ZIONSOLUTIONS LLC
An EnergySolutions Company

ZION STATION RESTORATION PROJECT

FINAL STATUS SURVEY
FINAL REPORT – PHASE 2, PART 2

NOVEMBER, 2019

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
AMCG	Average Member of the Critical Group
BcDCGL	Base Case Derived Concentration Guideline Level
BcSOF	Base Case Sum of Fractions
CAP	Corrective Action Program
CB	Catch Basin
C/LT	Characterization/License Termination
CsI	Cesium Iodide
CoC	Chain of Custody
DQA	Data Quality Assessment
DQO	Data Quality Objective
DCGL	Derived Concentration Guideline Level
DSAR	Defueled Safety Analysis Report
EMC	Elevated Measurement Comparison
ESCSG	Energy*Solutions* Commercial Services Group
FOV	Field of View
FSS	Final Status Survey
HSA	Historical Site Assessment
HTD	Hard-to-Detect

IC	Insignificant Contributor
IMB	Inner Missile Barrier
ID	Interior Diameter
ISFSI	Independent Spent Fuel Storage Installation
LTP	License Termination Plan
LBGR	Lower Bound of the Gray Region
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	Minimum Detectable Concentration
MDCR	Minimum Detectable Count Rate
NaI	Sodium Iodide
NIST	National Institute of Standards and Technology
ODCM	Offsite Dose Calculation Manual
OD	Outside Diameter
OMB	Outer Missile Barrier
OpDCGL	Operational Derived Concentration Guideline Level
OpSOF	Operational Sum of Fractions
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
PSDAR	Post Shutdown Decommissioning Activities Report
PWST	Primary Water Storage Tank
RCA	Radiologically Controlled Area
RA	Radiological Assessments
RASS	Remedial Action Support Surveys
RE	Radiological Engineer
ROC	Radionuclides of Concern
SER	Safety Evaluation Report
SOF	Sum of Fractions
SSC	Structures, Systems and Components
TEDE	Total Effective Dose Equivalent

TSD	Technical Support Document
UCL	Upper Confidence Level
USNRC	United States Nuclear Regulatory Commission
VCC	Vertical Concrete Cask
WWTF	Waste Water Treatment Facility
ZNPS	Zion Nuclear Power Station
ZSRP	Zion Station Restoration Project

1. INTRODUCTION

1.1 Executive Summary

The purpose of the second part of this Phase 2 Final Status Survey (FSS) Final Report (Phase 2, Part 2) is to provide a summary of the survey results and overall conclusions which demonstrate that buried pipe remaining in the end-state of the Zion Nuclear Power Station (ZNPS) facility, or portions of the site, meets the 25 mrem per year release criterion as established in Nuclear Regulatory Commission Regulation 10 CFR 20.1402 *"Radiological Criteria for Unrestricted Use."*

This report documents that FSS activities were performed consistent with the guidance provided in the "*Zion Nuclear Power Station, Units 1 and 2 - Issuance of Amendments 191 and 178 for the Licenses to Approve the License Termination Plan*" (LTP) (Reference 1); NUREG-1575, *"Multi-Agency Radiation Survey and Site Investigation Manual"* (MARSSIM) (Reference 2); ZS-LT-01, *"Quality Assurance Project Plan (for Characterization and FSS)"* (QAPP) (Reference 3); ZS-LT-300-001-001, *"Final Status Survey Package Development"* (Reference 4); ZS-LT-300-001-003, *"Isolation and Control for Final Status Survey"* (Reference 5); ZS-LT-300-001-004, *"Final Status Survey Data Assessment"* (Reference 6); as well as various other station implementing procedures.

The ZNPS LTP, along with the accompanying Safety Evaluation Report (SER), was approved on September 28, 2018.

The End State includes a range of buried piping, embedded piping and penetrations. Buried piping is defined as pipe that runs through soil. The list of buried piping, penetrations and embedded piping to remain is provided in Zion*Solutions* Technical Support Document (TSD) 14-016 "*Description of Embedded Piping, Penetrations, and Buried Pipe to Remain in Zion End State*" (Reference 7).

License Termination Plan Chapter 5, section 5 states,

> "The list of buried piping, penetrations and embedded piping to remain is provided in Zion*Solutions* TSD 14-016, *"Description of Embedded Pipe* [sic, "Piping"]*, Penetrations, and Buried Pipe to Remain in Zion End State"* (Reference 5-8). The list of end-state embedded pipe, buried pipe and penetrations presented in Attachment F to TSD 14-016 is intended to be a bounding end-state condition. No pipe that is not listed in Attachment F will be added to the end-state condition however, pipe can be removed from the list and disposed of as waste."

On May 7, 2019, as part of an FSS surveillance performed on the north portion of the Switchyard open land survey unit (10205) in accordance with Zion*Solutions* procedure

ZS-LT-300-001-003, Characterization/License Termination (C/LT) Technicians collected sediment samples from the bottom of manhole access points to the Switchyard storm drain. The storm drain systems were initially classified as "non-impacted" based on information taken from the *"Zion Station Historical Site Assessment"* (HSA) (Reference 8). In the sediment sample collected from the west access point, both Cs-137 and Co-60 were positively detected. Consequently, the discovery prompted a change of classification in accordance with Zion*Solutions* procedure ZS-LT-300-001-002, "*Survey Unit Classification*" (Reference 9). This storm drain was reclassified as a Class 2 buried pipe and subject to compliance demonstration as required by LTP Chapter 5, section 5.7.1.9.

Since this section of storm drain (approximately 1282 feet of piping) was previously classified as non-impacted, it was not included in Attachment F of TSD 14-016, identifying it as impacted buried piping that will remain. Section 5 of the LTP Revision 2 stated that no additional piping will be added to the impacted piping list as identified in Attachment F of TSD 14-016. It has been determined that leaving the storm drain piping does not adversely impact the release of the impacted area. Therefore, the LTP and TSD have been revised to reflect the acceptability of the pipe reclassification. Zion*Solutions* notified the NRC in June 2019 of the storm drain piping reclassification.

The FSS results provided herein assess and summarize that any residual radioactivity results in a Total Effective Dose Equivalent (TEDE) to an Average Member of the Critical Group (AMCG) that does not exceed 25 mrem per year, and the residual radioactivity has been reduced to levels that are as low as reasonably achievable (ALARA). The release criterion is translated into site-specific Derived Concentration Guideline Levels (DCGLs) for assessment and summary.

This FSS Final Report has been written consistent with the guidance provided in the LTP; NUREG-1757, Vol. 2, "*Consolidated Decommissioning Guidance; Characterization, Survey, and Determination of Radiological Criteria"* (Reference 10); MARSSIM; and the requirements specified in ZS-LT-300-001-005, "*Final Status Survey Data Reporting"* (Reference 11).

To facilitate the data management process, FSS Final Reports incorporate multiple Survey Unit Release Records. Release Records are complete and unambiguous records of the as-left radiological status of each specific survey unit. Sufficient data and information are provided in each Release Record to enable an independent re-creation and evaluation at some future time of both the survey activities and the derived results.

This report contains five (5) buried piping systems, Condensate Feed Water Supply and Recirculation, the Primary Water Supply Header, Diesel Generator Heat Exchangers Service Water Supply and Service Water Return, Service Water Supply Header, and the North Yard Storm Drain.

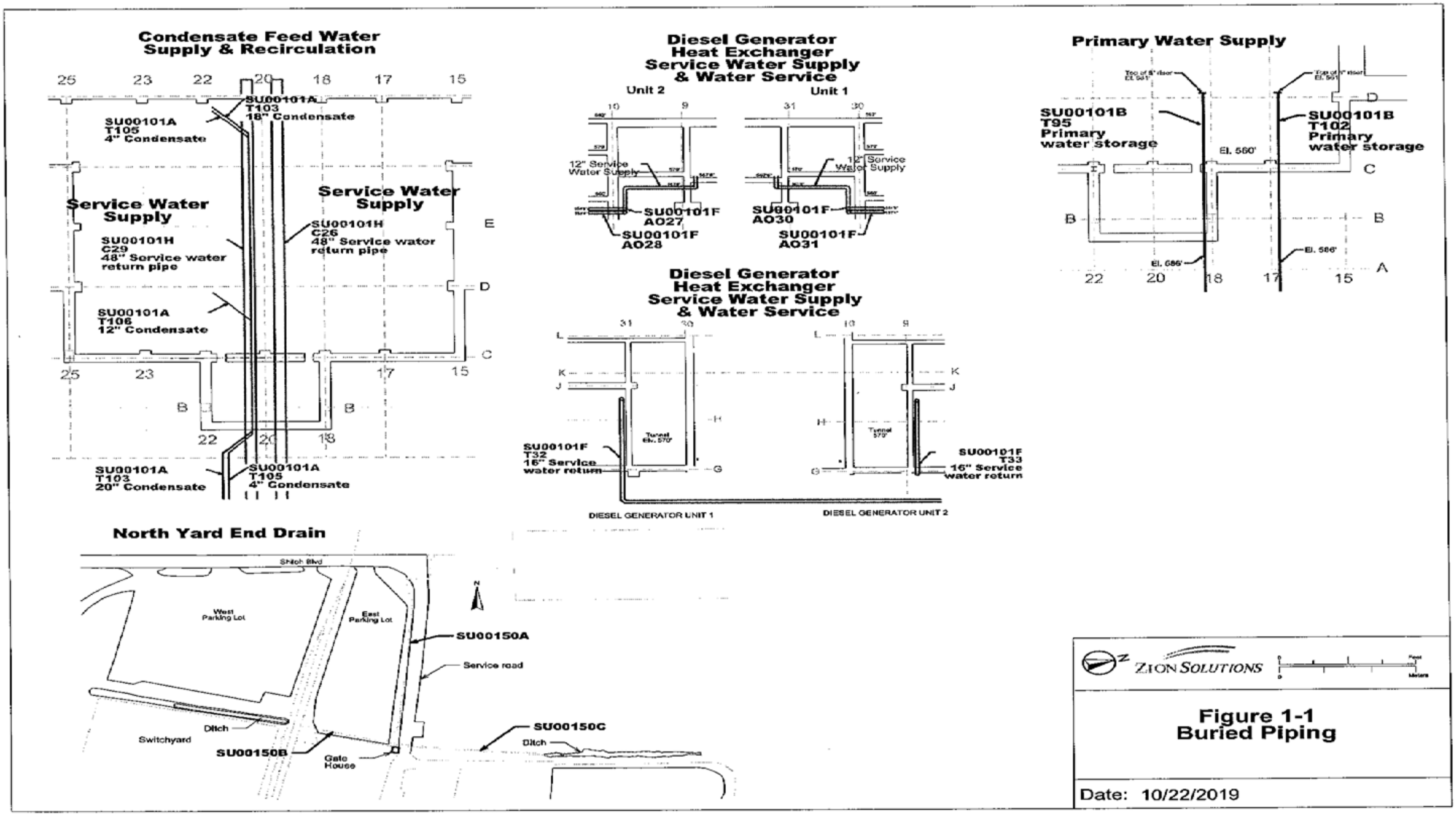
All FSS activities essential to data quality have been implemented and performed under approved procedures. Trained individuals, using properly calibrated instruments and laboratory equipment (sensitive to the suspected contaminants), performed the FSS of the Phase 2 survey units. The survey data for all Phase 2, Part 2 survey units demonstrate that the dose (TEDE) from residual radioactivity is less than the maximum annual dose (TEDE) of 25 mrem/year to the member of the public hypothesized. This dose limit corresponds to the release criterion for license termination of facilities as specified in 10 CFR 20.1402 "Radiological Criteria for Unrestricted Use". It also provides the basis and support for the release of these areas from the 10 CFR 50 licenses. Finally, meeting this release criterion satisfies the ALARA requirement of 10 CFR 20.1402.

Table 1-1, Survey Units Encompassed in Phase 2, Part 2 Report

Survey Unit	Name	Class(1)	Area (ft^2)	Pipe ID
00101A	Condensate Feed Water Supply and Recirculation Buried Pipe	3	2,455	T-103, T-105, and T-106
00101B	Primary Water Supply Header T-095 and T-102 Buried Pipe	2	308	T-095 and T-102
00101F	Diesel Generator Heat Exchangers Service Water Supply and Service Water Return Buried Pipe	3	956	AO-27, AO-28, AO-30, AO-31, TO-32, and TO-33
00101H	Service Water Supply Header CO-26 and CO-29 Buried Pipe	3	5,248	CO-26 and CO-29
00150A/B&C	North Yard Storm Drain Buried Piping	2	2,187	NA

(1) Indicates classification of buried pipe interior

Figure 1-1, Phase 2, Part 2 Survey Unit Release Record Buried Piping Designation



1.2 Phased Submittal Approach

To minimize the incorporation of redundant historical assessment and other FSS program information, and to facilitate potential phased releases from the current licenses, FSS Final Reports are provided in a phased approach. Zion*Solutions* estimates that a total of five (5) FSS Final Reports will be generated and submitted to the NRC during the decommissioning project.

The Phase 1 FSS Final Report, which was originally submitted to the NRC in October of 2018 and resubmitted in June 2019, encompassed the release of eight (8) Class 3 open land survey units.

The Phase 2 FSS Final Report was originally submitted to the NRC in March, 2019 and resubmitted in October, 2019, contained the thirty-one (31) Final Status survey units that encompassed the basement structures including the Unit 1 and Unit 2 Containments, the Spent Fuel Pool/Transfer Canal, the Auxiliary Building, the Crib House/Forebay, the Waste Water Treatment Facility (WWTF) and the Turbine Building.

This Phase 2, Part 2 FSS Final Report addresses buried pipe that is to remain onsite after decommissioning activities are completed.

The Phase 3 FSS Final Report will include the open land survey units encompassing primarily the southern portion of the site.

The Phase 4 FSS Final Report will include the open land areas encompassing primarily the northern portion of the site.

1.3 Phase 2, Part 2 Report

This Phase 2, Part 2 FSS Final Report addresses the buried piping remaining after decommissioning activities were completed. Specifically, this report includes the FSS results for the following buried pipe:

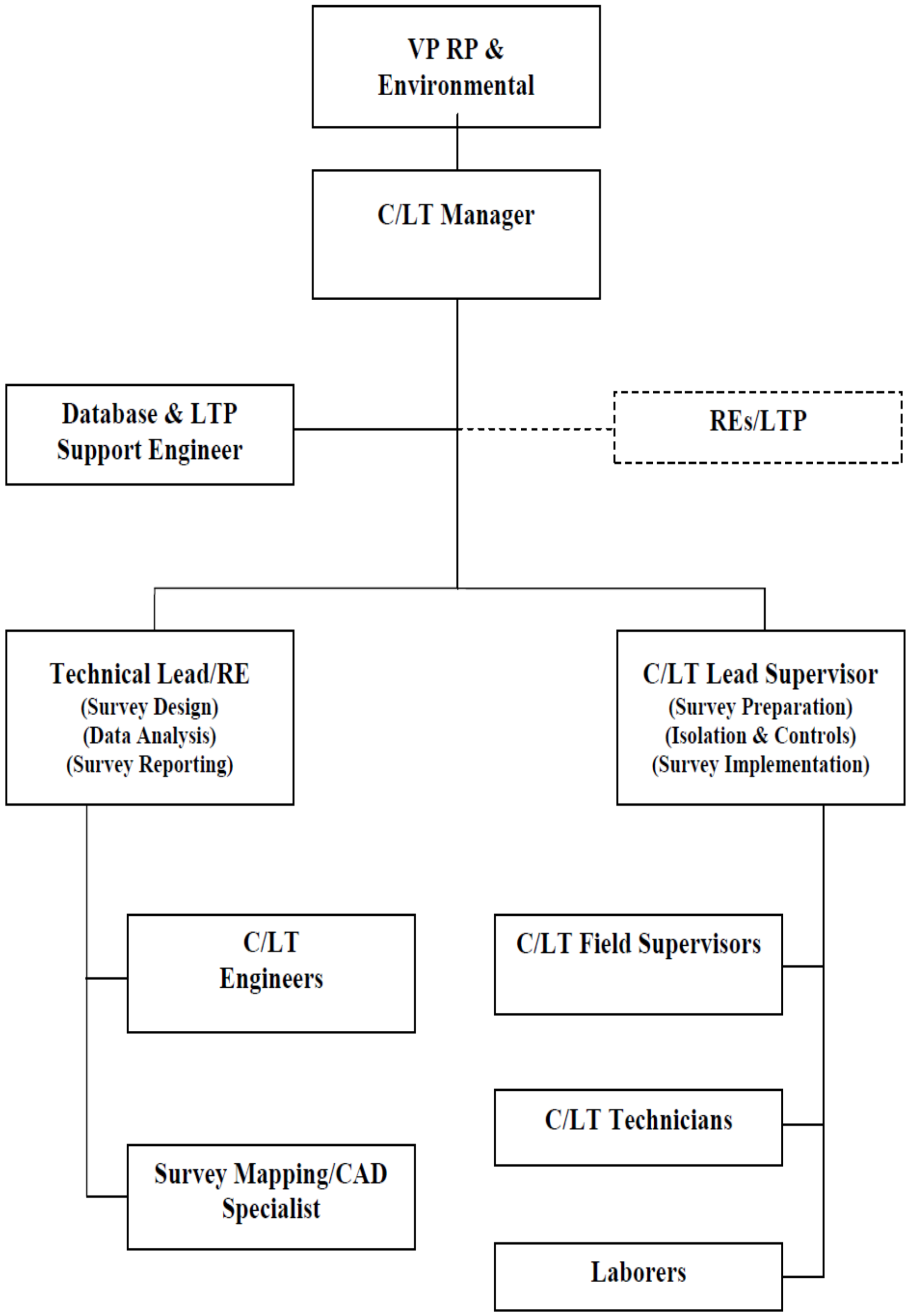
- Survey Unit 00101A - Condensate Feed Water Supply and Recirculation Buried Pipe (pipe IDs T-103, T-105, and T-106),
- Survey Unit 00101B - Primary Water Supply Header (pipes IDs T-095 and T-102),
- Survey Unit 00101F - Diesel Generator Heat Exchangers Service Water Supply and Service Water Return Buried Pipe (pipe IDs AO-27, AO-28, AO-30, AO-31, TO-32, and TO-33),
- Survey Unit 00101H - Service Water Supply Header (pipes IDs CO-26 and CO-29), and
- Survey Unit 00150A/B & C - North Yard Storm Drain Buried Piping.

2. FINAL STATUS SURVEY PROGRAM OVERVIEW

The FSS Program consists of the methods used in planning, designing, conducting, and evaluating FSS at the ZNPS site to demonstrate that the premises are suitable for release in accordance with the criteria for decommissioning in Title 10 CFR 20, Subpart E. Final Status Surveys serve as key elements to demonstrate that the TEDE to an AMCG from residual radioactivity does not exceed 25 mrem per year, and that all residual radioactivity at the site is reduced to levels that are ALARA.

To implement the FSS Program, Zion*Solutions* established the C/LT Group, within the Radiation Protection division, with sufficient management and technical resources to fulfill project objectives. The C/LT Group is responsible for the safe completion of all surveys related to characterization and final site closure. Approved site procedures and detailed TSDs direct the FSS process to ensure consistent implementation and adherence to the LTP and all applicable requirements. Figure 2-1 provides an organizational chart of the C/LT Group.

Figure 2-1, Characterization/License Termination Group Organizational Chart



2.1 Survey Planning

Following the cessation of commercial operation, the development and planning phase was initiated in 1999 by the HSA and the start of the site characterization process. The characterization process was iterative and continued until, in some cases, up to the time of completing FSS. The HSA consisted of a review of site historical records regarding plant incidents, radiological survey documents, and routine and special reports submitted by Exelon to various regulatory agencies. Along with these assessments, interviews with current and past site personnel, reviews of historical site photos, and extensive area inspections were performed to meet the following objectives:

- Develop the information necessary to support FSS design, including the development of Data Quality Objectives (DQO) and survey instrument performance standards.
- Develop the initial radiological information to support decommissioning planning, including building decontamination, demolition, and waste disposal.
- Identify any unique radiological or health and safety issues associated with decommissioning.
- Identify the potential and known sources of radioactive contamination in systems, surface or subsurface soils, groundwater, and on structures.
- Divide the ZNPS site into manageable areas or units for survey and classification purposes.
- Determine the initial classification of each survey area or unit as non-impacted or impacted. Impacted survey areas or units are Class 1, 2, or 3, as defined in MARSSIM.

Data Quality Objectives are qualitative and quantitative statements derived from the DQO process that clarify technical and quality objectives, define the appropriate type of data, and specify the tolerable levels or potential decision errors used as the basis for establishing the quality and quantity of data required to support inference and decisions. This process, described in MARSSIM and procedure ZS-LT-300-001-001, is a series of graded planning steps found to be effective in establishing criteria for data quality and guiding the development of FSS Sample Plans. DQOs developed and implemented during the initial phase of planning directed all data collection efforts.

The DQO approach consists of the following seven steps.

2.1.1 State the Problem

This step provides a clear description of the problem, identification of planning team members (especially the decision makers), a conceptual model of the hazard to be investigated, and the estimated resources required to perform the survey. The problem associated with FSS is to determine whether a given survey unit meets the radiological release criterion of 10 CFR 20.1402.

2.1.2 Identify the Decision

This step consists of developing a decision statement based on a principal study question (i.e., the stated problem) and determining alternative actions that may be taken based on the answer to the principle study question. Alternative actions identify the measures to resolve the problem. The decision statement combines the principal study question and alternative actions into an expression of choice among multiple actions. For the FSS, the principal study question is: Does residual radioactive contamination present in the survey unit exceed the established DCGL values? The alternative actions may include no action, investigation, resurvey, remediation, and reclassification.

2.1.3 Identify Inputs to the Decision

The information required depends on the type of media under consideration (e.g., soil, water, concrete) and whether existing data are sufficient or new data are needed to make the decision. If the decision can be based on existing data, then the source(s) will be documented and evaluated to ensure reasonable confidence that the data area acceptable. If new data are needed, then the type of measurements (e.g., scan, direct measurement, and/or sampling) will need to be determined.

2.1.4 Define the Study Boundaries

The step includes identification of the target population of interest, the spatial and temporal features of that population, the time frame for collecting the data, practical constraints, and the scale of decision making. In FSS, the target population is the set of samples or direct measurements that constitute an area of interest. The medium of interest is specified during the planning process. The spatial boundaries include the entire area of interest, including soil depth, area dimensions, contained water bodies, and natural boundaries. Temporal boundaries include activities impacted by time-related events including weather conditions, season, and operation of equipment under different environmental conditions, resource loading, and work schedule.

2.1.5 Develop a Decision Rule

The step develops the binary statement that defines a logical process for choosing among alternative actions. The decision rule is a clear statement using the "If...then..." format and includes action level conditions and the statistical parameter of interest.

2.1.6 Specify Tolerable Limits on Decision Errors

This step incorporates hypothesis testing and probabilistic sampling distributions to control the decision errors during data analysis. Hypothesis testing is a process based on the scientific method that compares a baseline condition (the null hypothesis) to an alternative condition (the alternative hypothesis). Hypothesis testing rests on the premise that the null hypothesis is true and that sufficient evidence must be provided to reject it.

2.1.7 Optimize the Design for Obtaining Data

The final step in the DQO process leads to the development of an adequate survey design. By using an on-site analytical laboratory, sampling and analysis processes are designed to provide near real-time data assessment during implementation of field activities and FSS. Gamma scans provide information on soil areas that have residual radioactivity greater than background and allow appropriate selection of biased sampling and measurement locations. This data will be evaluated and used to refine the scope of field activities to optimize implementation of the FSS design and ensure the DQOs are met.

As stated, the primary objective of the DQO process was to demonstrate that the level of residual radioactivity found in the soils in the land area survey units, including any areas of elevated activity, was equal to or below the site-specific DCGLs that correspond to the 25 mrem/yr release criterion.

At ZNPS, compliance is demonstrated through the summation of dose from four (4) distinct source terms for the end-state (basements, soils, buried pipe and groundwater). Each radionuclide-specific Base Case DCGL (BcDCGL) is equivalent to the level of residual radioactivity (above background levels) that could, when considered independently, result in a TEDE of 25 mrem per year to an AMCG. To ensure that the summation of dose from each source term is 25 mrem/year or less after all FSS is completed, the BcDCGLs are reduced based on an expected, or *a priori*, fraction of the 25 mrem/year dose limit from each source term. These reduced values are designated as Operational DCGLs (OpDCGL) and these OpDCGLs (LTP Chapter 5, section 5.2.4) are then used as the DCGL for the FSS design of the survey unit (calculation of surrogate DCGLs, investigations levels, etc.). Details of the OpDCGLs derived for each dose component and the basis for the applied *a priori* dose fractions are provided in Zion*Solutions* TSD 17-004, *"Operational Derived Concentration Guideline Levels for Final Status Survey"* (Reference 12).

Buried pipe is defined as a pipe that runs through soil. The critical group for the buried piping dose assessment is the Resident Farmer. The buried pipe DCGLs ($DCGL_{BP}$) expressed in units of dpm/100cm^2 were determined for two (2) scenarios; assuming that all pipe is excavated, and assuming that all pipe remains in situ. Although unrealistic, for the purpose of the bounding modeling approach used, the dose from the two scenarios is summed to determine the $DCGL_{BP}$. RESRAD was used to calculate $DCGL_{BP}$ for both the excavation and in situ buried pipe scenarios using the parameters developed for soil modified as necessary for the buried pipe source term geometry. Details on dose assessment methods are provide in LTP section 6.12.

Table 2-1 (reproduced from LTP Tables 5-9 and 5-10) provides a listing for the Base Case and Operational DCGLs for Buried Piping.

Table 2-1, – Base Case and Operational DCGLs for Buried Pipe

Radionuclide	Base Case Buried Pipe DCGL dpm/100cm^2	Operational Buried Pipe DCGL dpm/100cm^2
Co-60	2.64E+04	6.76E+03
Cs-134	4.54E+04	1.16E+04
Cs-137	1.01E+05	2.59E+04
Ni-63	4.89E+07	1.25E+07
Sr-90	4.50E+04	1.15E+04

The development of information to support decommissioning planning and execution was accomplished through a review of all known site radiological and environmental records. Much of this information was consolidated in the HSA, Zion*Solutions* TSD 14-028, "*Radiological Characterization Report*" (Reference 13), and in files containing copies of records maintained pursuant to Title 10 CFR 50.75(g)(1). These documents are discussed further in applicable sections of this report.

An initial objective of site characterization and assessment was to correlate the impact of a radiological event to physical locations on ZNPS site and to provide a means to correlate subsequent survey data. To satisfy these objectives, the entire 331-acre site was divided into survey areas. Survey area size determination was based upon the specific area and the most efficient and practical size needed to bound the lateral and vertical extent of contamination identified in the area. Survey areas that have no reasonable potential for contamination were classified as non-impacted. These areas had no radiological impact from site operations and are identified in the HSA. Survey areas with reasonable potential for contamination were classified as impacted.

Classification, as described in MARSSIM, is the process by which an area or survey unit is described according to its radiological characteristics and potential for residual radioactivity. Residual radioactivity could be evenly distributed over a large area, appear as small areas of elevated activity, or a combination of both. In some cases, there may be no residual radioactivity in an area or survey unit. Therefore, the adequacy and effectiveness of the FSS process depends upon properly classified survey units to ensure that areas with the highest potential for contamination receive a higher degree of survey effort.

The impacted survey areas established by the HSA were further divided into survey units.

The purpose of scan measurements is to confirm that the area was properly classified and that any small areas of elevated radioactivity are within acceptable levels (i.e., are less than the applicable Elevated Measurement Comparison ($DCGL_{EMC}$). Depending on the sensitivity of the scanning method used, the number of total surface contamination measurement locations may need to be increased so the spacing between measurements is reduced.

The amount of area to be covered by scan measurements is presented in Table 2-2, which is reproduced from Table 5.9 from MARSSIM.

Table 2-2, Recommended Survey Coverage

Area Classification	Surface Scans	Soil Samples/Static Measurements
Class 1	100%	Number of sample/measurement locations for statistical test, additional sample/measurements to investigate areas of elevated activity
Class 2	10% to 100%, Systematic and Judgmental	Number of sample/measurement locations for statistical test
Class 3	Judgmental (typically <10%)	Number of sample/measurement locations for statistical test

Prior to FSS, each survey unit's classification was reviewed and verified in accordance with the LTP and its implementing procedures. A classification change to increase the class could have been implemented without notification to regulatory authorities. A classification change to decrease the class could be implemented only after accurate assessment and notification to regulatory authorities as detailed in the LTP and its implementing procedures. Final classification was performed in conjunction with the preparation of the FSS Sample Plan. The Sample Plan reconciles all outstanding characterization data into the final characterization.

2.2 Survey Design

Final Status Surveys for the ZNPS site are designed following Zion*Solutions* procedures, the LTP, and MARSSIM guidance. FSS design utilizes the combination of traditional scanning surveys, systematic sampling protocols and investigative/judgmental methodologies to evaluate survey units relative to the applicable release criteria within each survey plan.

To aid in the development of an initial suite of potential Radionuclides of Concern (ROC) for the decommissioning of ZNPS, the analytical results of representative characterization samples collected at the site were reviewed. In general, the samples associated with these results were collected from within various waste/process streams and sent off site to meet the analysis criteria of 10 CFR 61, Subparts C and D. This initial suite of potential radionuclides was further refined by the Containment and Auxiliary Building concrete core data analysis. This analysis determined that Co-60, Cs-134, Cs-137, Ni-63, and Sr-90 accounted for 99.5% of all dose in the contaminated concrete mixes. For activated concrete, H-3, Eu-152, and Eu-154, in addition to the five aforementioned nuclides, accounted for 99% of the dose. Since activated

concrete will be removed and disposed of as waste, the final suite of ROC for all areas outside of the Containments does not include H-3, Eu-152, and Eu-154. In accordance with LTP Chapter 5, section 5.1, it was determined that the suite of ROC and radionuclide mixture derived for the Auxiliary Building concrete was considered as a reasonably conservative mixture to apply to soils and buried piping for FSS planning and implementation.

The final suite of potential radionuclides and the mixture is provided in Table 2-3 (reproduced from LTP Table 5-2).

Table 2-3, Dose Significant Radionuclides and Mixture

Radionuclide	% of Total Activity (normalized)(1)(2)
Co-60	0.92%
Cs-134	0.01%
Cs-137	75.32%
Ni-63	23.71%
Sr-90	0.05%

(1) Based on maximum percent of total activity from Table 20 of TSD 14-019, normalized to one for the dose significant radionuclides.
(2) Does not include dose significant radionuclides for activated concrete (H-3, Eu-152, Eu-154).

Characterization results determined that Co-60 and/or Cs-137 would be the primary ROC for the majority of survey design. Cs-137 characterization data for the survey units discussed in this report were used to determine the expected variability, number of samples required, and investigation levels for FSS design.

The dose contribution from each ROC was accounted for using the Sum of Fractions (SOF) to ensure that the total dose from all ROC did not exceed the dose criterion. The SOF or "unity rule" was applied to the data used for the survey planning, and data evaluation and statistical tests for soil sample analyses since multiple radionuclide-specific measurements were performed or the concentrations inferred based on known relationships. The application of the unity rule served to normalize the data to allow for an accurate comparison of the various data measurements to the release criteria. When the unity rule is applied, the $DCGL_W$ (used for the nonparametric statistical test) becomes one (1). The use and application of the unity rule was performed in accordance with section 4.3.3 of MARSSIM.

Survey design objectives included a verification of the survey instrument's ability to detect the radiation(s) of interest relative to the DCGL. As standard practice to ensure that this objective was consistently met, radiation detection instruments used in FSS were calibrated on a yearly frequency with a National Institute of Standards and Technology (NIST) traceable source in accordance with Zion*Solutions* procedures. Instruments were response checked before and after use. Minimum Detectable Count Rates (MDCR) were established and verified prior to

FSS. Control and accountability of survey instruments were maintained and documented to assure quality and prevent the loss of data.

The level of effort associated with planning a survey is based on the complexity of the survey, structural interferences/limitations, and the nature of the hazards. Guidance for preparing FSS plans was provided in procedure ZS-LT-300-001-001.

Final Status Surveys were conducted on the buried piping to demonstrate that the concentrations of residual radioactivity were equal to or below site-specific OpDCGLs.

Buried Piping was classified in accordance with Attachment F of Zion*Solutions* TSD 14-016 and continuing characterization results.

The FSS of buried pipe was performed utilizing a Ludlum Model 2350-1 Data Logger paired with a Ludlum sodium/iodide (NaI) or cesium iodide (CsI) gamma detector. In some cases, the detector was calibrated for a Cs-137 energy window in order to reduce the impact of Naturally Occurring Radioactive Material (NORM) in the surrounding soils. Each measurement had a calculated Field of View (FOV) for that specific piping diameter. One-minute static measurements were taken to quantify the activity in the pipe. The detector efficiencies were determined for each instrument using a wide range of pipe interior diameters and geometries with NIST traceable planar sources.

2.3 Survey Implementation

Final Status Survey implementation of the first four (4) buried pipe survey units, contained within this Phase 2, Part 2 report, commenced on May 7, 2018. FSS implementation for the remaining Phase 2, Part 2 buried pipe survey unit (00150A/B & C) commenced in July 25, 2019. Implementation was the physical process of the FSS Sample Plan execution for a given survey unit. Each Sample Plan was assigned to a Radiological Engineer (RE) for implementation and completion in accordance with the LTP, Zion*Solutions* procedures and the QAPP for Characterization and FSS. A walk-down and turnover survey was performed for each FSS survey unit in accordance with the Isolation and Control requirements of procedure ZS-LT-300-001-003. A turnover survey was performed within each FSS survey unit and consisted of surveys for loose surface contamination as well as the acquisition of several scoping measurements.

The tasks included in the implementation were:

- Verification and validation of personnel training as required by Training Department and Radiation Protection procedures.
- Survey Packages were developed in accordance with Zion*Solutions* procedure ZS-LT-300-001-001. The FSS unit was inspected and controlled in accordance with Zion*Solutions* procedure ZS-LT-300-001-003.

- Monitoring instrument calibration and routine performance checks, as detailed in ZS-RP-108-000-000, "*Radiological Instrumentation Program*" (Reference 14) and ZS-RP-108-004-012, "*Calibration and Initial Set-Up of the 2350-1*" (Reference 15).
- Implementation of applicable operating and health and safety procedures.
- Implementation of isolation of control of the survey unit in accordance with ZS-LT-300-001-003.
- Determination of the amount of surveys and sampling required to meet DQOs as described in ZS-LT-300-001-001.
- Proper techniques for collecting and handling FSS samples in accordance with Job Aid LT-JA-004, "*FSS Sample Collection*" (Reference 16).
- Maintaining Quality Assurance/Quality Control requirements (i.e., replicate measurements or samples) in accordance with the QAPP.
- Sample Chain of Custody maintained in accordance with ZS-LT-100-001-004, "*Sample Media Preparation for Site Characterization*" (Reference 17).
- Sample submission to approved laboratories in accordance with ZS-WM-131, "*Chain of Custody Protocol*" (Reference 18).
- Application of the DCGLs to sample results in accordance with the Data Quality Assessment (DQA) process as detailed in ZS-LT-300-001-004.
- Determination of investigation methodology and corrective actions, if applicable.

The FSS implementation and completion process resulted in the generation of field data and analysis data consisting of measurements taken with handheld radiation detecting equipment, observations noted in field logs, and radionuclide specific analysis. Data were stored electronically on the Zion*Solutions* common network.

2.4 Survey Data Assessment

Prior to proceeding with data evaluation and assessment, the assigned FSS Engineer ensured consistency between the data quality and the data collection process, and the applicable requirements.

The DQA process is an evaluation method used during the assessment phase of FSS to ensure the validity of FSS results and demonstrate achievement with the FSS Sample Plan objectives. A key step in the data assessment process converts all of the survey results to DCGL units, if necessary. The individual measurements and sample concentrations are compared to the DCGL for evidence of small areas of elevated activity or results that are statistical outliers. When practical, graphical analyses of survey data that depicts the spatial correlation of the measurements was used.

The DQO process was employed to determine the ROC for each FSS unit in this report. During FSS, concentrations for Hard to Detect (HTD) ROC, Ni-63 and Sr-90 were inferred using a surrogate approach. Cs-137 is the principle surrogate radionuclide for Sr-90. Co-60 is the principle surrogate radionuclide for Ni-63. The maximum ratios were used to infer HTD concentrations during FSS unless area specific ratios were determined. In these cases, the ratios used and their basis are described in the individual Release Record.

In accordance with LTP Chapter 5 section 5.6.4.1.1, the Type I decision error was set at 0.05 and the Type II decision error was set at 0.05. The upper boundary of the gray region was set at the $OpDCGL_{BP}$. The Lower Bound of the Gray Region (LBGR) was set at the expected fraction of the $OpDCGL_{BP}$.

2.5 Quality Assurance and Quality Control Measures

Quality assurance and control measures were employed throughout the FSS process to ensure that all decisions were based on data of acceptable quality. Quality assurance and control measures were applied to ensure:

- The plan was correctly implemented.
- The DQA process was used to assess results.
- DQOs were properly defined and derived.
- All data and samples were collected by individuals with the proper training and in adherence to approved procedures and sample plans.
- All instruments were properly calibrated and routinely performance checked.
- All collected data was validated, recorded, and stored in accordance with approved procedures.
- All required documents were properly maintained.
- Corrective actions were prescribed, implemented and tracked, as necessary.

Independent laboratories used for analysis of the samples collected during FSS maintain Quality Assurance Plans designed for their facility. Zion*Solutions* reviewed those plans, as required by ZS-QA-10, "*Quality Assurance Project Plan*" (Reference 19) and the QAPP for Characterization and FSS, prior to selection. In addition, regular vendor performance reviews, audits and/or surveillances of these laboratories were performed to ensure an adequate level of quality.

The Zion*Solutions* Quality Assurance (QA) department provided oversight of the C/LT Group on a consistent basis throughout the project at the Zion Station Restoration Project (ZSRP). QA surveillances have scrutinized the LTP, C/LT procedures, Sample Plans, and C/LT records. The responses to the QA surveillances are captured in the Corrective Action Program (CAP).

3. SITE INFORMATION

3.1 Site Description

Zion Nuclear Power Station, owned by Exelon Nuclear Generation, LLC (Exelon), is located in Zion, Illinois, on the west shore of Lake Michigan. The site is approximately 40 miles north of Chicago, Illinois, and 42 miles south of Milwaukee, Wisconsin.

The owner-controlled site consisted of approximately 331-acres, and within the owner-controlled site was an approximate 87-acre, fence-enclosed nuclear facility. The center of the community of Zion was approximately 1.6 miles from the plant location on the site. There are no schools or hospitals within one mile of the site, and no residences are within 2,000 feet of any ZNPS structures.

Westinghouse Electric Corporation, Sargent and Lundy Engineers, and the Commonwealth Edison Company (ComEd) jointly participated in the design and construction of ZNPS. The plant was comprised of two pressurized water reactors with supporting facilities. The primary coolant system for each unit employed a four-loop pressurized water reactor nuclear steam supply system housed in a steel-lined, reinforced concrete containment structure. Each unit employed a pressurized water reactor nuclear steam supply system furnished by Westinghouse Electric Corporation, designed for a power output of 3,250 MWt. The equivalent warranted gross and approximate net electrical outputs of the plant were 1085 MWe and 1050 MWe, for Unit 1 and Unit 2 respectively.

ZNPS was previously operated by Commonwealth Edison until it was permanently shut down on February 13, 1998. On March 9, 1998, ComEd certified to the NRC that all fuel assemblies had been permanently removed from both reactors and placed in the Spent Fuel Pool. The NRC acknowledged the certification of permanent cessation of power operation and permanent removal of fuel from the reactor vessels in a letter dated May 4, 1998. In 2000, the licenses were transferred from ComEd to Exelon. In 2008, the licenses were transferred to Zion*Solutions* to coordinate and execute the decommissioning of the site. The Post Shutdown Decommissioning Activities Report (PSDAR) (Reference 20) was submitted, in accordance with 10 CFR 50.82(a), in February 2000 and accepted by the NRC. An amended PSDAR was submitted in March 2008 to accommodate the transfer of the 10 CFR 50 licenses to Zion*Solutions* and to revise cost estimates and the decommissioning schedule. The Defueled Safety Analysis Report (DSAR) (Reference 21) was updated in October 2016. An evaluation of the structures, systems, and components (SSCs) was performed to determine the function these systems would perform in a defueled condition. With the relocation of the spent fuel to the Independent Spent Fuel Storage Installation (ISFSI), the license basis for the majority of the SSCs was changed and only minimal SSCs were needed to support the ongoing active decommissioning. The remaining SSCs needed to support active decommissioning had controls established in the DSAR and the Offsite Dose Calculation Manual (ODCM) (Reference 22).

On November 2, 2011, site characterization commenced. At the time these surveys were performed, the site-specific Zion*Solutions* characterization plans and procedures were still under development. Consequently, due to schedule restraints, Zion*Solutions* contracted the Energy*Solutions* Commercial Services Group (ESCSG) to perform characterization of the ISFSI location, the Vertical Concrete Cask (VCC) Construction Area, and the pathway for the new rail track. The results of these surveys were validated and integrated into the subsequent site-specific characterization program, which was approved in February of 2012. Initial scheduled site characterization efforts concluded on November 11, 2013. The results of site characterization are presented in LTP Chapter 2 as well as TSD 14-028.

3.2 Survey Unit Description

The following information is a description of each survey unit at the time of FSS. During this period, five (5) FSS survey units, contained in five (5) release records, were completed and the results are presented in this Phase 2, Part 2 Final Report. The five (5) release records are included in this final report as appendices.

3.2.1 Survey Unit 00101A - Condensate Feed Water Supply and Recirculation Buried Pipe (Pipe IDs T-103, T-105 & T-106)

The Condensate Feed Water Supply and Recirculation Buried Pipes consisted of three sections of 20-inch Outside Diameter (OD) Condensate pipe that ran under the Turbine Building basement floor slab. The T-103 section was approximately 226 feet long, running from the penetration in the Oil Room to a vertical through the Turbine Building basement floor slab. The pipe approached the east wall of the Turbine Building basement from the Crib House basement approximately 51 feet under the road from east to west at a depth of approximately the 586 foot elevation. The pipe then turned 90 degrees downward and ran a distance of 30 feet and turned 90 degrees west where it penetrated the east "A" wall of the Turbine Building basement at the 556 foot elevation. The pipe then ran from east to west under the Turbine Building basement floor slab. The remaining Condensate pipe branched into two different headers which both terminated on the 560 foot elevation (floor) of the Turbine Building. The T-105 section was approximately 221 feet in length and ran to the Condensate Recirculation pump. The T-106 section was approximately 21 feet in length and ran to Condensate Transfer and Make-up Pumps. The total length of the entire Condensate Feed Water Supply and Recirculation pipe identified by these three (3) sections of pipe was approximately 468 feet.

The Condensate pipes were cut inside the Turbine Building basement prior to the demolition and basement backfill. As they were not capped or isolated, there was unobstructed groundwater intrusion into each pipe. The T-105 pipe was accessible for survey measurements to be conducted. However, neither the T-103 nor the T-106 sections of this system were available for survey due to groundwater intrusion. Since the T-105 buried pipe was part of the same system, it was determined that measurements taken within the T-105 section of pipe

would be representative of radiological conditions within the system interior, including the two (2) pipes obstructed by groundwater intrusion.

Based on information from the Zion Station HSA, the initial classification for this buried pipe was Class 3. In accordance with Zion*Solutions* procedure ZS-LT-300-001-002, *"Survey Unit Classification,"* survey unit 00101A was classified as MARSSIM Class 3.

During the FSS of the Turbine Building and Crib House basements, radiological surveys were performed in several sections of Service Water Piping associated with the Circulating Water Intake Pipe and Circulating Water Discharge Tunnels. Radiological surveys were also performed to support the segmentation and removal of Condensate and Service Water pipe that was connected to the sections of end-state buried pipe.

Based upon completion of Survey Unit Classification Basis for final classification, which included a review of the historical information, the results of the survey data, and completion of a final Survey Unit Classification Worksheet, it was concluded that there was a low probability for the presence of residual radioactivity in these pipes in concentrations greater than 50% of the OpDCGLs, justifying a FSS unit classification of Class 3.

The three (3) pipes (Pipe IDs T-103, T-105 and T-106) that constituted this survey unit were situated below the level of ground water. Due to constant groundwater intrusion into pipes T-103 and T-106, these pipes were considered as "obstructed." In addition, due to their physical configuration and depth, complete removal of pipe sections T-103 and T-106 were also not feasible. However, pipe section T-105 was available for removal and the pipe was cut into sections and placed on the ground to the northeast of the Turbine Building.

FSS of the T-105 section of the Condensate Pipe began on May 11, 2017. A Ludlum Model 2350-1 was coupled with Ludlum Model 44-162 sodium iodide (NaI) gamma detector to perform this FSS. The detector was transported through the pipe interiors using the ¾" fiber rod. A one-minute static measurement was acquired at on-foot intervals throughout the interior of the accessible pipe (257 feet). For a 20-inch OD pipe, this equates to an areal scan coverage of 1,283.8 ft^2 of area, which is approximately 52.2% of the total internal surface area of the Condensate Pipe (2,456.1 ft^2).

3.2.2 Survey Unit 00101B - Primary Water Supply Header Buried Pipe (Pipe IDs T-095 and T-102)

The Primary Water Supply Header consisted of two sections of 6-inch ID pipe that ran under the Turbine Building basement floor slab. The pipe supplied water to the Primary Water Storage Tank (PWST). The length of the T-095 section was approximately 118 feet, running from the penetration in the Oil Room to a vertical through the Turbine Building basement floor slab. The length of the T-102 section was approximately 78 feet. During removal of the PWST and the associated piping, the pipe was cut at the 588 foot elevation above the elbow into the penetration though the Oil Room wall at the 556 foot elevation. The total length of the

two (2) pipe sections that made up the Primary Water Supply Header was approximately 196 linear feet. The entire internal area of the interior surfaces of the two pipes combined was 308 ft^2.

Survey unit 00101B was initially classified as Class 3 in accordance with Attachment F of TSD 14-016 and from information taken from the HSA. The survey unit was reclassified as Class 2 in accordance with Zion*Solutions* procedure ZS-LT-300-001-002, *"Survey Unit Classification."* Prior to performing the survey, the classification was changed to Class 2 in response to the discovery of detectable residual radioactivity during the removal of the PWST, which was serviced by the Primary Water Supply Header pipe.

Based upon completion of Survey Unit Classification Basis for final classification, which included a review of the historical information, the results of the survey data, and completion of a final Survey Unit Classification Worksheet, it was concluded that there was a probability for the presence of residual radioactivity in these pipes, however at concentrations less than the OpDCGL for buried pipe, justifying a FSS unit classification of Class 2

The pipes were cut inside the Turbine Building basement prior to the demolition and basement backfill. As they were not capped or isolated, there was unobstructed groundwater intrusion into each pipe. Sections for both the T-095 pipe and the T-102 pipe became inaccessible due to groundwater flooding into the pipe. Since the sections of the T-095 and T-102 pipe, as well as the sections of the pipe located above the 588 foot elevation slated for removal were part of the same system, it was determined that measurements taken within the removed sections of pipe would be representative of radiological conditions within the two (2) pipes obstructed by groundwater intrusion.

The Primary Water Supply Header pipe was surveyed with a Ludlum Model 2350-1 Data Logger paired with a Ludlum Model 44-157 NaI gamma detector. One-minute static measurements were taken to quantify the activity in the pipe. Each measurement had a calculated FOV of 1.57 ft^2. A minimum of one hundred (100) measurements were necessary to provide for 50% areal surface coverage for a Class 2 survey.

3.2.3 Survey Unit 00101F - Diesel Generator Heat Exchangers Service Water Supply and Service Water Return Buried Pipe (Pipe IDs AO-27, AO-28, AO-30, AO-31, TO-32, and TO-33)

The Diesel Generator Heat Exchanger Service Water Supply piping consists of 12-inch ID pipe that is 304.4 linear feet in length, which equates to a surface area of 956.3 ft^2. The piping consists of four (4) sections: for Unit 1, AO-30 (74.5 feet) and AO-31 (77.7 feet), and for Unit 2, AO-27 (74.5 feet) and AO-28 (77.7 feet). The openings for these pipe sections are on the Diesel Generator Room floor (567 foot elevation), and on the north and south walls of the Auxiliary Building (553 foot and 554 foot elevation).

The Diesel Generator Heat Exchanger Service Water Return buried piping consisted of two (2) sections of 15-inch ID ran 367.2 linear feet under the Turbine Building basement pad (TO-32 and TO-33). The pipes were cut on the floor opening thus exposing both pipes to groundwater intrusion. At the time of FSS, the Return sections of this pipe (Pipe IDs TO-32 and TO-33) were determined to be obstructed by unmitigated groundwater intrusion. Consequently, the measurements taken in the unobstructed sections (Pipe IDs AO-27, AO-28, AO-30, and AO-31) were deemed as representative of the entire pipe length. The total length of the piping of this survey unit was 671.6 linear feet (204.7 meters).

The Diesel Generator Heat Exchanger Service Water Supply and Return piping (Pipe IDs AO-27, AO-28, AO-30, AO-31, TO-32 and TO-33) were classified as MARSSIM Class 3 in accordance with Attachment F of TSD 14-016 and from information taken from the Zion Station HSA.

Based upon completion of Survey Unit Classification Basis for final classification, which included a review of the historical information, the results of the survey data, and completion of a final Survey Unit Classification Worksheet, it was concluded that there was a low probability for the presence of residual radioactivity in these pipes in concentrations greater than 50% of the OpDCGLs, justifying a FSS unit classification of Class 3.

The Diesel Generator Heat Exchanger Service Water Supply pipes were surveyed with a Ludlum Model 2350-1 Data Logger paired with a Ludlum Model 44-10 NaI gamma detector calibrated for a Cs-137 energy window. One-minute static measurements were taken to quantify the activity in the pipe. Each measurement had a calculated FOV for a 12-inch diameter piping of 3.14 ft^2 (2,919 cm^2). The total length of the piping of this survey unit was 671.6 linear feet. The Diesel Generator Heat Exchanger Service Water buried piping was not accessible at the time the survey was performed due to unmitigated groundwater intrusion into the pipe. However, the Diesel Generator Heat Exchanger Service Water Return piping was part of the same system as the Diesel Generator Heat Exchanger Service Water Supply piping and therefore, the radiological conditions in the Supply pipe were considered to be radiologically representative of the entire piping system.

3.2.4 Survey Unit 00101H - Service Water Supply Header Buried Pipe(Pipe IDs CO-26 and CO-29)

The Service Water Supply Header Buried Pipe (Pipe IDs CO-26 and CO-29) consisted of two (2) sections of 48-inch ID pipe that were approximately 208.8 feet in length. The piping ends at the G Wall of the Auxiliary Building on the 548 foot elevation. The piping ran under the Turbine Building basement. The two 48-inch Service Water Supply Header pipes exited the Auxiliary Building at the 550 foot elevation. The pipes traversed east approximately 10 feet beneath the 560 foot elevation Turbine Building floor and exited the Turbine Building Oil Room wall at the 548 foot elevation. The pipes then traversed 8 feet east, then rose vertically from the 548 foot elevation to the 579 foot elevation. The pipes continued eastward to the Crib

House wall. The horizontal sections traversing from the Turbine Building to the Crib House at the 579 foot elevation was cut and the ends at the Crib House were capped.

The Service Water Supply Header piping (Pipe IDs CO-26 and CO-29) was classified as MARSSIM Class 3 in accordance with Attachment F of TSD 14-016 and from information taken from the Zion Station HSA.

The Service Water Supply Header pipe was surveyed with a Ludlum Model 2350-1 Data Logger paired with a Ludlum Model 44-157 NaI gamma detector. One-minute static measurements were taken to quantify the activity in the pipe. Each measurement had a calculated FOV of 4.45 ft^2 (4,134 cm^2). Fifty-nine (59) measurements per pipe were necessary to provide for 10% areal surface coverage for a Class 3 survey. The total linear feet of pipe in this survey unit was approximately 417.6 feet.

Based upon completion of Survey Unit Classification Basis for final classification, which included a review of the historical information, the results of the survey data and, completion of a final Survey Unit Classification Worksheet, it was concluded that there was a low probability for the presence of residual radioactivity in these pipes in concentrations greater than 50% of the OpDCGLs, justifying a FSS unit classification of Class 3.

3.2.5 Survey Unit 00150A/B & C - North Yard Storm Drain Buried Piping

Section A of survey unit 00150A/B & C consisted of the buried 6-inch ID storm drain pipe that runs from the north end of the electrical switchyard to the open drainage ditch located in the southern portions of open land survey areas 10212 and 10213, flowing west to east into Lake Michigan. A second header is also located along the site access road in open land survey area 10214. This header ties into the west/east header under the site parking lot. The storm drain system itself consisted of 6-inch ID smooth wall steel pipe that was approximately 135 linear feet in length. This equated to an internal surface area of approximately 212 ft^2.

Section B of survey unit 00150A/B & C consisted of the buried 8-inch ID PVC storm drain pipe that was located along the access road north of the Protected Area and was approximately 515 linear feet in length, which equated to a surface area of 1,079 ft^2. This piping connected Catch Basin (CB)-1 to CB-6.

Section C of survey unit 00150A/B & C consisted of the buried 8-inch, 12-inch and 15-inch ID piping that was located along the side of the access road north of the Protected Area. The pipe was in three sections that totaled approximately 269 linear feet of pipe.

- The 8-inch ID PVC pipe ran from CB-7 to a capped off section of pipe. This section was approximately 35 linear feet in length, which equated to a surface area of 73 ft^2.
- The 12-inch ID smooth steel wall piping ran from CB-6 to CB-7. This section of pipe was approximately 119 linear feet in length, which equated to a surface area of 374 ft^2.
- The 15-inch corrugated steel piping ran from the West Ditch to CB-7. This section of pipe was approximately 115 linear feet in length, which equated to a surface area of 452 ft^2.

On May 7, 2019, as part of an FSS surveillance performed on the north portion of the Switchyard open land survey unit (10205) in accordance with Zion*Solutions* procedure ZS-LT-300-001-003, C/LT Technicians collected sediment samples from the bottom of manhole access points to the Switchyard storm drain. Both storm drain systems were initially classified as non-impacted from information taken from the HSA. In the sediment sample collected from the west access point (L2-10214C-RJGS-001-SM), both Cs-137 and Co-60 were positively detected at concentrations of 2.22E+00 pCi/g and 1.80E-01 pCi/g, respectively. Consequently, the discovery prompted a change of classification in accordance with Zion*Solutions* procedure ZS-LT-300-001-002. This storm drain, which had previously been classified as "non-impacted" was reclassified as a MARSSIM Class 2 buried pipe and subject to compliance demonstration as required by LTP Chapter 5, section 5.7.1.9.

License Termination Plan Chapter 5, section 5 states,

> "The list of buried piping, penetrations and embedded piping to remain is provided in Zion*Solutions* TSD 14-016, *"Description of Embedded Pipe* [sic, "Piping"]*, Penetrations, and Buried Pipe to Remain in Zion End State"* (Reference 5-8). The list of end-state embedded pipe, buried pipe and penetrations presented in Attachment F to TSD 14-016 is intended to be a bounding end-state condition. No pipe that is not listed in Attachment F will be added to the end-state condition however, pipe can be removed from the list and disposed of as waste."

TSD 14-016 is Reference 7 in this Final Report. Since this section of storm drain (approximately 1282 feet of piping) was previously classified as non-impacted, it was not included in Attachment F of TSD 14-016, identifying it as impacted buried piping that will remain. Section 5 of the LTP Revision 2 stated that no additional piping will be added to the impacted piping list as identified in Attachment F of TSD 14-016. It has been determined that leaving the storm drain piping does not adversely impact the release of the impacted area. Therefore, the LTP and TSD have been revised to reflect the acceptability of the pipe reclassification. ZionSolutions notified the NRC in June 2019 of the storm drain piping reclassification.

A final classification assessment was performed in accordance with procedure ZS-LT-300-001-002 as part of the survey design for FSS. The assessment confirmed that survey unit 00150A/B & C was correctly classified as MARSSIM Class 2.

3.3 Summary of Historical Radiological Data

The site historical radiological data for this Phase 2, Part 2 FSS Final Report incorporates the results of the HSA issued in 1999 and supplemented in 2006, and includes the initial characterization surveys completed in 2013.

3.3.1 Historical Site Assessment and Characterization Surveys

The HSA was a detailed investigation to collect existing information (from the start of ZNPS activities related to radioactive materials or other contaminants) for the site and its surroundings. The HSA focused on historical events and routine operational processes that resulted in contamination of plant systems, onsite buildings, surface and subsurface soils within the Radiologically Controlled Area (RCA). It also addressed support structures, open land areas and subsurface soils outside of the RCA but within the owner-controlled area. The information compiled by the HSA was used to establish initial area survey units and their MARSSIM classifications. This information was used as input into the development of site-specific DCGLs, remediation plans and the design of the FSS. The scope of the HSA included potential contamination from radioactive materials, hazardous materials, and other regulated materials.

The objectives of the HSA were to:

- Identify potential, likely, or known sources of radioactive and chemical contaminants based on existing or derived information.
- Distinguish portions of the site that may need further action from those that pose little or no threat to human health.
- Provide an assessment of the likelihood of contaminant migration.
- Provide information useful to subsequent continuing characterization surveys.
- Provide an initial classification of areas and structures as non-impacted or impacted.
- Provide a graded initial classification for impacted soils and structures in accordance with MARSSIM guidance.
- Delineate initial survey unit boundaries and areas based upon the initial classification.

The survey units established by the HSA were used as initial survey units for characterization. Prior to characterization, survey unit sizes were adjusted in accordance with the guidance provided in MARSSIM section 4.6 for the suggested physical area sizes for survey units for FSS.

Site characterization of the ZNPS was performed in accordance with ZS-LT-02, "*Characterization Survey Plan*" (Reference 23). It was developed to provide guidance and direction to the personnel responsible for implementing and executing characterization survey activities. The Characterization Survey Plan worked in conjunction with implementing procedures and survey unit specific survey instructions (sample plans) that were developed to safely and effectively acquire the requisite characterization data.

Characterization data acquired through the execution of the Characterization Survey Plan was used to meet three primary objectives:

- Provide radiological inputs necessary for the design of FSS.
- Develop the required inputs for the LTP.
- Support the evaluation of remediation alternatives and technologies and estimate waste volumes.

Characterization surveys were not specifically performed in any of the buried pipe survey units addressed in this report. During the performance of site characterization, most of the system interior surfaces of this buried pipe were not accessible. As decommissioning progressed, pipe interior surfaces were exposed and turnover surveys were performed as part of the FSS preparation. In addition, during the FSS of the Turbine Building and Crib House basements, radiological surveys were performed in several sections of Service Water Piping associated with the Circulating Water Intake system. No plant-derived radionuclides were positively identified during the performance of these surveys. In addition, radiological surveys were also performed to support the segmentation and removal of Condensate and Service Water pipe that was connected to the sections of end-state buried pipe. No gross radioactivity greater than background was identified during the scanning performed as part of those surveys.

In survey unit 00101B, the Primary Water Supply Header system was initially classified as MARSSIM Class 3 in accordance with Attachment F of TSD 14-016 and from information taken from the Zion Station HSA. The survey unit was reclassified as Class 2 in accordance with Zion*Solutions* procedure ZS-LT-300-001-002, *"Survey Unit Classification"* as detectable contamination was identified during the demolition of the PWST, which was serviced by the Primary Water Supply Header.

On May 7, 2019, as part of an FSS surveillance performed on the north portion of the Switchyard open land survey unit, C/LT Technicians collected sediment samples from the bottom of manhole access points to the Switchyard storm drain. In the sediment sample collected, both Cs-137 and Co-60 were positively detected. The discovery prompted a change of classification. This storm drain, which had previously been classified as "non-impacted" was reclassified as a MARSSIM Class 2 buried pipe and subject to compliance demonstration as required by LTP Chapter 5, section 5.7.1.9.

3.4 Conditions at the Time of Final Status Survey

Buried pipe is defined as a pipe that runs through soil. Designated sections of buried piping were remediated in place if necessary and subjected to FSS. The inventory of buried piping located below the 588 foot grade that was anticipated to remain and be subjected to FSS was provided in TSD 14-016. Since the issuance of TSD 14-016, decommissioning activities resulted in the removal and disposal of several buried pipe sections that were anticipated to remain. The only buried pipe that remained in the end-state following decommissioning are the pipe sections addressed in this report.

Compliance with the OpDCGL values, as presented in LTP Table 5-10, was demonstrated by measurements of total surface contamination. The radiological survey of pipe system interiors involved the insertion of appropriately sized detectors into the pipe interior by a simple "push-pull" methodology, whereby the position of the detector in the piping system can be easily determined in a reproducible manner.

Condensate Feed Water Supply and Recirculation – The only pipe remaining from this system is the pipe under the road which penetrated the east "A" wall of the Turbine Building basement at the 556 foot elevation and then ran from east to west under the Turbine Building basement floor slab. The pipes were cut inside the Turbine Building basement prior to the demolition and basement backfill. The T-103 and the T-106 sections were unavailable for survey due to groundwater intrusion. The T-105 pipe was accessible for survey measurements and, it was determined that measurements taken within the T-105 section of pipe would be representative of radiological conditions within the system interior, including the two (2) pipes obstructed by groundwater intrusion.

Primary Water Supply Header – The pipe consisted of two (2) sections of 6-inch ID pipe that ran under the Turbine Building basement floor slab. The length of the T-095 section was approximately 118 feet, running from the penetration in the Oil Room to a vertical through the Turbine Building basement floor slab. The length of the T-102 section was approximately 78 feet. Both the pipes were cut inside the Turbine Building basement prior to the demolition and basement backfill. As they were not capped or isolated, there was unobstructed groundwater intrusion into each pipe. Consequently, the portions of this system that were removed during decommissioning were surveyed as representative of the pipes obstructed by groundwater intrusion.

Diesel Generator Service Water Supply – The Diesel Generator Heat Exchanger Service Water Supply piping consists of a 12-inch ID pipe that is approximately 304.4 linear feet in length. The piping consists of 4 sections: for Unit 1, A030 (74.5 feet) and A031 (77.7 feet), and for Unit 2, A027 (74.5 feet) and A028 (77.7 feet). The openings for these pipe sections are on the Diesel Generator Room floor (567 foot elevation), and on the north and south walls of the Auxiliary Building (553 foot and 554 foot elevation).

Service Water Supply Header – The Service Water Supply Header piping consists of 2 runs of 48-inch ID pipe that is approximately 208.8 feet in length. The piping ends at the G Wall of the Auxiliary Building at 547 foot elevation. The piping runs under the Turbine Building.

North Yard Storm Drain – Consisted of the buried 6-inch, 8-inch, 12-inch and 15-inch ID storm drain pipe that runs from the north end of the electrical switchyard to the open drainage ditch located in the southern portions of open land survey areas 10212 and 10213, flowing west to east into Lake Michigan. A second header is also located along the site access road in open land survey area 10214.

3.5 Identification of Potential Contaminants

Zion*Solutions* TSD 11-001, *"Technical Support Document for Potential Radionuclides of Concern During the Decommissioning of the Zion Station"* (Reference 24) was prepared and approved in November 2011. The purpose of this document was to establish the basis for an initial suite of potential ROC for the decommissioning. Industry guidance was reviewed as well as the analytical results from the sampling of various media from past plant operations. Based on the elimination of some of the theoretical neutron activation products, noble gases and radionuclides with a half-life less than two years, an initial suite of potential ROC for the decommissioning of the ZNPS was prepared. The initial suite of potential ROC is provided in LTP Table 5-1.

3.6 Radionuclides of Concern and Mixture Fractions

LTP Chapter 2 provides detailed characterization data that describes current contamination levels in the basements. The survey data for basements is based on core samples obtained at biased locations with elevated contact dose rates and/or evidence of leaks/spills. TSD 14-019 evaluates the results of the concrete core analysis data from the Containments and Auxiliary Building and refines the initial suite of radionuclides potential ROC by evaluating the dose significance of each radionuclide.

LTP Chapter 6, section 6.5.2 discusses the process used to derive the ROC for the decommissioning of ZNPS, including the elimination of insignificant dose contributors from the initial suite consistent with the guidance in Section 3.3 of NUREG-1757. Based upon the analysis of the mixture in TSD 14-019, Table 19, it was determined that Co-60, Ni-63, Sr-90, Cs-134 and Cs-137 accounted for 99.5% of all dose in the contaminated concrete mixes. For activated concrete, H-3, Eu-152, and Eu-154, in addition to the five (5) aforementioned nuclides, accounted for 99% of the dose. Table 2-3 in this report presents the ROC for the decommissioning of ZNPS and the normalized mixture fractions based on the radionuclide mixture presented for the Auxiliary Building. This table is reproduced from LTP Chapter 5, Table 5-2.

3.7 Radiological Release Criteria

Prior to FSS process proceeding, the BcDCGLs were established to demonstrate compliance with the 25 mrem/year unrestricted release criterion. The BcDCGLs were calculated by analysis of various pathways (direct radiation, inhalation, ingestion, etc.), media (concrete, soils, and groundwater) and scenarios through which exposures could occur. Chapter 6 of the LTP describes in detail the approach, modeling parameters and assumptions used to develop the BcDCGLs.

Each radionuclide-specific BcDCGL is equivalent to the level of residual radioactivity (above background levels) that could, when considered independently, result in a TEDE of 25 mrem per year to an AMCG.

To ensure that the summation of dose from each source term is 25 mrem/yr or less after all FSS is completed, the BcDCGLs were reduced based on an expected, or *a priori*, fraction of the 25 mrem/year dose limit from each source term.

The reduced DCGLs, or "Operational" DCGLs can be related to the BcDCGLs as an expected fraction of dose based on an *a priori* assessment of what the expected dose should be based on the results of site characterization, process knowledge and the extent of planned remediation. The OpDCGL was then used as the DCGL for the FSS design of the survey unit (calculation of surrogate DCGLs, investigations levels, etc.). Details of the OpDCGLs derived for each dose component and the basis for the applied *a priori* dose fractions are provided in TSD 17-004.

Compliance will be demonstrated through the summation of dose from four (4) distinct source terms for the end-state (basements, soils, buried pipe and groundwater). Basements are comprised of the summation of four structural source terms (surfaces, embedded pipe, penetrations and fill). When applied to backfilled basement surfaces below 588 foot elevation, embedded pipe and penetrations, the DCGLs are expressed in units of activity per unit of area (pCi/m^2).

4. FINAL STATUS SURVEY PROTOCOL

4.1 Data Quality Objectives

The DQO process as outlined in Section 2 of this report was applied for each FSS Sample Plan and contains basic elements common to all FSS Sample Plans at ZSRP. An outline of those elements presented in the ZSRP FSS Sample Plans are as follows:

4.1.1 State the Problem

The problem: To demonstrate that the level of residual radioactivity in a survey unit does not exceed the release criteria of 25 mR/year TEDE and that the potential dose from residual radioactivity is ALARA.

Stakeholders: The primary stakeholders interested in the answer to the problem were Zion*Solutions* LLC, Exelon Nuclear Generation LLC (Exelon), the Illinois Environmental Management Agency (IEMA) and the United States Nuclear Regulatory Commission (USNRC).

The Planning Team: The planning team consisted of the assigned C/LT Engineer with input from other C/LT personnel as well as the Safety Department. The primary decision maker was the Technical Lead/Radiological Engineer with input from the C/LT Manager.

Schedule: The approximate time projected to mobilize, implement, and access an FSS unit.

Resources: The following resources were necessary to implement an FSS Sample Plan:

- C/LT Engineer to prepare the plan and evaluate data.

- C/LT Field Supervisor to monitor and coordinate field activities.
- Survey Mapping/CAD Specialist to prepare survey maps, layout diagrams, composite view drawings, and other graphics as necessary to support design and reporting.
- C/LT Technicians to perform survey activities, collect survey measurement data, and collect media samples.
- Chemistry/Analysis laboratory Staff to analyze samples as necessary.

4.1.2 Identify the Decision

Principal Study Question: Is the residual radionuclide concentrations found in the interior of the buried pipe surfaces equal to or below the applicable site-specific OpDCGLs?

Alternate Actions: Alternative actions include failure of the survey unit, remediation, reclassification, and resurvey.

The Decision: If the survey unit failed to demonstrate compliance with the release criteria, then the survey unit was not suitable for unrestricted release. The DQA process was reviewed to identify the appropriate additional action or combination of actions.

4.1.3 Identify Inputs to the Decision

Information Needed: The survey unit requiring evaluation of residual activity and its surface area. The characterization surveys and HSA were preliminary sources of information for FSS. New measurements of sample media were needed to determine the concentration and variability for those radionuclides potentially present at the site at the time of FSS.

Historical Information: The classification as originally identified in the HSA and the verification of that classification during characterization. The information included a summary of site processes or incidents that occurred in the survey unit.

Radiological Survey Data: The current radiological survey data from characterization, Remedial Action Support Surveys (RASS), Radiological Assessments (RAs), or turnover surveys. This information was used to develop a sample size for FSS.

Radionuclides of Concern: The ROC for the FSS of the Auxiliary Building are presented in Table 2-3 of this report. In accordance with LTP Chapter 5, section 5.1, it was determined that the suite of ROC and radionuclide mixture derived for the Auxiliary Building concrete was considered as a reasonably conservative mixture to apply to soils and buried piping for FSS planning and implementation.

Basis for the Action Level: The action levels for the Survey Units discussed in this Phase 2 report were provided in Table 5-25 of the LTP and reproduced in Table 4-1 below.

Table 4-1, Investigation Levels

Classification	Scan Investigation Levels	Direct Investigation Levels
Class 1	>Operation DCGL or >MDC_{scan} if MDC_{scan} is greater than Operational DCGL	>Operational $DCGL_W$
Class 2	>Operational DCGL or >MDC_{scan} if MDC_{scan} is greater than Operational DCGL	>Operational $DCGL_W$
Class 3	>Operational DCGL or >MDC_{scan} if MDC_{scan} is greater than Operational DCGL	>0.5 Operational $DCGL_W$

During FSS, concentrations for HTD ROC Ni-63 and Sr-90 were inferred using a surrogate approach. As presented in the LTP Chapter 5, section 5.2.11, Cs-137 is the principle surrogate radionuclide for Sr-90 and Co-60 is the principle surrogate radionuclide for Ni-63. The mean, maximum and 95% Upper Confidence Level (UCL) of the surrogate ratios for concrete core samples taken in the Auxiliary Building basements and Containments were calculated in TSD 14-019 and Table 5-15 of the LTP and are reproduced in Table 4-2. The maximum ratios were used in the surrogate calculations during FSS unless specific ratios were determined for a survey unit based on sample analysis.

Table 4-2, Surrogate Ratios

Ratios	Containment			Auxiliary Building		
	Mean	Max	95%UCL	Mean	Max	95%UCL
H-3/Cs-137	0.208	1.760	0.961	N/A	N/A	N/A
Ni-63/Co-60	30.623	442	193.910	44.143	180.450	154.632
Sr-90/Cs-137	0.002	0.021	0.010	0.001	0.002	0.002

For the FSS of the relevant survey units in this report, the surrogate OpDCGLs for Co-60 and Cs-137 were computed based on the maximum ratios from Table 4-2. The equation for calculating a surrogate DCGL is as follows:

Equation 1

$$Surrogate_{DCGL} = \frac{1}{\left[\left(\frac{1}{DCGL_{Sur}}\right) + \left(\frac{R_2}{DCGL_2}\right) + \left(\frac{R_3}{DCGL_3}\right) + \cdots \left(\frac{R_n}{DCGL_n}\right)\right]}$$

Where: $DCGL_{Sur}$ = Surrogate radionuclide DCGL

$DCGL_{2,3\ldots n}$ = DCGL for radionuclides to be represented by the surrogate

R_n = Ratio of concentration (or nuclide mixture fraction) of radionuclide "n" to surrogate radionuclide

Using the OpDCGLs presented in Table 2-1 for buried piping, and using the maximum ratios from Table 4-2, Table 4-3 presents the results of surrogate calculations performed for each survey unit addressed in this report.

Table 4-3, Surrogate OpDCGL Calculation Results

Survey Unit Number	Survey Unit Name	Co-60	Cs-134	Cs-137	Gross Gamma(1)
		(dpm/100cm^2)			
00101A	Condensate Feed Water Supply and Recirculation Buried Pipe	6.16E+03	1.16E+04	2.58E+04	2.49E+04
00101B	Primary Water Supply Header T-095 and T-102 Buried Pipe	6.16E+03	1.16E+04	2.58E+04	2.49E+04
00101F	Diesel Generator Service Water Supply and Service Water Return Buried Pipe	6.16E+03	1.16E+04	2.58E+04	2.49E+04
00101H	Service Water Supply Header CO-26 and CO-29 Buried Pipe	6.16E+03	1.16E+04	2.58E+04	2.49E+04
00150A/B & C	North End Storm Drain Buried Pipe	6.16E+03	1.16E+04	2.58E+04	2.48E+04

(1)-Indicates Gross Gamma surrogate value derived for piping surveys.

Investigation Levels: The investigation levels were based on the survey unit classification and the Table 4-1 values and are provided in the individual release records.

Sampling and Analysis Methods to Meet the Data Requirements: Final Status Survey planning and design hinges on coherence with the DQO process to ensure, through compliance with explicitly defined inputs and boundaries, that the primary objective of the survey is satisfied. The DQO process is described in the ZSRP LTP as outlined in Appendix D of MARSSIM.

The DQO process incorporates hypothesis testing and probabilistic sampling distributions to control decision errors during data analysis. Hypothesis testing is a process based on the scientific method that compares a baseline condition to an alternate condition. The baseline condition is technically known as the null hypothesis. Hypothesis testing rests on the premise that the null hypothesis is true and that sufficient evidence must be provided for rejection. In designing the survey plan, the underlying assumption, or null hypothesis was that residual activity in the survey unit exceeded the release criteria. Rejection of the null hypothesis would indicate that residual activity within the survey unit did not exceed the release criteria. Therefore, the survey unit would satisfy the primary objective of the FSS sample plan.

The primary objective of the FSS sample plan is to demonstrate that the level of residual radioactivity in a survey unit did not exceed the release criteria specified in the LTP and that the potential dose from residual radioactivity is ALARA.

4.1.4 Define the Boundaries of the Survey

Boundaries of the Survey: The actual physical boundaries as stated for each survey unit.

Temporal Boundaries: Estimated times and dates for the survey. Scanning and sampling in a survey unit was normally performed only during daylight and dry weather.

Constraints: The most common constraints were the weather, standing water and/or ice in a survey unit.

4.1.5 Develop a Decision Rule

Decision Rule: If any measurement data result exceeded the release criteria, the DQA process would then be used to evaluate alternative actions.

4.1.6 Specify Tolerable Limits on Decision Errors

The Null Hypothesis: Residual radioactivity in the survey unit exceeds the release criteria.

Type I Error: This is also known as the "α" error. This is the error associated with incorrectly concluding the null hypothesis has been rejected. In accordance with LTP section 5.6.4.1.1, the Type I error was set at 0.05 (5%).

Type II Error: This is also known as the "β" error. This is the error associated with incorrectly concluding the null hypothesis has been accepted. In accordance with LTP section 5.6.4.1.1, the Type II error was set at 0.05 (5%).

The Lower Bound of the Gray Region (LBGR): The LBGR was set at 50% of the OpDCGL. In using the unity rule, the OpDCGL becomes one (1) and the LBGR is set as 0.5.

4.1.7 Optimize Design

Type of Statistical Test: The Sign Test was selected as the non-parametric statistical test for FSS. The Sign Test is conservative as it increases the probability of incorrectly accepting the null hypothesis (i.e., the conclusion will be that the survey unit does not meet the release criteria) and does not require the selection or use of a background reference area.

Number of Systematic Measurements: The number of systematic measurements were determined based on survey unit classification.

In buried piping, measurements were typically acquired using a NaI detector that was transported into the pipe/penetration using a push-pull locomotion. The FOV for each measurement was conservatively assumed as 1-foot.

Number of Judgmental/Investigational Measurements and Locations: The selection of judgmental samples was at the discretion of the C/LT Engineer. The judgmental measurement locations were typically chosen to measure an area of interest. The individual release record identifies if/when judgmental samples were utilized.

If during the course of performing FSS, measurement results were encountered that were not as expected for the surface undergoing survey, then an investigation was performed to determine the cause of the discrepancy. If required. investigational measurements were acquired as part of a documented investigation within the individual survey unit and investigational measurements were collected to bound areas of elevated activity or to verify that conditions had not changed.

Number of Scan Areas and Locations: Scanning, in the traditional sense, is not applicable to the survey of pipe internal surfaces. Therefore, scan measurements were not performed as part of buried piping surveys.

Number of Measurements for Quality Control: The number of quality control measurements was 5% percent of the sample set. The locations for duplicate measurements were selected randomly using a random number generator.

Power Curve: The Prospective Power Curve, developed using characterization data and COMPASS software, showed adequate power for the survey design in each of the survey units.

A synopsis of the survey designs are provided in Table 4-4

Table 4-4, Synopsis of Survey Design

FEATURE	DESIGN BASIS				
Survey Unit #	00101A	00101B	00101F	00101H	00150A/B & C
Description	Condensate Feed Water Supply and Recirculation Buried Pipe	Primary Water Supply Header Buried Pipe	Diesel Generator Service Water Supply and Service Water Return Buried Pipe	Service Water Supply Header Buried Pipe	North Yard Storm Drain Buried Pipe
Pipe ID	T-103, T-105, and T-106	T-095 and T-102	AO-27, AO-28, AO-30, AO-31, TO-32, and TO-33	CO-26 and CO-29	None
Area (ft^2)	2,455	308	956.3	5,248	2,187
Number of Measurements	47	100	31	59 per pipe	272
Spacing	As needed to obtain a sufficient number of measurements for 10% areal coverage	One measurement every foot of accessible pipe	As needed to obtain sufficient measurements for 10% areal coverage	As needed to obtains sufficient measurements for 10% areal coverage	As needed to obtain a sufficient number of measurements for 25% areal coverage
DCGLs	Operational DCGLs Presented in Table 2-1 (buried pipe)				
Classification (Initial/Final)	3/3	3/2	3/3	3/3	Non-impacted/2
Investigation Level	>0.5 OpDCGL	Gross Gamma OpDCGL	>0.5 Gross Gamma OpDCGL	>0.5 Gross Gamma OpDCGL	Gross Gamma Operational DCGL Cs-137 Surrogate Operational DCGL
Scan Area Coverage	N/A	N/A	N/A	N/A	N/A
QC	5% Replicate Measurements				

4.2 Survey Unit Designation and Classification

Procedure ZS-LT-300-001-002 defines the decision process for classifying an area in accordance with the LTP and MARSSIM. Survey Unit classifications are provided in Table 4-4. The justification for each Survey Unit classification is delineated in the individual release records for each survey unit contained in Appendices 1-5 of this report.

4.3 Background Determination

Background was not subtracted from measurements during the FSS of buried pipe.

4.4 Final Status Survey Sample Plans

The level of effort associated with planning a survey is based on the complexity of the survey and nature of the hazards. Guidance for preparing FSS plans is provided in procedure ZS-LT-300-001-001. The FSS plan uses an integrated sample design that combines scanning surveys and sampling.

5. SURVEY DESIGN

Compliance with the Operational DCGL values was demonstrated by the measurements of total surface contamination. The survey of buried pipe was performed in the same manner as described for the survey of embedded pipe as discussed in section 5.5.5 of the LTP. The radiological survey of pipe interior surfaces involves the insertion of appropriately sized detectors into the pipe interior by a simple "push-pull" methodology, whereby the position of the detector in the piping system can be easily determined in a reproducible manner.

The detectors are configured in a fixed geometry relative to the surveyed surface, thus creating a situation where a defensible efficiency can be calculated. The detectors are then deployed into the actual pipe and timed measurements are acquired at intervals commensurate with the contamination potential of the pipe. A conservative "area of detection" is assumed for each pipe size. It is also conservatively assumed that any activity is uniformly distributed in the area of detection.

A static measurement is acquired at a pre-determined interval for the areal coverage to be achieved. The measurement output represents the gamma activity in gross cpm for each foot of piping traversed. This measurement value in cpm is then converted to dpm using the efficiency of the detector. The total activity in dpm is then adjusted for the assumed total effective surface area commensurate with the pipe diameter, resulting in measurement results in units of dpm/100cm^2. A surrogate correction based upon the radionuclide distribution present in the pipe is then applied to the gamma emission to account for the presence of other non-gamma emitting radionuclides in the mixture. This

measurement result represents a commensurate and conservative gross measurement that can be compared to the buried pipe OpDCGLs.

Radiological evaluations for piping that could not be accessed directly was performed via measurements taken in the same system where the radioactivity levels were deemed to either bound or be representative of the interior surface radioactivity levels providing that the conditions within the balance of the piping could be reasonably inferred based on those data.

5.1.1 Measurement Locations

For buried piping, each piping system or penetration was identified by plant drawings. TSD 14-016 was used to obtain a description and classification for each piping/penetration system. Specific information with regard to buried piping are provided in the release record for that survey unit. Generally, one-minute timed static measurements were taken throughout the accessible portion of that pipe. The frequency of the measurements was also provided in the survey unit release record. For example, if the buried piping system was identified as a Class 1 system, then one measurement would be taken for every foot of pipe interior surface to provide 100% areal coverage for that Survey Unit.

The total number of measurements actually acquired for each FSS Survey Unit is provided in Table 5-1.

Table 5-1, Number of FSS Measurements

Survey Unit	Non-Parametric Measurements	Quality Control Measurements	Judgmental/ Investigation Measurements	Total Measurements
00101A	257	18	0	275
00101B	253	17	0	270
00101F	256	17	0	273
00101H	132	7	0	139
0150A/B & C	272	18	0	290

5.2 Instrumentation

Radiation detection and measurement instrumentation for performing FSS is selected to provide both reliable operation and adequate sensitivity to detect the ROC identified at the site at levels sufficiently below the OpDCGL. Detector selection is based on detection sensitivity, operating characteristics and expected performance in the field.

The DQO process includes the selection of instrumentation appropriate for the type of measurement to be performed (i.e., scan measurements and sample analysis) that are

calibrated to respond to a radiation field under controlled circumstances; evaluated periodically for adequate performance to established quality standards; and sensitive enough to detect the ROC with a sufficient degree of confidence.

Specific implementing procedures control the issuance, use, and calibration of instrumentation used for FSS. The specific DQOs for instruments are established early in the planning phase for FSS activities, implemented by standard operating procedures and executed in the FSS Sample Plan.

5.2.1 Instrumentation Efficiencies

For the survey of buried pipes, the pipe detector was calibrated for the specific geometry relating to the piping OD. The most likely geometry for activity in these pipes is for the activity to be collected in the bottom of the pipe. To obtain an efficiency for this geometry, a mock-up of the lower half of the inner diameter of this pipe was created. The source was positioned on the bottom of the pipe. The detector was placed on the bottom of the pipe and the calibration readings obtained

The survey design required the use of a Ludlum Model 44-157 (2-inch x 2-inch) or 44-162, (3-inch x 3-inch) NaI detector to acquire measurements. Background was not to be subtracted from the measurements. The efficiency for each detector was determined in the same manner described above.

These detectors were principally used to detect gamma emitters and were calibrated using Cs-137 NIST traceable sources. Efficiencies were used to quantify the gamma emitters, and those results were used to infer concentrations of HTD ROC using the maximum ratios from LTP Chapter 5, Table 5-12.

Each detector was calibrated for specific pipe diameter ranges, with the lowest efficiency in each range used to survey all pipe diameters in that range resulting in accurate to slightly conservative results.

Specific detector efficiency information is provided in the release records that are attached to this report.

Table 5-2, reproduced from LTP Table 5-28, provides typical detector sensitivities.

Table 5-2, Typical FSS Instrument Detection Sensitivities

Instruments and Detectors [a]	Radiation	Background Count Time (minutes)	Typical Background (cpm)	Typical Instrument Efficiency [b] (ε_t)	Count Time (minutes)	Static MDC (dpm/100cm^2)	Scan MDC
Model 43-68	Beta-Gamma	1.0	300	0.258	1.0	256	612 [c]
Model 44-116	Beta	1.0	200	0.124	1.0	539	1990 [c]
Model 43-51	Beta	1.0	40	0.126		810	2782 [c]
Model 43-37	Beta-Gamma	1.0	1,200	0.236	1.0	119	372 [c]
Model 44-10	Gamma	1.0	8,000	N/A	0.02	N/A	5.2 pCi/g [d]
ISOCS	Gamma	Up to 60	N/A	60% relative	5-60	10% of the Operational DCGL (pCi/m^2)	N/A
Model 44-159 [e]	Gamma	1.0	700	0.024	1	5,250	N/A
Model 44-157 [e]	Gamma	1.0	6,300	0.212	1	1,750	N/A
Model 44-162 [e]	Gamma	1.0	16,000	0.510	1	1,150	N/A

[a]Detector models listed are used with the Ludlum 2350-1 Data Logger

[b]Typical calibration source used is Cs-137. The efficiency is determined by counting the source with the detector in a fixed position from the source (reproducible geometry). The ε_t value is based on ISO-7503-1 and conditions noted for each detector.

[c]Scan MDC, in dpm/100cm^2, for the 43-68 was calculated assuming a scan rate of 5.08 cm/sec, which is equivalent to a count time of 1.73 seconds (0.028 minutes) using a detector width of 8.8 cm. The 43-37 detector assumes a scan rate of 12.7 cm/s and results in a count time of 1.05 seconds (0.018 minutes) for a detector width of 13.34 cm. The 44-116 detector width is 2.54 cm and results in a count time of 1.00 seconds at 2.54 cm/s scan speed.

[d]Scan MDC in pCi/g is calculated using the approach described in section 6.7.2.1 of MARSSIM for a Cs-137 nuclide fraction of 0.95 and a Co-60 fraction of 0.05 with a determined detector sensitivity of 1000 and 430 cpm per uR/hr for each radionuclide respectively. The weighted MicroShield-determined conversion factor was 0.282 pCi/g per uR/hr.

[e]The efficiency varies for the pipe detectors depending on the pipe diameter used. The efficiency used for the table is the averaged efficiency value for the pipe diameters. The detectors and diameters are: model 44-159: 2-4 in. dia., model 44-157: 4-8 in. dia., model 44-162: 8-12 in. dia.

5.2.2 Instrumentation Sensitivities

The measurement sensitivity or MDC was determined *a priori* for the instruments and techniques used for FSS. The MDC is defined as the *a priori* activity level that a specific instrument and technique can be expected to detect 95% of the time. When stating the detection capability of an instrument, this value was used. The MDC is the detection limit, (*LD*), multiplied by an appropriate conversion factor to give units of activity. The critical level, (*LC*), is the lower bound on the 95% detection interval defined for *LD* and is the level at which there is a 5% chance of calling a background value "greater than background." This was the value used when actually counting samples or making direct radiation measurements. Any response above this level was considered as above background (i.e., a net positive result). This ensured 95% detection capability for *LD*. The MDC is dependent upon the counting time, geometry, sample size, detector efficiency and background count rate.

The detectors used for the buried pipe surveys were calibrated to capture the readily detectable principal radionuclides of interest. The Cesium/Iodide (CsI) detectors were ideal for small diameter pipes as they have a higher efficiency than the NaI detectors and are very efficient for the energies of interest in small sizes. They are typically manufactured in sizes that range from ½ by ½ inch (diameter and depth) to 1 inch diameter by 1.5 inches in depth. NaI was ideal for the large size pipes in detector sizes ranging from one by one inch to three by three inches. Both types are sensitive to the gamma energies emitted by Co-60 and Cs-137 and were calibrated using Cs-137 to which these detectors are slightly less sensitive to, (and slightly less efficient) than for the Co-60 gamma. When calibrated to Cs-137, the same detector is approximately 15 to 20% more sensitive to Co-60 than Cs-137 which adds a level of conservatism between the assumed and actual efficiencies.

5.2.3 Instrument Maintenance and Control

Control and accountability of survey instruments were maintained to assure the quality and prevent the loss of data. All personnel operating radiological instruments, analysis equipment, measurement location equipment etc., were qualified to operate any assigned equipment and recognize off normal results and indications.

5.2.4 Instrument Calibration

Instruments and detectors were calibrated for the radiation types and energies of interest or to a conservative energy source. Instrument calibrations were documented with calibration certificates and/or forms and maintained with the instrumentation and project records. Calibration labels were also attached to all portable survey instruments. Prior to using any survey instrument, the current calibration was verified and all operational checks were performed.

Instrumentation used for FSS was calibrated and maintained in accordance with approved Zion*Solutions* site calibration procedures. Radioactive sources used for calibration were traceable to the NIST and were obtained in standard geometries to match the type of samples being counted.

5.3 Survey Methodology

The LTP specifies the minimum amount of measurements required for each class as summarized in Table 5-3. The total fraction of scanning coverage is determined during the DQO process with the amount, and location(s) based on the likelihood of finding elevated activity during FSS.

Table 5-3, Recommended Scan Coverage

Area Classification	Surface Scans
Class 1	100%
Class 2	10% to 100%, Systematic and Judgmental
Class 3	Judgmental

5.3.1 Buried Pipe Surveys

Once remediation was completed in a section of pipe to the extent practicable, the residual radioactivity remaining in each accessible section of embedded piping was assessed and quantified by direct survey. The approach used for the radiological survey of the interior surfaces of embedded piping involved the insertion of a detector that was attached to the SeeSnake® camera system and transported through the pipe to the maximum deployment length, or to a location of drain drop. A simple "push-pull" methodology was used, whereby the position of the detector in the piping system could be easily determined in a reproducible manner. Footage was tabulated on the SeeSnake, then measurements were obtained at each one-foot location while backing out of the pipe section.

The piping detectors were configured in a fixed geometry relative to the surveyed surface, thus creating a situation where a defensible efficiency could be calculated. The detectors were then deployed into the actual pipe and timed measurements were acquired at an interval of one measurement for every foot of pipe. A conservative "area of detection" of one-foot was assumed. It was also conservatively assumed that any activity inside of the pipe was uniformly distributed in the area of detection.

For each detector and pipe diameter combination each diameter of pipe, an instrument efficiency factor was derived by placing a flexible Cs-137 radiological plane source into a pipe jig, depending on the diameter of the pipe to be surveyed. This created a geometry

similar to what would be encountered in the actual pipe. Using the known source activity, an efficiency factor was then derived for the detector in that geometry.

A background value was also determined for the detector/instrument combination to be used prior to deployment. The background value was obtained at the location where the pre-use response check of the instrument was performed. The background value was primarily used to ensure that the detector had not become cross-contaminated by any previous use. Background was not subtracted from any measurement.

Daily prior to use and daily following use, each detector was subjected to an Operational Response Check in accordance with procedure ZS-LT-300-001-006, *"Radiation Surveys of Pipe Interiors Using Sodium/Cesium Iodide Detectors"* (Reference 25). The Daily Operational Response Check compared the background response and the response to check sources ranges established for normal background and detector source response to ensure that the detector was working properly.

Once the detector was determined to be fully functional, it was then deployed to the field for insertion into the targeted piping. A one-minute static measurement was acquired at each foot traversed into the pipe. The detector output represented the gamma activity for each one-minute timed measurement in units of gross cpm. The gamma measurement value in units of cpm was then converted to units of dpm using the efficiency factor for the detector applicable to the diameter of the pipe surveyed.

Each measurement assumed a conservative "area of detection" for the detector of one foot. This assumption is conservative because there is additional instrument response from contamination located in the pipe at distances outside of the "area of detection." Consequently, the total activity from the measurement, in units of dpm is adjusted for the total effective surface area commensurate with the pipe diameter and the assumed "area of detection", resulting in measurement results in units of dpm/100cm^2. Using the appropriate conversion factors, the result is then converted to units of pCi/m^2. This measurement result represents a commensurate and conservative gamma surface activity for the one foot of pipe surface where the measurement was taken.

After completion of the FSS measurements in the pipe, the sample plan was reviewed to confirm the completeness of the survey and the survey data was validated in accordance with procedure ZS-LT-300-001-004. Data processing included converting measurement data into reporting units, validating instrument applicability and sensitivity, calculating relevant statistical quantities, and verification that all DQO had been met. In accordance with the procedure, a preliminary Data Assessment was prepared for each section of pipe surveyed.

5.3.2 Quality Control Surveys

The method used for evaluating Quality Control (QC) replicate measurements collected in support of the FSS program is specified in the QAPP. QC replicate data was assessed using criteria taken from the USNRC Inspection Manual, Inspection Procedure 84750, "*Radioactive Waste Treatment, and Effluent and Environmental Monitoring*" (Reference 26).

A minimum of 5% of the sample locations used in the FSS design were selected randomly using the Microsoft® Excel "RANDBETWEEN" function and submitted as "replicate measurements." It is desirable that when analyzed, there is agreement between the replicate measurements resulting in data acceptance. If there was no agreement between the measurements, the C/LT Engineer evaluated the magnitude and impact on survey design, the implementation and evaluation of results, as well as the need to perform additional measurements. If the C/LT Engineer had determined that the discrepancy affected quality or was detrimental to the implementation of FSS, then a Condition Report would have been issued.

To maintain the quality of the FSS, isolation and control measures were implemented throughout FSS activities until there was no risk of recontamination from decommissioning or when the survey area will be released from the licenses. In the event that isolation and control measures were compromised, a follow-up survey may be performed after evaluation.

6. SURVEY FINDINGS

Procedure ZS-LT-300-001-004 provides guidance to C/LT personnel to interpret survey results using the DQA process during the assessment phase of FSS activities.

The DQA process is the primary evaluation tool to determine that data are of the right type, quality and quantity to support the objectives of the FSS Sample Plan. The five steps of the DQA process are:

- Review the Sample Plan DQOs and the survey design.
- Conduct a preliminary data assessment.
- Select the statistical test.
- Verify the assumptions of the statistical test.
- Draw conclusions from the data.

Data validation descriptors described in MARSSIM Table 9.3 were used during the DQA process to verify and validate collected data as required by the QAPP for Characterization and FSS.

Hand held instruments utilized for surveying buried pipe were calibrated with NIST traceable sources, and the efficiencies used to quantify results taken from those calibrations. Prior to, and following each use, each hand held instrument was operationally verified using check sources to verify the instruments were operating within pre-determined acceptable ranges.

6.1 Survey Data Conversion

During the data conversion, the C/LT Engineer evaluated raw data for problems or anomalies encountered during Sample Plan activities (sample collection and analysis, handling and control, etc.) including the following:

- Recorded data,
- Missing values,
- Deviation from established procedure, and
- Analysis flags.

Once resolved, initial data conversion, which is part of preliminary data assessment was performed and consisted of converting the data into units relative to the release criteria (e.g., pCi/g) and calculating basic statistical quantities (e.g., mean, median, standard deviation). Table 6-1 provides a summary of the basic statistical properties for Phase 2, Part 2 systematic sample populations.

**Table 6-1, Basic Statistical Properties of Phase 2, Part 2
Survey Unit Non-Parametric Measurements**

Survey Unit	Description	Class	# of Measurements	Mean OpSOF	Max OpSOF	# OpSOF> 1	Mean BcSOF	Dose to Survey Unit (mrem/yr)
00101A	Condensate Feed Water Supply and Recirculation Buried Pipe	3	275	0.320	0.493	0	0.082	2.052
00101B	Primary Water Supply Header Buried Pipe	2	270	0.784	1.506	53	0.201	5.652
000101F	Diesel Generator Heat Exchangers Service Water Supply and Service Water Return Buried Pipe	3	273	0.144	0.488	0	0.037	0.922
00101H	Service Water Supply Header Buried Pipe	3	139	0.127	0.288	0	0.033	0.814
00150A/B& C	North Yard Storm Drain Buried Piping	2	290	0.107	0.276	0	0.027	0.683

6.2 Survey Data Verification and Validation

Items supporting DQO sample design and data were reviewed for completeness and consistency. This included:

- Classification history and related documents,
- Site description,
- Survey design and measurement locations,
- Analytic method and detection limits and validation that the required analytical method(s) were adequate for the radionuclides of concern,
- Sampling variability provided for the radionuclides of interest,
- QC measurements have been specified,
- Survey and sampling result accuracy have been specified,
- MDC limits,
- Field conditions for media and environment, and
- Field records.

Documentation, as listed, was reviewed to verify completeness and that it is legible:

- Field and analytical results,
- Field Logs,
- Instrument issue, return and source check records,
- Instrument downloads, and
- Measurement results relative to measurement location.

After completion of these previously mentioned tasks, a Preliminary Data Assessment record was initiated. This record served to verify that all data were in standard units in relation to the DCGLs and performed the calculation of the statistical parameters needed to complete data evaluation which, at a minimum, included the following:

- The number of observations (i.e., samples or measurements),
- The range of observations (i.e., minimum and maximum values),
- Mean,
- Median, and
- Standard deviation.

In order to adequately evaluate the data set, consideration as additional options included the coefficient of variation, measurements of relative standing (such as percentile), and other statistical applications as necessary (frequency distribution, histograms, skew, etc.). Finalization of the data review consisted of graphically displaying the data in distribution and percentile plots.

6.3 Anomalous Data/Elevated Scan Results and Investigation

FSS survey data was assessed to determine if the data set in question met the DQO process. This process was documented in accordance with ZS-LT-300-001-004, "*Final Status Survey Data Assessment*."

If during the assessment, it was determined that the data did not meet the DQOs identified in the survey package for that area, then an investigation would have been initiated.

The DQO process was used to evaluate the remediation, reclassification and/or resurvey actions to be taken if an investigation level was exceeded. Based upon the failure of the statistical test or the results of an investigation, LTP Chapter 5, Table 5-26 presents the actions that would be required.

6.3.1 Condensate Feed Water Supply and Recirculation Buried Pipe (Survey Unit 00101A)

FSS of the T-105 pipe interior surfaces commenced on May 11, 2017 using Ludlum Model 2350-1 #266668 coupled with Ludlum Model 44-162 #PR327894. The detector was transported through the pipe interiors using the ¾" fiber rod. Static measurements were taken at 1-foot intervals for 257 linear feet of piping from this survey unit. This covers 1,283.8 ft^2 of area, which is approximately 52.2% of the total surface area of 2,456.1 ft^2. The surveys were completed on May 15, 2017 using the same instrument/detector. A total of 257 measurements were taken. All readings were below an OpSOF of 0.5. As all measurements in the accessible pipe interior surface area were below an OpSOF of 0.5, no investigations were required or performed.

6.3.2 Primary Water Supply Header Buried Pipe (Survey Unit 00101B)

The Primary Water Supply Header FSS unit was classified as a Class 2 buried pipe. Of the 253 measurements taken inside of the pipe, 244 exceeded the gross gamma Action Level of 1.24E+04 dpm/100cm^2 and 53 exceeded an OpSOF of one. In accordance with LTP Chapter 5, section 5.6.4.6, encountering these measurements results in a Class 2 FSS unit would prompt the acquisition of additional measurements to bound the elevated areas of concern and, to reclassify the survey unit as Class 1. Reclassification would then prompt the requirement for 100% areal coverage which, in a pipe, is achieved by taking one measurement every foot of pipe. However, even though the Primary Water Supply

Header FSS unit was classified as Class 2 during survey design, the FSS was performed as if the pipe was Class 1. One measurement was taken for every foot of pipe that was accessible, achieving 100% areal coverage of accessible piping. In addition, the measurements taken clearly bound the areas of elevated activity, and the dose from measurements that exceeded an OpSOF of one was added to the mean Base Case SOF (BcSOF) for compliance.

License Termination Plan Chapter 5, section 5.6.4.2 states, "The Sign Test is the most appropriate test for FSS at Zion, as background is expected to constitute a small fraction of the $DCGL_w$ based on the results of characterization surveys. Consequently, the Sign Test will be applied when demonstrating compliance with the unrestricted release criteria without subtracting background." During the performance of data assessment on the survey data taken in survey unit 00101B, the cognizant Radiological Engineer (RE) postulated that the elevated activity detected by the FSS measurements was not due to residual radioactivity inside the pipe but rather from increases in ambient background due to the storage, movement, packaging and shipment of radioactive waste from the Unit 2 Containment and the Auxiliary Building in an adjacent survey unit. A review of the survey data shows that the measurements taken inside of the pipe were consistent for the first nine (9) measurements. Then an approximately 50% increase in activity over the next two (2) measurements. The activity again stayed consistent over the next nineteen (19) measurements, and then decreased again over the next four (4) measurements to the originally observed levels. This occurred several times, indicating the possible movement of a radioactive material package or packages through the area adjacent to where the pipe FSS was performed.

To investigate this possibility, a background study was performed in August 2019 on clean 6-inch diameter steel pipe jigs transported to and placed at the location on the ground where the buried pipe FSS was performed. This area is located adjacent to the now-removed WWTF and northeast of the Turbine Building footprint. The reason for the delay in performing this study so long after the completion of the FSS of the Primary Water Supply Header was due to waiting for potential contributors to background to be removed from the area in question. This background study was performed to assess the impact of radioactive commodity removal on the ambient background. During the time when the pipe surveys were performed in May 2017, large amounts of known radioactive commodities were removed from the Unit 2 Containment and Auxiliary Building and staged in a tent for eventual loading into railcars, and proper shipment and disposal as radioactive waste. The radioactive material staging and load-out area for the railcars was located approximately 800 feet from the FSS location.

Sample plan number S3-001101A-C was developed and implemented to quantify the background levels associated with the survey of piping at the surface. A Ludlum Model 44-157 pipe detector, attached to a Ludlum Model 2350 data logger, was inserted

approximately two (2) feet into the mock-up pipe and a series of 1-minute measurements were conducted. The results of the background study indicated that the average of the twenty (20) background measurements was 1,752 cpm. The maximum and minimum values were 1,805 cpm and 1,693 cpm, respectively.

Once the background assessment was complete, a study was performed to assess the impact of the current ambient background gross levels on the data reported during the FSS. The mean background level of 1,752 cpm was subtracted from the gross gamma result from each of the 253 systematic measurements and the OpSOF for each was recalculated. When subtracting the current background, the mean OpSOF is adjusted from the original value of 0.784 to a value of 0.117. The maximum observed OpSOF changes from the original value of 1.506 to 0.308. No measurement exceeded the OpDCGL for buried pipe.

6.3.3 Diesel Generator Heat Exchangers Service Water Supply and Service Water Return Buried Pipe (Survey Unit 00101F)

Two hundred fifty-six (256) static measurements were taken in the Diesel Generator Service Water Supply Header buried piping (Pipe ID AO-27, AO-28, AO-30, AO-31, TO-32 and TO-33).

All of the measurements taken inside the buried pipe were below an OpSOF of 0.5 when compared to the $OpDCGL_{BP}$.

No anomalies were observed during the performance or analyses of the survey.

6.3.4 Service Water Supply Header Buried Pipe (Survey Unit 00101H)

One hundred thirty-two (132) static measurements were taken in the Service Water Supply Header (Pipe IDs CO-26 and CO-29) buried piping.

All of the measurements taken inside the buried pipe were below an OpSOF of 0.5 when compared to the $OpDCGL_{BP}$.

No anomalies were observed during the performance or analyses of the survey.

6.3.5 North Yard Storm Drain Buried Piping (Survey Units 00150A/B&C)

Two hundred seventy-two (272) static measurements were taken in the North Yard Storm Drain buried pipe.

All of the measurements were below an OpSOF of one, when compared to the $OpDCGL_{BP}$.

No anomalies were observed during the performance or analyses of the survey.

6.4 Evaluation of Number of Sample/Measurement Locations in Survey Units

An effective tool utilized to evaluate the number of samples collected in the sampling scheme is the Retrospective Power Curve. The Retrospective Power Curve shows how well the survey design achieved the DQOs.

The Sign Test was selected as the statistical test for all Release Records submitted in this report. This test, performed in accordance with ZS-LT-300-001-004 demonstrates survey design adequacy. If the data passed the Sign Test, the null hypothesis is rejected and the survey unit can be released with no further actions required. For reporting purposes, all survey unit Release Records passed the Sign Test, indicating that the survey design was adequate (i.e. adequate number of samples was collected).

6.5 Comparison of Findings with Derived Concentration Guideline Levels

The SOF or "unity rule" was applied to FSS data in accordance with the guidance provided in Section 2.7 of NUREG-1757, Vol. 2, and the LTP. This was accomplished by calculating a fraction of the OpDCGL for each sample or measurement by dividing the reported concentration by the OpDCGL. If a sample had multiple ROC, then the fraction of the OpDCGL for each ROC was summed to provide a total OpSOF for the sample.

If a surrogate concentration was inferred as part of the survey design for the FSS, then the surrogate OpDCGL was used to derive the OpSOF. Unity rule equivalents were calculated for each measurement result using the surrogate adjusted OpDCGL (typically using gamma emitters), and then used to perform the Sign Test, if applicable.

A BcSOF was calculated for each ROC by dividing the reported mean concentration by the BcDCGL. A BcSOF of 1 is equivalent to the decision rule, meaning any measurement with a BcSOF of 1 or greater, would not meet the 25 mR/yr release criteria. The mean BcSOF was multiplied by 25 to establish the dose attributed to soil in a survey unit. The mean BcSOF and equivalent dose contribution for each Phase 2, Part 2 survey units is provided in Table 6-1.

6.5.1 Compliance Equation

There are four distinct source terms for the end-state at Zion: backfilled basements, soil, buried piping and groundwater. Demonstrating compliance with the dose criterion requires the summation of dose from the four source terms. The final compliance dose will be calculated using LTP Chapter 6, Equation 6-11 (reproduced below as Equation 3) after FSS has been completed in all survey units. The results of the FSS performed for each FSS unit will be reviewed to determine the maximum dose from each of the four source terms (e.g., basement, soil, buried pipe and existing groundwater if applicable) using the mean BcSOF of FSS results plus the dose from any identified elevated areas. The compliance dose must be less than 25 mrem/yr. The dose contribution from each

ROC is accounted for using the BcSOF to ensure that the total dose from all ROC does not exceed the dose criterion.

Equation 3

Compliance Dose = (Max $BcSOF_{BASEMENT}$ + Max $BcSOF_{SOIL}$ + Max $BcSOF_{BURIED\ PIPE}$ + Max $SOF_{GROUNDWATER}$) x 25 mrem/yr

where:

Compliance Dose	=	must be less than or equal to 25 mrem/yr,
Max $BcSOF_{BASEMENT}$	=	Maximum BcSOF (mean of FSS systematic results plus the dose from any identified elevated areas) for backfilled Basements (including surface, embedded pipe, penetrations and fill [if required]),
Max $BcSOF_{SOIL}$	=	Maximum BcSOF (mean of FSS systematic results plus the dose from any identified elevated areas) for open land survey units,
Max $BcSOF_{BURIED\ PIPE}$	=	Maximum BcSOF (mean of FSS systematic results plus the dose from any identified elevated areas) from buried piping survey units,
Max $SOF_{GROUNDWATER}$	=	Maximum SOF from existing groundwater

The term for each Basement includes the dose contributions from wall and floor surfaces within the Basement, the dose contribution from embedded pipe within the Basement, the dose contribution from penetrations within the Basement and the dose contribution from concrete fill in the Basement when clean concrete debris was used as fill. Each (structural surfaces, embedded pipe and penetrations) are surveyed separately during FSS. The dose from clean concrete fill is predetermined in accordance with LTP Chapter 5, Table 5-16, which is conservatively based on a maximum allowable MDC of 5,000 dpm/100cm^2.

6.6 Description of ALARA to Achieve Final Activity Levels

With the exception of some penetrations, embedded and buried piping, all contaminated and non-contaminated systems were disassembled, removed, packaged and shipped off-site as a waste stream commodity. Once commodity removal was complete, structural surfaces were remediated as necessary to meet the open-air demolition criteria. These criteria provided the removable contamination levels and contact exposure rates that allowed structures to be safely demolished without containment.

Typically, for pipe buried in soil, the pipe interiors were remediated to levels less than the site-specific DCGLs presented in Table 5-10 of the LTP, prior to FSS surveys being performed in accordance with section 5.7.1.8 of the LTP.

7. SUMMARY

Final Status Survey is the process used to demonstrate that the ZNPS structures and soils comply with the radiological criteria for unrestricted use specified in 10 CFR 20.1402. The purpose of FSS Sample Plan is to describe the methods to be used in planning, designing, conducting, and evaluating the FSS.

The two radiological criteria for unrestricted use specified in 10 CFR 20.1402 are 1) the residual radioactivity that is distinguishable from background radiation results in a TEDE to an AMCG that does not exceed 25 mrem/year, including that from groundwater sources of drinking water, and 2) the residual radioactivity has been reduced to levels that are ALARA.

All survey units addressed in this Final Report have met the DQOs of their respective FSS plans. The ALARA criteria as specified in Chapter 4 of the LTP were achieved. The EMC is not applicable to buried pipe.

All identified ROC were used for statistical testing to determine the adequacy of each survey unit for FSS. Evaluation of the data shows that none of the mean ROC concentration values exceeded their respective Operational DCGL; therefore, in accordance with the LTP Chapter 5, Section 5.10, the survey unit meets the release criterion.

In each survey unit, the sample data passed the Sign Test, the null hypothesis was rejected and the Retrospective Power Curve showed that adequate power was achieved. All survey units were properly classified.

It is the conclusion of this report that all survey units addressed within are acceptable for unrestricted release.

8. REFERENCES

1. "Zion Nuclear Power Station, Units 1 and 2 - Issuance of Amendments 191 and 178 for the Licenses to Approve the License Termination Plan"
2. NUREG-1575, Multi-Agency Radiation Survey and Site Investigation Manual
3. ZS-LT-01, Quality Assurance Project Plan (for Characterization and FSS)
4. Zion*Solutions* Procedure ZS-LT-300-001-001, "Final Status Survey Package Development"
5. Zion*Solutions* Procedure ZS-LT-300-001-003, "Isolation and Control for Final Status Survey"
6. Zion*Solutions* Procedure ZS-LT-300-001-004, "Final Status Survey Data Assessment"
7. Zion*Solutions* TSD 14-016, "Description of Embedded Piping, Penetrations, and Buried Pipe to Remain in Zion End State"
8. "Zion Station Historical Site Assessment"
9. Zion*Solutions* Procedure ZS-LT-300-001-002, "Survey Unit Classification"
10. Zion*Solutions* Procedure AD-11 "Regulatory Reviews; ZionSolutions Project"
11. NUREG-1757, Vol. 2, "Consolidated Decommissioning Guidance; Characterization, Survey, and Determination of Radiological Criteria"
12. Zion*Solutions* Procedure ZS-LT-300-001-005, "Final Status Survey Data Reporting"
13. Zion*Solutions* TSD 17-004, "Operational Derived Concentration Guideline Levels for Final Status Survey"
14. Zion*Solutions* TSD 14-028, Radiological Characterization Report
15. Zion*Solutions* Procedure ZS-RP-108-000-000, Radiological Instrumentation Program
16. Zion*Solutions* Procedure ZS-RP-108-004-012, "Calibration and Initial Set-Up of the 2350-1"
17. Zion*Solutions* Job Aid LT-JA-004, "FSS Sample Collection"
18. Zion*Solutions* Procedure ZS-LT-100-001-004, "Sample Media Preparation for Site Characterization"
19. Zion*Solutions* Procedure ZS-WM-131, "Chain of Custody Protocol"
20. ZS-QA-10, "Quality Assurance Project Plan"
21. Post Shutdown Decommissioning Activities Report

22. Defueled Safety Analysis Report

23. Offsite Dose Calculation Manual

24. ZS-LT-02, "Characterization Survey Plan"

25. Zion*Solutions* TSD 11-001, "Technical Support Document for Potential Radionuclides of Concern During the Decommissioning of the Zion Station"

26. Zion*Solutions* Procedure ZS-LT-300-001-006, Radiation Surveys of Pipe Interiors Using Sodium/Cesium Iodide Detectors

27. USNRC Inspection Manual, Inspection Procedure 84750, "Radioactive Waste Treatment, and Effluent and Environmental Monitoring"

9. APPENDICES

1. FSS Release Record, Survey Unit 00101A (Condensate Feed Water Supply and Recirculation Buried Pipe, Pipe IDs T-103, T-105 & T-106)
2. FSS Release Record, Survey Unit 00101B (Primary Water Supply Header Buried Pipe, Pipe IDs T-095 and T-102)
3. FSS Release Record, Survey Unit 00101F (Diesel Generator Heat Exchangers Service Water Supply and Service Water Return Buried Pipe, Pipe IDs AO-27, AO-28, AO-30, AO-31, TO-32, and TO-33)
4. FSS Release Record, Survey Unit 00101H (Service Water Supply Header Buried Pipe, Pipe IDs CO-26 and CO-29)
5. FSS Release Record, Survey Unit 00150A/B and C (North Yard Storm Drain Buried Piping)