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REPLY TO:

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September 4, 2001

Mr. Sam Nalluswami, Ph.D., P.E.
Decommissioning Branch
Division of Waste Management
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Mail Stop T7F27
Washington, DC 20555-0001

Dear Mr. Nalluswami:

Enclosed for your information and review are two copies of the Final Characterization Survey Report (with Appendices) for the Tobico Marsh State Game Area Site (License SUC-1581). As noted in my telephone message on August 31, 2001, we would like to sit down with your staff in Washington on or about October 1, 2001, to discuss draft DCLG's and dose calculations. Prior to that meeting, we will be providing you with additional materials specific to that discussion.

If you have any questions or comments, please feel free to call me at the number noted below.

Sincerely,

A handwritten signature in black ink, appearing to read "Denise Gruben".

Denise Gruben
Program Manager
Office of Property Management
517-335-4036

cc: Mr. Ed Kulzer, US NRC
Mr. David Minnaar, MDEQ
Mr. Tim Bertram, MDEQ
Mr. Christopher Dobyns, MDAG
Ms. Kelli Sobel, MDNR
Mr. Rick Dunkin, HESE

FINAL DRAFT

CHARACTERIZATION SURVEY REPORT

**Tobico Marsh SGA Site
Kawkawlin, Michigan**

Prepared for:

Harding ESE, Inc.
Under Contract Number 2004 to
Michigan Department of Natural Resources

Prepared by:

Cabrera Services, Inc.
809 Main Street
East Hartford, CT 06108

August 2001



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ACRONYMS

Ac	Actinium
AEC	Atomic Energy Commission
ALARA	As Low As Reasonable Achievable
ASTM	American Standards for Technology Manual
bgs	Below Ground Surface
Bi	Bismuth
CFR	Code of Federal Regulations
COC	Chain of Custody
CPM	Counts Per Minute
Cs	Cesium
DCGL	Derived Concentration Guideline Level
DQO	Data Quality Objectives
GPS	Global Positioning System
HAZWOPER	Hazardous Waste Operations and Emergency Response
HLA	Harding Lawson Associates, Inc.
ICR	Ignitability Corrosivity and Reactivity
ID	Inner Diameter
K	Potassium
LCTS	Leachate Collection and Treatment System
MARSSIM	Multi Agency Radiation Survey and Site Investigation Manual
MCL	Maximum Concentration Levels
MDC	Minimum Detectable Concentration

MDNR	Michigan Department of Natural Resources
MDPH	Michigan Department of Public Health
MSL	Mean Sea Level
MTC	Materials Testing Consultants, Inc.
NAD	North American Datum
NaI	Sodium Iodide
ND	Not Detected
NIST	National Institute for Standards and Technology
NORM	Naturally Occurring Radioactive Material
NRC	Nuclear Regulatory Commission
OD	Outer Diameter
ORAU	Oak Ridge Associated Universities
OSHA	Occupational Safety and Health Administration
Pa	Protactinium
Pb	Lead
pCi/g	Pico Curies per Gram
PID	Photo Ionization Detector
PPE	Personal Protective Equipment
QAE	Quality Assurance Engineer
QAPP	Quality Assurance Project Plan
QC	Quality Control
Ra	Radium
RCOPC	Radioactive Constituents of Potential Concern
ROC	Radioisotope of Concern

SDMP	Site Decommissioning Management Plan
SGA	State Game Area
SVOC	Semi-Volatile Organic Compound
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
Th	Thorium
Tl	Thallium
U	Uranium
USEPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WMI	Waste Management, Inc.

EXECUTIVE SUMMARY

The Tobico Marsh State Game Area Site characterization survey was performed to provide a radiological mapping of contaminants present in the MARSSIM Class 1, 2, and 3 areas on the Site. The mapping will provide the State of Michigan Department of Natural Resources (MDNR) with information necessary to plan and execute decommissioning. This action is one step in the process necessary to terminate MDNR's NRC license in accordance with Subpart E to Title 10, Part 20, of the U.S. Code of Federal Regulations (CFR).

This characterization survey report was designed to:

- document the Site radiological contamination results spatially (by depth and aerial extent), ultimately providing a graphical review and posting plot of the radiological contamination;
- provide sufficient detail to support finalization of the site-specific dose assessment, as low as reasonably achievable (ALARA) analysis, development of the Site Decommissioning Plan, and determination of potential disposal options for remediated wastes; and
- document data of sufficient quality and quantity to provide the basis for the development of a final status survey in areas suspected to be free of contamination (i.e., Class 2 and Class 3 Survey areas).

During previous investigations and historical review, radioactive constituents of potential concern (RCOPCs) were developed. The RCOPCs used during the planning for characterization are isotopes of thorium and their progeny; specifically, thorium-232 in secular equilibrium with its progeny and thorium-230 with small relative quantities of radium-226 and its progeny. Secondary RCOPCs include isotopes of uranium.

A Site conceptual model was developed based on the results of previous investigations and historical data reviews, and describes the assumed in-situ Site conditions. The design of the Site survey was based upon model expectations that include radioactive contamination present in the center of the Site. The contamination was assumed to reside in a horizontal layer between the bottom surface of the Site clay cap and the upper surface of the sand layer. No radioactive contamination was expected below a native clay layer present beneath the sand layer.

In-situ sodium iodide (NaI) gamma measurements were performed to estimate the lateral and vertical extent of radioactive materials present in the Site, to provide an estimate of thorium-232 activity concentrations and to develop a three-dimensional rendering of Site radiological contaminants. GeoProbe[®] casings were driven to a depth equal to or greater than the upper boundary of the native clay layer at selected measurement locations. A 1" x 1" Bicron G1 NaI crystal detector was inserted into the casing and provided thorium-232 gross gamma and spectroscopic data. The gross gamma measurements were performed at one-foot intervals starting one foot below the ground surface (bgs), and continuing to the casing bottom.

Spectroscopic gamma measurements were collected at biased locations based on gross gamma counts.

Grab soil samples were collected and analyzed using contract laboratory gamma and alpha spectroscopy to correlate and verify gross gamma measurements for the radionuclides of concern. Soil samples were used to determine the levels of thorium-230, an alpha emitter not detectable by NaI analysis as well as to provide soil concentration estimates for radium-226 and isotopes of uranium. Soil and water samples were also used to measure site-specific hydrogeological parameters, water potability, and chemical waste characteristics of the soil. These are important parameters for pathway modeling and proper waste characterization.

The characterization survey gross gamma survey produced approximately 6,000 data points. These data were used to develop gross gamma count contours by vertical elevations to provide a three-dimensional view of the Site contamination. Based on this data, the majority of the site-contaminated volume was determined to be limited to approximately one nine-foot thick layer (587 feet to 579 feet above mean sea level (MSL)). Small amounts of radioactivity in excess of background levels range to depths of about 22 feet bgs. All radioactive contamination, regardless of depth, remains within the Site Class 1 boundaries. No radioactive contamination was found in the Class 2 or Class 3 survey areas.

Thorium-232 activity concentrations detected during the characterization survey ranged from background levels to approximately 2,000 pCi/g in one isolated area. The thorium-230 activity concentrations ranged from background levels to approximately 440 pCi/g. Radium-226 activity concentrations were co-located with elevated Th-230 and were approximately 3% of the thorium-230 activity concentration. The radium-226 levels ranged from background to 11 pCi/g. This radium-226 level is consistent with assumptions regarding the relationship of Th-230 and Ra-226 as documented in the Characterization Survey Work Plan (CABRERA 1999b). Overall uranium-234, -235, and -238 activity concentrations detected at the Tobico Site are present at concentrations typical of U.S. Soils and are present only at background levels.

The characterization survey gross gamma survey minimum detectable concentration (MDC) in soil is estimated as 1.3 pCi/g for thorium-232. The thorium-230 to thorium-232 activity ratios detected varied from 0.5:1 to 11:1. The thorium ratios do not vary widely over the Site but rather are clustered in areas by what appears to be different waste streams. Activity above background was found to be within the confines of the MARSSIM Class 1 survey unit.

1.0 INTRODUCTION

The Tobico Marsh State Game Area Site (Site), also known as the SCA/Hartley and Hartley Landfill, is a closed waste disposal Site listed on the United States Nuclear Regulatory Commission's (NRC) Site Decommissioning Management Plan (SDMP). Inclusion on the SDMP resulted from past disposal of magnesium-thorium wastes at the Site. The State of Michigan Department of Natural Resources (MDNR), which owns a portion of the Site, has an NRC license, No. SUC-1581, to possess the radioactive material buried therein. The MDNR intends to terminate its license and release the Site in accordance with Subpart E to Title 10, Part 20, of the U.S. Code of Federal Regulations (10 CFR 20) (NRC 1997a). To assist MDNR in this goal, the MDNR retained its contractor, Harding Lawson Associates (HLA) and HLA's subcontractors Cabrera Services, Inc. (Cabrera), Paragon Analytics, Inc. (Paragon), and Stearns Drilling (Stearns), Inc., to perform a characterization survey of the Site.

This characterization survey report describes the methodology employed and the results obtained during the characterization survey investigation of radiological and chemical contaminants at the Site. The work performed for this Report is a subset of the Characterization Work Plan (CABRERA 1999b) and the QAPP (CABRERA 1999c and CABRERA 2000). This report's purpose is to document and report the radiological contamination measurement results, obtained from in-situ downhole gamma measurements and volumetric samples analyzed by gamma and alpha spectroscopy, with respect to source depth and isotopic source term. Chemical and physical characteristics of the Site including chemical constituents, Site geology, and geotechnical parameters, are also documented to support future reports detailing site-specific dose assessment, DCGL development, and the development of a Site Decommissioning Plan.

1.1 Objectives

The primary objectives of this characterization survey report are to:

- document the Site radiological contamination results spatially (by depth and aerial extent), ultimately providing a graphical review and posting plot of the radiological contamination;
- provide sufficient detail to support finalization of the site-specific dose assessment, as low as reasonably achievable (ALARA) analysis, development of the Site Decommissioning Plan, and determination of potential disposal options for remediated wastes; and
- document data of sufficient quality and quantity to provide the basis for the development of a final status survey in areas suspected to be free of contamination (i.e., Class 2 and Class 3 Survey areas).

The characterization survey was also designed to provide information inputs recommended by the guidance contained in Draft Regulatory Guide DG-4006, *Demonstrating Compliance with the Radiological Criteria for License Termination* (NRC 1998), and NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM)* (NRC 1997). NUREG-1727, "NMSS Decommissioning Standard Review Plan" (NRC 2000) was not released until 2000. However a draft of this document, released in 1999 for public review, was used to help determine possible regulatory requirements, scope, and direction for the characterization survey. These documents provide a framework that is acceptable to the NRC for designing final status surveys in support of NRC license termination. The data collected during this investigation will provide the basis for decisions on remedial actions, DCGL development, and subsequent final status surveys. The ultimate project objective is to demonstrate compliance with the license termination criteria contained in Title 10 of the Code of Federal Regulations (CFR) Part 20, Subpart E, license termination criteria.

1.2 Site Description

The Site consists of a closed waste-disposal facility covered with a clay cap and surrounded by a bentonite slurry wall. The Site is part of a former industrial waste-disposal area, where an estimated 18,000 barrels of spent solvents, oils, and other liquid and solid wastes were disposed of during the 1960s and early 1970s. Low-level radioactive waste in the form of magnesium-thorium slag was also disposed of at the Site beginning late in 1970. The Site, which was opened in the mid-1950s, was originally operated by the Hartley family as part of the Hartley and Hartley Landfill. In a formal land exchange in 1973, the Hartleys conveyed the Site to the State of Michigan in return for lands bordering their landfill Site. Later that year, SCA, Inc. of Massachusetts acquired the larger Hartley and Hartley Landfill Site (which is south and east of the state Site), although the Hartleys continued to manage the facility. From this time on, the non-state site was referred to as the SCA Landfill. At the end of 1984, Waste Management, Inc. (WMI) acquired SCA, Inc. and became the owner of the Hartley and Hartley Landfill. In 1998, the Site changed hands again when WMI was purchased by USA Waste. The Site covers approximately three acres of land within the State of Michigan's Tobico Marsh State Game Area and is located within Kawkawlin Township, Bay County, Michigan (Figures 1-1, 1-2, and 3-1).

1.2.1 Physical Description

Approximately 50 to 100 feet of glacial till underlies the Site, forming the upper confining layer of a deep, brackish, confined aquifer. The till is composed of clay and silt and a trace of gravel. It is very dense, unstratified, and heterogeneous, and is reported to have a permeability of 5.4×10^{-8} cm/s (Appendix B). Post-glacial beach sand deposits 5 to 8 feet thick overlie the till. Thin peat laminations are encountered in the sand deposits. Peat deposits are thicker in natural topographic depressions and are reported up to four feet thick. In undisturbed areas near the Site, black highly organic topsoil has formed.

Swampy wetland conditions and ponded water prevail in the Tobico Marsh SGA. Artificial surface drainage patterns have been established with areal drainage by the Indian Town Drain

(see Figure 1-2). The post-glacial beach sand deposits beneath the Site serve as an unconfined aquifer. This aquifer has a saturated thickness of up to 8 feet east of the Site and less than 1 foot west of the Site where the till layer surfaces. The unconfined aquifer is reported to have a permeability of about 6.4×10^{-3} cm/s (Appendix B). Due to its shallow depth, groundwater movement on the Site is directly influenced by the surface water drainage system, whether man-made or natural.

With the exception of the overlying sands, the geologic conditions are not conducive to vertical mobility of water between aquifers. The low conductivity glacial till underlying the sands is an impediment to vertical migration of groundwater and its contents.

1.2.2 Pre-operational Site History

A black and white photograph, taken April 11, 1954, portrays the area prior to the initiation of disposal operations by Hartley & Hartley, the original Site operators. A pond, currently located immediately north of the Site, is not visible on this photograph. In its place appears a raised area that is not marsh (probably a beach sand deposit). Surface water bodies currently located south and southwest of the adjoining SCA landfill are not present on the photograph.

The first invasive activity to take place on the parcel of land now occupied by the Site was the construction of a road in the late 1950s. The road was apparently constructed to provide access for the excavation of sand deposits located immediately north of the Site. This sand excavation appears to have created the pond currently located immediately north of the Site.

1.3 Operational Site History

The following list provides brief highlights of the Site's operational history. A more extensive historical account is provided in the Characterization Survey Work Plan (CABRERA 1999b).

- Following construction of the access road in the late 1950s, waste disposals included foundry sands, drummed liquid chemicals, cutting oils, oil-field tank bottoms, and oil field brines. Records do not indicate subsurface burials.
- Routine inspection reports in February of 1969 show that dumping activities had extended onto what would become State of Michigan property. Total area of trespass was approximately three acres. A rudimentary road consisted of crushed drums was constructed. Illegal dumping continued into the early 1970s.
- An aerial photograph from July of 1969 depicts disposal activities of the time. Visible white and/or gray piles were tentatively identified as non-radioactive slag originating from a magnesium casting operation at a nearby Dow Chemical facility (Figure 1-3)
- During the period April of 1970 to July of 1970, a sand cover was installed over the extended portion of the disposal area. A 1973 aerial photograph shows the formerly

visible disposal areas covered with sand. Following the sand cover installation, limited disposal continued through approximately 1973, when the State of Michigan acquired the Site.

- During the period August 1970 to June 1971, Wellman Dynamics exchanged a series of letters with the Michigan Department of Public Health (MDPH), seeking permission to bury thorium-bearing wastes at the Hartley Site in accordance with AEC regulations. Due to AEC's refusal to allow non-licensed radioactive material disposal at the Hartley Site, MDPH rejected Wellman Dynamics' request.
- During these exchanges, and subsequent to the sand cover installation, radioactive waste in the form of magnesium-thorium slag was dumped on the surface at the Site. No data were located indicating subsurface burial of these materials. It should be noted that the magnesium-thorium (radioactive) slag is visually similar to the slag originating from magnesium (non-radioactive) casting operations. More detail on radioactive waste disposal at the Site is provided below.
- In 1983, following a geophysical survey by the State of Michigan to locate buried metallic materials, the Site's slurry wall (approximately three feet thick and keyed into the underlying glacial till) and clay cap (approximately two to five feet thick) were constructed, forming the currently existing waste cell. No evidence was found indicating that the sand cover was moved during installation of the cap and walls
- Following slurry wall and cap installation, the Leachate Collection and Treatment System (LCTS) was constructed to remove water from the waste cell, treat it for non-radioactive contaminants, and discharge it to a sanitary sewer system. The LCTS has never been operated. As a result, the building and treatment components never came in contact with leachate from the Site. In 2000, the carbon units in the building were removed from the Site. Figure 1-4 is a 1998 aerial photograph showing the Tobico Marsh SGA Site. The Site borders, LCTS structure, and concrete wash pad are currently unchanged. Downhole characterization survey borings are not visible since this activity took place in 1999 and 2000.

Placement of the magnesium thorium slag on top of the sand cover is believed to have begun, in September of 1970, primarily on the road through the central portion of the Site or in areas immediately adjacent to the road where the surrounding marsh had been filled.

The probability of the migration of slag placed on the sand cover is very low. Since the magnesium-thorium slag is not readily soluble in water, the potential for the materials to dissolve in water and spread with the migration of either surface water or groundwater is limited. Physical transport of the materials after they were placed on the ground, however, may have occurred via runoff and subsequent disposal operations.

Disposal operations at the Site (including truck traffic, bull dozing, etc.) subsequent to the placement of radioactive material on the ground surface may have redistributed the material to

a small degree. The extent to which this redistribution would have occurred is limited by the presence of the marsh (it is believed that heavy equipment did not travel routinely from the fill areas out onto the marshy areas).

With placement of the clay cap and the slurry wall, it is assumed that magnesium-thorium slag became encapsulated in the cell bounded by the low permeability clay till on the bottom, the slurry wall on the sides, and the clay cap on top. This encapsulation effectively ended any potential for further physical transport of the radioactive materials beyond the confines of the cell.

1.4 Radioactive Constituents of Potential Concern (RCOPC)

RCOPCs were developed during previous investigations and historical data review. The RCOPCs used during the planning for characterization are isotopes of thorium and their progeny; specifically, Th-232 in secular equilibrium with its progeny and Th-230 with small relative quantities of radium-226 and its progeny. Secondary RCOPCs include isotopes of uranium.

1.5 Site Natural Background Radionuclide Concentrations

Soil samples collected during a preliminary background assessment (ABB 1998) were compared with published average radionuclide concentrations for Michigan and the United States. It was found that the Site samples exhibited concentrations similar to or lower than the State and national averages for the majority of the analytes. Comparisons of background radionuclide concentrations for surface and subsurface soils are provided below.

Summary of Natural Background Radionuclide Concentrations (pCi/g)

Radionuclide	TOBICO Background surface soils	TOBICO background subsurface soils	MI Soils ⁽¹⁾	U.S. Soils ⁽²⁾	U.S. Soils ⁽³⁾
Thorium-232	0.252 +/- 0.35 ⁽⁴⁾	0.246 +/- 0.18	0.56 +/- 0.35	1.0	0.97 (0.11-3.4) ⁽⁵⁾
Uranium-238	0.391 +/- 0.87	0.183 +/- 0.22	NR ⁽⁶⁾	1.8	1.0 (0.11 - 3.8)
Potassium-40	9.60 +/- 6.1	11.6 +/- 3.9	NR	11	NR

⁽¹⁾ (Myrick 1983)

⁽²⁾ (Lowder 1964)

⁽³⁾ (UNSCEAR 1988)

⁽⁴⁾ values preceded by "+/-" represent the 95% confidence level of the reported average

⁽⁵⁾ values reported in parentheses represent typical ranges of radionuclide concentrations

⁽⁶⁾ NR indicates the value was not reported

1.6 Site Conceptual Model

Based on results of previous investigations and historical data reviews, a Site conceptual model was developed to describe the assumed in-situ Site conditions. Some points relevant to the Site characterization survey are:

- Radioactive contamination was expected to be found down the center of the Site, where surveys performed prior to cap placement identified radioactive contaminants.
- Radioactive contamination was expected to exist in a horizontal layer between the bottom surface of the clay cap and the top surface of the native clay.
- The native clay layer underlying the Site was expected to be encountered between 13 and 15 feet below ground surface (bgs).
- Radioactive contamination was not expected to be found below the native clay layer.

1.7 Reference Coordinate System

During the characterization survey, a Global Positioning System (GPS)-based system (grid) was used to establish a grid system. All sampling and measurement locations were established using the same GPS system.

2.0 DATA QUALITY OBJECTIVES

The data quality objectives (DQO) process is a tool by which the planning phase of the Data Life Cycle is carried out (NRC 1997). DQOs were developed for this survey and used in its design. The DQO process specific to this project is described in detail in the work plan (CABRERA 1999b). The resulting DQOs, as well as the survey results relating to each one, are discussed in Section 4.0 of this report.

3.0 CHARACTERIZATION SURVEY METHODOLOGY

Samples and radiological measurements were collected in accordance with approved Tobico Marsh SGA procedures and the Characterization Survey Work Plan (CABRERA 1999b). Measurement locations were posted on a map of the Site, included as Figure 3-1. Survey activities fall into two general categories: direct radiation measurements and sample collection and analysis. Each of these is discussed in the following sections.

Both gamma radiation measurements and samples were also collected in a background, or reference area, located approximately 0.25 mile from the Site.

3.1 Direct Gamma Radiation Measurements

As discussed in Section 0, radioactive material was expected to be encountered only below the Site's clay cap. Routine monthly walkovers of 100% of the Site using a gamma sensitive microrem meter verified that radioactive material present at the Site remained in a subsurface position. No changes to background levels were noted during routine walkovers that were conducted prior to, during, or after characterization surveys were performed. These results are the same as described by the previous Scoping Survey Report (HLA 1998a).

Characterization survey direct radiation measurements were obtained from subsurface areas. Access to these subsurface areas obtained through use of a 66-DT GeoProbe[®] unit that advanced steel casings into the ground under hydraulic power. The casings were 2.125 inches in outer diameter (OD) and 1.5 inches in inner diameter (ID). Radiological surveys were carried out in accordance with the Site license and approved Tobico Marsh SGA procedures, as well as lower tier procedures and work instructions prepared specifically to control Site characterization tasks. The methods and rationale used to determine numbers and locations of measurements is discussed fully in the work plan (CABRERA 1999b). Specific methodologies are described in the following sections.

3.1.1 Downhole Gross Gamma Measurements Using NaI Detector

In-situ sodium iodide (NaI) gamma measurements were performed to estimate the lateral and vertical extent of radioactive materials and estimate Th-232 activity concentrations. At each selected measurement location, the drilling contractor inserted a GeoProbe[®] casing to a depth equal to or within the upper margin of the native clay layer beneath the marsh. Integrated measurements were performed at one-foot intervals starting one foot below the ground surface (bgs), continuing to the casing bottom. Measurements were made using a 1" x 1" Bicron G1 NaI crystal coupled to a laptop computer-based spectroscopic analysis system. The detector was placed into a ripstop nylon sleeve and lowered into the steel casing by means of an attached cable. At each one-foot interval, gross gamma count rates over an energy range from approximately 20 keV to approximately 1,000 keV were recorded during the 10-second measurement period. Throughout the survey, the spectroscopy system's energy calibration was maintained to avoid non-radiological (e.g., weather, etc.) gain issues. Increments of 1 foot were chosen to provide sufficient vertical definition for the three-dimensional rendering of the Site.

3.1.2 Downhole Spectroscopic Measurements Using NaI Detector

The in-situ NaI gamma detection system described in Section 3.1.1, operating in spectroscopic mode, was used to quantify the Th-232 concentrations in subsurface soils. These measurements followed the gross gamma measurements and locations (i.e., depths) and were selected based upon field review of the gross gamma data to determine appropriate depths. Collection times for spectroscopic data were 300 and 900 seconds "live time" in duration.

At each downhole measurement location, a single 900-second spectroscopic count was taken at the location of highest gross gamma counts within that GeoProbe® casing. In addition, four or five 300-second spectroscopic counts were collected at other locations within that downhole casing at depths exhibiting higher gross gamma readings. The detected activities were compared to laboratory analytical results for sub-surface soil sample collected via a 66-DT GeoProbe®.

The measured activity concentrations of Th-232 results were based on the principle of secular equilibrium and the results of sample analyses. Data was analyzed by translating NaI net total absorption peak response into Th-232 activity concentration using the Canberra Genie 2000 software. Th-232 activity concentrations were quantified by measuring its radioactive progeny and assuming secular equilibrium in the thorium series. The Pb-212 progeny provided the best detection sensitivity, based on actual results, and was selected as the primary Th-232 surrogate. The Pb-212 and other Th-232 progeny that were evaluated, along with their associated gamma lines are listed below.

<u>Radionuclide</u>	<u>Gamma Line (keV)</u>	<u>Gamma Emissions per Decay of Th-232</u>
Ac-228	911	0.27
Pb-212	239	0.43
Tl-208	583	0.30

The NaI spectroscopy system was calibrated with a reference material in a configuration similar to that expected in the field in order to determine the efficiency of the instrument. The reference standard consisted of a six-gallon plastic bucket filled with monazite sand with a section of GeoProbe® casing inserted into the center of the bucket. The Th-232 activity concentration in the sand was quantified by laboratory gamma spectroscopy analysis of the sand by an NRC-licensed, analytical laboratory. Prior to laboratory analysis, the sand was thoroughly mixed. All sand was analyzed, in one-liter aliquots, prior to transfer into the reference standard. The NaI system was then calibrated using this reference standard by inserting the detector into the GeoProbe® casing and performing five ten-minute counts. Net peak count rates for each of the gamma lines listed above was recorded. The average net count rate and associated variance was entered into the Canberra Genie 2000 software to develop an efficiency curve and associated errors. This efficiency curve was used to quantify Th-232 activity concentrations during Site measurements.

3.2 Sample Collection and Analysis

Subsurface soil samples from the Site were collected and screened in the field and submitted to Paragon for laboratory analyses. Hydrogeological samples were analyzed by Materials Testing Consultants, Inc. (MTC) and ignitability analysis was provided by Severn Trent Laboratories Inc. (STL). Analyses performed fall into three general categories: radiological, chemical, and hydrogeological. Each of these categories is discussed in Sections 3.3, 3.4, and 3.5, respectively.

3.2.1 Sample Documentation

Collected samples were assigned a unique sample identification number and recorded in the field logbook. At a minimum, recorded information included the sample location, identification number, and date collected. If a sample could not be collected due to drilling conditions, weather conditions, or equipment failure, the information was documented in the field logbook and the Field Operations Leader was notified.

A chain of custody was maintained on samples collected during the characterization survey. The purpose of the chain of custody is to document sample possession from the time of collection to receipt at the analytical laboratory. The analytical laboratory was instructed that if complete chain of custody records did not accompany each sample shipment, the laboratory was not to analyze the sample(s). The Senior Radiological Engineer and/or the QA Engineer were responsible for reviewing, and ensuring the accuracy and completeness of, the chain of custody forms. Chain of custody (COC) forms included the following information for each sample:

- the sample identification number;
- date and time of sample collection;
- sample matrix (i.e., soil, sediment);
- required analyses; and
- special handling requirements, if any.

Additionally, chain of custody forms included signatures of individuals relinquishing and receiving sample custody and the associated date and time. The copy of the chain of custody forms included in laboratory data packages is considered the "official" custody record for the samples.

Samples collected during the characterization survey were temporarily stored on-site. Per the laboratory protocol, there are no specified holding time requirements for radiological samples. If a sample was slated to be analyzed for chemical parameters, the sample was kept on ice and analyzed within the appropriate holding time. Prior to shipment, the sample containers were surveyed for external loose contamination, decontaminated if necessary and released for shipment. Collected samples were properly packaged, documented, and released to a courier.

3.2.2 Sampling Methodology

Access to the subsurface areas, from which all project samples were obtained, was gained through use of a 66-DT GeoProbe® unit that advanced steel casings into the ground under hydraulic power. The casings were 2.125 inches OD and 1.5 inches ID. Samples were obtained using standard 66-DT GeoProbe® sampling accessories, including Macro-Core® and dual tube sampling tools. GeoProbe® borings were advanced using a GeoProbe® sampling system. Soil samples were collected continuously (for soil description purposes), and at

discrete depths (for analytical testing) using either a 2-inch inner-diameter (I.D.), 2-foot-long core or a 3-inch I.D., 5-foot-long dual tube.

3.3 Radiological Analyses

Two types of radiological analyses were performed on characterization samples, gamma spectroscopy and alpha spectroscopy. The former was performed both on-site, in the field laboratory, and off site at Paragon, while the latter was performed only at Paragon. The field laboratory was used as a screening tool for the majority of samples collected for both radiological and chemical analyses. Samples screened on-site during performance of the characterization survey data were used to estimate Th-232 activity concentration. The field screening techniques for determining when analyses would be performed on each sample are described in Section 3.9 of the Characterization Survey Work Plan (CABRERA 1999b).

A gamma library of natural radionuclides (i.e., the actinium, thorium, and uranium series and K-40) and Cs-137 was used for all gamma spectroscopic analyses. Based on analytical results and the assumption of secular equilibrium, Th-232 concentration was inferred from the activity concentration of its progeny.

Isotopic uranium and/or isotopic thorium alpha spectroscopic analyses were performed on selected samples. Isotopic uranium quantified U-234, U-235, and U-238, while isotopic thorium analyses quantified Th-228, Th-230, and Th-232.

3.4 Chemical Analyses

Soil samples requiring chemical analyses were submitted to Paragon and STL. These samples were analyzed for volatile organic compounds (VOCs) using USEPA Method 8260 (with methanol preservation for total analysis samples only), semi-volatile organic compounds (SVOCs) using USEPA Method 8270, Metals (arsenic, barium, cadmium, chromium, lead, selenium, silver, and mercury) using USEPA Method 6061, and Pesticides and Herbicides using USEPA Method 8080. The samples were also analyzed for waste characterization parameters (Reactive Cyanide, Reactive Sulfide, Ignitability (Method 1030), and pH). A Toxicity Characteristic Leaching Procedure (TCLP) extract for each sample was also analyzed for VOCs, SVOCs, Metals, Pesticides, and Herbicides.

3.5 Hydrogeologic Analyses

Samples were specifically collected to determine the conductivity of the Site soils to fulfill one of the characterization survey's DQOs. The samples were collected in an unimpacted area within 1 mile of the Site and later submitted to Materials Testing Consultants, Inc. (MTC) in Grand Rapids, Michigan. Soil samples consisted of one clay sample and one sand sample. The clay sample was analyzed using ASTM Method D 5084, which measures the hydraulic conductivity of saturated porous materials. The sand sample was analyzed using ASTM Method D 2434, which measures the hydraulic conductivity on granular soils.

Another project DQO was to determine whether Site surface and subsurface waters are potable because this characteristic has impact on dose modeling. As such, both surface water and ground water samples were collected and analyzed. These samples were collected within a 1-mile radius of the Site in areas that were not anticipated to be impacted by the Site.

4.0 CHARACTERIZATION SURVEY RESULTS

This section presents results of characterization measurements and analysis of data. Basic results and summary statistics are presented, data presentation figures and tables are introduced, and some data anomalies are identified and data is qualified appropriately. Evaluation and analysis of these results relative to the Site Conceptual Model is presented in Section 5.7.

4.1 Subsurface Gross Gamma Radiation Measurements

As described previously subsurface gross gamma radiation measurements were performed in GeoProbe[®] casings using a Bicron G1 1" x 1" NaI detector coupled to a Canberra Inspector. At each measurement location, gross gamma measurements were performed at one-foot intervals in the casing using a count time of 10 seconds. Measurements were also performed in the Reference Area using the same technique.

Gross gamma results are assumed to be proportional to the Th-232 activity concentration at the measurement location, as other ROCs are either proportional to Th-232 activity concentration or do not have significant gamma emissions. The estimated efficiency of the detector for quantifying Th-232 in-situ gamma response is 500 net counts per minute (cpm) per pCi/g of Th-232 above background. The estimated detection sensitivity of the gross gamma measurements to quantify Th-232 in excess of background is approximately 1.3 pCi/g (see Appendix D for details).

4.1.1 Reference Area Results

The results of subsurface gross gamma measurements in the Reference Area are provided in Appendix E-1. Reference Area gross gamma measurements were performed at 375 locations in 40 casings. The maximum measurements depth was 14 feet bgs. The Reference Area gross gamma response averaged 137 ± 96 (2σ) counts per ten seconds with a minimum of 52 and maximum of 258.

4.1.2 Site Results

Site subsurface gross gamma measurement locations are identified on Figure 3-1. Only the bias measurement locations are labeled to maintain figure clarity. The remaining Class 1, Class 2, and Class 3 location identifiers are based on a systematic labeling system. The results of Site subsurface gross gamma measurements are provided in Appendix E-2. Site gross gamma measurements were performed at 5,926 locations in 397 casings. The maximum

measurements depth was 29 feet bgs. The Site gross gamma response averaged 200 ± 923 (2σ) counts per ten seconds. The range of observed values is 20 to 61,054 counts.

4.1.2.1 Gross Gamma Contours

The gross gamma data represents the largest single set of subsurface radiological data that has been collected at the Site to date. As stated previously, the thousands of measurements are presented in tabular form in Appendix E-2 along with the location of each measurement (i.e., easting, northing, and elevation). This positionally correlated data set was reduced using geospatial modeling techniques to present it in a more usable, graphical, manner that supports decision making. The following geospatial modeling approach was implemented:

- The data points were imported as three dimensional scatter points and a bounding grid of approximately 15 foot by 15 foot by 1 foot (in the northing, easting, and elevation coordinates, respectively) was placed around the extremes of the mass of points.
- The estimated values for counts per 10 seconds at each grid node were developed using a natural neighbors interpretation routine that considered only the 8 nearest points. In addition, distances in the vertical (elevation) dimension were scaled up by a factor of ten to account for the greater variability, and considerably larger density, of values in that direction.
- Isosurfaces (3D contours) were developed for the grid data for the following values of counts per 10 seconds: 300, 500, 1,000, 2,000, and 5,000. This series of values was chosen to best depict the extent of just-above-background values and the areas of elevated radioactivity at the same time. It should be noted that all gross gamma count contours greater than 5,000, regardless of magnitude, are grouped in the 5,000 contour.
- Horizontal grid layers were isolated one by one and the resulting contours (of above values) were then exported to ESRI's ARCVIEW and superimposed over a base map derived from an AutoCAD drawing.

As stated above, gross gamma count contours are presented in divisions of 300, 500, 1,000, 2,000, and 5,000 counts per 10 seconds. Based on the data analysis documented in Appendix D, which assumes that gross gamma response is directly proportional to Th-232 activity concentration, the estimated Th-232 activity concentration corresponding to each contour division are as follows:

10-Second Gross Gamma Contour Counts	Soil Thorium-232 Concentration Above Background, pCi/g
300	1.6
500	4
1000	10
2000	22
5000	58

The results of the geospatial modeling contours are presented in Figures 4-1 through 4-24. With the exception of Figures 4-22 through 4-24, which are cross sectional views, each figure shows prominent Site features, the Site grid system, and the final MARSSIM Class 1, 2, and 3 area divisions (following modifications as described in Section 5.7). The following paragraphs briefly describe the figures. Interpretation of the results depicted in the figures relative to the Site Conceptual Model is provided in Section 5.7.

Figure 4-1 presents the maximum gross gamma count in each vertical column (i.e., casing) by horizontal location. This figure presents a two dimensional picture of radiological gross gamma count rates in excess of background levels and, thus, approximates the maximum horizontal extent of radionuclide contaminants.

Figures 4-2 through 4-20 present gross gamma count contours by elevation. Contours are provided in one-foot elevation increments from 591 feet above mean sea level (MSL) (Figure 4-2) to 573 feet above MSL (Figure 4-20). These figures present a two dimensional picture of radiological gross gamma count rates in excess of background levels at each elevation and thus approximate the maximum horizontal extent of radionuclide contaminants at each elevation.

Figures 4-22 through 4-24 present vertical cross sectional views of the gross gamma contours (i.e., easting or northing versus elevation). Figure 4-21 identifies the cross sectional view locations and direction of view. The intent of these figures is to provide estimates of the vertical extent of gross gamma count rates in excess of background levels.

Figure 4-25 presents a summary of all gross gamma data. Nine gross gamma count contour plots, grouped by elevation, are presented at a 10° viewing angle and stacked. Filled gross gamma contours are presented in two categories, 300 to 500 counts and greater than 500 counts. The maximum gross gamma count value for each measurement location in an elevation group was used to develop the contours. The intent of this figure is to provide a three dimensional estimate of the vertical extent of gross gamma count rates in excess of background levels. It should be noted that the geospatial modeling technique used to estimate contour divisions in Figure 4-25 is slightly different than the technique described above for

Figures 4-1 through 4-24. This technique used a nearest neighbor geospatial model with a 15 foot bounding limit.

4.2 Subsurface In-situ NaI Gamma Spectroscopy Measurements

As described previously, subsurface in-situ gamma spectroscopy measurements were performed in GeoProbe® casings using a Bicron G1 1" x 1" NaI detector coupled to a Canberra Inspector. Typically, subsurface in-situ gamma spectroscopy measurements were performed at six depths at each measurement location. Five measurements were performed using a five-minute counting interval and one measurement was performed using a 15-minute counting interval. Measurements depths were biased based on the results of gross gamma measurements in an attempt to quantify any observed elevated locations.

Subsurface in-situ gamma spectroscopy results provide estimates of the Th-232 activity concentration at the measurement location, the error associated with the estimate, and/or the minimum detectable Th-232 activity concentration (MDC). Activity estimates are provided for measurements where the net peak count rate exceeded the critical level at the 95% confidence level. When results did not exceed the critical level, only the MDCs are provided.

4.2.1 Reference Area Results

The results of subsurface in-situ gamma spectroscopy measurements in the Reference Area are provided in Appendix F-1. Reference Area in-situ gamma spectroscopy measurements were performed at 170 locations in 40 casings. The maximum measurement depth was 14 feet bgs. Only three of the 170 measurements identified Th-232 (i.e., had net count rates greater than the counting instrumentation critical level). These three positive detections averaged 1.8 ± 1.5 (2σ) pCi/g of Th-232 with a minimum of 1.6 and maximum of 2.2 pCi/g. It should be noted that the two sigma relative error associated with the three positive detections averaged approximately 80%. These positive results are suspected to be false-positives based on anticipated and measured background activity concentrations of Th-232; although they could be true positives in light of their large relative error.

4.2.2 Site Results

The results of subsurface in-situ gamma spectroscopy measurements in Site areas are provided in Appendix F-2. Site in-situ gamma spectroscopy measurements were performed at 2,518 locations in 397 casings. The maximum measurement depth was 26 feet bgs. Of the 2,518 measurements performed, 131 identified Th-232 (i.e., had net count rates greater than the counting instrumentation critical level) resulting in a positive detection. These positive detections averaged 33 ± 106 (2σ) pCi/g of Th-232 with a minimum of 1.3 and maximum of 804 pCi/g.

4.2.2.1 Graphical Presentation - Posting Plot

As stated previously, the thousands of measurements are presented in tabular form in Appendix F-2 along with the location of each measurement (i.e., easting, northing, and

elevation). This positionally correlated data set was reduced by generating a posting plot to present it in a more usable, graphical, manner that supports decision making.

Figure 4-27 presents the maximum in-situ gamma spectroscopy Th-232 result in each vertical column (i.e., casing) by horizontal location. It should be noted that only results that exceed their associated MDC are reported. The figure also presents prominent Site features and contours of the maximum gross gamma count in each vertical column by horizontal location generated using nearest neighbor interpolation. The purpose of this figure is to provide estimates of Th-232 activity concentrations in areas where elevated gamma count rates were observed and to demonstrate that elevated Th-232 was not falsely identified in areas where elevated gross gamma count rates were not observed. Figure 4-27 shows only two locations where in-situ gamma spectroscopy Th-232 concentrations above background (2 pCi/g), were identified and where the gross gamma counts were not elevated. It is suspected that these results are false-positives, similar to those identified in the Reference Area. The gamma spectroscopy and gross gamma data agree well with each other.

4.3 Results of Volumetric Sample Analyses

Subsurface soil samples were collected, screened as necessary in the field and submitted to Paragon, MTC, or STL for analyses. Analyses performed falls into three general categories: radiological, hydrogeological, and chemical.

4.3.1 Radiological Sample Results

As discussed in Section 3.3, radiological samples were analyzed via gamma spectroscopy and/or alpha spectroscopy at Paragon Analytics. The alpha spectroscopic samples were analyzed for isotopic uranium and/or isotopic thorium, while gamma spectroscopy was performed to identify any gamma emitting natural series radionuclides and Cs-137. A total of 52 samples were analyzed: 34 receiving thorium alpha spectroscopy; 34 receiving uranium alpha spectroscopy; and, all samples receiving gamma spectroscopy. Five field duplicate samples were also collected and analyzed for QA purposes. Samples were collected at various depths throughout the Site. Complete radiological sample results are presented in Table 4-1. These results are summarized as follows:

4.3.1.1 Gamma Spectroscopy Results

All fifty-two samples were analyzed by Paragon Analytics using gamma spectroscopy. The following list summarizes gamma spectroscopic analytical results from all Site areas.

Results of Gamma Spectroscopic Sample Analysis by Radionuclide, pCi/g

<u>Nuclide</u>	<u>Average</u>	<u>Standard Deviation</u>	<u>Minimum</u>	<u>Maximum</u>
Th-232	15	311	-870	1910
Ac-228	53	179	0.05	1260

Pb-212	71	250	0.44	1730
Tl-208	19	65	0.11	442
Pa-234m	7.7	29	-10	210
Th-234	0.96	9.5	-45	20
Ra-226	2.6	3.1	0.43	14
Pb-214	1.8	2.4	0.07	11
Bi-214	1.7	2.1	0.30	9.2
U-235	0.39	1.3	-1.40	5.7
Cs-137	0.03	0.09	-0.15	0.46
K-40	15	20	-4.3	141

It should be noted that the statistical quantities above consider all sample results, regardless of their statistical validity (i.e., sample results less than the 95% critical level are included in the statistics). Although this is an appropriate technique for estimating average concentrations, it should be recognized that maximum concentrations and averages may have large relative errors.

Some sample results should be qualified based on review of the gamma spectroscopy results against alpha spectroscopy results and fundamental concepts of physics and gamma spectroscopy. The results of this review are summarized as follows.

- **Ra-226 Results Potentially Overestimated:** Ra-226 results appear to be overestimated for the majority of the samples based on comparison of Ra-226 results to Pb-214 and Bi-214 results. This is because the gamma line used to quantify Ra-226, 186.2 keV, is not readily resolvable from the U-235 185.7 keV gamma line. Thus, U-235 in the samples contributed to the 186 keV peak resulting in an overestimate of Ra-226. Paragon Analytics' procedure included sealing of samples and a 21-day ingrowth period for Ra-226 daughters in order to establish Ra-226 short-lived daughter equilibrium. Thus, Pb-214 and Bi-214 results provide a more appropriate estimate of Ra-226 activity concentration.
- **U-235 Results Potentially Overestimated:** U-235 results appear to be overestimated for many of the samples based on comparison of gamma spectroscopy results to alpha spectroscopy results. This is because the gamma line used to quantify U-235, 185.7 keV, is not readily resolvable from the Ra-226 186.2 keV gamma line. Thus, Ra-226 in the samples contributed to the 186 keV peak resulting in an overestimate of U-235.
- **Th-234 Results Potentially Overestimated in Samples with Elevated Ac-228:** Th-234 results appear to be overestimated for some of the samples based on comparison of gamma spectroscopy results to U-238 alpha spectroscopy results; Th-234 and U-238 are in secular equilibrium in the samples and thus should have equal activities. This potential overestimation is because one of the gamma lines used to quantify Th-234, 93 keV, is not readily resolvable from an x-ray emitted by Ac-228 at approximately the same energy.

- **Pa-234m Results Potentially Overestimated:** Pa-234m results appear to be overestimated for some of the samples based on comparison of gamma spectroscopy results to U-238 alpha spectroscopy results; Pa-234m and U-238 are in secular equilibrium in the samples and thus should have equal activities. An explanation for this potential overestimation was not identified.

4.3.1.2 Alpha Spectroscopy Results

The following list summarizes alpha spectroscopic analytical results from all Site areas. Thirty-four samples were analyzed by thorium and uranium alpha spectroscopy.

Results of Alpha Spectroscopic Analysis by Radionuclide, pCi/g

<u>Nuclide</u>	<u>Average</u>	<u>Standard Deviation</u>	<u>Minimum</u>	<u>Maximum</u>
Th-232	50	120	0.15	650
Th-228	57	144	0.13	790
Th-230	71	118	0.15	443
U-235	0.12	0.21	0.01	1.1
U-238	0.67	0.56	0.09	2.2
U-234	1.0	1.9	0.12	11

Isotopic uranium results for sample E6NWSS0301 has a 66% relative error and should not be used quantitatively. The reported activity concentrations for this sample were as follow:

U-234	U-235	U-238
10.6 ± 2.2 pCi/g	1.1 ± 0.7 pCi/g	1.2 ± 0.7 pCi/g

The large relative uncertainties associated with this measurement, Site historical data, and the lack of any credible evidence of enriched concentrations of U-235 being placed at the Site lead to the conclusion that U-235 is not present at the Site at concentrations above normally occurring background levels. Only natural uranium is a RCOPC for the Site. It is concluded, therefore, that there was an error in the isotopic uranium analysis of this sample.

4.3.1.3 Graphical Presentation - Posting Plots

Positionally correlated Th-232 gamma spectroscopy results were reduced by generating a posting plot to present the data in a more usable, graphical manner that supports decision making.

Figure 4-26 presents the maximum gamma spectroscopy Th-232 result in each vertical column (i.e., casing) by horizontal location, based on quantification of Ac-228 and the assumption of secular equilibrium. The figure also presents prominent Site features and contours of the maximum gross gamma count in each vertical column by horizontal location

generated using nearest neighbor interpolation. The purpose of this figure is to provide estimates of Th-232 activity concentrations in areas where elevated gamma count rates were observed and to demonstrate that elevated Th-232 was not observed in areas where elevated gross gamma count rates were not observed.

4.3.1.4 *Th-230 to Th-232 Ratio*

Considering that Th-230 is essentially a pure alpha emitter and is not readily detectable in the field, one project goal was to use analytical sample results to develop a ratio of Th-230 to Th-232. This ratio could then be applied to in-situ measurements of Th-232 to offer an approximate Th-230 concentration for the same location.

The ratio of Th-230 to Th-232 activity concentrations are reported in Table 4-2 for each of the 34 samples that were analyzed for isotopic thorium by alpha spectroscopy. Th-230 to Th-232 ratios averaged 2.4 ± 3.1 (2σ):1 with a minimum of 0.5:1 and a maximum of 11:1. Such a large range of ratios was not anticipated. In order to better understand the variation of this ratio, a posting plot was generated.

Figure 4-28 spatially presents the Th-230 to Th-232 ratio for each sample analyzed. The figure also presents prominent Site features and contours of the maximum gross gamma count in each vertical column by horizontal location generated using nearest neighbor interpolation. As can be seen in the figure, Th-230 to Th-232 ratios are not widely variable across the Site. Instead, like ratios are clustered in what appear to be different waste streams, based on the spatial distribution of ratios relative to the areas of elevated gamma count rates.

One waste stream area encompasses a significant portion of the Site and includes the entire central, northeastern, and southeastern portions of the Site. The Th-230 to Th-232 ratio in these areas is approximately 1:1 with a range of 0.5:1 to 2:1. A second waste stream includes two areas, one in the northwest and one in the southwest portion of the Site. The Th-230 to Th-232 ratios in these areas ranges from 4:1 to 11:1.

4.3.2 *Results of Hydraulic Conductivity Samples*

The results of samples collected and analyzed for hydraulic conductivity are discussed in detail in Appendix B. Samples of both the sand and clay that underlie the Site were collected and analyzed. These samples were collected from Site areas containing sand and clay native to the area. The results of the sample analyses indicate that the hydraulic conductivity of the landfill soils are 5.4×10^{-8} cm/sec and 6.4×10^{-3} cm/sec for clay and sand components for soils, respectively.

4.3.3 *Results of Water Potability Samples*

The results of samples collected and analyzed for potability are discussed in detail in Appendix B. Analysis of groundwater and surface water samples collected to establish potability indicate that it is not possible to rule out the potential use of either as a source of potable water. The only drinking water standards exceeded were secondary Maximum

Concentration Levels (MCLs) for iron, total dissolved solids (TDS), chloride, and sulfate. Secondary MCLs are used only for aesthetic purposes (i.e., color, odor, taste, etc.)

4.3.4 Results of Waste (Chemical) Characterization Samples

The results of samples collected and analyzed for chemical waste characterization are discussed in detail in Appendix A. While various chemicals were detected in the soil, none of the TCLP concentrations exceeded the 40 CFR Part 216.24 "Maximum Concentration of Contaminants for Toxicity Characteristics". Reactive cyanide and reactive sulfide were not detected and there are no other apparent reasons to believe the waste soil is reactive as defined in 40 CFR 261.23. Also, because the pH is not less than 2.5 or greater than 12.5, this waste would not be considered corrosive as defined in 40 CFR 261.21. Based on the analytical results, none of the samples would be considered ignitable in accordance with 40 CFR 261.22.

Based on the analytical results currently available and generator knowledge, there are no indications that the soil containing radioactive and chemical waste material at the Site would be considered a hazardous waste, as defined in 40 CFR Part 261.

5.0 DISCUSSION AND INTERPRETATION OF SURVEY RESULTS

The purpose of this section is to collectively discuss and interpret the results of the characterization survey. Results are evaluated against specific DQOs established in the Characterization Survey Work Plan (CABRERA 1999b). In addition, results are compared against the assumptions and premises of the Site Conceptual Model upon which the characterization survey was, in part, designed.

5.1 Site Source Term

A principal DQO of the characterization survey was to better-define the Site source term (i.e., radionuclides present and their activity concentrations). Previous investigations identified isotopes of thorium and their radioactivity decay progeny as the primary RCOPCs. Uranium isotopes were also established as a RCOPC during previous efforts implemented by the NRC's contractor, Oak Ridge Associated Universities (ORAU). Subsequent sampling and analysis efforts implemented for the State of Michigan confirmed the presence of elevated concentrations of thorium isotopes and their radioactive decay progeny, but did not confirm the presence of uranium isotopes. Based upon the results of this characterization survey, RCOPCs are no different than previously established and documented in the conceptual model.

5.1.1 Thorium-232 and its Radioactive Progeny

Characterization survey in-situ gamma radiation measurements and sample analyses confirmed the presence of Th-232 and its radioactive progeny in secular equilibrium. Figures 4-26 and 4-27 provide posting plots of Th-232 activity concentrations measured by gamma spectroscopy sample analyses and in-situ gamma spectroscopy, respectively. Site Th-232

activity concentrations ranged from background levels to as high as approximately 2,000 pCi/g in one isolated area.

Analytical sample results are reported in Table 4-1. All samples were analyzed by gamma spectroscopy analysis and 34 samples were analyzed by alpha spectroscopy for isotopic thorium concentrations. In many cases, gamma spectroscopy and alpha spectroscopy results for the same sample are not in good agreement, especially when substantial concentrations of Th-232 were measured. Gamma spectroscopy uses a large sample mass (approximately 500 grams), whereas alpha spectroscopy uses a small sample mass (approximately 2 grams). As such, this poor agreement indicates that the thorium is not homogeneously distributed in small masses, such as a one-kilogram sample. Similar conclusions regarding the homogeneity of the waste were reached during analysis of scoping survey samples.

5.1.2 Thorium-230 and Radium-226

Characterization survey sample analyses confirmed the presence of Th-230 and Ra-226 in excess of background levels. Site Th-230 activity concentrations ranged from background levels to as high as approximately 440 pCi/g; Ra-226 activity concentrations ranged from background to as high as approximately 11 pCi/g. Elevated Ra-226 activity concentrations were co-located with elevated Th-230 and were approximately 3% of the Th-230 activity concentration. This is consistent with assumptions regarding the relationship of Th-230 and Ra-226 documented in the Characterization Survey Work Plan (CABRERA 1999b); elevated Ra-226 is therefore assumed to result from decays of Th-230, its direct parent radionuclide.

Figure 4-28 spatially presents the Th-230 to Th-232 ratios. As can be seen in the figure, Th-230 to Th-232 ratios are not widely variable across the Site. Instead, like ratios are clustered in what appear to be different waste streams, based on the spatial distribution of ratios relative to areas of elevated gamma count rates. Thus, a single Th-230 to Th-232 ratio is not applicable to the Site (unless a bounding conservative ratio is assumed).

5.1.3 Uranium Isotopes

Uranium isotopes were established as a RCOPC during previous efforts implemented by the NRC's contractor, ORAU, but were not identified during previous State of Michigan investigations. Characterization survey results confirm that the uranium activity concentrations are considerably lower than elevated thorium concentrations.

To assess the potential for the presence and quantity of uranium as a RCOPC, uranium alpha spectroscopy was performed on 34 samples collected at locations where the in-situ field measurements indicated the presence of elevated radioactivity. The laboratory analytical analysis indicated the presence of U-238 and U-234 at levels comparable to background values as described previously in Section 1.5. The average and standard deviation statistics for the measurement results of these isotopes were compared with the Tobico surface soils, Tobico subsurface soils, and U.S soils as listed in Section 1.5. Additionally, Th-232 and Th-230 to U-238 and U-234 ratios and their associated sample population standard deviations were calculated and compared. The measured U-235 values, being small, have relative errors

ranging from 30 to 200 percent (1 sigma). Consequently, U-235 concentrations at the Site are statistically indistinguishable from background concentrations. The overall concentration of uranium detected on the Tobico Site is present at concentrations typical of U.S. soils and are present only at background levels based on the following:

- U-238 measurements in soils at Tobico exist at an average concentration of 0.68 ± 0.54 (1 SD) pCi/g and are comparable to U.S. soils ranging from 0.11-3.8 pCi/g U-238 (Section 1.5).
- U-238/U-234 ratios were measured at approximately 1:1 ratios for the majority of the samples analyzed. Ratios ranged from 0.1 to 1.3.
- Uranium isotopes found with thorium isotopes at Tobico do not appear to be present at the Site as a result of magnesium-thorium slag placement since the ratios of Th-232:U-238, Th-230:U-238, Th-232:U-234, and Th-230:U-234 have large relative errors that exceed 170% at one standard deviation. Uranium isotopes present at the Site as a direct result of magnesium-thorium slag placement would be expected to have more consistent Th:U ratios if the uranium were present in the slag initially. It is concluded that the uranium present at Tobico is due to naturally occurring concentrations in the soil present at the Site.
- Measured U-235 concentrations are generally low and have large relative errors in the reported values associated with them. Sixteen of 33 samples showed U-235 concentrations above the MDC. Closer examination of these concentration values show large uncertainties in the reported value associated with the measurements on the order of 30-100%. One sample indicated a U-235 concentration of 1.1 pCi/g with a 66% relative error. Based on historical data, the lack of any credible evidence of enriched concentrations of U-235 being placed at the Site, and the large uncertainties associated with the measurements, it is concluded that U-235 is not present at the Site at concentrations above normally occurring background levels.

5.1.4 Potassium-40

Past Site investigations (ABB 1997) identified elevated K-40 in Site groundwater samples. Characterization survey sample analyses identified the presence of K-40 in excess of background levels in soil. Site K-40 activity concentrations in soil ranged from background levels to as high as approximately 141 pCi/g. K-40 in excess of background was measured in soil samples collected in the vicinity of monitoring well MW/RL-9.

The elevated K-40 is likely due to chemical contaminants disposed of at the Site. In addition, K-40 is naturally occurring radioactive material (NORM) and is not specifically regulated by the NRC.

5.2 Three-Dimensional Extent of Radioactive Contamination

A principal DQO of the characterization survey was to develop a three-dimensional model of Site contaminants. This was accomplished through performance of thousands of gross gamma radiation measurements, which are assumed to be proportional to Th-232 activity concentration. Figures 4-1 through 4-25 provide a graphical presentation of Site locations where gamma radiation levels, and thus Th-232 activity concentrations, are in excess of background levels.

Review of Figure 4-1, which presents the maximum gross gamma count in each casing, indicates that the horizontal extent of radioactivity in excess of background levels is limited to the center of the Site. Figures 4-2 through 4-20 provide estimates of the horizontal extent of contamination in one-foot elevation increments.

Figure 4-25 provides a summary of the three-dimensional contaminant model. The majority of the contaminated Site volume is limited to a nine-foot layer (elevation range of 587 feet to 579 feet above MSL). Radioactivity in excess of background levels was not identified above 590 feet MSL or below 570 feet MSL.

5.3 Comparison of Reference Area Gross Counts to Site Area Gross Counts

Comparisons of gross count histograms between the reference area and the Class 1, Class 2, and Class 3 areas can show differences between distributions which could be interpreted as one indication of the presence of potential radioactivity above background.

Figures 5-2 through 5-5 are histograms that depict 10-second gross counts for the reference area and the Site Class 1, 2, and 3 areas. These frequency distributions show a similar relationship between the reference area (Figure 5-2) and the Class 2 and 3 areas of the Site (Figure 5-3). The distributions of both of these histograms show a clear bimodal distribution. The peaks in both distributions are centered at 80 gross counts per 10-seconds and 170 –180 gross counts per 10-seconds. The reference area averaged 137 ± 96 (2σ) counts for the 10-second counts while the Site Class 2 and Class 3 areas averaged 155 ± 96 (2σ) counts for the 10-second counts. No 10-second count values greater than 300 (equivalent to 1.6 pCi/g) were observed in either area. This shows that the reference area (background level of thorium) and the Class 2 and 3 areas are similar in their gross background counts and distribution of these counts. Class 2 and 3 areas do not appear to have radioactivity above background levels based on this comparison.

Figure 5-4 is a histogram depicting the 10-second gross counts from the Site Class 1 area. The distribution of data from this area shows only one peak and has 180 samples with 10-second counts greater than 300. This is significant in that the reference area had no values above 300 counts. The Site Class 1 area averaged 208 ± 1998 (2σ) counts for the 10-second counts. The maximum count in the Site Class 1 area is 61,054, well above any reference or Site Class 2 and 3 area values. This would indicate the presence of radioactivity in the Class 1 area at levels greater than seen in the reference area. Figure 5-5 presents the

same data as figure 5-4 but with a log scale to allow improved visualization of the number of measurements.

The data from the reference area and the Site Class 2 and 3 areas indicates that these locations appear to have the same natural background radioactivity and distribution. The Class 1 area shows clear indication of gross radioactivity greater than the reference area.

5.4 Hydraulic Conductivity of Site Soils

Samples of both sand and clay that underlay the Site were collected and analyzed. The results of the sample analyses indicate that the hydraulic conductivity of the landfill soils is approximately 5.4×10^{-8} cm/sec to 6.4×10^{-3} cm/sec for clay and sand components for soils, respectively. These hydraulic conductivities show that areas where clay exists are essentially impervious to the transmission of water and dissolved contaminants it may contain. The sandy components of the soil have a higher level of transmission and would not prevent significant transport of water-soluble contaminants. Appendix B provides additional detail.

5.5 Groundwater/Surface Water Potability

Analysis of groundwater and surface water samples collected to establish potability indicate that it is not possible to rule out the potential use of either as a source of potable water. Since the only drinking water standards exceeded were secondary Maximum Concentration Levels (MCLs) for iron, total dissolved solids (TDS), chloride, and sulfate, both groundwater and surface water may be used as a source of potable water. Therefore, site-specific dose assessment models for the Site may include water pathways analyses that assume the potential utilization of water from the Site area. Appendix B provides additional detail.

5.6 Chemical Characteristics of Radioactively Contaminated Materials

Various chemicals were detected in the contents of landfill. The analytical results of these soils indicate that the waste materials present in the soil at the Site would not be considered a hazardous waste, as defined in 40 CFR Part 261. Appendix A provides additional detail of the chemical characteristics of the soil.

5.7 Comparison of Results to Site Conceptual Model

The Site conceptual model, as noted in Section 1.6, was developed based on results of investigations conducted prior to the characterization survey and historical data reviews. The characterization survey confirmed the conceptual model as described in Section 1.6.

5.7.1 Lateral Extent and Location of Radioactive Contaminants

Based on the Site conceptual model, radioactive contamination was expected to be found down the center of the Site, where surveys performed prior to cap placement identified radioactive contaminants. Figure 5-1 identifies areas where the previous surveys identified

radioactive contaminants and shows the boundaries of MARSSIM Class 1, 2, and 3 survey units established for the characterization survey.

The results of the characterization survey support the Site conceptual model assumptions regarding lateral extent and location of radioactive contaminants. Radioactive contamination was generally identified where historical information indicated it would be laterally (see Figure 4-1). It should be noted that the lateral extent was slightly greater than anticipated. As such, the Class 1 area was slightly increased during execution of the characterization survey as shown in Figure 3-1. This slight disagreement with the conceptual model is likely due to small scaling errors when transferring past survey data to current Site maps.

5.7.2 Vertical Extent of Radioactive Contaminants

Consistent with the conceptual model, radioactive contamination was not identified below the upper surface of the natural clay layer that underlays the Site. However, in some locations, the depth to the native clay layer was considerably greater than anticipated (as deep as 26' bgs). In addition, Th-232 as high as 100 pCi/g was identified in a clay depression at approximately 19' bgs.

Based on these observations, it was speculated that prior to sand cover installation and Site capping, there may have been some areas where excavations had occurred (presumably to support Site waste disposal activities). The presence of radioactive material near the bottom of one of these depressions indicates that radioactive disposal activities may have occurred prior to sand cover installation or pushed down during historical Site construction activities. This is contrary to the conceptual model.

Subsequent to the identification of the first depression containing an elevated radiological measurement, a search for depressions was enacted during the characterization survey field work (see Appendix C). The results of this search identified one other area where depth to clay was greater than previously anticipated (total of two depressions). However, no additional radioactive contamination at depths greater than anticipated was identified.

6.0 QUALITY ASSURANCE

A Quality Assurance program was first implemented during the Scoping Survey in accordance with the Tobico Marsh Quality Assurance Project Plan (QAPP). The QAPP specified requirements for general project management, sampling and analyses, documentation, data management, and data validation and verification. A Quality Assurance Engineer was responsible for independent oversight of the QAPP implementation. The Senior Radiological Engineer had overall responsibility for ensuring that the requirements of the QAPP were implemented on a day-to-day basis during performance of field work, during data review and evaluation, and during preparation of this report.

6.1 General Project Management

Personnel involved in the characterization survey activities were trained to ensure that they understood their work assignment(s), responsibilities, and work-related hazards. Individuals involved in performing the characterization survey attended a four-hour lecture on radiological fundamentals and successfully completed the associated examination. Personnel working on the Site were required to provide documentation of successful completion of a 40 hour HAZWOPER training course as required per OSHA standards in 29 CFR 1910.120. Project personnel were required to read the current Health and Safety Plan and the Characterization Survey Work Plan (CABRERA 1999b), and to be trained in their requirements. In addition, on-the-job training was provided to personnel as needed, on a task-by-task basis. This type of training included, but was not limited to, implementation of and compliance with the following: procedures for use of instruments and performing the survey; the Radiation Safety Program; the Health and Safety Plan; and the QAPP.

6.2 Instrumentation and Measurements

6.2.1 Instrumentation

Instruments specified in the work plan (CABRERA 1999b) were used to make radiological measurements. The Senior Radiological Engineer ensured that individuals were trained in the use of instruments, verified that the instruments were in proper operating condition, and ensured that the instruments met the required detection sensitivity. The following instrument requirements delineated in Section 6.0 of the QAPP, were adhered to:

- Instrumentation had current calibration records;
- Calibration records were kept on site during the characterization survey for review and inspection.
- Instrumentation were operated in accordance with either a written procedure or manufacturer's manual. The procedure and/or manual were used to provide guidance to field personnel on the proper use and to identify limitations of the instrument.
- Prior to daily use, instruments used to obtain radiological data were inspected for physical damage and erroneous readings in accordance with associated procedures.
- Prior to daily use, instrumentation was response checked by comparing the instrument response to a designated source to instrument specific response check criteria obtained at the time of calibration, in accordance with the associated instrument procedure.
- Instrumentation that did not meet the specified requirements of calibration, inspection, or response check was removed from operation.

6.2.2 Measurements

Measurements were collected and documented in accordance with approved Tobico Marsh SGA procedures and the Characterization Survey Work Plan (CABRERA 1999b). Once

collected, measurements were documented on survey forms. At a minimum, the recorded information included instrument calibration date information, instrument model and serial number, date and time of survey, and name of individual(s) performing the survey. If a measurement was not collected due to drilling issues, weather concerns, or equipment failure, the Senior Radiological Engineer or designee was notified.

6.3 Volumetric Samples

6.3.1 Sampling Method

Volumetric samples were collected in accordance with approved Tobico Marsh SGA procedures and the Characterization Survey Work Plan (CABRERA 1999b). Sampling equipment and methodologies specified in approved procedures and/or the Work Plan were used. Collected samples were assigned unique alphanumeric identification numbers that were recorded in the field logbook. At a minimum, recorded information includes the sample location and depth, the alphanumeric identification number, and the date and time the sample was collected.

6.3.2 Sample Handling and Chain-Of-Custody

Chain of custody forms were maintained on volumetric samples collected during the characterization survey to document sample possession from the time of collection, to receipt at the analytical laboratory. The chain of custody forms were reviewed by the Senior Radiological Engineer and/or designee and accompanied each sample shipment to the analytical laboratory. Each chain of custody form included the signatures of the individuals that relinquished and received the samples and the associated date and time. The forms also included the following information for each sample: alphanumeric sample identification number; date and time of sample collection; sample matrix (i.e., soil or sediment); required analyses; and any special handling requirements.

Samples collected for laboratory analysis were temporarily stored on-site prior to shipment. At all times, samples were either in the possession of the characterization survey team, in view of the characterization survey team, or transferred to a secured (i.e., locked) location. Prior to leaving the Site for archive, the sample shipping containers were surveyed for external radiological contamination in accordance with applicable Tobico Marsh SGA procedures.

Samples slated to be analyzed for chemical parameters were kept on ice and analyzed within the appropriate holding time. Per the laboratory protocol, there are no specified holding time requirements for radiological samples.

6.4 Field Instrument and Laboratory Quality Control Results

Precision is a measure of agreement between measurements and is evaluated quantitatively based on objective performance criteria. Precision was evaluated by instrumentation response checks, control charts, duplicate measurements, and duplicate sample analyses.

6.4.1 Instrument Response Checks

Precision of field instrumentation was evaluated by performing daily source response checks and duplicate field measurements. The results of the daily response checks were evaluated against established QC response check criteria in accordance with approved Tobico Marsh SGA procedures. These response checks were performed by analyzing a radioactive source in a predetermined standard geometry and ensuring that the instrument response was within established control limits. Both gross gamma counts and energy specific counts were collected and evaluated.

To ensure satisfactory operation, the downhole NaI portable instrumentation gross gamma response was compared to established control limits, equal to $\pm 20\%$ of the expected response. Data was collected daily, entered on a control chart, and checked prior to use to ensure in-situ measurement instruments were operating properly. Figures 6-1 through 6-4 provide gross gamma control charts for the NaI instruments used to collect in-situ downhole characterization data. All data for these control charts fell within the $\pm 20\%$ control limit except for the following:

- SN C443E on 10/4/99

The instrument in question was evaluated, found to be operating properly, and had a daily check performed a second time. The second instrument daily calibration check fell within established control limits and the instrument was considered operable. No collected data was invalidated.

The downhole NaI portable instrumentation spectroscopic response at the 239 keV energy (Pb-212) was examined on a daily basis to ensure satisfactory operability. The NaI gamma spectroscopy system was response checked daily in accordance with approved Tobico Marsh SGA procedures. Control charts were developed for each NaI detector used in the field with standard 2-sigma investigation and 3-sigma action levels. The 2-sigma level was used as an investigation trigger to initiate management evaluation of equipment operability. The 3-sigma level indicates an unacceptable level of performance that would result in the recalibration and redetermination of control chart action points or other evaluation and corrective action.

Figures 6-5 through 6-8 show control charts for the NaI instruments used to collect spectroscopic in-situ downhole characterization data. All data for these control charts fell within the 2-sigma investigation level except for the following:

- SN C443E on 10/26/99 and
- SN C641D on 5/15/00

The instruments in question were evaluated, found to be operating properly, and had a daily check performed a second time. The second instrument daily calibration checks fell within the 2-sigma investigation level and the instrument was considered operable. No instrument data exceeded the 3-sigma action level. No collected data was invalidated.

The analytical laboratory was responsible for ensuring that their instruments were response checked and responded within established acceptance criteria. Response check data associated with instrumentation quality assurance was documented by the laboratory, and reviewed by the Senior Radiological Engineer/designee.

The daily source checks and control chart data for both gross gamma counts and spectroscopic data indicated that the downhole NaI portable detection equipment was operating properly during use. Equipment not meeting standards was not used. No data was invalidated.

6.4.2 Duplicate NaI Gross Gamma Measurements

In order to evaluate the precision of NaI gross gamma measurement process, ten percent of the NaI detector measurements were re-performed in the same manner and location as the initial measurements, as specified in the QAPP. These duplicate measurements were typically performed by a different surveyor. Of the 5,926 NaI gross gamma counts that were collected during the NaI gross gamma scan survey, 465 duplicate values were re-determined.

The duplicate gross gamma measurements were compared to each other using the relative percent difference methodology. The relative percent difference is computed using the following equation:

$$\text{Relative \% Difference} = \frac{X_1 - X_2}{(X_1 + X_2) / 2} * 100$$

Where: X_1 = value of initial measurement

X_2 = value of duplicate measurement

The relative percent difference values for each downhole gross gamma duplicate measurement is presented in Table 6-1. A relative percent difference of less than or equal to 20% is considered to show good agreement.

The relative percent difference methodology works well for higher count values but fails more frequently when the count range value is small and runs below about 100 counts. This effect

is due to counting statistics associated with the low counts. Poor correlation of duplicate measurements in areas of hot spots might also be expected due to the highly variable radiation field presented to the detection system from a hot spot. The poor comparison of a duplicate sample in these areas are likely to be due to small vertical positioning differences rather than an equipment variation.

Table 6-1 values demonstrate that downhole NaI gross gamma surveys counts exhibit an acceptable level of repeatability with 82% of all samples passing the acceptance criteria.

6.4.3 Duplicate In-Situ Gamma Spectroscopy Measurements

In order to evaluate the precision of in-situ gamma spectroscopy measurement process, approximately ten percent of the in-situ gamma spectroscopy measurements were re-performed in the same manner and location as the initial measurements, as specified in the QAPP.

Precision of the duplicate in-situ gamma spectroscopy measurements was quantitatively determined by calculating a Z-Score value for each data set. The premise of this statistical test is that the initial and duplicate measurements each provide a measure of the average radioactivity concentration in a volume of soil. Normal distribution statistics establish a level at which the probability of obtaining a difference of a specified magnitude is unlikely. The Z-Score equation is derived on this basis and establishes that a Z-score greater than 2.57 would only be observed 1% of the time if the only difference between the two measurements is the statistical nature of radioactive decay. It further establishes that there is a 99% probability that differences greater than 2.57 are due to differences in performance of the analysis and analytical equipment (e.g. slightly different locations, change in calibration).

The Z-Score value for the data set, is calculated using the following equation, and comparing it to a performance criteria of less than or equal to 2.57.

$$Z = \frac{|I - D|}{\sqrt{\sigma_I^2 + \sigma_D^2}}$$

Where: I, D, = value of (I)nitial and (D)uplicate measurements; and,

σ = one standard deviation associated with (I)nitial and (D)uplicate measurements.

The Z-Score value for the downhole NaI spectroscopic duplicate measurements are presented in Table 6-2. It is noted that many of the spectroscopic results are below detection limits. If one or more of the duplicate values are not detected, a Z-score cannot be calculated. Therefore a total of just 10 data sets for the downhole NaI duplicate spectroscopy results have Z-Scores computed with a corresponding pass/fail notation.

For those spectroscopic results below detection limits, it is noteworthy to observe that the detection system accurately identifies non-detectable values during the duplicate measurement process. Detectable activity was identified in only 8 of 139 measurement pairs where either the initial or the duplicate sample showed no detectable activity. This gives qualitative assurance that, at the threshold between no activity and low levels of activity, that false data is not generated.

Where duplicate Z-Scores were calculated there was agreement with 7 of 10 samples. Three measurements fell outside the Z-Score acceptance criteria. The 3 results that fell outside the Z-Score acceptance criteria are likely due to small changes in detector vertical positioning. These results are acceptable, with 70% of the samples passing the Z-Score acceptance criteria.

6.4.4 Laboratory Duplicate Gamma and Alpha Spectroscopy Analyses

The contractor radioanalytical laboratory performed duplicate analysis on 5 soil samples. Duplicated analysis was performed on gamma and alpha spectroscopy samples for the RCOPCs. The results were compared using the Z-Score analysis and presented in Table 6-3.

Approximately 86% of the duplicate samples pass the Z-Score test. The results are acceptable.

6.4.5 Comparison of Downhole NaI Spectroscopy and Laboratory Samples

Table 6-4 is a comparison table showing downhole spectroscopic NaI results to volumetric soil samples analyzed by the laboratory. A total of 24 laboratory samples were analyzed for Th-232 by gamma spectroscopy and compared to the same downhole location spectroscopic NaI detector results. As described in Section 3.1.2, Pb-212 was used as the primary Th-232 surrogate due to detection sensitivity. In addition, gamma spectroscopy utilizes a larger soil mass (approximately 500 grams) than alpha spectroscopy (approximately 2 grams). The larger mass sample helps to eliminate errors associated with non-homogeneity of soil samples that may occur when small samples are counted (see Section 5.1). Laboratory duplicate sample analyses also show similar improved correlation using gamma spectroscopy results rather than alpha spectroscopy for soil samples (Table 6-3).

The Table 6-4 Z-Score comparison shows 9 samples indicating good agreement with each other. Of the remaining 15 cases, 9 results show Th-232 concentrations based upon downhole NaI as being greater than the laboratory reported result. The remaining 6 samples show a lower reported value based upon the downhole NaI result.

It is likely that for those cases in which the laboratory result is lower than the downhole NaI result, that the soil volumetric sample missed the higher activity noted by the NaI detector. This is not entirely unexpected since soil samples were collected using a different casing. The soil collection casings were driven into the ground as close as practical (within 1 - 3 feet) to the downhole NaI detector casing. Since the casings used to collect soil are small compared to the sampling space detected by the downhole NaI detector, small pockets of activity could be more easily missed with a volumetric soil sample as opposed to the larger field that the NaI detector can identify.

Conversely, lower activity downhole NaI detector results than those identified by laboratory grab samples may be due to positioning differences between the downhole NaI measurement and the volumetric soil sample. As expected fewer of these results are noted because of the larger "sampling" area.

Seventy-five percent of the NaI downhole spectroscopic results are equal to or conservative with respect to the volumetric laboratory samples. This demonstrates that an in-situ downhole NaI detector contained within the probe boring (sealed from ground chemical contaminants), correlates well with the laboratory volumetric sampling analytical data. This counting method is a viable technique to characterize the Th-232 activity concentration in terms of both lateral and vertical extent at the Tobico Marsh State Game Area Site. Appendix D (Downhole NaI efficiency factor) provides the methodology through which downhole NaI gross gamma counts are converted to Th-232 soil concentration.

6.4.6 Comparison of Downhole NaI Th-232 Based on Gross Gamma and Laboratory Samples

Table 6-5 compares downhole NaI Th-232 activity fraction based upon gross gamma counts to volumetric soil sample laboratory results. A total of 24 laboratory samples were analyzed for Th-232 by gamma spectroscopy and compared to the same downhole location gross gamma results. The gross gamma results were converted to Th-232 concentrations above background utilizing the methodology described in Appendix D ("Downhole NaI efficiency factor").

Activity concentrations ratios computed for Table 6-5 are estimated from Th-232 based on NaI gross counts, NaI spectroscopic data, and NaI determined background from a nearby reference area. This allows the derivation of an efficiency factor that when applied converts the downhole gross gamma response to Th-232 equivalent activity concentration above background levels.

The best estimate values shown in Table 6-5 are generally conservative with respect to the laboratory soil sample analysis. The average ratio is 8.7 with several ratio values ranging from 30 to 73 times the laboratory reported value of Th-232. As described previously the differences are likely due to positioning which will have a more pronounced effect on volumetric samples as opposed to in-situ measurements. About 75% of the gross gamma results provide Th-232 activity concentrations equal to or greater than the volumetric sample

results. Six cases occurred in which the laboratory sample was higher than that reported based upon the gross gamma results.

The downhole Th-232 results based upon gross gamma response provide an effective means to identify Th-232 activity concentrations at the Site both laterally and vertically. The results have a conservative bias with respect to volumetric soil sampling.

6.4.7 Laboratory Spike and Blank Analyses

The laboratory evaluated analytical accuracy by performing laboratory spike analyses, as specified in their quality assurance procedures (PAI, 1997). Spike analyses consist of the laboratory adding a known quantity of radioactive material, or analyte, to representative media, analyzing the spiked media, and measuring the spike concentration. The results of the spike analysis are compared to the expected results based on the spike concentration. Laboratory spikes were performed and analyzed for each type of laboratory analysis that was performed (i.e., gamma spectroscopy, isotopic thorium alpha spectroscopy, isotopic uranium alpha spectroscopy, and gross alpha/beta).

Laboratory spike analyses were reviewed for completeness and validity. None of the measured spike values reported by the laboratory differed from the known spike values by more than +/-20 percent. The laboratory spike analyses results were also evaluated for bias, or a systematic error in one direction (i.e. positive or negative). Based on this evaluation, bias did not result in systematic errors.

6.4.8 Laboratory Blanks

Reports of laboratory blank analyses were reviewed for completeness and validity. Laboratory blank analyses results were less than the analytical detection sensitivity for the majority of the analyses performed. It should be noted that some alpha spectroscopy blank analyses were slightly above the analytical detection sensitivity. However, the magnitudes of the blank analyses that were above the detection sensitivity were small relative to concentrations of the radionuclides of concern in the field samples. Based on this review, sample results were not adversely affected by internal laboratory contamination, supporting the analytical accuracy of the results.

6.5 Data Verification

Data verification was used to ensure that the requirements stated in the planning documents (e.g., Characterization Survey Work Plan, Operating Procedures, and the QAPP), are implemented as required. Data verification is an ongoing process of assessing data and data collection activities for compliance with the planning documents. As such, the data verification process began as part of the implementation (data collection) phase of the survey.

The individual responsible for data verification during the implementation phase of the survey was the Senior Radiological Engineer. All individuals performing field survey activities assisted in identifying and documenting problems and deficiencies as they were discovered.

Following the survey implementation phase, any individuals performing review and assessment of the survey data were responsible for data verification. Details on data verification activities are provided in the project QAPP.

Data verification, in general, is accomplished by reviewing and monitoring data and data collection activities for compliance with the requirements of the planning documents, and documenting and reporting any problems and/or deficiencies. The following activities and data, at a minimum, were continually assessed during the data life cycle. Problems and/or deficiencies were documented, reported to the Project Manager, and corrected as they occurred.

- Data collection activities that are governed by the requirements of an operating procedure were monitored by the Senior Radiological Engineer/Designee, who had knowledge of the associated requirements.
- The performance of field measurement systems was monitored by the Senior Radiological Engineer/Designee through the use of daily quality control checks of instrument background and response.

Verification of analytical laboratory data was accomplished by ensuring that results were returned for all samples, the proper analytical and field methods were used, analyses were performed for the desired radionuclide parameters using proper analytical methods, and the requirements of the laboratory were met.

Verification of field measurement data consisted of establishing that data was recorded correctly, field instruments were properly calibrated, and survey forms, chain of custody forms, and logbooks were accurate and complete. Any problems with data were documented, and the Project Manager took any necessary preventive and corrective actions.

7.0 CONCLUSIONS

The Site characterization survey was extensive and complete -- meeting design objectives. This survey provides an inclusive and unambiguous record of the radiological status of the Site that details the extent of contamination. The design objectives were addressed through a comprehensive survey program that utilized downhole in-situ NaI detector gross gamma measurements spread laterally over the Site MARSSIM Class 1, 2 and 3 areas. These data, coupled with downhole in-situ NaI detector spectroscopic measurements and volumetric soil laboratory gamma and alpha spectroscopy analyses, provide a clear picture of the lateral and vertical extent of radioactive constituents of potential concern (RCOPCs) on the Site.

From the Site characterization survey data it is concluded that:

- Contaminant concentrations of Th-232 and Th-230 follow the Site conceptual model and are present in areas near the center of the Class 1 survey unit. All radioactive contamination was found to exist between the bottom of the clay cap and the top of the native clay layer underlying the Site. The lateral extent of the contamination remains within the bounds of the Site Class 1 survey area.
- Data from the reference area and the Site Class 2 and 3 areas indicates that these locations appear to have the same natural background radioactivity level and distribution.
- Radioactive contamination was found at vertical elevations deeper than anticipated in one native clay depression. This resulted in additional Site area investigation to search for other depressions in the native clay. The search identified one other area where the depth to native clay was greater than previously anticipated (total of two depressions). However, no additional radioactive contamination at depths greater than anticipated was identified. The Site radioactive contamination remains consistent with the conceptual model, in which radioactive contamination was not identified below the upper surface of the natural clay layer that underlies the Site.
- Th-230 to Th-232 activity ratios on the Site ranged from a minimum of 0.5:1 to a maximum of 11:1. The Th-230 to Th-232 ratios are not widely variable across the Site but instead, are clustered in what appears to be two different thorium waste stream areas.

The first waste stream area encompasses the majority of the Site, including the entire central, northeastern, and southeastern portions of the Site. The Th-230 to Th-232 ratio in these areas is approximately 1:1 with a range of 0.5:1 to 2:1. The second waste stream includes two areas, one in the northwest and one in the southwest portion of the Site. The Th-230 to Th-232 ratios in these areas ranges from 4:1 to 11:1.

- Analytical results for groundwater and surface water samples show drinking water exceedances only for secondary maximum concentration levels (MCLs) for iron, total dissolved solids, chloride, and sulfate. Groundwater and surface water in the vicinity of the Site can be considered a potential source of potable water.
- Various chemicals were detected in the soil, but none of the TCLP concentrations exceeded the 40 CFR Part 261.24 maximum concentration of contaminants for toxicity characteristics. The analytical results indicate that the soil containing radioactive and chemical waste material at the Site would not be considered a hazardous waste, as defined in 40 CFR Part 261.
- The Site characterization investigation method using NaI in a casing (sealed from ground chemical contaminants) correlates well with the laboratory volumetric sampling analytical data. The in-situ downhole NaI gross gamma counting method is a viable technique to characterize the Th-232 activity concentration in terms of both lateral and vertical extent at the Tobico Marsh State Game Area Site.

8.0 REFERENCES

1. ABB 1997 *Evaluation of Analytical Results, Groundwater/Leachate Samples from The Tobico Marsh State Game Area Site*, ABB Environmental Services, Inc., August, 1997
2. ABB 1997a *Scoping Survey Work Plan, Tobico Marsh State Game Area*, ABB Environmental Services, Inc., October, 1997.
3. ABB 1998 *Preliminary Background Assessment Report, Volume I*, ABB Environmental Services, Inc., April, 1998.
4. CABRERA 1998 *Proposal 98-002 for Radiological Consulting Services, MDNR - Tobico Marsh SGA Site*, Cabrera Services, Inc., July, 1998.
5. CABRERA 1998a *Technical Memorandum, Waste Profile Issues Related to Waste Disposal Options for the Tobico Marsh SGA Site*, December, 1998.
6. CABRERA 1999 *Determination of Boundaries and Preliminary Classifications of Survey Areas for the Characterization Survey*. Cabrera Services, Inc., February, 1999.
7. CABRERA 1999a *Preliminary Dose Assessment, MDNR Tobico Marsh SGA*, Cabrera Services, Inc., April, 1999.
8. CABRERA 1999b *Characterization Survey Work Plan, Tobico Marsh SGA*, Cabrera Services, Inc., July 1999.
9. CABRERA 1999c *Quality Assurance Project Plan, Tobico Marsh SGA*, Cabrera Services, Inc., October 1999.
10. CABRERA 2000 *Quality Assurance Project Plan, Tobico Marsh SGA (rev. 1)*, Cabrera Services, Inc., February 2000
11. HLA 1998 *Historical Site Assessment, Tobico Marsh State Game Area*, Harding Lawson Associates, July 1998.
12. HLA 1998a *Scoping Survey Report, Tobico Marsh State Game Area*, Harding Lawson Associates, October, 1998.
13. Lowder 1964 "Field Spectrometric Investigations of Environmental Radiation in the USA", Lowder, W. J. Condon, and H. L. Beck, *The Natural Radiation Environment*, 1964.

14. MDPH 1983 *Radioactivity Survey of DNR Land Near Bay City, Michigan*, Memorandum from R. DeHaan (Environmental Monitoring Unit) to J. Hennigan (Nuclear Facilities and Environmental Monitoring Section), Michigan Department of Public Health, May 2, 1983.
15. Myrick 1983 "Determination of Concentrations of Selected Radionuclides in Surface Soil in the U.S.", Myrick, B.A. and F. F. Haywood, *Health Physics Journal*.
16. NRC 1997 NUREG-1575, *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM).
17. NRC 1997a Subpart E to Title 10, Part 20, of the U.S. Code of Federal Regulations (10 CFR 20), 1997.
18. NRC 1998 Draft Regulatory Guide DG-4006, *Demonstrating Compliance with the Radiological Criteria for License Termination*, August, 1998.
19. NRC 2000 NUREG-1727, *NMSS Decommissioning Standard Review Plan*
20. ORAU 1985 *Radiological Survey of the SCA Chemical Services, Inc. Landfill Site, Bay City, Michigan*, Oak Ridge Associated Universities, July, 1985
21. Shleien 1992 *The Health Physics and Radiological Health Handbook, Revised Edition*, Bernard Shleien, Ed., 1992.
22. UNSCEAR 1988 *Sources, Effects, and Risks of Ionizing Radiation*, United Nations Scientific Committee on the Effects of Atomic Radiation, 1988.

TABLES

TABLE 4-1
GAMMA AND ALPHA SPECTROSCOPY RESULTS (pCi/g)

Sample ID: Depth (bgs): Northing ⁽⁶⁾ : Easting ⁽⁶⁾ :	D5NESS0101		E5NESS0101		E5NESS0101		E6NWBIAS01SS0101		E6NWSS0101	
	7.5-8.5'	MDC ⁽²⁾	6-7'	MDC ⁽²⁾	10.5-11.5'	MDC ⁽²⁾	5.5-6.5'	MDC ⁽²⁾	5.5-6.5'	MDC ⁽²⁾
	132225.1 2103897.0		132274.5 2103893.5		132260.6 2103898.5		132267.8 2103900.4		132276.5 2103909.5	
Analysis ⁽⁴⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾
U-238(alpha)	NP ± NP	NP	0.176 ± 0.071	0.036	NP ± NP	NP	0.17 ± 0.13	0.19	0.122 ± 0.04	0.018
U-235(alpha)	NP ± NP	NP	0 ± 0.021	0.059	NP ± NP	NP	0.022 ± 0.058	0.14	0.033 ± 0.02	0.018
U-234(alpha)	NP ± NP	NP	0.159 ± 0.069	0.059	NP ± NP	NP	0.3 ± 0.16	0.14	0.16 ± 0.05	0.018
Th-232(alpha)	NP ± NP	NP	16.3 ± 3.6	0.61	NP ± NP	NP	9.5 ± 1.6	0.11	NP ± NP	NP
Th-230(alpha)	NP ± NP	NP	111 ± 20	0.5	NP ± NP	NP	85 ± 13	0.15	NP ± NP	NP
Th-228(alpha)	NP ± NP	NP	15.5 ± 3.5	1.5	NP ± NP	NP	9.4 ± 1.6	0.32	NP ± NP	NP
U-235	1.2 ± 0.45	0.26	0.82 ± 0.42	0.46	2.67 ± 0.65	0.44	0.04 ± 0.19	0.32	3.8 ± 2.6	2.4
Th-234	0.72 ± 0.31	1.1	0.4 ± 3.2	3.3	1.3 ± 1.9	1.9	1.22 ± 0.41	1.5	8.5 ± 7.5	10
Th-232	0 ± 11	19	0 ± 49	82	-4 ± 18	30	-3 ± 14	24	60 ± 160	270
Pa-234m	1.1 ± 3.8	6.6	0 ± 40	5.9	-1 ± 13	9.6	2.8 ± 5.8	9.9	3 ± 18	32
Ac-228	3.81 ± 0.67	0.18	25.1 ± 4.2	0.22	7.8 ± 1.3	0.21	3.32 ± 0.62	0.28	38.7 ± 6.6	1.1
Ra-226	0.66 ± 0.19	0.14	4.08 ± 0.75	0.24	1.08 ± 0.25	0.26	1.58 ± 0.31	0.18	6.8 ± 1.8	1.1
Pb-214	0.62 ± 0.16	0.13	2.84 ± 0.51	0.15	0.76 ± 0.2	0.16	1.18 ± 0.25	0.18	4.48 ± 0.95	0.68
Pb-212	3.97 ± 0.66	0.062	27 ± 4.5	0.18	7.9 ± 1.3	0.095	3.62 ± 0.68	0.17	50 ± 8.4	0.88
Bi-214	0.42 ± 0.12	0.1	3.04 ± 0.57	0.17	0.81 ± 0.24	0.18	1.11 ± 0.22	0.13	4.7 ± 1.3	0.78
Tl-208	1.33 ± 0.23	0.053	7.8 ± 1.3	0.085	2.64 ± 0.45	0.088	1.14 ± 0.22	0.081	12.6 ± 2.2	0.3
Cs-137	0.102 ± 0.068	0.063	0.189 ± 0.044	0.05	0.015 ± 0.04	0.067	0.029 ± 0.039	0.065	-0.03 ± 0.16	0.27
K-40	7.8 ± 1.5	0.65	9.2 ± 1.7	0.57	12.9 ± 2.3	0.86	16.9 ± 3.1	1	-4.3 ± 1.6	3.7

TABLE 4-1

GAMMA AND ALPHA SPECTROSCOPY RESULTS (pCi/g)

Sample ID:	E6NWSS0301	E6SWSS0102	E6SWSS0201 ⁽⁶⁾	E9SWSS0101	F6SSESS0101	
Depth (bgs):	6.5 - 7.5'	7 - 8'	9.5-10.5'	5-6'	4.5-5.5'	
Northing ⁽⁵⁾ :	132276.5	132259.8	132259.8	132258.4	132286.2	
Easting ⁽⁵⁾ :	2103909.5	2103907.0	2103907.0	2104001.7	2103923.7	
Analysis ⁽⁴⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾
U-238(alpha)	1.24 ± 0.68	0.68	NP ± NP	NP	NP ± NP	NP
U-235(alpha)	1.1 ± 0.73	0.96	NP ± NP	NP	NP ± NP	NP
U-234(alpha)	10.6 ± 2.2	1.2	NP ± NP	NP	NP ± NP	NP
Th-232(alpha)	53 ± 10	1.9	NP ± NP	NP	NP ± NP	NP
Th-230(alpha)	443 ± 65	0.72	NP ± NP	NP	NP ± NP	NP
Th-228(alpha)	55 ± 11	6.3	NP ± NP	NP	NP ± NP	NP
U-235	4.6 ± 2.5	2.7	0 ± 1.3	0.15	0 ± 17	0.26
Th-234	18.9 ± 8.6	13	-0.13 ± 0.093	0.78	-4 ± 11	3.6
Th-232	-20 ± 170	290	-0.1 ± 6.7	11	321 ± 75	81
Pa-234m	11 ± 21	35	0.9 ± 3	5.2	0 ± 14	5.7
Ac-228	67 ± 11	0.88	0.56 ± 0.17	0.14	1.78 ± 0.39	0.18
Ra-226	10.9 ± 2.5	1.1	0.5 ± 0.12	0.1	1.74 ± 0.32	0.14
Pb-214	8.7 ± 1.8	0.87	0.288 ± 0.087	0.088	1.25 ± 0.23	0.094
Pb-212	83 ± 14	1	0.56 ± 0.11	0.051	1.91 ± 0.32	0.053
Bi-214	7.6 ± 1.7	0.75	0.47 ± 0.11	0.075	1.33 ± 0.28	0.099
Tl-208	19.7 ± 3.3	0.41	0.158 ± 0.058	0.047	0.65 ± 0.12	0.046
Cs-137	0 ± 0.18	0.31	0.212 ± 0.05	0.039	0.001 ± 0.022	0.037
K-40	12.2 ± 3.3	2.5	6.2 ± 1.2	0.51	7.1 ± 1.5	0.59
					12.9 ± 2.3	0.52

TABLE 4-1

GAMMA AND ALPHA SPECTROSCOPY RESULTS (pCi/g)

Sample ID: Depth (bgs): Northing ⁽⁶⁾ : Easting ⁽⁹⁾ :	F7NEBS01W		F7NESS0101		F7NWSS0101		F7NWSS0102		F7SWSS0101	
	5.5-6.5'	MDC ⁽²⁾	5.5-6.5	MDC ⁽²⁾	7.5-8.5'	MDC ⁽²⁾	9.5-10.5'	MDC ⁽²⁾	5.5-6.5'	MDC ⁽²⁾
Analysis ⁽⁴⁾	Result ^(1,3)		Result ^(1,3)		Result ^(1,3)		Result ^(1,3)		Result ^(1,3)	
U-238(alpha)	0.99 ± 0.29	0.086	0.92 ± 0.14	0.02	0.67 ± 0.3	0.26	0.159 ± 0.052	0.019	0.52 ± 0.12	0.044
U-235(alpha)	0.023 ± 0.047	0.1	0.052 ± 0.021	0.016	0.19 ± 0.18	0.26	0.013 ± 0.015	0.019	0.047 ± 0.029	0.026
U-234(alpha)	1.1 ± 0.31	0.14	0.9 ± 0.14	0.02	0.58 ± 0.33	0.42	0.131 ± 0.047	0.0099	0.51 ± 0.12	0.032
Th-232(alpha)	128 ± 20	0.46	2.83 ± 0.57	0.042	197 ± 28	0.8	0.152 ± 0.049	0.02	2.73 ± 0.5	0.033
Th-230(alpha)	126 ± 19	0.46	2.65 ± 0.54	0.049	157 ± 23	1.1	0.15 ± 0.048	0.017	2.97 ± 0.54	0.039
Th-228(alpha)	132 ± 20	1.1	3.19 ± 0.66	0.2	184 ± 27	2.1	0.134 ± 0.049	0.044	2.58 ± 0.48	0.14
U-235	-0.4 ± 3.7	0.78	1.13 ± 0.36	0.33	0 ± 3.7	1.9	-0.13 ± 0.6	0.57	-0.07 ± 0.59	0.66
Th-234	18.5 ± 3.1	4.1	0.6 ± 1.1	1.1	-6 ± 10	10	5.8 ± 2.8	3.1	17.3 ± 5.1	3.2
Th-232	9 ± 83	140	10 ± 13	21	-30 ± 130	220	5 ± 35	61	0 ± 31	53
Pa-234m	13.2 ± 5.8	8.9	3.4 ± 3.6	6.1	1 ± 16	28	-0.6 ± 9.5	14	-2 ± 85	13
Ac-228	94 ± 15	0.25	3.43 ± 0.6	0.14	47.3 ± 8	0.82	0.05 ± 0.19	0.36	42.6 ± 7.1	0.36
Ra-226	5.92 ± 1	0.26	1.27 ± 0.24	0.16	1.67 ± 0.88	0.89	0.62 ± 0.55	0.51	0.53 ± 0.17	0.31
Pb-214	1.92 ± 0.37	0.22	1 ± 0.19	0.11	0.8 ± 0.45	0.56	0.36 ± 0.3	0.3	0.47 ± 0.16	0.2
Pb-212	109 ± 18	0.3	4.02 ± 0.68	0.1	60 ± 10	0.81	0.48 ± 0.25	0.22	52 ± 8.6	0.15
Bi-214	1.74 ± 0.33	0.19	0.88 ± 0.19	0.11	1.21 ± 0.65	0.61	0.3 ± 0.25	0.3	0.36 ± 0.16	0.23
Tl-208	30.7 ± 5.1	0.14	1.19 ± 0.22	0.066	13.8 ± 2.3	0.28	0.13 ± 0.081	0.096	15.4 ± 2.5	0.17
Cs-137	-0.002 ± 0.055	0.093	-0.001 ± 0.027	0.045	-0.01 ± 0.15	0.26	-0.012 ± 0.045	0.079	-0.002 ± 0.072	0.12
K-40	21.2 ± 4.2	0.98	10.5 ± 2	0.65	13.4 ± 4.4	2.8	9 ± 2	1.6	-0.34 ± 0.95	1

TABLE 4-1
GAMMA AND ALPHA SPECTROSCOPY RESULTS (pCi/g)

Sample ID: Depth (bgs): Northing ⁽⁵⁾ : Easting ⁽⁵⁾ :	G11SS0101		G7NESS0101		G7NESS0201		G7NESS0202		G7NNWSS0101	
	5 - 6'		7 - 8'		7.5 - 8.5'		7.0 - 8.5'		8.0-9.0'	
	132339.6		132341.1		132341.1		132341.1		132340.9	
	2104096.7		2103957.2		2103957.2		2103957.2		2103949.0	
Analysis ⁽⁴⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾
U-238(alpha)	NP ± NP	NP	2.24 ± 0.83	0.6	0.52 ± 0.16	0.074	1.93 ± 0.35	0.02	NP ± NP	NP
U-235(alpha)	NP ± NP	NP	0.38 ± 0.44	0.69	0.023 ± 0.03	0.06	0.149 ± 0.07	0.046	NP ± NP	NP
U-234(alpha)	NP ± NP	NP	3.5 ± 1.1	0.77	0.69 ± 0.19	0.074	1.57 ± 0.3	0.079	NP ± NP	NP
Th-232(alpha)	NP ± NP	NP	124 ± 20	1.7	97 ± 19	2.9	650 ± 120	24	NP ± NP	NP
Th-230(alpha)	NP ± NP	NP	64 ± 11	1.9	107 ± 20	3.2	434 ± 85	18	NP ± NP	NP
Th-228(alpha)	NP ± NP	NP	136 ± 22	4.7	130 ± 24	11	790 ± 140	50	NP ± NP	NP
U-235	-0.03 ± 0.26	0.16	-0.5 ± 2.7	3.7	-0.6 ± 4.8	6.9	-1.4 ± 6.6	10	0.93 ± 0.33	0.31
Th-234	-0.4 ± 0.88	0.73	1 ± 12	21	8 ± 22	37	-45 ± 34	52	1.26 ± 0.37	1.3
Th-232	0.1 ± 7.1	12	90 ± 270	460	-880 ± 490	810	1910 ± 770	1200	3 ± 26	44
Pa-234m	-0.6 ± 6.4	5.8	28 ± 28	46	7 ± 55	93	210 ± 85	130	6.4 ± 3.1	4.8
Ac-228	0.59 ± 0.16	0.12	130 ± 22	2.1	382 ± 63	3.2	1260 ± 210	5.9	1.52 ± 0.3	0.15
Ra-226	0.71 ± 0.16	0.13	4.2 ± 1.7	1.4	7.4 ± 2.8	2.5	13.2 ± 6.8	4.4	2.91 ± 0.5	0.19
Pb-214	0.53 ± 0.12	0.11	2.22 ± 1	1.1	4.5 ± 2.3	2.2	11.1 ± 4.1	3.3	2.15 ± 0.37	0.099
Pb-212	0.56 ± 0.15	0.086	194 ± 32	1.5	630 ± 100	2.9	1730 ± 290	4.3	1.49 ± 0.25	0.058
Bi-214	0.56 ± 0.15	0.097	3 ± 1.2	0.99	5.2 ± 2	1.7	9.2 ± 4.8	3.1	2.07 ± 0.41	0.13
Tl-208	0.106 ± 0.08	0.046	46.2 ± 7.7	0.6	175 ± 29	1.2	442 ± 73	1.9	0.54 ± 0.1	0.044
Cs-137	-0.007 ± 0.022	0.037	-0.08 ± 0.3	0.5	0.03 ± 0.54	0.9	0.03 ± 0.85	1.4	-0.002 ± 0.021	0.036
K-40	6.1 ± 1.2	0.9	23.3 ± 7.7	4.2	66 ± 18	8.7	141 ± 30	11	10.7 ± 1.8	0.54

TABLE 4-1
GAMMA AND ALPHA SPECTROSCOPY RESULTS (pCi/g)

Sample ID: Depth (bgs): Northing ^(b) : Easting ^(b) :	G7NSWSS0101		G7SEBIAS01ESS01		G7SESS0101		G8NWBIAS01SS0101		H10SS0101	
	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾
11.5-12.5'			6.5-7.5		6-7'		6.5-7.5		6.5 - 7.5'	
132323.0			132321.5		132321.5		132340.7		132361.2	
2103947.4			2103953.7		2103953.7		2103974.9		2104054.5	
Analysis ⁽⁴⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾
U-238(alpha)	0.83 ± 0.13	0.02	0.74 ± 0.24	0.085	0.41 ± 0.15	0.083	0.094 ± 0.091	0.13	NP ± NP	NP
U-235(alpha)	0.047 ± 0.026	0.034	0.083 ± 0.081	0.12	0.058 ± 0.061	0.094	0.031 ± 0.052	0.096	NP ± NP	NP
U-234(alpha)	0.9 ± 0.14	0.032	0.87 ± 0.27	0.13	0.51 ± 0.17	0.11	0.19 ± 0.12	0.13	NP ± NP	NP
Th-232(alpha)	3.93 ± 0.81	0.076	27.1 ± 4.3	0.21	67 ± 13	0.8	27 ± 4	0.09	NP ± NP	NP
Th-230(alpha)	3.13 ± 0.67	0.096	13.1 ± 2.2	0.24	30.6 ± 6.6	0.69	31.2 ± 4.6	0.11	NP ± NP	NP
Th-228(alpha)	5.1 ± 1	0.24	27.5 ± 4.4	0.36	65 ± 12	1.5	24.9 ± 3.7	0.23	NP ± NP	NP
U-235	0 ± 18	0.54	0.06 ± 0.39	0.66	0.22 ± 0.39	0.65	0.25 ± 0.38	0.64	0 ± 1.5	0.2
Th-234	10.6 ± 4.2	3.1	1.3 ± 5.3	8.9	-7 ± 3	4.1	6.1 ± 1.5	3	0.64 ± 0.66	1.1
Th-232	-5 ± 23	40	-20 ± 180	310	-110 ± 68	110	0 ± 29	49	3 ± 22	38
Pa-234m	2.6 ± 8.2	14	2.3 ± 6.5	11	26 ± 11	9.7	18 ± 16	16	2.9 ± 3.2	5.4
Ac-228	9.1 ± 1.6	0.41	24.5 ± 4.1	0.32	52.4 ± 8.7	0.28	26.1 ± 4.4	0.45	0.59 ± 0.16	0.16
Ra-226	2.11 ± 0.42	0.32	2.43 ± 0.45	0.23	1.34 ± 0.3	0.23	1.5 ± 0.35	0.36	0.43 ± 0.13	0.14
Pb-214	1.59 ± 0.31	0.21	2.43 ± 0.43	0.14	0.8 ± 0.24	0.18	1 ± 0.27	0.31	0.311 ± 0.093	0.098
Pb-212	10.2 ± 1.7	0.27	24.7 ± 4.1	0.12	57.9 ± 9.6	0.25	30.8 ± 5.1	0.27	0.476 ± 0.09	0.054
Bi-214	1.52 ± 0.31	0.22	1.22 ± 0.25	0.17	0.94 ± 0.21	0.16	1.3 ± 0.38	0.27	0.32 ± 0.1	0.1
Tl-208	2.89 ± 0.53	0.14	8.3 ± 1.4	0.12	15.8 ± 2.6	0.11	8.8 ± 1.5	0.15	0.165 ± 0.05	0.038
Cs-137	0.021 ± 0.059	0.099	0.034 ± 0.056	0.093	-0.007 ± 0.047	0.079	0.044 ± 0.071	0.12	0.227 ± 0.043	0.028
K-40	20.4 ± 3.6	1.2	11 ± 2	0.78	16.8 ± 3	0.86	7.7 ± 2.1	1.3	13.5 ± 2.3	0.57

TABLE 4-1
GAMMA AND ALPHA SPECTROSCOPY RESULTS (pCi/g)

Sample ID: Depth (bgs): Northing ^(b) : Easting ^(a) :	H7NWSS0303	H7NWSS0305	H7NWSS03A	H7NWSS0401	H7NWSS0501	H7SEBIAS01ESS0101
	21 - 22'	25.9'	NA ⁽¹⁾	21-25'	NA ⁽²⁾	12.5-13.5'
	132374.3 2103940.1	132374.3 2103940.1	132374.3 2103940.1	132374.3 2103940.1	132374.3 2103940.1	132357.9 2103958.1
Analysis ⁽⁴⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾
U-238(alpha)	0.46 ± 0.1	0.0082	0.315 ± 0.07	0.019	0.309 ± 0.063	0.014
U-235(alpha)	0.05 ± 0.03	0.022	0.019 ± 0.02	0.019	0.017 ± 0.014	0.02
U-234(alpha)	0.44 ± 0.09	0.029	0.363 ± 0.08	0.017	0.236 ± 0.053	0.02
Th-232(alpha)	6.86 ± 0.97	0.02	0.48 ± 0.1	0.022	4.79 ± 0.93	0.053
Th-230(alpha)	3.89 ± 0.57	0.015	0.52 ± 0.11	0.028	3.05 ± 0.63	0.064
Th-228(alpha)	7.5 ± 1.1	0.04	0.52 ± 0.11	0.049	6.5 ± 1.2	0.18
U-235	-0.4 ± 1.8	1.8	-0.2 ± 3.2	1.4	0 ± 1.1	0.26
Th-234	0 ± 100	11	4.6 ± 4.6	8	-4 ± 55	3.5
Th-232	50 ± 140	240	-20 ± 120	210	-15 ± 71	120
Pa-234m	-3 ± 40	47	-10 ± 180	42	7.6 ± 4.9	5.2
Ac-228	8.4 ± 1.8	1	1.8 ± 1.1	1.2	4.53 ± 0.77	0.14
Ra-226	2.6 ± 1.5	1.4	2 ± 1.1	1.3	0.44 ± 0.11	0.1
Pb-214	1.16 ± 0.69	0.82	0.82 ± 0.57	0.89	0.306 ± 0.084	0.086
Pb-212	13 ± 2.4	0.79	1.31 ± 0.92	0.66	1.24 ± 0.23	0.11
Bi-214	1.8 ± 1.1	0.94	1.42 ± 0.79	0.91	0.345 ± 0.095	0.076
Tl-208	2.68 ± 0.59	0.36	0.36 ± 0.26	0.32	1.49 ± 0.25	0.044
Cs-137	0.46 ± 0.19	0.26	-0.04 ± 0.17	0.3	0.011 ± 0.022	0.037
K-40	14.2 ± 5.9	5.1	26.6 ± 6.3	5.2	10.7 ± 1.9	0.46
			16.3 ± 3.1	1.2	13.9 ± 2.4	0.48
					-0.1 ± 2.6	0.16
			0.36 ± 0.27	0.32	0.71 ± 0.36	0.85
			0.73 ± 0.57	1.6	-1.4 ± 6.9	12
			0 ± 14	23	0.2 ± 3.2	5.5
			6.5 ± 6.3	10	0.89 ± 0.23	0.15
			1.16 ± 0.37	0.29	0.87 ± 0.16	0.12
			1.21 ± 0.33	0.26	0.69 ± 0.13	0.067
			0.83 ± 0.26	0.22	0.98 ± 0.21	0.091
			1.24 ± 0.23	0.11	0.59 ± 0.13	0.089
			1.02 ± 0.33	0.19	0.204 ± 0.073	0.041
			0.35 ± 0.14	0.097	0.001 ± 0.019	0.031
			0.01 ± 0.041	0.069	13.9 ± 2.4	0.48
			16.3 ± 3.1	1.2	-0.01 ± 0.11	0.14
					0.156 ± 0.068	0.63
					0.5 ± 6.6	11
					1.5 ± 2.9	4.8
					0.64 ± 0.16	0.094
					0.53 ± 0.12	0.1
					0.45 ± 0.11	0.074
					0.68 ± 0.14	0.07
					0.37 ± 0.1	0.076
					0.191 ± 0.054	0.041
					0.006 ± 0.017	0.028
					10.6 ± 1.8	0.45

TABLE 4-1
GAMMA AND ALPHA SPECTROSCOPY RESULTS (pCi/g)

Sample ID:	M7SESS0101	M7SWSS010J	M8SESS0101	M9NESS0101	REFSS0401	
Depth (bgs):	6.0-7.0	NA ⁽³⁾	4.5-5.5'	4 - 5'	NA ⁽⁴⁾	
Northing ⁽⁵⁾ :	132515.7	132516.5	132517.3	132531.8		
Easting ⁽⁵⁾ :	2103951.3	2103934.0	2103985.0	2104017.2		
Analysis ⁽⁴⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾
U-238(alpha)	0.22 ± 0.13	0.14	0.15 ± 0.05	0.033	NP ± NP	NP ± NP
U-235(alpha)	0.19 ± 0.11	0.04	0.05 ± 0.03	0.033	NP ± NP	NP ± NP
U-234(alpha)	0.4 ± 0.16	0.11	0.17 ± 0.06	0.043	NP ± NP	NP ± NP
Th-232(alpha)	25.2 ± 4.1	0.55	19.8 ± 3.1	0.13	NP ± NP	NP ± NP
Th-230(alpha)	278 ± 39	0.43	185 ± 27	0.11	NP ± NP	NP ± NP
Th-228(alpha)	28.3 ± 4.6	0.87	27.6 ± 4.3	0.37	NP ± NP	NP ± NP
U-235	5.7 ± 3.2	3.1	4.3 ± 2.7	2.4	-0.01 ± 0.46	0.17
Th-234	-10 ± 13	14	8.8 ± 2.8	8.1	0.78 ± 0.27	0.89
Th-232	180 ± 200	330	0 ± 78	130	0 ± 7.2	12
Pa-234m	9 ± 23	40	13 ± 25	43	-0.8 ± 9.7	5.5
Ac-228	62 ± 11	1.1	46.6 ± 8	1.2	1.38 ± 0.27	0.12
Ra-226	13.9 ± 3.3	1.4	9.3 ± 1.7	1.2	0.74 ± 0.16	0.13
Pb-214	9.9 ± 1.8	0.8	8.5 ± 1.5	0.56	0.68 ± 0.16	0.1
Pb-212	45.3 ± 7.6	1.5	65 ± 11	0.52	1.4 ± 0.24	0.05
Bi-214	8.5 ± 2.3	1	6.1 ± 1.3	0.86	0.48 ± 0.14	0.1
Tl-208	18.2 ± 3	0.32	13.6 ± 2.4	0.5	0.44 ± 0.1	0.049
Cs-137	-0.15 ± 0.21	0.35	0.02 ± 0.21	0.36	0 ± 0.021	0.036
K-40	9.7 ± 4.2	3.5	10.9 ± 5.5	4.7	9.7 ± 1.7	0.45
					12.4 ± 2.5	1.2
					-0.004 ± 0.087	0.15
					0.5 ± 0.31	0.65
					1.4 ± 6.6	11
					3 ± 3.3	4.3
					0.71 ± 0.16	0.15
					0.99 ± 0.19	0.097
					0.71 ± 0.15	0.081
					0.88 ± 0.16	0.065
					0.74 ± 0.15	0.069
					0.233 ± 0.061	0.041
					-0.002 ± 0.022	0.037
					14.1 ± 2.4	0.46

Notes:

NP Sample analysis not performed

⁽¹⁾ Errors reported at the 95% confidence level.⁽²⁾ Minimum detectable concentrations (MDCs) reported at the 95% confidence level.⁽³⁾ Results listed as reported directly from the laboratory.⁽⁴⁾ The suffix "(alpha)" following radionuclide title represents performance of alpha spectroscopy analysis, if no "(alpha)" suffix, then gamma spectroscopy analysis was performed.⁽⁵⁾ Northing and easting values are tied to the Michigan State Plane Coordinate System, North American Datum (NAD) 1983.⁽⁶⁾ For sample E6SWSS0201, Ra-226 activity was calculated directly from the 185.99 keV peak due to damaged container and subsequent lack of time for proper daughter nuclide ingrowth.NA⁽¹⁾ This sample was analyzed for disposal purposes.NA⁽²⁾ This sample was analyzed for disposal purposes.NA⁽³⁾ This sample was analyzed for disposal purposes.NA⁽⁴⁾ This result is a reference (background) area sample

TABLE 4-2

RATIOS OF Th-230 TO Th-232 SAMPLE RESULTS

Sample ID	Depth (ft bgs)	Northing ⁽³⁾	Easting ⁽³⁾	Th-230 ⁽¹⁾⁽²⁾⁽⁴⁾ (pCi/g)	MDC (pCi/g)	Th-232 ⁽¹⁾⁽²⁾⁽⁴⁾ (pCi/g)	MDC (pCi/g)	Ratio Th-230 to Th-232
E9SWSS0101	5-6'	132258.4	2104001.7	2.8 ± 0.6	0.054	1.6 ± 0.4	0.063	1.8 ± 0.5
E6SWSS0201 ⁽⁶⁾	9.5-10.5'	132259.8	2103907.0	80.0 ± 15.0	0.079	19.4 ± 3.8	0.035	4.1 ± 1.1
E6NWBIAS01SS0101	5.5 - 6.5'	132267.8	2103900.4	85.0 ± 13.0	0.15	9.5 ± 1.6	0.11	8.9 ± 2.0
E5NESS0101	6-7'	132274.5	2103893.5	111.0 ± 20.0	0.5	16.3 ± 3.6	0.61	6.8 ± 1.9
E6NWSS0301	6.5 - 7.5'	132276.5	2103909.5	443.0 ± 65.0	0.72	53.0 ± 10.0	1.9	8.4 ± 2.0
F7SWSS0101	5.5-6.5'	132293.9	2103937.0	3.0 ± 0.5	0.039	2.7 ± 0.5	0.033	1.1 ± 0.3
F7NWSS0102	9.5 - 10.5'	132307.2	2103941.9	0.2 ± 0.0	0.017	0.2 ± 0.0	0.02	1.0 ± 0.4
F7NWSS0101	7.5 - 8.5'	132307.2	2103941.9	157.0 ± 23.0	1.1	197.0 ± 28.0	0.8	0.8 ± 0.2
F7NESS0101	5.5-6.5'	132307.2	2103955.6	2.7 ± 0.5	0.049	2.8 ± 0.6	0.042	0.9 ± 0.3
G7SEBIAS01ESS01	6.5-7.5'	132321.5	2103953.7	13.1 ± 2.2	0.24	27.1 ± 4.3	0.21	0.5 ± 0.1
G7SESS0101	6-7'	132321.5	2103953.7	30.6 ± 6.6	0.69	67.0 ± 13.0	0.8	0.5 ± 0.1
G7NSWSS0101	11.5-12.5'	132323.0	2103947.4	3.1 ± 0.7	0.096	3.9 ± 0.8	0.076	0.8 ± 0.2
G8NWBIAS01SS0101	6.5-7.5'	132340.7	2103974.9	31.2 ± 4.6	0.11	27.0 ± 4.0	0.09	1.2 ± 0.2
G7NESS0101	7 - 8'	132341.1	2103957.2	64.0 ± 11.0	1.9	124.0 ± 20.0	1.7	0.5 ± 0.1
G7NESS0201	7.5 - 8.5'	132341.1	2103957.2	107.0 ± 20.0	3.2	97.0 ± 19.0	2.9	1.1 ± 0.3
G7NESS0202	7.0 - 8.5'	132341.1	2103957.2	434.0 ± 85.0	18	650.0 ± 120.0	24	0.7 ± 0.2
H7NWSS0305	25.9'	132374.3	2103940.1	0.5 ± 0.1	0.028	0.5 ± 0.1	0.022	1.1 ± 0.3
H7NWSS0101	18.5 - 19.5'	132374.3	2103940.1	0.9 ± 0.2	0.071	1.0 ± 0.3	0.071	0.9 ± 0.3
H7NWSS0102	20.5 - 21.5'	132374.3	2103940.1	1.7 ± 0.3	0.016	2.1 ± 0.3	0.026	0.8 ± 0.2
H7NWSS0401	21-25'	132374.3	2103940.1	3.1 ± 0.6	0.064	4.8 ± 0.9	0.053	0.6 ± 0.2
H7NWSS0303	21 - 22'	132374.3	2103940.1	3.9 ± 0.6	0.015	6.9 ± 1.0	0.02	0.6 ± 0.1
H7NWREF01A	21.5-22.5'	132374.3	2103940.1	7.0 ± 1.3	0.058	11.1 ± 1.9	0.05	0.6 ± 0.2
H7NWSS0302	18.5 - 19.5'	132374.3	2103940.1	24.0 ± 3.8	0.086	39.0 ± 5.9	0.23	0.6 ± 0.1
H9NESS0101	6.5-7.5'	132376.1	2104019.9	2.8 ± 0.4	0.024	2.0 ± 0.3	0.022	1.5 ± 0.3
I7SESS0101	8.5 - 9.5'	132390.1	2103956.3	4.1 ± 1.1	0.15	4.0 ± 1.1	0.42	1.0 ± 0.4
I7NEBIAS01SS0101	8.5-9.5'	132394.9	2103959.9	46.0 ± 7.3	0.18	81.0 ± 13.0	0.15	0.6 ± 0.1
K6NWSS0101	8.5 - 9.5'	132469.2	2103908.7	2.2 ± 0.4	0.028	1.7 ± 0.3	0.03	1.3 ± 0.3
M7SESS0101	6.0-7.0	132515.7	2103951.3	278.0 ± 39.0	0.43	25.2 ± 4.1	0.55	11.0 ± 2.4
M7SWSS010J	NA	132516.5	2103934.0	185.0 ± 27.0	0.11	19.8 ± 3.1	0.13	9.3 ± 2.0
M9NESS0101	4 - 5'	132531.8	2104017.2	1.0 ± 0.2	0.026	0.6 ± 0.1	0.03	1.7 ± 0.4

Notes:

⁽¹⁾ Errors reported at the 95% confidence level.⁽²⁾ Minimum detectable concentrations (MDCs) reported at the 95% confidence level.⁽³⁾ Northing and easting values are tied to the Michigan State Plane Coordinate System, North American Datum (NAD) 1983.⁽⁴⁾ Results collected from Table 6-2 and are alpha spectroscopy analyses

TABLE 6-1

NaI GROSS GAMMA 10-SECOND DUPLICATE RESULTS

Location	Northing ⁽²⁾	Easting ⁽²⁾	MSL ⁽¹⁾	Initial	Duplicate	% Diff	Pass ⁽³⁾
A8 - DM01	132135.48	2103979.98	586	154	117	24	FAIL
A8 - DM01	132135.48	2103979.98	585	158	158	0	PASS
A8 - DM01	132135.48	2103979.98	584	231	231	0	PASS
A8 - DM01	132135.48	2103979.98	583	69	81	17	PASS
A8 - DM01	132135.48	2103979.98	582	172	160	7	PASS
A8 - DM01	132135.48	2103979.98	581	256	219	14	PASS
A8 - DM01	132135.48	2103979.98	580	175	155	11	PASS
A8 - DM01	132135.48	2103979.98	579	165	146	12	PASS
A8 - DM01	132135.48	2103979.98	578	69	61	12	PASS
A8 - DM01	132135.48	2103979.98	577	229	230	0	PASS
A8 - DM01	132135.48	2103979.98	576	223	224	0	PASS
A8 - DM01	132135.48	2103979.98	575	219	238	9	PASS
A8 - DM01	132135.48	2103979.98	574	186	179	4	PASS
A8 - DM01	132135.48	2103979.98	573	145	154	6	PASS
D6SE	132229.99	2103919.31	572	184	142	23	FAIL
D6SE	132229.99	2103919.31	571	179	135	25	FAIL
D6SE	132229.99	2103919.31	570	80	57	29	FAIL
D6SE	132229.99	2103919.31	569	187	187	0	PASS
D6SE	132229.99	2103919.31	568	77	77	0	PASS
D6SE	132229.99	2103919.31	567	155	153	1	PASS
D6SE	132229.99	2103919.31	566	192	195	2	PASS
D6SE	132229.99	2103919.31	575	175	179	2	PASS
D6SE	132229.99	2103919.31	574	61	63	3	PASS
D6SE	132229.99	2103919.31	573	164	173	5	PASS
D6SE	132229.99	2103919.31	572	203	189	7	PASS
D6SE	132229.99	2103919.31	571	150	136	9	PASS
D6SE	132229.99	2103919.31	588	210	188	10	PASS
D6SE	132229.99	2103919.31	587	70	82	17	PASS
D7SW	132229.75	2103935.13	586	174	173	1	PASS
D7SW	132229.75	2103935.13	585	84	85	1	PASS
D7SW	132229.75	2103935.13	584	76	75	1	PASS
D7SW	132229.75	2103935.13	583	196	193	2	PASS
D7SW	132229.75	2103935.13	582	240	228	5	PASS
D7SW	132229.75	2103935.13	581	186	175	6	PASS
D7SW	132229.75	2103935.13	580	127	136	7	PASS
D7SW	132229.75	2103935.13	579	59	53	10	PASS
D7SW	132229.75	2103935.13	589	191	167	13	PASS
D7SW	132229.75	2103935.13	588	147	166	13	PASS
D7SW	132229.75	2103935.13	587	208	174	16	PASS
D7SW	132229.75	2103935.13	586	60	70	17	PASS
D7SW	132229.75	2103935.13	585	56	46	18	PASS
D7SW	132229.75	2103935.13	584	168	137	18	PASS
E10 - DM02	132269.23	2104042.91	589	158	219	39	FAIL
E10 - DM02	132269.23	2104042.91	588	52	67	29	FAIL
E10 - DM02	132269.23	2104042.91	587	59	74	25	FAIL
E10 - DM02	132269.23	2104042.91	586	194	194	0	PASS
E10 - DM02	132269.23	2104042.91	585	144	169	17	PASS
E10 - DM02	132269.23	2104042.91	584	126	104	17	PASS
E10 - DM02	132269.23	2104042.91	583	154	143	7	PASS
E10 - DM02	132269.23	2104042.91	582	186	181	3	PASS
E10 - DM02	132269.23	2104042.91	581	93	75	19	PASS
E10 - DM02	132269.23	2104042.91	580	150	137	9	PASS
E10 - DM02	132269.23	2104042.91	579	247	213	14	PASS

TABLE 6-1

NaI GROSS GAMMA 10-SECOND DUPLICATE RESULTS

Location	Northing ⁽²⁾	Easting ⁽²⁾	MSL ⁽¹⁾	Initial	Duplicate	% Diff	Pass ⁽³⁾
E10 - DM02	132269.23	2104042.91	578	73	87	19	PASS
E10 - DM02	132269.23	2104042.91	577	193	155	20	PASS
E10 - DM02	132269.23	2104042.91	576	186	184	1	PASS
E5 - SNE	132267.71	2103892.30	575	313	120	62	FAIL
E5 - SNE	132267.71	2103892.30	574	192	159	17	PASS
E5 - SNE	132267.71	2103892.30	573	172	171	1	PASS
E5 - SNE	132267.71	2103892.30	589	188	174	7	PASS
E5 - SNE	132267.71	2103892.30	588	174	176	1	PASS
E5 - SNE	132267.71	2103892.30	587	87	76	13	PASS
E5 - SNE	132267.71	2103892.30	586	187	197	5	PASS
E5 - SNE	132267.71	2103892.30	585	145	137	6	PASS
E5 - SNE	132267.71	2103892.30	584	182	173	5	PASS
E5 - SNE	132267.71	2103892.30	583	255	248	3	PASS
E5 - SNE	132267.71	2103892.30	582	133	144	8	PASS
E5 - SNE	132267.71	2103892.30	581	268	263	2	PASS
E5 - SNE	132267.71	2103892.30	580	167	194	16	PASS
E5 - SNE	132267.71	2103892.30	579	173	159	8	PASS
E5NE	132274.53	2103893.46	578	148	185	25	FAIL
E5NE	132274.53	2103893.46	577	112	148	32	FAIL
E5NE	132274.53	2103893.46	576	180	178	1	PASS
E5NE	132274.53	2103893.46	575	215	210	2	PASS
E5NE	132274.53	2103893.46	574	164	169	3	PASS
E5NE	132274.53	2103893.46	573	176	167	5	PASS
E5NE	132274.53	2103893.46	572	158	169	7	PASS
E5NE	132274.53	2103893.46	589	171	183	7	PASS
E5NE	132274.53	2103893.46	588	170	157	8	PASS
E5NE	132274.53	2103893.46	587	176	159	10	PASS
E5NE	132274.53	2103893.46	586	186	165	11	PASS
E5NE	132274.53	2103893.46	585	174	152	13	PASS
E5NE	132274.53	2103893.46	584	81	92	14	PASS
E5NE	132274.53	2103893.46	583	1204	1025	15	PASS
E5NNEDM01	132275.93	2103901.15	582	100	130	30	FAIL
E5NNEDM01	132275.93	2103901.15	581	933	927	1	PASS
E5NNEDM01	132275.93	2103901.15	580	186	191	3	PASS
E5NNEDM01	132275.93	2103901.15	579	194	199	3	PASS
E5NNEDM01	132275.93	2103901.15	578	2394	2285	5	PASS
E5NNEDM01	132275.93	2103901.15	577	196	205	5	PASS
E5NNEDM01	132275.93	2103901.15	576	119	113	5	PASS
E5NNEDM01	132275.93	2103901.15	589	214	202	6	PASS
E5NNEDM01	132275.93	2103901.15	588	184	173	6	PASS
E5NNEDM01	132275.93	2103901.15	587	194	209	8	PASS
E5NNEDM01	132275.93	2103901.15	586	265	236	11	PASS
E5NNEDM01	132275.93	2103901.15	585	182	205	13	PASS
E5NNEDM01	132275.93	2103901.15	584	190	217	14	PASS
E5NNEDM01	132275.93	2103901.15	583	180	208	16	PASS
E5NW	132274.09	2103873.65	582	151	189	25	FAIL
E5NW	132274.09	2103873.65	581	162	159	2	PASS
E5NW	132274.09	2103873.65	580	180	176	2	PASS
E5NW	132274.09	2103873.65	579	162	166	2	PASS
E5NW	132274.09	2103873.65	589	192	184	4	PASS
E5NW	132274.09	2103873.65	588	176	184	5	PASS
E5NW	132274.09	2103873.65	587	159	169	6	PASS
E5NW	132274.09	2103873.65	586	179	166	7	PASS

TABLE 6-1

NaI GROSS GAMMA 10-SECOND DUPLICATE RESULTS

Location	Northing ⁽²⁾	Easting ⁽²⁾	MSL ⁽¹⁾	Initial	Duplicate	% Diff	Pass ⁽³⁾
A8 - DM01	132135.48	2103979.98	586	154	117	24	FAIL
A8 - DM01	132135.48	2103979.98	585	158	158	0	PASS
A8 - DM01	132135.48	2103979.98	584	231	231	0	PASS
A8 - DM01	132135.48	2103979.98	583	69	81	17	PASS
A8 - DM01	132135.48	2103979.98	582	172	160	7	PASS
A8 - DM01	132135.48	2103979.98	581	256	219	14	PASS
A8 - DM01	132135.48	2103979.98	580	175	155	11	PASS
A8 - DM01	132135.48	2103979.98	579	165	146	12	PASS
A8 - DM01	132135.48	2103979.98	578	69	61	12	PASS
A8 - DM01	132135.48	2103979.98	577	229	230	0	PASS
A8 - DM01	132135.48	2103979.98	576	223	224	0	PASS
A8 - DM01	132135.48	2103979.98	575	219	238	9	PASS
A8 - DM01	132135.48	2103979.98	574	186	179	4	PASS
A8 - DM01	132135.48	2103979.98	573	145	154	6	PASS
D6SE	132229.99	2103919.31	572	184	142	23	FAIL
D6SE	132229.99	2103919.31	571	179	135	25	FAIL
D6SE	132229.99	2103919.31	570	80	57	29	FAIL
D6SE	132229.99	2103919.31	569	187	187	0	PASS
D6SE	132229.99	2103919.31	568	77	77	0	PASS
D6SE	132229.99	2103919.31	567	155	153	1	PASS
D6SE	132229.99	2103919.31	566	192	195	2	PASS
D6SE	132229.99	2103919.31	575	175	179	2	PASS
D6SE	132229.99	2103919.31	574	61	63	3	PASS
D6SE	132229.99	2103919.31	573	164	173	5	PASS
D6SE	132229.99	2103919.31	572	203	189	7	PASS
D6SE	132229.99	2103919.31	571	150	136	9	PASS
D6SE	132229.99	2103919.31	588	210	188	10	PASS
D6SE	132229.99	2103919.31	587	70	82	17	PASS
D7SW	132229.75	2103935.13	586	174	173	1	PASS
D7SW	132229.75	2103935.13	585	84	85	1	PASS
D7SW	132229.75	2103935.13	584	76	75	1	PASS
D7SW	132229.75	2103935.13	583	196	193	2	PASS
D7SW	132229.75	2103935.13	582	240	228	5	PASS
D7SW	132229.75	2103935.13	581	186	175	6	PASS
D7SW	132229.75	2103935.13	580	127	136	7	PASS
D7SW	132229.75	2103935.13	579	59	53	10	PASS
D7SW	132229.75	2103935.13	589	191	167	13	PASS
D7SW	132229.75	2103935.13	588	147	166	13	PASS
D7SW	132229.75	2103935.13	587	208	174	16	PASS
D7SW	132229.75	2103935.13	586	60	70	17	PASS
D7SW	132229.75	2103935.13	585	56	46	18	PASS
D7SW	132229.75	2103935.13	584	168	137	18	PASS
E10 - DM02	132269.23	2104042.91	589	158	219	39	FAIL
E10 - DM02	132269.23	2104042.91	588	52	67	29	FAIL
E10 - DM02	132269.23	2104042.91	587	59	74	25	FAIL
E10 - DM02	132269.23	2104042.91	586	194	194	0	PASS
E10 - DM02	132269.23	2104042.91	585	144	169	17	PASS
E10 - DM02	132269.23	2104042.91	584	126	104	17	PASS
E10 - DM02	132269.23	2104042.91	583	154	143	7	PASS
E10 - DM02	132269.23	2104042.91	582	186	181	3	PASS
E10 - DM02	132269.23	2104042.91	581	93	75	19	PASS
E10 - DM02	132269.23	2104042.91	580	150	137	9	PASS
E10 - DM02	132269.23	2104042.91	579	247	213	14	PASS

TABLE 6-1

NaI GROSS GAMMA 10-SECOND DUPLICATE RESULTS

Location	Northing ⁽²⁾	Easting ⁽²⁾	MSL ⁽¹⁾	Initial	Duplicate	% Diff	Pass ⁽³⁾
E10 - DM02	132269.23	2104042.91	578	73	87	19	PASS
E10 - DM02	132269.23	2104042.91	577	193	155	20	PASS
E10 - DM02	132269.23	2104042.91	576	186	184	1	PASS
E5 - SNE	132267.71	2103892.30	575	313	120	62	FAIL
E5 - SNE	132267.71	2103892.30	574	192	159	17	PASS
E5 - SNE	132267.71	2103892.30	573	172	171	1	PASS
E5 - SNE	132267.71	2103892.30	589	188	174	7	PASS
E5 - SNE	132267.71	2103892.30	588	174	176	1	PASS
E5 - SNE	132267.71	2103892.30	587	87	76	13	PASS
E5 - SNE	132267.71	2103892.30	586	187	197	5	PASS
E5 - SNE	132267.71	2103892.30	585	145	137	6	PASS
E5 - SNE	132267.71	2103892.30	584	182	173	5	PASS
E5 - SNE	132267.71	2103892.30	583	255	248	3	PASS
E5 - SNE	132267.71	2103892.30	582	133	144	8	PASS
E5 - SNE	132267.71	2103892.30	581	268	263	2	PASS
E5 - SNE	132267.71	2103892.30	580	167	194	16	PASS
E5 - SNE	132267.71	2103892.30	579	173	159	8	PASS
E5NE	132274.53	2103893.46	578	148	185	25	FAIL
E5NE	132274.53	2103893.46	577	112	148	32	FAIL
E5NE	132274.53	2103893.46	576	180	178	1	PASS
E5NE	132274.53	2103893.46	575	215	210	2	PASS
E5NE	132274.53	2103893.46	574	164	169	3	PASS
E5NE	132274.53	2103893.46	573	176	167	5	PASS
E5NE	132274.53	2103893.46	572	158	169	7	PASS
E5NE	132274.53	2103893.46	589	171	183	7	PASS
E5NE	132274.53	2103893.46	588	170	157	8	PASS
E5NE	132274.53	2103893.46	587	176	159	10	PASS
E5NE	132274.53	2103893.46	586	186	165	11	PASS
E5NE	132274.53	2103893.46	585	174	152	13	PASS
E5NE	132274.53	2103893.46	584	81	92	14	PASS
E5NE	132274.53	2103893.46	583	1204	1025	15	PASS
E5NNEDM01	132275.93	2103901.15	582	100	130	30	FAIL
E5NNEDM01	132275.93	2103901.15	581	933	927	1	PASS
E5NNEDM01	132275.93	2103901.15	580	186	191	3	PASS
E5NNEDM01	132275.93	2103901.15	579	194	199	3	PASS
E5NNEDM01	132275.93	2103901.15	578	2394	2285	5	PASS
E5NNEDM01	132275.93	2103901.15	577	196	205	5	PASS
E5NNEDM01	132275.93	2103901.15	576	119	113	5	PASS
E5NNEDM01	132275.93	2103901.15	589	214	202	6	PASS
E5NNEDM01	132275.93	2103901.15	588	184	173	6	PASS
E5NNEDM01	132275.93	2103901.15	587	194	209	8	PASS
E5NNEDM01	132275.93	2103901.15	586	265	236	11	PASS
E5NNEDM01	132275.93	2103901.15	585	182	205	13	PASS
E5NNEDM01	132275.93	2103901.15	584	190	217	14	PASS
E5NNEDM01	132275.93	2103901.15	583	180	208	16	PASS
E5NW	132274.09	2103873.65	582	151	189	25	FAIL
E5NW	132274.09	2103873.65	581	162	159	2	PASS
E5NW	132274.09	2103873.65	580	180	176	2	PASS
E5NW	132274.09	2103873.65	579	162	166	2	PASS
E5NW	132274.09	2103873.65	589	192	184	4	PASS
E5NW	132274.09	2103873.65	588	176	184	5	PASS
E5NW	132274.09	2103873.65	587	159	169	6	PASS
E5NW	132274.09	2103873.65	586	179	166	7	PASS

TABLE 6-1

NaI GROSS GAMMA 10-SECOND DUPLICATE RESULTS

Location	Northing ⁽²⁾	Easting ⁽²⁾	MSL ⁽¹⁾	Initial	Duplicate	% Diff	Pass ⁽³⁾
F5SE	132291.87	2103890.51	589	166	178	7	PASS
F5SE	132291.87	2103890.51	588	217	198	9	PASS
F5SE	132291.87	2103890.51	587	155	172	11	PASS
F5SE	132291.87	2103890.51	586	107	119	11	PASS
F5SE	132291.87	2103890.51	585	201	227	13	PASS
F5SE	132291.87	2103890.51	584	129	147	14	PASS
F5SE	132291.87	2103890.51	583	167	192	15	PASS
F5SE	132291.87	2103890.51	582	78	66	15	PASS
F5SE	132291.87	2103890.51	581	191	154	19	PASS
F6 - NSW	132292.31	2103913.29	580	74	56	24	FAIL
F6 - NSW	132292.31	2103913.29	579	89	67	25	FAIL
F6 - NSW	132292.31	2103913.29	578	154	151	2	PASS
F6 - NSW	132292.31	2103913.29	577	94	92	2	PASS
F6 - NSW	132292.31	2103913.29	576	208	203	2	PASS
F6 - NSW	132292.31	2103913.29	590	203	208	2	PASS
F6 - NSW	132292.31	2103913.29	589	152	146	4	PASS
F6 - NSW	132292.31	2103913.29	588	164	178	9	PASS
F6 - NSW	132292.31	2103913.29	587	186	170	9	PASS
F6 - NSW	132292.31	2103913.29	586	147	132	10	PASS
F6 - NSW	132292.31	2103913.29	585	179	156	13	PASS
F6 - NSW	132292.31	2103913.29	584	243	190	22	FAIL
F6 - NSW	132292.31	2103913.29	583	205	177	14	PASS
F6 - NSW	132292.31	2103913.29	582	167	137	18	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	586	3568	2176	39	FAIL
F7 - NE - BIAS 1W	132301.46	2103947.79	582	67	53	21	FAIL
F7 - NE - BIAS 1W	132301.46	2103947.79	581	49	61	24	FAIL
F7 - NE - BIAS 1W	132301.46	2103947.79	579	139	140	1	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	578	127	126	1	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	573	208	211	1	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	587	226	221	2	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	584	296	303	2	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	575	214	220	3	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	585	11448	12012	5	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	588	175	164	6	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	574	217	198	9	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	572	213	190	11	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	589	153	171	12	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	583	82	92	12	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	576	172	145	16	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	577	117	137	17	PASS
F7 - NE - BIAS 1W	132301.46	2103947.79	580	140	114	19	PASS
F7NE	132307.17	2103955.57	579	1067	1346	26	FAIL
F7NE	132307.17	2103955.57	578	127	100	21	FAIL
F7NE	132307.17	2103955.57	590	159	203	28	FAIL
F7NE	132307.17	2103955.57	589	50	67	34	FAIL
F7NE	132307.17	2103955.57	588	219	225	3	PASS
F7NE	132307.17	2103955.57	587	177	183	3	PASS
F7NE	132307.17	2103955.57	586	162	168	4	PASS
F7NE	132307.17	2103955.57	585	72	69	4	PASS
F7NE	132307.17	2103955.57	584	219	201	8	PASS
F7NE	132307.17	2103955.57	583	147	163	11	PASS
F7NE	132307.17	2103955.57	582	102	89	13	PASS
F7NE	132307.17	2103955.57	581	143	164	15	PASS

TABLE 6-1

NaI GROSS GAMMA 10-SECOND DUPLICATE RESULTS

Location	Northing ⁽²⁾	Easting ⁽²⁾	MSL ⁽¹⁾	Initial	Duplicate	% Diff	Pass ⁽³⁾
F7NE	132307.17	2103955.57	580	54	62	15	PASS
F7NE	132307.17	2103955.57	579	161	191	19	PASS
F7NSWDM01	132293.79	2103945.51	578	67	83	24	FAIL
F7NSWDM01	132293.79	2103945.51	577	226	221	2	PASS
F7NSWDM01	132293.79	2103945.51	576	84	86	2	PASS
F7NSWDM01	132293.79	2103945.51	575	982	1047	7	PASS
F7NSWDM01	132293.79	2103945.51	574	174	187	7	PASS
F7NSWDM01	132293.79	2103945.51	573	200	216	8	PASS
F7NSWDM01	132293.79	2103945.51	572	61	56	8	PASS
F7NSWDM01	132293.79	2103945.51	571	167	183	10	PASS
F7NSWDM01	132293.79	2103945.51	570	66	73	11	PASS
F7NSWDM01	132293.79	2103945.51	569	144	161	12	PASS
F7NSWDM01	132293.79	2103945.51	568	180	158	12	PASS
F7NSWDM01	132293.79	2103945.51	567	211	185	12	PASS
F7NSWDM01	132293.79	2103945.51	590	196	228	16	PASS
F7NSWDM01	132293.79	2103945.51	589	457	367	20	PASS
F7NW	132307.15	2103941.85	588	140	141	1	PASS
F7NW	132307.15	2103941.85	587	723	711	2	PASS
F7NW	132307.15	2103941.85	586	193	189	2	PASS
F7NW	132307.15	2103941.85	585	1414	1383	2	PASS
F7NW	132307.15	2103941.85	584	167	157	6	PASS
F7NW	132307.15	2103941.85	590	160	171	7	PASS
F7NW	132307.15	2103941.85	589	164	177	8	PASS
F7NW	132307.15	2103941.85	588	158	173	9	PASS
F7NW	132307.15	2103941.85	587	280	242	14	PASS
F7NW	132307.15	2103941.85	586	2231	2550	14	PASS
F7NW	132307.15	2103941.85	585	898	764	15	PASS
F7NW	132307.15	2103941.85	584	194	158	19	PASS
F7NW	132307.15	2103941.85	583	224	266	19	PASS
F7NW	132307.15	2103941.85	582	185	148	20	PASS
F8NE	132306.04	2103988.89	581	159	193	21	FAIL
F8NE	132306.04	2103988.89	580	50	61	22	FAIL
F8NE	132306.04	2103988.89	579	78	101	29	FAIL
F8NE	132306.04	2103988.89	578	186	183	2	PASS
F8NE	132306.04	2103988.89	577	67	64	4	PASS
F8NE	132306.04	2103988.89	576	58	55	5	PASS
F8NE	132306.04	2103988.89	590	195	213	9	PASS
F8NE	132306.04	2103988.89	589	147	133	10	PASS
F8NE	132306.04	2103988.89	588	152	167	10	PASS
F8NE	132306.04	2103988.89	587	124	139	12	PASS
F8NE	132306.04	2103988.89	586	153	172	12	PASS
F8NE	132306.04	2103988.89	585	162	186	15	PASS
F8NE	132306.04	2103988.89	584	67	77	15	PASS
F8NE	132306.04	2103988.89	583	46	55	20	PASS
F8SE	132292.42	2103988.30	582	182	142	22	FAIL
F8SE	132292.42	2103988.30	581	125	154	23	FAIL
F8SE	132292.42	2103988.30	580	54	69	28	FAIL
F8SE	132292.42	2103988.30	579	47	66	40	FAIL
F8SE	132292.42	2103988.30	578	134	140	4	PASS
F8SE	132292.42	2103988.30	577	209	220	5	PASS
F8SE	132292.42	2103988.30	576	210	197	6	PASS
F8SE	132292.42	2103988.30	590	187	199	6	PASS
F8SE	132292.42	2103988.30	589	168	185	10	PASS

TABLE 6-1

NaI GROSS GAMMA 10-SECOND DUPLICATE RESULTS

Location	Northing ⁽²⁾	Easting ⁽²⁾	MSL ⁽¹⁾	Initial	Duplicate	% Diff	Pass ⁽³⁾
F8SE	132292.42	2103988.30	588	56	62	11	PASS
F8SE	132292.42	2103988.30	587	66	74	12	PASS
F8SE	132292.42	2103988.30	586	82	72	12	PASS
F8SE	132292.42	2103988.30	585	163	139	15	PASS
F8SE	132292.42	2103988.30	584	149	176	18	PASS
G7 - NNE	132341.62	2103967.30	583	187	139	26	FAIL
G7 - NNE	132341.62	2103967.30	582	164	220	34	FAIL
G7 - NNE	132341.62	2103967.30	581	259	203	22	FAIL
G7 - NNE	132341.62	2103967.30	591	218	165	24	FAIL
G7 - NNE	132341.62	2103967.30	590	198	151	24	FAIL
G7 - NNE	132341.62	2103967.30	589	208	162	22	FAIL
G7 - NNE	132341.62	2103967.30	588	175	139	21	FAIL
G7 - NNE	132341.62	2103967.30	587	175	145	17	PASS
G7 - NNE	132341.62	2103967.30	586	187	156	17	PASS
G7 - NNE	132341.62	2103967.30	585	531	451	15	PASS
G7 - NNE	132341.62	2103967.30	584	166	155	7	PASS
G7 - NNE	132341.62	2103967.30	583	198	159	20	PASS
G7 - NNE	132341.62	2103967.30	582	160	137	14	PASS
G7 - NNE	132341.62	2103967.30	581	186	151	19	PASS
G7 - NNE	132341.62	2103967.30	589	165	153	7	PASS
G7 - NNE	132341.62	2103967.30	590	210	181	14	PASS
G7 - NNE	132341.62	2103967.30	589	245	207	16	PASS
G7 - NNE	132341.62	2103967.30	588	166	152	8	PASS
G7 - NNE	132341.62	2103967.30	587	382	389	2	PASS
G7 - SNW	132332.43	2103940.76	586	211	211	0	PASS
G7 - SNW	132332.43	2103940.76	585	195	160	18	PASS
G7 - SNW	132332.43	2103940.76	584	158	153	3	PASS
G7 - SNW	132332.43	2103940.76	583	196	176	10	PASS
G7 - SNW	132332.43	2103940.76	582	79	71	10	PASS
G7 - SNW	132332.43	2103940.76	581	158	129	18	PASS
G7 - SNW	132332.43	2103940.76	580	90	76	16	PASS
G7 - SNW	132332.43	2103940.76	591	187	192	3	PASS
G7 - SNW	132332.43	2103940.76	590	232	230	1	PASS
G7 - SNW	132332.43	2103940.76	589	297	300	1	PASS
G7 - SNW	132332.43	2103940.76	588	189	187	1	PASS
G7 - SNW	132332.43	2103940.76	587	255	251	2	PASS
G7 - SNW	132332.43	2103940.76	586	150	156	4	PASS
G7 - SNW	132332.43	2103940.76	585	250	246	2	PASS
G7 - SSW	132314.98	2103941.41	584	168	118	30	FAIL
G7 - SSW	132314.98	2103941.41	583	184	264	43	FAIL
G7 - SSW	132314.98	2103941.41	582	186	165	11	PASS
G7 - SSW	132314.98	2103941.41	581	353	351	1	PASS
G7 - SSW	132314.98	2103941.41	580	165	160	3	PASS
G7 - SSW	132314.98	2103941.41	579	193	179	7	PASS
G7 - SSW	132314.98	2103941.41	578	238	269	13	PASS
G7 - SSW	132314.98	2103941.41	577	141	134	5	PASS
G7 - SSW	132314.98	2103941.41	576	158	146	8	PASS
G7 - SSW	132314.98	2103941.41	575	243	281	16	PASS
G7 - SSW	132314.98	2103941.41	590	192	200	4	PASS
G7 - SSW	132314.98	2103941.41	589	173	180	4	PASS
G7 - SSW	132314.98	2103941.41	588	189	187	1	PASS
G7 - SSW	132314.98	2103941.41	587	272	283	4	PASS
G7SE	132321.45	2103953.70	586	50	66	32	FAIL

TABLE 6-1

NaI GROSS GAMMA 10-SECOND DUPLICATE RESULTS

Location	Northing ⁽²⁾	Easting ⁽²⁾	MSL ⁽¹⁾	Initial	Duplicate	% Diff	Pass ⁽³⁾
G7SE	132321.45	2103953.70	585	183	183	0	PASS
G7SE	132321.45	2103953.70	584	140	139	1	PASS
G7SE	132321.45	2103953.70	583	161	158	2	PASS
G7SE	132321.45	2103953.70	582	211	217	3	PASS
G7SE	132321.45	2103953.70	591	173	180	4	PASS
G7SE	132321.45	2103953.70	590	74	70	5	PASS
G7SE	132321.45	2103953.70	589	179	169	6	PASS
G7SE	132321.45	2103953.70	588	5699	6082	7	PASS
G7SE	132321.45	2103953.70	587	192	206	7	PASS
G7SE	132321.45	2103953.70	586	331	365	10	PASS
G7SE	132321.45	2103953.70	585	83	92	11	PASS
G7SE	132321.45	2103953.70	584	1861	1546	17	PASS
G7SE	132321.45	2103953.70	583	129	151	17	PASS
G7SNEDM01	132332.51	2103956.38	586	2178	2916	34	FAIL
G7SNEDM01	132332.51	2103956.38	587	587	317	46	FAIL
G7SNEDM01	132332.51	2103956.38	584	20464	22105	8	PASS
G7SNEDM01	132332.51	2103956.38	585	51577	61054	18	PASS
H7 - NNW	132374.84	2103949.30	584	163	258	58	FAIL
H7 - NNW	132374.84	2103949.30	583	113	185	64	FAIL
H7 - NNW	132374.84	2103949.30	582	139	236	70	FAIL
H7 - NNW	132374.84	2103949.30	581	133	373	180	FAIL
H7 - NNW	132374.84	2103949.30	580	184	531	189	FAIL
H7 - NNW	132374.84	2103949.30	579	194	625	222	FAIL
H7 - NNW	132374.84	2103949.30	578	191	392	105	FAIL
H7 - NNW	132374.84	2103949.30	577	130	166	28	FAIL
H7 - NNW	132374.84	2103949.30	576	132	161	22	FAIL
H7 - NNW	132374.84	2103949.30	575	142	174	23	FAIL
H7 - NNW	132374.84	2103949.30	574	121	143	18	PASS
H7 - NNW	132374.84	2103949.30	594	164	185	13	PASS
H7 - NNW	132374.84	2103949.30	593	214	245	14	PASS
H7 - NNW	132374.84	2103949.30	592	143	148	3	PASS
H7 - NSE	132360.20	2103966.86	591	185	135	27	FAIL
H7 - NSE	132360.20	2103966.86	590	160	152	5	PASS
H7 - NSE	132360.20	2103966.86	589	176	147	16	PASS
H7 - NSE	132360.20	2103966.86	588	195	185	5	PASS
H7 - NSE	132360.20	2103966.86	587	197	180	9	PASS
H7 - NSE	132360.20	2103966.86	586	92	100	9	PASS
H7 - NSE	132360.20	2103966.86	585	161	167	4	PASS
H7 - NSE	132360.20	2103966.86	584	164	153	7	PASS
H7 - NSE	132360.20	2103966.86	583	133	143	8	PASS
H7 - NSE	132360.20	2103966.86	582	147	165	12	PASS
H7 - NSE	132360.20	2103966.86	581	162	194	20	PASS
H7 - NSE	132360.20	2103966.86	580	190	194	2	PASS
H7 - NSE	132360.20	2103966.86	579	88	95	8	PASS
H7 - NSE	132360.20	2103966.86	578	214	188	12	PASS
H7 - NSE	132360.20	2103966.86	577	242	232	4	PASS
H7 - NSE	132360.20	2103966.86	576	123	130	6	PASS
H7 - NSE	132360.20	2103966.86	592	172	180	5	PASS
H7 - NSE	132360.20	2103966.86	591	161	160	1	PASS
H7 - NSE	132360.20	2103966.86	590	171	185	8	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	575	189	151	20	FAIL
H7 - SE - BIAS 1W	132346.37	2103948.92	582	49	63	29	FAIL
H7 - SE - BIAS 1W	132346.37	2103948.92	586	152	152	0	PASS

TABLE 6-1

NaI GROSS GAMMA 10-SECOND DUPLICATE RESULTS

Location	Northing ⁽²⁾	Easting ⁽²⁾	MSL ⁽¹⁾	Initial	Duplicate	% Diff	Pass ⁽³⁾
H7 - SE - BIAS 1W	132346.37	2103948.92	590	165	164	1	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	579	129	128	1	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	580	117	116	1	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	583	64	63	2	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	592	136	139	2	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	593	139	134	4	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	588	159	153	4	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	589	150	156	4	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	581	72	75	4	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	574	197	185	6	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	587	162	152	6	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	577	123	115	7	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	571	178	193	8	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	578	129	140	9	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	572	184	167	9	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	570	179	160	11	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	573	206	182	12	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	585	948	835	12	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	584	257	225	12	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	591	147	169	15	PASS
H7 - SE - BIAS 1W	132346.37	2103948.92	576	164	138	16	PASS
H7NW	132374.33	2103940.13	575	221	172	22	FAIL
H7NW	132374.33	2103940.13	574	190	187	2	PASS
H7NW	132374.33	2103940.13	573	134	131	2	PASS
H7NW	132374.33	2103940.13	572	637	618	3	PASS
H7NW	132374.33	2103940.13	571	178	172	3	PASS
H7NW	132374.33	2103940.13	570	172	178	3	PASS
H7NW	132374.33	2103940.13	569	202	193	4	PASS
H7NW	132374.33	2103940.13	568	138	146	6	PASS
H7NW	132374.33	2103940.13	567	5856	6219	6	PASS
H7NW	132374.33	2103940.13	566	119	127	7	PASS
H7NW	132374.33	2103940.13	565	249	230	8	PASS
H7NW	132374.33	2103940.13	564	207	190	8	PASS
H7NW	132374.33	2103940.13	563	205	187	9	PASS
H7NW	132374.33	2103940.13	562	204	186	9	PASS
H7NW	132374.33	2103940.13	561	118	107	9	PASS
H7NW	132374.33	2103940.13	560	263	237	10	PASS
H7NW	132374.33	2103940.13	559	172	191	11	PASS
H7NW	132374.33	2103940.13	558	194	170	12	PASS
H7NW	132374.33	2103940.13	594	174	203	17	PASS
H8SNWDM01	132366.93	2103971.76	593	2044	1630	20	FAIL
H8SNWDM01	132366.93	2103971.76	592	82	63	23	FAIL
H8SNWDM01	132366.93	2103971.76	591	82	83	2	PASS
H8SNWDM01	132366.93	2103971.76	590	169	172	2	PASS
H8SNWDM01	132366.93	2103971.76	589	82	79	4	PASS
H8SNWDM01	132366.93	2103971.76	588	211	199	5	PASS
H8SNWDM01	132366.93	2103971.76	587	242	228	6	PASS
H8SNWDM01	132366.93	2103971.76	592	191	203	6	PASS
H8SNWDM01	132366.93	2103971.76	591	147	157	7	PASS
H8SNWDM01	132366.93	2103971.76	590	121	130	7	PASS
H8SNWDM01	132366.93	2103971.76	589	185	201	8	PASS
H8SNWDM01	132366.93	2103971.76	588	193	210	9	PASS
H8SNWDM01	132366.93	2103971.76	587	188	171	9	PASS

TABLE 6-1

NaI GROSS GAMMA 10-SECOND DUPLICATE RESULTS

Location	Northing ⁽²⁾	Easting ⁽²⁾	MSL ⁽¹⁾	Initial	Duplicate	% Diff	Pass ⁽³⁾
H8SNWDM01	132366.93	2103971.76	586	45	53	18	PASS
I7SNWDM01	132401.03	2103941.51	585	1890	2454	30	FAIL
I7SNWDM01	132401.03	2103941.51	584	132	183	38	FAIL
I7SNWDM01	132401.03	2103941.51	583	167	274	64	FAIL
I7SNWDM01	132401.03	2103941.51	582	72	122	69	FAIL
I7SNWDM01	132401.03	2103941.51	581	274	599	119	FAIL
I7SNWDM01	132401.03	2103941.51	580	123	283	130	FAIL
I7SNWDM01	132401.03	2103941.51	579	167	202	21	FAIL
I7SNWDM01	132401.03	2103941.51	578	68	89	31	FAIL
I7SNWDM01	132401.03	2103941.51	577	223	238	7	PASS
I7SNWDM01	132401.03	2103941.51	576	68	73	8	PASS
I7SNWDM01	132401.03	2103941.51	575	201	185	8	PASS
I7SNWDM01	132401.03	2103941.51	592	217	197	9	PASS
I7SNWDM01	132401.03	2103941.51	591	214	238	11	PASS
I7SNWDM01	132401.03	2103941.51	590	219	193	12	PASS
K7 - SNE	132463.02	2103958.27	589	154	215	40	FAIL
K7 - SNE	132463.02	2103958.27	588	154	211	37	FAIL
K7 - SNE	132463.02	2103958.27	587	150	212	41	FAIL
K7 - SNE	132463.02	2103958.27	586	141	207	47	FAIL
K7 - SNE	132463.02	2103958.27	585	667	516	23	FAIL
K7 - SNE	132463.02	2103958.27	592	109	199	83	FAIL
K7 - SNE	132463.02	2103958.27	591	48	64	33	FAIL
K7 - SNE	132463.02	2103958.27	590	67	90	34	FAIL
K7 - SNE	132463.02	2103958.27	589	90	127	41	FAIL
K7 - SNE	132463.02	2103958.27	588	157	202	29	FAIL
K7 - SNE	132463.02	2103958.27	587	65	77	18	PASS
K7 - SNE	132463.02	2103958.27	586	179	177	1	PASS
K7 - SNE	132463.02	2103958.27	585	120	139	16	PASS
K7 - SNE	132463.02	2103958.27	584	1264	1428	13	PASS
N8-SSE-DM01	132535.93	2103987.76	583	212	271	28	FAIL
N8-SSE-DM01	132535.93	2103987.76	582	73	246	237	FAIL
N8-SSE-DM01	132535.93	2103987.76	581	293	1106	277	FAIL
N8-SSE-DM01	132535.93	2103987.76	580	179	226	26	FAIL
N8-SSE-DM01	132535.93	2103987.76	579	222	183	18	PASS
N8-SSE-DM01	132535.93	2103987.76	578	160	168	5	PASS
N8-SSE-DM01	132535.93	2103987.76	577	74	76	3	PASS
N8-SSE-DM01	132535.93	2103987.76	576	95	89	6	PASS
N8-SSE-DM01	132535.93	2103987.76	575	94	98	4	PASS
N8-SSE-DM01	132535.93	2103987.76	574	155	174	12	PASS
N8-SSE-DM01	132535.93	2103987.76	573	166	176	6	PASS
N8-SSE-DM01	132535.93	2103987.76	572	196	163	17	PASS

Notes:

⁽¹⁾ MSL represents Mean Sea Level and is presented in units of feet⁽²⁾ Northing and easting values are tied to the Michigan State Plane Coordinate System, North American Datum (NAD) 1983⁽³⁾ PASS means sample is less than or equal a 20% difference between the initial and duplicate value

TABLE 6-2

NaI DOWNHOLE SPECTROSCOPY DUPLICATE RESULTS

Location ID	Northing ⁽¹⁾	Easting ⁽¹⁾	Depth (ft bgs) ⁽²⁾	Pb-212 Initial	Pb-212 Dup	Z-Score	Pass?
A8-DM-02.10	132135.5	2103980.0	10	ND ±	ND ±		
A8-DM-02.11	132135.5	2103980.0	11	ND ±	ND ±		
A8-DM-02.12	132135.5	2103980.0	12	ND ±	ND ±		
A8-DM-02.13	132135.5	2103980.0	13	ND ±	ND ±		
A8-DM-02.9	132135.5	2103980.0	9	ND ±	ND ±		
D6SE2-11	132230.0	2103919.3	11	ND ±	ND ±		
D6SE2-13	132230.0	2103919.3	13	ND ±	ND ±		
D6SE2-3	132230.0	2103919.3	3	ND ±	ND ±		
D6SE2-5	132230.0	2103919.3	5	ND ±	ND ±		
D6SE2-7	132230.0	2103919.3	7	ND ±	ND ±		
D6SE2-9	132230.0	2103919.3	9	ND ±	ND ±		
D7SW2-11	132229.8	2103935.1	11	ND ±	ND ±		
D7SW2-13	132229.8	2103935.1	13	ND ±	ND ±		
D7SW2-3	132229.8	2103935.1	3	ND ±	ND ±		
D7SW2-5	132229.8	2103935.1	5	ND ±	ND ±		
D7SW2-7	132229.8	2103935.1	7	1.71 ± 1.15	ND ±		
D7SW2-9	132229.8	2103935.1	9	ND ±	ND ±		
E10-DM-03.10	132269.2	2104042.9	10	ND ±	ND ±		
E10-DM-03.11	132269.2	2104042.9	11	ND ±	ND ±		
E10-DM-03.12	132269.2	2104042.9	12	ND ±	ND ±		
E10-DM-03.13	132269.2	2104042.9	13	ND ±	ND ±		
E10-DM-03.4	132269.2	2104042.9	4	ND ±	ND ±		
E10-DM-03.5	132269.2	2104042.9	5	ND ±	ND ±		
E5NE2-11	132274.5	2103893.5	11	ND ±	ND ±		
E5NE2-13	132274.5	2103893.5	13	ND ±	ND ±		
E5NE2-3	132274.5	2103893.5	3	ND ±	ND ±		
E5NE2-5	132274.5	2103893.5	5	ND ±	ND ±		
E5NE2-7	132274.5	2103893.5	7	13.31 ± 4.81	18.94 ± 5.56	1.75	PASS
E5NE2-9	132274.5	2103893.5	9	ND ±	ND ±		
E5NNE4-10	132275.9	2103901.2	10	ND ±	ND ±		
E5NNE4-13	132275.9	2103901.2	13	ND ±	ND ±		
E5NNE4-3	132275.9	2103901.2	3	ND ±	ND ±		
E5NNE4-6	132275.9	2103901.2	6	16.76 ± 5.80	17.16 ± 5.80	0.12	PASS
E5NNE4-7	132275.9	2103901.2	7	ND ±	ND ±		
E5NNE4-8	132275.9	2103901.2	8	ND ±	2.37 ± 1.62		
E5NW2-11	132274.1	2103873.7	11	ND ±	ND ±		
E5NW2-13	132274.1	2103873.7	13	ND ±	ND ±		
E5NW2-3	132274.1	2103873.7	3	ND ±	ND ±		
E5NW2-5	132274.1	2103873.7	5	ND ±	ND ±		
E5NW2-7	132274.1	2103873.7	7	ND ±	ND ±		
E5NW2-9	132274.1	2103873.7	9	ND ±	ND ±		
E5-SNE-DM-02.11	132267.7	2103892.3	11	ND ±	ND ±		
E5-SNE-DM-02.12	132267.7	2103892.3	12	ND ±	ND ±		
E5-SNE-DM-02.13	132267.7	2103892.3	13	ND ±	ND ±		
E5-SNE-DM-02.7	132267.7	2103892.3	7	2.49 ± 1.16	ND ±		
E6SW-2-13	132259.8	2103907.0	13	ND ±	ND ±		
E6SW-2-3	132259.8	2103907.0	3	ND ±	ND ±		
E6SW-2-5	132259.8	2103907.0	5	ND ±	ND ±		
E6SW-2-7	132259.8	2103907.0	7	10.55 ± 7.24	11.65 ± 4.66	0.32	PASS
E6SW-2-8	132259.8	2103907.0	8	ND ±	ND ±		
E9NE2-11	132278.6	2104024.8	11	ND ±	ND ±		
E9NE2-13	132278.6	2104024.8	13	ND ±	ND ±		
E9NE2-3	132278.6	2104024.8	3	ND ±	ND ±		
E9NE2-5	132278.6	2104024.8	5	ND ±	ND ±		
E9NE2-7	132278.6	2104024.8	7	ND ±	ND ±		
E9NE2-9	132278.6	2104024.8	9	1.79 ± 7.24	ND ±		
E9NW2-11	132280.0	2104006.9	11	ND ±	ND ±		
E9NW2-13	132280.0	2104006.9	13	ND ±	ND ±		
E9NW2-3	132280.0	2104006.9	3	ND ±	ND ±		

TABLE 6-2

NaI DOWNHOLE SPECTROSCOPY DUPLICATE RESULTS

Location ID	Northing ⁽¹⁾	Easting ⁽¹⁾	Depth (ft bgs) ⁽²⁾	Pb-212 Initial	Pb-212 Dup	Z-Score	Pass?
E9NW2-7	132280.0	2104006.9	7	1.81 ± 1.19	ND ±		
E9NW2-9	132280.0	2104006.9	9	ND ±	ND ±		
F5SE3-11	132291.9	2103890.5	11	ND ±	ND ±		
F5SE3-13	132291.9	2103890.5	13	ND ±	ND ±		
F5SE3-3	132291.9	2103890.5	3	ND ±	ND ±		
F5SE3-5	132291.9	2103890.5	5	ND ±	ND ±		
F5SE3-7	132291.9	2103890.5	7	ND ±	ND ±		
F5SE3-9	132291.9	2103890.5	9	ND ±	ND ±		
F6-NSW-DM02.4	132292.3	2103913.3	4	ND ±	ND ±		
F6-NSW-DM02.5	132292.3	2103913.3	5	ND ±	ND ±		
F6-NSW-DM02.7	132292.3	2103913.3	7	ND ±	ND ±		
F6-NSW-DM02.11	132292.3	2103913.3	11	ND ±	ND ±		
F6-NSW-DM02.12	132292.3	2103913.3	12	ND ±	ND ±		
F7NE-BIAS-1W.4	132301.5	2103947.8	4	ND ±	ND ±		
F7NE-BIAS-1W.5	132301.5	2103947.8	5	ND ±	ND ±		
F7NE-BIAS-1W.6	132301.5	2103947.8	6	167.7 ± 43	75.00 ± 22.20	11.48	FAIL
F7NE-BIAS-1W.7	132301.5	2103947.8	7	ND ±	ND ±		
F7NE-BIAS-1W.16	132301.5	2103947.8	16	ND ±	ND ±		
F7NE2-13	132307.2	2103955.6	13	ND ±	ND ±		
F7NE2-3	132307.2	2103955.6	3	ND ±	ND ±		
F7NE2-5	132307.2	2103955.6	5	ND ±	ND ±		
F7NE2-6	132307.2	2103955.6	6	23.36 ± 6.55	10.90 ± 3.82	3.87	FAIL
F7NW2-10	132307.2	2103941.9	10	17.82 ± 7.24	13.48 ± 7.27	1.14	PASS
F7NW2-11	132307.2	2103941.9	11	ND ±	ND ±		
F7NW2-13	132307.2	2103941.9	13	ND ±	ND ±		
F7NW2-3	132307.2	2103941.9	3	ND ±	ND ±		
F7NW2-6	132307.2	2103941.9	6	ND ±	ND ±		
F7NW2-7	132307.2	2103941.9	7	ND ±	ND ±		
F7NW2-8	132307.2	2103941.9	8	ND ±	ND ±		
F7NW2-9	132307.2	2103941.9	9	ND ±	ND ±		
F8NE2-13	132306.0	2103988.9	13	ND ±	ND ±		
F8NE2-3	132306.0	2103988.9	3	ND ±	ND ±		
F8NE2-5	132306.0	2103988.9	5	ND ±	ND ±		
F8NE2-9	132306.0	2103988.9	9	ND ±	ND ±		
F8SE2-13	132305.9	2103971.6	13	ND ±	ND ±		
F8SE2-3	132305.9	2103971.6	3	ND ±	ND ±		
F8SE2-5	132305.9	2103971.6	5	ND ±	ND ±		
F8SE2-7	132305.9	2103971.6	7	ND ±	1.47 ± 1.14		
F8SE2-9	132305.9	2103971.6	9	ND ±	ND ±		
G7-NNE-DM01.3a	132341.6	2103967.3	3	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
G7-NNE-DM01.7a	132341.6	2103967.3	7	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
G7-NNE-DM01.9a	132341.6	2103967.3	9	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
G7-NNE-DM01.10a	132341.6	2103967.3	10	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
G7-NNE-DM01.14a	132341.6	2103967.3	14	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
G7-NNE-DM01.17a	132341.6	2103967.3	17	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
G7SE2-11	132321.5	2103953.7	11	ND ±	ND ±		
G7SE2-13	132321.5	2103953.7	13	ND ±	ND ±		
G7SE2-3	132321.5	2103953.7	3	ND ±	ND ±		
G7SE2-5	132321.5	2103953.7	5	ND ±	ND ±		
G7SE2-7	132321.5	2103953.7	7	63.55 ± 19.31	42.82 ± 14.83	3.55	FAIL
G7SE2-9	132321.5	2103953.7	9	ND ±	ND ±		
G7SNE3-73	132332.5	2103956.4	7.3	804 ± 191	798 ± 192	0.28	PASS
G7-SNW-DM-01.3	132332.4	2103940.8	3	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
G7-SNW-DM-01.4	132332.4	2103940.8	4	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
G7-SNW-DM-01.7	132332.4	2103940.8	7	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
G7-SNW-DM-01.8	132332.4	2103940.8	8	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
G7-SNW-DM-01.9	132332.4	2103940.8	9	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
G7-SSW-DM01.14D	132315.0	2103941.4	14	ND ±	ND ±		

TABLE 6-2

NaI DOWNHOLE SPECTROSCOPY DUPLICATE RESULTS

Location ID	Northing ⁽¹⁾	Easting ⁽¹⁾	Depth (ft bgs) ⁽²⁾	Pb-212 Initial	Pb-212 Dup	Z-Score	Pass?
G7-SSW-DM01.7D	132315.0	2103941.4	7	ND ±	ND ±		
G7-SSW-DM01.9D	132315.0	2103941.4	9	ND ±	ND ±		
G7-SSW-DM01.10D	132315.0	2103941.4	10	ND ±	ND ±		
G7-SSW-DM01.11D	132315.0	2103941.4	11	ND ±	ND ±		
G7-SSW-DM01.12D	132315.0	2103941.4	12	1.85 ± 1.28	ND ±		
H7-NNW-DM-01.6	132374.8	2103949.3	6	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
H7-NNW-DM-01.11	132374.8	2103949.3	11	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
H7-NNW-DM-01.13	132374.8	2103949.3	13	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
H7-NNW-DM-01.16	132374.8	2103949.3	16	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
H7-NNW-DM-01.19	132374.8	2103949.3	19	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
H7-NNW-DM-01.22	132374.8	2103949.3	22	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
H7-NSE-DM0	132360.2	2103966.9	4	ND ±	ND ±		
H7NW2-19	132374.3	2103940.1	19	123 ± 31.6	113 ± 29.5	1.29	PASS
H7SE-Bias-1W.7	132346.4	2103948.9	7	ND ±	ND ±		
H7SE-Bias-1W.9	132346.4	2103948.9	9	3.31 ± 3.1	ND ±		
H7SE-Bias-1W.10	132346.4	2103948.9	10	ND ±	ND ±		
I10-DM-02.11	132393.6	2104056.3	11	ND ±	ND ±		
I10-DM-02.13	132393.6	2104056.3	13	ND ±	ND ±		
I10-DM-02.4	132393.6	2104056.3	4	ND ±	ND ±		
I10-DM-02.6	132393.6	2104056.3	6	ND ±	ND ±		
I7SNW3-10	132401.0	2103941.5	10	ND ±	ND ±		
I7SNW3-13	132401.0	2103941.5	13	ND ±	ND ±		
I7SNW3-3	132401.0	2103941.5	3	ND ±	ND ±		
I7SNW3-8	132401.0	2103941.5	8	ND ±	ND ±		
I7SNW3-9	132401.0	2103941.5	9	32.27 ± 9.06	27.37 ± 7.95	1.19	PASS
J10-DM-02.12	132425.2	2104055.4	12	ND ±	ND ±		
J10-DM-02.4	132425.2	2104055.4	4	ND ±	ND ±		
J10-DM-02.6	132425.2	2104055.4	6	ND ±	ND ±		
K7-SNE-DM01.3	132463.0	2103958.3	3	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
K7-SNE-DM01.5	132463.0	2103958.3	5	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
K7-SNE-DM01.7	132463.0	2103958.3	7	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
K7-SNE-DM01.8	132463.0	2103958.3	8	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
K7-SNE-DM01.14	132463.0	2103958.3	14	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
K7-SNE-DM01.17	132463.0	2103958.3	17	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
N8-SSE-DM01.1	132535.9	2103987.8	1	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
N8-SSE-DM01.3	132535.9	2103987.8	3	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
N8-SSE-DM01.4	132535.9	2103987.8	4	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
N8-SSE-DM01.5	132535.9	2103987.8	5	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
N8-SSE-DM01.7	132535.9	2103987.8	7	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		
N8-SSE-DM01.11	132535.9	2103987.8	11	NA ⁽¹⁾ ±	NA ⁽¹⁾ ±		

Notes:

⁽¹⁾ Northing and easting values are tied to the Michigan State Plane Coordinate System, North American Datum (NAD) 1983

⁽²⁾ ft bgs represents feet below ground surface

ND Represents Not Detected

NA Represents Not Applicable

NA⁽¹⁾ Represents paperwork showing that a duplicate measurement was performed, but measurement file has been corrupted therefore no results can be presented

Table 6-3
Gamma and Alpha Spectroscopy Duplicate Results

Sample ID	D5NSES0101					E5NESS0101				
	Original (pCi/g)		Replicate (pCi/g)		Z-Score	Original (pCi/g)		Replicate (pCi/g)		Z-Score
	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾		Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	
U-238(alpha)	NP ± NP	NP	NP ± NP	NP	NA	0.176 ± 0.071	0.036	0.21 ± 0.08	0.048	0.68
U-235(alpha)	NP ± NP	NP	NP ± NP	NP	NA	0 ± 0.021	0.059	0.02 ± 0.03	0.057	1.01
U-234(alpha)	NP ± NP	NP	NP ± NP	NP	NA	0.159 ± 0.069	0.059	0.18 ± 0.07	0.057	0.36
Th-232(alpha)	NP ± NP	NP	NP ± NP	NP	NA	16.3 ± 3.6	0.61	30.4 ± 5.8	0.63	4.13
Th-230(alpha)	NP ± NP	NP	NP ± NP	NP	NA	111 ± 20	0.5	227 ± 38	0.53	5.40
Th-228(alpha)	NP ± NP	NP	NP ± NP	NP	NA	15.5 ± 3.5	1.5	31.5 ± 6.1	1.1	4.55
U-235	1.2 ± 0.45	0.26	0.72 ± 0.33	0.28	1.72	0.82 ± 0.42	0.46	1.57 ± 0.73	0.77	1.78
Th-234	0.72 ± 0.31	1.1	-0.3 ± 1.3	0.95	1.53	0.4 ± 3.2	3.3	12 ± 4.1	3.3	4.46
Th-232	0 ± 11	19	0.7 ± 9.4	16	0.10	0 ± 49	82	-26 ± 34	46	0.87
Pa-234m	1.1 ± 3.8	6.6	-0.1 ± 3.7	5.7	0.45	0 ± 40	5.9	3.1 ± 7.7	13	0.15
Ac-228	3.81 ± 0.67	0.18	2.15 ± 0.39	0.15	4.28	25.1 ± 4.2	0.22	28.5 ± 4.7	0.37	1.08
Ra-226	0.66 ± 0.19	0.14	0.47 ± 0.11	0.14	1.73	4.08 ± 0.75	0.24	4.56 ± 0.88	0.38	0.83
Pb-214	0.62 ± 0.16	0.13	0.41 ± 0.11	0.092	2.16	2.84 ± 0.51	0.15	3.69 ± 0.67	0.3	2.02
Bi-214	0.42 ± 0.12	0.1	0.268 ± 0.066	0.079	2.22	3.04 ± 0.57	0.17	3.41 ± 0.66	0.28	0.85
Pb-212	3.97 ± 0.66	0.062	2.18 ± 0.36	0.053	4.76	27 ± 4.5	0.18	33.8 ± 5.6	0.15	1.89
Tl-208	1.33 ± 0.23	0.053	0.71 ± 0.13	0.052	4.69	7.8 ± 1.3	0.085	9.8 ± 1.6	0.17	1.94
Cs-137	0.102 ± 0.068	0.063	0.008 ± 0.027	0.046	2.57	0.189 ± 0.044	0.05	0.2 ± 0.15	0.16	0.14
K-40	7.8 ± 1.5	0.65	7.6 ± 1.3	0.47	0.20	9.2 ± 1.7	0.57	7.4 ± 1.7	1.1	1.50

Table 6-3
Gamma and Alpha Spectroscopy Duplicate Results

Sample ID	H10SS0101					H8SNWSS0101				
	Original (pCi/g)		Replicate (pCi/g)		Z-Score	Original (pCi/g)		Replicate (pCi/g)		Z-Score
	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾		Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	
U-238(alpha)	NP ± NP	NP	NP ± NP	NP	NA	0.47 ± 0.12	0.043	0.51 ± 0.14	0.061	0.43
U-235(alpha)	NP ± NP	NP	NP ± NP	NP	NA	0.061 ± 0.042	0.049	0.032 ± 0.04	0.073	1.00
U-234(alpha)	NP ± NP	NP	NP ± NP	NP	NA	0.46 ± 0.12	0.035	0.39 ± 0.12	0.085	0.82
Th-232(alpha)	NP ± NP	NP	NP ± NP	NP	NA	6.4 ± 1.2	0.069	8.3 ± 1.5	0.043	1.98
Th-230(alpha)	NP ± NP	NP	NP ± NP	NP	NA	11.1 ± 2	0.089	9 ± 1.7	0.072	1.60
Th-228(alpha)	NP ± NP	NP	NP ± NP	NP	NA	7.4 ± 1.4	0.2	8.4 ± 1.6	0.16	0.94
U-235	0 ± 1.5	0.2	0 ± 1.9	0.21	0.00	-0.05 ± 0.55	0.3	-0.2 ± 2	0.26	0.14
Th-234	0.64 ± 0.66	1.1	-10 ± 100	3.3	0.21	-4 ± 66	3.9	0.5 ± 1.1	1.2	0.14
Th-232	3 ± 22	38	0 ± 0	84	0.27	-870 ± 170	130	0 ± 920	21	1.86
Pa-234m	2.9 ± 3.2	5.4	-0.2 ± 8.7	6	0.67	1.2 ± 3.1	5.2	7.4 ± 6.6	6.1	1.70
Ac-228	0.59 ± 0.16	0.16	0.3 ± 0.14	0.13	2.73	6.5 ± 1.1	0.19	5.59 ± 0.94	0.11	1.26
Ra-226	0.43 ± 0.13	0.14	0.287 ± 0.086	0.12	1.83	0.84 ± 0.18	0.13	0.81 ± 0.21	0.13	0.22
Pb-214	0.311 ± 0.093	0.098	0.205 ± 0.093	0.098	1.61	0.77 ± 0.16	0.084	0.61 ± 0.15	0.1	1.46
Bi-214	0.32 ± 0.1	0.1	0.203 ± 0.084	0.087	1.79	0.61 ± 0.13	0.095	0.58 ± 0.15	0.095	0.30
Pb-212	0.476 ± 0.09	0.054	0.243 ± 0.053	0.049	4.46	6.5 ± 1.1	0.056	5.98 ± 0.99	0.062	0.70
Tl-208	0.165 ± 0.05	0.038	0.063 ± 0.035	0.041	3.34	1.97 ± 0.33	0.052	1.86 ± 0.31	0.054	0.49
Cs-137	0.227 ± 0.043	0.028	0.181 ± 0.063	0.038	1.21	0.002 ± 0.025	0.042	0.013 ± 0.027	0.046	0.60
K-40	13.5 ± 2.3	0.57	11.5 ± 2	0.55	1.31	12.4 ± 2.2	0.53	12.4 ± 2.2	0.53	0.00

Table 6-3
Gamma and Alpha Spectroscopy Duplicate Results

Sample ID	L10SS0101				
	Original (pCi/g)		Replicate (pCi/g)		Z-Score
	Result ^(1,3)	MDC ⁽²⁾	Result ^(1,3)	MDC ⁽²⁾	
U-238(alpha)	NP \pm NP	NP	NP \pm NP	NP	NA
U-235(alpha)	NP \pm NP	NP	NP \pm NP	NP	NA
U-234(alpha)	NP \pm NP	NP	NP \pm NP	NP	NA
Th-232(alpha)	NP \pm NP	NP	NP \pm NP	NP	NA
Th-230(alpha)	NP \pm NP	NP	NP \pm NP	NP	NA
Th-228(alpha)	NP \pm NP	NP	NP \pm NP	NP	NA
U-235	0.33 \pm 0.14	0.15	0 \pm 1.8	0.16	0.37
Th-234	0.18 \pm 0.37	0.64	-4 \pm 75	2.4	0.11
Th-232	2 \pm 12	21	-3 \pm 48	81	0.20
Pa-234m	4.1 \pm 2.4	2.6	0.2 \pm 2.4	4.2	2.30
Ac-228	0.47 \pm 0.11	0.081	0.55 \pm 0.16	0.12	0.82
Ra-226	0.63 \pm 0.12	0.085	0.66 \pm 0.13	0.089	0.34
Pb-214	0.471 \pm 0.091	0.049	0.51 \pm 0.11	0.065	0.55
Bi-214	0.46 \pm 0.11	0.067	0.457 \pm 0.099	0.065	0.04
Pb-212	0.466 \pm 0.08	0.029	0.388 \pm 0.07	0.036	1.47
Tl-208	0.136 \pm 0.036	0.023	0.202 \pm 0.063	0.031	1.82
Cs-137	-0.001 \pm 0.01	0.018	0.001 \pm 0.015	0.026	0.22
K-40	12.7 \pm 2.1	0.29	11.8 \pm 2	0.38	0.62

Notes: NA Represents Not Applicable

NA Represents Not Applicable
 NP Represents sample analyses based upon laboratory gamma spectroscopy.

(¹) Errors reported at the 95% confidence level.

⁽²⁾ Minimum detectable concentrations (MDCs) reported at the 95% confidence level.

⁽³⁾ Results listed as reported directly from the laboratory.

(4) The suffix "(alpha)" following radionuclide title represents performance of alpha spectroscopy analysis, if no "(alpha)" suffix, then gamma spectroscopy analysis was performed.

Table 6-4

Comparison of NaI Spectroscopic and Laboratory Sample Results

Sample ID	Cabrera Downhole NaI		Paragon Lab Soil Sample Data		Z-score
	Th-232 ⁽³⁾ (pCi/g)		Th-232 ⁽³⁾ (pCi/g)		
	Results	MDC	Results	MDC	
E5-NE-SS0101	13.31 ± 4.81	4.36	27 ± 4.5	0.18	4.1
E5-NE-SS0101 DUP	18.94 ± 5.56	4.81	33.8 ± 5.6	0.15	3.7
E6-NW-BIAS-01.7	5.42 ± 2.21	NA	3.62 ± 0.68	0.17	1.5
E6-NW-SS0101	50.77 ± 16.46	18.7	50 ± 8.4	0.88	0.1
E6-SW-SS0102	10.55 ± 7.24	9.91	0.56 ± 0.11	0.051	2.7
E6-SW-SS0201	11.65 ± 4.66	5.67	10.2 ± 1.8	0.43	0.6
F7-NE-BIAS-01W.6	54.78 ± 13.95	10.2	109 ± 18	0.3	4.7
F7-NE-SS0101	23.4 ± 6.55	4.88	4.02 ± 0.68	0.1	5.8
F7-NW-SS0102	13.48 ± 7.27	8.81	0.48 ± 0.25	0.22	3.5
F7-SW-SS0101	46.91 ± 12.74	7.58	52 ± 8.6	0.15	0.6
G7-NE-SS0101	111 ± 33.61	27.1	194 ± 32	1.5	3.5
G7-SE-BIAS-01E.7	35.38 ± 8.27	6.08	24.7 ± 4.1	0.12	2.3
G7-SE-SS0101	63.55 ± 19.31	19.2	57.9 ± 9.6	0.25	0.5
G8-NW-BIAS-01.7	21.34 ± 6.7	7.64	30.8 ± 5.1	0.27	2.2
H7-NW-SS0101	122.9 ± 31.55	11.9	2.86 ± 0.52	0.19	7.5
H7-NW-SS0201	112.8 ± 29.46	11	4.14 ± 0.73	0.15	7.2
H7-NW-SS0501	6.28 ± 3.47	4.95	0.98 ± 0.21	0.091	3.0
H7-SE-BIAS01E-SS0101	55.12 ± 12.4	7.09	0.68 ± 0.14	0.07	8.6
H8-SNW-SS0101 DUP	25.31 ± 7.37	6	5.98 ± 0.99	0.062	5.1
I7-NE-BIAS-01-SS0101	94.1 ± 21.83	10.7	162 ± 27	0.43	3.8
I7-NW-SS0101	4.54 ± 2.46	3.74	28.5 ± 4.7	0.17	8.9
I7-SE-SS0101	9.56 ± 5.22	7.13	7.8 ± 1.3	0.25	0.6
K6-NW-SS0101	4.38 ± 2.01	2.94	2.49 ± 0.49	0.27	1.8
L9-NW-SS0101	4.64 ± 2.58	3.32	0.442 ± 0.077	0.032	3.2

- Notes: ⁽¹⁾ Errors reported at the 95% confidence level.
⁽²⁾ Minimum detectable concentrations (MDCs) reported at the 95% confidence level.
⁽³⁾ Th-232 result inferred via Pb-212 activity concentration

Table 6-5

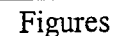
Comparison of Nal Gross Counts Converted to Th-232 Concentration and Laboratory Sample Results

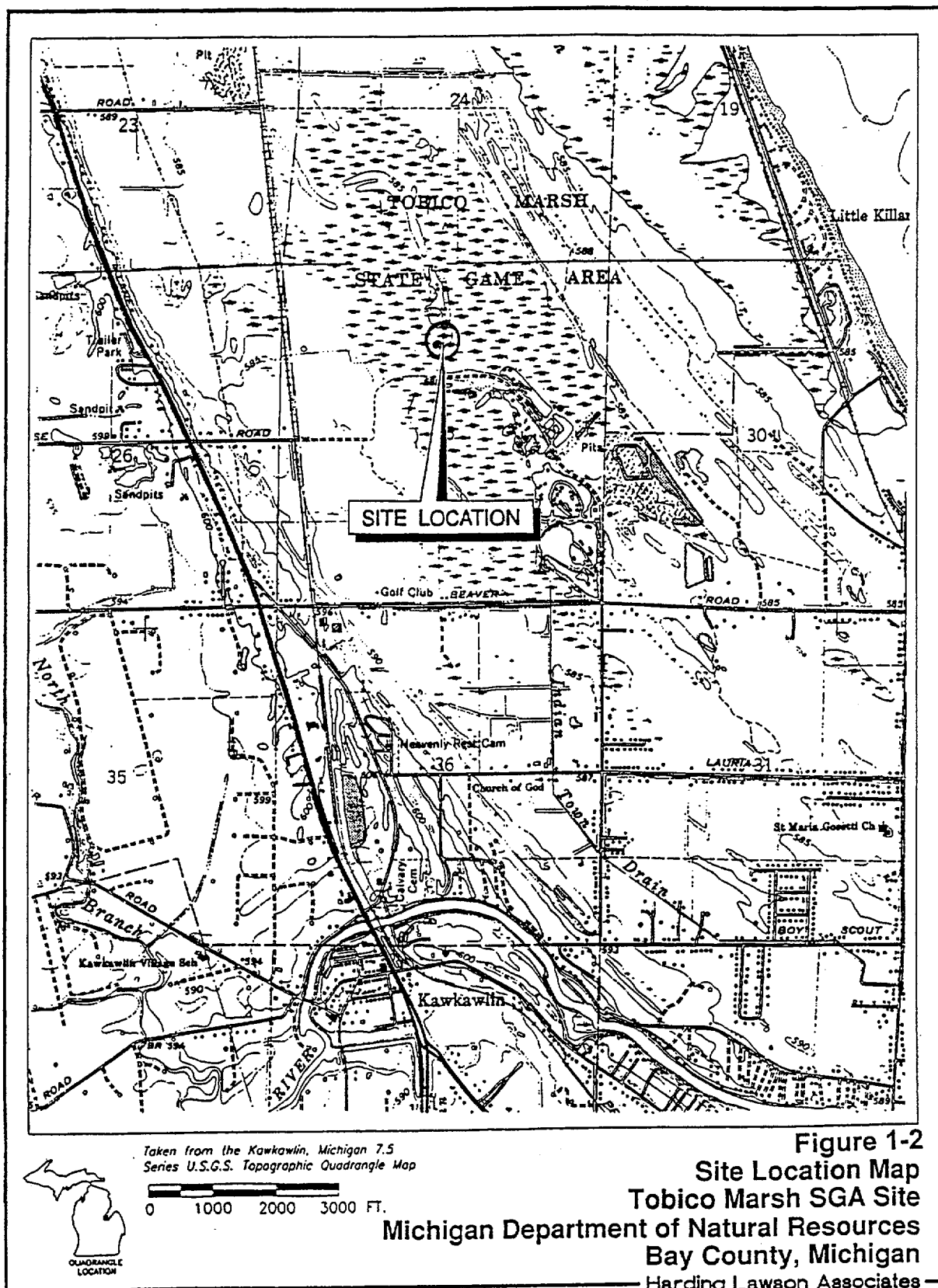
Sample ID	Cabrera Downhole Nal Gross Gamma Counts Converted to Th-232 ⁽³⁾ (pCi/g)	Paragon Lab Soil Sample Data Th-232 ⁽³⁾ pCi/g		Ratio Best Estimate Th-232 Concentration to Lab Soil Sample
	Best Estimate Th-232 Concentration ⁽⁴⁾	Results	MDC	
E5-NE-SS0101	10.3	27 ± 4.5	0.18	0.4
E5-NE-SS0101 DUP	10.3	33.8 ± 5.6	0.15	0.3
E6-NW-BIAS-01.7	7.1	3.62 ± 0.68	0.17	2.0
E6-NW-SS0101	57.8	50 ± 8.4	0.88	1.2
E6-SW-SS0102	18.4	0.56 ± 0.11	0.051	32.9
E6-SW-SS0201	14.6	10.2 ± 1.8	0.43	1.4
F7-NE-BIAS-01W.6	142.1	109 ± 18	0.3	1.3
F7-NE-SS0101	14.1	4.02 ± 0.68	0.1	3.5
F7-NW-SS0102	14.6	0.48 ± 0.25	0.22	30.4
F7-SW-SS0101	37.5	52 ± 8.6	0.15	0.7
G7-NE-SS0101	168.3	194 ± 32	1.5	0.9
G7-SE-BIAS-01E.7	24.8	24.7 ± 4.1	0.12	1.0
G7-SE-SS0101	71.0	57.9 ± 9.6	0.25	1.2
G8-NW-BIAS-01.7	66.9	30.8 ± 5.1	0.27	2.2
H7-NW-SS0101	72.6	2.86 ± 0.52	0.19	25.4
H7-NW-SS0201	14.0	4.14 ± 0.73	0.15	3.4
H7-NW-SS0501 ⁽⁵⁾	n/a	0.98 ± 0.21	0.091	n/a
H7-SE-BIAS01E-SS0101	49.8	0.68 ± 0.14	0.07	73.3
H8-SNW-SS0101 DUP	17.6	5.98 ± 0.99	0.062	2.9
I7-NE-BIAS-01-SS0101	118.3	162 ± 27	0.43	0.7
I7-NW-SS0101	6.3	28.5 ± 4.7	0.17	0.2
I7-SE-SS0101	27.8	7.8 ± 1.3	0.25	3.6
K6-NW-SS0101	2.9	2.49 ± 0.49	0.27	1.2
L9-NW-SS0101	4.3	0.442 ± 0.077	0.032	9.8
			Average	8.7

Notes:

- (1) Errors reported at the 95% confidence level
- (2) Minimum detectable concentration (MDCs) reported at the 95% confidence level
- (3) Th-232 result inferred via Pb-212 activity concentration
- (4) Best estimate values computed using formulation discussed in Appendix D
- (5) This result is sample overflow and cannot be traced to any particular sample gross count location

FIGURES



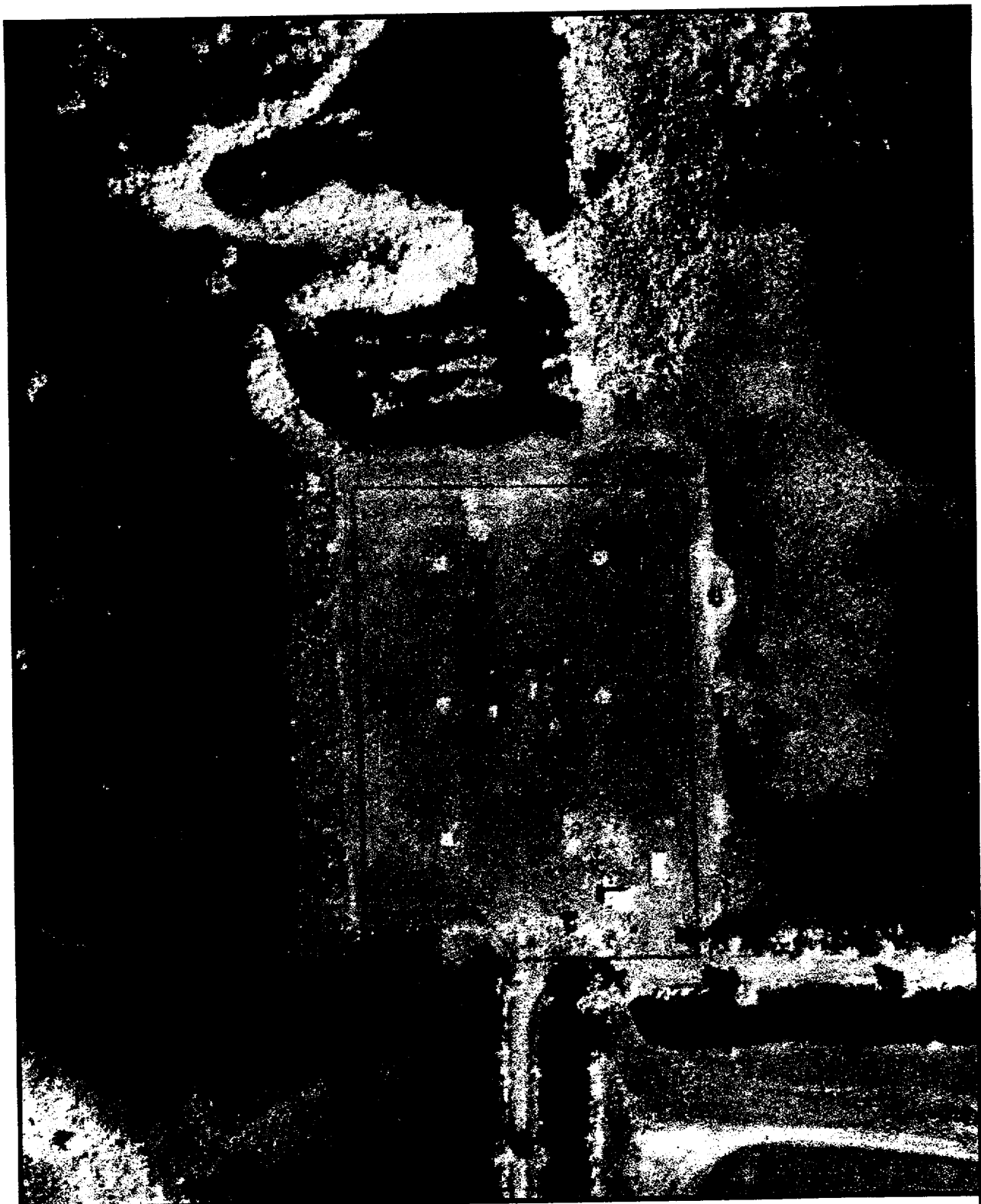


**THIS PAGE IS AN
OVERSIZED DRAWING OR
FIGURE,
THAT CAN BE VIEWED AT THE
RECORD TITLED:
FIGURE 1-3.
"1969 AERIAL PHOTOGRAPH
AND MAP
TOBICO MARSH SGA SITE"**

WITHIN THIS PACKAGE

NOTE: Because of these page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.

D-1



 **Harding ESE**
A MACTEC COMPANY



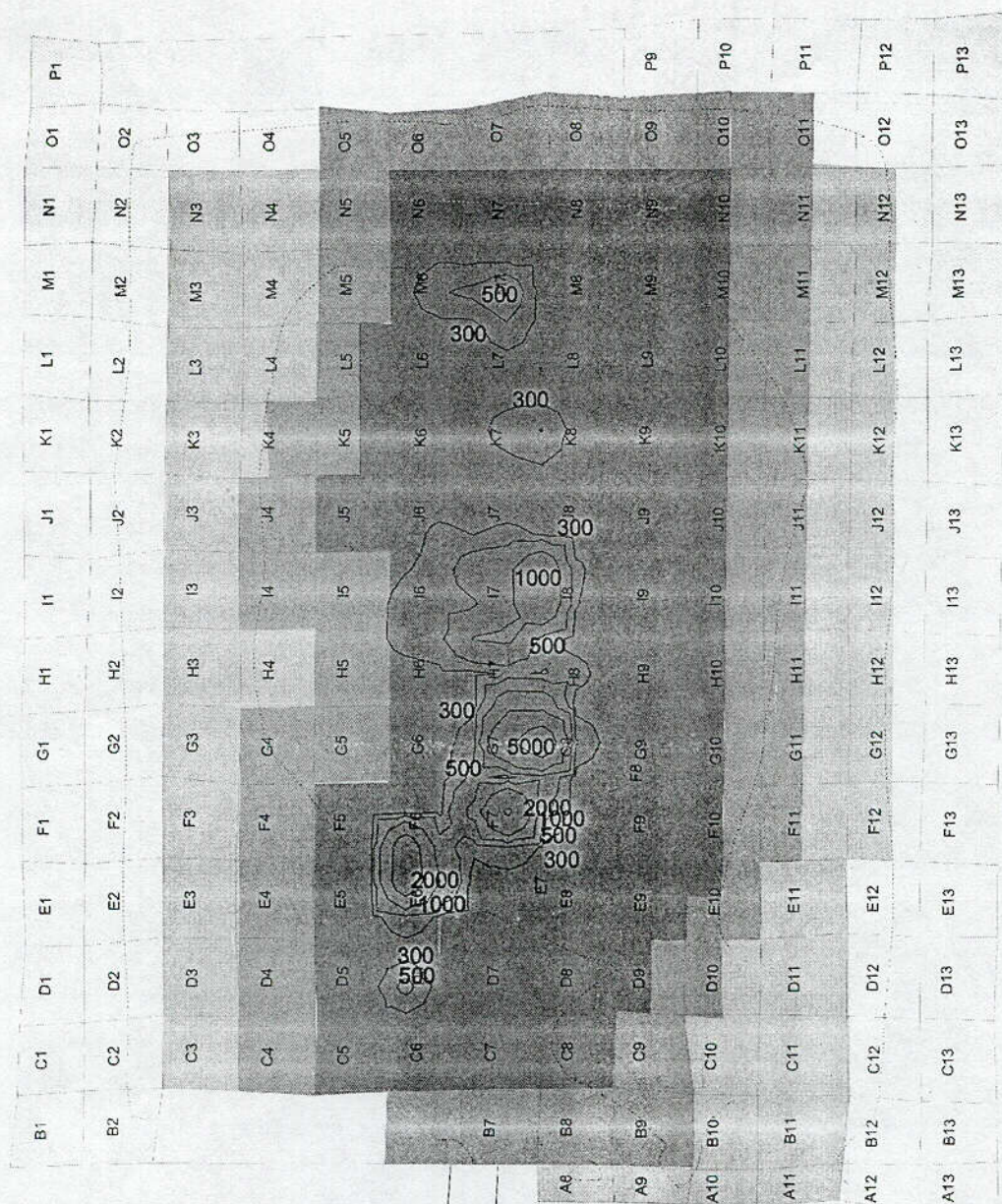
FIGURE 1-4
1998 AERIAL PHOTOGRAPH
TOBICO MARSH SGA SITE

**THIS PAGE IS AN
OVERSIZED DRAWING OR
FIGURE,
THAT CAN BE VIEWED AT THE
RECORD TITLED:
FIGURE 3-1.
"SITE MAP
TOBICO MARSH SGA SITE"**

WITHIN THIS PACKAGE

NOTE: Because of these page's large file size, it may be more convenient to copy the file to a local drive and use the Imaging (Wang) viewer, which can be accessed from the Programs/Accessories menu.

D-2



- Base CAD drawing
- Buildings
- Topography Contours
- Fence Line
- Roads
- Concrete
- Sampling Grid
- Impacted Areas
- Non-Impacted
- Class 1
- Class 2
- Class 3
- Roads

50 0 50 100 Feet

Figure 4-1.
Counts Contours - Maximum in Vertical Column
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

(Counts are 10 sec. response
of 1" X 1" NaI crystal detector)

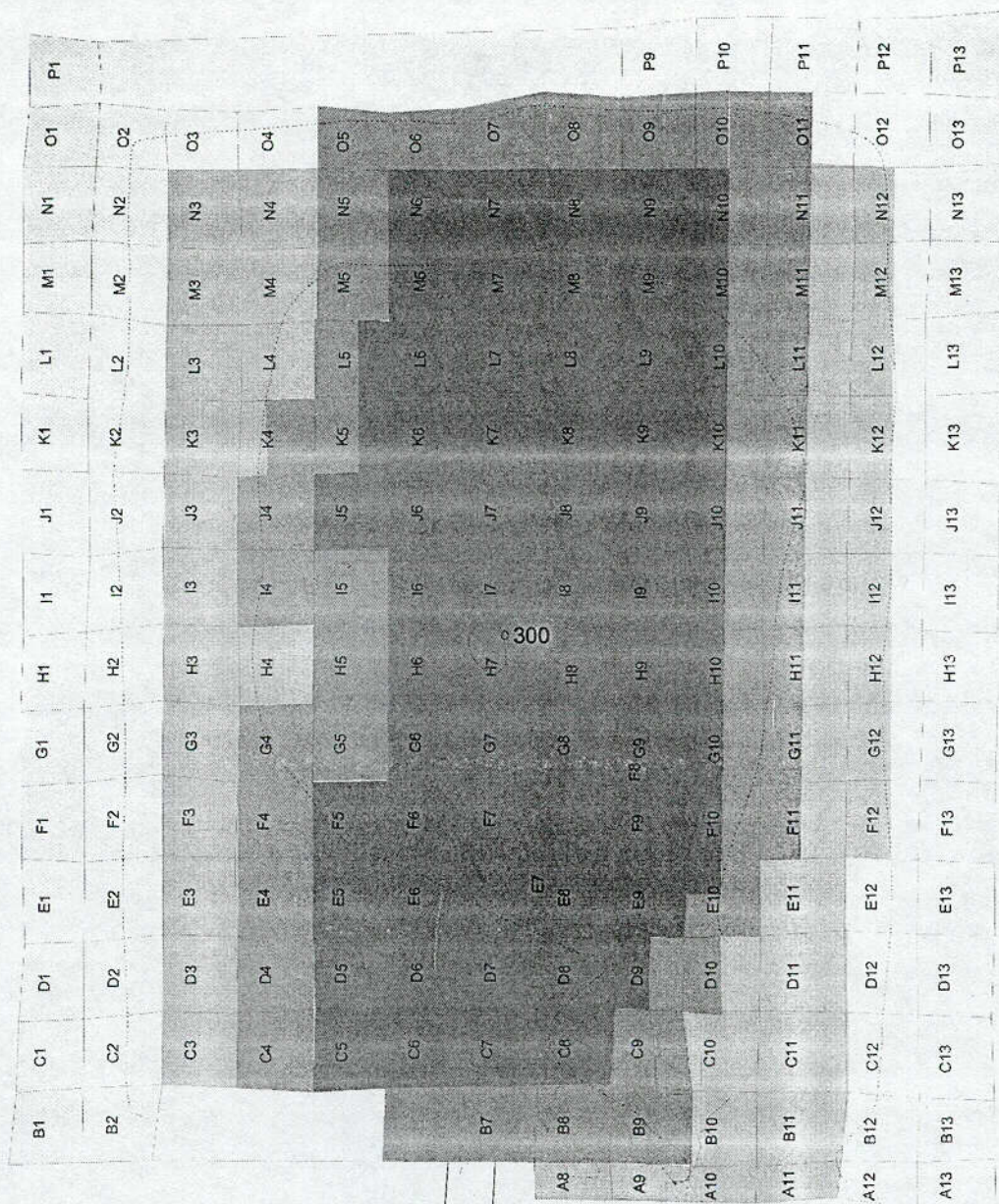
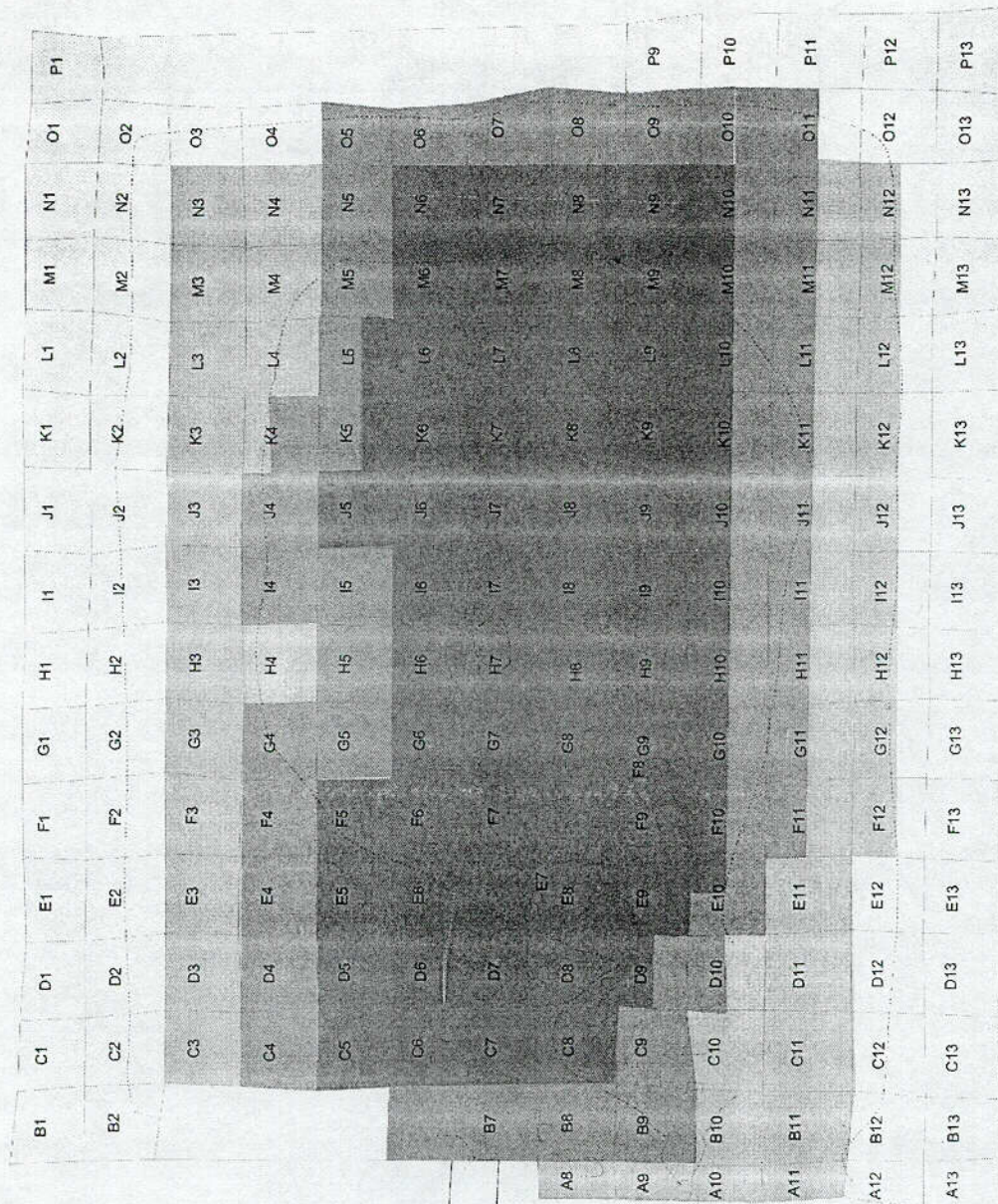


Figure 4-2.
Counts Contours - 591 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

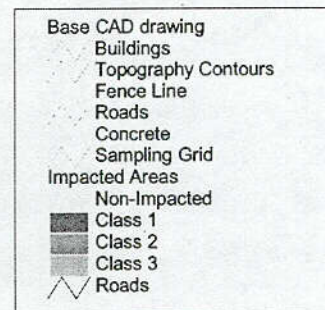
50 0 50 100 Feet

(Counts are 10 sec. response
of 1" X 1" NaI crystal detector)



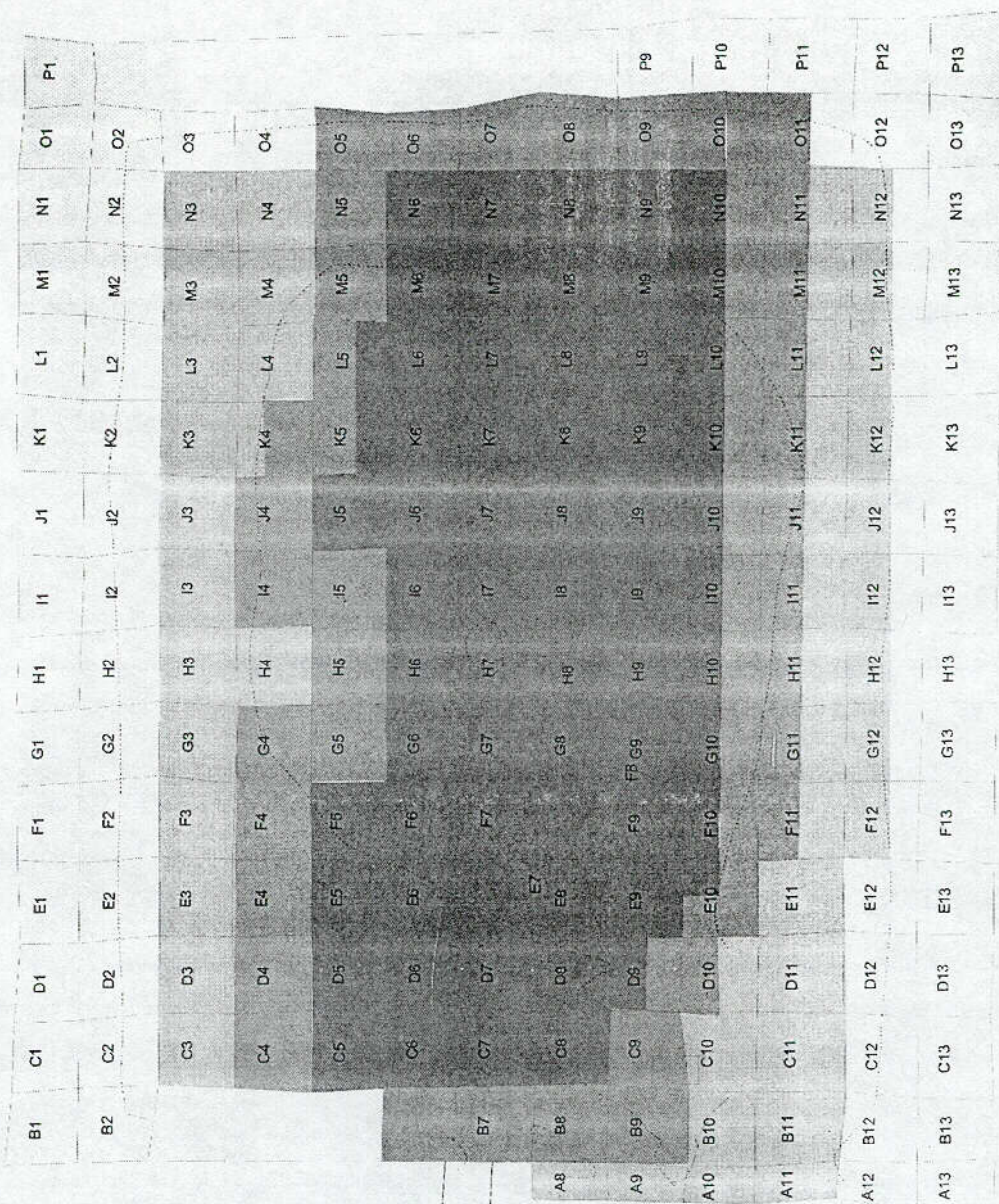
(No contours. All values below 300 counts)

Figure 4-3.
Counts Contours - 590 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan



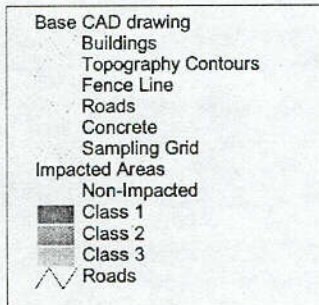
50 0 50 100 Feet

(Counts are 10 sec. response
 of 1" X 1" NaI crystal detector)



(No contours. All values below 300 counts)

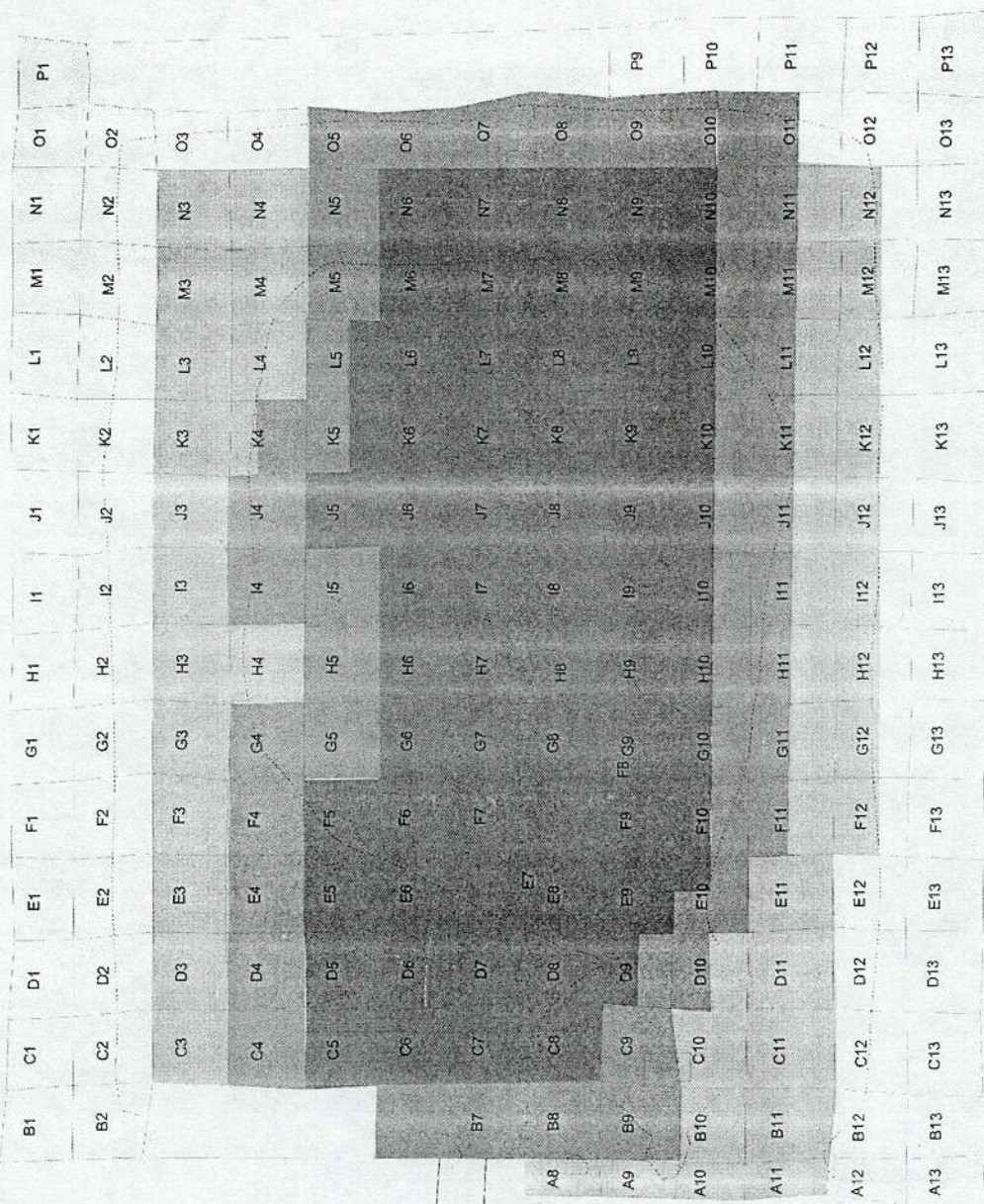
Figure 4-4.
Counts Contours - 589 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan



50 0 50 100 Feet

(Counts are 10 sec. response
of 1" X 1" NaI crystal detector)

C04



(No contours. All values below 300 counts)

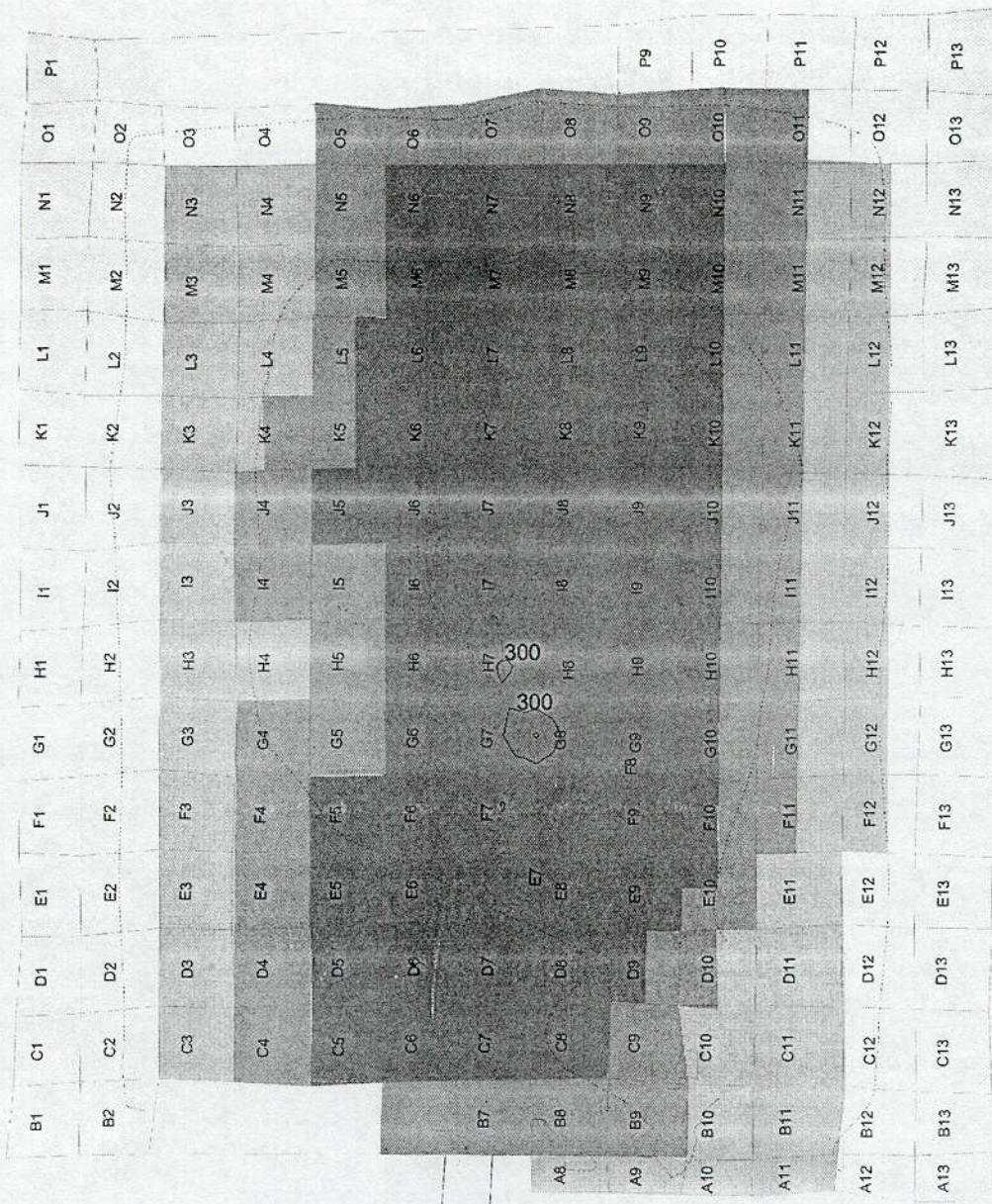


- Base CAD drawing
- Buildings
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- Sampling Grid
- Impacted Areas
- Non-Impacted
- Class 1
- Class 2
- Class 3
- Roads

50 0 50 100 Feet

(Counts are 10 sec. response of 1" X 1" NaI crystal detector)

Figure 4-5.
Counts Contours - 588 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

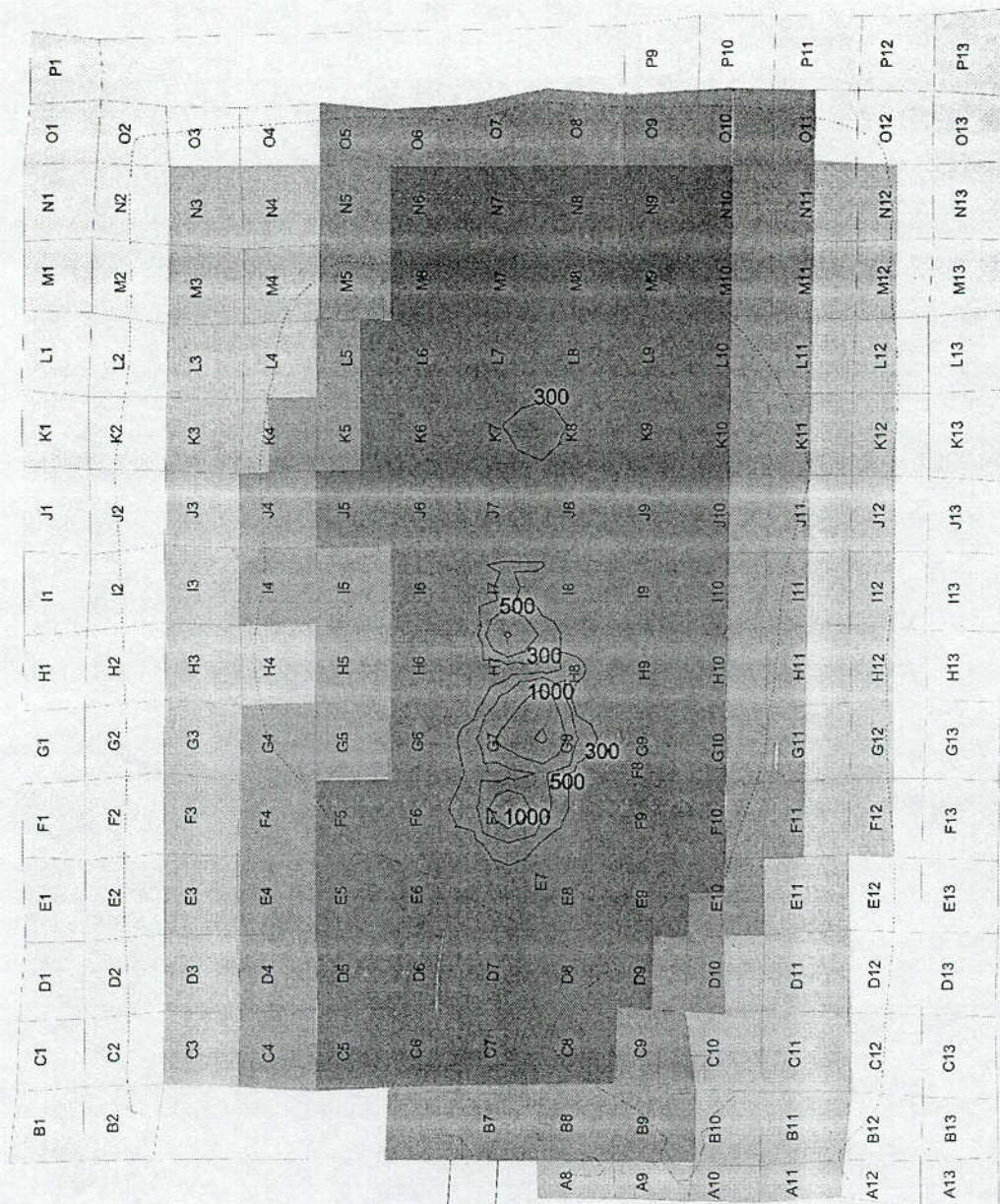


- Base CAD drawing
- Buildings
- Topography Contours
- Fence Line
- Roads
- Concrete
- Sampling Grid
- Impacted Areas
- Non-Impacted
- Class 1
- Class 2
- Class 3
- Roads

50 0 50 100 Feet

(Counts are 10 sec. response of 1" X 1" NaI crystal detector)

Figure 4.6.
 Counts Contours - 587 Feet Elevation
 Tobico Marsh SGA Site
 Michigan Department of Natural Resources
 Bay County, Michigan



- Base CAD drawing
- Buildings
- Topography Contours
- Fence Line
- Roads
- Concrete
- Sampling Grid
- Impacted Areas
- Non-Impacted
- Class 1
- Class 2
- Class 3
- Roads

50 0 50 100 Feet

(Counts are 10 sec. response of 1" X 1" NaI crystal detector)

Figure 4-7.
Counts Contours - 586 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

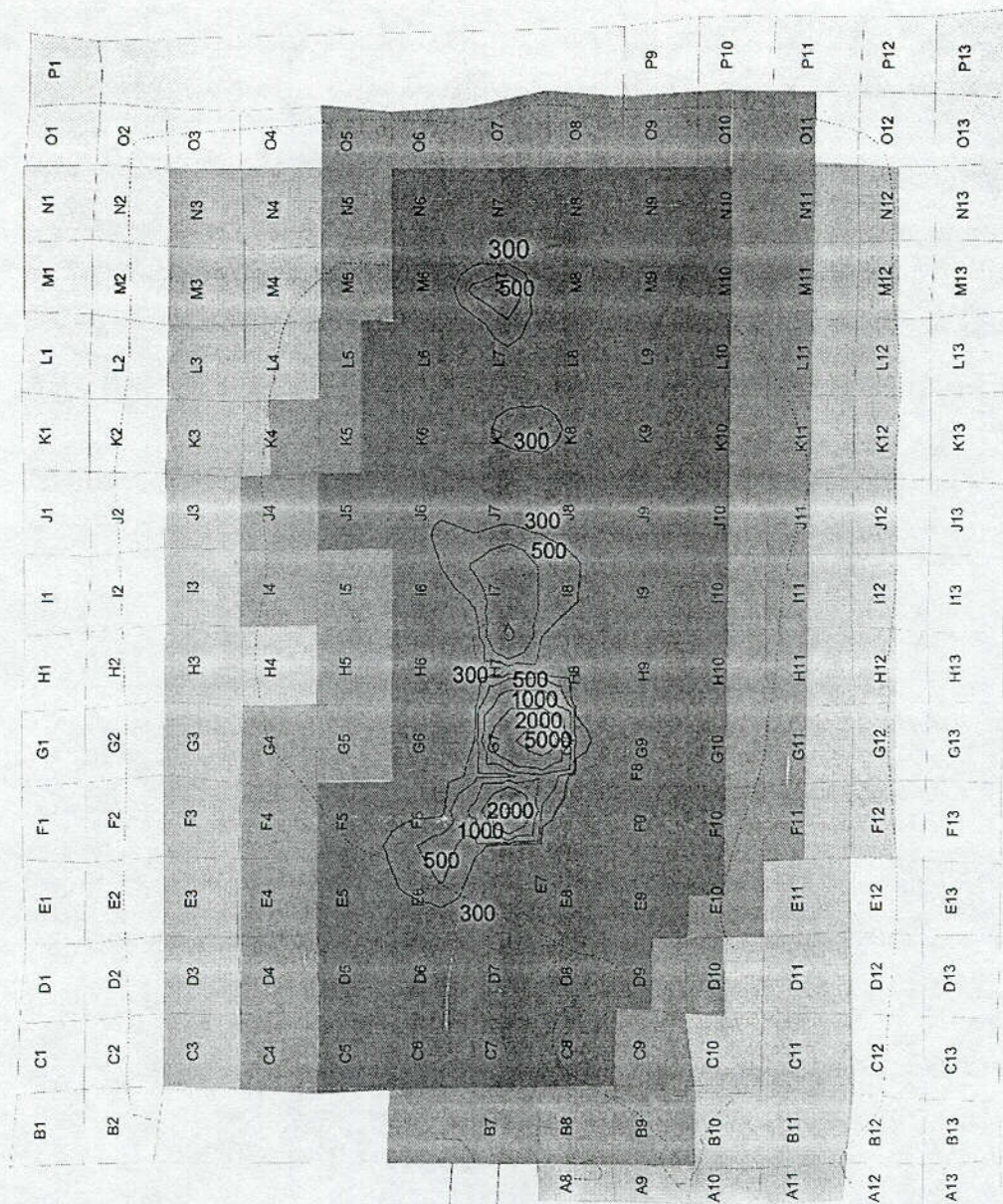


Figure 4-8.
 Counts Contours - 585 Feet Elevation
 Tobico Marsh SGA Site
 Michigan Department of Natural Resources
 Bay County, Michigan

50 0 50 100 Feet

(Counts are 10 sec. response
 of 1" X 1" NaI crystal detector)

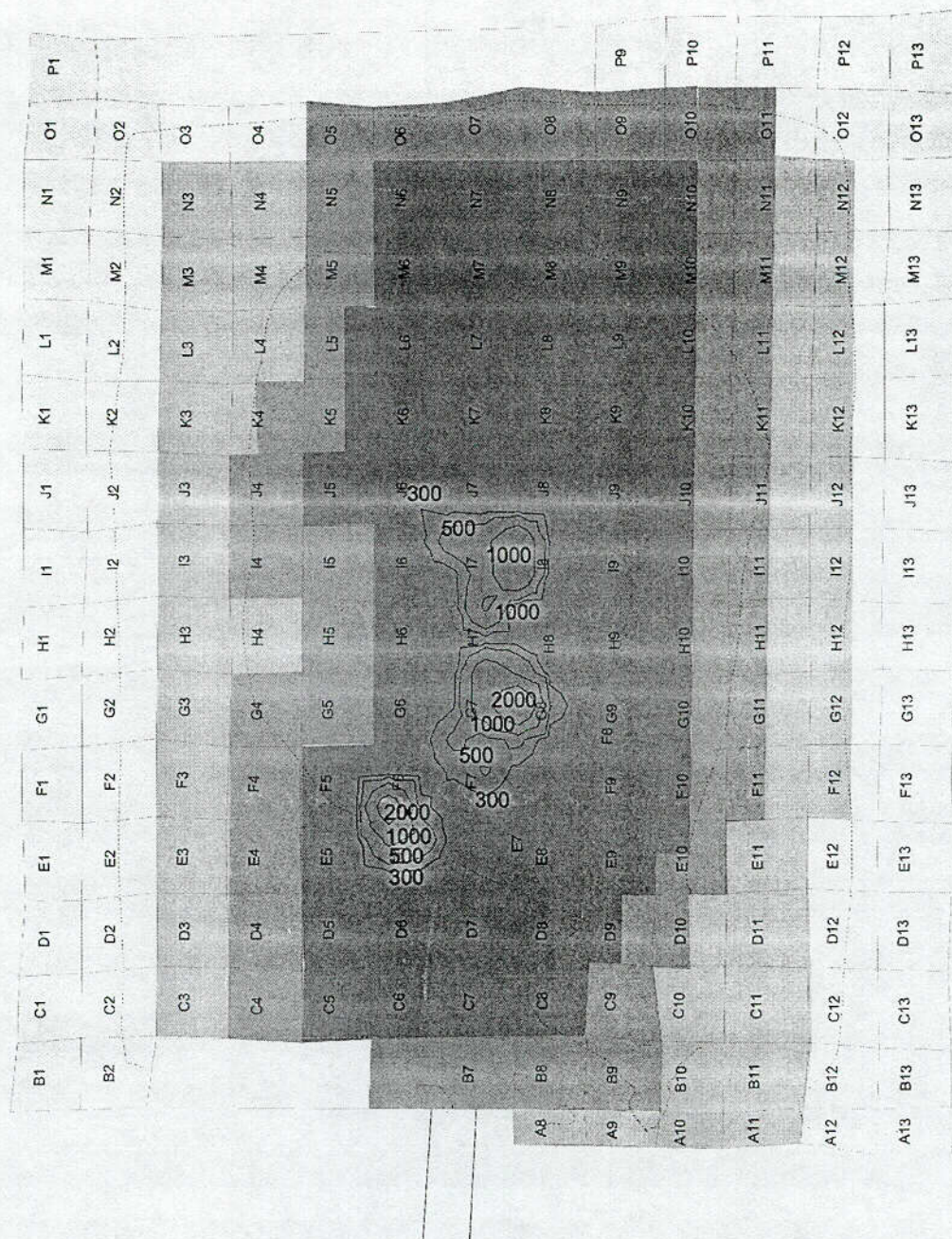
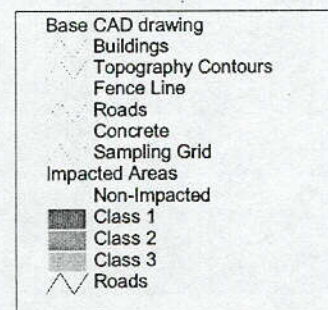
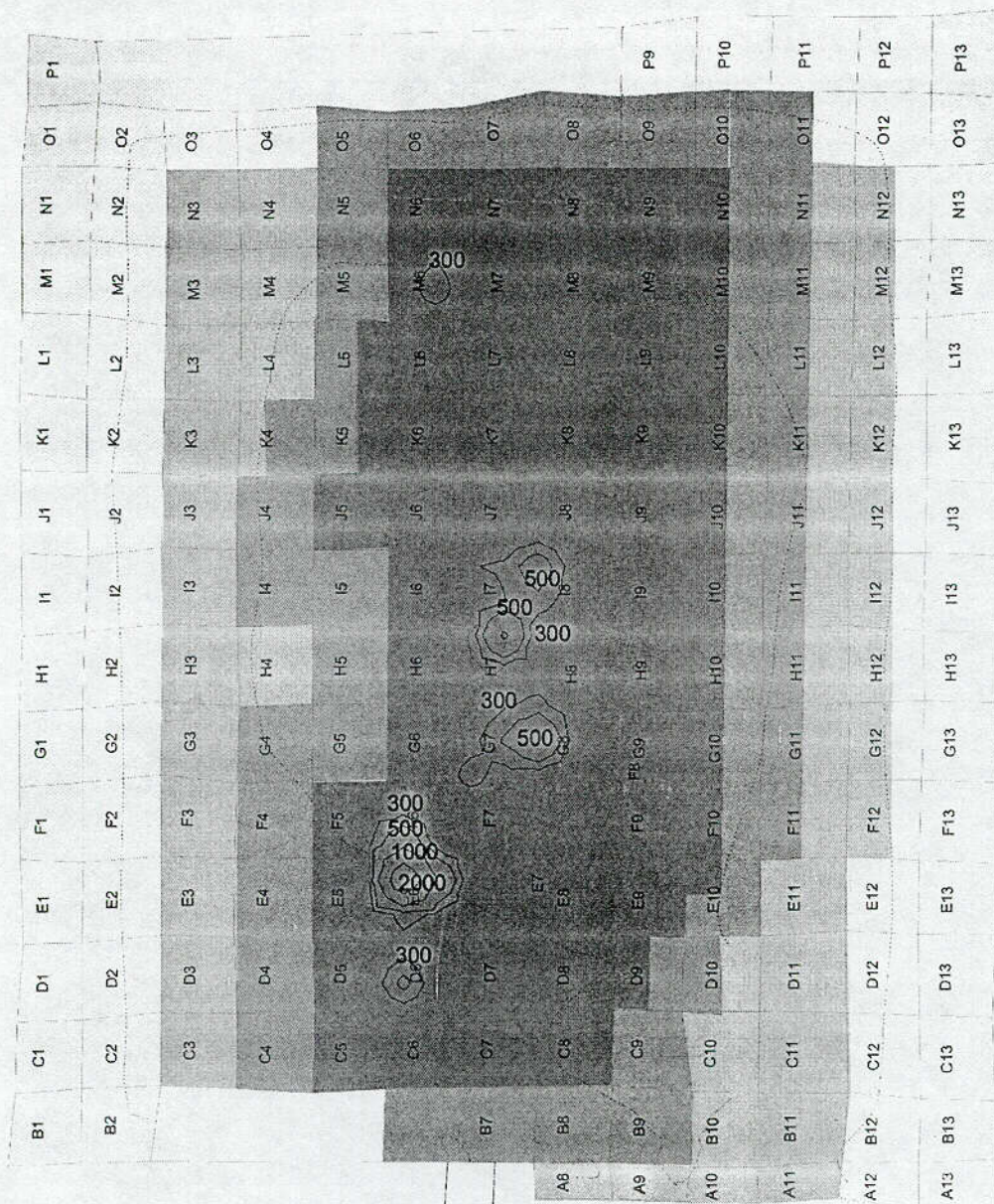


Figure 4-9.
 Counts Contours - 584 Feet Elevation
 Tobico Marsh SGA Site
 Michigan Department of Natural Resources
 Bay County, Michigan

50 0 50 100 Feet

(Counts are 10 sec. response
 of 1" X 1" NaI crystal detector)



50 0 50 100 Feet

(Counts are 10 sec. response of 1" X 1" NaI crystal detector)

Figure 4-10.
Counts Contours - 583 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

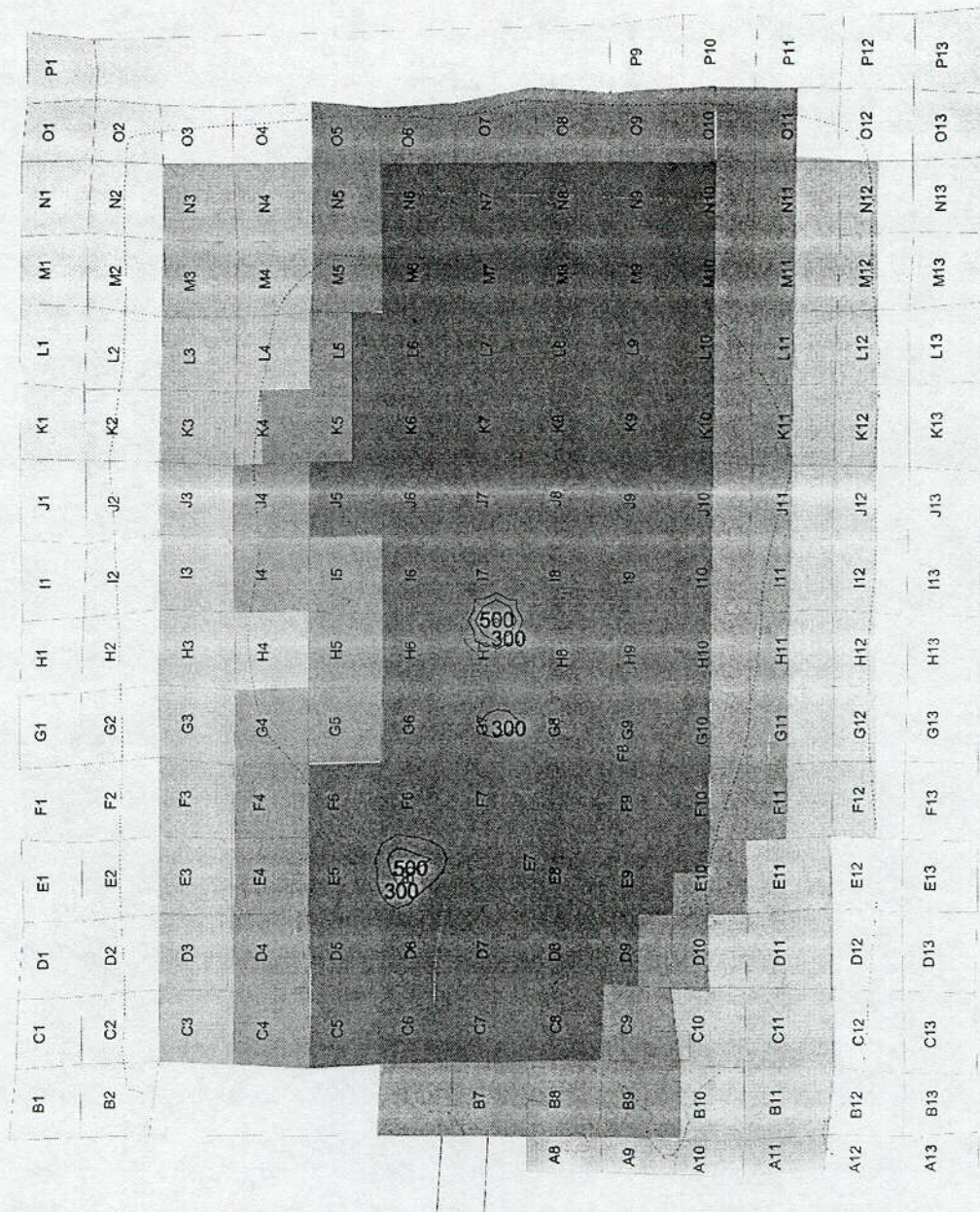
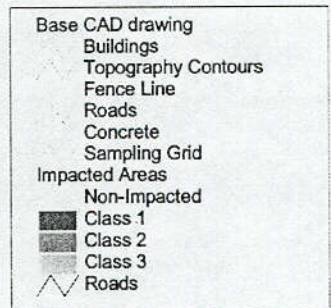


Figure 4-11.
 Counts Contours - 582 Feet Elevation
 Tobico Marsh SGA Site
 Michigan Department of Natural Resources
 Bay County, Michigan



(Counts are 10 sec. response
 of 1" X 1" NaI crystal detector)

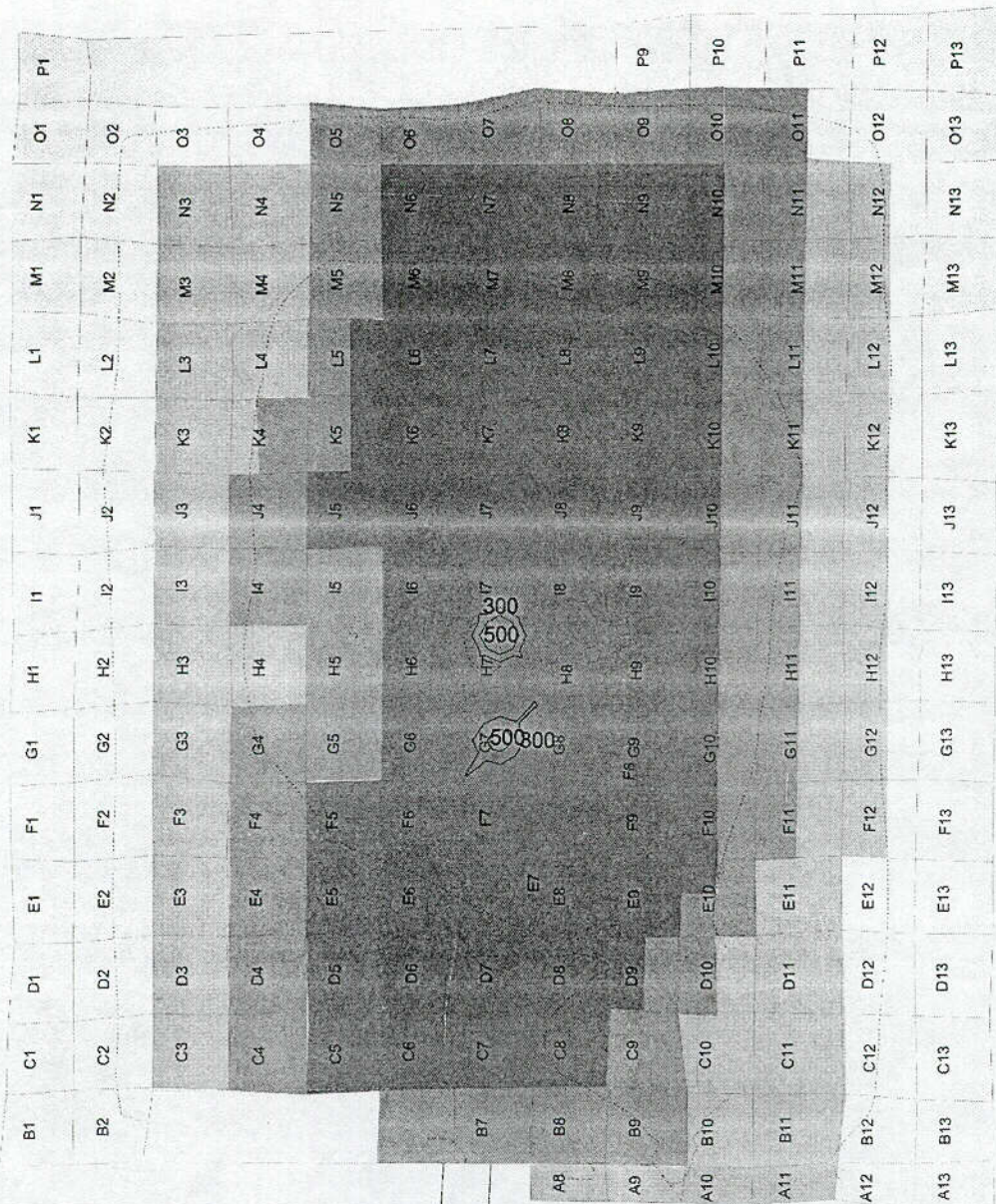


Figure 4-12.
Counts Contours - 581 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

- Base CAD drawing
- Buildings
- Topography Contours
- Fence Line
- Roads
- Concrete
- Sampling Grid
- Impacted Areas
- Non-Impacted
- Class 1
- Class 2
- Class 3
- Roads

50 0 50 100 Feet

(Counts are 10 sec. response
of 1" X 1" NaI crystal detector)

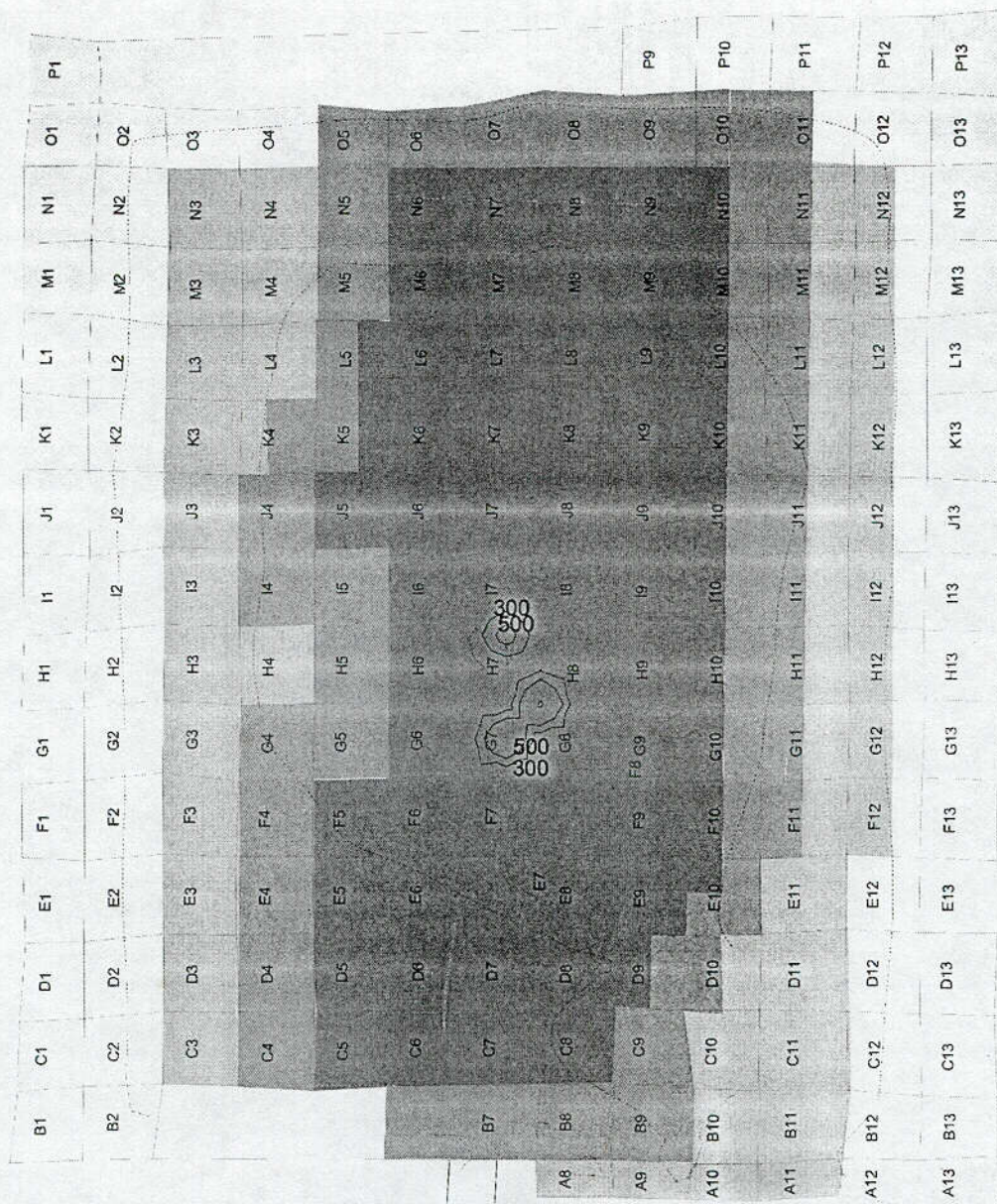
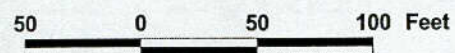
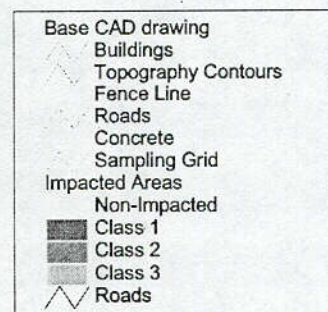
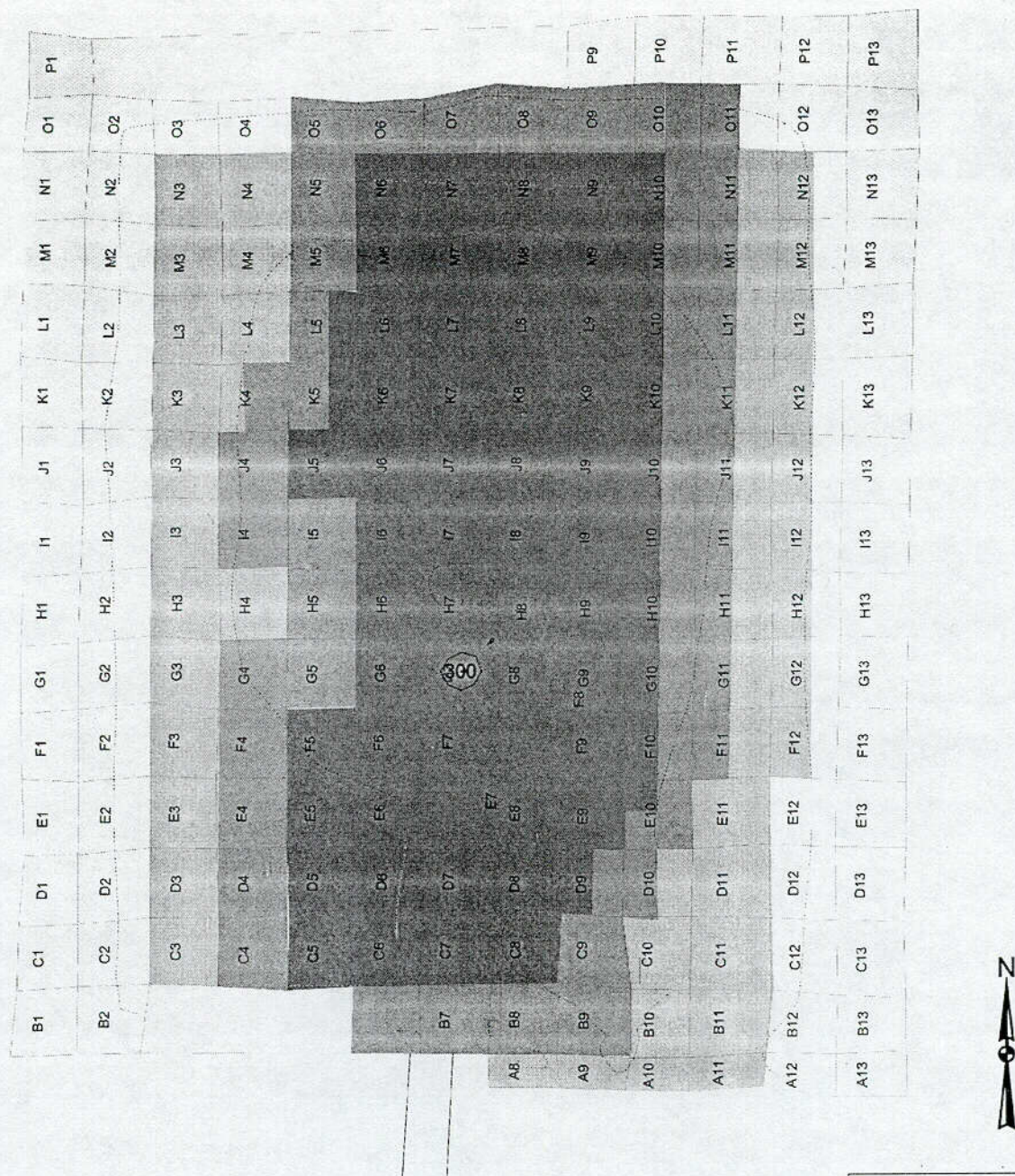


Figure 4-13.
 Counts Contours - 580 Feet Elevation
 Tobico Marsh SGA Site
 Michigan Department of Natural Resources
 Bay County, Michigan



(Counts are 10 sec. response
 of 1" X 1" NaI crystal detector)



- Base CAD drawing
- Buildings
- Topography Contours
- Fence Line
- Roads
- Concrete
- Sampling Grid
- Impacted Areas
- Non-Impacted
- Class 1
- Class 2
- Class 3
- Roads

50 0 50 100 Feet

(Counts are 10 sec. response of 1" X 1" NaI crystal detector)

Figure 4-14.
Counts Contours - 579 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

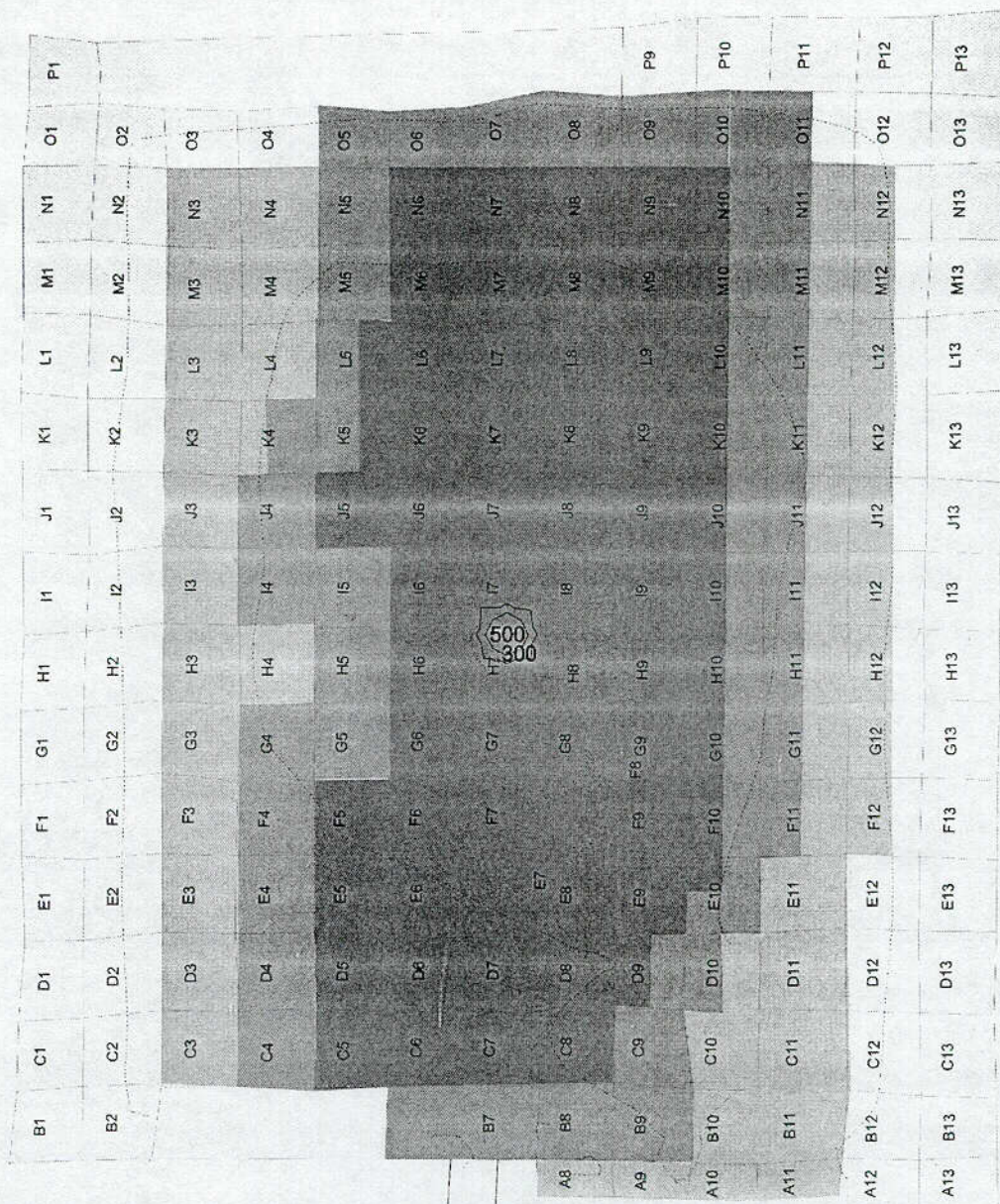


Figure 4-15.
Counts Contours - 578 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

50 0 50 100 Feet

(Counts are 10 sec. response
of 1" X 1" NaI crystal detector)

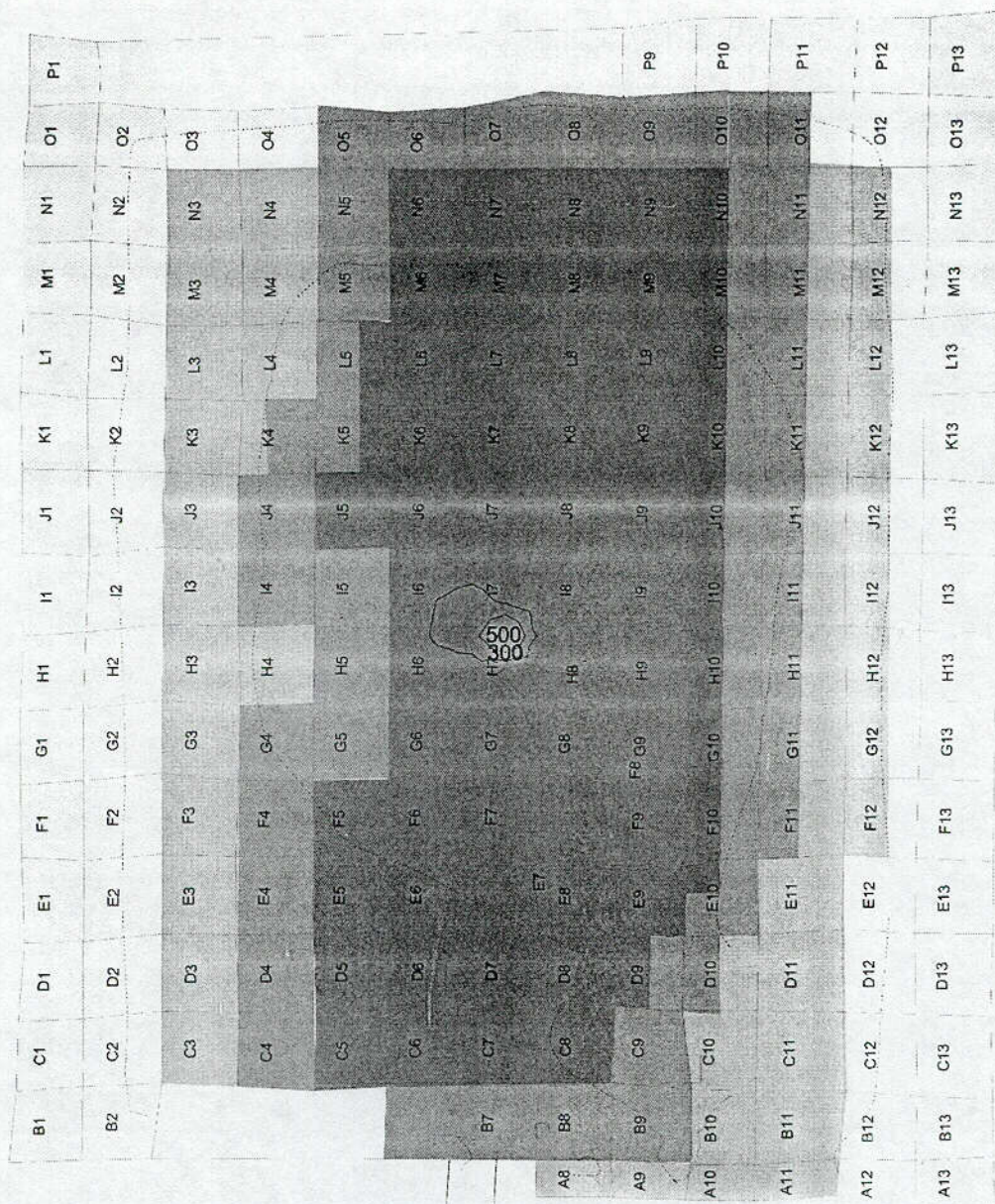


Figure 4-16.
Counts Contours - 577 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

50 0 50 100 Feet

(Counts are 10 sec. response
of 1" X 1" NaI crystal detector)

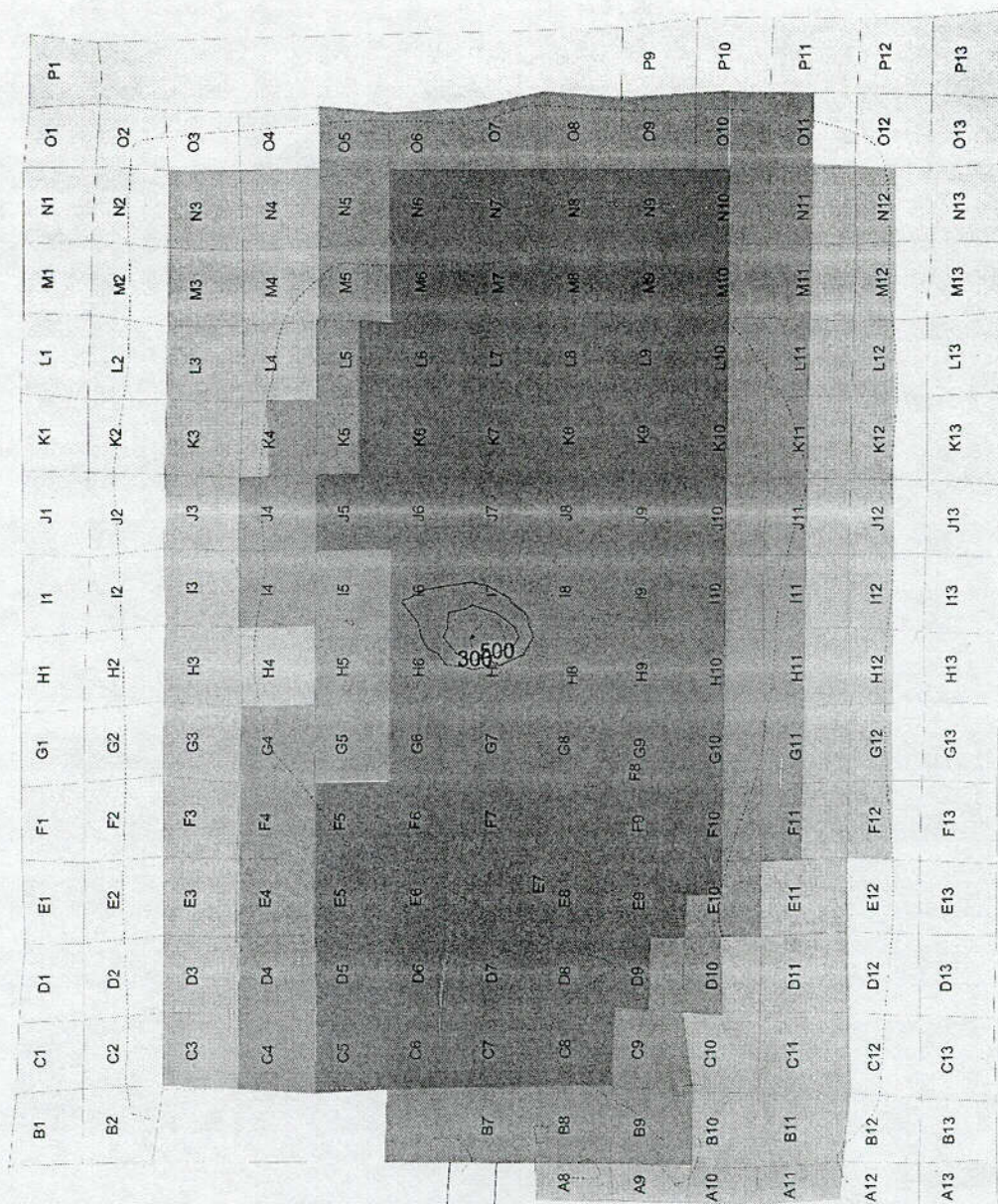
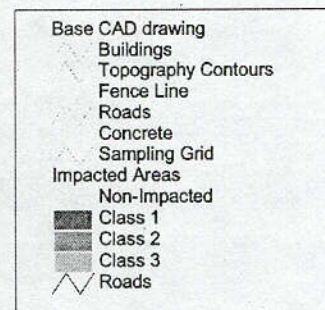
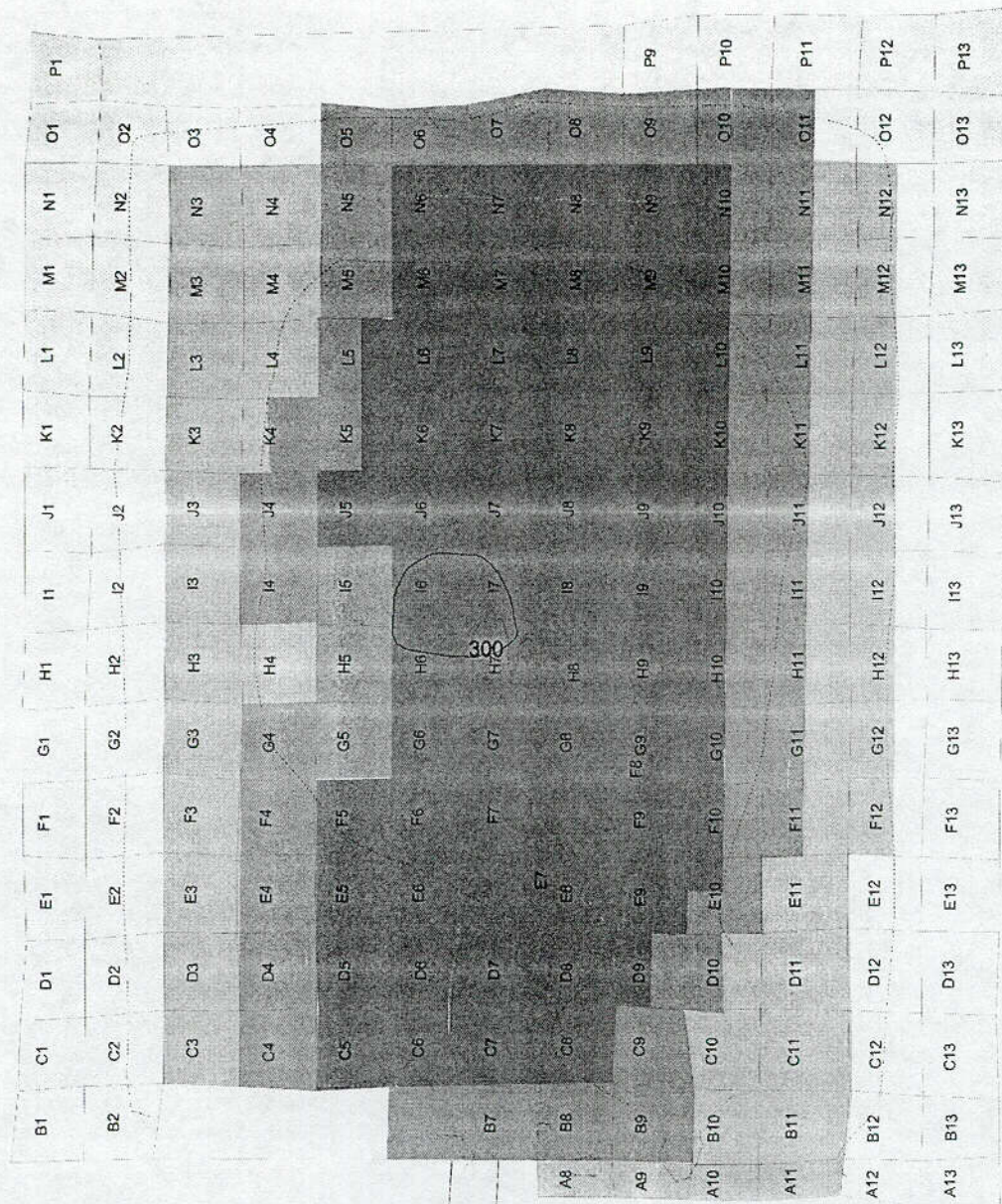


Figure 4-17.
 Counts Contours - 576 Feet Elevation
 Tobico Marsh SGA Site
 Michigan Department of Natural Resources
 Bay County, Michigan



50 0 50 100 Feet

(Counts are 10 sec. response
 of 1" X 1" NaI crystal detector)



- Base CAD drawing
- Buildings
- Topography Contours
- Fence Line
- Roads
- Concrete
- Sampling Grid
- Impacted Areas
 - Non-Impacted
 - Class 1
 - Class 2
 - Class 3
- Roads

50 0 50 100 Feet

(Counts are 10 sec. response
of 1" X 1" NaI crystal detector)

Figure 4-18.
Counts Contours - 575 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

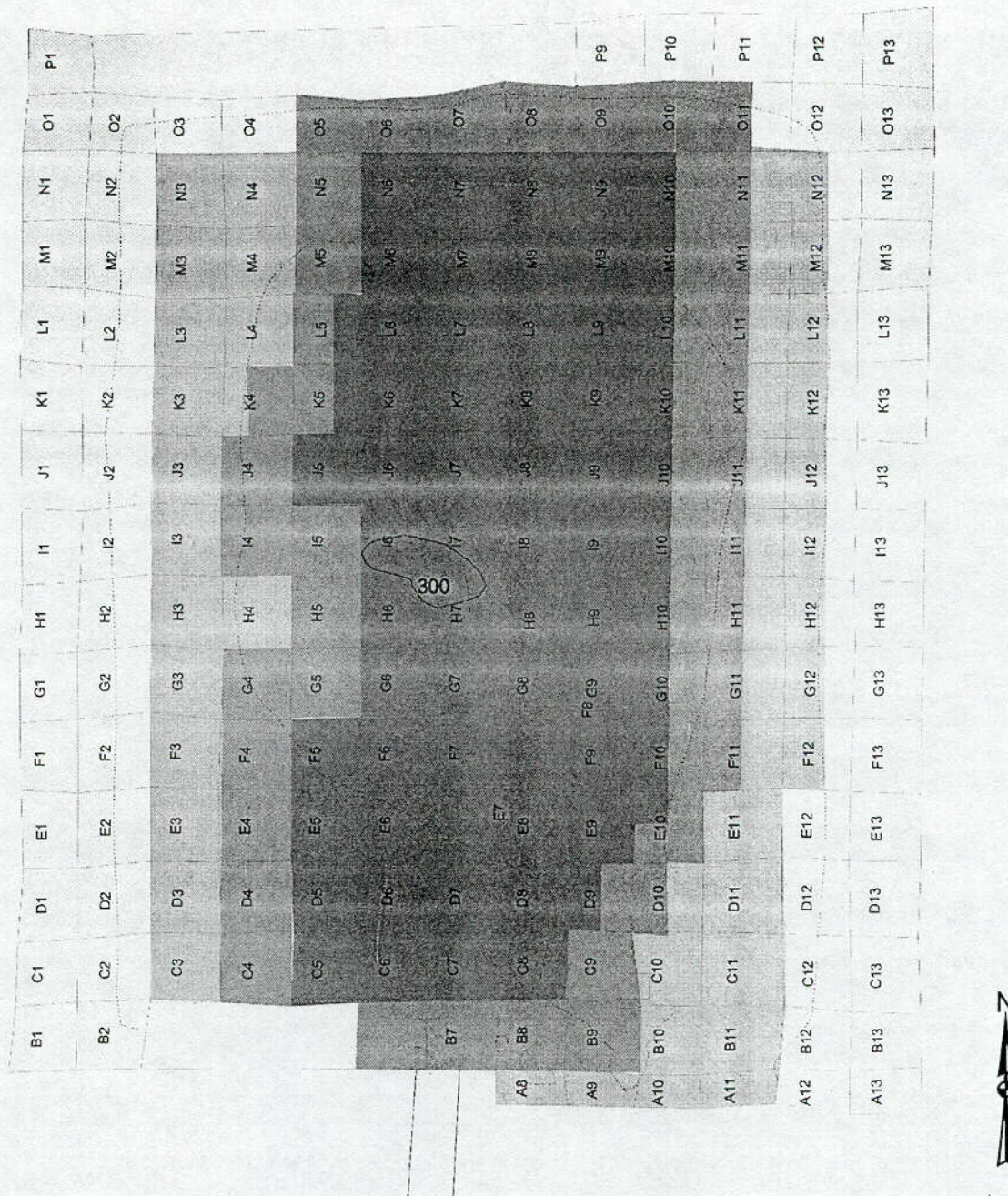
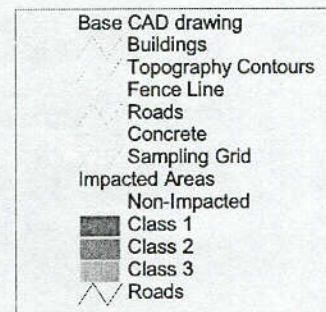
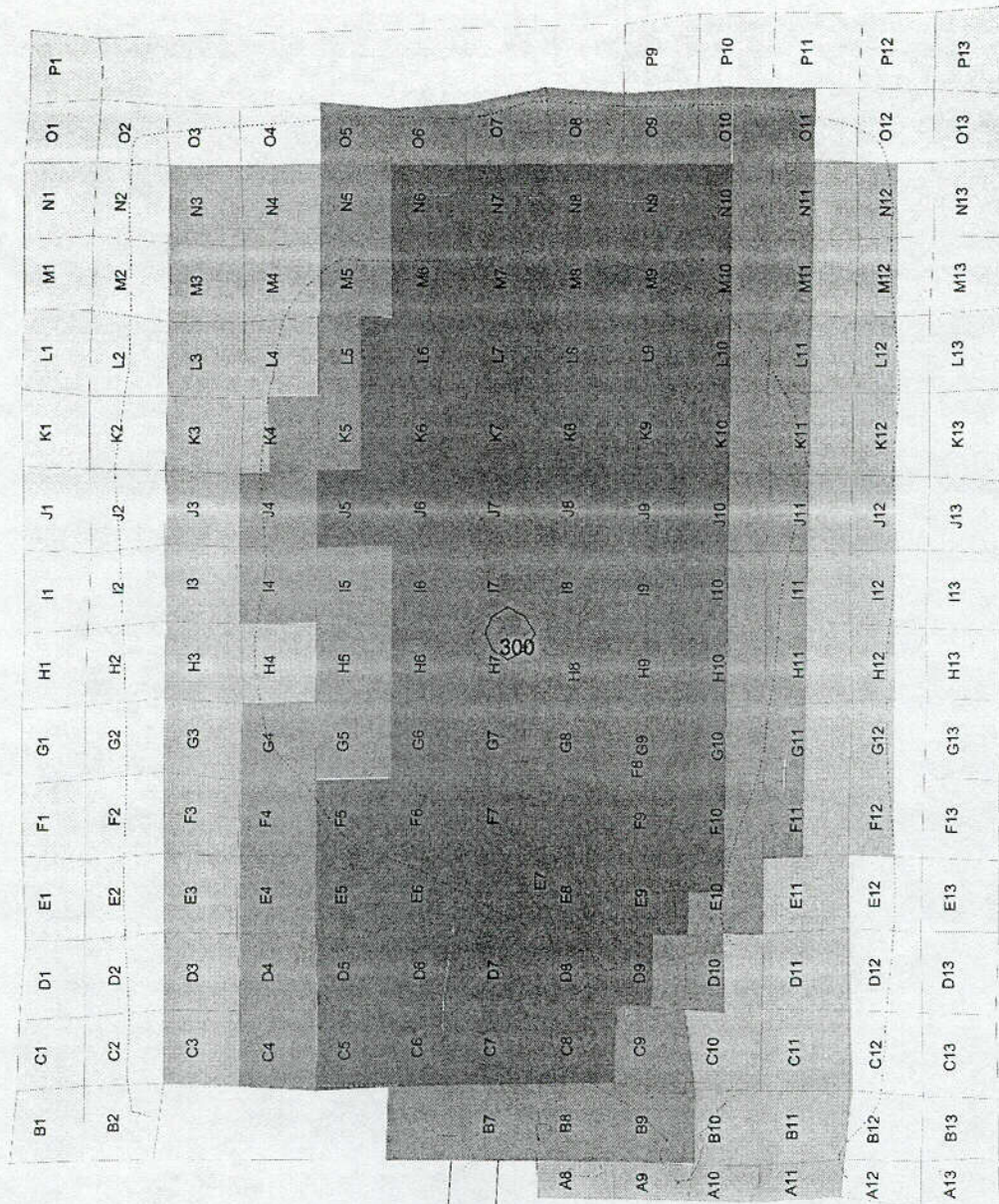


Figure 4-19.
Counts Contours - 574 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan



50 0 50 100 Feet

(Counts are 10 sec. response
of 1" X 1" NaI crystal detector)



- Base CAD drawing
- Buildings
- Topography Contours
- Fence Line
- Roads
- Concrete
- Sampling Grid
- Impacted Areas
- Non-Impacted
- Class 1
- Class 2
- Class 3
- Roads

50 0 50 100 Feet

(Counts are 10 sec. response
of 1" X 1" NaI crystal detector)

Figure 4-20.
Counts Contours - 573 Feet Elevation
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

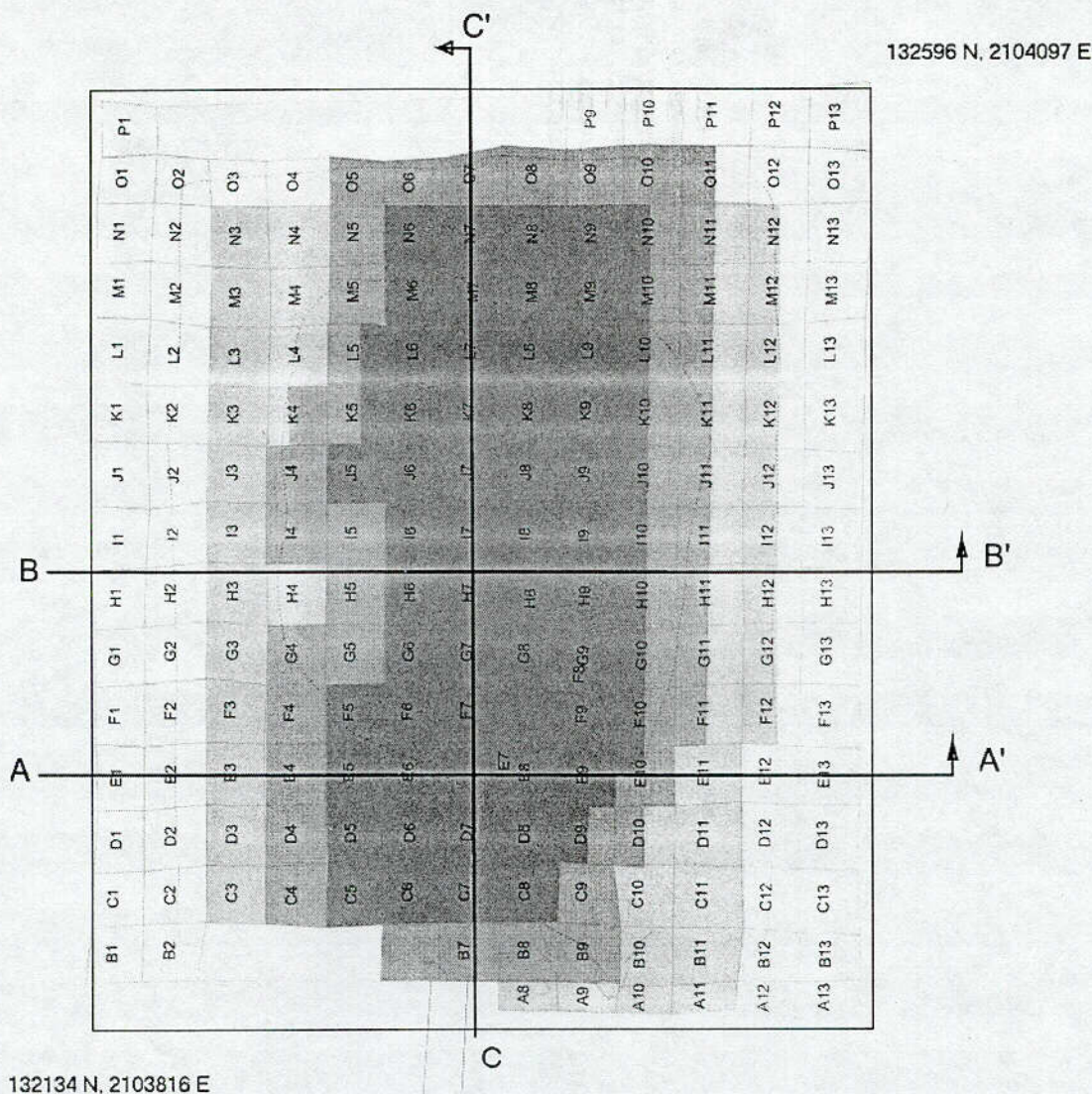


Figure 4-21.
 Cross Section Locations
 Tobico Marsh SGA Site
 Michigan Department of Natural Resources
 Bay County, Michigan

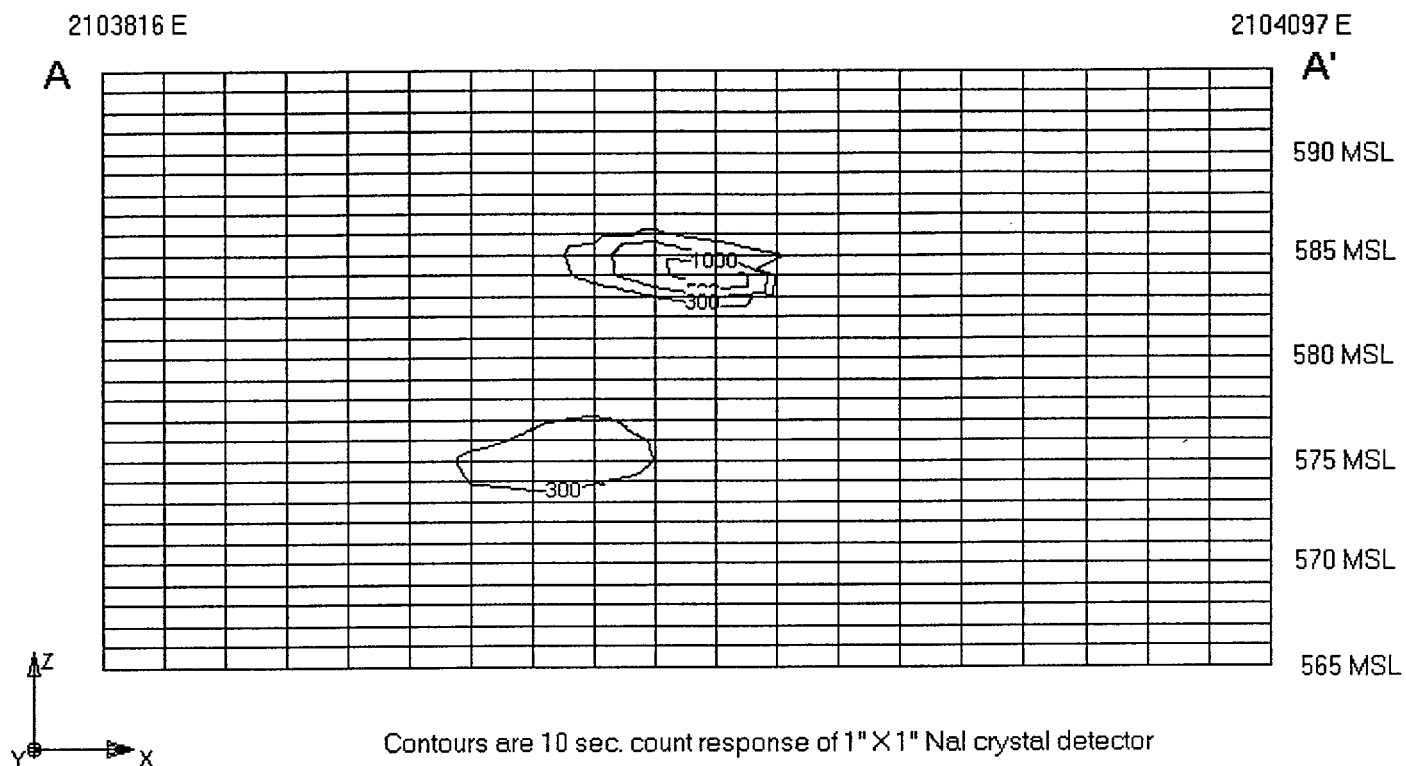


Figure 4-22. Cross Section A-A'

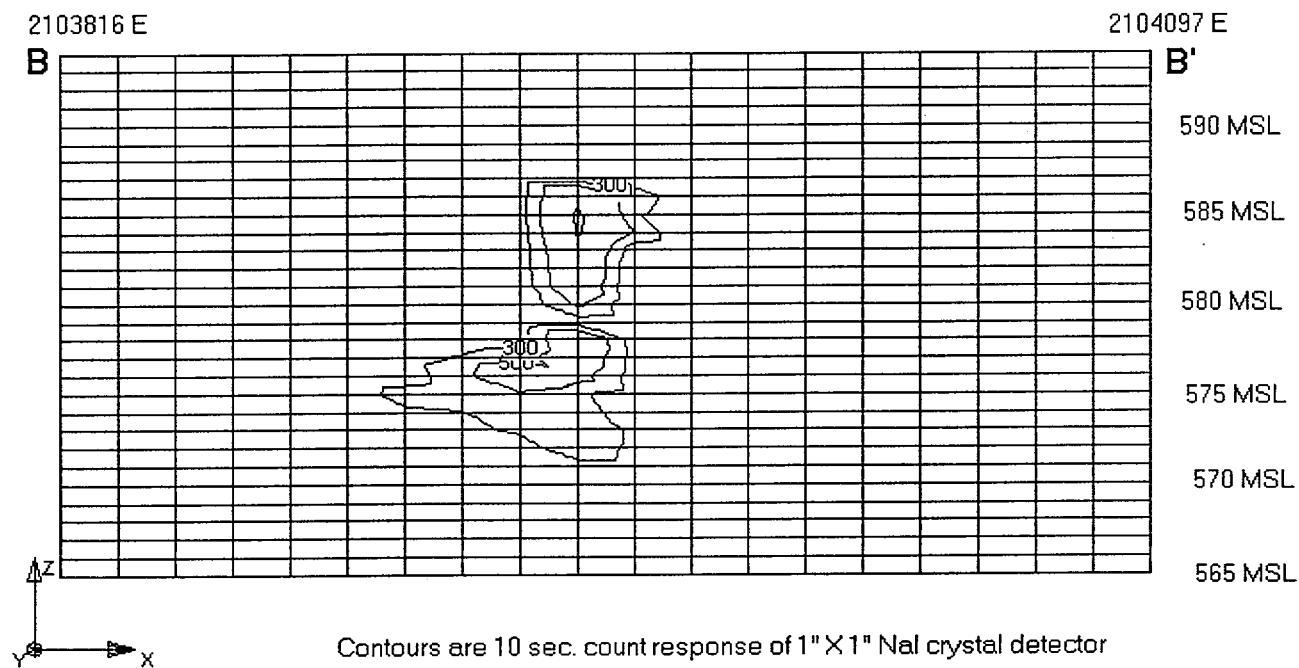


Figure 4-23. Cross Section B-B'

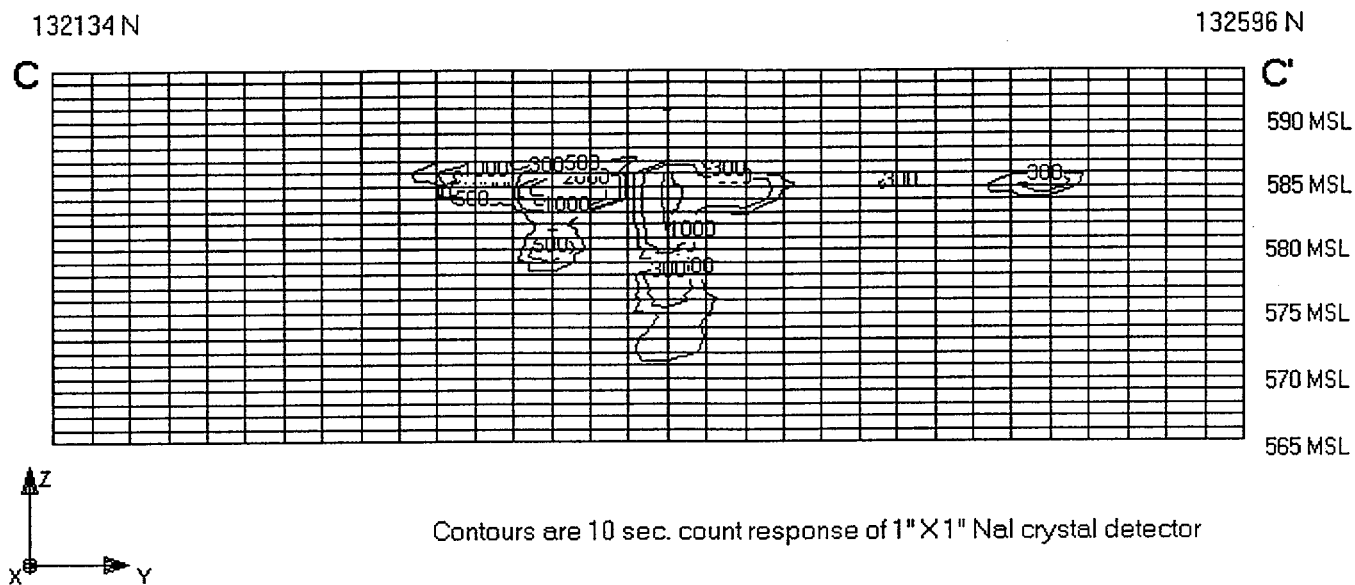


Figure 4-24. Cross Section C-C'

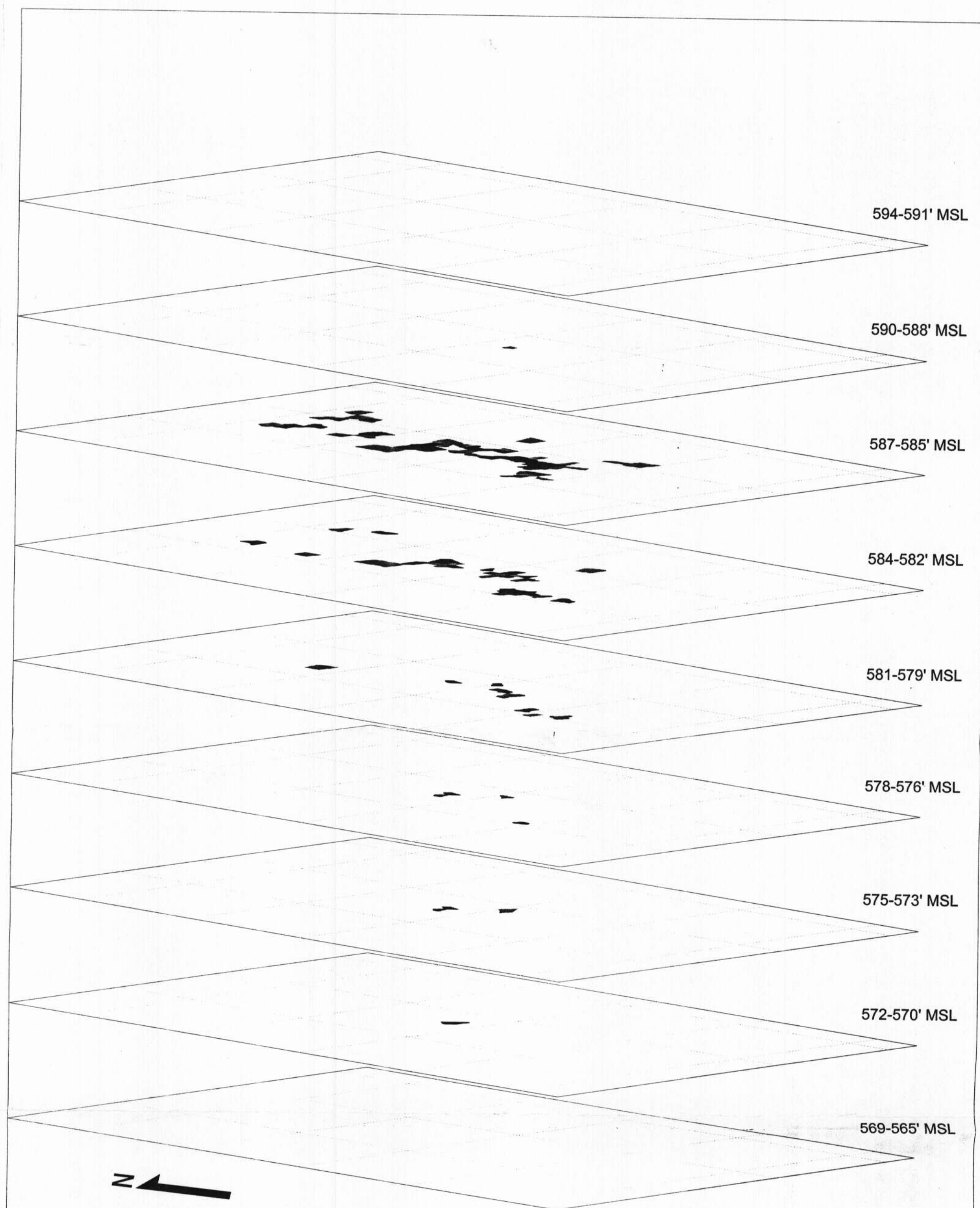


Figure 4-25
 Max Gross Gamma Count Contours
 Grouped by Elevation
 Tobico Marsh SGA Site
 Michigan Department of Natural Resources
 Bay County, Michigan

300 to 500 Count Contour
 >500 Count Contour

(Counts are 10 sec. response
 of 1" x 1" NaI crystal detector)

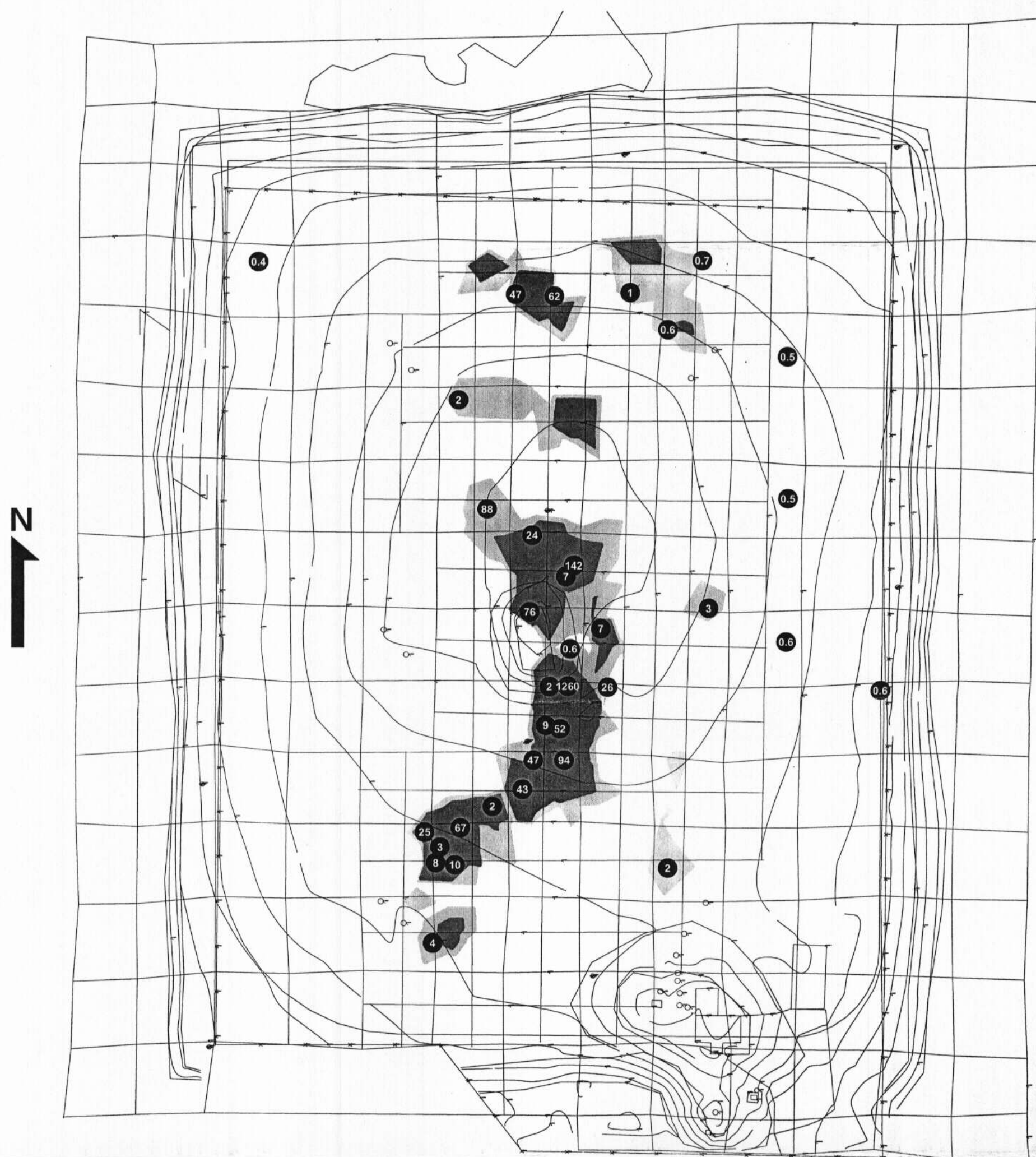


Figure 4-26
 Max Th-232 Sample Results with
 Max Gross Gamma Count Contours
 Tobico Marsh SGA Site
 Michigan Department of Natural Resources
 Bay County, Michigan

Max Th-232 sample result (pCi/g) based on gamma spectroscopy sample results

300 to 500 Count Contour

>500 Count Contour

(Counts are 10 sec. response of 1" x 1" NaI crystal detector)

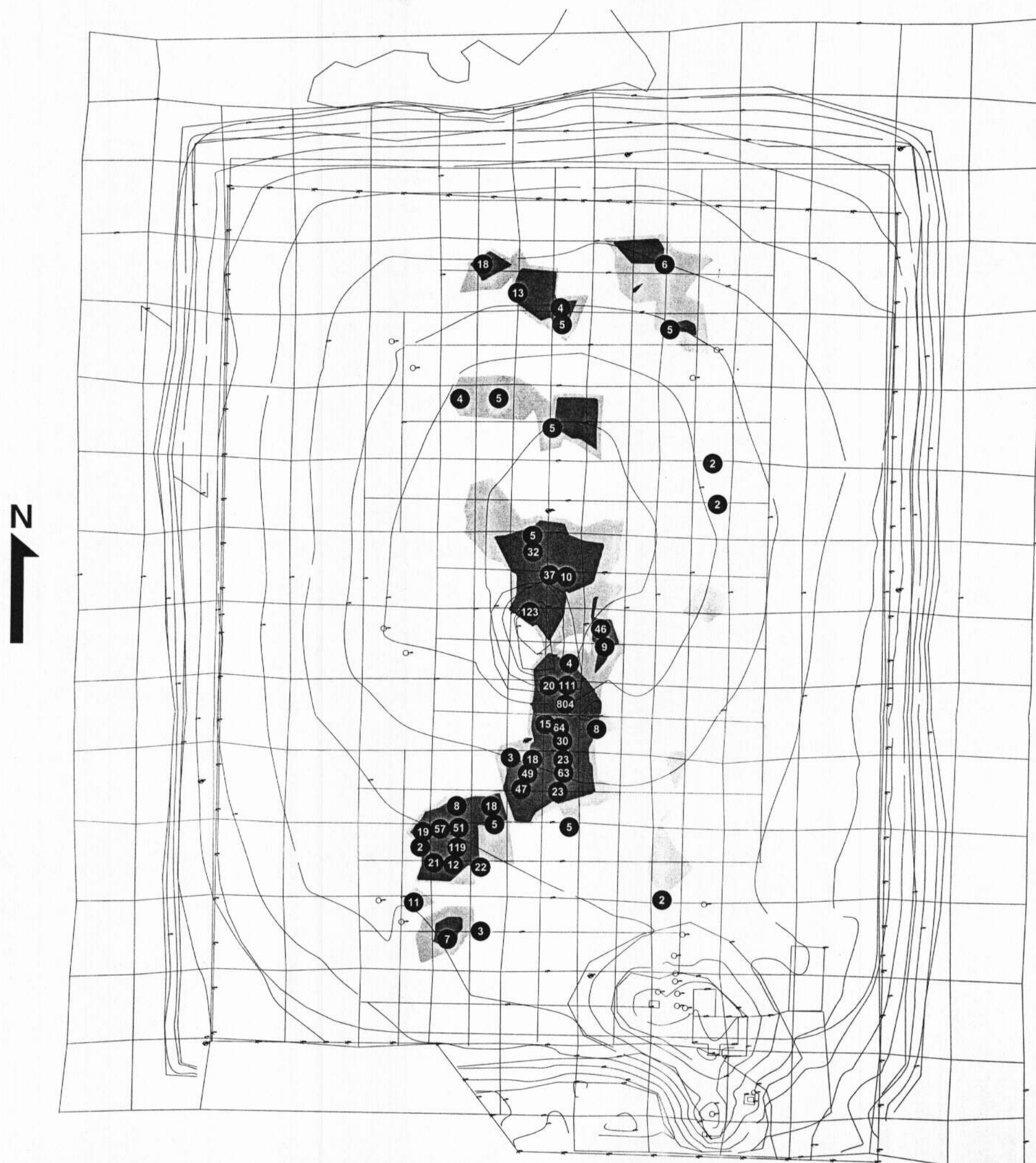


Figure 4-27
Max Th-232 Downhole In Situ Gamma Spectroscopy
Results with Max Gross Gamma Count Contours
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

Max Th-232 downhole in situ NaI gamma spectroscopy result (pCi/g)

300 to 500 Count Contour

>500 Count Contour

(Counts are 10 sec. response
of 1" x 1" NaI crystal detector)

C24

N

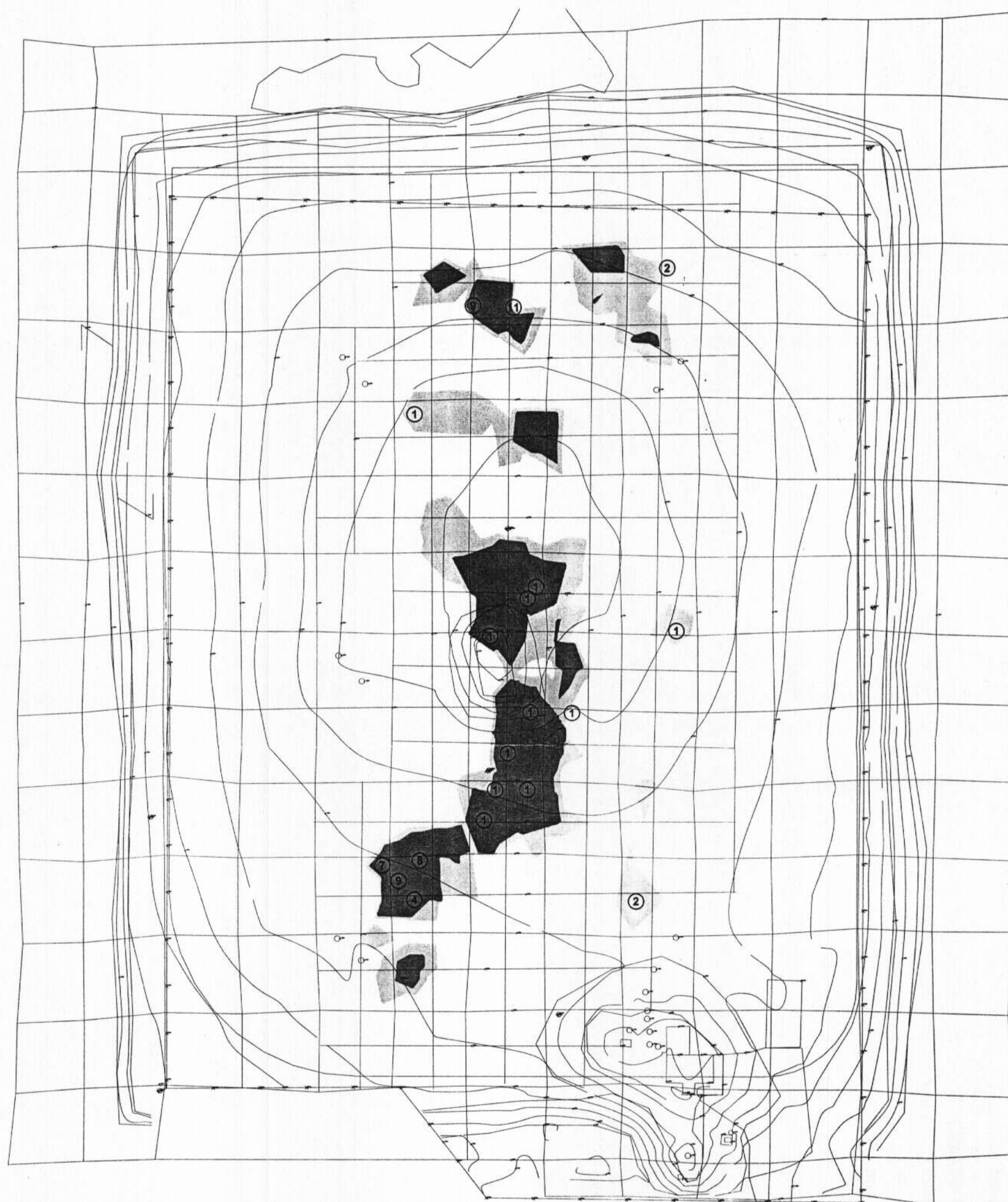


Figure 4-28
Th-230 to Th-232 Ratio with
Max Gross Gamma Count Contours
Tobico Marsh SGA Site
Michigan Department of Natural Resources
Bay County, Michigan

Th-230 to Th-232 ratio based on alpha spectroscopy sample results

300 to 500 Count Contour

>500 Count Contour

(Counts are 10 sec. response of 1" x 1" NaI crystal detector)

C25

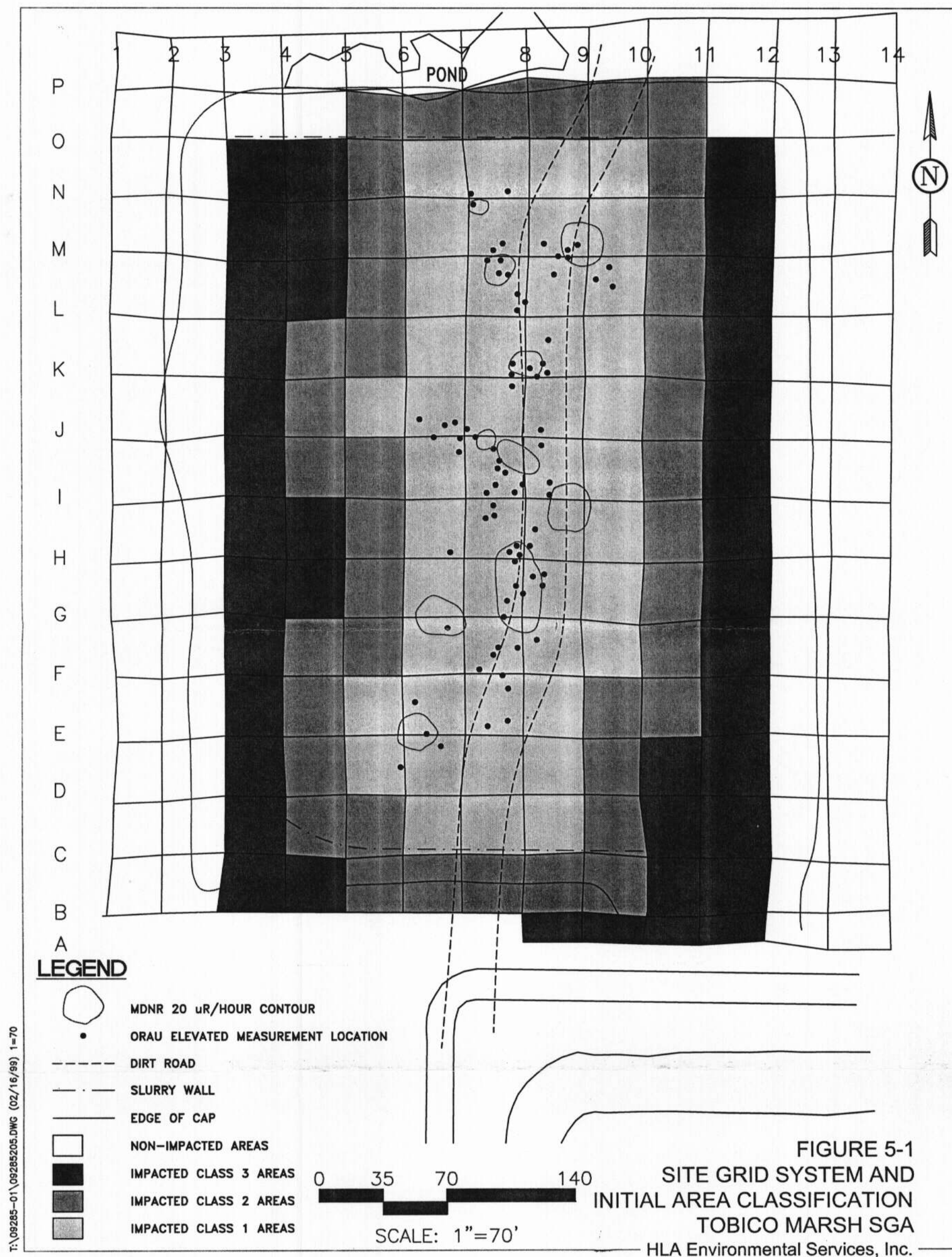


FIGURE 5-2
REFERENCE AREA 10-SECOND GROSS GAMMA COUNTS HISTOGRAM

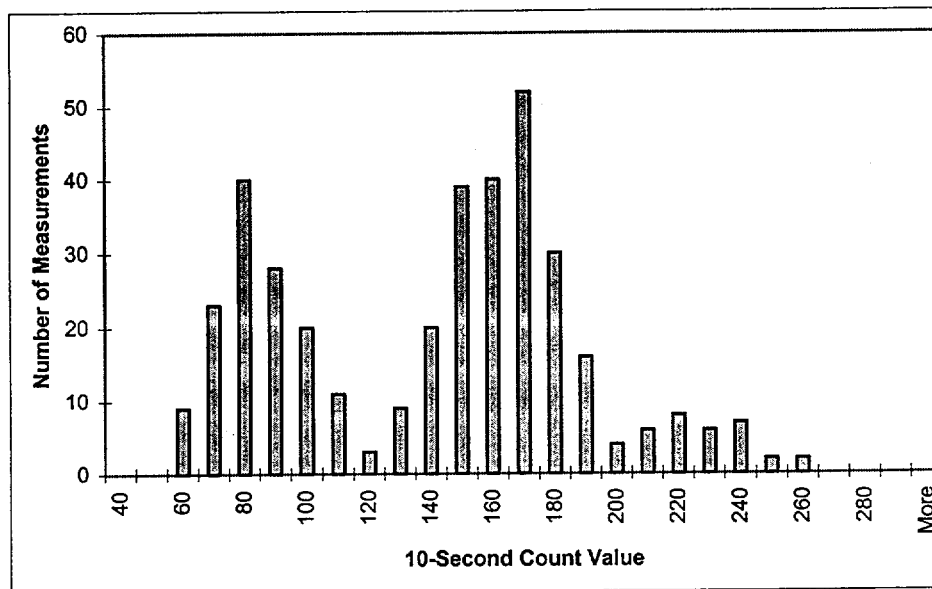


FIGURE 5-3
CLASS 2 AND 3 10-SECOND GROSS GAMMA COUNTS HISTOGRAM

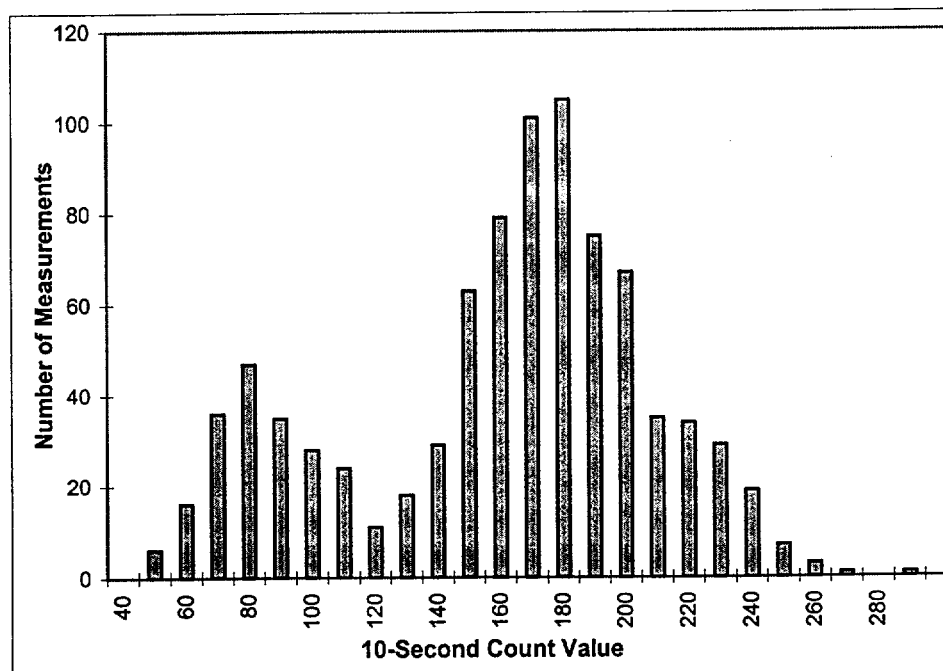


FIGURE 5-4
CLASS 1 10-SECOND GROSS GAMMA COUNTS HISTOGRAM

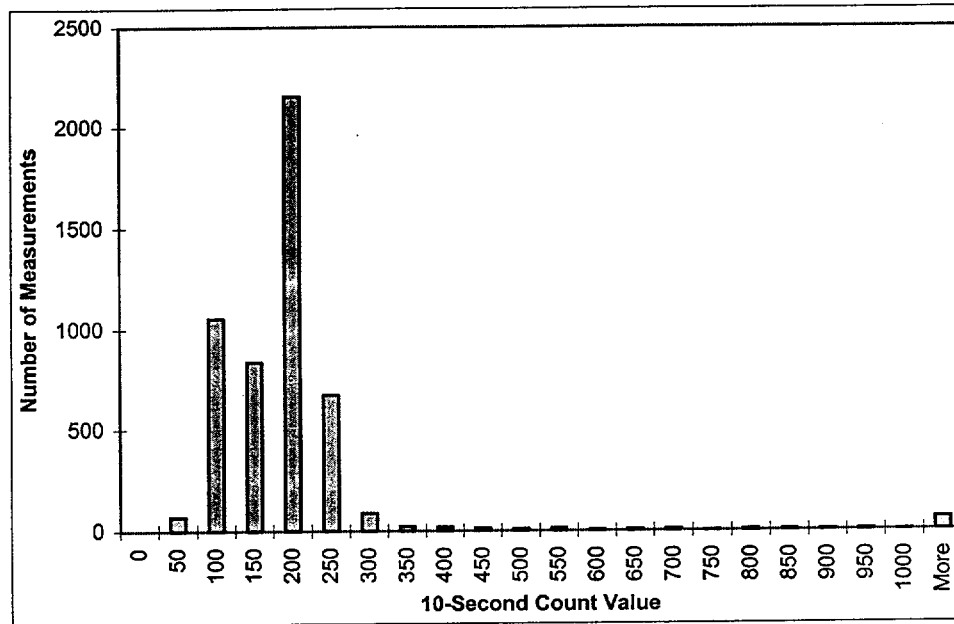


FIGURE 5-5
CLASS 1 10-SECOND GROSS GAMMA COUNTS HISTOGRAM
(LOG SCALE)

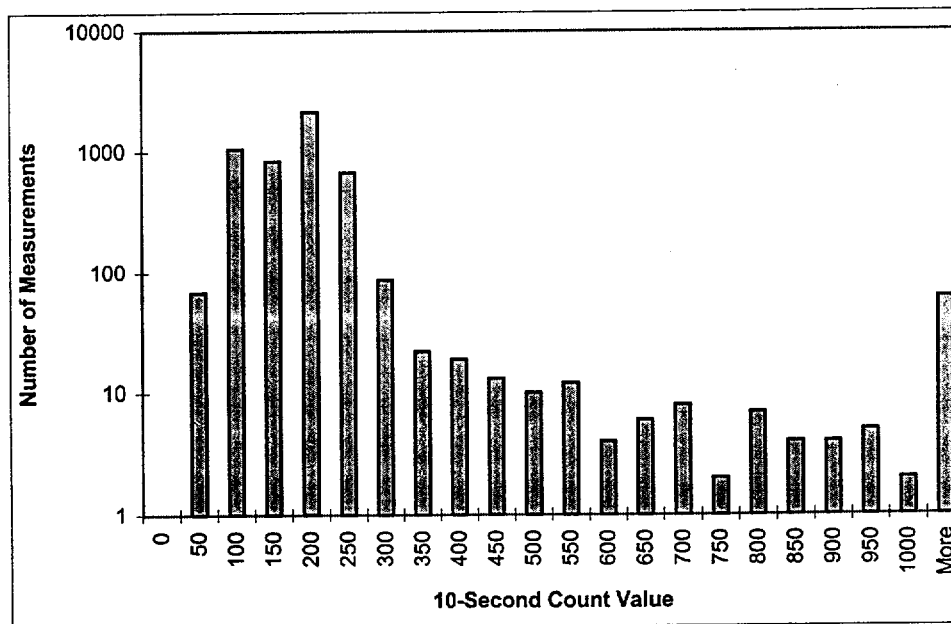


Figure 6-1
Year 1999 Gross Gamma Control Chart for Downhole NaI SN: C443E

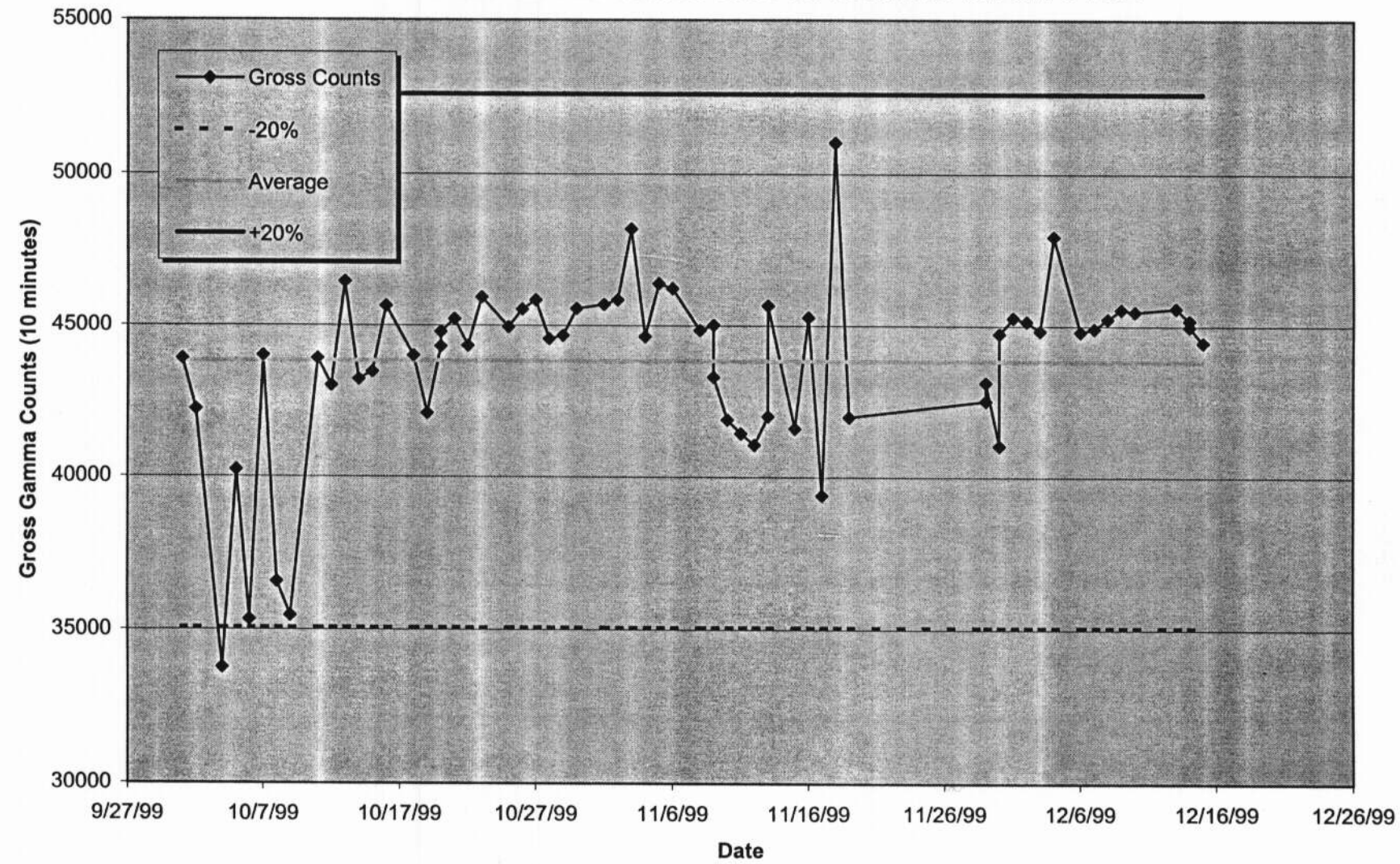


Figure 6-2
Year 2000 Gross Gamma Control Chart for Downhole NaI SN: C361G

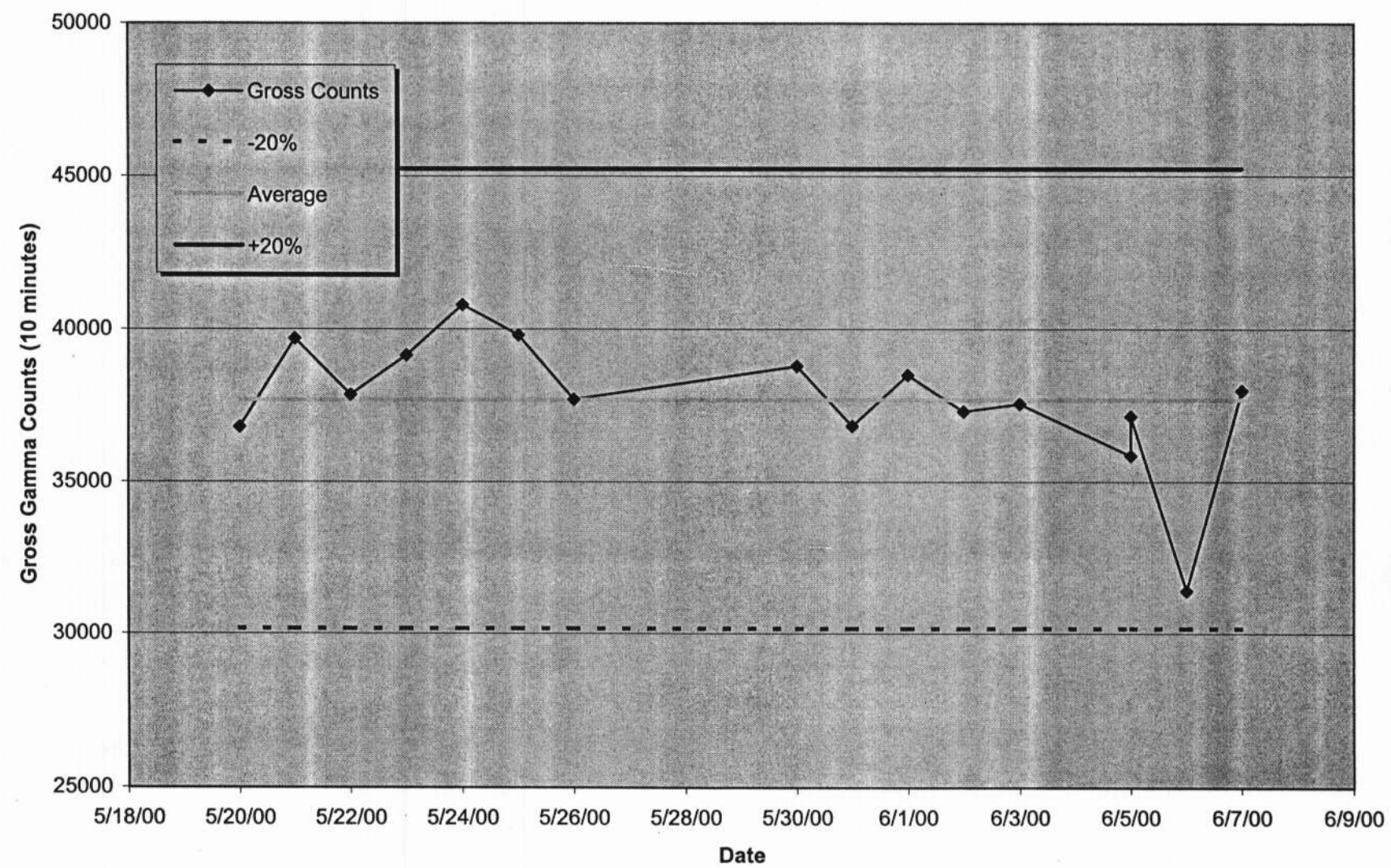


Figure 6-3
Year 2000 Gross Gamma Control Chart for Downhole Nal SN: C443E

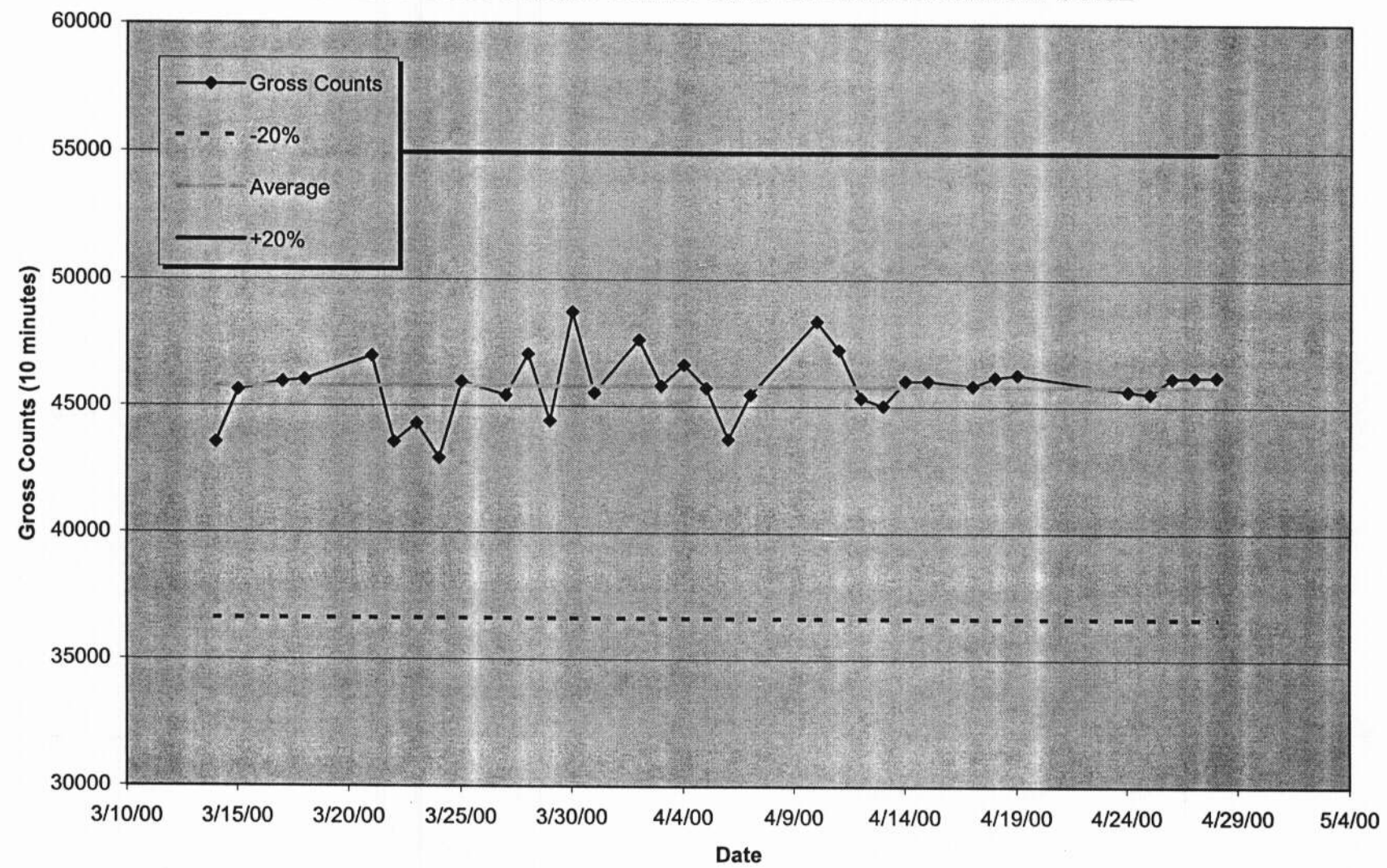


Figure 6-4
Year 2000 Gross Gamma Control Chart for Downhole NaI SN: C614D

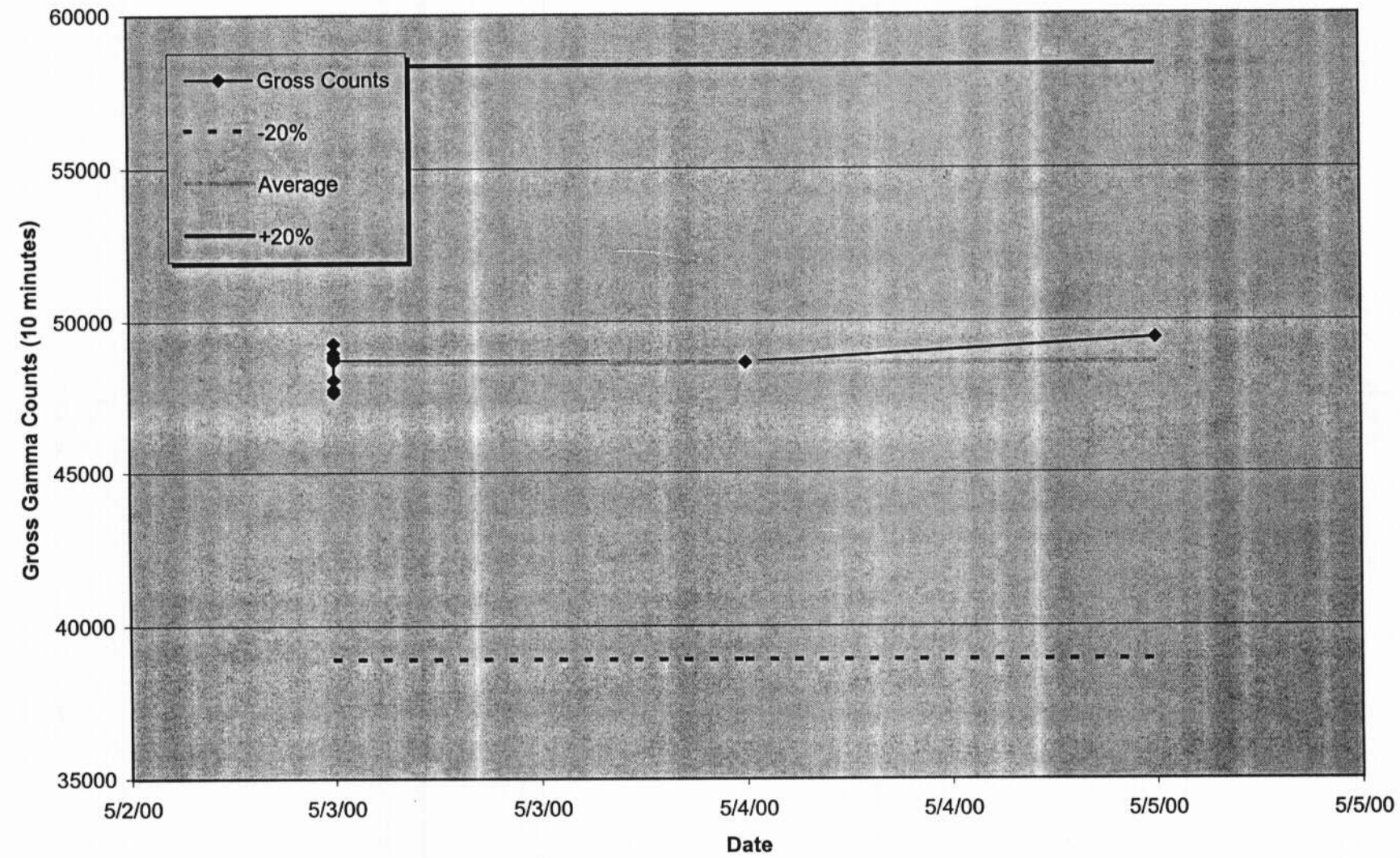


Figure 6-5
Year 1999 Spectroscopic Control Chart for Downhole NaI SN: C443E

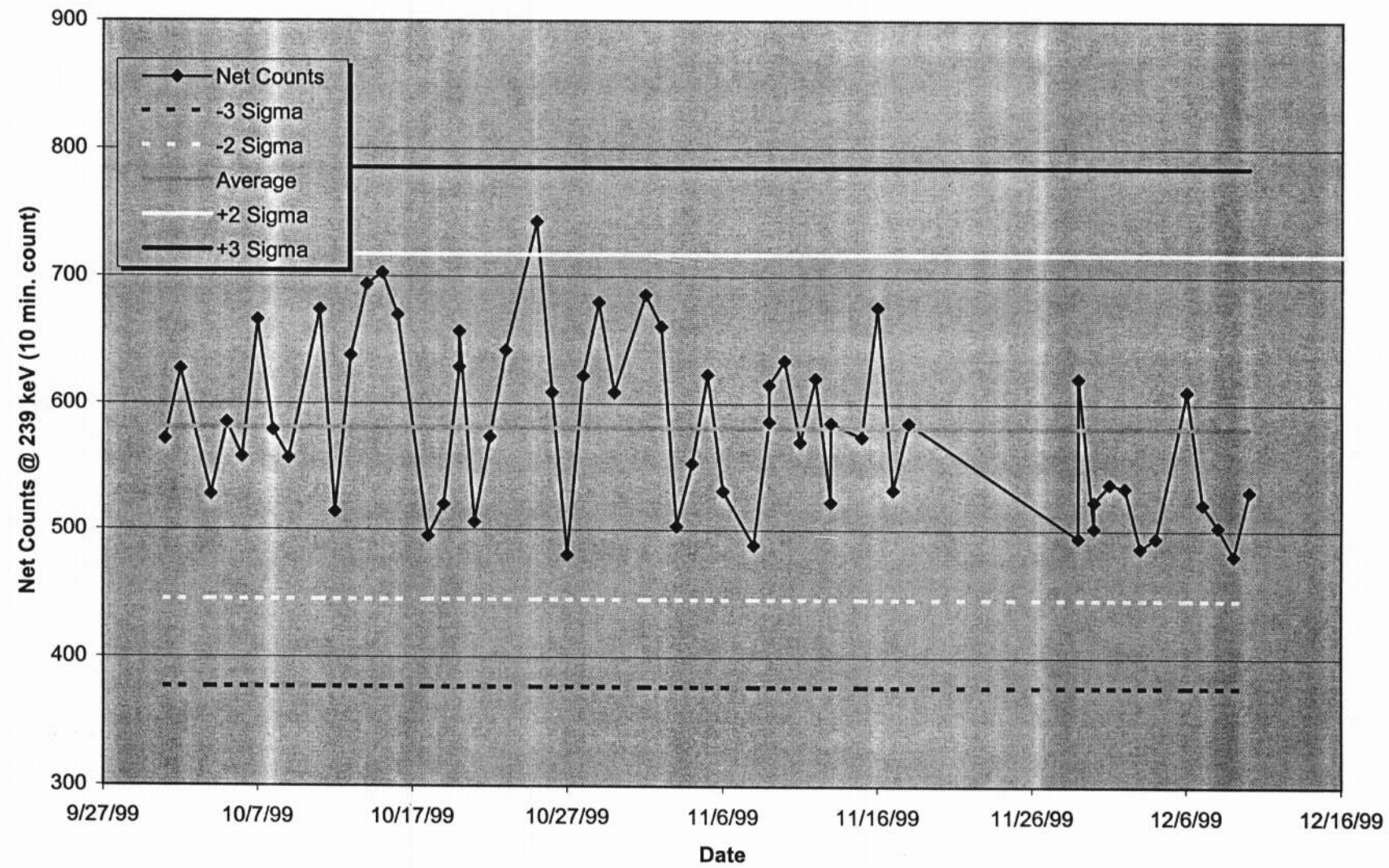


Figure 6-6
Year 2000 Spectroscopic Control Chart for Downhole NaI SN: C361G

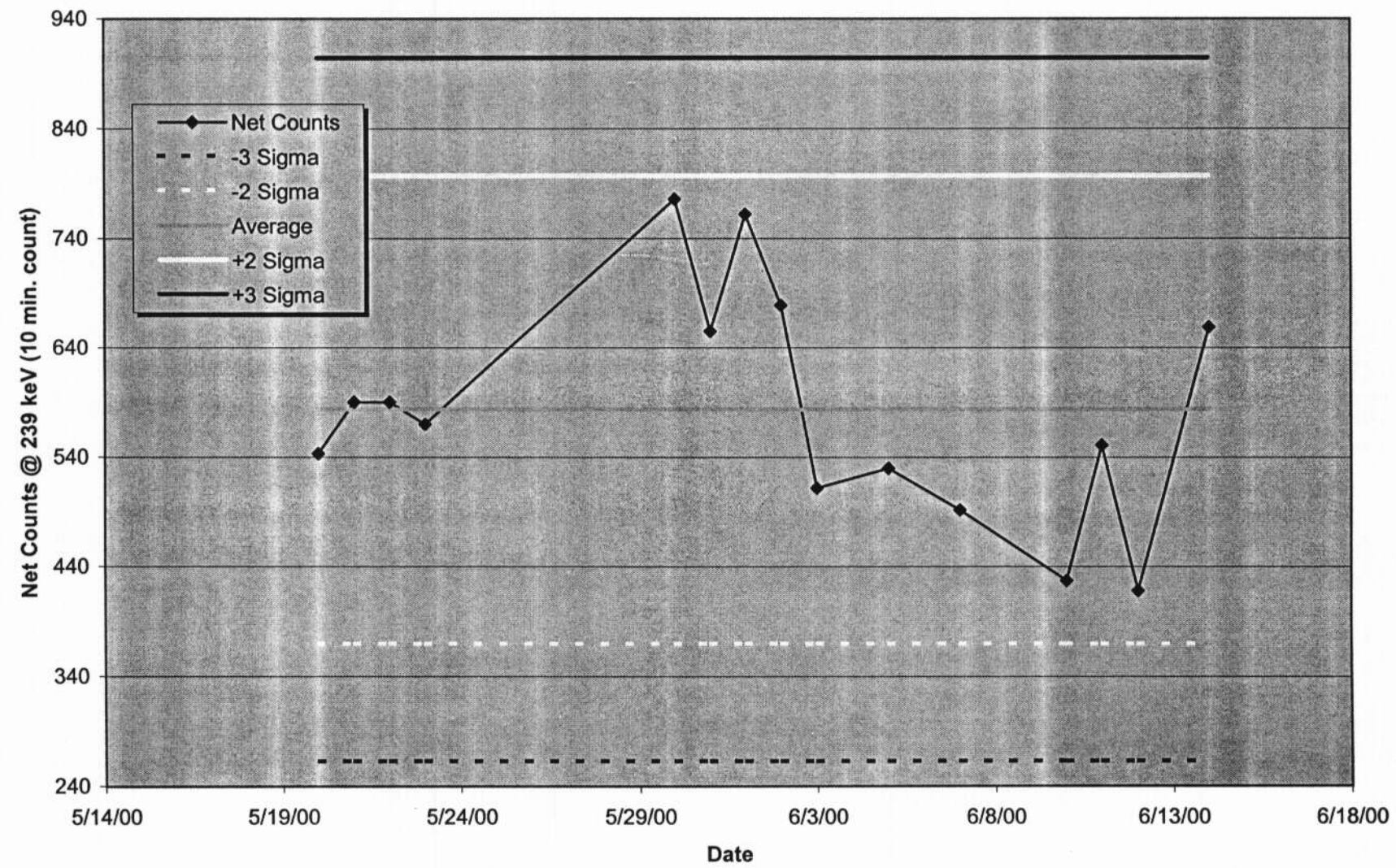


Figure 6-7
Year 2000 Spectroscopic Control Chart for Downhole NaI SN: C443E

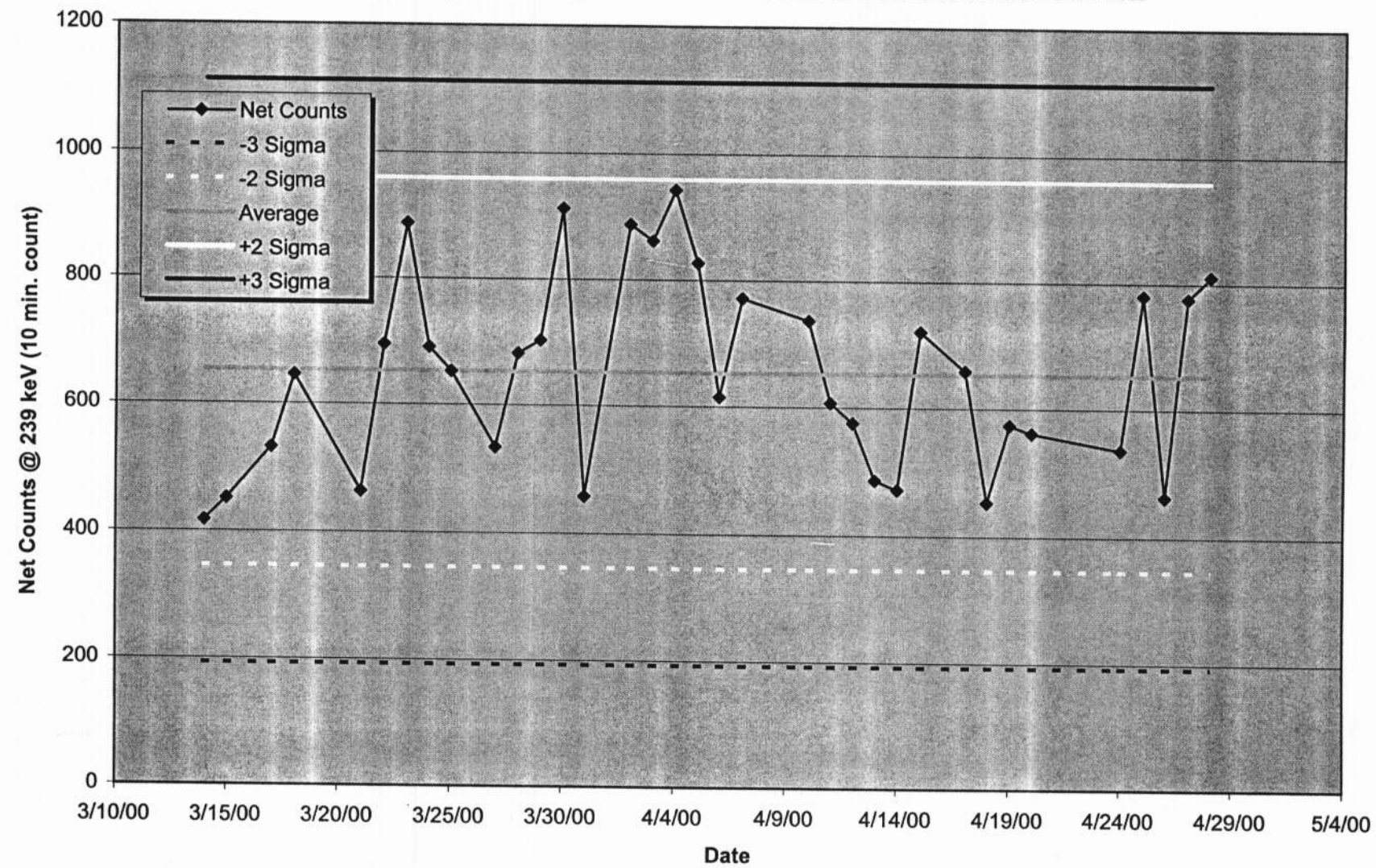


Figure 6-8
Year 2000 Spectroscopic Control Chart for Downhole NaI SN: C614D

