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Southwest Division
Naval Facilities Engineering Command
Contracts Department
1220 Pacific Highway, Building 127, Room 112
San Diego, CA 92132-5190

CONTRACT NO. N68711-98-D-5713
CTO No. 0072

FINAL

WORK PLAN

Revision 0
July 9, 2004

BUILDING 819 DISPOSITION SURVEY

HUNTERS POINT SHIPYARD
SAN FRANCISCO, CALIFORNIA

DCN: FWSD-RAC-04-2284

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July 9, 2004
FWSD-RAC-04-2284
5.0

Naval Facilities Engineering Command
Southwest Division
Attn: Mr. Ralph Pearce
1220 Pacific Highway
San Diego, CA 92132-5190

SUBJECT: FINAL BUILDING 819 DISPOSITION SURVEY REVISION 0, HUNTERS POINT SHIPYARD, SAN FRANCISCO, CALIFORNIA.

Reference: Contract N68711-98-D-5713, Environmental Remedial Action Contract For Sites Southern California, Arizona, New Mexico, and Southern Nevada

Dear Mr. Pearce

Enclosed is the Final Building 819 Disposition Survey, Revision 0, dated July 9, 2004 for Hunters Point Shipyard, San Francisco, California. If you have any questions or require additional information, please contact me at (619) 471-3517.

Sincerely,

Charles Stanfield
Project Manager

Enclosures: Final Building 819 Disposition Survey

TETRA TECH FW, INC.

TRANSMITTAL/DELIVERABLE RECEIPT

Contract No. N68711-98-D-5713 (RAC III)

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TO: Contracting Officer
Naval Facilities Engineering Command
Southwest Division
Ms. Beatrice Appling, 02R1.BA
1220 Pacific Highway
San Diego, CA 92132-5190

DATE: 07/27/04
CTO: 0072
LOCATION: Hunters Point Shipyard

FROM: [signature]
Neil Hart, Program Manager

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TABLE OF CONTENTS

PAGE

TABLE OF CONTENTS
(Continued)

TABLE OF CONTENTS
(Continued)

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS AND ACRONYMS

µCi/mL	microcuries per milliliter
µR/hr	microroentgens per hour
α	alpha
β	beta
γ	gamma
ANSI	American National Standards Institute
cm	centimeter
cm^2	square centimeters
cm/s	centimeters per second
CFR	Code of Federal Regulations
Cs-137	Cesium-137
cpm	counts per minute
DAC	derived air concentration
dpm	disintegrations per minute
DCGL	derived concentration guideline level
DoD	Department of Defense
DON	Department of the Navy
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FSS	Final Status Survey
HPS	Hunters Point Shipyard
ISO	International Organization for Standardization
keV	kilo-electron volt
LBGR	lower boundary of the gray region
LLRW	low-level radioactive waste
m	meters
m^2	square meters
m/s	meters per second
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual

ABBREVIATIONS AND ACRONYMS
(Continued)

MDC	minimum detectable concentration
MDCR	minimum detectable count rate
MeV	mega-electron volt
mg/cm^2	milligrams square centimeters
N/A	not applicable
NaI	sodium iodide
NIST	National Institute of Standards and Technology
NRDL	Naval Radiological Defense Laboratory
NRC	Nuclear Regulatory Commission
NWT	New World Technology, Inc.
pCi/g	picocuries per gram
PRG	Preliminary Remediation Goal
Ra-226	Radium-226
RASO	Radiological Affairs Support Office
RCT	Radiological Control Technician
RSS	Radiological Safety Section
RWP	radiation work permit
SOP	Standard Operating Procedure
Triple A	Triple A Machine Shop, Inc.
TtFW	Tetra Tech FW, Inc.

1.0 INTRODUCTION

This Work Plan describes the activities and methods for the disposition survey to be performed at Building 819, at the former Hunters Point Shipyard (HPS) in San Francisco, California. The work is being performed under contract to Tetra Tech FW, Inc. (TtFW) on behalf of the Southwest Division Naval Facilities Engineering Command, with radiological support provided by the Naval Sea Systems Command Detachment, Radiological Affairs Support Office (RASO).

The purpose of this plan is to describe the radiological survey methodology required to demonstrate compliance with the release criteria based on *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) guidelines [Department of Defense (DoD) et al., 2000]. Planned activities will consist of conducting surveys at Building 819, a structure that could be impacted by prior radiological operations performed by the former Naval Radiological Defense Laboratory (NRDL) and HPS. The building is located in Parcel D and serves as the main sewage pumping station for the shipyard. The surveys results will be used to document the radiological status for compliance with the release criteria for materials and equipment (drain system piping and pumps) existing in the building, building wet well, and dry well. Removal of sanitary sewer pump station components is to be performed at Building 819 in portions of the wet well, as well as selected locations in adjacent rooms, followed by drain line extraction from multiple floor area locations. A MARSSIM final status survey for unrestricted release of the site following drain system component removal will be conducted under a separate follow-on survey plan.

Contaminated material designated for removal will be cleaned, sized, loaded into containers, and then prepared for disposal at an approved, licensed disposal facility. Such debris and material will be surveyed and then processed for disposal as either low-level radioactive waste (LLRW) or non-contaminated, free release scrap material.

TtFW, formerly Foster Wheeler Environmental Corporation, personnel will manage and perform the hands-on work while New World Technology, Inc. (NWT) personnel will perform the radiological control and oversight for all operations being conducted. All personnel assigned to perform work under this plan will successfully complete prerequisite training in radiation safety awareness. Job-specific radiation work permits (RWPs) will be used as a radiological control support tool to all work covered by this plan.

If contamination is found on building surfaces during performance of this Work Plan, it will be necessary to implement decontamination procedures. While minor contamination will be remediated per existing NWT Standard Operating Procedures (SOPs), the identification of significant concentrations of radioactive material will require remediation under a separate Work Plan.

Figure 1-1 presents a layout of Building 819.

2.0 SITE DESCRIPTION AND HISTORY

The HPS site lies entirely within the corporate boundaries of the City of San Francisco, California, near its southern boundary with San Mateo County. HPS is located on San Francisco Bay at the southeast corner of the city of San Francisco. The site encompasses 493 acres on land and 443 acres below water on the point of a high, rocky, 2-mile-long peninsula projecting southeastward into the bay.

The Department of the Navy (DON) purchased the HPS site from Bethlehem Steel in 1941. After a significant buildup during World War II, the shipyard diversified as a major fleet support center performing ship repair throughout the Korean Conflict. The shipyard operated as a general repair facility specializing in submarines, aircraft carrier overhaul and ship repair operations through the early 1970s. The workload consisted primarily of the repair and conversion of conventionally powered ships, repair of diesel submarines, and non-radiological work on nuclear-powered ships. The shipyard conducted repair and maintenance on radium bearing gauges and dials, and performed radiography using radioactive materials.

In 1946, the Radiological Safety Section (RSS) was established at the shipyard. The RSS was eventually renamed the NRDL and functioned as a separate command from 1950 to 1969. Originally established for the decontamination and disposition of ships involved in nuclear weapons tests in the Pacific, the mission was expanded to include the study of nuclear weapons effects.

The DON closed HPS in 1974 and most of the site was then leased to a commercial ship repair company, Triple A Machine Shop, Inc. (Triple A) from 1976 to 1986. Triple A dedicated more than 80 percent of the shipyard to the repair of commercial and naval vessels and subleased unused facilities to private warehousing, industrial, and commercial firms. Some of these same businesses are still operating at HPS, now under direct leases with the DON.

Prior to 1974, there was a high potential for release of quantities of licensed radioactive material and radium to the sanitary sewage system from shipyard and/or NRDL operations. Contamination was identified in the sanitary sewer lines on Cochrane Street during the Phase V Radiological Investigations. Additional surveys of other sewer and drain lines are pending.

In 1986, control of the shipyard was again assumed by the DON and annexed to Naval Station Treasure Island for the docking and repair of several DON surface ships. The DoD ultimately closed the shipyard as part of the Base Closure and Realignment Act of 1991. Currently, the Southwest Division Naval Facilities Engineering Command manages the HPS property in conjunction with the San Francisco Redevelopment Advisory Board.

Many HPS buildings and structures are now leased to private tenants and DON-related entities, primarily for maritime and non-maritime industrial and artistic purposes. Property use currently supports a diverse range of functions as evidenced by the presence of storage units, art studios, machine workshops, woodworking shops, auto restoration garages, recreational vehicle parking, and sites used for the filming of movies.

Building 819 is a sewage lift station that contains dry and wet wells both approximately 20 feet deep. Located at HPS, Building 819 is constructed of reinforced concrete walls, with flat concrete roofs, no windows, and a single access door. The DON may plan to install a redesigned sewage pumping system in the wet well of Building 819. Radioactive material may be present in the wet wells that contain the sewage prior to being pumped off base and the internals of piping, pumps, and related components, as a result of past activities at HPS. Therefore, a radiological survey that will sufficiently characterize the radiological status of the portions of Building 819 and its components will be conducted. This protocol will also allow for the characterization and/or removal of any radioactive sources and/or material that would interfere with work to be performed in the pumping station. These activities involve access inside multiple portions of the structure.

3.0 ENVIRONMENTAL CONSIDERATIONS

Natural resources at the site will not be used or affected as a result of this project. At this time, project activities are not anticipated to create traffic impacts. Noise generation from site activities will not require the use of hearing protection in the immediate area. Dust generation during survey and disassembly activities will be minimal and will not require sampling actions. Airborne discharges involving radioactive materials are not likely to occur during planned activities; however, air sampling will be performed to provide verification that airborne radioactive discharges did not occur. Water samples will be obtained from the wet well, analyzed and discharged to the existing bypass system following verification that the water meets radioactive discharge limits identified in Section 4.2. If the water samples do not meet the discharge limits, it will be pumped to a storage tank for subsequent treatment and or disposal as radioactive waste.

4.0 PLANNING PHASE OF RADIOLOGICAL SURVEYS

4.1 RADIONUCLIDES OF CONCERN

HPS site records indicate a potential presence of radioactive materials within the sanitary sewer system. Historical research confirmed that radiological activities occurred throughout the shipyard. Two radionuclides of concern have been identified for measurement purposes. Table 4-1 lists those radionuclides of concern. The principle types of radiation (alpha, beta, and gamma) and associated half-lives are also identified for measurement applications.

TABLE 4-1

RADIONUCLIDES OF CONCERN

Radioisotope	Half-life	Radiations
Radium (Ra)-226	1,600 years	Alpha/gamma (α,γ)
Cesium (Cs)-137	30 years	Beta/gamma (β^-,γ)

Notes:

Types of radiation: α - alpha, γ - gamma, β^- - beta

4.2 RELEASE CRITERIA

Building 819 will be considered acceptable for release for a Final Status Survey (FSS) if residual radioactivity meets the release criteria. The criteria were obtained from Nuclear Regulatory Commission (NRC) Regulatory Guide 1.86 (1974). The release limits for structures and surfaces are listed Table 4-2. The release limits for water and solid samples are listed in Table 4-3.

TABLE 4-2

RELEASE LIMITS FOR RADIONUCLIDES OF CONCERN

Radionuclide	Radiation	Limit (Fixed) (dpm per 100 cm^2)	Limit (Removable) (dpm per 100 cm^2)
Radium (Ra)-226	Alpha (α)	100	20
Cesium (Cs)-137	Beta/gamma (β^-,γ)	5,000	1,000

Notes:

Types of radiation: α - alpha, γ - gamma, β^- - beta
cm^2 – square centimeters
dpm – disintegrations per minute

TABLE 4-3

RELEASE LIMITS FOR SAMPLES

Radionuclide	Industrial Reuse – Soil[a] (pCi/g)
Radium (Ra)-226	1 > background, not to exceed 2
Cesium (Cs)-137	0.13[b]

Notes:

[a] EPA PRGs for soil for outdoor worker (EPA, 2002)

[b] Decay-corrected PRG for industrial reuse provided by EPA Region 9.

EPA – U.S. Environmental Protection Agency

pCi/g – picocuries per gram

PRG – Preliminary Remediation Goal

4.3 SURVEY GRIDS

A reference coordinate system will be laid out for each survey unit. A square grid system will be used. The length, L, of a side of the square grid is determined by the total number of samples or measurements to be taken. The length of the square will determine the distance between survey data points. The length or spacing of the grids will be calculated for each of the survey units using the following equation:

Equation 1

$$L = \sqrt{\frac{A}{N}}$$

Where:

L = length of squares grids [meters (m)]

A = surface area of the survey unit [square meters (m^2)]

N = statistically calculated number of samples

4.4 DATA QUALITY OBJECTIVES

The data quality objective (DQO) process is a series of planning steps for establishing criteria for data quality and survey design development. The level of planning is based on the complexity of the areas to be surveyed.

4.4.1 State the Problem

It must be determined if the site-specific release guideline has been met or if remediation is warranted. Therefore, the decision to be made can be stated: "Do the results of the survey meet the alpha release limit of 100 disintegrations per minute (dpm) per 100 square centimeters (cm^2) for Radium-226 (Ra-226)? Do they meet the beta/gamma release limit of 1,000 dpm per 100 cm^2 for Cesium-137 (Cs-137)?"

It is anticipated that successful completion of activities described in this Work Plan will provide sufficient data for the recommendation of Building 819 for a FSS. Resources available to provide the necessary data include the following:

- Activities outlined in this Work Plan
- MARSSIM guidance (DoD et al., 2000) for ensuring statistically valid data

4.4.2 Identify the Decision

The need to provide data for the release of Building 819 for a FSS requires performing radiological surveys as specified in this Work Plan.

The primary use of the data expected to result from completion of this Work Plan is to provide information and verification of data obtained to support the recommendation of Building 819 for a FSS.

4.4.3 Inputs to the Decision

Radiological surveys required to support the release for FSS of Building 819 will include:

- One hundred percent gamma scan surveys of each of the survey units and sanitary sewer pump station components with 2-inch by 2-inch sodium iodide (NaI) detectors or equivalent. Results within 3 sigma of background levels are considered acceptable.
- One hundred percent alpha/beta scan surveys of each of the survey units and sanitary sewer pump station components with gas flow proportional detectors or equivalent. Results within the release criteria for fixed contamination are considered acceptable.
- Systematic static alpha, beta, and gamma static readings in each survey grid. Results within the release criteria for fixed contamination are considered acceptable.
- Systematic swipe sampling of each of the survey units. Results within the release criteria for loose surface contamination are considered acceptable.
- Systematic exposure rate measurements within each survey unit. Results within 3 sigma of background levels are considered acceptable.

4.4.4 Definition of Study Boundaries

The spatial boundaries for this disposition survey effort are shown in Figure 1-1. Each survey unit will be 100 percent alpha, beta, and gamma scan surveyed. Static alpha, beta, and gamma readings, swipe samples, and exposure rate measurements will be collected from the identified systematic locations in each of the survey units.

4.4.5 Development of a Decision Rule

4.4.5.1 Release Limits

The release limits for this survey are listed in Table 4-2.

4.4.5.2 Alternative Actions

Readings greater than the release limits will be further investigated by solid sampling to identify the extent of the contamination and radionuclides present.

4.4.6 Limits on Decision Errors

Actions to minimize errors will be instituted during the data collection phase of the radiological survey. American National Standards Institute (ANSI)-qualified radiation survey personnel will perform the survey and record the data. Automated recording of survey data will be used where possible to minimize errors. Data transcribing is the second phase where errors may arise. To avoid data errors for manual surveys, experienced personnel will record and transcribe data.

The ongoing on-site analyses and evaluation of survey results provide a final check for errors, which if detected, can be corrected.

There are two types of decision errors that can be made when performing the statistical tests described in this plan. The first type of decision error, called a Type I error, occurs when the null hypothesis is rejected when it is actually true. A Type I error is sometimes called a "false positive." The probability of a Type I error is usually denoted by α. The Type I error rate is often referred to as the significance level or size of the test.

The second type of decision error, called a Type II error, occurs when the null hypothesis is not rejected when it is actually false. A Type II error is sometimes called a "false negative." The probability of a Type II error is usually denoted by β . The *power* of a statistical test is defined as the probability of rejecting the null hypotheses when it is false. It is numerically equal to $1-\beta$, where β is the Type II error rate.

This survey is designed to limit Type I and Type II errors to 5 percent. It is important to minimize the chances that area grids exceeding the release limits will be missed (Type I Error) and area grids meeting the release limits will be rejected as too high (Type II Error). The probability of either of these occurring will be set at a maximum of 5 percent.

In demonstrating that this objective is met, the null hypothesis (H_o) is tested that residual contamination exceeds the release criterion; the alternative hypothesis (H_a) is then tested that residual contamination meets the release criterion.

4.4.7 Optimizing Data Collection

4.4.7.1 Review Outputs and Existing Data for Consistency

Radioactive source readings will be used to check instruments for consistency prior to use in each daily shift. The instrument will only be used after readings are compared and agree within +/- 20 percent of predetermined responses. The on-site Project Supervisor will review the information each day to verify that equipment is operating satisfactorily.

A knowledgeable individual who is not involved in the direct data collection process (Health Physics Supervisor) will review the survey data on a daily basis. This will ensure an ongoing independent review for consistency of all survey data collected.

4.4.7.2 Develop Data Collection Design Alternatives

The MARSSIM guidelines (DoD et al., 2000) will be used and a 95 percent confidence level for detecting radioactivity above the release levels will be assumed with Type I and Type II errors limited to 5 percent.

4.4.7.3 Data Collection Design Alternatives

The data collection design alternatives may change slightly if assumptions are revised based on conditions in the field being different than the furnished information derived from historical research and current knowledge of the building.

4.4.7.4 Select Most Resource-Effective Survey Design

As indicated above, the survey design specified for use in this Work Plan was developed and has been successfully used to perform radiological disposition surveys. Combined with the use of qualified and experienced personnel, this design is considered as both efficient and resource effective.

4.4.7.5 Document Operational Details and Theoretical Assumptions

Operational details for the radiological survey process have been developed for and are included as part of this Work Plan. The theoretical assumptions are based on guidelines contained in MARSSIM (DoD et al., 2000). Specific assumptions regarding types of radiation measurements, instrument detection capabilities, quantities and locations of data to be collected, and investigation levels are contained in this Work Plan.

5.0 DISPOSITION SURVEYS

The MARSSIM (DoD et al., 2000), the *Nonparametric Statistical Methodology for the Design and Analysis of the Final Status Decommissioning Survey Guide* (NUREG-1505; NRC, 1998), and the *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions Guide* (NUREG-1507; NRC, 1997) were used as guidance in designing and conducting the disposition surveys.

5.1 OBJECTIVE OF THE DISPOSITION SURVEY

MARSSIM (DoD et al., 2000), NUREG-1505 (NRC, 1998), and NUREG-1507 (NRC, 1997) were used as guidance documents in the design and conduct of this Work Plan. The objective of the disposition survey is to demonstrate that identified residual radioactivity levels meet the release criterion. In demonstrating that this objective is met, the null hypothesis (H_o) is tested that residual contamination exceeds the release criterion; the alternative hypothesis (H_a) is then tested that residual contamination meets the release criterion.

5.2 ANCILLARY EQUIPMENT AND MATERIALS

At a minimum, the following steps will be used in conducting all radiological surveys associated with the sanitary sewer pump station components and drain piping. NWT SOPs will be used in conjunction with this Work Plan. All surveys will be performed by an ANSI-qualified Radiological Control Technician (RCT).

1. Perform routine instrument operational checks by visually inspecting the equipment for damage, confirmation of current calibration by inspecting the attached calibration sticker, battery check, and response check.
2. The average background will be determined by performing at least 16 measurements at random locations within the designated background reference area. The detector probe should be held approximately 4 inches from the surface area for gamma and 0.25 inches from the surface area for alpha/beta radiation. The detector should be allowed to stabilize for at least 30 seconds before a background count is taken. The average of all of the counts taken will be the background. Background scan ranges will also be collected for reference data.
3. The 3-sigma value, lower limit of detection and minimum detectable concentration (MDC) will be calculated using the results of the average background and recorded on the appropriate NWT form.
4. All daily instrument check and background measurements shall be documented on the appropriate forms referenced in the NWT SOPs. ***(Note:*** All NWT forms will be kept on file in the field office. Copies will be submitted to others when required.)
5. The entire surface area of the equipment or material shall be surveyed with the instrument used to perform the background measurements. Technicians should move

slowly (less than 1 detector width per second) over the surface area, keeping the detector probe approximately 4 inches from the surface area for gamma and 0.25 inches from the surface area for alpha/beta radiation.

6. Swipes will be taken to ensure that there is no removable contamination present. Should the levels exceed those listed in Table 4-2, the sanitary sewer pump station components will be packaged as LLRW or decontaminated using existing NWT procedures.

7. Airborne activity monitoring and engineering controls (if necessary) will be used while sanitary sewer system components are being dismantled. In order to control occupational exposures, establish personal protective equipment, and determine respiratory protection requirements, monitoring and trending for airborne radioactive material will be performed as necessary by the assigned RCT. Engineering controls will be implemented if required to maintain airborne concentrations well below 10 percent of the applicable derived air concentration (DAC) value for the radionuclides of concern (Table 5-1). Engineering controls, if necessary, will be accomplished using a variety of alternatives, such as, but not limited to:

    - High-efficiency particulate air filtered vacuum/ventilation units
    - Misting dusty areas using spray bottles with water
    - Cleaning dusty areas using damp rags
    - Sealing openings to contaminated surfaces with tape, plastic coverings and/or similar materials

    Note: If, during the course of work, a DAC value exceeds 10 percent of the allowed limit, all ongoing activities will cease and the affected location will be posted and placed in a secure and stable condition until the source of the airborne concentration is eliminated and levels are confirmed to be below 10 percent of the DAC.

TABLE 5-1

DERIVED AIR CONCENTRATION

Radionuclide	Radiation	DAC (μCi/mL)	10% DAC (μCi/mL)
Radium (Ra)-226	Alpha (α)	3.0 E-10	3.0 E-11
Cesium (Cs)-137	Beta/gamma (β^-, γ)	6.0 E-8	6.0 E-9

Notes:

Types of radiation: α - alpha, γ - gamma, β^- - beta
μCi/mL – microcuries per milliliter
DAC – derived air concentration

The above guideline values were determined using Title 10 Code of Federal Regulations (CFR), Part 20, Appendix B.

5.2.1 Sanitary Sewer Pump Station Components

To facilitate the disposition surveys inside Building 819, it will be necessary to remove all the sanitary sewer pump station components from the building. All sanitary sewer pump station components located inside of Building 819 have the potential to be impacted radiologically. To ensure that radioactively contaminated material is not inadvertently removed from the building, items will have to be surveyed for release. Dismantling, removal, cleaning, and downsizing of the sewage pumping system will be accomplished with equipment typically used for demolition (wrenches, chop saws, saw-z-alls, and so forth). Upon removal and prior to waste container placement, components will be downsized as needed. Downsizing will be accomplished with traditional tools used for cutting (band saws, chop saws, saw-z-alls, cutting torches, and so forth). Water spray will be applied to keep dust to a minimum. Extracted piping will be sized and prepared for packaging in accordance with specified shipping and disposal container limitations.

In addition to the requirements in Section 5.2, materials determined to meet release standards will be removed from the building and staged in a non-impacted building following survey. All materials removed from Building 819 will be held until RASO has reviewed and verified that the survey results meet the release criteria.

5.2.2 Drain System

There are two pumps, two sump pumps, three pumping suction legs and discharge piping currently inside Building 819. The drainage systems for these items may potentially be impacted from radiological activities associated with HPS. Components will be removed and surveyed. If contamination is detected above established background levels, RASO will provide guidance on the disposition and/or remediation of the drain system components. Piping and components that are not removed from the building will be surveyed in place. If contamination is found, the equipment will be removed and packaged as low-level radioactive waste.

5.3 SURVEY UNITS

Once the sanitary sewer pump station components have been removed, Building 819 will then be divided into four distinct survey units in an effort to ensure all structure surfaces have been surveyed. Table 5-2 presents a summary of the survey units.

Figure 1-1 represents a drawing detailing the layout of the Building 819.

Building 819 will be divided into a total of four survey units of different sizes to facilitate the grid process. The concentrations of radioactive material in each of the survey units are not expected to vary significantly from one survey unit to the other. The survey and sampling frequency coverage in each survey unit is based on Equation 1 (Section 4.3).

5.3.1 Survey Unit 1

Survey Unit 1 will encompass the entire floor area and lower walls (up to 2 meters) of the wet well and will undergo a 100 percent scan survey. Twenty-four discrete static reading surveillance points will be spaced 2 meters apart, originating from a random start point. Figure 5-1 identifies the approximate survey unit layout and surveillance points.

There are three suction legs to the sewer pumping station located in the wet well. These three pipes will be surveyed for alpha, beta, and gamma radiation. Samples will also be collected from within the pipes. If no contamination is found, the pipes will be plugged with pneumatic pipe plugs. If contamination is found, the pipes will be removed from the wet well and packaged as LLRW.

5.3.2 Survey Unit 2

Survey Unit 2 will be comprised of the entire floor area and lower walls (up to 2 meters) of the dry well and will undergo a 100 percent scan survey. Twenty discrete static reading surveillance points will be spaced 2 meters apart, originating from a random start point. Figure 5-2 identifies the approximate survey unit layout and surveillance points.

5.3.3 Survey Unit 3

Survey Unit 3 will be comprised of the bypass culvert and will undergo a 100 percent scan survey. Twenty-three discrete static reading surveillance points will be spaced 1.5 meters apart, originating from a random start point. Figure 5-3 identifies the approximate survey unit layout and surveillance points.

5.3.4 Survey Unit 4

Survey Unit 4 will be comprised of the inlet culvert and will undergo a 100 percent scan survey. Twenty-six discrete static reading surveillance points will be systematically spaced 2 meters apart, originating from a random start point. Figure 5-4 identifies the approximate survey unit layout and surveillance points.

6.0 IMPLEMENTATION PHASE OF SURVEYS

6.1 SURVEY INSTRUMENTS

Instruments will be selected that are suitable for the physical and environmental conditions at the site. The instruments and measurement methods selected will be able to detect the radionuclide of concern or radiation types of interest, and are, in relation to the survey or analytical technique, capable of measuring levels that are equal to or less than the release limits. Table 6-1 identifies the instrumentation resources available to support of the survey objectives. Each instrument is explained in further detail in the following sections.

6.1.1 Instruments for the Scan Surveys for Alpha and Beta Surface Activity

Surface scan surveys for alpha and beta radiation will be conducted with Ludlum Model 43-68 and Model 43-37 alpha-beta gas proportional probes or equivalent and Ludlum Model 2360 alpha/beta rate meter/scaler or equivalent. The probes will have 0.8 milligrams per square centimeters (mg/cm^2) or 0.4 mg/cm^2-thick Mylar windows. The detector will be moved over the surface being surveyed at a rate of 1 inch per second. The detector will be held within ¼ inch of the surface being surveyed. Audible indicators will be used during the surveys

6.1.2 Instruments for the Direct Measurements for Alpha and Beta Surface Activity

Direct surface contamination surveys for alpha and beta radiation will be conducted with Ludlum Model 43-68 alpha-beta gas proportional probe or equivalent and Ludlum Model 2360 alpha/beta rate meters/scalers or equivalent. The probe will have 0.8 mg/cm^2 or 0.4 mg/cm^2-thick Mylar windows. Direct measurements will be conducted with the detector approximately ¼ inch above the surface for a period of 2 minutes.

6.1.3 Instrument for Gamma Surveys

Surveys for gamma (photon) radiation will be performed using a Ludlum Model 2350-1 data logger, equipped with a command device and a Ludlum Model 44-10 scintillation detector, which uses a 2-inch by 2-inch NaI crystal. Capable of detecting gamma photon energies ranging from 60 kilo-electron volts (keV) to 3 mega-electron volts (MeV), the instrument is programmed to respond to the full spectrum of gamma photon energies. Static photon measurements require positioning the detector assembly approximately 4 inches [10 centimeters (cm)] above the designated surveillance surface and completing a stationary 60-second survey. Scan measurements are obtained by traversing a path at a maximum speed (scan rate) of approximately 0.5 meters per second (m/s) and slowly moving the detector assembly in a serpentine (S-shaped) pattern, while maintaining the detector 2.5 to 4 inches (6 to 10 cm) above the area being surveyed. NaI scintillation detectors are very sensitive to gamma radiation and are ideal for locating elevated radiation levels above background.

6.1.4 Gross Beta-Gamma-Alpha Loose Surface Contamination Surveys

Loose surface contamination surveys of alpha and beta/gamma emitters will be performed using cloth smears. The swipe survey will be performed by wiping over an area of 100 cm^2 (approximately 4 inches by 4 inches) with a cloth smear, and applying moderate pressure. Samples will be processed using a Protean IPC 9025 counter. The Protean IPC 9025 is a gas flow proportional alpha/beta radiation counter, which features a low-background counting chamber. A microprocessor allows for data processing, and the unit provides a full range of simultaneous alpha and beta analysis at levels required for environmental release surveillance. Data is reported in units of dpm per 100 cm^2.

6.1.5 Instrument for Exposure Rate Surveys

Exposure rate surveys, obtained approximately 1 meter from contact with area surfaces, are conducted with use of a Ludlum Model 19 MicroR meter. Compatible with anticipated exposure rates, the instrument is equipped with an internally mounted 1-inch by 1-inch NaI scintillation detector that is integral to the meter housing. The MicroR meter provides optimum performance in measuring low-level gamma photon radiation readings, which are readily provided on the meter face in units of microroentgens per hour (µR/hr). Readings will be obtained after allowing the instrument to stabilize for approximately 1 minute.

6.2 BACKGROUND REFERENCE AREA RADIATION LEVELS

Background radiation levels for the building will be determined by obtaining sixteen 2-minute static gamma readings, taken at approximately 4 inches above the ground with a 2-inch by 2-inch NaI gamma scintillation detector system (Ludlum Model 2350-1 data logger, coupled to a Ludlum Model 44-10 NaI detector). A minimum of sixteen static 2-minute alpha/beta readings will be collected maintaining the detector approximately 0.25 inches (6 millimeters) above the area surveyed. Sixteen exposure rate measurements will be collected from waist level (approximately 1 meter) above the surface area being surveyed. Background radiation readings will be collected from a non-impacted building of similar construction. The mean value for these readings will be used as the building background radiation levels. Reference area readings will be collected using the same serial numbered instruments that will be used to collect survey unit readings.

6.3 DETERMINATION OF INSTRUMENT EFFICIENCY (E_I) FOR ALPHA AND BETA SURFACE ACTIVITY MEASUREMENTS

The instrument efficiency (ϵ_I) is determined during calibration and is defined as the ratio between the net count rate [in counts per minute (cpm)] of the instrument and the surface emission rate of the calibration source for a specified geometry. The surface emission rate is the 2π particle fluence that is affected by both the attenuation and backscatter of the radiation emitted from the calibration source.

Equation 2 will be used to calculate the instrument efficiency in counts per particle, although efficiency is typically reported as having no units or unitless.

Equation 2

$$\varepsilon_i = \frac{R_{S+B} + R_B}{q_{2\Pi}\left(W_A / S_A\right)}$$

Where:

R_{S+B} = the gross count rate of the calibration measurement (cpm)
R_B = the background count rate in cpm
$q_{2\pi}$ = surface emission rate of the calibration source [National Institute of Standards and Technology (NIST) traceable]
W_A = Active area of the detector window (cm^2)
S_A = Area of the source (cm^2)

Note: This equation assumes that the dimensions of the calibration source are sufficient to cover the window of the instrument detector. If the dimensions of the calibration source are smaller than the detector's window, set W_A equal to the dimensions of the calibration source (set the quotient of W_A and S_A equal to 1).

The instrument efficiency is determined during calibration by obtaining static counts with the detector over a calibration source that has a NIST traceable surface emission rate. The 2π particle fluence rate is corrected for decay, attenuation and scatter. Then, the surface emission rate of the source must be corrected for the area subtended by the probe. Factors that can also affect the instruments efficiency are discussed below.

- Calibration Sources. The calibration sources selected emit alpha or beta radiation with energies similar to those expected from the contaminant in the field (similar to the expected radionuclide(s) of concern).
- Source Geometry Factors. The instrument efficiency is determined with a calibration source equal to or greater than the area of the probe.

- Source-to-detector Distance. The detector is calibrated at a source-to-detector distance that is the same as the detector-to-surface distance used in the field.
- Window Density Thickness. The detector is calibrated with a probe window density thickness that is the same as the probe window density thickness used in the field.
- Detector-related Factors - Ambient Conditions. If ambient conditions such as the temperature, pressure, and humidity vary significantly, during calibration and during field use, corrections to the detector's response will be considered.

6.4 DETECTION SENSITIVITY—STATIC AND SCAN MINIMUM DETECTABLE CONCENTRATION

Note: The calculations in this section are for illustrative purposes only. The instrument efficiencies presented were calculated from experiments conducted by NWT with gas proportional detectors that had a 0.4-mg/cm^2-thick window. Actual static and scan MDC calculations will be performed at the time of the survey using the equations below. The counting time for the gross alpha/beta static direct measurement readings will be adjusted accordingly to achieve less than or equal to 75 percent of gross alpha and gross beta residual surface activity release limits.

6.4.1 Static MDC

The static MDC is the level of radioactivity, on a surface, that is practically achievable by the overall measurement process. The conventional equation, Equation 3, is used to calculate instrument MDCs in dpm per 100 cm^2 when the background and sample are counted for the same time intervals.

Equation 3

$$MDC = \frac{3 + 4.65\sqrt{C_B * T_B}}{\varepsilon_i \varepsilon_s \frac{W_A}{100\ cm^2} T_B}$$

Where:

C_B	=	background count rate (cpm)
T_B	=	background counting time (min)
ε_i	=	instrument efficiency (count per particle)
ε_s	=	contaminated surface efficiency (particle per disintegration)
W_A	=	area of the detector window (cm^2)

If the background and sample are counted for different time intervals, Equation 4 is used to calculate the MDC in dpm per 100 cm^2.

Equation 4

$$MDC = \frac{3 + 3.29\sqrt{R_B T_{S+B}\left(1 + \frac{T_{S+B}}{T_B}\right)}}{\varepsilon_i \varepsilon_s \frac{W_A}{100\ cm^2} T_{S+B}}$$

Where:

R_B	=	background count rate (cpm)
T_B	=	background counting time (min)
T_{S+B}	=	sample counting time (min)
ε_i	=	the instrument efficiency (count per particle)
ε_S	=	the contaminated surface efficiency (particle per disintegration)
W_A	=	the area of the detector window (cm^2)

6.4.2 Surface Efficiency (ε_s) for Surface Activity Measurements

The surface efficiency term in Equation 4 is used to determine the 4π total efficiency for a particular surface and condition. Suitable values are based on the radiation and radiation energy, and are primarily impacted by the backscatter and self-absorption characteristics of the surface on which the contamination exists in the field. Backscatter is most affected by the energy of the radiation and the density of the surface material. Self-absorption characteristics or attenuation are also a function of the radiation's energy and surface condition. Surfaces typically encountered in the field include concrete, wood, dry wall, plaster, carpet, and metal. Surface conditions include both physical effects, such as scaled concrete, and the effect of surface coatings (dust, paint, rust, water, and oil).

In the absence of experimentally determined surface efficiencies, ISO 7503-1 [International Organization for Standardization (ISO), 1998] and NUREG-1507 (NRC, 1997) provide conservative recommendations for surface efficiencies. ISO 7503-1, recommends a surface efficiency of 0.5 for maximum beta energies exceeding 0.5 MeV and use of a surface efficiency of 0.25 for beta energies between 0.15 and 0.4 MeV and for alpha emitters (ISO, 1988). NUREG-1507 (NRC, 1997) provides surface efficiencies based on studies performed primarily at Oak Ridge Institute for Science and Education. In general, NUREG-1507 indicates that the ISO rule-of-thumb for surface efficiencies is conservative, particularly for beta-emitting radionuclides with end-point energies between 0.25 MeV and 0.4 MeV.

The surface condition in Building 819 is poured concrete that is slightly covered with dust. One of the radionuclides of concern occurs naturally in concrete and produce a wide range of beta and alpha energies. The surface efficiency used in accordance with ISO 7503-1 is 0.25.

6.4.3 Probe Area Correction Factor for Surface Activity Measurements

In Equation 3, W_A is the size of the "active" area of the detector window. If the area of the detector window (cm^2) does not equal 100 cm^2, it is necessary to convert the detector response to units of dpm per 100 cm^2.

6.4.4 Calculation of Static MDC for Beta Surveys (126-cm^2 Probe)

The following example illustrates the calculation of the MDC in dpm/100 cm^2 β γ for the large-area gas proportional instrument with a 126-cm^2 probe area that will be used for the direct measurement surveys that will be performed inside Building 819 during the disposition survey. The measurement and background counting times are each 2 minutes:

Where:

Instrument Efficiency: 25%
Surface Efficiency Factor: 25%
Background Count Rate: 200 cpm
Sample Count Time: 2 minutes
Probe Area Size: 126 cm^2

The MDC is calculated using the following equation:

$$MDC = \frac{3 + 4.65\sqrt{200 * 2}}{0.25 * 0.25 * 2 * \frac{126}{100}} = 610 \text{ dpm/100cm}^2\ \beta\gamma$$

6.4.5 Calculation of Static MDC for Beta Surveys (582-cm^2 Probe)

The following example illustrates the calculation of the MDC in dpm/100 cm^2 β γ for the large-area gas proportional instrument with a 582-cm^2 probe area that will be used for the direct measurement surveys that will be performed inside Building 819 during the disposition survey. The measurement and background counting times are each 2 minutes:

Where:

Instrument Efficiency: 25%
Surface Efficiency Factor: 25%
Background Count Rate: 1,000 cpm
Sample Count Time: 2 minutes
Probe Area Size: 582 cm^2

The MDC is calculated using the following equation:

$$MDC = \frac{3 + 4.65\sqrt{1000 * 2}}{0.25 * 0.25 * 2 * \frac{582}{100}} = 290 \text{ dpm/100cm}^2\ \beta\gamma$$

6.4.6 Calculation of Static MDC for Alpha Surveys (126-cm^2 Probe)

The following example illustrates the calculation of the MDC in dpm/100 cm^2 α for the large-area gas proportional instrument with a 126-cm^2 probe area that will be used for the direct measurement surveys that will be performed inside Building 819 during the disposition survey. The measurement and background counting times are each 2 minutes:

Where:

Instrument Efficiency: 25%
Surface Efficiency Factor: 25%
Background Count Rate: 2 cpm
Sample Count Time: 2 minutes
Probe Area Size: 126 cm^2

The MDC is calculated using the following equation:

$$MDC = \frac{3 + 4.65\sqrt{2 * 2}}{0.25 * 0.25 * 2 * \frac{126}{100}} = 78 \text{ dpm/100cm}^2\ a$$

6.4.7 Calculation of Static MDC for Alpha Surveys (582-cm^2 Probe)

The following example illustrates the calculation of the MDC in dpm/100 cm^2 α for the large-area gas proportional instrument with a 582-cm^2 probe area that will be used for the direct measurement surveys that will be performed inside Building 819 during the disposition survey. The measurement and background counting times are each 2 minutes:

Where:

Instrument Efficiency: 25%
Surface Efficiency Factor: 25%
Background Count Rate: 10 cpm
Sample Count Time: 2 minutes
Probe Area Size: 582 cm^2

The MDC is calculated using the following equation:

$$MDC = \frac{3 + 4.65\sqrt{10 * 2}}{0.25 * 0.25 * 2 * \frac{582}{100}} = 33 \text{ dpm/100cm}^2\ a$$

6.5 SCANNING MINIMUM DETECTABLE COUNT RATE (MDCR)

The minimum detectable number of net source counts in the scan interval, for an ideal observer, can be arrived at by multiplying the square root of the number of background counts (in the scan interval) by the detectability value associated with the desired performance (as reflected in *d'*) as shown in Equation 5.

Equation 5

$$MDCR = d'\sqrt{b_i} \times {}^{60}\!/_{i}$$

Where:

d' = index of sensitivity (α and β error)
b_i = number of background counts in scan time interval (count)
I = scan or observation interval (s)

6.5.1 Determination of MDCR and Use of Surveyor Efficiency (Beta, 582-cm² Probe)

The minimum detectable number of net source counts in the interval is given by S_i. Therefore, for an ideal observer, the number of source counts required for a specified level of performance can be arrived at by multiplying the square root of the number of background counts by the detectability value associated with the desired performance (as reflected in *d'*), as shown in the equation below.

$$S_i = d'\sqrt{b_i}$$

The following example illustrates the calculation of the MDCR in dpm/100 cm² βγ for the large-area gas proportional instrument with a 582-cm² probe area that will be used for the scan surveys that will be performed inside Building 819 during the disposition survey. The background count rate for these detectors is typically 1,000 to 1,200 cpm βγ. For this calculation, a background count rate of 1,000 cpm will be used. It will be assumed that a typical source remains under the probe for 2 seconds during the scan; therefore, the average number of background counts in the observation interval is 33.3 [b_i = 1000 × (2/60)]. The required rate of true positives will be 95 percent, and the false positives will be 5 percent.

From Table 6.5 of MARSSIM (DoD et al., 2000), the value of d' representing this performance goal is 3.28.

The minimum detectable number of net source counts, S_i, needed will be estimated by multiplying 5.78 (the square root of 33.3) by 3.28 (the d' value); so, S_i equals 18.9.

The MDCR, in cpm, may be calculated by:

$$MDCR = S_i(60/i)$$
$$MDCR = 18.9(60/2) = 567cpm$$

The $MDCR_{Surveyor}$ is calculated assuming a surveyor efficiency (p) of 0.5 and a background count rate of 10 cpm as follows:

$$MDCR_{Surveyor} = \frac{MDCR}{\sqrt{p}} = \frac{567}{\sqrt{0.5}} = 802cpm$$

6.5.2 Determination of MDCR and Use of Surveyor Efficiency (Beta, 126-cm^2 Probe)

The minimum detectable number of net source counts in the interval is given by S_i. Therefore, for an ideal observer, the number of source counts required for a specified level of performance can be arrived at by multiplying the square root of the number of background counts by the detectability value associated with the desired performance (as reflected in *d'*), as shown in the equation below.

$$S_i = d'\sqrt{b_i}$$

The following example illustrates the calculation of the MDCR in dpm/100 cm^2 $\beta\gamma$ for the large-area gas proportional instrument with a 126-cm^2 probe area that will be used for the scan surveys that will be performed inside Building 819 during the disposition survey. The background count rate for these detectors is typically 150 to 200 cpm $\beta\gamma$. For this calculation, a background count rate of 200 cpm will be used. It will be assumed that a typical source remains under the probe for 2 seconds during the scan; therefore, the average number of background counts in the observation interval is 6.7 [b_i = 200 × (2/60)]. The required rate of true positives will be 95 percent, and the false positives will be 5 percent.

From Table 6.5 of MARSSIM (DoD et al., 2000), the value of d' representing this performance goal is 3.28.

The minimum detectable number of net source counts, S_i, needed will be estimated by multiplying 2.6 (the square root of 6.7) by 3.28 (the d' value); so, S_i equals 8.5.

The MDCR, in cpm, may be calculated by:

$$MDCR = 8.5(60/2) = 255cpm$$
$$MDCR = S_i(60/i)$$

The $MDCR_{Surveyor}$ is calculated assuming a surveyor efficiency (p) of 0.5 and a background count rate of 200 cpm as follows:

$$MDCR_{Surveyor} = \frac{MDCR}{\sqrt{p}} = \frac{255}{\sqrt{0.5}} = 361cpm$$

6.5.3 Determination of MDCR and Use of Surveyor Efficiency (Alpha, 582-cm^2 Probe)

The minimum detectable number of net source counts in the interval is given by S_i. Therefore, for an ideal observer, the number of source counts required for a specified level of performance can be arrived at by multiplying the square root of the number of background counts by the detectability value associated with the desired performance (as reflected in *d'*), as shown in the equation below.

$$S_i = d'\sqrt{b_i}$$

The following example illustrates the calculation of the MDCR in dpm/100 cm^2 α for the large-area gas proportional instrument with a 582-cm^2 probe area that will be used for the scan surveys that will be performed inside Building 819 during the disposition survey. The background count rate for these detectors is typically 2 to 10 cpm α. For this calculation, a background count rate of 10 cpm will be used. It will be assumed that a typical source remains under the probe for 2 seconds during the scan; therefore, the average number of background counts in the observation interval is 0.33 [$b_i = 10 \times (2/60)$]. The required rate of true positives will be 95 percent, and the false positives will be 5 percent.

From Table 6.5 of MARSSIM (DoD et al., 2000), the value of d' representing this performance goal is 3.28.

The minimum detectable number of net source counts, S_i, needed will be estimated by multiplying 0.57 (the square root of 0.33) by 3.28 (the *d'* value); so, S_i equals 1.9.

The MDCR, in cpm, may be calculated by:

$$MDCR = S_i(60 / i)$$

$$MDCR = 1.9(60 / 2) = 57cpm$$

The $MDCR_{Surveyor}$ is calculated assuming a surveyor efficiency (p) of 0.5 and a background count rate of 10 cpm as follows:

$$MDCR_{Surveyor} = \frac{MDCR}{\sqrt{p}} = \frac{57}{\sqrt{0.5}} = 81cpm$$

6.5.4 Determination of MDCR and Use of Surveyor Efficiency (Alpha, 126-cm^2 Probe)

The minimum detectable number of net source counts in the interval is given by S_i. Therefore, for an ideal observer, the number of source counts required for a specified level of performance can be arrived at by multiplying the square root of the number of background counts by the detectability value associated with the desired performance (as reflected in *d'*), as shown in the equation below.

The following example illustrates the calculation of the MDCR in dpm/100 cm^2 α for the large-area gas proportional instrument with a 126-cm^2 probe area that will be used for the scan surveys that will be performed inside Building 819 during the disposition survey. The background count rate for these detectors is typically zero to 2 cpm α. For this calculation, a background count rate of 2 cpm will be used. It will be assumed that a typical source remains under the probe for 2 seconds during the scan; therefore, the average number of background counts in the observation interval is 0.06 [$b_i = 4 \times (2/60)$]. The required rate of true positives will be 95 percent, and the false positives will be 5 percent.

From Table 6.5 of MARSSIM (DoD et al., 2000), the value of d' representing this performance goal is 3.28.

The minimum detectable number of net source counts, S_i, needed will be estimated by multiplying 0.26 (the square root of 0.067) by 3.28 (the d' value); so, S_i equals 0.85.

The MDCR, in cpm, may be calculated by:

$$MDCR = S_i(60 / i)$$

$$MDCR = 0.85(60 / 2) = 26$$

The $MDCR_{Surveyor}$ is calculated assuming a surveyor efficiency (p) of 0.5 and a background count rate of 2 cpm as follows:

$$MDCR_{SURVEYOR} = \frac{MDCR}{\sqrt{P}} = \frac{26}{\sqrt{0.5}} = 37cpm$$

6.6 SCAN MDC

The scan MDC is determined from the MDCR by applying conversion factors that account for detector and surface characteristics and surveyor efficiency. As discussed below, the MDCR accounts for the background level, performance criteria (*d'*), and observation interval. The observation interval during scanning is the actual time that the detector can respond to the contamination source. This interval depends on the scan speed, detector size in the direction of the scan, and area of elevated activity.

The scan MDC for structure surfaces is calculated using Equation 6.

Equation 6

$$Scan\ MDC = \frac{MDCR}{\sqrt{p}\ \varepsilon_i \varepsilon_s \frac{W_A}{100\ cm^2}}$$

Where:

MDCR = discussed in Section 6.5.3
p = surveyor efficiency factor
ε_i = instrument efficiency (count per particle)
ε_s = contaminated surface efficiency (particles per disintegration)
W_A = area of the detector window (cm^2)

6.6.1 Scan MDCs for Building and Structure Surfaces (Beta-Gamma, 126-cm² Probe)

$$ScanMDC = \frac{MDCR}{\sqrt{p}\ \varepsilon_i \varepsilon_s \frac{probe\ area\ in\ cm^2}{100cm^2}}$$

The scan MDC for structure surfaces may be calculated:

Where:

MDCR = minimum detectable count rate
ε_I = instrument efficiency
ε_S = surface efficiency
p = surveyor efficiency

The scan MDC (in dpm/100 cm^2) for Cs-137 (most conservative instrument efficiency) on the surfaces inside Building 819 may be determined for a background level of 200 cpm and a 2-second observation interval using a hand-held gas proportional detector (126-cm^2 probe area). For the specified level of performance, a 95 percent true positive rate and 5 percent false positive rate will be required.

In Table 6.5 of MARSSIM (DoD et al., 2000), d' equals 3.28 and the MDCR is 255 cpm. Using a surveyor efficiency of 0.5 and assuming instrument and surface efficiencies of 0.25 and 0.25, respectively, the scan MDC is calculated using the equation below:

$$Scan\ MDC = \frac{255}{\sqrt{0.5}\ (0.25)(0.25)(1.26)} = 4580 dpm/100cm^2 \beta\gamma$$

Using the above equations found in Chapter 6 of MARSSIM (DoD et al., 2000), the detection sensitivity for such surveys for Cs-137 using the above survey parameters and a large-area gas proportional detector is approximately 4,580 dpm/100 cm^2 beta-gamma.

6.6.2 Scan MDCs for Building and Structure Surfaces (Beta-Gamma, 582-cm^2 Probe)

The scan MDC for structure surfaces may be calculated as:

$$ScanMDC = \frac{MDCR}{\sqrt{p}\ \varepsilon_i \varepsilon_s \frac{probe\ area\ in\ cm^2}{100cm^2}}$$

Where:

MDCR = minimum detectable count rate
ε_I = instrument efficiency
ε_s = surface efficiency
p = surveyor efficiency

The scan MDC (in dpm/100 cm^2) for Cs-137 (most conservative instrument efficiency) on the surfaces inside Building 819 may be determined for a background level of 1,000 cpm and a 2-second observation interval using a hand-held gas proportional detector (582-cm^2 probe area). For the specified level of performance, a 95 percent true positive rate and 5 percent false positive rate will be required.

In Table 6.5 of MARSSIM (DoD et al., 2000), d' equals 3.28 and the MDCR is 567 cpm. Using a surveyor efficiency of 0.5 and assuming instrument and surface efficiencies of 0.25 and 0.25, respectively, the scan MDC is calculated using the equation below:

$$Scan\ MDC = \frac{567}{\sqrt{0.5}\ (0.25)(0.25)(5.82)} = 2204 dpm / 100 cm^2 \beta\gamma$$

Using the above equation found in Chapter 6 of MARSSIM (DoD et al., 2000), the detection sensitivity for such surveys for Cs-137 using the above survey parameters and a large-area gas proportional detector is approximately 2,204 dpm/100 cm^2 beta-gamma.

6.6.3 Scan MDCs for Building and Structure Surfaces (Alpha, 126-cm² Probe)

Scanning for alpha emitters differs significantly from scanning for beta and gamma emitters in that the expected background response of most alpha detectors is very close to zero. The following sections cover scanning for alpha emitters. Assumptions are made that the surface being surveyed is similar in nature to the material on which the detector was calibrated. In this respect, the approach is purely theoretical. Surveying surfaces that are dirty, non-planar, or weathered can significantly affect the detection efficiency and therefore bias the expected MDC for the scan. The use of reasonable detection efficiency values instead of optimistic values is highly recommended.

Since the time a contaminated area is under the probe varies and the background count rate of some alpha instruments is less than 1 cpm, it is not reasonable to determine a fixed MDC for scanning. Instead, it is more practical to determine the probability of detecting an area of contamination at a predetermined derived concentration guideline level (DCGL) for given scan rates.

For alpha survey instrumentation with backgrounds ranging from less than 1 to 3 cpm, a single count provides a surveyor sufficient cause to stop and investigate further. Assuming this to be true, the probability of detecting given levels of alpha surface contamination can be calculated by use of Poisson summation statistics.

Given a known scan rate and a surface contamination release limit, the probability of detecting a single count while passing over the contaminated area is

$$P(n \geq 1) = 1 - e^{\frac{-GEd}{60v}}$$

Where:

P(n ≥1)	=	probability of observing a single count
G	=	contamination activity (dpm)
E	=	detector efficiency (4π)
D	=	width of detector in direction of scan (cm)
V	=	scan speed [centimeters per second (cm/s)]

The following example illustrates the calculation of the probability for the large-area gas proportional instrument with a 126-cm^2 probe area that will be used for the scan surveys that will be performed inside Building 819 during the disposition survey:

$$0.76 = 1 - e^{\frac{-100*0.06*14.4}{60(1.0)}}$$

Where:

G = 100 dpm
E = 6%
D = 14.4 cm
v = 1.0

Once a count is recorded and the guideline level of contamination is present, the surveyor should stop and wait until the probability of getting another count is at least 90 percent. This time interval can be calculated by:

$$t = \frac{13,800}{CAE}$$

Where:

t = time period for static count(s)
C = contamination guideline (dpm/100 cm^2)
A = physical probe area (cm^2)
E = detector efficiency (4π)

Therefore:

$$18 \text{ seconds} = \frac{13,800}{100*126*0.06}$$

Where:

t = time period for static count(s)
C = 100 dpm/100 cm^2
A = 126 cm^2
E = 6%

Using the above equations found in Chapter 6 of MARSSIM (DoD et al., 2000), the probability of detecting 100 dpm/100 cm^2 alpha is approximately 76 percent.

Using the following equation (Abelquist, 2001), one can calculate the activity of a 100-cm^2 "hot spot" with a 90 percent probability of detection:

$$\alpha\ scanMDC = \frac{[-\ln(1-P(n \geq 1))]60}{t\varepsilon_s\varepsilon_i}$$

Where:

t	=	Dwell time over source (seconds)
ε_I	=	Instrument efficiency (counts per particle)
ε_s	=	Contaminated surface efficiency (particles per disintegration)

Therefore:

$$221\ \text{dpm}/100\text{cm}^2 = \frac{[-\ln(1-0.9)]60}{0.25*0.25*10}$$

6.6.4 Scan MDCs for Building and Structure Surfaces (Alpha, 582-cm^2 Probe)

The larger (582-cm^2) gas proportional detectors have background count rates on the order of 5 to 10 cpm, and a single count will not cause a surveyor to investigate further. A counting period long enough to establish that a single count indicates an elevated contamination level would be prohibitively inefficient. For these types of instruments, the surveyor usually will need to get at least 2 counts while passing over the source area before stopping for further investigation.

Assuming this to be a valid assumption, the probability of getting two or more counts can be calculated by:

$$P(n \geq 2) = 1 - e^{-\frac{(GE+B)t}{60}}\left(1 + \frac{(GE+B)t}{60}\right)$$

Where:

P(n ≥2)	=	probability of getting 2 or more counts during the time interval *t*
T	=	d/v, dwell time over source (s)
G	=	contamination activity (dpm)
E	=	detector efficiency (4π)
B	=	background count rate (cpm)

The following example illustrates the calculation of the probability for the large-area gas proportional instrument with a 582-cm^2 probe area that will be used for the scan surveys that will be performed inside Building 819 during the disposition survey:

$$0.94 = 1 - e^{-\frac{(100*0.06+10)17.2}{60}}\left(1 + \frac{(100*0.06+10)17.2}{60}\right)$$

Where:

$P(n \geq 2)$	=	probability of getting 2 or more counts during the time interval t
T	=	43.8/2.54
G	=	100 dpm
E	=	6%
B	=	10 cpm

Using the above equations found in Chapter 6 of MARSSIM (DoD et al., 2000), the probability of detecting 100 dpm/100 cm^2 alpha is approximately 94 percent.

6.7 SOP/QUALITY ASSURANCE PROCEDURES

All survey instruments will be calibrated with NIST traceable standards prior to the start of the project. The survey instruments will be source-checked daily prior to and after each surveillance activity. Daily checks of laboratory equipment will follow the procedural guidance for the specific instrument.

6.8 STATISTICAL TESTS

Regulatory guidance, as identified in MARSSIM (DoD et al., 2000), recommends use of the sign test to conservatively evaluate surveillance results that will be obtained from this survey. The sign test application will be used to evaluate, as applicable, alpha, beta, and gamma measurement data. Positive findings will result in solid sample collection and/or additional analysis within the area(s) of concern. If all readings are below the release limit, statistical testing will not be required.

6.8.1 Determining the Numbers of Data Points for the Sign Test

The number of data points, N, to be obtained for the sign test is derived using Table 5.5 in MARSSIM (DoD et al., 2000) or by calculating data in Equation 7:

Equation 7

$$N = \left(\frac{(Z_{1-\alpha} + Z_{1-\beta})^2}{4(Sign\ p - 0.5)^2}\right)(1.2)$$

Where:

$Z_{1-\alpha}$ = Type I decision error level
$Z_{1-\beta}$ = Type II decision error level
Sign p = random measurement probability, which is based on relative shift discussed below in Section 6.8.2

The second term in the equation increases the number of data points by 20 percent. The value of 20 percent is selected to account for a reasonable amount of uncertainty in the parameters used to calculate N and still allow flexibility to account for some lost or unusable data.

6.8.2 Relative Shift

Sign p in Equation 7 above is based on the relative shift. The relative shift is equal to Δ/σ, where Δ is equal to DCGL-lower boundary of the gray region (LBGR) and σ is an estimate of the standard deviation of the measured values in the survey unit. The LBGR is the net median concentration of the contaminant in the survey unit. Since this value is unknown, MARSSIM suggests using a value for the LBGR of ½DCGL, which is used. Likewise, there is no estimate of the standard deviation of the contaminant in the survey unit, especially when no contaminant is expected. Therefore, σ is assigned the value of the standard deviation of the measurement values in the reference area.

7.0 SCOPE OF ACTIVITIES

7.1 BACKGROUND REFERENCE AREA RADIATION LEVELS

Background radiation levels will be established for the building by obtaining a minimum of sixteen random 2-minute static alpha, beta readings and 1-minute gamma readings, taken at approximately 4 inches above the ground for gamma surveys and 0.25 inches for alpha/beta surveys, from areas unlikely to be affected by the radioactive materials that could be present on the site. The mean value for these readings will be used as the building background levels. Reference area readings will be collected using the same serial-numbered instruments that will be used to collect survey unit readings.

A non-impacted area within HPS will be used as the background reference area. The area will have similar physical, chemical, geological, radiological, and biological characteristics as the survey unit being evaluated.

7.2 REFERENCE GRIDS

The survey unit will be divided into grids that are no larger than 100 m^2. A minimum of 16 systematic surveillance points will be established in the survey unit grids to identify individual reading locations.

7.3 SURVEY ACTIVITIES

Survey units will undergo 100 percent alpha, beta, and gamma scan surveys; systematic static alpha, beta, and gamma measurements; swipe sample measurements; and exposure rate measurements. For this effort, the survey and sample analysis methods focus on the alpha, beta, and gamma radiations emitted from the isotopes of concern.

8.0 INTERPRETATION OF DISPOSITION SURVEY DATA-STATISTICAL CONSIDERATIONS

8.1 DEMONSTRATION OF COMPLIANCE

When determining compliance with remediation goals, the entire survey unit is examined. One measurement does not determine compliance. Rather, the survey data are examined statistically. The three compliance tests are summarized in Table 8-1 and include the following considerations:

- Compare the largest measurement to the smallest background measurement.
- Compare the average measurement to the average background measurement.
- Use the sign test (MARSSIM; DoD et al., 2000) to determine if the survey data (less background) exceeds the release limits.

8.2 NULL HYPOTHESIS

Using the MARSSIM methodology, the null hypothesis is stated as "the residual activity in the survey unit [that] exceeds the release criteria". Thus, in order to pass the survey unit (that is, release the area), the null hypothesis must be rejected. The objective of surveillance surveys will be to demonstrate that residual radioactivity levels meet the release criterion. In demonstrating that the objective is met, the null hypothesis (H_o) is tested that residual contamination exceeds the release criterion; the alternative hypothesis (H_a) is then tested that residual contamination meets the release criterion.

8.3 STATISTICAL TESTS

Should readings from the survey area exceed the release criteria, two statistical tests will be used to evaluate fixed measurement data from disposition surveys. For gamma radiation measurements, the paired t-test will be used to compare background radiation readings to survey unit measurements. The sign test will be used for testing the data collected from alpha/beta measurements. To determine data needs for these tests, the acceptable probability of making Type I decision errors (0.05) and Type II decision errors (0.05) is established using the DQO process.

8.3.1 Paired t-test

For the paired t-test, the data is dependent. There is a one-to-one correspondence between the values in the two samples (survey unit and reference area), for example, the same radiation source measured in the survey unit and a non-impacted area, or same radiation source measured at different times. The main assumption is that the differences should be normally distributed.

The paired sample t-test is used to determine whether there is a significant difference between the average values of the same measurement made under two different conditions. Both measurements are made on each unit in a sample, and the test is based on the paired differences between these two values. The usual null hypothesis is that the difference in the mean values is zero.

8.3.2 Sign Test

The sign test is designed to test a hypothesis about the location of a population distribution. It is most often used to test the hypothesis about a population median and often involves the use of matched pairs, for example, before and after data, in which case, it tests for a median difference of zero. The sign test does not require the assumption that the population is normally distributed.

The sign test is a nonparametric test that may be of use when it is only necessary (or possible) to know if observed differences between two conditions are significant. The sign test is structured to denote change in magnitude, as opposed to any attempt at quantitative measurement.

9.0 HEALTH AND SAFETY PLAN

The NWT *Radiological Health Program Manual* (2002), supplemented with field-related SOPs, is used to address controls necessary for radiologically safe and correct operations. All other health and safety requirements are contained in the *Final Base-Wide Health and Safety Plan* (TtFW, 2004).

10.0 TRAINING

Personnel operating the survey detection equipment are qualified based on training and experience.

Designated personnel performing work under this Work Plan will successfully complete prerequisite training in radiation safety awareness. Awareness training provides the worker with a basic knowledge of the hazards, health concerns, and protective practices related to radiation and radioactive materials. Training will be documented on the appropriate NWT form. A copy will be provided to TtFW and kept in the project field office while the original will be maintained at NWT corporate headquarters in Livermore, California.

11.0 WHOLE-BODY EXTERNAL RADIATION MONITORING

All personnel conducting fieldwork under this Work Plan will be issued and required to wear dosimetry from a National Voluntary Laboratory Accreditation Program-participating vendor to monitor and track occupational external whole-body exposure. If not already on file, all personnel issued a dosimeter will be required to complete a NRC Form 4. The NRC Form 4 provides a complete record of the personnel's occupational radiation exposure history. Each completed Form 4 will be maintained by NWT at the Livermore office with a copy kept on site. Copies of all documentation will be provided to TtFW for incorporation in the project files.

12.0 RADIATION WORK PERMITS

RWPs will specify activities including all radiological safety requirements pertinent to planned work. Prior to beginning assignments, all personnel performing tasks covered by this Work Plan (including personnel assigned after the project begins) will be required to read and acknowledge that they understand all of the requirements by signing the RWP. Changes to RWP requirements will be conveyed to all personnel working under the requirements of the RWP prior to implementation. In such instances, personnel will again be required to read and indicate an understanding of the revision(s) by signing the RWP prior to continuing assigned work. The assigned RCT is authorized to immediately upgrade any RWP requirement based on field conditions encountered but may not downgrade requirements without prior approval by the NWT Radiation Safety Office Representative.

13.0 COMMUNICATION

The Project Manager or designee shall ensure that crew members understand their obligation to safety and ensure that members are familiar with the elements of the safety program. A copy of this Work Plan will be maintained in the work area. Daily safety tailgate meetings will be held prior to the start of the workday to discuss safety issues and planned work activities for the day. TtFW and subcontractor personnel will be required to attend scheduled meetings on a daily basis. Documentation of all safety and planning representatives' attendance, as well as topics of discussion, will be maintained with records retained in the project management office.

14.0 RECORDS

All training records and accident investigation documents will be maintained.

The final project report will contain records and information necessary to document and support the release of the site for unrestricted reuse. All generated records for the project shall be maintained in the project management office. Records that must be controlled and maintained during the project and presented in the disposition survey report, in addition to site activities, are:

- Instrument calibration data
- Survey records
- Sample location records
- Sample analysis results (if any)
- Transportation documentation (if applicable)
- Disposal verification records (provided by the disposal facility upon disposal, if applicable)

Listed records, with the exception of the transportation documentation and disposal verification records (if required), will be maintained on site during project activities. Listed records will be transmitted with the final project report and will be maintained at the NWT corporate office in Livermore, California.

15.0 QUALITY ASSURANCE

15.1 EQUIPMENT

The instruments and systems will be calibrated using the manufacturer's calibration protocol to NIST traceable sources. Daily source checks will be performed to verify proper operation of detectors and detection systems.

15.2 DATA

Data will be maintained electronically in the project management office. Backup copies of data will be made routinely and maintained in a file. Further, backup copies of survey and sample results will routinely be made to compact disks or other removable media.

16.0 DATA REVIEW

The supervision team will review data at the end of each survey to determine the validity of the results and adequate coverage of the survey area.

16.1 DATA ASSESSMENT

Basic statistical quantities will be calculated for the data in order to identify patterns, relationships, and any type anomaly.

17.0 REFERENCES

Department of Defense (DoD), Department of Energy, Nuclear Regulatory Commission (NRC), and U.S. Environmental Protection Agency (EPA). 2000. *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM). NUREG-1575. August.

Abelquist, E.W. 2001. *Decommissioning Health Physics A, Handbook for MARSSIM Users.* Institute of Physics Publishing.

International Organization for Standardization (ISO). 1998. *Evaluation of Surface Contamination – Part 1: Beta-emitters (Maximum Beta Energy Greater than 0,15 MeV) and Alpha-emitters.* ISO 7503-1.

Nuclear Regulatory Commission (NRC). 1974. Regulatory Guide 1.86. *Termination of Operating Licenses for Nuclear Reactors.* ML003740243. June.

NRC. 1997. *Minimum Detectable Concentrations with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions Guide.* NUREG-1507.

NRC. 1998. *A Nonparametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys.* NUREG-1505.

New World Technology, Inc. (NWT). 2002. *Radiological Health Program Manual.*

Tetra Tech FW, Inc. (TtFW). 2004. *Final Base-Wide Health and Safety Plan.* Hunters Point Shipyard, San Francisco, California. April 23.

U.S. Environmental Protection Agency (EPA). 2002. Region 9 Preliminary Remediation Goals Table.

TABLES

TABLE 5-2

SURVEY UNIT TABLE

Survey Unit Number	Survey Unit Size (square feet)	Survey Unit Size (square meters)	Length of Sampling Grid Pattern (feet)	Length of Sampling Grid Pattern (meters)
#1 – Wet Well	954.2	88.6	7.7	2.0
#2 – Dry Well	1040.4	96.7	8.1	2.0
#3 – Bypass Culvert	663.6	61.7	6.4	1.5
#4 – Inlet Culvert	994.5	92.4	7.9	2.0

Note: Measurements are approximate and may change slightly with actual field conditions.

TABLE 6-1

INSTRUMENTATION FOR RADIOLOGICAL SURVEYS

Measurement/ Technique	Type of Instrumentation		Typical Background	Typical Efficiency (%)	Detection Sensitivity
	Detector	Meter			
Surface gamma scans	NaI 2-inch x 2-inch scintillation Ludlum Model 44-10	Ludlum Model 2350-1 data logger	100 to 12,000 cpm; varies with calibration γ	0.86 γ	150 - 1,500 cpm γ
Static alpha/beta scans	Large-area gas proportional, Ludlum Model 43-68 (126 cm^2)	Count rate meter Ludlum Model 2360 data logger	150-250 cpm β 0-2 cpm α	~6 β Total Efficiency ~12 α Total Efficiency	~ 110 dpm/100 cm^2 β ~ 20 dpm/100 cm^2 α
	Large-area gas proportional, Ludlum Model 43-37 (582 cm^2)		200-400 cpm β 1-5 cpm α		
Direct measurement static alpha/beta	Large-area gas proportional, Ludlum Model 43-68 (126 cm^2)	Count rate meter Ludlum Model 2360 data logger	150-250 cpm β 0-2 cpm α	~6 β Total Efficiency ~12 α Total Efficiency	~ 110 dpm/100 cm^2 β ~ 20 dpm/100 cm^2 α
Direct measurement static gamma	NaI 2-inch x 2-inch scintillation Ludlum Model 44-10	Ludlum Model 2350-1 data logger	100 to 12,000 cpm; varies with calibration γ	0.86 γ	200-2,000 cpm γ varies with calibration
Exposure rates	NaI scintillation MicroR meter Ludlum Model 19	(Same as detector)	7-8 μR/hr	N/A	2 μR/hr
Gross alpha/beta on smears (swipes)	Protean low-background gas flow proportional counter IPC9025	N/A	1-5 cpm β 0-0.5 cpm α	~62 β ~27 α	4-10 dpm/100 cm^2 β 2-5 dpm/100 cm^2 α

Notes:

α – alpha
β – beta
γ – gamma
μR/hr – microroentgens per hour
cm^2 – square centimeters
cpm – counts per minute
dpm – disintegrations per minute
N/A – not applicable
NaI – sodium iodide

TABLE 8-1

STATISTICAL COMPARISONS WITH THE RELEASE LIMIT

Survey Result	Conclusion
Difference between the largest survey measurement and the smallest background measurement is less than the release limit.	Material meets release criterion.
Difference between the average survey measurement and the average background measurement is greater than the release limit.	Material does not meet release criterion.
Difference between the average survey measurement and the average background measurement is less than the release limit, but the difference between any site measurement and any background measurement exceeds the release limit.	Material meets release criterion if sign test is negative.

FIGURES

FIGURE 1-1

BUILDING 819 LAYOUT

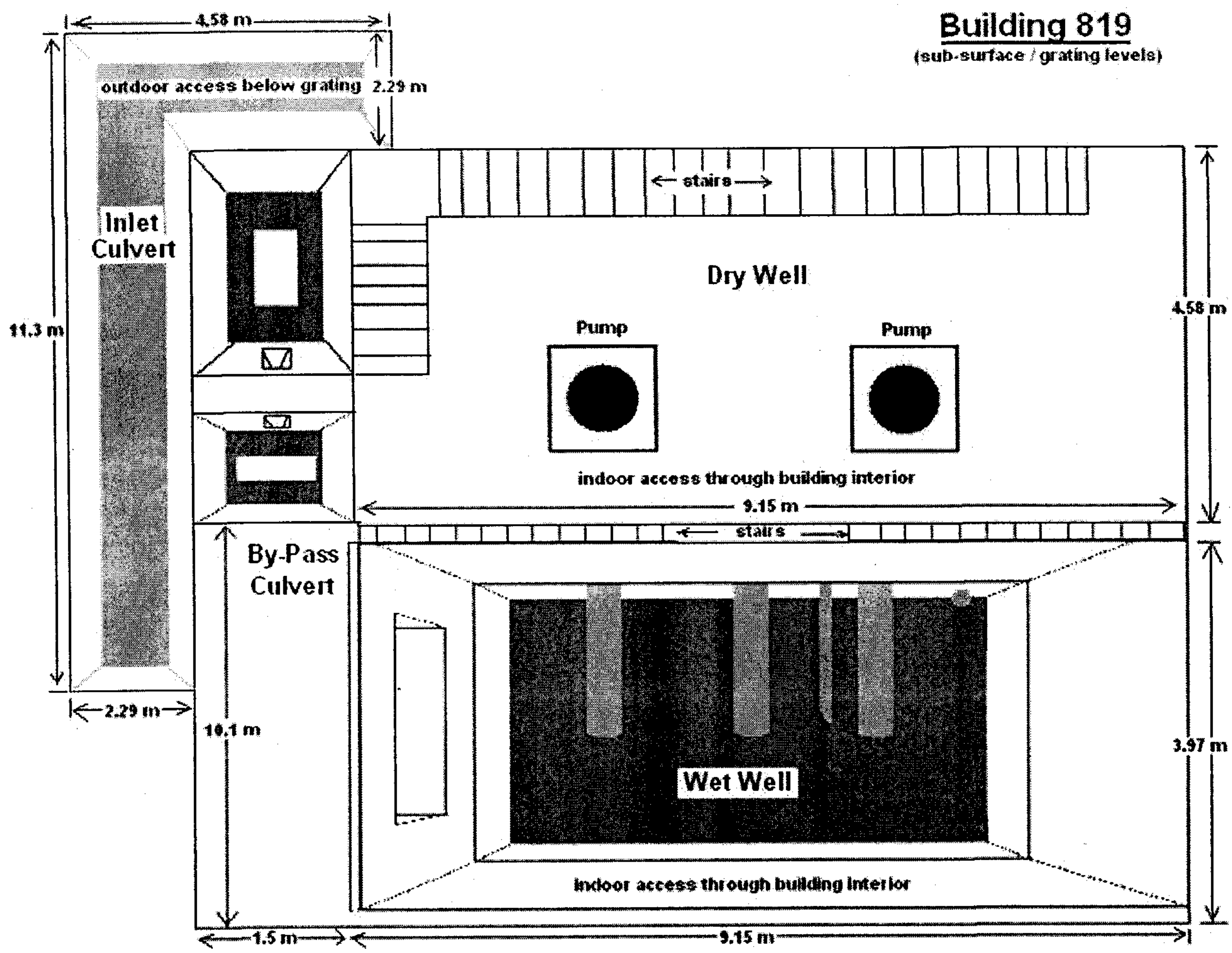

FIGURE 5-1

SURVEY UNIT 1 – BUILDING 819 WET WELL

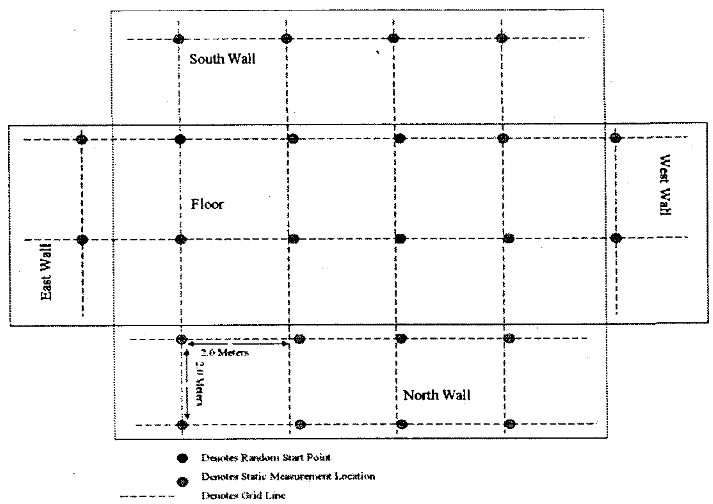

FIGURE 5-2

SURVEY UNIT 2 – DRY WELL

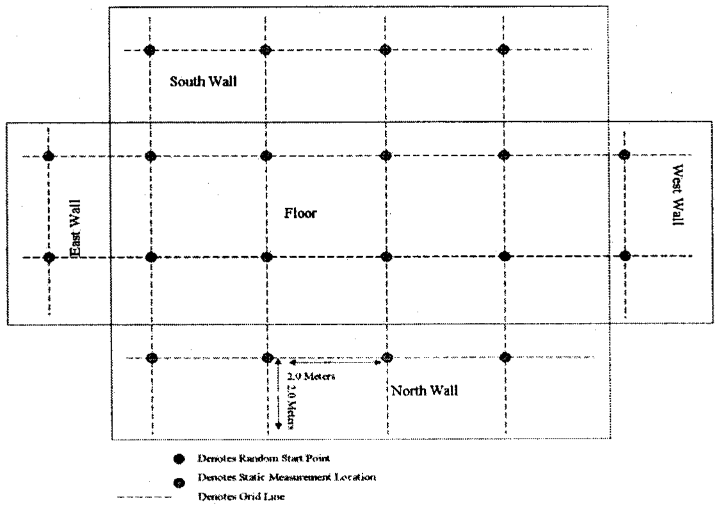

FIGURE 5-3

SURVEY UNIT 3 – BYPASS CULVERT

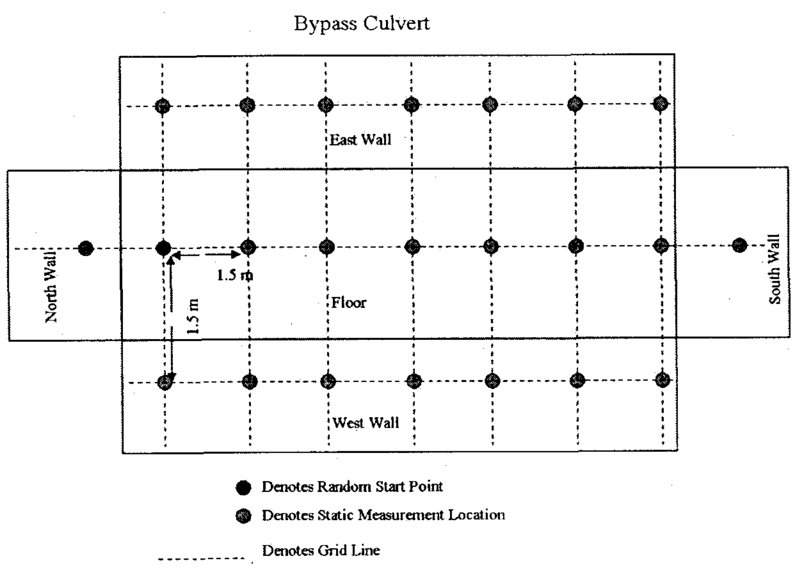

FIGURE 5-4

SURVEY UNIT 4 – INLET CULVERT