ROADMAP

Introduction to MARSSIM

The Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) provides detailed guidance for planning, implementing, and evaluating environmental and facility radiological surveys conducted to demonstrate compliance with a dose- or risk-based regulation. The MARSSIM guidance focuses on the demonstration of compliance during the final status survey following scoping, characterization, and any necessary remedial actions.

The process of planning the survey, implementing the survey plan, and assessing the survey results prior to making a decision is called the Data Life Cycle. MARSSIM Chapter 2 and Appendix D provide detailed guidance on developing appropriate survey designs using the Data Quality Objectives (DQO) Process to ensure that the survey results are of sufficient quality and quantity to support the final decision. The survey design process is described in MARSSIM Chapters 3, 4, and 5. Guidance on selecting appropriate measurement methods (*i.e.*, scan surveys, direct measurements, samples) and measurement systems (*i.e.*, detectors, instruments, analytical methods) is provided in MARSSIM Chapters 6 and 7 and Appendix H. Data Quality Assessment (DQA) is the process of assessing the survey results, determining that the quality of the data satisfies the objectives of the survey, and interpreting the survey results as they apply to the decision being made. The DQA process is described in MARSSIM Chapter 2 and Appendix E and is applied in MARSSIM Chapter 8. Quality Assurance and Quality Control (QA/QC) procedures are developed and recorded in survey planning documents, such as a Quality Assurance Project Plan (QAPP) which is described in MARSSIM Chapter 9.

MARSSIM does not provide guidance for translating the release criterion into derived concentration guideline levels (DCGLs). MARSSIM discusses contamination of surface soil and building surfaces in detail. If other media (*e.g.*, ground water, surface water, subsurface soil, equipment, vicinity properties) are potentially contaminated at the time of the final status survey, modifications to the MARSSIM survey design guidance and examples may be required.

The Goal of the Roadmap

The goal of the roadmap is to present a summary of the major steps in the design, implementation, and assessment of a final status survey and to identify where guidance on these steps is located in MARSSIM. A brief description of each step is included in the roadmap along with references to the sections of MARSSIM that provide more detailed guidance.

This roadmap provides the user with basic guidance from MARSSIM combined with "rules of thumb" (indicated by ☞) for performing compliance demonstration surveys. The roadmap is not designed to be a stand-alone document, but to be used as a quick reference to MARSSIM for

users already familiar with the process of planning and performing surveys. Roadmap users will also find flow charts summarizing the major steps in the Radiation Survey and Site Investigation Process, combined with references to sections in MARSSIM where detailed guidance may be found. In addition, the roadmap serves as an overview and example for applying MARSSIM guidance at sites with radioactive contamination of surface soil and building surfaces. The roadmap assumes a working knowledge of MARSSIM terminology. If such knowledge is lacking, the user may refer to Section 2.2 of MARSSIM for definitions of key terms. In addition, a complete set of definitions is provided in the Glossary.

Data Life Cycle

Compliance demonstration is simply a decision as to whether or not a survey unit meets the release criterion. For most sites, this decision is supported by statistical tests based on the results of one or more surveys. The initial assumption used in MARSSIM is that each survey unit is contaminated above the release criterion until proven otherwise. The surveys are designed to provide the information needed to reject this initial assumption. MARSSIM recommends using the Data Life Cycle as a framework for planning, implementing, and evaluating survey results prior to making a decision. Figure 1 summarizes the major activities associated with each phase of the Data Life Cycle.

Planning Stage

The survey design is developed and documented using the Data Quality Objectives (DQO) Process (Section 2.3.1, Appendix D). The DQOs for the project are established and preliminary surveys (*e.g.*, scoping, characterization) are performed to provide information necessary to design the final status survey for compliance demonstration. The DQOs for the project are re-evaluated for each of the preliminary surveys. The preliminary surveys may provide information for purposes other than compliance demonstration that are not discussed in MARSSIM. For example, a characterization survey may provide information to support evaluation of remedial alternatives. In addition, any of the preliminary surveys may be designed to demonstrate compliance with the release criterion as one of the survey objectives. These alternate survey designs are developed based on site-specific considerations (Section 2.6). The planning phase of the Data Life Cycle produces a final status survey design that is used for demonstrating compliance with the release criterion. This design is recorded in planning documents, such as a Quality Assurance Project Plan (QAPP) described in Section 9.2.

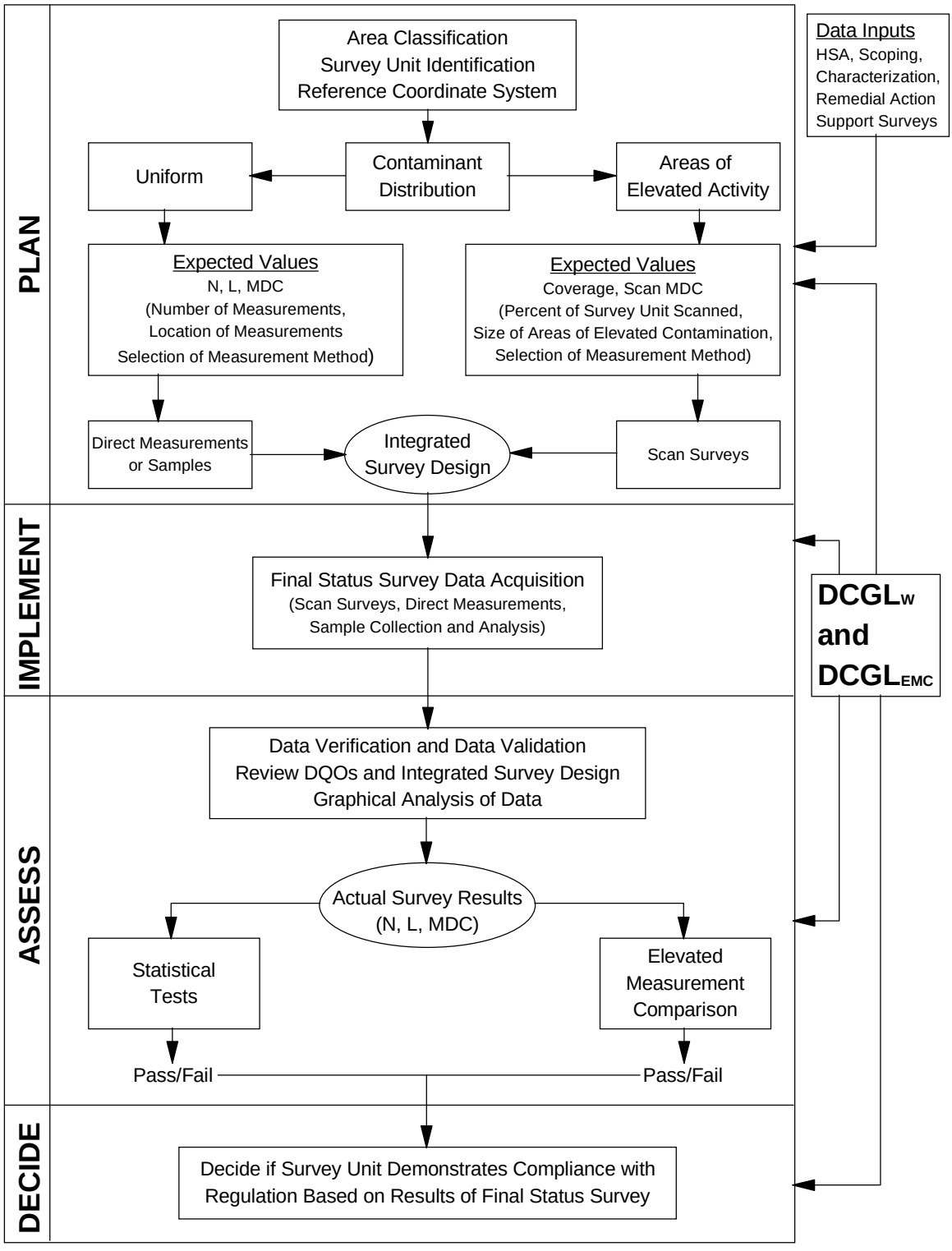

Figure 1 The Data Life Cycle Applied to a Final Status Survey

A minimum amount of information is needed from the preliminary surveys to develop an effective final status survey design. This includes

- Sufficient information to justify classification and specification of boundaries for survey units (the default is Class 1 which results in the highest level of survey effort)
- An estimate of the variability of the contaminant concentration in the survey unit (σ_s) and the reference area (σ_r) if necessary

After the preliminary surveys are completed, the final status survey design can be developed. Figure 2 presents the major steps in the development of a survey design that integrates scanning surveys with direct measurements and sampling. Most of the steps are easy to understand and references to appropriate sections of MARSSIM are included in the flowchart. Several of these steps are important enough to justify additional discussion in this guide. These steps are

- Classify Areas by Contamination Potential
- Group/Separate Areas into Survey Units
- Determine Number of Data Points
- Select Instrumentation
- Develop an Integrated Survey Design

Classify Areas by Contamination Potential (Section 4.4)

Classification is a critical step in survey design because it determines the level of survey effort based on the potential for contamination. Overestimating the potential for contamination results in an unnecessary increase in the level of survey effort. Underestimating the potential for contamination greatly increases the probability of failing to demonstrate compliance based on the survey results. There are two key decisions made when classifying areas: 1) is the average activity in the area likely to exceed the $DCGL_W$, and 2) is the contamination present in small areas of elevated activity or is the contamination distributed relatively homogeneously across the area. Each of these decisions is considered separately when designing the survey and then combined into an integrated survey design. Class 1 areas, prior to remediation, are impacted areas with concentrations of residual radioactivity that exceed the $DCGL_W$. Class 2 areas are impacted areas where concentrations of residual activity that exceed the $DCGL_W$ are not expected. Class 3 areas are impacted areas that have a low probability of containing areas with residual radioactivity. The information obtained from the preliminary surveys is crucial for classifying areas (see Figure 2.4).

☞ Area classification considers both the level of contamination relative to the $DCGL_W$ and the distribution of the contamination. The contamination may be uniformly distributed or present as small areas of elevated activity.

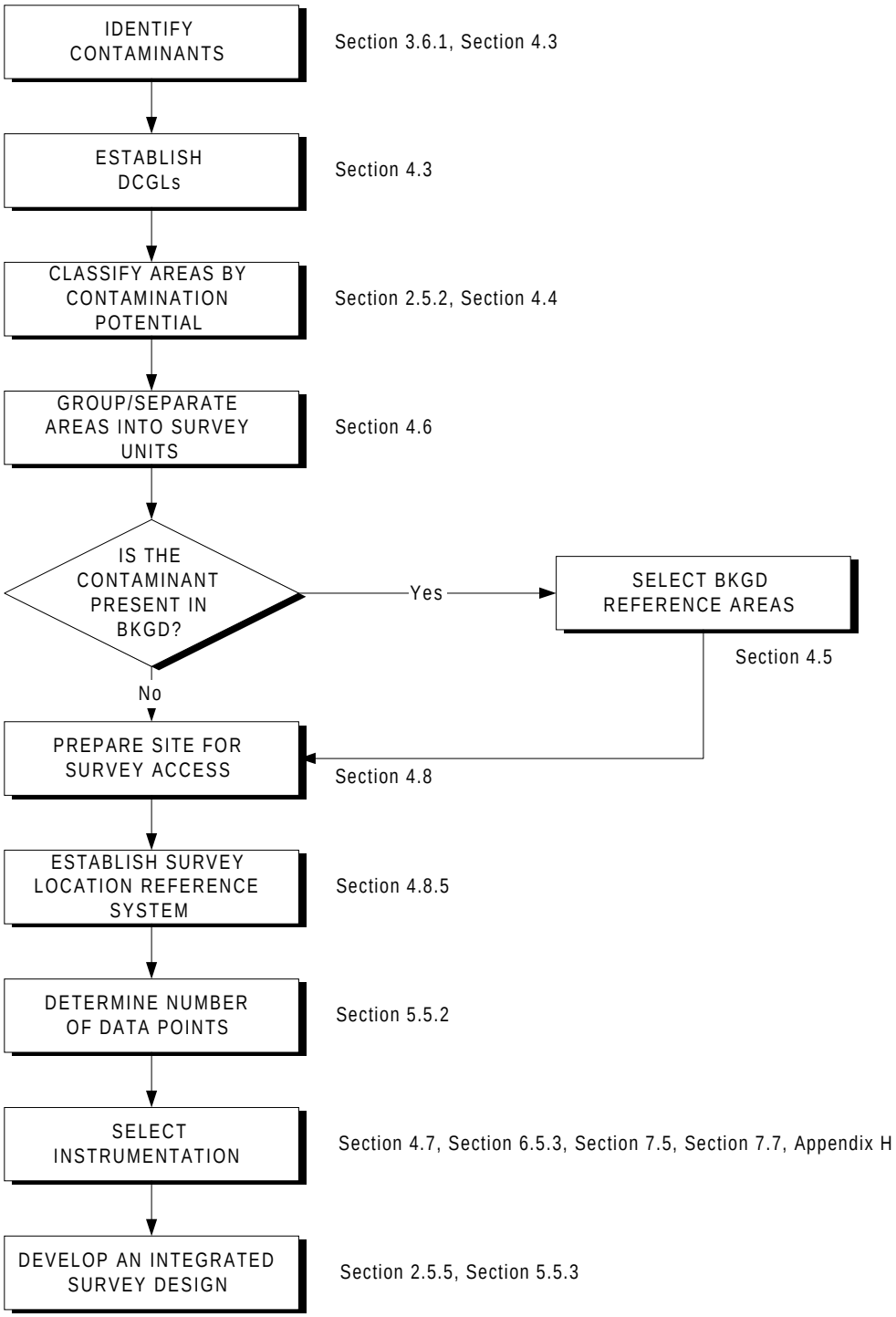

Figure 2 Flow Diagram for Designing a Final Status Survey

Group/Separate Areas into Survey Units (Section 4.6)

Survey units are limited in size based on classification, exposure pathway modeling assumptions, and site-specific conditions. Table 1 provides suggested survey unit areas based on area classification. The rationale for selecting a larger survey unit area should be developed using the DQO Process and fully documented.

Table 1 Suggested Survey Unit Areas

Classification	Suggested Area
Class 1	
Structures	up to 100 m^2
Land Areas	up to 2,000 m^2
Class 2	
Structures	100 to 1,000 m^2
Land Areas	2,000 to 10,000 m^2
Class 3	
Structures	no limit
Land Areas	no limit

☞ Survey unit areas should be consistent with exposure pathway modeling assumptions used to develop DCGLs.

Determine Number of Data Points (Section 5.5.2)

The number of data points is determined based on the selection of a statistical test, which in turn is based on whether or not the contaminant is present in background. Figure 3 presents a flow chart for determining the number of data points.

The first step in determining the number of data points is to specify the acceptable decision error rates, α and β. Decision error rates are site-specific and selected using the DQO Process. Changes in the values of α and β may result from successive iterations of the DQO Process.

☞ Values for α and β are site-specific and selected using the DQO Process.

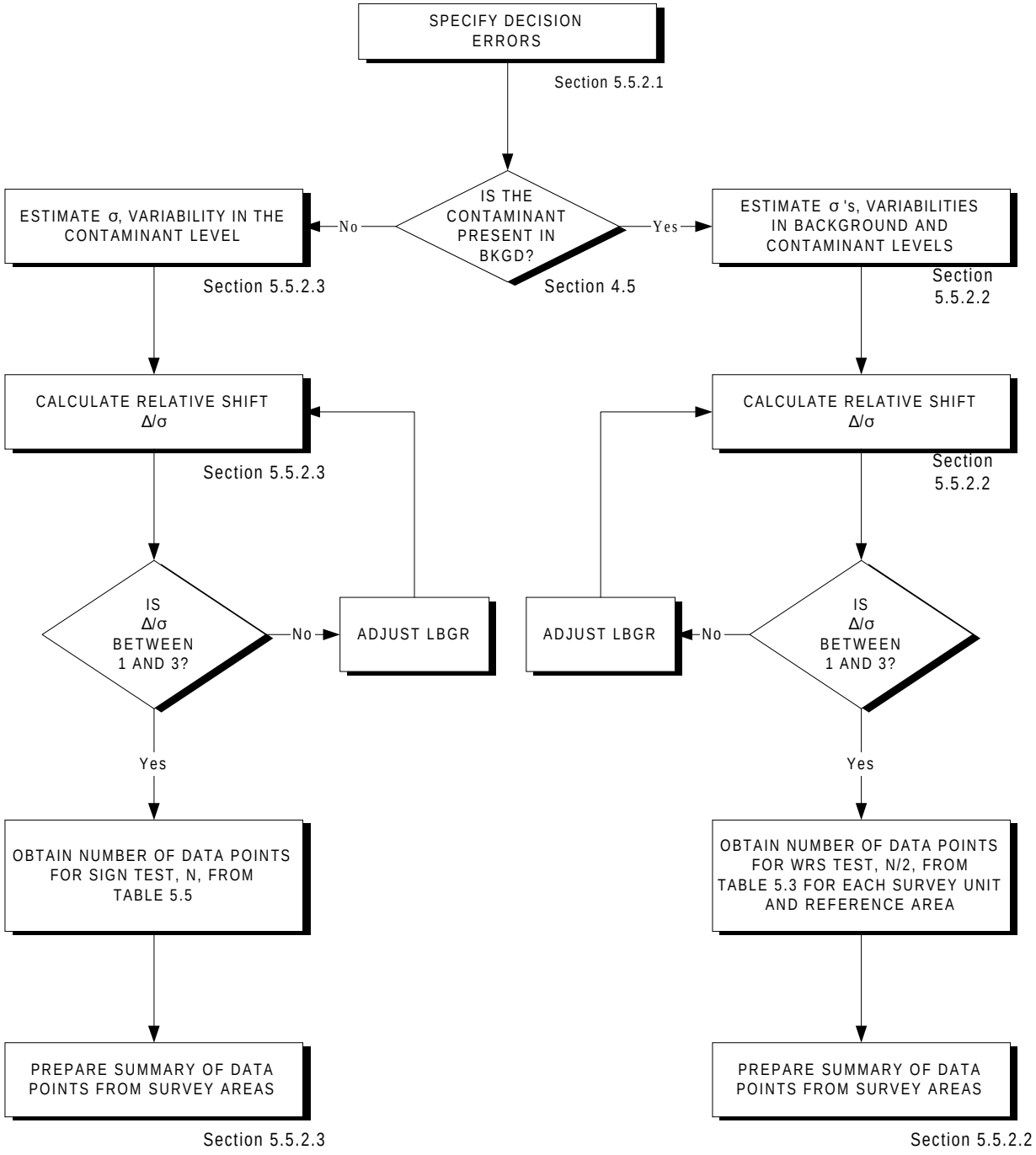

Figure 3 Flow Diagram for Determining the Number of Data Points

The next step, after determining whether or not the contaminant is present in background, is to estimate the variability of the contaminant concentration, σ. The standard deviation of the contaminant concentration determined from the preliminary survey results should provide an appropriate estimate of σ. If the contaminant is present in background, the variability in the survey unit (σ_s) and the variability in the reference area (σ_r) should both be estimated. The larger of the two values should be selected for determining the number of data points. Underestimating σ can underestimate the number of measurements needed to demonstrate compliance with the regulation, which increases the probability the survey unit will fail the statistical test. Overestimating σ can result in collecting more data than is necessary to demonstrate compliance.

☞	It is better to overestimate values of σ_s and σ_r.

☞	When σ_s and σ_r are different, select the larger of the two values.

The third step is to calculate the relative shift, Δ/σ. The variability of the contaminant concentration, σ, was determined in the previous step. The shift, Δ, is equal to the width of the gray region. The upper bound of the gray region is defined as the $DCGL_W$. The lower bound of the gray region (LBGR) is a site-specific parameter, adjusted to provide a value for Δ/σ between one and three. Δ/σ can be adjusted using the following steps:

- Initially select LBGR to equal one half the $DCGL_W$. This means $\Delta = (DCGL_W - LBGR)$ also equals one half the $DCGL_W$. Calculate Δ/σ.
- If Δ/σ is between one and three, obtain the appropriate number of data points from Table 5.3 or Table 5.5.
- If Δ/σ is less than one, select a lower value for LBGR. Continue to select lower values for LBGR until Δ/σ is greater than or equal to one, or until LBGR equals zero.
- If Δ/σ is greater than three, select a higher value for LBGR. Continue to select higher values for LBGR until Δ/σ is less than or equal to three.

Alternatively, Δ/σ can be adjusted by solving the following equation and calculating Δ/σ:

$$LBGR = DCGL_W - \sigma$$

If LBGR is less than zero, Δ/σ can be calculated as $DCGL_W/\sigma$.

☞	Adjust the LBGR to provide a value for Δ/σ between one and three.

The final step in determining the number of data points is to obtain the appropriate value from Table 5.3 or Table 5.5. Table 5.3 provides the number of data points for each survey unit and each reference area when the contaminant is present in background (N/2). Table 5.5 provides the number of data points for each survey unit when the contaminant is not present in background (N).

Select Instrumentation (Section 4.7, Section 6.5.3, Section 7.5, Section 7.7, Appendix H)

Instrumentation or measurement techniques should be selected based on detection sensitivity to provide technically defensible results that meet the objectives of the survey. Because of the uncertainty associated with interpreting scanning results, the detection sensitivity of the selected instruments should be as far below the DCGL as possible. For direct measurements and sample analyses, minimum detectable concentrations (MDCs) less than 10% of the DCGL are preferable while MDCs up to 50% of the DCGL are acceptable.

☞	Estimates of the MDC that minimize potential decision errors should be used for planning surveys.

Develop an Integrated Survey Design (Section 5.5.3)

The integrated survey design combines scanning surveys with direct measurements and sampling. The level of survey effort is determined by the potential for contamination as indicated by the survey unit classification. This is illustrated in Figure 4. Class 3 survey units receive judgmental scanning and randomly located measurements. Class 2 survey units receive scanning over a portion of the survey unit based on the potential for contamination combined with direct measurements and sampling performed on a systematic grid. Class 1 survey units receive scanning over 100% of the survey unit combined with direct measurements and sampling performed on a systematic grid. The grid spacing is adjusted to account for the scan MDC (Section 5.5.2.4).

Table 2 provides a summary of the recommended survey coverage for structures and land areas. Modifications to the example survey designs may be required to account for other contaminated media (*e.g.*, ground water, subsurface soil).

Implementation Phase

The objectives outlined in the QAPP are incorporated into Standard Operating Procedures (SOPs). The final status survey design is carried out in accordance with the SOPs and the QAPP resulting in the generation of raw data. Chapter 6, Chapter 7, and Appendix H provide information on measurement techniques.

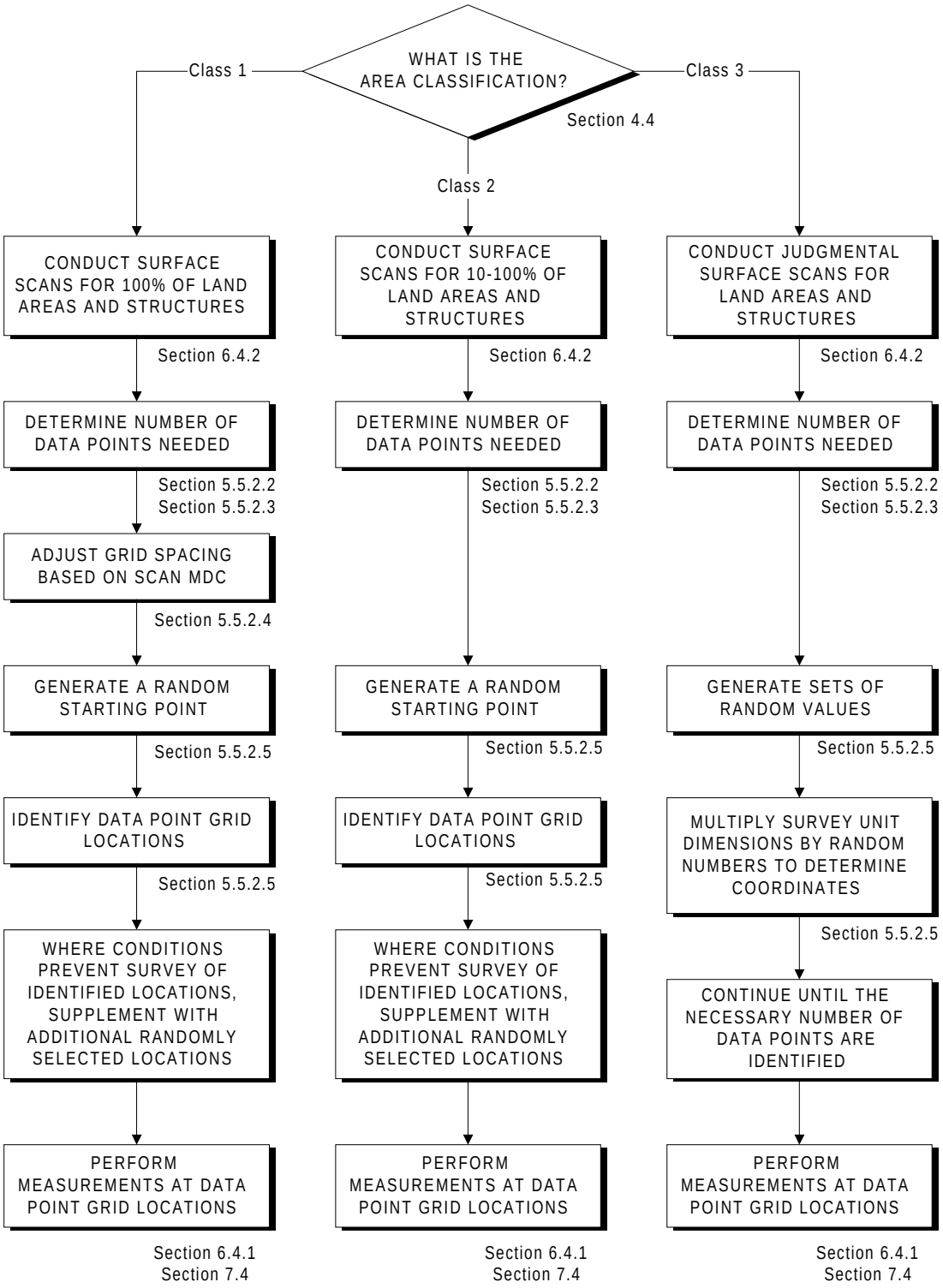

Figure 4 Flow Diagram for Developing an Integrated Survey Design

Table 2 Recommended Survey Coverage for Structures and Land Areas

Area Classification	Structures		Land Areas	
	Surface Scans	Surface Activity Measurements	Surface Scans	Surface Soil Measurements
Class 1	100%	Number of data points from statistical tests (Sections 5.5.2.2 and 5.5.2.3); additional direct measurements and samples may be necessary for small areas of elevated activity (Section 5.5.2.4)	100%	Number of data points from statistical tests (Sections 5.5.2.2 and 5.5.2.3); additional direct measurements and samples may be necessary for small areas of elevated activity (Section 5.5.2.4)
Class 2	10 to 100% (10 to 50% for upper walls and ceilings) Systematic and Judgmental	Number of data points from statistical tests (Sections 5.5.2.2 and 5.5.2.3)	10 to 100% Systematic and Judgmental	Number of data points from statistical tests (Sections 5.5.2.2 and 5.5.2.3)
Class 3	Judgmental	Number of data points from statistical tests (Sections 5.5.2.2 and 5.5.2.3)	Judgmental	Number of data points from statistical tests (Sections 5.5.2.2 and 5.5.2.3)

Assessment Phase

The assessment phase of the Data Life Cycle includes verification and validation of the survey results combined with an assessment of the quantity and quality of the data. As previously stated, both the average level of contamination in the survey unit and the distribution of the contamination within the survey unit are considered during area classification. For this reason, the assessment phase includes a graphical review of the data to provide a visual representation of the radionuclide distribution, an appropriate statistical test to demonstrate compliance for the average concentration of a uniformly distributed radionuclide, and the elevated measurement comparison (EMC) to demonstrate compliance for small areas of elevated activity.

The survey data are verified to ensure that SOPs specified in the survey design were followed and that the measurement systems were performed in accordance with the criteria specified in the QAPP (Section 9.3.1). The data are validated to ensure that the results support the objectives of the survey, as documented in the QAPP, or permit a determination that these objectives should

be modified (Section 9.3.2). The Data Quality Assessment (DQA) process is then applied using the verified and validated data to determine if the quality of the data satisfies the data user's needs. DQA is described in Appendix E and is applied in Chapter 8.

The first step in DQA is to review the DQOs and survey design to ensure that they are still applicable. For example, if the data suggest that a survey unit is misclassified, the DQOs and survey design would be modified for the new classification.

The next step is to conduct a preliminary data review to learn about the structure of the data and to identify patterns, relationships, or potential anomalies. This review should include calculating basic statistical quantities (*i.e.*, mean, standard deviation, median) and graphically presenting the data using at least a histogram and a posting plot. The results of the preliminary data review are also used to verify the assumptions of the tests. Some of the assumptions and possible methods for assessing them are summarized in Table 3. Information on diagnostic tests is provided in Section 8.2 and Appendix I.

Table 3 Methods for Checking the Assumptions of Statistical Tests

Assumption	Diagnostic
Spatial Independence	Posting Plot (Figure 8.1)
Symmetry	Histogram (Figure 8.2) Quantile Plot (Figure I.2)
Data Variance	Sample Standard Deviation (Section 8.2)
Power is Adequate	Retrospective Power Chart (Sign Test, Figure I.5) (WRS Test, Figure I.6)

The final step in interpreting the data is to draw conclusions from the data. Table 4 summarizes the statistical tests recommended in MARSSIM. Section 8.3 provides guidance on performing the Sign test when the contaminant is not present in background. Section 8.4 provides guidance on performing the Wilcoxon Rank Sum (WRS) test when the contaminant is present in background.

Table 4 Summary of Statistical Tests

Radionuclide not in background and radionuclide-specific measurements made:

Survey Result	Conclusion
All measurements less than $DCGL_W$	Survey unit meets release criterion
Average greater than $DCGL_W$	Survey unit does not meet release criterion
Any measurement greater than $DCGL_W$ and the average less than $DCGL_W$	Conduct Sign test and elevated measurement comparison

Radionuclide in background or radionuclide non-specific (gross) measurements made:

Survey Result	Conclusion
Difference between maximum survey unit measurement and minimum reference area measurements is less than $DCGL_W$	Survey unit meets release criterion
Difference of survey unit average and reference area average is greater than $DCGL_W$	Survey unit does not meet release criterion
Difference between any survey unit measurement and any reference area measurement greater than $DCGL_W$ and the difference of survey unit average and reference area average is less than $DCGL_W$	Conduct WRS test and elevated measurement comparison

Table 5 provides examples of final status survey investigation levels for each survey unit classification and type of measurement. For a Class 1 survey unit, measurements above the $DCGL_W$ are not necessarily unexpected. However, a measurement above the $DCGL_W$ at one of the discrete measurement locations might be considered unusual if it were much higher than all of the other discrete measurements. Thus, any discrete measurement that is above both the $DCGL_W$ and the statistical-based parameter for the measurements should be investigated further. Any measurement, either at a discrete location or from a scan, that is above the $DCGL_{EMC}$ should be flagged for further investigation.

In Class 2 or Class 3 areas, neither measurements above the $DCGL_W$ nor areas of elevated activity are expected. Any measurement at a discrete location exceeding the $DCGL_W$ in these areas should be flagged for further investigation. Because the survey design for Class 2 and Class 3 survey units is not driven by the EMC, the scanning MDC might exceed the $DCGL_W$. In this case, any indication of residual radioactivity during the scan would warrant further investigation.

Table 5 Summary of Investigation Levels

Survey Unit Classification	Flag Direct Measurement or Sample Result When:	Flag Scanning Measurement Result When:
Class 1	> $DCGL_{EMC}$ or > $DCGL_W$ and > a statistical-based parameter value	> $DCGL_{EMC}$
Class 2	> $DCGL_W$	> $DCGL_W$ or > MDC
Class 3	> fraction of $DCGL_W$	> $DCGL_W$ or > MDC

Because there is a low expectation for residual radioactivity in a Class 3 area, it may be prudent to investigate any measurement exceeding even a fraction of the $DCGL_W$. The level one chooses here depends on the site, the radionuclides of concern, and the measurement and scanning methods chosen. This level should be set using the DQO Process during the survey design phase of the Data Life Cycle. In some cases, the user may also decide to follow this procedure for Class 2 and even Class 1 survey units.

Both the measurements at discrete locations and the scans are subject to the EMC. The result of the EMC does not in itself lead to a conclusion as to whether the survey unit meets or exceeds the release criterion, but is a flag or trigger for further investigation. The investigation may involve taking further measurements in order to determine that the area and level of the elevated residual radioactivity are such that the resulting dose or risk meets the release criterion.[1] The investigation should also provide adequate assurance that there are no other undiscovered areas of elevated residual radioactivity in the survey unit that might result in a dose exceeding the release criterion. This could lead to a re-classification of all or part of a survey unit—that is, unless the results of the investigation indicate that reclassification is not necessary.

Decision Making Phase

A decision is made, in coordination with the responsible regulatory agency, based on the conclusions drawn from the assessment phase. The results of the EMC are used to demonstrate compliance with the dose- or risk-based regulation for small areas of elevated activity, while the nonparametric statistical tests are used to demonstrate that the average radionuclide concentration in the survey unit complies with the release criterion. The objective is to make technically defensible decisions with a specified level of confidence.

[1] Rather than, or in addition to, taking further measurements, the investigation may involve assessing the adequacy of the exposure pathway model used to obtain the DCGLs and area factors, and the consistency of the results obtained with the Historical Site Assessment and the scoping, characterization, and remedial action support surveys.

The EMC consists of comparing each measurement from the survey unit with the investigation levels in Table 5. The EMC is performed for measurements obtained from the systematic or random sample locations as well as locations flagged by scanning surveys. Any measurement from the survey unit that is equal to or greater than the investigation level indicates an area of relatively higher concentration and is investigated, regardless of the outcome of the nonparametric statistical tests.

☞ Any measurement from the survey unit that is equal to or greater than the investigation level indicates an area of relatively higher concentration and is investigated, regardless of the outcome of the nonparametric statistical tests.

The result of the Sign test or the WRS test is the decision to reject or not to reject the null hypothesis that the survey unit is contaminated above the $DCGL_W$. Provided that the results of any investigations triggered by the EMC have been resolved, a rejection of the null hypothesis leads to the decision that the survey unit meets the release criterion. If necessary, the amount of residual radioactivity in the survey unit can be estimated so that dose or risk calculations can be made. In most cases, the average concentration is the best estimate for the amount of residual radioactivity.

Summary

The roadmap presents a summary of the planning, implementation, assessment, and decision making phases for a final status survey and identifies where guidance on these phases is located in MARSSIM. Each step in the process is described briefly along with references to the sections of MARSSIM to which the user may refer for more detailed guidance. Flow charts are provided to summarize the major steps in the Radiation Survey and Site Investigation Process, again citing appropriate sections of MARSSIM. In addition to providing the user with basic guidance from MARSSIM, the roadmap also includes “rules of thumb” for performing compliance demonstration surveys.