, available resources, members of the project team:** e.g., The purpose might be to evaluate current sediment quality conditions, historical conditions, evaluate remediation effects, or validate a sediment model. It is important to review and evaluate available historical data relevant to the study at this point in the process.

- ✓ **Identify the decision; the questions(s) the study attempts to address**: e.g., Is site A more toxic than site B?; Are sediments in Lake Y less toxic now than they used to be?; Does the sediment at site D need to be remediated? What point or nonpoint sources are contributing to sediment contamination?

- ✓ **Identify inputs to the decision: information and measurements that need to be obtained**; e.g., analyses of specific contaminants, toxicity test results, biological assessments, bioaccumulation data, habitat assessments, hydrology, and water quality characterization.

- ✓ **Define the study boundaries (spatial and temporal).** Identify potential sources of contamination; determine the location of sediment deposition zones; determine the frequency of sampling and need for a seasonal sampling and/or sampling during a specific index period; consider areas of previous dredged or fill material discharges/disposal. Consideration of hydraulic patterns, flow event frequency, and/or sedimentation rates could be critical for determining sampling frequency and locations.

- ✓ **Develop a decision rule: define parameters of interest and determine the value of a parameter that would cause follow-up action of some kind**; e.g., exceedance of Sediment Quality Guideline value, NOAA Effect Range Median (ERM) value, or toxicity effect (e.g., 50% mortality), results in some action (Long et al., 1995). For example, in the Great Lakes Assessment and Remediation of Contaminated Sediments (ARCS) Program, one decision rule was: if total PCB concentration exceeds a particular action level, then the sediments will be classified as toxic and considered for remediation (GLNPO, 1994). Specifying decision rules or criteria is especially critical in sediment remediation programs and any study in which the results could be subject to legal scrutiny (e.g., superfund).

- ✓ **Specify limits on decision errors:** establish the measurement quality objectives (MQOs) which include determining the level of confidence required from the data; precision, bids, representativeness, and completeness of data; the sample size (weight or volume) required to satisfy the analytical methods and QA/QC program for all analytical tests; the number of samples required, to be within limits on decision errors, and compositing needed, if any.

- ✓ **Optimize the design:** choose appropriate sampling and processing methods; select appropriate method for determining the location of sampling stations; select an appropriate positioning method for the site and study. Consult historical data and a statistician <u>before</u> the study begins regarding the sampling design (i.e., the frequency, number, and location of field-collected samples) that will best satisfy study objectives.

For most programs, a Sampling and Analysis Plan (SAP) is developed prior to sampling which should describe the study objectives, sampling design and procedures, and other aspects of the DQO process outlined above (see Appendix B for an example of SAP requirements recommended by Washington State Department of Ecology). The following sections provide guidance on many of the primary issues that should be addressed in the study plan.

2.2 Study Plan Considerations

Monitoring and assessment studies are performed for a variety of reasons (ITFM, 1995) and sediment assessment studies can serve many different purposes. Developing an appropriate sampling plan is one of the most critical steps in monitoring and assessment studies. The sampling plan, including definition of the site and sampling design, will be a product of the general study objectives (Figure 2-1). Station location, selection, and sampling methods will necessarily follow from the study design. Ultimately, the study plan should control extraneous sources of variability or error to the extent possible so that data are appropriately representative of the sediment and fulfill the study objectives.

2.2.1 Definition of the Study Area and Study Site

The study area refers to the body of water that contains the study site(s) to be monitored and/or assessed, as well as adjacent areas (land or water) that might affect or influence the conditions of the study site. The study site refers to the body of water and associated sediments to be monitored and/or assessed. EMAP, for example, often defines a site as an area of concern (AOC) which might extend several miles in length, or may encompass large geographical or coastal areas. CERCLA defines a site in terms of a specific source of contamination such as a waste disposal area.

The size of the study area will greatly influence the type of sampling design (see Section 2.3) and site positioning methods that are appropriate (see Section 2.6). The boundaries of the study area need to be clearly defined at the outset and should be outlined on a hydrographic chart or topographic map.

Common purposes of sediment quality studies:

- Status and trends
- Evaluating program or BMP (best management practice) effectiveness
- Validating sediment quality models
- Designing regulatory programs
- Identifying whether significant contamination exists and extent of contamination
- Identifying sources of contamination
- Ranking existing and identifying emerging problems
- Establishing goals for sediment remediation
- Evaluating dredged or fill material discharges/disposal

2.2.2 Controlling Sources of Variability

A key factor in effectively designing a sediment quality study is controlling those sources of variability in which one is not interested (USEPA 2000a,b). There are two major sources of variability that, with proper planning, can be minimized, or at least accounted for, in the design process, thereby ensuring a successful study. In statistical terms, the two sources of variability are sampling error and measurement error (USEPA 2000b; Solomon et al., 1997).

Sampling error is the error attributable to selecting a certain sampling station that might not be representative of the site or population of sample units (e.g., an estuary or a CERCLA site). Sampling error is controlled by either: (1) using unbiased methods to select stations if one is performing general monitoring of a given site (USEPA, 2000b); or (2) several stations along a spatial gradient if a specific location is being targeted (see Section 2.3).

Measurement error is the degree to which the investigator accurately characterizes the sampling unit or station. Thus, measurement error includes components of natural spatial and temporal variability within the sample unit as well as actual errors of omission or commission by the investigator. Measurement error is controlled by using standardized and comparable methods: standardized methods include proper training of personnel and quality assurance procedures. To help minimize measurement error, each station should be sampled in the same way, within a site or study, using a standardized set of procedures and in the same time frame to minimize confounding sources of variability (see Section 2.2.3). In analytical laboratory or toxicity procedures, measurement error is estimated by duplicate determinations on some subset of samples (but not necessarily all). Similarly, in field investigations, some subset of sample units (e.g., 10% of the sites) should be measured more than once to estimate measurement error (see Replicate and Composite Samples, Section 2.4.3).

Measurement error can be reduced by analyzing multiple observations at each station (e.g., multiple grab samples at each sampling station, multiple observations during a season), or by collecting depth-integrated, or spatially integrated (composite) samples (see Section 2.4.3).

Checklist
To minimize measurement error:

- ✓ Sample all stations similarly within a study
- ✓ Use standardized procedures
- ✓ Sample during the same time period
- ✓ Collect and analyze multiple samples at a station
- ✓ Collect and analyze composited samples

Optimizing sampling design requires consideration of tradeoffs among the measures used, the effect that is considered meaningful, desired power, desired confidence, and resources available for the sampling program. Statistical power is the ability of a given sampling design to detect an effect that actually exists, and will be a product of the collection methods, analytical procedures, and quality control processes used. Power is typically expressed as the probability of correctly finding a difference among sites or between reference and test sites (e.g., toxicity or biological impairment) when one exists. For a fixed confidence level (e.g., 90%), power can be increased by increasing the sample size or the number of replicates (see Section 2.4.3 for more information). Most programs do not estimate power of their sampling design because this generally requires prior information such as pilot sampling, which entails further resources. One study (Gilfillan et al., 1995) reported power estimates for a shoreline monitoring program following the Valdez oil spill in Prince William Sound, Alaska. However, these estimates were computed after the sampling took place. It is desirable to estimate power before sampling is performed to ensure credibility of non-significant results (see Appendix C).

2.2.3 Sampling Using an Index Period

Most monitoring programs do not have the resources to characterize variability or to assess sediment quality for all seasons. Sampling can be restricted to an **index period** when biological and/or toxicological measures are expected to show the greatest response to pollution stress and within-season variability is small (Holland, 1985; Barbour et al., 1999). This type of sampling might be especially advantageous for characterizing sediment toxicity, sediment chemistry, and benthic macroinvertebrate and other biological assemblages (USEPA, 2000c). In addition, this approach is useful if sediment contamination is related to, or being separated from, high flow events. By sampling overlying waters during both low and high flow conditions, the relative contribution of each to pollutant loads or sediment contamination can be better assessed, thereby better directing remedial activities, or other watershed improvements.

Those programs that sample the same site over multiple years (e.g., many EMAP and superfund studies), are interested in obtaining comparable data with which they can assess changes over time, or following remediation (GLNPO, 1994). In these cases, index period sampling is especially useful because hydrological regime (and therefore biological processes) is likely to be more similar between similar seasons than among different seasons.

2.3 Sampling Designs

As mentioned in earlier sections of this chapter, the type of sampling design used is a function of the study Data Quality Objectives and more specifically, the types of questions to be answered by the study. A summary of various sampling designs is presented in Figure 2-3 along with recommendations concerning the conditions under which a given design is appropriate. Generally, sampling designs fall into two major categories: random or probabilistic, and targeted (USEPA, 2000b). USEPA (2000b;c) present a thorough discussion of sampling design issues and detailed information on different sampling designs. Some program-specific guidance documents (e.g., USEPA/ACOE 1991, 1998 for dredged material disposal issues) also discuss relevant sampling designs. Table 2-1 presents suggested sampling designs given different overall objectives and constraints. Appendix A presents hypothetical examples of sediment quality monitoring designs given different objectives or regulatory applications.

Sampling Design refers to the array, or network, of sampling sites selected for a monitoring program; usually taking one of two forms:

- *Probabilistic Design* — Network that includes sampling sites selected randomly in order to provide an unbiased assessment of the condition of the waterbody at a scale above the individual site or stream; can address questions at multiple scales.
- *Targeted Design* — Network that includes sampling sites selected based on known existing problems, knowledge of upcoming events in the watershed, or a surrounding area that will adversely affect the waterbody such as development or deforestation; or installation of BMPs or habitat restoration that are intended to improve waterbody quality; provides assessments of individual sites or reaches.

2.3.1 Probabilistic and Random Sampling

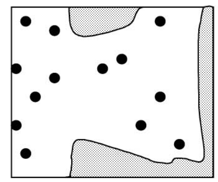
Probability-based or random sampling designs avoid bias in the results of sampling by randomly assigning and selecting sampling locations. A probability design requires that all sampling units have a known probability of being selected. Both EPA's Environmental Monitoring Assessment Program and NOAA's National Status and Trends Program use a probabilistic sampling design to infer regional and national patterns with respect to contamination or biological effects.

Sites can be selected on the basis of a truly random scheme or in a systematic way (e.g., sample every 10 meters along a randomly chosen transect). In ***simple random sampling***, all sampling units have an equal probability of selection. This design is appropriate for estimating means and totals of environmental variables if the population is homogeneous. To apply simple random sampling, it is necessary to identify all potential sampling times or locations, then randomly select individual times or locations for sampling.

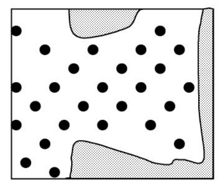
In ***grid or systematic*** sampling, the first sampling location is chosen randomly and all subsequent stations are placed at regular intervals (e.g. 50m apart) throughout the study area. Clearly, the number of sampling locations could be large if the study area is large and one desires “fine-grained” contaminant or toxicological information. Thus, depending on the types of analyses desired, such sampling might become expensive unless the study area is relatively small and/or the density of stations (that is how closely spaced are the stations) is relatively low. Grid sampling might be effective for detecting previously unknown “hot spots” in a limited study area.

Sampling Methods

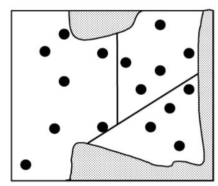
Simple Random: Samples are independently located at random



Systematic: Samples are located at regular intervals



Stratified: The study area is divided into nonoverlapping strata and samples are obtained from each



Multistage: Large primary units are selected which are then subsampled

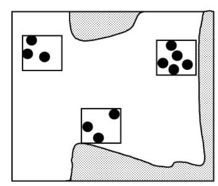


Figure 2-3. Description of various sampling methods. Adapted from USEPA, 2000c.

In ***stratified designs***, the selection probabilities might differ among strata. Stratified random sampling consists of dividing the target population into non-overlapping parts or subregions (e.g., ecoregions, watersheds, or specific dredging or remediation sites) termed strata to obtain a better estimate of the mean or total for the entire population. The information required to delineate the strata and estimate sampling frequency must either be known prior to sampling using historic data, available information and knowledge of ecological function, or obtained in a pilot study. Sampling locations are randomly selected from within each of the strata. Stratified random sampling is often used in sediment quality monitoring because certain environmental variables can vary by time of day, season, hydrodynamics, or other factors. Major environmental monitoring programs that incorporate a stratified random design include EPA’s Mid-Atlantic Integrated Assessment (MAIA). One disadvantage of using random designs is the possibility of encountering unsampleable sites that were randomly selected by the computer. Such problems result in the need to reposition the vessel to an alternate location. Furthermore, if one is sampling to determine the percent spatial extent of degradation, it might be important to sample beyond the boundaries of the study area to better evaluate the limits of the impacted area.

A related design is ***multistage*** sampling in which large subareas within the study area are first selected (usually on the basis of professional knowledge or previously collected information). Stations are then randomly located within each subarea to yield average or pooled estimates of the variables of interest (e.g., concentration of a particular contaminant or acute toxicity to *Hyalella*) for each subarea. This type of sampling is especially useful for statistically comparing variables among specific parts of a study area.

Table 2-1. Suggestions for selecting an appropriate sampling design (from USEPA 2000b).

If you are...	and you have...	consider using...	in order to...
performing a screening phase of an investigation and with an understanding of a relatively small-scale problem	a limited budget and/or a limited schedule	judgmental or targeted sampling	assess whether further investigation is warranted that should include a statistical probabilistic sampling design.
developing an understanding of when contamination is present	adequate budget for the number of samples needed	systematic sampling	have coverage of the time periods of interest.
developing an understanding of where contamination is present	adequate budget for the number of samples needed	grid sampling	have coverage of the area of concern and have a given level of confidence that you would have detected a hot spot of a given size.
estimating a population mean	adequate budget	systematic or grid sampling	also produce information on spatial or temporal patterns.
	budget constraints and analytical costs that are high compared to sampling costs	compositing	produce an equally precise or a more precise estimate of the mean with fewer analyses and lower cost.
	budget constraints and professional knowledge or inexpensive screening measurement that can assess the relative amounts of the contaminant at specific field sample locations	ranked set sampling	reduce the number of analyses needed for a given level of precision.
estimating a population mean or proportion	spatial or temporal information on contaminant patterns	stratified sampling	increase the precision of the estimate with the same number of samples, or achieve the same precision with fewer samples and lower cost.
delineating the boundaries of an area of contamination	a field screening method	stratified sampling	simultaneously uses all observations in estimating the mean.
estimating the prevalence of a rare trait	analytical costs that are high compared to sampling costs	random and composite sampling	produce an equally precise or more precise estimate of the prevalence with fewer analyses and lower cost.
assessing whether a population contains a rare trait	the ability to physically mix aliquots from the samples and then retest additional aliquots	composite sampling and retesting	classify all samples at reduced cost by not analyzing every sample.

Recommendation Box #1
What type of sampling strategy should be used?

- ➡ Historical data, if available, should be considered when selecting sampling stations.
- ➡ Location of sediment depositional zones can be important in defining subareas for sampling or for stratifying sampling in some programs.
- ➡ If the objective of the survey is to identify areas of toxic and/or contaminated sediments on a quantitative spatial and/or temporal basis (e.g., superfund site), a systematic or regular grid-sampling strategy might be most appropriate (USEPA, 2000b).
- ➡ If the monitoring objective is to determine sediment contamination originating from a specific source or tributary, a targeted site location design might be most appropriate. Factors affecting dispersion of substances or materials from the point source (e.g., currents) should be considered.
- ➡ Stratified random sampling should be used where historical, sediment-mapping data are available and there are well-defined zones of different sediment types or adjacent land uses (Burton, 1991). This design is commonly used in NOAA National Status and Trends (NS&T) monitoring of sediment quality to ensure that the data can be attributed to the strata in which they were collected (Long et al., 1996).
- ➡ For dredge management programs, multi-stage, stratified-random, or even targeted sampling is often appropriate, since the need is to represent specific areas to be dredged and disposed.
- ➡ For watershed or regional assessment programs, a probabilistic sampling design might be most appropriate.
- ➡ Small-scale, targeted study designs might require many samples within a small area if fine spatial resolution is needed (e.g., Superfund).

Use of random sampling designs might also miss relationships among variables, especially if there is a relationship between an explanatory and a response variable. As an example, estimation of benthic response or contaminant concentration, in relation to a discharge or landfill leachate stream, requires sampling targeted around the potential contaminant source, including stations presumably unaffected by the source (e.g., Warwick and Clarke, 1991). A simple random selection of stations is not likely to capture the entire range needed because most stations would likely be relatively removed from the location of interest.

2.3.2 Targeted Sampling Designs

In ***targeted*** (also referred to as ***judgmental*****,** or ***model-based***) designs, stations are selected based on prior knowledge of other factors, such as contaminant loading, depth, salinity, and substrate type. The sediment studies conducted in the Clark Fork River (Pascoe and DalSoglio, 1994; Brumbaugh et al., 1994), in which contaminated areas were a focus, used a targeted sampling design.

Targeted designs are useful if the objective of the investigation is to screen an area(s) for the presence or absence of contamination at levels of concern, such as risk-based screening levels or toxicity, or to compare specific sediments against reference conditions or biological guidelines. In general, targeted sampling is appropriate for situations in which any of the following apply (USEPA, 2000b):

- The site boundaries are well defined or the site physically distinct (e.g., superfund or CERCLA site, proposed dredging unit).
- Small numbers of samples will be selected for analysis/characterization.
- Information is desired for a particular condition (e.g., “worst case”) or location.
- There is reliable historical and physical knowledge about the feature or condition under investigation.
- The objective of the investigation is to screen an area(s) for the presence or absence of contamination at levels of concern, such as risk-based screening levels. (Note that if such contamination is found, follow-up sampling is likely to involve one or more statistical designs to compare specific sediments against reference conditions, chemical or biological guidelines, or applicable sediment quality values).
- Schedule or budget limitations preclude the possibility of implementing a statistical design.
- Experimental testing of a known pollution gradient to develop or verify testing methods or models (i.e., as in evaluations of toxicity tests, Long et al., 1990).

Because targeted sampling designs often can be quickly implemented at a relatively low cost, this type of sampling can often meet schedule and budgetary constraints that cannot be met by implementing a statistical design. In many situations, targeted sampling offers an additional important benefit of providing an appropriate level-of-effort for meeting investigation objectives without excessive consumption of project resources.

Targeted sampling, however, limits the inferences made to the stations actually sampled and analyzed. Extrapolation from those stations to the overall population from which the stations were sampled is subject to unknown selection bias. This bias might be unimportant for those regulatory programs in which information is needed for a particular condition or location (e.g., Dredged Management Materials Program or Superfund).

2.4 Measurement Quality Objectives

As noted in Section 2.1, a key aspect of the DQO process is specifying measurement quality objectives (MQOs): statements that describe the amount, type, and quality of data needed to address the overall project objectives.

Appendix B presents examples of MQOs and sampling designs that have been used in several different programs. Also included in Appendix B is excerpted information from Washington Department of Ecology’s Sampling and Analysis Plan Guidance (WDE, 1995). Similar to Quality Assurance Project Plans (QAPP) mentioned earlier in Section 2.1, a Sampling and Analysis Plan includes, among other things, many of the elements of the Data Quality Objectives Process, including MQOs.

A key factor determining the types of MQOs needed in a given project or study is the types of analyses required because these will determine the amount of sample required (see Section 2.4.1) and how samples are processed (see Chapter 4). The case examples presented in Appendix B illustrate a variety of chemical, biological, and toxicological analyses that are often included in sediment quality monitoring projects. Metals, organic chemicals (including pesticides, PAHs, and PCBs), whole sediment toxicity, and organism bioaccumulation of specific target chemicals, are frequently analyzed in many sediment monitoring programs.

A number of other, more "conventional" parameters, are also often analyzed as well to help interpret chemical, biological, and toxicological data collected in a project. Table 2-2 summarizes many of the commonly measured conventional parameters and their uses in sediment quality studies (WDE, 1995). It is important that conventional parameters receive as much careful attention, in terms of sampling and sample processing procedures, as do the contaminants or parameters of direct interest. The guidance presented in Chapters 3 and 4 provides information on proper sampling and sample processing procedures, respectively, to ensure that one has appropriate samples for these analyses.

This section concentrates on three aspects of MQO development that are generally applicable to all sediment quality studies, regardless of the particular program or objectives: sample volume, number of samples, and replication vs. composite sampling.

Checklist
MQOs are defined in terms of the following attributes:

- ✓ **Detection Limit** – The lowest concentration of an analyte that a specified analytical procedure can reliably detect.
- ✓ **Bias** – The difference between an observed value and the "true" value (or known concentration) of the parameter being measured; bias is the first component of accuracy, which is the ability to obtain precisely a nonbiased (true) value.
- ✓ **Precision** – The level of agreement among multiple measurements of the same characteristic; precision is the second component of accuracy.
- ✓ **Representativeness** – The degree to which the data collected accurately represent the population of interest (e.g., contaminant concentrations).
- ✓ **Comparability** – The similarity of data from different sources included within individual or multiple data sets; the similarity of analytical methods and data from related projects across areas of concern.
- ✓ **Completeness** – The quantity of data that is successfully collected with respect to the amount intended in the experimental design.

2.4.1 Sample Volume

Before commencing a sampling program, the type and number of analyses and tests should be determined, and the required volume of sediment per sample calculated. Each physicochemical and biological test requires a specific amount of sediment which, for chemical analyses, depends on the detection limits attainable and extraction efficiency by the procedure and, for biological testing, depends on the test organisms and test method. Typical sediment volume requirements for each end use are summarized in Table 2-3. Specific program guidance should be consulted regarding sample volumes that might be required.

Table 2-2. Conventional sediment variables and their use in sediment investigations (Adapted from WDE, 1995).

Conventional Sediment Variable	Use
Total organic carbon (TOC)	• Normalization of the concentrations of nonionizable organic compounds • Identification of appropriate reference sediments for biological tests
Acid Volatile Sulfide (AVS)	• Normalization of the concentrations of divalent metals in anoxic sediments
Sediment grain size	• Identification of appropriate reference sediments for biological tests • Interpretation of sediment toxicity test data and benthic macroinvertebrate abundance data • Evaluation of sediment transport and deposition • Evaluation of remedial alternatives
Total solids	• Expression of chemical concentrations on a dry-weight basis
Ammonia	• Interpretation of sediment toxicity test data
Total sulfides	• Interpretation of sediment toxicity test data

When determining the sample volumes necessary, one must know what is required for all of the sample analyses (considering adequate replication) and it is also helpful to know the general characteristics of the sediments being sampled. For example, if interstitial water analyses or elutriate tests are to be conducted, the percent water (or percent dry weight) of the sediment will greatly affect the amount of water extracted. Many non-compacted, depositional sediments have interstitial water contents ranging from 30 to 70%. However, interstitial waters are very difficult to remove from sandy or gravel-rich sediments.

For benthic macroinvertebrate bioassessment analyses, sampling a prescribed area of benthic substrate is at least as important as sampling a given volume of sediment. In many programs, macroinvertebrates are sampled using multiple grab samples within a given station location, typically to a standard sediment depth (e.g., per 10-20 cm of sediment; Klemm et al., 1990; GLNPO, 1994; Long et al., 1996; USEPA 2000c). More than 6 liters of sediment from each station might be necessary in order to have adequate numbers of organisms for analyses, especially in many lakes, estuaries, and large rivers (Barbour et al., 1999). However, this is very site specific and should be determined by the field sampling crew. This only applies to whole sediment sampling methods and not to surficial stream methods using methods such as kick-nets and Surber samplers. If the sediment quality triad approach is used (i.e., biological, toxicological, and physicochemical analyses performed on samples from the same sites), more than 10 liters of sediment from each site might be required depending on the specific analyses conducted. NOAA routinely collects 7-8 liters of sediment at each station for multiple toxicity tests and chemical analyses (Long et al., 1996).

Table 2-3. Typical sediment volume requirements for various analyses per sample

Sediment Analysis	Minimum Sample Volume
Inorganic chemicals	90 mL
Non-petroleum organic chemicals	230 mL
Other chemical parameters (e.g., total organic carbon, moisture content)	300 mL
Particle size	230 mL
Petroleum hydrocarbons[1]	250-1000 mL
Acute and chronic whole sediment toxicity tests[2]	1-2 L
Bioaccumulation tests[3]	15 L
Benthic macroinvertebrate assessments	8-16 L
Pore water extraction	2 L
Elutriate preparation	1 L

[1] The maximum volume (1000 mL) is required only for oil and grease analysis; otherwise, 250 mL is sufficient.

[2] Amount needed per whole sediment test (i.e., one species) assuming 8 replicates per sample and test volumes specified in USEPA, 2000d

[3] Based on an average of 3 L of sediment per test chamber and 5 replicates (USEPA, 2000d).

Recommendation Box #2

How many samples and how much sample volume should be collected?

- ➡ The testing laboratory should be consulted to confirm the amount of sediment required for all desired analyses.
- ➡ The amount of sediment needed from a given site will depend on the number and types of analyses to be performed. If biological, toxicological, and chemical analyses are required (sediment triad approach), then at least 10 liters of sediment might be required from each station.
- ➡ Since sampling events might be expensive and/or difficult to replicate, it is useful to collect extra samples if possible, in the event of problems encountered by the analytical laboratories, failure of performance criteria in assays, or need to verify/validate results.
- ➡ Consider compositing samples from a given station or across similar station types to reduce the number of samples needed.

2.4.2 Number of Samples

> **Considerations**
> ***The appropriate number of samples is usually determined by...***
>
> ! size of the study site
>
> ! type and distribution of the contaminants being measured
>
> ! characteristics and homogeneity of the sediment
>
> ! concentrations of contaminants likely to be found in the sediments
>
> ! sample volume requirements
>
> ! desired level of statistical resolution or precision

The number of samples collected directly affects the representativeness and completeness of the data for purposes of addressing project goals. As a general rule, a greater number of samples will yield better definition of the areal extent of contamination or toxicity. Many programs specify a certain number of samples per location (e.g., CERCLA site or dredging unit).

Accordingly, sample requirements should be determined on a case-by-case basis. The number of samples to be collected will ultimately be an outcome of the questions asked. For example, if one is interested in characterizing effects of a point source or a gradient (e.g., effects of certain tributaries or land uses on a lake or estuary), then many samples in a relatively small area might need to be collected and analyzed. If, however, one is interested in screening "hot spots" or locations of high contamination within a watershed or water body, relatively few samples at regularly-spaced locations might be appropriate. In most monitoring and assessment studies, the number of samples to be collected usually results from a compromise between the ideal and the practical. The major practical constraints are the costs of analyses and logistics of sample collection.

The major costs associated with the collection of sediment samples are those for travel to the site and for sample analysis. The costs of actual on-site sampling are minimal by comparison. Consequently, it is good practice to collect an excess number of samples, and a subset equal to the minimum number required is selected for analysis. The archived replicate samples can be used to replace lost samples, for data verification, to rerun analyses yielding questionable results, or for the independent testing of *a posteriori* hypotheses that might arise from screening the initial data. However, storage of sediments might result in changes in bioavailability of chemical contaminants (see Section 4.5). Therefore, follow-up testing of archived samples should be done cautiously.

2.4.3 Replicate and Composite Samples

Replicate Samples

As mentioned in the previous section, the number of samples collected and analyzed will always be a compromise between the desire of obtaining high quality data that fully addresses the overall project objectives (MQOs) and the constraints imposed by analytical costs, sampling effort, and study logistics. Therefore, every sampling program needs to find a balance between obtaining information to satisfy the stated DQOs or study goals in a cost-effective manner, and yet have enough confidence in the data to make appropriate decisions (e.g., remediation, dredging; Step 3 in the DQO process, Figure 2-2). Two different concepts are used to satisfy this challenge: replication and sample compositing.

Replication is used to assess precision of a particular measure and can take many forms depending on the type of precision desired. For most programs, analytical replicates are the most frequently used form of replication because most MQOs are concerned with analytical data quality (see examples in

Appendix B). The extent of analytical replication (duplicates) varies with the program or study DQOs. Performing duplicate analyses on at least 10% of the samples collected is considered satisfactory for most programs (GLNPO, 1994; USEPA/ACOE, 1991; PSEP, 1997a; USEPA/ACOE, 1998). An MQO of ≤ 20 - 30% relative percent difference (RPD) is commonly used for analytical replicates depending on the analyte.

Field replicates can provide useful information on the spatial distribution of contaminants at a station and the heterogeneity of sediment quality within a site. Furthermore, field replicates provide true replication at a station (analytical replicates and split samples at a station provide a measure of precision for a given sample, not the station) and therefore can be used to statistically compare analyses (e.g., toxicity, tissue concentration, whole sediment concentration) across stations.

Checklist

Replication can take several forms and satisfy different purposes:

- ✓ Collect field replicate samples at a station if there is a need to statistically compare results among stations within a site.
- ✓ Analytical replicates: separate laboratory analyses on subsamples from the same field sample.
- ✓ Field replicates: separate samples collected at a station each of which is analyzed individually.
- ✓ Field-split replicates: a single field sample is split into subsamples, each of which is then analyzed individually.
- ✓ Compositing samples is one way to reduce the number of replicates needed for analysis.

Results of field replicate analysis yield the overall variability or precision of both the field and laboratory operations (as well as the variability between the replicate samples themselves, apart from any procedural error). Because field replicate analyses integrate a number of different sources of variability, they might be difficult to interpret. As a result, failure to meet a precision MQO for field replicates might or might not be a cause of concern in terms of the overall study objectives but would suggest some uncertainty in the data. Many monitoring programs perform field replicates at 10% of the stations sampled in the study as a quality control procedure. An MQO of ≤ 30 - 50% relative percent difference (RPD) is typically used for field replicates depending on the analyte (see examples in Appendix B). Many regulatory programs (e.g., Dredged Disposal Management within the Puget Sound Estuary Program) routinely use 3-5 field replicates per station. Appendix C summarizes statistical considerations in determining the appropriate number of replicate samples given different sampling objectives.

Split sample replication is less commonly performed in the field because many programs find it more useful to quantify data precision through the use of analytical and field replicates described above. However, split sample replication is frequently used in the laboratory in toxicity and bioaccumulation analyses (USEPA, 2000d) and to verify homogeneity of test material in spiked sediment tests (see Section 5.3). In the field, samples are commonly split for different types of analyses (e.g., toxicity, chemistry, benthos) rather than to replicate a given sample. This type of sample splitting or subsampling is further discussed in Section 4.2.

Composite Samples

A composite sample is one that is formed by combining material from more than one sample or subsample. Because a composite sample is a combination of individual aliquots, it represents an "average" of the characteristics making up the sample. Compositing, therefore, results in a less detailed description of the variability within the site as compared to taking field replicates at each station. However, for characterizing a single station, compositing is generally considered an excellent way to provide quality data with relatively low uncertainty. Furthermore, many programs find it useful to average the naturally heterogeneous physicochemical conditions that often exist within a station (or dredging unit, for example), even within a relatively small area (GLNPO, 1994; PSEP, 1997a; ASTM, 2000a). Many programs find it useful to composite 3-5 samples from a given location or depth strata (PSEP, 1997a; GLNPO, 1994).

Considerations
Composite samples are collected because they...

! Yield a single "average estimate for a given station with less cost than using replicates.

! Can obtain useful information over many stations at reduced analytical costs.

! Are an efficient way to provide sufficient sample volume for multiple types of analyses, particularly biological/toxicity analyses.

Compositing is also a practical way to control analytical costs while providing information from a large number of stations. For example, with relatively little more sampling effort, five analyses can be performed to characterize a project segment or site by collecting 15 samples and combining sets of three into five composite samples. The increased coverage afforded by taking composite samples might justify the increased time and cost of collecting the extra 10 samples in this case (USEPA/ACOE, 1998). Compositing is also an important way to provide the large sample volumes required for some biological tests (see Table 2-1) and for multiple types of analyses (e.g., physical, chemical, toxicity, and benthos). However, compositing is not recommended where combining samples could serve to "dilute" a highly toxic but localized sediment "hot spot" (WDE, 1995; USEPA/ACOE, 1998). Also, samples from stations with very different grain size characteristics or different stratigraphic layers of core samples should not be composited (see Section 4.3).

Checklist
Before sampling:

✓ Review available information about the site including physical conditions and potential contaminant sources.

✓ Inspect the site to confirm that the sampling design and procedure chosen are feasible.

✓ Perform a pilot or screening sampling, if possible, to ensure that sampling equipment and procedures are adequate for the types of stations selected.

2.5 Site-Specific Considerations for Selecting Sediment Sampling Stations

Several site-specific factors might ultimately influence the appropriate location of sampling stations, both for large-scale monitoring studies, in which general sediment quality status is desired, and for smaller, targeted studies, in determining the need for sediment remediation. If a targeted or stratified random sampling design is chosen, it might be important to locate sediment depositional and erosional areas to properly identify contaminant regimes. Table 2-4 presents a summary of site-specific factors that should be considered when developing a sampling plan. A comprehensive review of such considerations is provided by Mudroch and MacKnight (1994).

Table 2-4. Practical considerations for site-specific selection of sampling stations in developing a sampling plan.

Activity	Consideration
Determination of areas where sediment contamination might occur	Hydrologic information • quality and quantity of runoff • potential depositional inputs of total suspended solids • up-wellings • seepage patterns
Determination of depositional and erosional areas	Bathymetric maps and hydrographic charts • water depth • zones of erosion, transport, and deposition • bathymetry • distribution, thickness, and type of sediment • velocity and direction of currents • sedimentation rates Climatic conditions • prevailing winds • seasonal changes in temperature, precipitation, solar radiation, etc. • tides, seiches • seasonal changes in anthropogenic and natural loadings
Determination of potential sources of contamination	Anthropogenic considerations location of urban centers • historical changes in land use • types, densities, and size of industries • location of waste disposal sites • location of sewage treatment facilities • location of stormwater outfalls and combined sewer overflows • location, quantity, and quality of effluents • previous monitoring and assessment or geochemical surveys • location of dredging and open-water dredged material disposal sites • location of historical waste spills
Factors affecting contaminant bioavailability	Geochemical considerations • type of bedrock and soil/sediment chemistry • physical and chemical properties of overlying water
Determination of representativeness of samples	• area to be characterized • volume to be characterized • depth to be characterized • possible stratification of the deposit to be characterized

2.5.1 Review Available Data

Review of available historical and physical data is critical in the sample selection process and subsequent data interpretation. Local experts should be consulted to obtain information on site conditions and the origin, nature, and degree of contamination. Other potential sources of information include government agency records, municipal archives, harbor commission records, past geochemical analyses, hydrographic surveys, bathymetric maps, and dredging/disposal history. Potential sources of contamination should be identified and their locations noted on a map or chart of the proposed study area. It is important that recent hydrographic or bathymetric data be used in identifying representative sampling locations, especially for dredging or other sediment removal projects. The map or chart should also note adjacent land and water uses (e.g., fuel docks, storm drains, etc.). The quality and age of the available data should be critically weighed.

2.5.2 Site Inspection

A physical inspection of the site is strongly recommended when developing a study plan, in order to assess the completeness and validity of the collected historical data, and to identify any significant changes that might have occurred at the site or study area (Mudroch and MacKnight, 1994). A site inspection of the immediate drainage area and upstream watershed might also identify potential stressors (such as erosion), and help determine appropriate sampling gear (such as corer vs. grab samplers and boat type) and sampling logistics.

If resources allow, it is useful to perform some screening or pilot sampling and analyses at this stage to further refine the actual sampling design needed. Pilot sampling is particularly helpful in defining appropriate station locations for targeted sampling or to identify appropriate strata or subareas in stratified or multistage sampling, respectively.

2.5.3 Identify Sediment Deposition and Erosional Zones

When study DQOs direct sampling to the highest contamination levels or specific subareas of a site, it might be important to consider sediment deposition and sediment erosional zones, since grain size and related physicochemical characteristics (including conventional parameters such as total organic carbon and acid volatile sulfide, as well as contaminants), are likely to vary between these two types of zones. Depositional zones typically contain fine-grained sediment deposits which are targeted in some sampling programs because fine-grained sediments tend to have higher organic carbon content (and are therefore a more likely repository for pollutants) relative to larger sediment particle size fractions (e.g., sand and gravel) (ASTM, 2000a; Environment Canada, 1994). However, for some programs such as remediation dredging evaluations or superfund, eroding sediment beds and non-depositional zones might be of most concern as these could be a major source of pollutants in the water column and in organisms (USEPA/ACOE, 1991,1998).

Various non-disruptive technologies are available to assist in the location of fine-grained sediments ranging from simplistic to more advanced. For example, use of a steel rod or PVC pipe can be used in many shallow areas to quickly and easily probe the sediment surface to find coarse (sand, gravel) vs. fine sediments (silt, clay). This technique can not, however, determine sediment grain size at depth. Other more advance methods, including acoustic survey techniques (e.g., low frequency echo sounding, seismic reflections, etc.) and side-scan sonar used with a sub-bottom profiler (Wright et al., 1987), can provide useful information on surficial as well as deeper sediment profiles. However, these techniques are often limited in their accuracy and have high equipment costs (Guignè et al., 1991).

Aerial reconnaissance, with or without satellite imagery, might assist in visually identifying depositional zones where clear water conditions exist. These methods are not reliable, however, if waters are turbid. Other methods that can be used to locate sediment deposition zones include grab sampling, inspection by divers, or photography using an underwater television camera or remotely operated vehicle (Burton, 1992; ASTM, 2000a).

2.6 Positioning Methods for Locating Sampling Stations

The most important function of positioning technology is to determine the location of the sampling station (e.g., latitude and longitude), so that the user can later re-sample to the same position (USEPA, 1987). Knowing the precise location of sampling stations is also important so that regulators can determine if the area(s) of interest have been sampled. There are a variety of navigation and/or position-fixing systems available, including optical or line-of-site techniques, electronic positioning systems, and satellite positioning systems. Global Positioning System (GPS) is generally regarded as the positioning technique of choice as it is accurate, readily available, and often less expensive than many other comparably sophisticated systems. Given the removal of selective availability of satellite data by the U.S. military, GPS is now capable of high accuracy positioning (1-10 m). The characteristics, advantages, and disadvantages of a variety of positioning systems are summarized in Appendix D.

Recommendation Box #3
How should station positioning be performed?

➡ Depending on level of accuracy needed, regular calibration of the positioning system by at least two methods might be required to ensure accuracy.

➡ For monitoring and assessment studies of large areas (e.g., large lakes or offshore marine environments), where an accuracy of ± 100 m typically is sufficient, either the Long Range Navigation (LORAN) or Global Positioning System (GPS) system is recommended.

➡ For near-shore areas, or areas where the sampling stations are numerous or located relatively close together, GPS or a microwave system should be used if the required position accuracy is less than 10 m. Where visible or suitable and permanent targets are available, RADAR can be used if the required position accuracy is between 10 and 100 m.

➡ For small water bodies and urban waterfronts, GPS is often capable of giving precise location information. Alternatively, visual angular measurements (e.g., sextant) by an experienced operator, a distance line, or taut wire could also provide accurate and precise positioning data.

Regardless of the type of system selected, calibration of the system is recommended by using at least two of these methods to ensure accuracy particularly for stations that will be reoccupied. At each sampling station, a fathometer or meter wheel can be used to determine the sampling depth. This will ensure that the water is the desired depth and the bottom is sufficiently horizontal for proper operation of sampling equipment. Ideally, it is best to print out a copy of the ship's location from the GPS monitor navigation chart, as well as the latitude / longitude, so the sampling station can be placed in a spatial context.

2.7 Preparations for Field Sampling

Proper preparation for any field sampling study is an essential part of Quality Assurance that ensures a successful project outcome and adherence to the objectives specified in the Quality Assurance Project Plan (QAPP). Chapter 7 further discusses related Quality Assurance/Quality Control procedures that should be used in sediment quality studies.

Prior to performing field work, characteristics of the site and accessibility of the individual sampling stations should be ascertained. Pictures of sampling stations both before as well as during sampling are often useful to ensure that the correct stations were sampled and to document weather and water conditions during sampling. Adequate reconnaissance of stations prior to sampling is also valuable for preparing against potential sampling hazards or unforeseen difficulties. Such a reconnaissance can also help determine the necessary time needed to perform the desired sampling (i.e., time to get from one station to the next).

Checklist
Logistical Considerations:

- ✓ site description
- ✓ study site accessibility
- ✓ adequate sampling platform
- ✓ qualified personnel
- ✓ specific responsibilities of field crew
- ✓ locating and maintaining stations
- ✓ adequate time for sampling
- ✓ adequate space and equipment
- ✓ communication system
- ✓ access to temporary field storage
- ✓ health, safety, and waste management
- ✓ emergency plans and equipment
- ✓ number of samples to be collected
- ✓ sample holding times

The appropriate vessel or sampling platform is one of the most important considerations in preparing for field sampling. The vessel must be appropriate for the water body type, and should provide sufficient space and facilities to allow collection, any on-board manipulation, and storage of samples. Ice chests or refrigeration might be required for sample storage, depending on the time course of the operation. The vessel should provide space for storage of decontamination materials, as well as clean sampling gear and containers to avoid contamination risks associated with normal vessel operations. Space for personal safety equipment is also required.

Additionally, the vessel should be equipped with sufficient winch power and cable strength to handle the weight of the sampling equipment, taking into account the additional suction pressure associated with extraction of the sediments. Large sampling devices typically weigh between 50 and 400 kg empty, and when filled with wet sediment might weigh from 125 to over 500 kg.

Care should be taken in operating the vessel to minimize disturbances of the sediment to be sampled as well as sampling equipment. This would include physical disturbance through propellar action and chemical contamination from engines or stack emissions. For example, Page et al. (1995) reported that they positioned the ships' stern into the wind to prevent stack gases from blowing onto sampling equipment during deployment, recovery, and subsampling of sediments in Prince William Sound, Alaska.

The sampling plan and projected time schedule should be posted for view by all personnel. The names, addresses, and telephone numbers of all participants involved with the preparation and execution of the sampling program should be available to all participants, and the duties and responsibilities of each participant clearly documented. The study supervisor should ensure that the appropriate personnel clearly understand their role and are capable of carrying out their assigned responsibilities and duties. Contingency planning should address the need for backup personnel in the event of accident or illness.

A variety of sampling and sample handling equipment and supplies are often needed in sediment monitoring studies. Besides the actual samplers themselves (e.g., grab or core device to be used), equipment is needed to remove and process the samples such as spatulas, scoops, pans or buckets, and gloves. If it is important to maintain anoxic conditions of the sample, a glovebox and inert gas source (e.g., nitrogen) is needed. Sample storage and transport equipment and supplies need to be available as well. These include refrigeration, ice chests, dry ice or ice, insulation material to stabilize samples in transport, custody seals, and shipping airbills.

The reagents for cleaning, operating or calibrating equipment, and/or for collecting, preserving or processing samples should be handled by appropriately qualified personnel and the appropriate data for health and safety (e.g., Material Safety Data Sheets) should be available. Written approved protocols and standard operating procedures (including QA/QC requirements) should be readily accessible at all times, to ensure proper and safe operation of equipment. Data forms and log books should be prepared in advance so that field notes and data can be quickly and efficiently recorded. Extra forms should be available in the event of a mishap or loss. These forms and books should be waterproof and tear resistant. Under certain circumstances audio or audio/video recordings might prove valuable.

All equipment used to collect and handle samples must be cleaned and all parts examined to ensure proper functioning before going into the field. A repair kit should accompany each major piece of equipment in case of equipment failure or loss of removable parts. Backup equipment and sampling gear should be available.

Checklist

Equipment and/or reagents needed:

- ✓ sampling equipment and spare parts
- ✓ sample handling equipment
- ✓ special sample handling equipment (e.g., glovebox or shielded compartment).
- ✓ decontamination and cleaning equipment
- ✓ field measurement equipment and supplies
- ✓ sample storage supplies/equipment
- ✓ sample transport supplies
- ✓ personnel supplies
- ✓ maps, navigation, and communication equipment

Storage, transport, and sample containers, including extra containers should be available in the event of loss or breakage (see Section 4.2 for more information on appropriate containers). These containers should be pre-cleaned and labeled appropriately (i.e., with a waterproof adhesive label to which the appropriate data can be added, using an indelible ink pen capable of writing on wet surfaces). The containers must have lids that are fastened securely, and if the samples are collected for legal purposes, they should be transported to and from the field in a locked container with custody seals secured on the lids. Samples to be frozen before analyses must not be filled to the lids. Leave a 10% headspace to accommodate expansion during freezing. Whether for legal purposes or not, all samples should be accompanied by a chain-of-custody form that documents field samples to be submitted for analyses (see Chapter 7). Transport supplies also include shipping airbills and addresses.

A sample-inventory log and a sample-tracking log should be prepared in advance of sampling. A single person should be responsible for these logs who will track the samples from the time they are collected until they are analyzed and disposed of or archived.

2.8 Health and Safety

Collection and processing of sediments for analyses and testing might involve substantial risks to personal safety and health; particularly in situations involving potentially hazardous materials or challenging sampling conditions. If a Quality Assurance Project Plan (QAPP) or a Sampling and Analysis Plan (SAP) is prepared prior to sampling, it should include or reference health and safety procedures. A health and safety field officer should be appointed to ensure that personnel use safety precautions and equipment applicable to the operation of the vessel, the sampling equipment, and sample handling. Personnel collecting or handling sediment samples should not work alone, and they should take all safety precautions necessary for the prevention of bodily injury and illness which might result from sampling activities (e.g., boat safety), ingestion or invasion of infectious agents, inhalation or absorption of corrosive or toxic substances through skin contact, or asphyxiation. Because sediment collection often occurs without complete knowledge of the source or degree of hazard, contact with sediment should to be minimized by: (1) using gloves, laboratory coats, safety glasses, face shields and respirators, as appropriate, and (2) manipulating sediments in open air, under a ventilated hood, or in an enclosed glove box. USEPA (1986a), Walters and Jameson (1984), and the Occupational Health and Safety Administration (OSHA) standards provide guidance on safe sediment handling. Program specific guidance should be consulted first when available (e.g., Washington Department of Ecology's Sampling and Analysis Plan Guidance [WDE, 1995] or Puget Sound Estuaries Program [PSEP, 1997a]). Other references (e.g., ASTM, 2000b; Waters, 1980) should also be consulted concerning special safety procedures for sampling and handling samples from hazardous waste sites. The NOAA Diving Manual (NOAA, 1991) or the EPA Diving Safety Manual (USEPA, 1997b) should be consulted for information regarding diving safety plans and protocols.

Recommendation Box #4
What health and safety precautions should be followed?

- ➡ Follow Coast Guard approved safety procedures, including use of life vests.
- ➡ All samples must be handled in a manner that satisfies the Quality Assurance Project Plan, Standard Operating Procedures, and DQOs.
- ➡ Skin contact with sediment should be minimized to avoid potential contact with hazardous substances. Protective clothing and equipment (e.g., gloves, boots, lab coats or aprons, safety glasses, and respirator) are recommended during sampling, sample handling, and preparation of test substances or sediments.
- ➡ Handling of samples should be performed in a well-ventilated area (e.g., outside, in a fume hood, or in an enclosed glove box) to minimize the inhalation of sediment gases such as hydrogen sulfide if present.
- ➡ A spill control protocol should be in place in the sampling vessel and laboratory.
- ➡ Disposal of all hazardous waste should be in accordance with applicable laws, guidelines, and regulations.
- ➡ Provide procedures regarding hazard assessment (chemical and physical hazards).
- ➡ Provide procedures regarding decontamination.
- ➡ Meet the training and medical monitoring requirements.
- ➡ Provide emergency planning and emergency contacts.