WSMR 2002

DEPARTMENT OF THE ARMY
U.S. ARMY WHITE SANDS MISSILE RANGE
100 HEADQUARTERS AVENUE
WHITE SANDS MISSILE RANGE, NEWMEXICO 88002-5000

November 22,2002

REPLY TO
ATTENTION OF
Environment and Safety Directorate

Ms. Cheryl Frischkorn
State of New Mexico Environment Department - HWB
2905 Rodeo Park Drive East
Building 1
Santa Fe, New Mexico 87505

NOV 2002

Subject: RCRA FACILITY INVESTIGATION (RFI) AT THE LANCE MISILE IMPACT SITE SWMU 168 ON WHITE SANDS NATIONAL MONUMENT, WHITE SANDS MISSILE RANGE (WSMR) EPA ID No. NM2750211235, HWB-WSMR-99-012

Dear Ms. Frischkorn:

Enclosed you will find the subject report, dated November 2002. The RFI data analysis included Unsymmetrical Dimethylhydrazine (UDMH), Nitrosodimethylamine (NDMA), Nitrodimethylamine (DMN), Volatile Organics (BTEX), and RCRA Metals, Toxic Characteristic Leaching Procedure (TCLP) Metals and water chemistry from soil and groundwater sampling events for the Lance Missile Impact RFI, conducted March thru May 2002.

The data indicated that no constituent tested identified any action levels or concern. This report summarizes the RFI in accordance with environmental requirements for the Lance Missile Impact.

Copies are being furnished to Mr. James Harris, Region VI EPA; Mr. James Mack, White Sands National Monument, and to MEVATEC Corporation.

Please contact Mr. Javier Mendoza of our office at (505) 678-1007 if you have any questions.

Sincerely,

Thomas A. Ladd

Thomas A. Ladd
Director, Environment and Safety Directorate

Enclosure

WSMR-03-003

White Sands Missile Range Environmental Document
Report WS-ES-EC-0240

RCRA Facility Investigation of the Lance Missile Impact Site SWMU 168 on the White Sands National Monument

November 2002

LIBRARY COPY

White Sands Missile Range
Environment and Safety Directorate
White Sands Missile Range, New Mexico 88002

REPORT DOCUMENTATION PAGE			OMB No. 0704-0188

Public reporting burden for this collection of information estimated to average 1 hour per response, including the time for reviewing instructions. Send comments regarding this burden estimate or any other aspects of this collection information including suggestions for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302 and to the Office of Management and Budget Paperwork Reduction Project (0704-0188), Washington DC 20503

1. AGENCY USE ONLY (LEAVE BLANK)	2. REPORT DATE November 2002	3. REPORT TYPE AND DATES COVERED November 2002

4. TITLE AND SUBTITLE

RCRA Facility Investigation of the Lance Missile Impact Site (SWMU 168) on the White Sands National Monument

5. FUNDING NUMBERS

6. AUTHOR(S)

Bradley Davis, Geologist

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

MEVATEC Corporation
Box 399
WSMR, NM 88002

8. PERFORMING ORGANIZATION REPORT NUMBER

900A8/02/001F

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Department of the Army
U.S. Army White Sands Missile Range
100 Headquarters Avenue
ATTN: CSTE-DTC-WS-ES-EC (Javier Mendoza)
White Sands Missile Range, NM 88002

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

WS-ES-EC-0240

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT (MAXIMUM 200 WORDS)

On 14 December 1999, a Lance Missile launched from White Sands Missile Range impacted within the White Sands National Monument on property managed by the National park Service. Detailed in this report is the RCRA Facility Investigation of the impact site.

14. SUBJECT TERMS

Mark Number: 200-1q
Lance Missile, RCRA, RFI, SWMU 168, IRFNA, UDMH, NDMA, DMN, BTEX, Soil Borings, Monitoring Wells, ground water

15. NUMBER OF PAGES
43

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

RCRA FACILITY INVESTIGATION OF THE LANCE MISSILE IMPACT SITE (SWMU 168) ON THE WHITE SANDS NATIONAL MONUMENT

Submitted to:

U.S. Army
White Sands Missile Range
Environment and Safety Directorate
White Sands Missile Range, New Mexico 88002-5048

November 2002

Submitted by:

MEVATEC Corporation
Building 126
White Sands Missile Range, New Mexico 88002

EXECUTIVE SUMMARY

On 14 December 1999, a Lance missile launched from White Sands Missile Range (WSMR) impacted within the White Sands National Monument (WSNM) near Lake Lucero on property managed by the National Park Service (NPS). Propellant used in the Lance missile included Unsymmetrical Dimethylhydrazine (UDMH) and Inhibited Red Fuming Nitric Acid (IRFNA). The missile penetrated the ground surface and exposed the water table at approximately three feet (ft) below ground surface (bgs). The impact created a crater approximately 18 ft in diameter and 5 ft deep. The New Mexico Environment Department (NMED) has designated the Lance impact site as Solid Waste Management Unit (SWMU) 168.

Detailed in this report is the Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) of the impact site. The purpose of this RFI is to supplement previous investigations by obtaining information to further characterize the geology and hydrology of the site area and extent of possible soil and groundwater contamination.

The RFI was conducted to identify possible soil and/or ground-water contamination, determine possible contaminant transport pathways, and evaluate the potential for human or ecological exposure. Field activities to support these objectives consisted of the following:

- surface geophysical survey,
- collection and analysis of soil samples from borings around the impact crater, and
- installation and sampling of groundwater monitoring wells.

All collected soil and water samples were analyzed for UDMH, Nitrosodimethylamine (NDMA), Nitrodimethylamine (DNM), benzene, toluene, ethylbenze, xylene and total RCRA metals. All analyte detections were well below their respective NMED residential SSLs. None of the soil or water samples contained detectable concentrations of the Lance missile fuel component, UDMH, or its breakdown components, NDMA or DMN.

Soil borings and monitoring wells for this investigation were positioned such that samples were collected from locations where contamination would likely be present (within soils surrounding the impact crater, within water exposed within the crater, and within ground water down gradient from the crater). However, no Contaminants of Potential Concern (COPCs) were detected in the course of this investigation. The results of this investigation indicate that contamination from the Lance missile impact has not occurred. Subsequently, this RFI has determined that no routes (air, soil, surface water, or ground water) for exposure to human health exist at the site.

TABLE OF CONTENTS

Section **Page**

EXECUTIVE SUMMARY ii

ACRONYMS vi

1.0 INTRODUCTION 8
- 1.1 Objectives and Scope 8
- 1.2 Approach and Implementation 8
- 1.3 White Sands Missile Range - Background 9
- 1.4 White Sands National Monument – Background 9

2.0 SITE DESCRIPTION 11
- 2.1 Regional Geology 11
- 2.2 Regional Hydrology 12
  - 2.2.1 Climatology 12
  - 2.2.2 Surface Water 12
  - 2.2.3 Groundwater 12
- 2.3 Lance Missile Impact Site Characteristics 13

3.0 PREVIOUS INVESTIGATIONS 16
- 3.1 Initial Site Visit 16
- 3.2 26 January 2000 Sampling Event 16
- 3.3 Follow-On Sampling Event 16
- 3.4 Follow-On Assessment 18

4.0 RCRA FACILITY INVESTIGATION 18
- 4.1 Field Investigation 18
  - 4.1.1 Geophysical Survey 19
  - 4.1.2 Hollow-Stem Augering 21
- 4.2 Data Analysis 30
  - 4.2.1 Site Specific Lithology/Hydrology 30
  - 4.2.2 Soil Data Chemical Analysis 31
  - 4.2.3 Ground-Water Flow Direction 34
  - 4.2.4 Ground-Water Sampling 35

5.0 SITE CONCEPTUAL MODEL 36

6.0 SITE ASSESSMENT 39
- 6.1 Human Health 39
  - 6.1.1 Contaminants of Potential Concern 39
  - 6.1.2 Air Exposure Pathway 39
  - 6.1.3 Soil Exposure Pathway 39
  - 6.1.4 Surface Water Exposure Pathway 39
  - 6.1.5 Ground-Water Exposure Pathway 40
- 6.2 Ecological 40

TABLE OF CONTENTS
continued

Section **Page**

7.0 CONCLUSIONS....41

8.0 RECOMMENDATION FOR SITE CLOSURE....42

REFERENCES....43

List of Figures

Figure 1-1. Location of White Sands Missile Range, White Sands National Monument. 10
Figure 2-1. Mexican Highland Section, Basin and Range Province, Tularosa Basin Cross Section. 11
Figure 1-4. Potentiometric Surface Map of the Area Around Lake Lucero. 15
Figure 3-1. Sample locations for Follow-On Sampling Event. 17
Figure 4-1. Geophysical Survey Interpretation Summary Map.... 20
Figure 4-2. Soil Borings and Monitoring Well Locations Superimposed on the Geophysical Survey Interpretation Summary Map (modified from Blackhawk Geosciences, Inc., 2002) 22
Figure 4-3. Ground Water Flow Direction (three-point problem).... 35
Figure 4-4. Interpreted Cross-Section of the Lance Missile Impact Site. 38
Figure 6-1. Topographic Map of the Lance Missile Impact Site.... 40

List of Tables

Table 4-1. EM-61 Anomalies.... 20
Table 4-2. Magnetometer Anomalies.... 21
Table 4-4. RFI Analytical Constituents for Soil and Ground Water.... 26
Table 4-5. GPS Coordinates.... 27
Table 4-6. Analytical Results from the Impact Crater Soil Borings. 34
Table 4-7. Depth to Water Measurements.... 35
Table 4-8. Water pH, Temperature, and Conductivity Measurements. 36
Table 4-9. Analytical Results from the Lance Impact Water Sampling. 37

List of Photographs

Photograph 2-1. Alkali Flats Area of White Sands National Monument.... 13
Photograph 2-2. Lance Missile Impact Crater.... 14
Photograph 3-1. Follow-On Sampling Event. 17
Photograph 4-1. Geophysical Survey (EM-61). 19
Photograph 4-2. Geophysical Survey (Magnetometer). 19
Photograph 4-3. Assembly of CS-1000 Trailer Mounted Drill Rig (motor assembly). 23
Photograph 4-4. Assembly of CS-1000 Trailer Mounted Drill Rig 24
Photograph 4-5. Fully Assembled CS-1000 Trailer Mounted Drill Rig. 24
Photograph 4-6. CS-1000 Drill Rig set up on 0168-SB01. 25
Photograph 4-7. Collection of Soil Sample for Chemical Analysis. 27
Photograph 4-8. Installation of Monitoring Well Casing. 28
Photograph 4-9. Protective above Grade Aluminum Shroud. 29

TABLE OF CONTENTS
concluded

Section		Page
APPENDIX A	ASSESSMENT REPORT OF THE LANCE MISSILE IMPACT ON 14 DECEMBER 1999 INTO THE WHITE SANDS NATIONAL MONUMENT, JULY 2000	
APPENDIX B	SPECIAL USE PERMIT ISSUED BY THE WSNM	
APPENDIX C	GEOPHYSICAL SURVEY AT THE WHITE SANDS NATIONAL MONUMENT WHITE SANDS MISSILE RANGE NEW MEXICO	
APPENDIX D	MONITORING WELL COMPLETION DIAGRAMS	
APPENDIX E	MONITORING WELL SURVEY	
APPENDIX F	FIELD LITHOLOGIC LOGS	
APPENDIX G	EPA REGION IV RECOMMENDED ECOLOGICAL SCREENING VALUES	

ACRONYMS

ac	acre
ASTM	American Society for Testing and Materials
ATEC	U.S. Army Test and Evaluation Command
bgs	below ground surface
cm	centimeter
COPC	Contaminant of Potential Concern
DMN	N-Nitrodimethylamine
DPM	Deputy Program Manager
DQO	Data Quality Objectives
EOD	Explosive Ordnance Disposal
ft	feet
GFCI	Ground Fault Circuit Interrupter
GPS	Global Positioning System
ha	hectare
HA	hand auger
HAZWOPER	Hazardous Waste Operations
IDLH	immediately dangerous to life and health
IDW	investigation derived waste
IRFNA	Inhibited Red Fuming Nitric Acid
km	kilometer
LEL	lower explosive limit
m	meter
mg/kg	milligram(s) per kilogram
mg/l	milligram(s) per liter
ml	milliliter
MW	Monitoring Well
NASA	National Aeronautics and Space Administration
NDMA	N-Nitrosodimethylamine
NMED	New Mexico Environment Department
NPS	National Park Service
O.D.	open diameter
OSHA	Occupational Safety and Health Administration
PEL	permissible exposure limit
PID	photo-ionization detector
POC	point of contact
PPE	personal protective equipment
ppm	parts per million
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act
RESV	Recommended Ecological Screening Value
RFI	RCRA Facility Investigation
RPD	Relative Percent Difference
SSHSP	Site Specific Health and Safety Plan
SSL	Soil Screening Levels
SWMU	Solid Waste Management Unit
TB	Trip Blank
TBD	to be determined

ACRONYMS
(*concluded*)

TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TI	Technical Inspector
UDMH	Unsymmetrical Dimethyl Hydrazine
UEL	Upper Explosive Limit
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UXO	Unexploded Ordnance
WSNM	White Sands National Monument
WSMR	White Sands Missile Range

RCRA FACILITY INVESTIGATION AT THE LANCE MISSILE IMPACT SITE (SWMU 168) ON THE WHITE SANDS NATIONAL MONUMENT

1.0 INTRODUCTION

On 14 December 1999, a Lance missile launched from White Sands Missile Range (WSMR) impacted within the White Sands National Monument (WSNM) near Lake Lucero on property managed by the National Park Service (NPS). The Lance missile carried a simulated warhead composed of a mass of welded steel pipe covered by thin metal forming a tip. Propellant used in the Lance missile included Unsymmetrical Dimethylhydrazine (UDMH) and Inhibited Red Fuming Nitric Acid (IRFNA). The missile penetrated the ground surface and exposed the water table at approximately 0.9 meters (m) (3 feet (ft)) below ground surface (bgs). The impact created a crater approximately 5.5 m (18 ft) in diameter and 1.5 m (5 ft) deep. The New Mexico Environment Department (NMED) has designated the Lance impact site as Solid Waste Management Unit (SWMU) 168.

1.1 Objectives and Scope

The purpose of this investigation is to supplement previous investigations by obtaining information to further characterize the geology and hydrology of the site area and extent of possible soil and groundwater contamination. More specifically, the objectives of this investigation are to determine:

- if soil and/or ground water at the site was contaminated by the Lance missile impact;
- possible contaminant transport pathways; and
- the potential for human or ecological exposure.

Analytical results from soil and ground water sampling at the Lance impact site are compared to the NMED Soil Screening Levels (SSLs) (NMED, 2000) to accurately determine if the former construction landfill poses a risk to human health or the environment.

1.2 Approach and Implementation

The approach and implementation to meet the project objectives consisted of:

- geophysical survey to locate Lance missile debris below ground surface (bgs).
- advancing eight 3 m (10 ft) deep soil borings around the perimeter of the impact crater. Four of the eight borings were augered 1.5 m (5 ft) north, south, east, and west of the lip of the crater. The remaining four borings were augered 3m (10 ft) northeast, northwest, southeast, and southwest of the crater. Soil samples were collected from the borings at the surface, and approximately at 1.5 m (5 ft) and 3 m (10 ft) depths depending on site conditions.
- hand augering and collection of soil samples near geophysical anomalies away from the impact crater;
- installation and sampling of eight ground-water monitoring wells around the periphery of the impact crater. Two of the wells are installed north of the crater for collection of

background water samples. Soil samples were collected from the northern wells to serve as background soil; and

- collection of one water sample from the crater.

1.3 White Sands Missile Range - Background

WSMR is a Developmental Test Command (DTC) installation. The majority of the installation is situated within the Tularosa Basin; with areas along the western and northwestern boundary extending into the Jornada del Muerto Basin. WSMR is located in Doña Ana, Socorro, Lincoln, Otero, and Sierra Counties, New Mexico. The Main Post area of WSMR is located at the southwestern corner of the installation, approximately 27 miles (43.4 km) east-northeast of Las Cruces, NM and 45 miles (72.4 km) north of El Paso, TX (Figure 1-1). The headquarters and most installation support activities are located at the Main Post area. WSMR is the largest land-area military installation in the United Sates, comprised of nearly 3,200 square miles (8,288 sq. km) of land. The installation is approximately 99 miles (159 km) long and 25 to 40 miles (40.22 to 64.4 sq. km) wide.

WSMR was established July 9, 1945 as White Sands Proving Ground (name was changed to WSMR in 1958), to be America's testing range for the new concept of missile weapons. The New Mexico desert was selected to be the nation's testing range for several reasons: the desert is sparsely populated, has almost year-round clear weather and unlimited visibility, and as such, affords relatively easy recovery of spent missiles.

WSMR now functions as an outdoor laboratory consisting of a large complex of test ranges, launch sites, impact areas and instrumentation sites required to develop and test tactical and strategic weapons and weapons systems. WSMR is designated as a national range whose mission is the support of missile development and test programs for the Army, Navy, Air Force, NASA and other government agencies.

1.4 White Sands National Monument – Background

WSNM, administered by the NPS, is located in the southeastern portion of WSMR (Figure 1-1) and is 59,703 hectares (ha) (147,526 acres [ac]) in area. The monument, established in 1933, was designated as a National Park due to its globally unique gypsum sand dunes. The monument boundary encloses the gypsum dunes, alkali flats, and Lake Lucero (source of the gypsum sand). Approximately 500,000 people visit the WSNM on a yearly basis to see the world's largest gypsum dune field. The sands dunes, up to 60 ft (18 m) in height, also provide a unique habitat for wildlife that have successfully adapted to this environment. Additionally, the WSNM supports desert ecology research and education programs.

Formation of the WSNM is due to several geologic processes. Water flowing into the Tularosa Basin will either infiltrate the ground surface or pool in low areas of the basin. Lake Lucero is one of the lowest points in the basin and will occasionally fill with water. Evaporation of the water results in the deposition of gypsum. The alkali flats area in the Monument is the result of previous gypsum deposition from the Pleistocene Lake Otero. The dunes at WSNM are formed from the wind erosion of gypsum from Lake Lucero and the alkali flats and re-deposition and accumulation to the west.

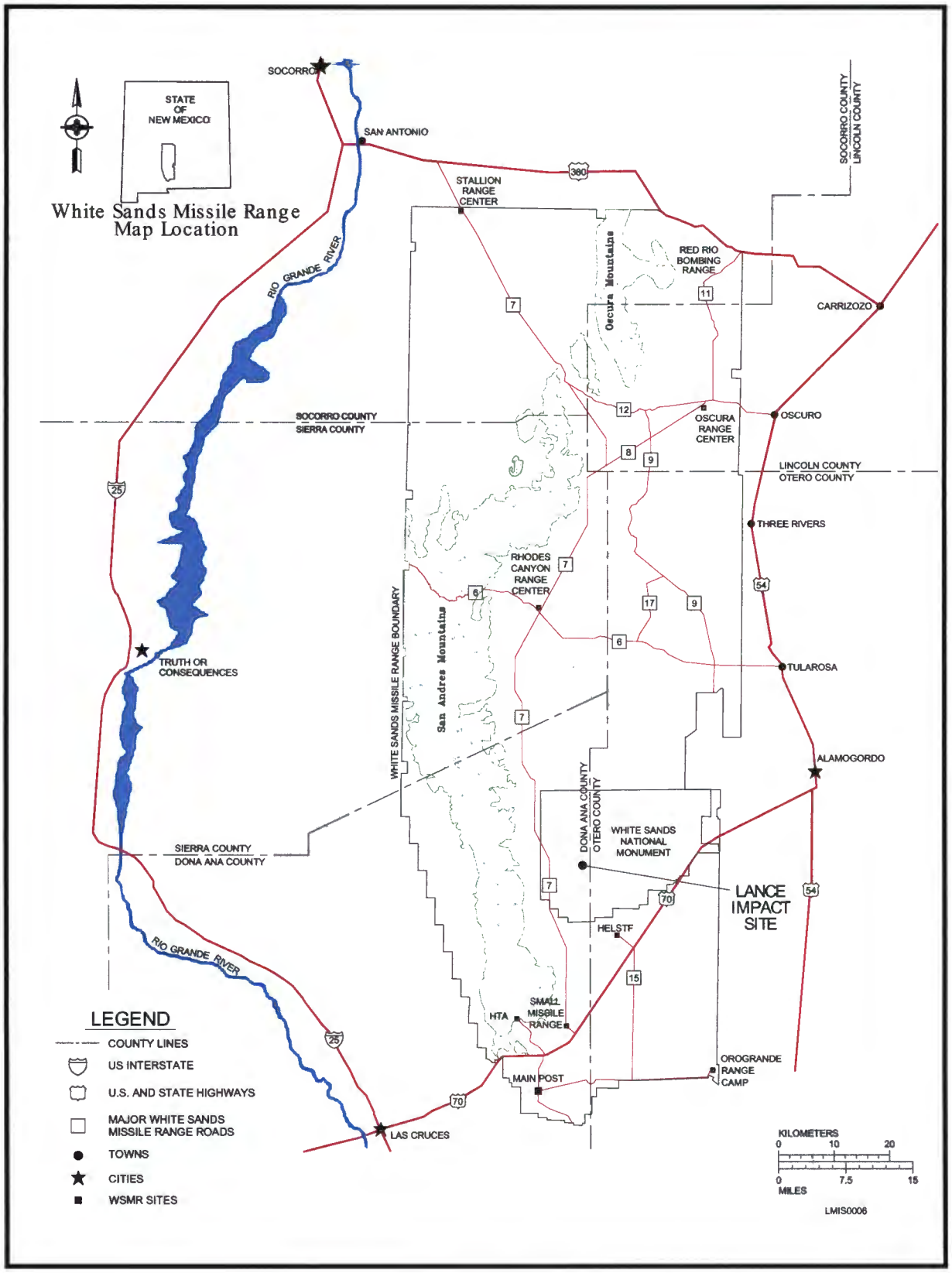


Figure 1-1.
Location of White Sands Missile Range, White Sands National Monument.

2.0 SITE DESCRIPTION

2.1 Regional Geology

WSMR lies within the Mexican Highland Section of the Basin and Range Province. This province is characterized by a series of tilted fault blocks forming longitudinal, asymmetric ridges or mountains and broad intervening basins. The major portion of WSMR lies within the Tularosa Basin, which is bounded on the west by the Organ, San Augustin, and San Andres Mountains (Figure 2-1).

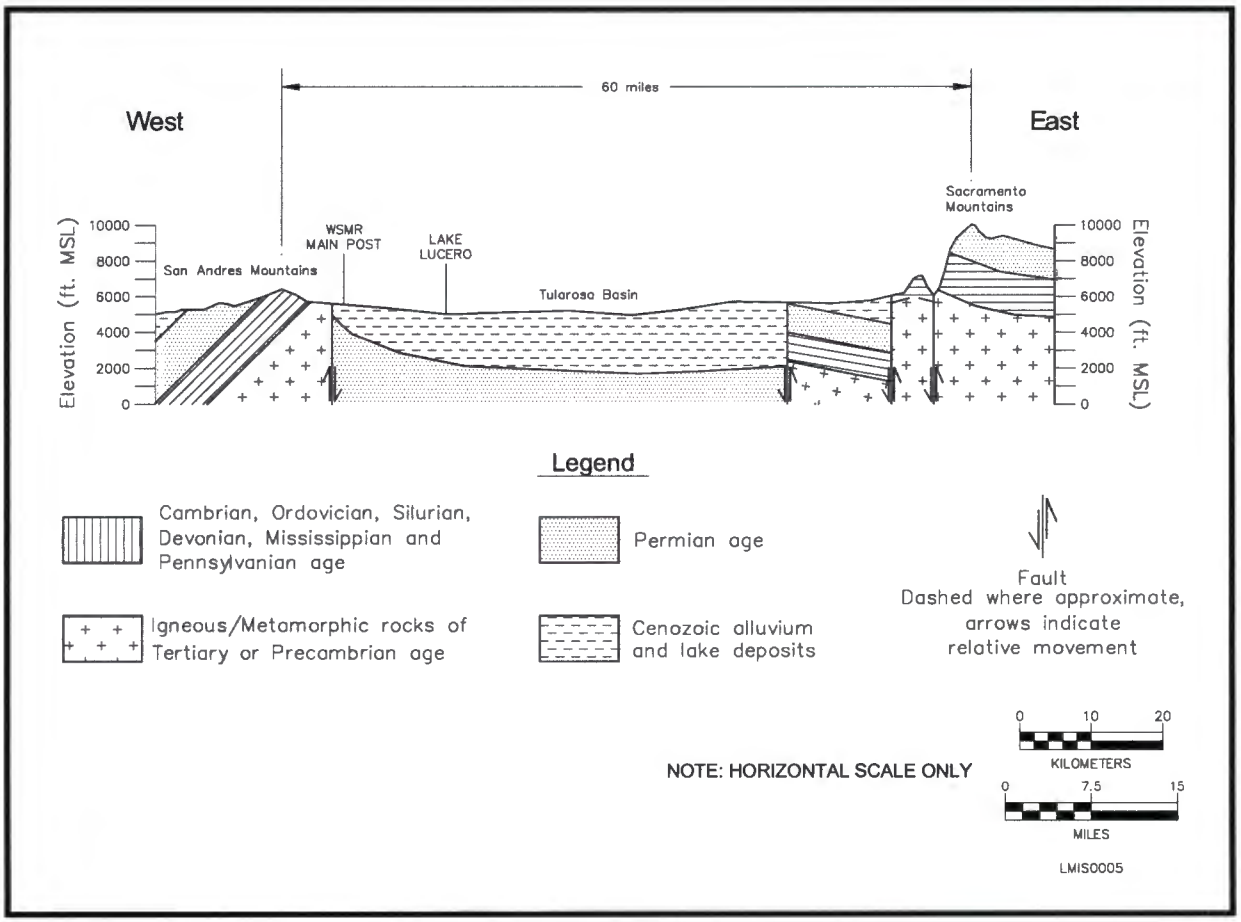


Figure 2-1.
Mexican Highland Section, Basin and Range Province, Tularosa Basin Cross Section.

The Tularosa Basin contains thick sequences of Tertiary and Quaternary age alluvial and Bolson fill deposits. These sediments, more than 1,524 m (5,000 ft) thick in some areas, consist mainly of silt, sand, gypsum and clay weathered from the surrounding mountain ranges. The average elevation of the basin floor is 1,219 m (4,000 ft) above mean sea level and surface features consist of flat sandy areas, sand dunes, basalt flows, and playas (dry lake beds). Average elevation of mountains range from 1,737 m (5,700 ft) at San Augustin Pass to more than 2,743 m (9,000 ft) at Salinas Peak, the tallest peak at WSMR.

The nature of the Bolson-fill deposits varies both laterally and vertically throughout the Main Post Area. Coarse-grained, poorly sorted sediments deposited near mountain fronts grade into fine-grained, well sorted sediments towards the center of the basin (Kelly, 1973). Sediments further from the mountain fronts also contain a greater percentage of clay and gypsum. Vertically, the sediments are reported to become finer-grained and more consolidated until reaching a laterally continuous clay unit at about 1,000 ft below ground surface (Kelly and Hearne, 1976).

In general, the stratigraphy is represented by unconsolidated to partially consolidated, fine to medium-grained sand with subordinate amounts of clay. Caliche is present as discrete layers and nodules throughout the stratigraphic section. Although no faults are mapped within the immediate area, quaternary faulting is known to exist within the region. These faults are reported to occur within the unconsolidated Bolson sediments, trend north to south, and are most common near the mountain fronts.

2.2 Regional Hydrology

2.2.1 Climatology

The WSMR Main Post is located at an elevation of almost 4,000 ft (1,219 m) above mean sea level. Snowfall is infrequent, although heavy snows have occurred. With an average rainfall of only 10.8 inches (27.4 cm), mostly occurring during late summer as thunderstorms, often accompanied by hail, the area is considered semi-arid. Intense localized thunderstorms have caused flash flooding in the past. Average summer high temperature is 92°F with lows of about 65°F. During the winter months (December, January and February), the average high is 57°F, with lows of about 36°F. Average annual humidity readings are approximately 37 percent.

2.2.2 Surface Water

Very little surface water exists at WSMR due to the low annual precipitation, high evapotranspiration rates, and high infiltration characteristics of the soils. During the summer season when thunderstorm activity is most common, playas within the basin may contain standing water. Arroyos that drain the surrounding mountains usually contain water only following heavy precipitation events. The Tularosa Basin is a closed basin with no surface water drainage outside of WSMR.

2.2.3 Groundwater

Groundwater within the basement-cored uplifts in the Basin and WSMR region of New Mexico generally occurs under unpredictable fracture-flow conditions in the Precambrian basement rock. Faults defining the boundaries between ranges and basins are major sites of recharge to the regional groundwater. Recharge to the regional aquifer is from precipitation falling on the mountain ranges and alluvial fans, which border the Bolson on the west. This precipitation infiltrates the unconsolidated, relatively coarse deposits of the alluvial fans, and the resultant groundwater flows toward the center of the Tularosa Bolson, generally to the east-southeast. However, groundwater flow direction may be altered locally, because of the pumping of water supply wells. The groundwater within the western Tularosa Bolson region is presumed to discharge to the south as underflow into the contiguous, northern Hueco Bolson of western Texas.

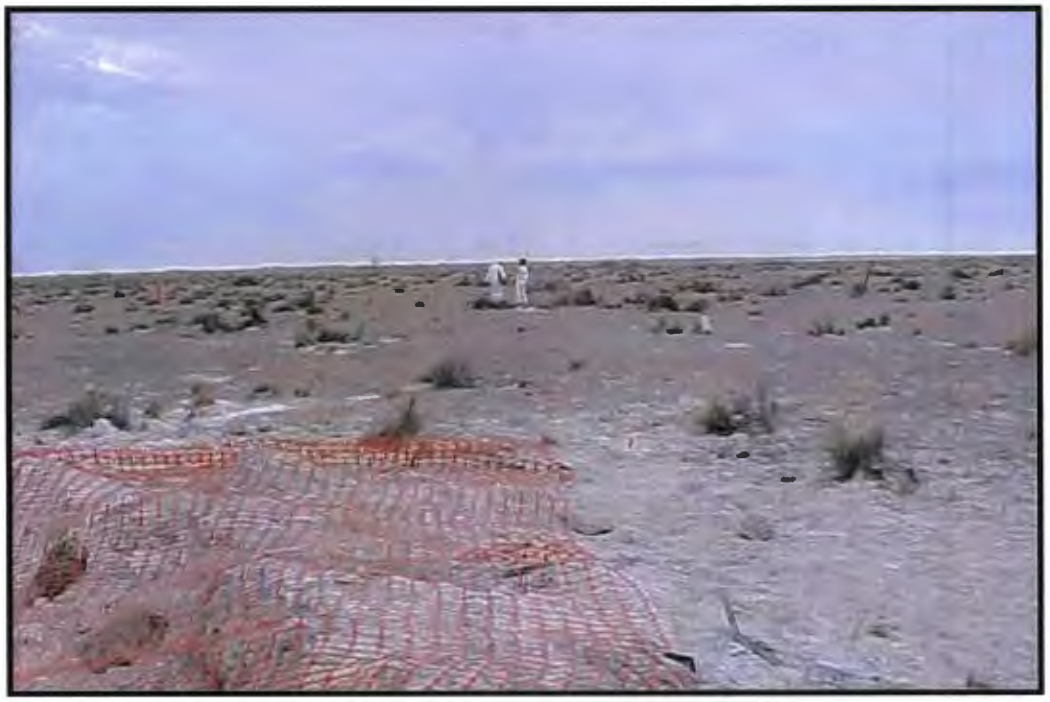
No surface expressions of groundwater discharge have been reported within the western Tularosa Bolson. Dissolved constituents, total dissolved solids (TDS), in groundwater increase with distance eastward from the mountain front, reflecting the increased residence time of groundwater moving from the western Bolson margin toward the center of the Tularosa Bolson (within the Tularosa Basin).

The WSMR Main Post obtains its potable water supply from the aquifer in the upper Bolson deposits. This aquifer consists of a wedge-shaped belt of potable water more than 30 miles (48.27 km) long (from north to south), and 3 to 5 miles east from the mountain front. Groundwater in the vicinity of the Main Post is of sufficient quality (less than 1,000 mg/L total dissolved solids) for human consumption. McClean (1970) reported this freshwater zone extends down to about 1,800 ft (549 m) below ground surface.

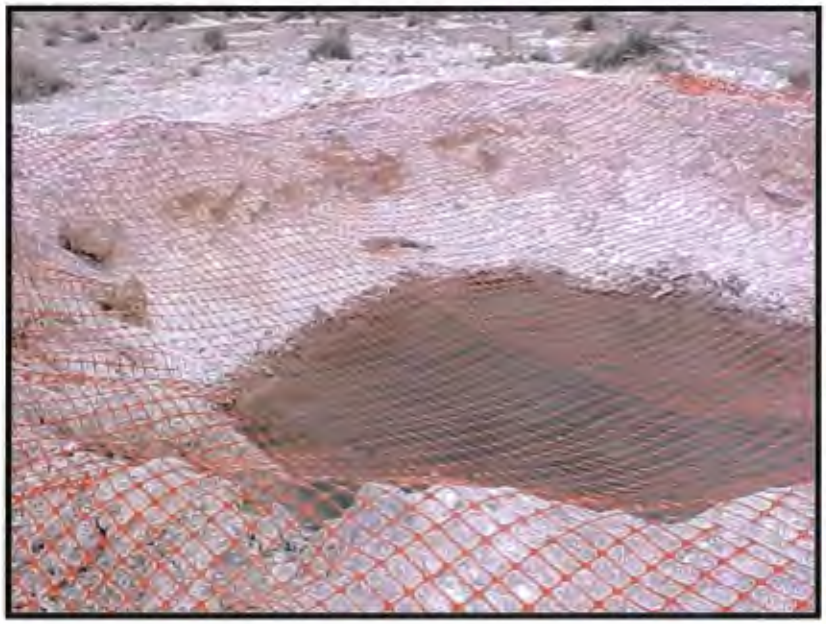
To the east, groundwater becomes more mineralized, primarily with sulfate and chloride. This is attributed to the slow lateral migration rate of groundwater from recharge to discharge areas, and the presence of readily soluble minerals in the Bolson sediments.

2.3 Lance Missile Impact Site Characteristics

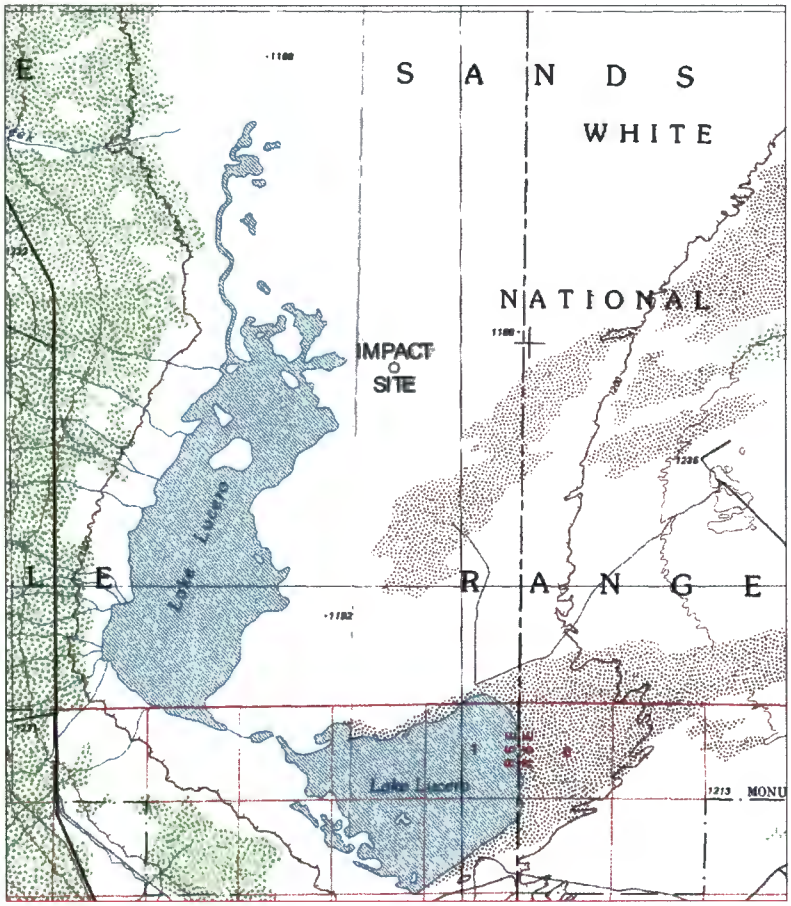
The impact site (Photographs 2-1 and 2-2) is located within the alkali flats area of the WSNM approximately one mile east of Lake Lucero (Figure 2-2). Depth to ground water at the impact site is approximately 0.9 m (3 ft) bgs. The ground water has a Total Dissolved Solids (TDS) concentration of greater than 20,000 milligrams per liter (mg/l). The mineral gypsum is highly soluble and adds to the TDS concentration of the ground water in this region.



Photograph 2-1.
Alkali Flats Area of White Sands National Monument



Photograph 2-2. Lance Missile Impact Crater.



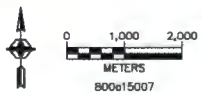


Figure 2-2.
Contour Map of Lance Missile Impact Site

Allmendinger and Titus (1973) describe the geology of the alkali flats area in the vicinity of Lake Lucero as consisting of gypsum grains and gypsum crystal fragments making up the bulk of the upper 10 to 25 feet bgs. They describe this upper unit as being thinly bedded and very compact. Small amounts of clay were reported to occur in these beds. Below this unit are more typical lacustrine (lake) deposits consisting of sand, silt, and clay. Well developed gypsum crystals were noted in the clay units which suggested they grew in place from concentrated brine water. These lower deposits probably represent older lake bottom sediments deposited at some point in the past when the lake covered a more extensive area.

Allmendinger and Titus (1973) describe the water table in this area near Lake Lucero as lying less than 3 m (10 ft) bgs, but more commonly falls between 0.6 m (2 ft) and 1.2 m (4 ft) bgs. The potentiometric surface of this area, as shown in Figure 2-3, shows the ground-water gradient to be to the west, south-west. This potentiometric surface map was developed from test holes drilled around the periphery of Lake Lucero in the late 1960's.

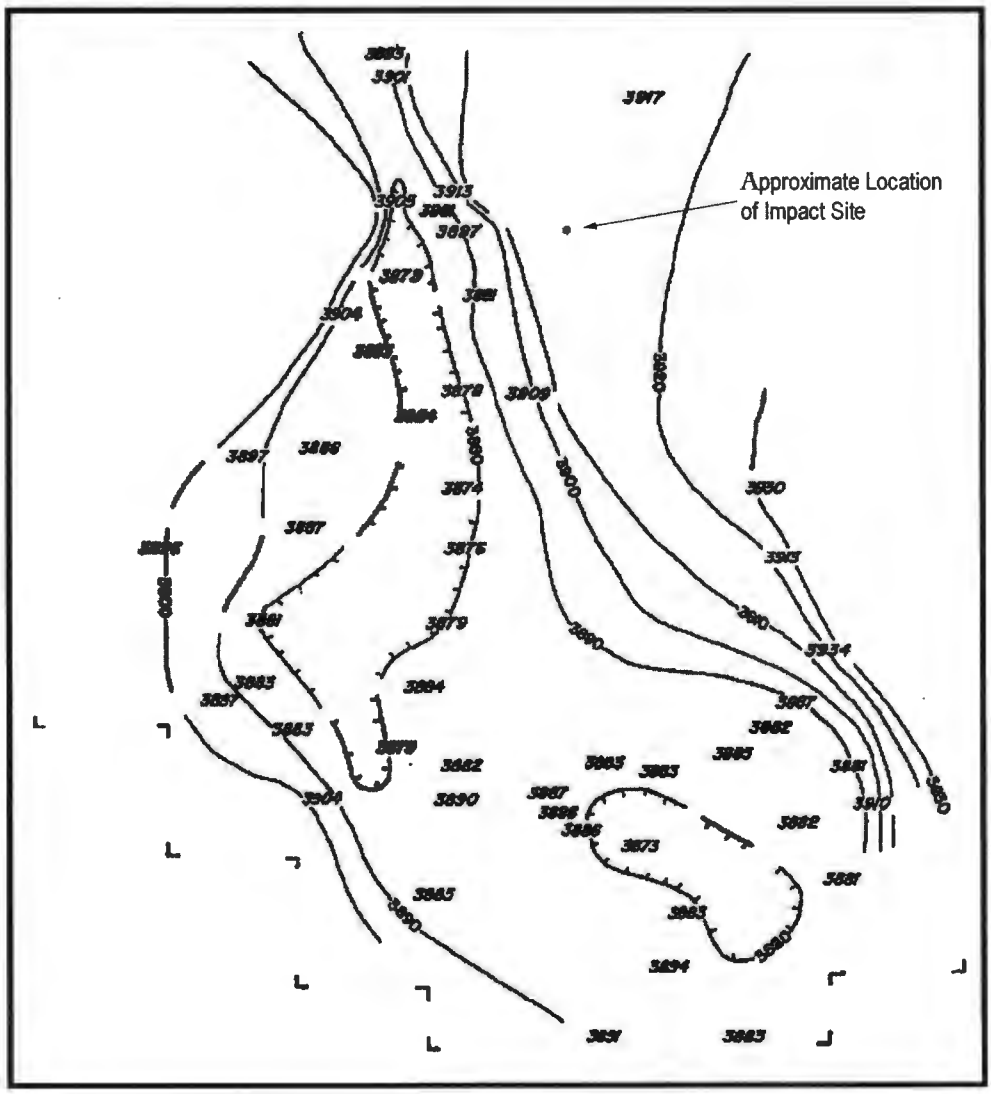


Figure 2-3. Potentiometric Surface Map of the Area Around Lake Lucero. (Allmendinger and Titus, 1973).

The impact site, as part of the WSNM, has not been developed. The nearest construction is Range Road 7 that is approximately 4 miles from the site. There have been no wastes handled at this site with the exception of the missile impact.

3.0 PREVIOUS INVESTIGATIONS

Information available on previous investigations, including laboratory reports, is included in the report titled, *Assessment Report of the Lance Missile Impact on 14 December 1999 into the White Sands National Monument,* July 2000 (Appendix A).

3.1 Initial Site Visit

An initial assessment of the impact site by two Explosive Ordnance Disposal (EOD) team members was conducted on 16 December 1999 to provide a quick visual and chemical assessment of the impact site for the establishment of baseline conditions. Soil and water samples were collected and analyzed for contaminants of concern. The analysis indicated a small amount of contamination from the impact. The initial site visit team concluded that since there was no debris visible on the surface, the missile must be below the surface of the water table, possibly with the propellant tanks somewhat intact (WSMR, 2000).

3.2 26 January 2000 Sampling Event

Six soil and three water samples were collected and analyzed for IRFNA, UDMH, TDS, and pH. Four soil samples were collected from the edge of the crater at the four compass points (north, south, east, and west). Additionally, two background soil samples were collected. One background water sample and two water samples collected from the crater were also analyzed. UDMH was not detected in any of the soil or water samples. IRFNA was detected in the soil samples collected from background samples and samples collected from the edge of the crater ranging from 7.1 mg/kg to 10.2 mg/kg. IRFNA was detected in the background water sample and the crater water samples ranging from 3.2 mg/kg to 8.7 mg/kg. Due to the expected dissociation of IRFNA, the laboratory analyzed for nitrate [breakdown component] and reported as IRFNA.

3.3 Follow-On Sampling Event

On 28 February 2000, soil and water samples were collected from the site as follows (Photograph 3-1 and Figure 3-1):

- Four soil samples were collected at the surface around the impact crater at the four compass points (north, south, east, and west).
- Two additional soil samples were collected at the surface approximately 46 meters (150 ft) east and west of the impact crater.
- Two water samples were collected from standing water in the crater. One sample was collected from the surface of the crater water and one sample was collected from a depth of approximately 4 ft below the surface
- One background water sample was collected from a hand-augured boring of approximately 4 ft below ground surface, 150 ft east of the impact crater.

Photograph 3-1. Follow-On Sampling Event.

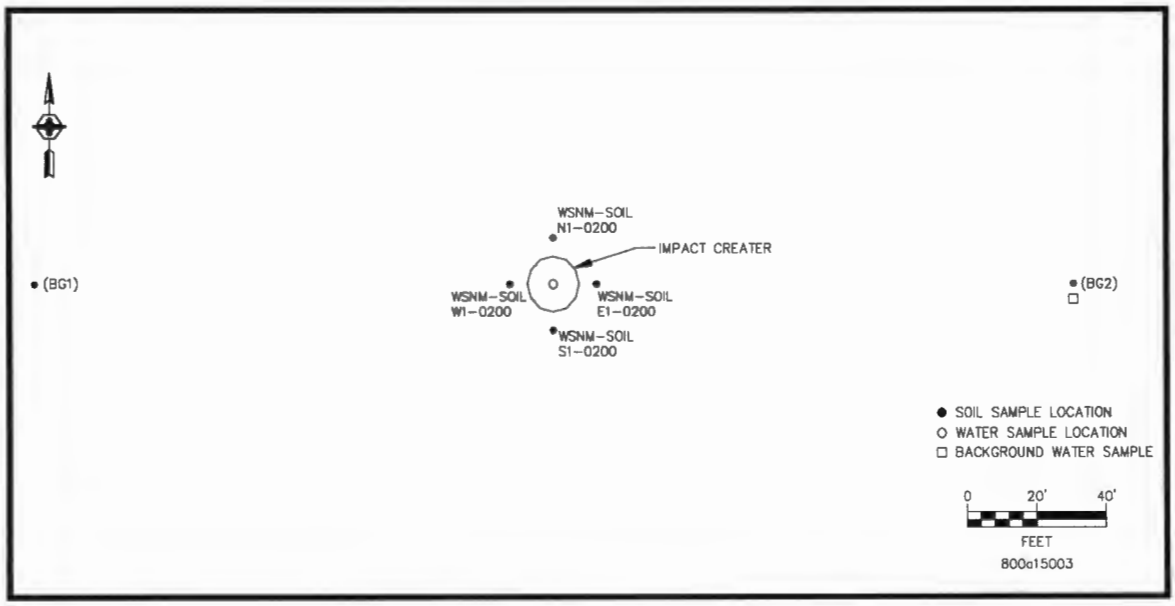


Figure 3-1. Sample locations for Follow-On Sampling Event.

All samples were analyzed for UDMH and N-Nitrosodimethylamine (NDMA) and N-Nitrodimethylamine (DMN), and water quality parameters. NDMA and DMN are the breakdown components of UDMH. UDMH and NDMA were not detected in any of the collected samples. DMN was detected in the two water samples collected from the crater at 0.09 µg/l. None of the contaminants were detected in the soil samples.

3.4 Follow-On Assessment

On 16 March 2000, a follow-on assessment recovery team inspected the site. The team consisted of a technical team comprised of various experts in missile testing, analysis, and recovery. The purpose of the follow-on assessment was to provide an in-depth analysis of the ground impact site to include a detailed search and collection of debris, debris location, debris assessment, crater definition, and soil and water conditions.

The recovery team noted the following:

- Lance missile debris on the surface less than 20 ft from the crater.
- Lance missile debris on the lip of the crater exposed to the air.
- Lance missile debris in the crater protruding from the water.
- Pieces of the simulated warhead section among the debris.
- Pieces of the liquid propellant tanks found among the debris.
- Chemical analysis results of soil and water samples taken on 16 December 1999 revealed an almost non-existent Lance related contamination. Results of the 28 February 2000 sampling analysis indicated no measurable contamination.

Conditions for assessment of missile debris during the follow-on assessment including increased time on-site and the uncovering of surface debris due to erosion allowed the recovery team to make a more accurate inventory of debris than the initial site investigation team. Based on the location, number, and types of Lance pieces found, the opinion of the recovery team is that the Lance missile suffered considerable catastrophic structural damage at the surface plane, enough to rupture the propellant tanks at the surface. This indicates that most of the missile debris is not deep and the contamination released took place on or near the surface. Pieces of the liquid propellant tanks found on the surface indicate that the tanks ruptured between the surface and a few feet into the ground. Calculations of the physics of the missile flight indicate that even if it were possible for the missile to be intact, it could be no deeper than 23 feet bgs. Based on the experience of the recovery team, no chemical contamination could occur at that depth due to the propellant tanks rupturing at the surface. It was the opinion of the recovery team that analysis for contamination should be limited to the surface (WSMR, 2000).

4.0 RCRA FACILITY INVESTIGATION

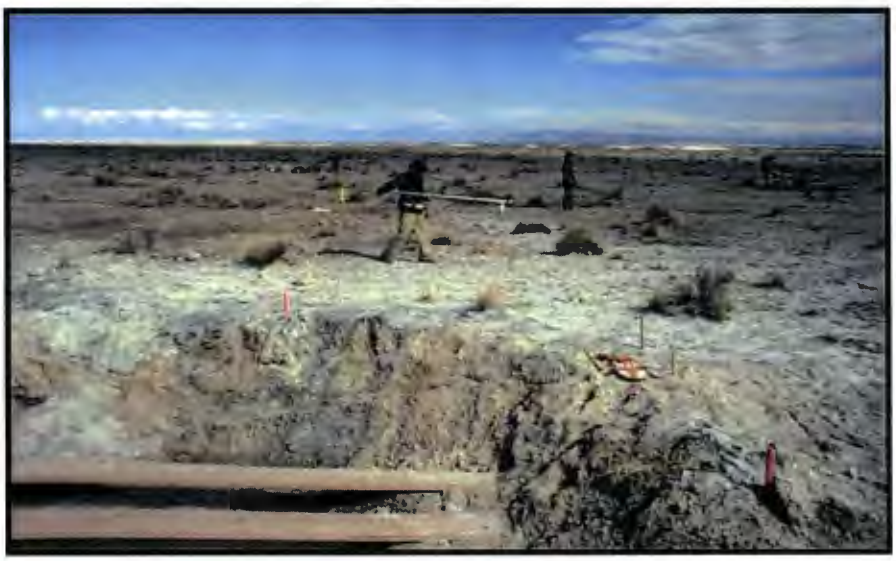
4.1 Field Investigation

The field investigation for this RFI consisted of a geophysical survey, soil boring/sampling, monitoring well installation/groundwater sampling, and crater water sampling. The WSNM issued a Special Use Permit (Appendix B) to WSMR for access to install and operate subsurface drilling analysis and testing equipment at the Lance missile impact site on the WSNM.

4.1.1 Geophysical Survey

A surface geophysical survey (Appendix C) (Blackhawk Geosciences, Inc., 2002) was conducted on 5 February 2002 at the impact site on a 100 ft grid, centered on the impact crater, to aid in the delineation of the Lance missile debris. A combination of an EM-61 metal detector (Photograph 4-1) and magnetometer (Photograph 4-2) was used to determine the nature and extent of the impact debris. The EM-61 metal detector has the ability to detect both aluminum and ferrous iron to a depth of approximately 12 to 15 ft bgs in the type of soils at the impact site. The magnetometer has the ability to detect ferrous iron down to a depth of approximately 50 ft bgs in soils of this type.

Photograph 4-1. Geophysical Survey (EM-61).



Photograph 4-2. Geophysical Survey (Magnetometer).

Five EM-61 anomalies were detected at the impact site (Table 4-1) (Figure 4-1). A significant increase in recorded instrument response was detected in the center of the survey grid, occurring both in and around the impact crater. This anomaly is mapped in Figure 4-1 as EM-61 anomaly "A" (red color on Figure 4-1). Several other smaller anomalies are mapped "B" through "E" (red color on Figure 4-1) and probably represent smaller metallic parts of the Lance missile.

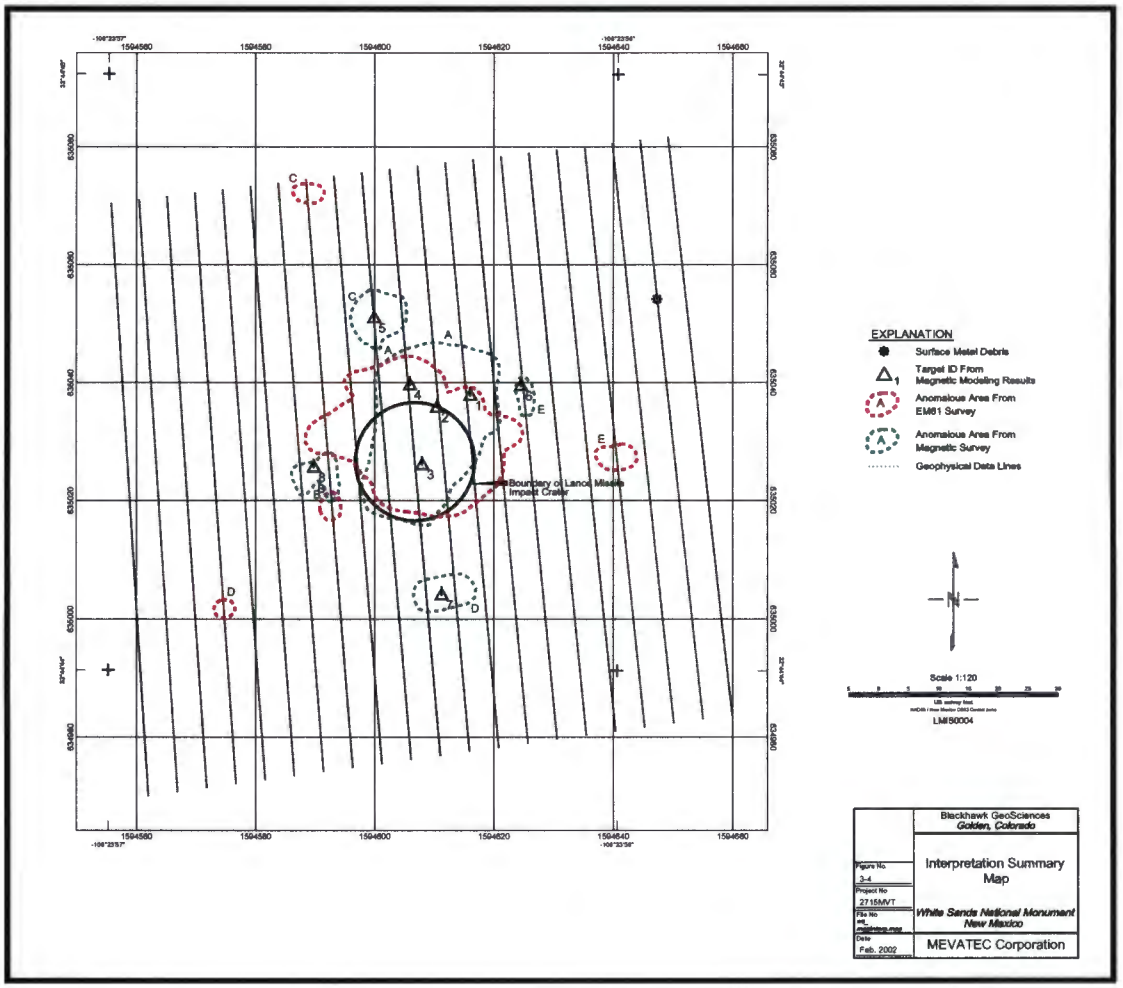


Figure 4-1. Geophysical Survey Interpretation Summary Map.

Table 4-1. EM-61 Anomalies.

Anomaly	Northing	Easting	Comment
A	1594606.54	635029.49	Very large and significant anomaly. Likely comprised of several targets. Corresponds to magnetometer anomaly "A"
B	1594592.79	635019.04	Small confined target. May correspond to magnetometer anomaly "B".
C	1594588.71	635072.03	Isolated, small target. No corresponding magnetometer anomaly.
D	1594574.59	635002.05	Small confined target. No corresponding magnetometer anomaly.
E	1594640.50	635027.18	Isolated, small target. No corresponding magnetometer anomaly.

Five magnetic anomalies from the magnetometer were also detected at the impact site (Table 4-2 and Figure 4-1). A significant increase in recorded instrument response from the magnetometer was detected in the center of the grid corresponding to the EM-61 anomaly "A" (red color on Figure 4-1). This magnetometer anomaly is mapped in Figure 4-1 as magnetic survey anomaly "A" (green color on Figure 4-1). Several other smaller anomalies are mapped "B" through "E" (green color on Figure 4-1) and probably represent smaller metallic parts of the Lance missile.

Table 4-2. Magnetometer Anomalies

Anomaly	Northing	Easting	Comment
A	1594610.92	635034.07	Very large magnetometer anomaly. Likely comprised of several objects. Corresponds to EM-61 anomaly "A".
B	1594590.21	635024.81	Weak anomaly. Likely corresponds to EM-61 anomaly "B".
C	1594600.03	635050.64	Strong magnetic anomaly. No corresponding EM-61 anomaly.
D	1594610.89	635004.38	Significant isolated anomaly. No corresponding EM-61 anomaly.
E	1594625.05	635038.16	Weak anomaly. No corresponding EM-61 anomaly.

The most significant result from the geophysical survey is the correspondence between both the EM-61 and magnetometer methods in the center of the survey grid (located over the impact crater to just north of the crater). This area represents the bulk of the buried portion of the Lance missile. The remaining anomalies represent smaller portions of Lance missile debris. Where the EM-61 detected an anomaly without a corresponding magnetometer anomaly, the object may be non-ferrous (possibly aluminum). Where the magnetometer detected an anomaly without a corresponding EM-61 anomaly, the object is likely ferrous iron. The deepest object detected during the survey was at approximately 3 m (9.7 ft) bgs beneath the center of the impact crater.

4.1.2 Hollow-Stem Augering

On 19-26 March 2002, 16 soil borings were augered using hollow-stem drilling techniques at the Lance missile impact site for the collection of subsurface soil samples and installation of ground-water monitoring wells. Figure 4-2 shows soil boring and monitoring well locations with respect to the geophysical anomaly data. Also, three borings were hand augered for collection of additional soil samples. Table 4-3 lists all soil borings including soil boring identification and sample depths.

Table 4-3. Lance Missile Impact RFI Soil Borings.

Soil Boring	Sample Identification	Sample Depth Interval (ft bgs)	Soil Boring	Sample Identification	Sample Depth Interval (ft bgs)
SB-01	0168-SB01-(0.0-0.5)	0.0-0.5	SB-06	0168-SB06-(0.0-0.5)	0.0-0.5
	0168-SB01-(5.0-7.0)	5.0-7.0		0168-SB06-(4.0-6.0)	4.0-6.0
	0168-SB01-(9.0-9.8)	9.0-9.8		0168-SB06-(9.0-11.0)	9.0-9.5
SB-02	0168-SB02-(0.0-0.5)	0.0-0.5	SB-07	0168-SB07-(0.0-0.5)	0.0-0.5
	0168-SB02-(4.0-6.0)	4.0-6.0		0168-SB07-(4.0-6.0)	4.0-6.0
	0168-SB02-(9.0-11.0)	9.0-9.8		0168-SB07-(9.0-11.0)	9.0-9.5

Soil Boring	Sample Identification	Sample Depth Interval (ft bgs)	Soil Boring	Sample Identification	Sample Depth Interval (ft bgs)
SB-03	0168-SB03-(0.0-0.5)	0.0-0.5	SB-08	0168-SB08-(0.0-0.5)	0.0-0.5
	0168-SB03-(5.0-7.0)	5.0-7.0		0168-SB08-(4.0-6.0)	4.0-6.0
	0168-SB03-(8.0-10.0)	8.0-8.5		0168-SB08-(9.0-11.0)	9.0-9.7 .
SB-04	0168-SB04-(0.0-0.5)	0.0-0.5	LMW-02	0168-LMW02-(0.0-0.5)	0.0-0.5
	0168-SB04-(5.0-6.0)	5.0-6.0		0168-LMW02-(5.0-7.0)	5.0-7.0
	0168-SB04-(9.0-110.)	9.0-9.7		0168-LMW02-(10.0-11.0)	10.0-11.0
SB-05	0168-SB05-(0.0-0.5)	0.0-0.5	LMW-03	0168-LMW03-(0.0-0.5)	0.0-0.5
	0168-SB05-(4.0-6.0)	4.0-6.0		0168-LMW03-(4.0-6.0)	4.0-6.0
	0168-SB05-(9.0-11.0)	9.0-9.5		0168-LMW03-(9.0-11.0)	9.0-9.6

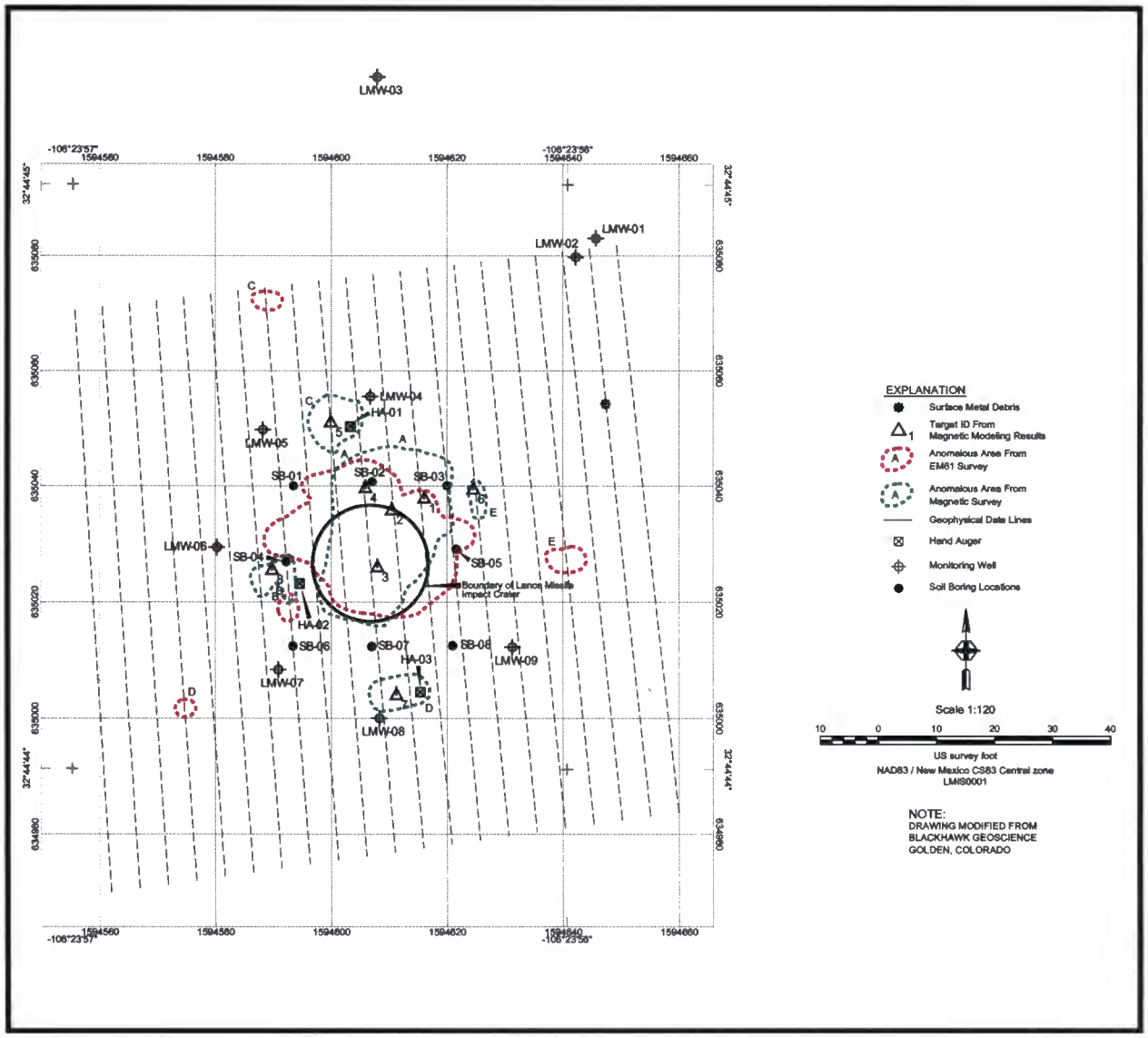


Figure 4-2.
Soil Borings and Monitoring Well Locations Superimposed on the Geophysical Survey Interpretation Summary Map (modified from Blackhawk Geosciences, Inc., 2002)

Logistics

Due to the remoteness of the site and the inability to travel overland to the actual impact site, it was necessary to air lift all field equipment and personnel for the investigation. Army Air UH-1 Helicopters were used for this task. Personnel and equipment were staged at Seehorn site located on Range Road 7 approximately 5 miles west of the impact site. All equipment and personnel were transported from Seehorn on 19 March 2002 to the impact site on the WSNM. A CS-1000 trailer mounted drill rig was used for this investigation for its ability to be transported by helicopter. The drill rig consists of 5 components each of which was individually air lifted to the site. Photographs 4-3 through 4-5 shows the drill rig being pieced together at the impact site. Following completion of the soil borings and monitoring well installation on 26 March 2002, all equipment was air lifted out of the WSNM back to Seehorn. The helicopter remained on standby at the site during the duration of the field investigation to ensure transportation of personnel from the site in case of an emergency.

Photograph 4-3. Assembly of CS-1000 Trailer Mounted Drill Rig (motor assembly).

Photograph 4-4. Assembly of CS-1000 Trailer Mounted Drill Rig (drill mast assembly).

Photograph 4-5. Fully Assembled CS-1000 Trailer Mounted Drill Rig.

Soil Borings and Sampling

Eight (8) soil borings (Figure 4-2) were completed to refusal at the compass points around the impact crater. Soil samples were collected from each boring starting at the surface and continuing to depth at approximate 5 foot intervals for a total of 3 soil samples per boring. The first set of four soil borings were completed at a distance of 5 ft from the crater lip directly north, south, east, and west of the crater. The second set of four soil borings were completed at a distance of 10 ft from the crater lip directly northeast, southeast, northwest, and southwest of the crater. Hand auger samples were collected at specific locations out from the crater that corresponded to magnetic anomalies (Figure 4-2). Additionally, soil samples were collected from the augering of the monitoring wells upgradient of the impact site (LMW-02 and LMW-03) and analyzed for background concentrations. A total of 30 primary soil samples were collected and analyzed for the constituents listed in Table 4-4 on the following page. Four "blind" duplicate samples were also collected and analyzed for the same constituents for laboratory analytical quality control (QC).

Soil borings were completed using a continuous-flight, hollow-stem auger mounted on a CME-1000 drill rig (Photograph 4-6). The soil borings were augered using 11-centimeter (4.5 inch) inside diameter, 1.5 m (5 ft) length auger flights. Stainless steel 0.6 m (2 ft) long 5 cm (2 inch) O.D. split-barrels were used to collect samples for chemical analysis. The split-barrel samplers were driven with a hammer over a depth of 30.5 cm to 61 cm (12 to 24 inches).

Photograph 4-6. CS-1000 Drill Rig set up on 0168-SB01.

Table 4-4. RFI Analytical Constituents for Soil and Ground Water.

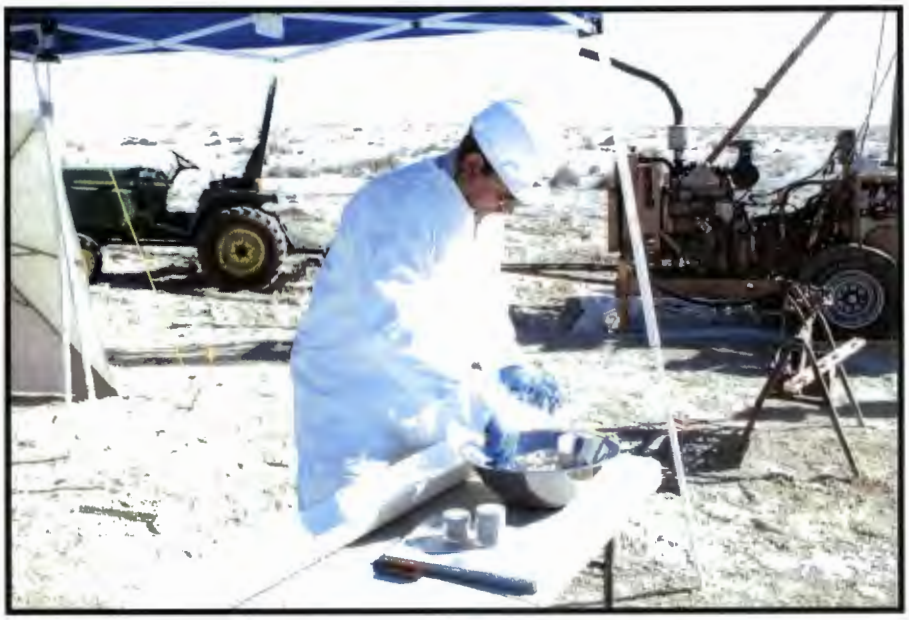
Analytical Parameter	Analytical Method	Soil Lab Reporting Limit (mg/Kg)	Groundwater Lab Reporting Limit (mg/L)
Unsymmetrical Dimethylhydrazine (UDMH)	Note 1	0.06	0.01
Nitrosodimethylamine (NDMA)	EPA 607	1.5E-4	5.0E-6
Nitrodimethylamine (DMN)	EPA 607	1.5E-4	5.0E-6
Benzene	SW846-8260B	1.0E-2	5.0E-3
Toluene	SW846-8260B	1.0E-2	5.0E-3
Ethylbenzene	SW846-8260B	1.0E-2	5.0E-3
Xylene	SW846-8260B	1.0E-2	5.0E-3
Physical Characteristics			
Specific Conductivity	EPA 120.1	NA	10.0
Laboratory pH	EPA 150.1	NA	NA
Total Dissolved Solids	EPA 160.1	NA	10.0
Dissolved Chloride	EPA 300.0	NA	0.10
Nitrate	EPA 300.0	NA	2.0
Dissolved Sulfate	EPA 300.0	NA	10
Bicarbonate Alkalinity/Carbonate Alkalinity	EPA 310.1	NA	1.0
RCRA Metals			
Arsenic	SW 846-6010A	1.0	0.005
Barium	SW 846-6010A	10.0	0.006
Cadmium	SW 846-6010A	1.00	0.0005
Chromium	SW 846-6010A	1.0	0.004
Lead	SW 846-6010A	1.0	0.003
Mercury	SW 846-7000A	0.10	0.0002
Selenium	SW 846-6010A	1.0	0.005
Silver	SW 846-6010A	1.0	0.01
TCLP Metals		**(Leachate mg/L)**	
Arsenic	EPA 1311/6010A	0.05	NA
Barium	EPA 1311/ 6010A	0.10	NA
Cadmium	EPA 1311/ 6010A	0.05	NA
Chromium	EPA 1311/ 6010A	0.10	NA
Lead	EPA 1311/ 6010A	0.05	NA
Mercury	EPA 1311/7000A	0.001	NA
Selenium	EPA 1311/ 6010A	0.05	NA
Silver	EPA 1311/ 6010A	0.10	NA

NA - Not applicable to the analysis.
Note 1 – High performance Liquid Chromatography with Amperometric Detection.

When the split-barrel was removed from the boring and opened, any material appearing to be slough was removed. With the exception of volatile sample collection, soil from the split-barrel was placed in a stainless steel bowl and then composited with a decontaminated stainless steel trowel. Compositing consisted of breaking aggregates apart and mixing the soil together to homogenize the soil as much as possible. Following compositing the soil from this bowl was placed into the sampling jars. Volatile samples were collected directly from the split-barrel sampler without compositing and placed directly into the sample jar. Excess soil around the top of the sample jars was wiped away with a clean paper towel to ensure the cap would fit tightly.

A Multi-RAE photo-ionization detector (PID) was used to collect volatile readings from the sampling apparatus immediately upon removal from the subsurface. No anomalous readings for VOCs, CO, or H_2S were detected with the PID.

Depth-discrete soil samples were collected at the indicated depth interval (Table 4-1) of the bottom 0.3 m (1 ft) of the soil boring. When the split-barrel was removed from the boring and opened, the soil core was carefully transferred to a clean polyvinyl chloride (PVC) for lithologic logging by the field geologist and for collection of chemical samples (Photograph 4-7). All soil cores were photographed for documentation and inclusion in the RFI project files. Chemical samples were placed in clean, new glass jars with Teflon-lined caps provided by the laboratory and packed with zero headspace.



Photograph 4-7. Collection of Soil Sample for Chemical Analysis.

Following completion of each soil boring, the boring was backfilled using bentonite chips. Drill cuttings were placed in 55-gallon open topped drums and secured. The location of each soil boring was surveyed using a Global Positioning System (GPS) unit to an accuracy of plus or minus 1 m (3.2 ft). GPS coordinates collected at the Lance impact site are included in Table 4-5.

Table 4-5. GPS Coordinates.

GPS Point	Northing UTM	Easting UTM	Elevation (ft)
SB-01	3623961.392	368926.264	3896.8
SB-02	3623962.23	368931.235	3897.02
SB-03	3623962.648	368935.388	3897.49
SB-04	3623956.333	368927.857	3899.5
SB-05	3623957.124	368936.467	3899.44
SB-06	3623951.464	368928.568	3899.67
SB-07	3623951.662	368932.66	3899.47
SB-08	3623952.648	368936.614	3900.44

All soil samples collected for this investigation were assigned sample numbers as follows:

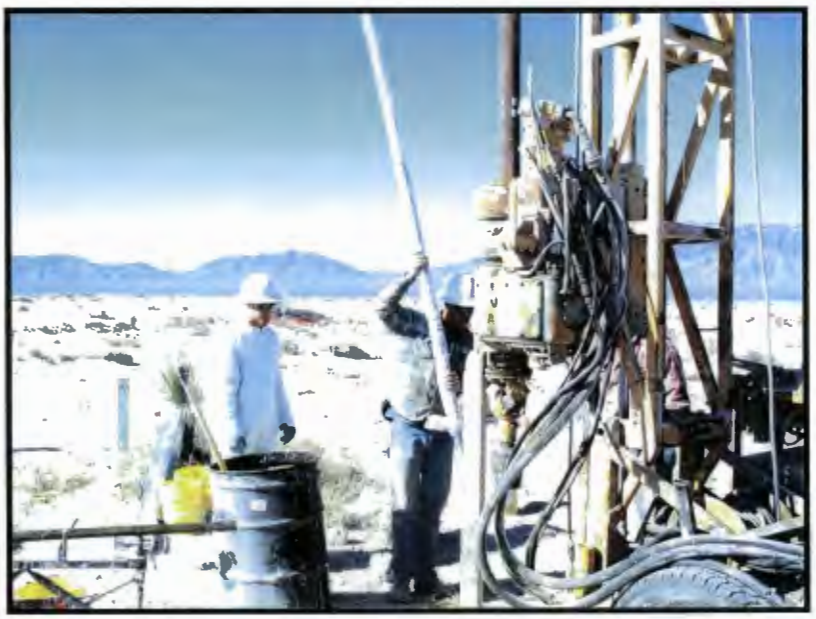
For surface and subsurface soil samples: #### xxyy (zzz.z)

where:
- #### = SWMU number or well number prefix
- xx = sample location type
  - where: HA = hand auger
  - BH = bore hole
  - LMW = Lance monitor well
- yy = sample location number
- zzz.z = sample depth interval

Monitoring Well Installation

The design for the monitoring well installation (LMW-02 through LMW-08) was based on the need to confirm the direction of ground-water flow at the impact site and to provide monitoring wells for ground-water sampling and analysis.

The well riser for the monitoring wells installed for this investigation consisted of new threaded, flush joint, stainless steel Schedule 40 pipe of 5 cm (2-inch) nominal diameter. A one ft (0.3 m) section of riser pipe (sand trap), with a bottom cap, was constructed at the base of the screen (Photograph 4-8). Screen and riser sections were joined by threaded flush-joint couplings, to form water-tight unions that retain 100% of the strength of the screen. Solvent glues, cements, or adhesive tapes were not used to join sections of pipe and screen. Stainless steel riser and screen was chosen based on ground-water chemistry. If the organic fuel was present in the ground water, PVC pipe may react with it. Additionally, the stainless steel will provide excellent resistance to corrosion and oxidation which may be encountered with high TDS ground water.



Photograph 4-8. Installation of Monitoring Well Casing.

The well screen for the groundwater monitoring wells consisted of new, threaded, flush joint, nominal 2-inch (5 cm) diameter Schedule 40 stainless steel. The screens were non-contaminating, factory constructed, of "continuous wrap" design. Field slotted or cut screen was not used. The slot size for the well screen used is No. 5 size (0.005 inch) so that it would be compatible with the aquifer and gravel pack material.

A 2 ft seal consisting of bentonite pellets and chips was placed into the annular space between the riser and boring wall. The bentonite seal was installed above the filter pack and hydrated by charging the hole with approved potable water.

Filter pack material consisted of clean, washed, well graded, rounded to subrounded silica sand. Grain size (20-40 mesh size with uniformity coefficient in the range of 1.1-1.6) was selected so as to exclude the majority of the material in the aquifer. The filter pack was placed 1 foot below the base of the sand trap to just above the top of the screened interval.

Upon completion of the well, a PVC cap was installed to help prevent material from entering the well. A protective above-grade aluminum shroud with a locking cap was centered around the well (Photograph 4-9). The protective well casing rose approximately 0.6 m (2 ft) above ground level. To minimize impact to the site, as requested by the WSNM, a well pad was not constructed for the monitoring wells. The well construction completion diagrams for the monitoring wells are included in Appendix D.

Photograph 4-9. Protective above Grade Aluminum Shroud.

All wells were developed following installation. Development continued until the pH, temperature, and conductance of the groundwater had stabilized. Stability was defined as three consecutive sets of temperature and conductance values within ± 5 percent of each other, and pH within 0.1 units. The volume of water removed between measurement sets was 19 liters (l) (5 gallons). Approximately 35 gallons was removed from each well during the development process. All development water was containerized in 55-gallon closed top drums.

On 13 May 2002, all monitoring wells were surveyed by Donohue Land Surveys (P.L.S. 8172) to the nearest 0.01 ft. The survey included the latitude and longitude coordinates for the monitoring well brass caps and the elevation of the brass cap and well riser (Appendix E).

4.2 Data Analysis

Soil and water samples for analysis of metals, DMN, NDMA, and benzene, toluene, ethylbenzene, and xylene (BTEX) were delivered by Federal Express to Laucks Testing Laboratories (940 South Harney Street; Seattle, Washington 98108). Samples for UDMH analysis were delivered by courier to the National Aeronautics and Space Administration (NASA), Lyndon B. Johnson Space Center, White Sands Test Facility (Las Cruces, New Mexico 88004) for analysis. All soil and water samples collected for the Lance missile impact RFI arrived at the laboratory in good condition and within temperature requirements (2° C to 6° C) with the exception of ground-water samples from LMW-04 and LMW-05 sent to Laucks Testing Laboratories. The cooler for these samples arrived at the laboratory at 8.0 °C which was slightly above temperature requirements for BTEX. The analytical method for metals does not require temperature preservation. The UDMH samples were delivered directly to the NASA laboratory within temperature requirements. Results for the LMW-04 and LMW-05 samples were consistent with all other samples collected at the site. The higher temperature should have had negligible effects on the samples.

All samples were extracted and analyzed within Environmental Protection Agency (EPA) maximum holding times for each analyte. Requirements for the soil sampling and analysis are included in Table 4-4.

4.2.1 Site Specific Lithology/Hydrology

The site specific lithology in the immediate area of the Lance missile impact was obtained from the field geologist's lithologic logs of the soil borings. A copy of all field logs is included as Appendix F. The interval from ground surface to 2 m (7 ft) bgs is characterized as mottled white/grey unconsolidated fine gypsum sand and silt with dark black organic matter. This zone is saturated from approximately 0.8 m (2.5 ft) to approximately 2 m (7 ft) bgs. From 2 m (7 ft) bgs to 3.7 m (12 ft) bgs, the interval is characterized as mottled white/grey consolidated gypsum sand with organic matter. The lithologic interval from approximately 2 m (7 ft) to approximately 3.5 m (11.5 ft) bgs is unsaturated (dry). A saturated zone is present from approximately 3.5 m (11.5 ft) to approximately 3.7 m (12 ft) bgs. The interval from 3.7 m (12 ft) to 3.8 m (12.5 ft) bgs is characterized as dry solid crystalline halite.

The soil boring for LMW-01 (believed to be upgradient of the impact crater) was the first and the deepest boring augered at the Lance impact site. It was augered to a depth of 3.8 m (12.5 ft) bgs where the auger became stuck in the compact gypsum/halite. LMW-01 was augered using continuous coring. All other soil borings were augered with samples collected using a split spoon and driven with a hammer (as described in Section 4.1.2.2). Refusal at approximately 2.9 m (9.5 ft) bgs occurred in all of the soil borings using the split spoon sampling technique. Auger refusal is commonly determined after 50 hammer blow counts for driving the split spoon 6 inches or less. During soil sampling for this investigation, we commonly drove the split spoon less than one ft (7 to 8 inches) using up to 100 hammer blow counts.

Augering through the compacted gypsum layer, from 2m (7 ft) bgs to 3.5 m (11.5 ft) bgs, was much slower than the uncompacted gypsum sand and silt layers above. The rate for augering/sampling through the uncompacted gypsum materials ranged from 1.5 to 3 minutes per foot. The augering/sampling rate through the compacted gypsum increased to range from 5 to 11 minutes per foot. The performance of the drill rig noticeably decreased while augering in the compacted gypsum layer.

The unsaturated, compact gypsum and underlying halite were determined by the on-site geologist to be confining layers and the decision was made (in consultation with NMED HWB) not to drill beneath them to prevent possible contaminant migration. This confining layer is compact enough to prevent migration of water from the overlying saturated zone.

This decision was supported by evidence from the geophysical survey. The results of the geophysical survey indicated that the deepest penetration of the Lance missile was 9.7 ft bgs. If fuel was present in the missile components at 9.7 ft bgs, then it was possible that drilling beneath this interval could possible create a path for contaminant migration downward.

4.2.2 Soil Data Chemical Analysis

Table 4-6 lists analytical results from soil sampling at the Lance missile impact site as compared to NMED SSLs. Samples from 0168-LMW02 and 0168-LMW03 represent background conditions at the site. None of the samples were detected in concentrations above there respective NMED SSLs. All samples collected had no detectable concentrations of UDMH, NDMA, or DMN. Benzene was detected in the HA02 sample (one sample only) at 0.007 mg/kg. This detection was just above the laboratory detection limit of 0.004 mg/kg and is likely laboratory contamination. There were no detections of toluene, ethylbenzene, or xylene. Concentrations of total RCRA metals were consistent with background concentrations.

Table 4-6. Analytical Results from the Impact Crater Soil Borings.

Analytes	NMED SSL	0168-SB01			0168-SB02			0168-SB03			0168-SB04			0168-SB05		
		0.0-0.5	5.0-7.0	9.0-9.8	0.0-0.5	4.0-6.0	9.0-9.5	0.0-0.5	5.0-7.0	8.0-8.6	0.0-0.5	5.0-7.0	9.0-9.7	0.0-0.5	4.0-6.0	9.0-9.5
Volatiles (mg/kg)																
Unsymmetrical Dimethylhydrazine UDMH	NE	<0.063	<0.081	<0.090	<0.061	<0.073	<0.082	<0.064	<0.076	<0.089	<0.066	<0.069	<0.067	<0.063	<0.069	<0.061
Nitrosodimethylamine NDMA	0.095	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Nitrodimethylamine DMN	NE	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Benzene	6.4	<0.004	<0.004	<0.005	<0.004	<0.004	<0.005	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Toluene	180	<0.004	<0.004	<0.005	<0.004	<0.004	<0.005	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Ethylbenzene	68	<0.004	<0.004	<0.005	<0.004	<0.004	<0.005	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Xylenes	63	<0.004	<0.004	<0.005	<0.004	<0.004	<0.005	<0.004	<0.004	<0.005	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
RCRA Metals (mg/kg)																
Arsenic	3.9	1.1	1.2	1.0B	1.3	1.4	1.1B	<0.40	0.57B	<0.60	0.60B	1.3	0.67B	0.53B	1.7	<0.40
Barium	5,200	27.1	18.9B	46.2	44.8	23.0	12.6B	31.3	21.2B	5.2B	22.8	26.5	6.9B	18.5B	115	2.1B
Cadmium	70	0.12B	0.15B	0.12B	0.19B	0.09B	0.07B	0.07B	0.06B	<0.07	<0.06	0.09B	0.07B	0.05B	0.27B	<0.05
Chromium	230	1.3	1.0B	3.6	3.6	1.0B	2.2	0.70B	0.99B	0.76B	1.1B	0.39B	2.1	0.98	6.7	0.63B
Lead	400	1.1	0.69B	2.3	3.9	0.91B	1.5	0.79B	0.59B	0.61B	1.2	1.3	1.3	1.0	4.3	0.34B
Selenium	390	0.41B	0.87B	0.97B	0.41B	1.1B	0.67B	0.45B	0.94B	<0.39	0.76B	1.1B	0.29B	<0.26	1.3	<0.26
Silver	390	0.10B	<0.03	<0.04	<0.03	<0.03	<0.04	<0.03	<0.03	<0.04	<0.03	<0.011	<0.009	<0.03	<0.03	<0.03
Mercury	6.5	<0.010	<0.011	<0.014	<0.007	<0.010	<0.014	<0.007	<0.012	<0.014	<0.011	<0.03	<0.03	<0.010	<0.011	<0.011
TCLP Metals (mg/l)																
Arsenic	5.0*	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043
Barium	100.0*	0.277B	0.0684B	0.0449B	0.153B	0.0604B	0.0813B	0.135B	0.667B	0.0431B	0.107B	0.0439B	0.089B	0.182B	0.108B	0.0544B
Cadmium	1.0*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	5.0*	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Lead	5.0*	<0.024	<0.024	<0.024	<0.024	<0.024	0.024B	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024
Selenium	1.0*	<0.028	<0.028	<0.028	0.031B	<0.028	0.0312B	<0.028	<0.028	<0.028	<0.028	<0.028	<0.028	<0.028	<0.028	<0.028
Silver	5.0*	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Mercury	0.2*	0.00032B	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.002	<0.0002	<0.002	<0.0002

< Less than the indicated laboratory reporting limit.
NE Not Established.
* Maximum Concentration of Contaminants for Toxicity Characteristic.
B The reported value was less than the laboratory reporting limit but greater than the instrument detection limit.

Table 4-6. Analytical Results from the Impact Crater Soil Borings. *(continued)*

Analytes	NMED SSL	0168-SB06			0168-SB07			0168-SB08			0168-HA01 (2.0-3.0)	0168-HA02 (5.0-6.0)	0168-HA03 (9.0-10.0)
		0.0-0.5	4.0-6.0	9.0-9.5	0.0-0.5	4.0-6.0	9.0-9.5	0.0-0.5	4.0-6.0	9.0-9.7			
Volatiles (mg/kg)													
Unsymmetrical Dimethylhydrazine UDMH	NE	<0.065	<0.074	<0.060	<0.062	<0.076	<0.061	<0.062	<0.073	<0.063	<0.072	<0.076	<0.077
Nitrosodimethylamine NDMA	0.095	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Nitrodimethylamine DMN	NE	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Benzene	6.4	<0.004	<0.004	<0.004	<0.003	<0.004	<0.004	<0.003	<0.004	<0.004	<0.004	0.007	<0.004
Toluene	180	<0.004	<0.004	<0.004	<0.003	<0.004	<0.004	<0.003	<0.004	<0.004	<0.004	<0.004	<0.004
Ethylbenzene	68	<0.004	<0.004	<0.004	<0.003	<0.004	<0.004	<0.003	<0.004	<0.004	<0.004	<0.004	<0.004
Xylene	63	<0.004	<0.004	<0.004	<0.003	<0.004	<0.004	<0.003	<0.004	<0.004	<0.004	<0.004	<0.004
RCRA Metals (mg/kg)													
Arsenic	3.9	0.99	1.2	<0.46	0.80B	0.83B	0.83B	<0.38	1.4	<0.48	1.6	0.88B	<0.47
Barium	5,200	34.2	40.5	8.8B	8.4B	29.8	28.4	11.0B	9.2B	11.5B	61.9	33.2	17.6B
Cadmium	70	0.06B	0.09B	<0.05	<0.05	<0.05	0.10B	0.06B	0.13B	0.08B	0.17B	0.10B	0.09B
Chromium	230	1.1	3.9	0.96B	0.83B	2.7	1.9	0.68B	2.7	2.0	4.6	2.0	0.71B
Lead	400	0.84B	1.9	0.78B	0.78B	1.5	1.5	0.70B	2.0	1.4	3.4	1.6	0.76B
Selenium	380	0.37B	0.85B	0.56B	0.69B	0.89B	0.71B	<0.25	0.84B	0.55B	4.5	0.91B	0.64B
Silver	380	<0.03	<0.03	0.05B	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.010	<0.011	<0.011B
Mercury	6.5	<0.007	<0.008	<0.009	<0.010	<0.013	<0.008	<0.010	<0.010	<0.013	<0.04	<0.03	<0.03
TCLP Metals (mg/l)													
Arsenic	5.0*	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043	<0.043
Barium	100.0*	0.170B	0.113B	0.0591B	0.156B	0.0938B	0.0918B	0.117B	0.0986B	0.0573B	0.121B	0.070B	0.0829B
Cadmium	1.0*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	5.0*	<0.007	<0.007	<0.007	<0.007	<0.007	0.0447	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Lead	5.0*	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024
Selenium	1.0*	<0.028	0.0305B	<0.028	<0.028	0.0315B	<0.028	<0.028	<0.028	<0.028	0.0297B	<0.028	<0.028
Silver	5.0*	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Mercury	0.2*	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002

< Less than the indicated laboratory reporting limit.
NE Not Established.
* Maximum Concentration of Contaminants for Toxicity Characteristic.
B The reported value was less than the laboratory reporting limit but greater than the instrument detection limit.

Table 4-6. Analytical Results from the Impact Crater Soil Borings.
(concluded)

Analytes mg/kg	NMED SSL	0168-LMW02 (background)			0168-LMW03 (background)		
		0.0-0.5	5.0-7.0	10.0-11.0	0.0-0.5	4.0-6.0	9.0-9.6
Volatiles (mg/kg)							
Unsymmetrical Dimethylhydrazine UDMH	NE	<0.060	<0.075	<0.057	<0.064	<0.075	<0.060
Nitrosodimethylamine NDMA	0.095	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Nitrodimethylamine DMN	NE	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Benzene	6.4	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Toluene	180	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Ethylbenzene	68	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Xylene	63	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
RCRA Metals (mg/kg)							
Arsenic	3.9	<0.39	1.2	<0.39	0.70 B	3.0	<0.39
Barium	5,200	11.1B	27.7	19.3	24.6	21.6	3.5B
Cadmium	70	0.05B	0.08B	0.05B	0.14B	0.10B	0.08B
Chromium	230	0.53B	1.4	1.0	1.4	0.87B	0.74B
Lead	400	0.59B	1.0	0.78B	1.4	1.6	0.86B
Selenium	380	0.28B	0.53B	<0.26	0.60B	3.0	0.40B
Silver	380	<0.03	<0.03	<0.03	<0.012	<0.011	<0.010
Mercury	6.5	<0.009	<0.011	<0.009	<0.03	<0.03	<0.03
TCLP Metals (mg/l)							
Arsenic	5.0*	<0.043	<0.043	<0.043	<0.043	0.0647B	<0.043
Barium	100.0*	0.153B	0.734B	<0.0547B	0.131	0.0519B	0.0594B
Cadmium	1.0*	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Chromium	5.0*	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Lead	5.0*	<0.024	<0.024	<0.024	<0.024	<0.024	<0.024
Selenium	1.0*	<0.028	<0.028	<0.028	<0.028	0.0292B	<0.028
Silver	5.0*	<0.003	<0.003	<0.003	<0.003	0.003B	<0.003
Mercury	0.2*	<0.0002	<0.0002	<0.0002	<0.002	<0.0002	<0.0002

< Less than the indicated laboratory reporting limit.
NE Not Established.
* Maximum Concentration of Contaminants for Toxicity Characteristic.
B The reported value was less than the laboratory reporting limit but greater than the instrument detection limit.

4.2.3 Ground-Water Flow Direction

Prior to sampling monitoring wells, the water level was measured to the nearest 0.01 ft with an electronic water level indicator. Water levels in the monitoring wells were measured from a mark at the top of the stainless steel casing (north side of the casing). The water level indicator probe was decontaminated prior to and after use by rinsing with water meeting requirements of ASTM Type II reagent water. Table 4-7 lists all depth to water measurements including surveyed (professional) elevation of brass cap and top of casing. Figure 4-3 shows monitoring well locations with ground-water elevations. A three-point problem has been completed and overlays the Figure 4-3 monitoring wells indicating ground-water flow direction. Based on the May 2002 depth to water (DTW) measurements and ground-water elevation, the ground-water flow direction is to N70W. However, the ground-water gradient (0.0004) is so shallow that ground water at the Lance impact site is near horizontal.

Table 4-7. Depth to Water Measurements.

Well I.D.	TOC Elevation (Surveyed) feet	Brass Cap Elevation (Surveyed) feet	LOC (Surveyed) feet	DTW from TOC (May 2002) feet	DTW BGS (May 2002) feet	Groundwater Elevation (May 2002) feet
LMW-02	3,895.02	3,893.15	1.87	4.25	2.38	3,890.77
LMW-03	3,895.36	3,893.17	2.19	4.60	2.41	3,890.76
LMW-04	3,894.72	3,892.68	2.04	3.95	1.91	3,890.77
LMW-05	3,894.80	3,893.00	1.80	4.06	2.25	3,890.75
LMW-06	3,894.41	3,892.57	1.84	3.66	1.82	3,890.75
LMW-07	3,894.89	3,892.85	2.04	4.11	2.07	3,890.78
LMW-08	3,895.03	3,892.89	2.14	4.24	2.10	3,890.79
LMW-09	3,894.98	3,892.97	2.01	4.20	2.19	3,890.78

TOC Top of Casing. LOC Length of Casing. DTW Depth to Water.

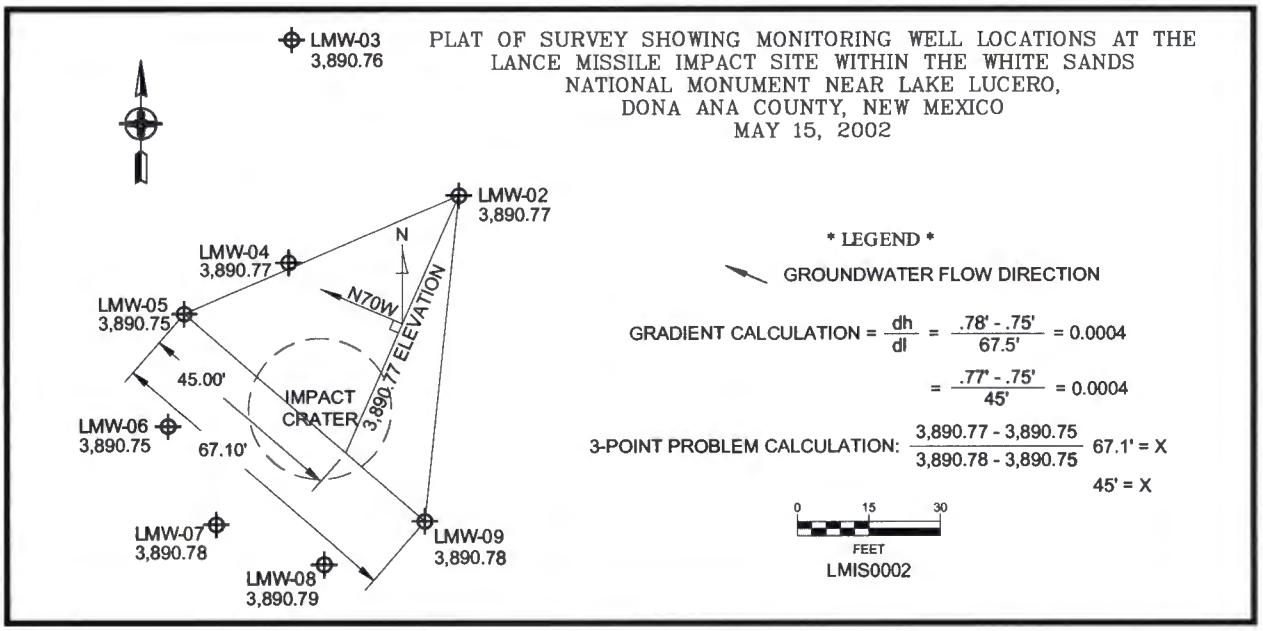


Figure 4-3. Ground Water Flow Direction (three-point problem) (modified from Donohue Land Survey, 2002).

4.2.4 Ground-Water Sampling

Ground-water sampling was conducted on 13-14 May 2002 following sufficient time for the monitoring wells to equilibrate. Prior to sampling, monitoring wells were purged in order to obtain samples of formation water. All purging of the 2-inch diameter wells was performed with 1-inch disposable bailers. Purging of all wells continued until three casing volumes were removed and the field parameters of pH, temperature and conductivity stabilized. These parameters were considered stable when three consecutive readings had a temperature $\pm$ 0.5° C, pH was $\pm$ 0.1 units and conductivity was $\pm$ 1%. All purged water was containerized in 55-gallon closed top drums. All of the monitoring wells were sampled with new, clean Teflon bailers. New nylon bailer cord was used with each bailer at all of the wells. Sample containers were filled directly from the bailer. All containers were supplied by the analytical laboratory pre-cleaned according to USEPA protocols. Groundwater pH, temperature, and conductivity was measured using a Hydac® Water Quality Monitor and is included in Table 4-8.

Table 4-8. Water pH, Temperature, and Conductivity Measurements.

Well #	Water Sample Temperature °C (°F)	Water Sample Conductivity (µS/cm)	Water Sample pH
LMW-02	18.5 (65.3)	>19,999	8.30
LMW-03	17.4 (63.3)	>19,999	8.42
LMW-04	21.1 (70.0)	>19,999	8.11
LMW-05	19.9 (67.9)	>19,999	8.09
LMW-06	18.6 (65.5)	>19,999	7.75
LMW-07	16.7 (62.0)	>19,999	8.06
LMW-08	22.3 (72.2)	>19,999	7.95
LMW-09	20.5 (68.9)	>19,999	7.90

µS/cm Microsiemens per centimeter.

4.2.1 Ground-Water Chemical Analysis

With the exception of sulfate, chloride, and total dissolved solids (TDS), all detections were well below there respective New Mexico Water Quality Control Commission (WQCC) Standards. Sulfate was detected above the WQCC standard of 600 mg/l ranging from 16,000 mg/l to 44,000 mg/l in the ground-water samples. Chloride was detected above the WQCC standard of 250 mg/l ranging from 440 mg/l to 1,100 mg/l. TDS was detected above the 1,000 mg/l WQCC standard ranging from 23,000 mg/l to 63,000 mg/l. These concentrations are consistent with the high dissolved solids concentrations expected in waters of the Tularosa Basin as discussed in Sections 2.2.3 and 2.3. The analytical laboratory reported UDMH, NDMA, DMN, benzene, toluene, ethylbenzene, and xylene as all less than their respective laboratory reporting limits (ND-Not Detected). All detected RCRA metals concentrations were below their respective WQCC standards. All contaminants analyzed during this RFI are included in Table 4-9 (on following page) along with their detected concentrations or reporting limits if not detected.

5.0 SITE CONCEPTUAL MODEL

The work plan for this investigation called for 8 soil borings around the crater to be augered and sampled to a depth of 25 ft bgs. Additionally, "nests" of monitoring wells were planned to sample ground-water at shallow, intermediate, and deeper depths. However, auger refusal was encountered at approximately 3 m (10 ft) bgs. Therefore, all soil borings and monitoring wells were not completed past this interval.

It was determined in the field that this depth and below represented a "boundary layer" which would act to retard possible contaminant migration. The lithology of the site (as described in Section 4.2.1) and information given by the geophysical survey indicating that missile debris was no deeper than 9.7 ft bgs supports this determination. Based on available data, the compact gypsum retarded the penetration of the missile causing debris to come to rest no deeper than 3 m (9.7 ft) bgs which is much shallower than the estimate from the Follow-On Assessment (Section 3.4) of 7 m (23 ft) bgs conducted in March 2000.

Table 4-9. Analytical Results from the Lance Impact Water Sampling.

Analytes	WQCC Std.	LMW-02	LMW-03	LMW-04	LMW-05	LMW-06	LMW-07	LMW-08	LMW-09	Surface Water in Crater
Volatiles (mg/l)										
Unsymmetrical Dimethylhydrazine UDMH	NE	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Nitrosodimethylamine NDMA	NE	<0.00001	<0.00001	<0.00001	<0.00001	0.000005J	<0.00001	<0.00001	<0.00001	<0.00001
Nitrodimethylamine DMN	NE	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Benzene	0.01	<0.02	<0.02	<0.02	<0.001	<0.001	<0.02	<0.001	<0.001	<0.001
Toluene	NE	<0.02	<0.02	<0.02	<0.001	<0.001	<0.02	<0.001	<0.001	<0.001
Ethylbenzene	0.75	<0.02	<0.02	<0.02	<0.001	<0.001	<0.02	<0.001	<0.001	<0.001
Xylene	0.62	<0.02	<0.02	<0.02	<0.001	<0.001	<0.02	<0.001	<0.001	<0.001
Total RCRA Metals (mg/l)										
Arsenic	NE	0.0263	0.021	0.0063B	0.0107	0.0106	0.0306	0.0112	0.0266	<0.0043
Barium	NE	0.359	0.138B	0.117B	0.218	0.266	0.206	0.202	0.527	0.0048B
Cadmium	NE	0.0034B	0.0024B	0.00076B	0.0011B	0.0014B	0.0047B	0.0013B	0.0024B	<0.0005
Chromium	NE	0.0361	0.0469	0.0095B	0.0396	0.0139	0.121	0.0191	0.0268	<0.0007
Lead	NE	0.0254	0.0066B	0.0052B	0.0104	0.0091B	0.0277	0.0096B	0.035	<0.0024
Selenium	NE	0.0167	0.0102	0.0061B	0.0074B	0.0096B	0.0183	0.0062B	0.0174	0.0038B
Silver	NE	<0.0003	0.00095B	<0.0003	<0.0003	<0.0003	<0.0011	<0.0003	<0.0003	<0.0003
Mercury	NE	<0.0004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
Dissolved RCRA Metals (mg/l)										
Arsenic	0.1	0.0086B	0.0056B	0.0062B	<0.0043	0.0067B	0.0058B	0.0053B	0.0126	0.0054B
Barium	1.0	0.0072B	0.0049B	0.0078B	0.0091B	0.0089B	0.0059B	0.012B	0.0178B	0.0067B
Cadmium	0.01	<0.0005	0.00054B	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.00059B	0.00071B
Chromium	0.05	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007	<0.0007
Lead	0.05	<0.0024	<0.0024	<0.0024	<0.0024	<0.0024	<0.0024	<0.0024	<0.0024	<0.0024
Selenium	0.05	0.0043B	<0.0028	0.0054B	0.0038B	0.0064B	0.0058B	0.0044B	0.0113	0.0069B
Silver	0.05	<0.0003	0.00035B	0.00052B	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003
Mercury	0.002	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
Nutrients, Physical Characteristics, and Ions (mg/l)										
Nitrate	10.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.0	<2.0
Sulfate	600	**21,000**	**61,000**	**41,000**	**23,000**	**17,000**	**44,000**	**23,000**	**13,000**	**16,000**
Bicarbonate	NE	120	160	100	120	110	150	120	110	84
Carbonate	NE	<4	28	<4	<4	<8	<4	<4	<8	32
Chloride	250	**620**	**810**	**740**	**580**	160	**690**	**450**	**440**	**1,100**
Conductance#	NE	32,000	51,000	42,000	27,000	23,000	41,000	26,000	21,000	21,000
pH	6-9	8.1	8.6	8.3	8.6	7.7	8.3	8.2	7.5	8.9
TDS	1,000	**38,000**	**63,000**	**55,000**	**34,000**	**25,000**	**57,000**	**30,000**	**23,000**	**23,000**

< Less than the indicated laboratory reporting limit.
NE Not Established.
Units for conductance are micromhos per centimeter (µmhos/cm).
Bold Detection in bold is higher than the New Mexico Standard.
B The reported value was less than the laboratory reporting limit but greater than the instrument detection limit.

Figure 4-4 is a cross-section of the Lance missile impact site. The cross-section was interpreted from the lithologic logs of the soil borings (as described in Section 4.2.1) and the geophysical survey (Section 4.1.1). The majority of the Lance missile debris is located from the center of the impact crater to approximately 3 m (10 ft) north of the lip of the crater. From approximately 0.8 m (2.5 ft) to approximately 2 m (7 ft) bgs the uncompacted gypsum sand and silt is saturated with ground water. The compacted gypsum interval from approximately 2 m (7 ft) to approximately 3.5 m (11.5 ft) bgs is unsaturated (dry). The deepest debris from the Lance missile is within this dry interval.

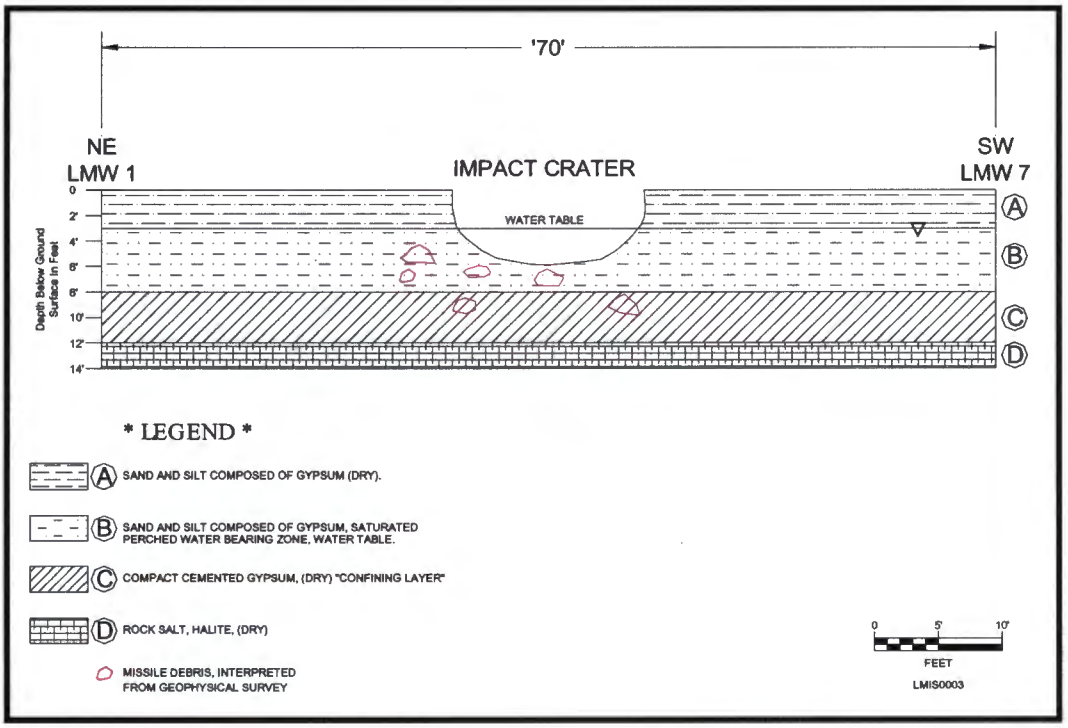


Figure 4-4. Interpreted Cross-Section of the Lance Missile Impact Site.

Given the analytical data from the soil samples and water samples collected during this RFI, no contaminants of concern (UDMH, NDMA, or DMN) were detected. This indicates that a release from the Lance missile to the surrounding soil and the saturated interval has not occurred or has dissipated through chemical reactions as follows:

- The propellant tanks probably ruptured upon impact causing a vigorous reaction between the IRFNA and UDMH. A hydrazine nitrate salt reaction product would slowly hydrolyze in water to form dilute nitrate compounds. However, nitrate was only detected in the sample from LMW-09 (2.0 mg/l).

- If only IRFNA was released, it would react with any oxidizable material present to form compounds. The IRFNA would likely dissipate through dilution in water forming a weak acidic nitrate solution.

- If only UDMH were released, it would react with any reducible compounds present in the environment to form a hydrazine-salt. UDMH is water soluble, so it would be expected to dilute in the ground water.

6.0 SITE ASSESSMENT

6.1 Human Health

6.1.1 Contaminants of Potential Concern

All analytical results from this investigation were compared to their respective screening levels (NMED residential SSLs and WQCC Standards) (Sections 5.1 and 5.2). No contaminants were detected within the collected soil samples above their respective NMED residential SSLs. In fact, the Lance missile propellant, UDMH, and its breakdown components, NDMA and DMN, were not detected above their laboratory reporting limits in any of soil or ground-water samples. With the exception of sulfate, chloride, and TDS, no analytes were detected in ground water in concentrations greater than their respective WQCC standards. The detected concentrations of sulfate, chloride, and TDS are consistent with the high dissolved solids concentrations expected in waters of the Tularosa Basin as discussed in Sections 2.2.3 and 2.3.

As stated in the *Technical Background Document for Development of Soil Screening Levels* (NMED, 2000), any contaminants exhibiting concentrations in excess of the SSLs represent the initial soil Contaminants of Potential Concern (COPC) list for a given site. Based on the analytical results from this investigation and guidance from the technical background document, there are no contaminants of potential concern identified at the Lance missile impact of WSNM (SWMU 168).

6.1.2 Air Exposure Pathway

The air exposure pathway is considered incomplete for the following reasons: There are no COPCs identified at the site and the surface samples collected during this RFI revealed no analyte concentrations in excess of screening levels (NMED residential SSLs).

6.1.3 Soil Exposure Pathway

The pathway for exposure to soil contaminants is considered incomplete for the following reasons: There are no COPCs identified at this site; the site is unoccupied and located within a relatively inaccessible area of the WSNM; and there are no residents, workers, schools, or daycare facilities within two miles of SWMU 168.

6.1.4 Surface Water Exposure Pathway

Figure 6-1 is a topographic map showing a 5-mile contiguous area surrounding the Lance missile impact site. The surface water exposure pathway is considered incomplete for the following reasons: There are no COPCs identified at the site; the closest intermittent water body is Lake Lucero which lies approximately one mile to the west of the impact site; and there are no intermittent or ephemeral streams leading away from the site.

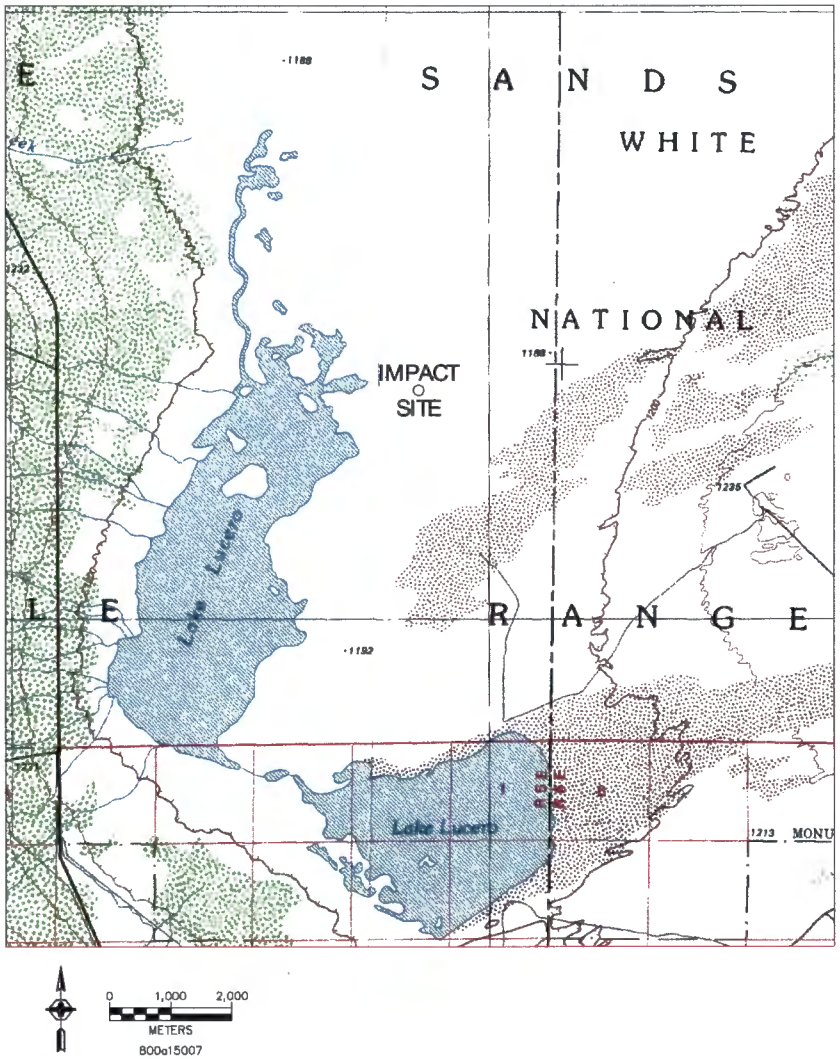


Figure 6-1. Topographic Map of the Lance Missile Impact Site.

6.1.5 Ground-Water Exposure Pathway

The ground-water exposure pathway is considered incomplete for the following reasons: there are no COPCs identified at the impact site; the ground-water gradient at the site is 0.0004 which is nearly horizontal indicating very low flowing water to stagnant water at the site; and the water has such high TDS concentrations that it is not used for potable or non-potable uses.

6.2 Ecological

An ecological risk assessment is not warranted at this time. There were no COPCs identified at the Lance impact site. Neither UDMH, NDMA, or DMN were detected above the laboratory reporting limits at the site. The one benzene detection (0.007 mg/kg) is well below the EPA Region IV Recommended Ecological Screening Value (RESV) (Friday, 1998) (Appendix G) of 0.05 mg/kg. With the exception of chromium and selenium, the detected RCRA metals were below the EPA Region IV RESVs. The chromium and selenium concentrations fall within the background concentrations detected at the site.

7.0 CONCLUSIONS

This RFI was conducted to determine if contamination from the Lance missile impact (SWMU 168) has contaminated soil and/or ground water within the WSNM. The following actions were performed to determine if contamination resulted from the Lance missile impact:

- Geophysical survey to locate Lance missile debris bgs.
- Eight 3 m (10 ft) deep soil borings were augered around the perimeter of the impact crater. Soil samples were collected from the borings at the surface, and approximately at 1.5 m (5 ft) and 3 m (10 ft) depths depending on site conditions.
- Hand augering and collection of soil samples near geophysical anomalies away from the impact crater;
- Installation and sampling of eight ground-water monitoring wells around the periphery of the impact crater.
- Collection of one water sample from the crater.

The most significant result from the geophysical survey is the correspondence between both the EM-61 and magnetometer methods in the center of the survey grid (located over the impact crater to just north of the crater). This area represents the bulk of the buried portion of the Lance missile. The remaining anomalies represent smaller portions of Lance missile debris. The deepest object detected during the survey was at approximately 3 m (9.7 ft) bgs beneath the center of the impact crater. The deepest debris at the Lance impact site (9.7 ft) is within a dry compacted gypsum layer described in Section 4.2.1 as a confining layer. Once the buried missile debris was discovered with the geophysical survey, it was determined that the original configuration for the soil borings and monitoring wells was adequate to ensure that if contamination had occurred at the site, it would be discovered. Three hand auger samples were added to the site work at specific locations corresponding to magnetic anomalies away from the crater.

All collected soil and water samples were analyzed for UDMH, NDMA, DNM, benzene, toluene, ethylbenze, xylene and total RCRA metals. All analyte detections were well below their respective NMED residential SSLs. None of the soil or water samples contained detectable concentrations of the Lance missile fuel component, UDMH, or its breakdown components, NDMA or DMN.

Soil borings and monitoring wells for this investigation were positioned such that samples were collected from locations where contamination would likely be present (within soils surrounding the impact crater, within water exposed within the crater, and within ground water down gradient from the crater). However, no COPCs were detected in the course of this investigation. The results of this investigation indicate that contamination from the Lance missile impact has not occurred. Subsequently, this RFI has determined that no routes (air, soil, surface water, or ground water) for exposure to human health exist at the site.

8.0 RECOMMENDATION FOR SITE CLOSURE

Information collected to date indicates that potential adverse effects posed by the Lance missile impact are lessened by the remote location of the site, the inaccessibility of this area of the WSNM to the public and the quality of ground water. Demography, land use, ground-water use and surface-water use do not pose health risks to humans. The site is remote, unoccupied, and inaccessible to WSMR workers and the public. The closest drinking water supply wells are located approximately 7 miles southwest of the impact site on the alluvial fan deposits of the San Andres Mountains.

With the approval of the NMED and the WSNM, the following actions are recommended for site closure:

- Empty contents of the soil cuttings (IDW) drums into the impact crater;
- Empty well development water, purge water, and decontamination water at the impact site;
- Close impact crater by shoveling crater ejecta and surrounding soil to the specification of the WSNM;
- Remove all IDW drums from the site; and
- Remove all remaining Lance missile surface debris, survey stakes, and all other debris material associated with the RFI.

REFERENCES

Allmendinger, R.J. and Titus, F.B., 1973. Regional Hydrology and Evaporative Discharge as a Present-Day Source of Gypsum at White Sands National Monument, New Mexico. New Mexico Bureau of Mines and Mineral Resources Open File Report 55.

Blackhawk Geosciences, Inc., 2002. *Geophysical Surveys at the White Sands National Monument White Sands Missile Range, New Mexico.* Project Number 2715MVT. February.

Friday, G.P., 1998. *Ecological Screening Values for Surface Water, Sediment, and Soil.* Westinghouse Savannah River Company, Savannah River Technology Center, (WSRC-TR-98-00110), Aiken, SC 29808.

Kelly, T.E. and Hearne, G.A., 1976. The Effects of Groundwater Development on the Water Supply of the Post Headquarters Area, White Sands Missile Range, New Mexico: U.S. Geological Survey Open File Report 72-308.

McClean, J.S. 1970. Saline Groundwater Resources of the Tularosa Basin, New Mexico: Department of the Interior, U.S. Office of Saline Water Research and Development Progress Report 561, 128 p.

New Mexico Environment Department (NMED), 2000. *Technical Background Document for Development of Soil Screening Levels.* Hazardous Waste Bureau and Groundwater Quality Bureau Voluntary Remediation Program. December.

U.S. Environmental Protection Agency, 1989. RCRA Facility Investigation (RFI) Guidance, Development of an RFI Sampling and Analysis Plan and General Considerations for RCRA Facility Investigations, Office of Solid Waste, EPA 530/SW-89-031.

U.S. Environmental Protection Agency, 1994. SW-846 Test Methods for Evaluating Solid Waste: Physical/Chemical Methods, U.S. EPA, Office of Solid Waste and Emergency Response, second update to 3rd edition.

U.S. Environmental Protection Agency, 1994. RCRA Corrective Action Plan, Office of Waste Programs Enforcement, Office of Solid Waste, OSWER Directive 9902.3-2A. May.

WSMR, 1989. White Sands Missile Range Part B Permit (NM2750211235). September.

WSMR, 2000. Assessment Report of the Lance Missile Impact on 14 December 1999 into the White Sands National Monument. July.

APPENDIX A

ASSESSMENT REPORT OF THE LANCE MISSILE IMPACT ON 14 DECEMBER 1999
INTO THE WHITE SANDS NATIONAL MONUMENT, JULY 2000

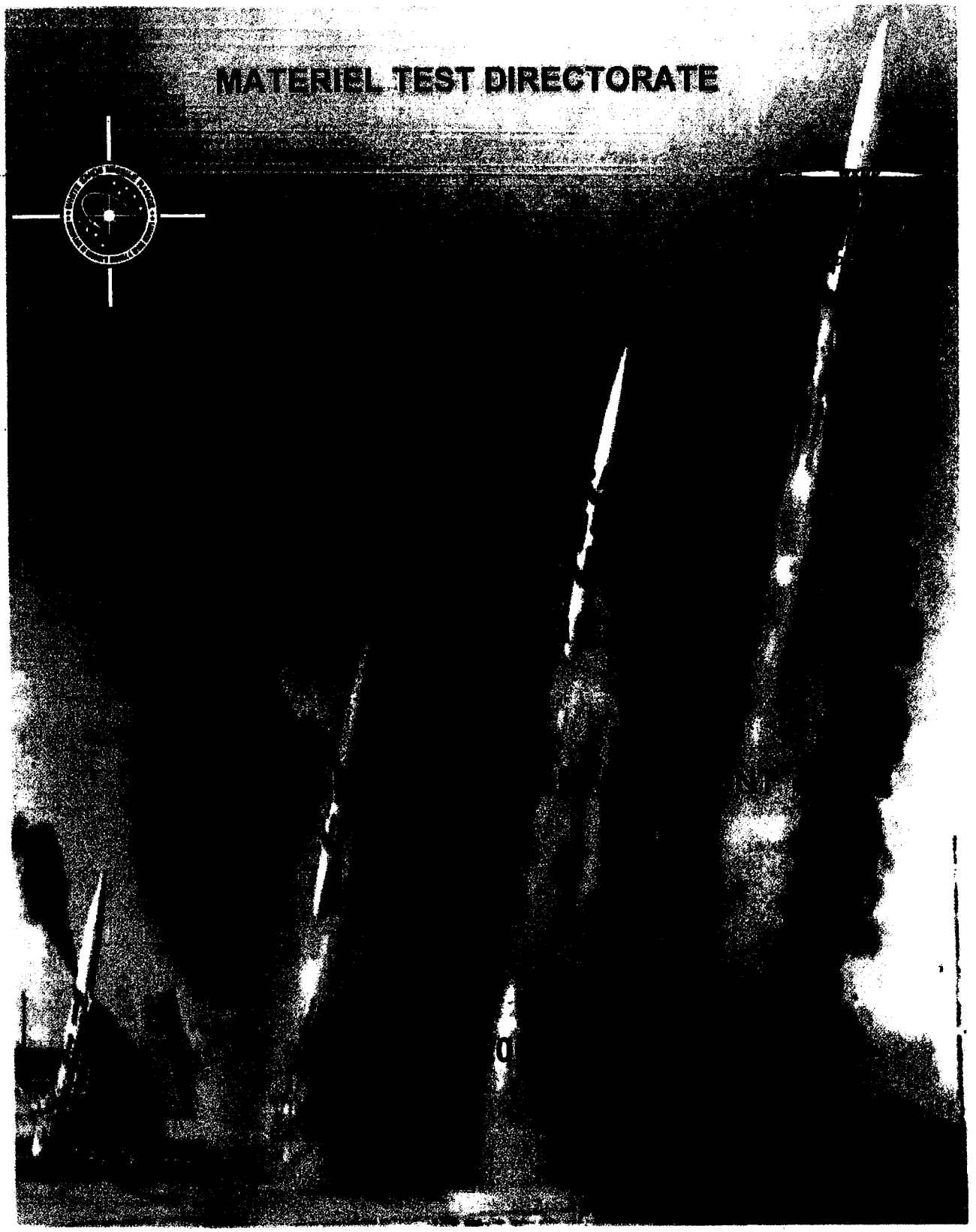

MATERIEL TEST DIRECTORATE

TABLE OF CONTENTS

1.0 PURPOSE 1

2.0 SYSTEM DESCRIPTION 1

3.0 BACKGROUND 2

4.0 ISSUE 2

5.0 OBJECTIVE 2

6.0 UPDATE AND ANALYSIS STATUS 2

6.1 Initial Assessment 2
6.2 Initial Assessment Analysis 3
6.3 Initial Assessment Conclusions 3
6.4 Follow-On Assessment 3
6.5 Follow-On Assessment Analysis 4
6.6 Follow-On Assessment Conclusions 4

7.0 RECOMMENDATION 5

ENCLOSURES

Enclosure 1 – Lance Missile System Description
Enclosure 2 – Memorandum for MT-MT, Lance Mission Support
Enclosure 3 – Impact Site and Predicted Ground Track Charts
Enclosure 4 – Memorandum for MT-MT, Lance Propellants
Enclosure 5 – Memorandum for Commander, White Sands Test Center, Remediation Actions for the Lance Missile Impact at White Sands National Monument with enclosures (11 pages)
Enclosure 6 – Photographs (10) of the Impact Area and Missile Debris
Enclosure 7 – Memorandum for ES-EC, Analysis Support with enclosures (7 pages)
Enclosure 8 – Lance Warhead Configuration
Enclosure 9 – Lance Impact Coordinates/Missile Depth Calculations

LANCE MISSILE IMPACT ASSESSMENT REPORT

1.0 PURPOSE

This report provides information regarding the 14 December 1999 Lance missile that impacted into the White Sands National Monument (WSNM). Although the investigation is still ongoing, this document reports findings to date, analysis performed to date, and conclusions based on evidence collected from surveys conducted of the impact crater and surrounding area.

2.0 SYSTEM DESCRIPTION

The Lance missile is a single-stage, two phase, liquid bi-propellant vehicle consisting of a warhead section and a main missile motor assembly section totaling 20 feet in length. The missile has different payload configurations (see Enclosure 1). When the Lance missile is used as a target, it does not carry an explosive warhead and the missile payload section is modified to contain ballast and instrumentation. The Lance missile flies a ballistic trajectory of up to 130km. The missile requires a solid propellant gas generator to produce a boost and sustain phase during the launch process. The liquid propellant which drives the missile during flight consist of a fuel and oxidizer; unsymmetrical dimethylhydrazine (UDMH) and inhibited red fuming nitric acid (IRFNA), respectively. The properties of the chemicals include:

- Unsymmetrical Dimethylhydrazine (UDMH)
  - UDMH is a liquid propellant rocket engine fuel, clear in color with an ammonia-like, fishy odor. It is a flammable, hygroscopic, mobile liquid, which is miscible with water. UDMH is strongly basic, a powerful reducing agent and has a significant vapor pressure.
  - UDMH is highly toxic to humans via contact, ingestion and breathing.
- Inhibited Red Fuming Nitric Acid (IRFNA)
  - IRFNA is composed of Nitric Acid (81.6-84.8%) Nitrogen Dioxide (13-15%), Water (1.5-2.5%) and Hydrogen Fluoride Inhibitor (0.7%)
  - IRFNA is a liquid propellant rocket engine oxidizer, orange-red in color, strongly fuming, and evolves nitric acid vapor and nitrogen oxides.
  - IRFNA is a highly corrosive oxidizing agent, which will vigorously attack most metals.
  - IRFNA is highly corrosive to humans via direct contact, causing burns to all tissues and is highly toxic via ingestion and breathing.

When IRFNA and UDMH come in contact, they ignite spontaneously with a very energetic reaction. In addition to the large amount of heat formed, the reaction products are water and hydrazine-nitrate salt. The reaction products are very finely divided and disperse rapidly in the air due to the heat of reaction and the rocket's motion through the atmosphere.

3.0 BACKGROUND

The Lance missile began testing at White Sands Missile Range (WSMR) in 1965. Lance missiles were fielded in the 1970's and used by the United States and other NATO countries. Since the Lance missile has been replaced by a new generation of missiles, the remaining Lance missiles are used as targets for air defense systems undergoing development and production testing. Throughout the years WSMR has launched over 530 Lance missiles.

On 14 December 1999, a Lance missile, launched as a target, encountered unresolved internal technical problems causing the missile to conclude proper propulsion early. The missile, launched from LER-4 and intended to impact at a Lance WIT area, fell short and impacted into the WSNM near Lake Lucero (see Enclosures 2 and 3). The missile pierced the ground exposing the water table 3 to 4 feet below the surface,

4.0 ISSUE

WSMR and the State of New Mexico are in the process of negotiating and defining the requirements for mitigation of the potential contamination of sub-surface water in the WSNM caused by the missile impact.

5.0 OBJECTIVE

The Material Test Directorate (MT) has responsibility to provide an engineering assessment of the impact site to ascertain the condition of the Lance missile upon impact in an effort to determine the degree of potential contamination based on the debris distribution and crater analysis.

6.0 UPDATE AND ANALYSIS STATUS

6.1 Initial Assessment

6.1.1 An initial assessment of the impact site was conducted on 16 December 1999. This two-day delay was necessary to prepare a safety plan and coordinate with the WSNM staff, since this was, at that time, a potentially hazardous operation.

6.1.2 The purpose of the initial assessment was to provide a quick-look visual and chemical assessment of the impact site for the establishment of baseline conditions.

6.1.3 Conducting the initial site inspection of 16 December 1999 was a two-person WSMR Army EOD team, flown in by helicopter, wearing chemical protection suits and breathing apparatuses. Protective suits were needed because of the potential high concentration of liquid propellants in the air (see Enclosure 4). Due to the extreme hazard that potentially existed, the initial recovery team effort was kept to the absolute minimum. The team was at the site for approximately 20 minutes.

6.1.4 The EOD team collected soil and water samples, returned to the helicopter and evacuated the site. The team generated an initial general report of the area upon return to main post.

6.2 Initial Assessment Analysis

An analysis of the surrounding soil and water in the crater revealed a small amount of contamination.

6.3 Initial Assessment Conclusions

Since there was no debris visible on the surface, an initial conclusion drawn from the initial site visit was that the missile must be below the surface of the water table, possibly with the fuel tanks somewhat intact. Often with Lance impacts, on surfaces much more dense than the Lake Lucero monument area, large obvious pieces of debris are easily seen from the air. The initial fly-over revealed no such large debris, adding support to the conclusion that all the missile debris was underground (this conclusion would latter be updated as a result of the follow-on assessment). As a result, the WSMR environmental office issued a tentative remediation proposal (see Enclosure 5). This proposal recommended continued re-sampling and an environment-monitoring program to track any fuel contamination.

6.4 Follow-On Assessment

6.4.1 On 16 March 2000, with permission from the WSNM, a follow-on assessment recovery team inspected the site. This was a technical team comprised of various experts in missile testing, analysis, and recovery.

6.4.2 The purpose of a follow-on assessment was to provide an in-depth analysis of the ground impact site to include a detailed search and collection of debris, debris location, debris assessment, photography, crater definition, and soil and water conditions. Realizing that the initial ground inspection team had been limited in time and could not conduct a detailed assessment, a recovery team was assembled as soon as the WSMR environmental office deemed it safe to visit the site without protective suits or breathing apparatuses. Plans at the initial assessment had always included a more in-depth follow-on assessment to be conducted at the site, once the hazards to personnel were reduced to an acceptable level.

6.4.3 Comprised of experienced personnel, the recovery team, based on engineering judgement, determined the disposition of the missile and its impact. The recovery team discovered:

- Lance missile debris on the surface less than 20 feet from the crater
- Lance missile debris on the lip of the crater exposed to the air
- Lance missile debris in the crater protruding out of the water

6.4.4 Photo 1 (Enclosure 6) shows the crater. In this picture debris can be seen at the lip of the crater and in the water. Photo 2 shows debris in the water and photo 3 shows debris on the lip of the crater. Photos 4 through 8 show pieces of debris collected on the surface around the crater. Photo 9 shows pieces from the warhead section while photo 10 shows pieces from the liquid propellant tanks.

6.5 Follow-On Assessment Analysis

Analysis of the information collected during the follow-on assessment is still ongoing, but several new findings have been made and new facts have been revealed to include:

- Pieces of the simulated warhead section among the debris
- Pieces of the liquid propellant tanks found among the debris
- Chemical analysis results of soil and water samples taken on 16 December 1999, 26 January 2000, and 28 February 2000 revealed an almost non-existence Lance-related contamination in December, and no measurable contamination in January and February (see Enclosure 7)

6.6 Follow-On Assessment Conclusions

6.6.1 Based on the location, number, and types of Lance pieces found, the opinion of the recovery team (including the missile flight safety analysis) is that the Lance missile did suffer considerable catastrophic structural damage at the surface plane, enough to rupture the liquid propellant tanks at the surface level. This indicates that most, if not all of the missile debris, is not very deep and that the contamination took place on or near the surface level. The most solid parts of the Lance missile are the engine and the simulated warhead. With the missile angle of entry at 70.71 degrees to the plane of the earth, the simulated warhead would have gone the deepest, but even this section is not solid undeformable bullet-shaped concrete item as previously believed. The simulated warhead for this Lance missile was a mass of welded steel pipe covered by a thin metal, forming a tip (see Enclosure 8).

6.6.2 Based on empirical data found at the site during the follow-on assessment, findings indicate an impact with the ground catastrophic to the integrity of the Lance missile. Pieces of liquid propellant tanks found indicate that the tanks ruptured between the surface and a few feet into the ground. Calculations on the physics of the missile flight by Army experts (see Enclosure 9) indicate that even if it were possible for the missile to be intact, it could be no deeper than 23 feet. However, it is far more likely that the benign simulated warhead section was stripped of most connecting parts and is alone at a depth no greater than 23 feet. It is likely that the simulated warhead consumed a portion of this downward energy with an explosive ground impact. It is our experience that no chemical contamination could occur because the tanks were stripped and ripped apart at or near the surface. It is our opinion that contamination measurements should be limited to only a few feet below the surface.

6.6.3 Empirical evidence indicates to our missile and recovery experts that any contamination due to the rupture of those tanks has already taken place and took place at the surface level to a few feet below. Surface level contamination has been measured under the latest sampling, and the analysis, which includes the latest soil and water samples from the crater, shows little or no contamination.

6.6.4 Wind, rain, and erosion have now made it possible to see debris previously covered by dust and soil from the impact cloud, allowing the second assessment team to see debris not visible to the first.

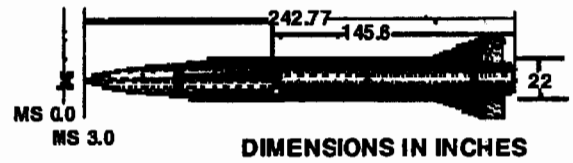
6.6.5 Where there was once some indication for some to think that an intact missile was underground in the water table, there is none now because of the debris found. In fact, debris can be seen in the crater actually protruding out of the water table, which indicates that even more debris is under the surface, and not an intact missile. It is our conclusion that all the environmental damage that the Lance missile can do has been done. Except for the physical existence of an unnatural crater in the area, the chemical contamination took place on or near the surface, was measured, and found to be negligible (see Enclosure 7).

7.0 RECOMMENDATION

Based on the findings, and the fact that the water was unsuitable for both agriculture or drinking before the incident, we recommend that WSMR take the position that no further environmental measurement is necessary. In addition, WSMR should send a team to the impact site, flown in and out by helicopter, to collect and remove all metallic debris in and around the crater.

Lance Missile System Description

Length 245.77 in. (from MS 0.0)
Propulsion system: bi-propellant liquid; storable
Guidance system: self-contained; directional and velocity control

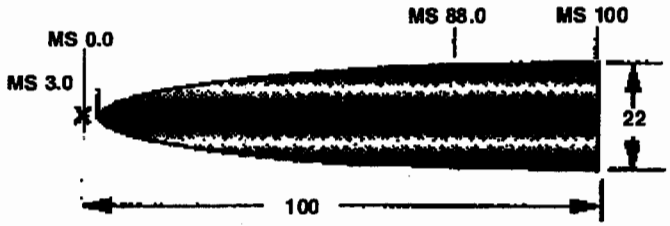


DIMENSIONS IN INCHES

MASS PROPERTIES

ITEM		WEIGHT (lb)
Missile Round	with heavy warhead section (launch)	3367
	with light warhead section (launch)	2855
	less warhead section and control surfaces	2309
Propellants	Fuel, UDMH	[illegible]
	Oxidizer, IRFNA	[illegible]
Control Surfaces	Large honeycomb - M250 (light warhead section)	[illegible]
	Small forged aluminum - M30 (heavy warhead section)	[illegible]

WARHEAD SECTION



Length: 100 in. from MS 0.0 (97 in. actual)
Maximum diameter: 22 in. between MS 88.0 and 100.0

Types:
- M251 A1 HE (Tactical) (995 lb)
- M252 Practice, Light (469 lb)
- XM276 Practice, Heavy (995 lb)

CSTE-DTC-WS-MT-AW (70) 14 Jan 2000

MEMORANDUM FOR MT-MT

SUBJECT: Lance Mission Support

1. On 10, 14, and 15 Dec 99, the Warheads Test branch supported Patriot and Lance missions. The Lance missile fired on 10 Dec 99 was for the Patriot tracking mission. Two Lance missiles fired on 14 Dec 99 were the target for the Patriot missile. The two missiles did not reach their intended impact area and Patriot did not engage either target. A third Lance was fired on 15 Dec 99 and Patriot engaged the Lance target missile. The following is a summary of the post flight search and recovery operations.

2. The Lance missile fired on 10 Dec 99 monolithically impacted east of Church site. A helicopter Global Position System (GPS) impact location of the crater was taken (see enclosure). The impact crater will be filled in with dirt after a six month waiting period as required by the Lance Missile Target Environmental Assessment.

3. The first Lance missile fired on 14 Dec 99 fell short of the intended impact. The missile monolithically impacted northeast of Rhodes Canyon. A helicopter Global Position System (GPS) impact location of the crater was taken (see enclosure). The impact crater will be filled in with dirt after a six month waiting period as required by the Lance Missile Target Environmental Assessment.

4. The second Lance missile fired on 14 Dec 99 fell short of the intended impact. The missile monolithically impacted northeast of Lake Lucero in the White Sands National Monument. A helicopter Global Position System (GPS) impact location of the crater was taken (see enclosure). The Environmental Compliance office is coordinating the missile mishap incident with the Monument and State Environmental personnel.

5. The Lance missile fired on 15 Dec 99 was intercepted by the Patriot missile. No intercept debris was located.

6. The coordinates are in datum's, WGS 84 and NAD 27 using the coordinate systems UTM (meters) and Geodetic (Lat and Lon). All personnel using coordinates should note and list on all correspondence what datum the data is in.

7. Point of contact for this action is Ms. Robin M. Wilson, 678-4310.

Encl
as

RICHARD D. OVERLEY
Chief, Warheads Test Branch

LANCE
GPS IMPACT LOCATIONS
10, 14, 15 Dec 99

LANCE MONOLITHIC IMPACT 10 DEC 99

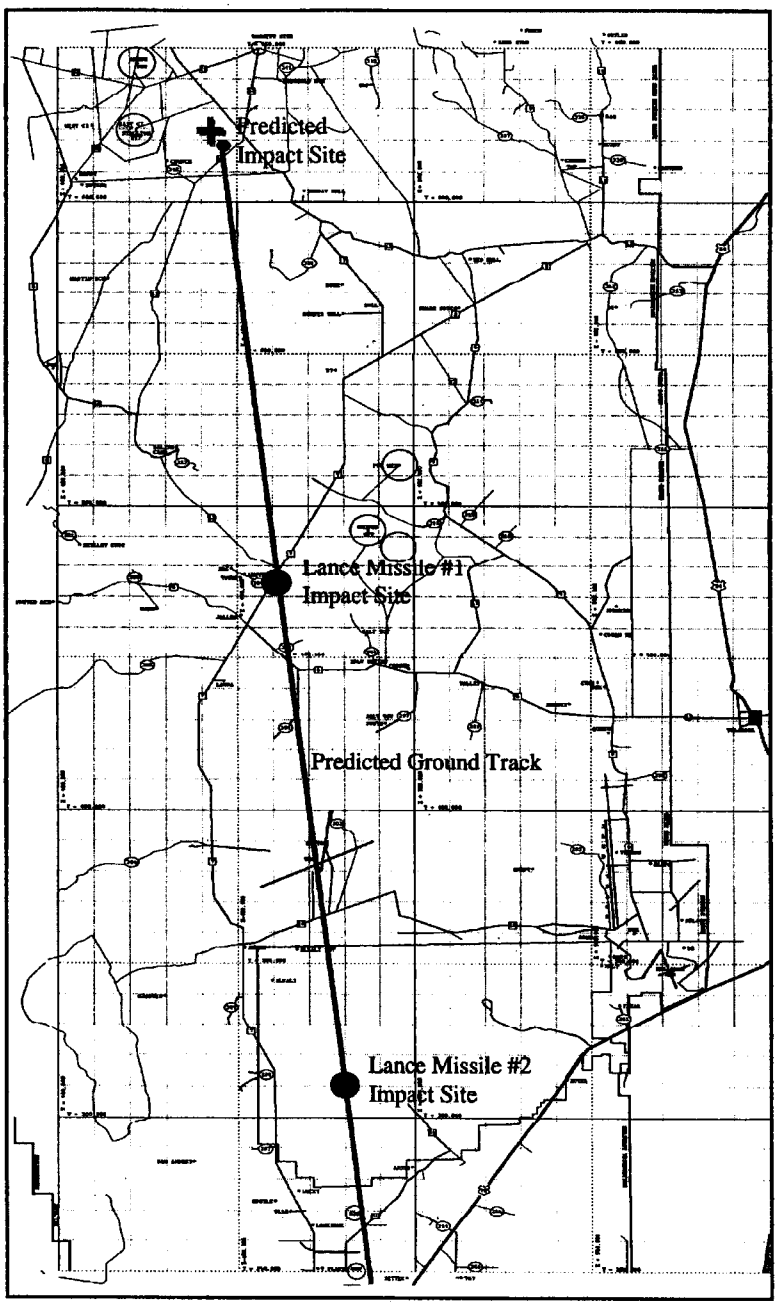
WGS84				NAD27			
Lat	33°	35.603'	E 359951 (m)	Lat	33°	35.598'	E 360000
Lon	106°	30.559'	N 3718093 (m)	Lon	106°	30.525'	N 3717890

LANCE MONOLITHIC IMPACT 14 DEC 99 FIRST MISSILE

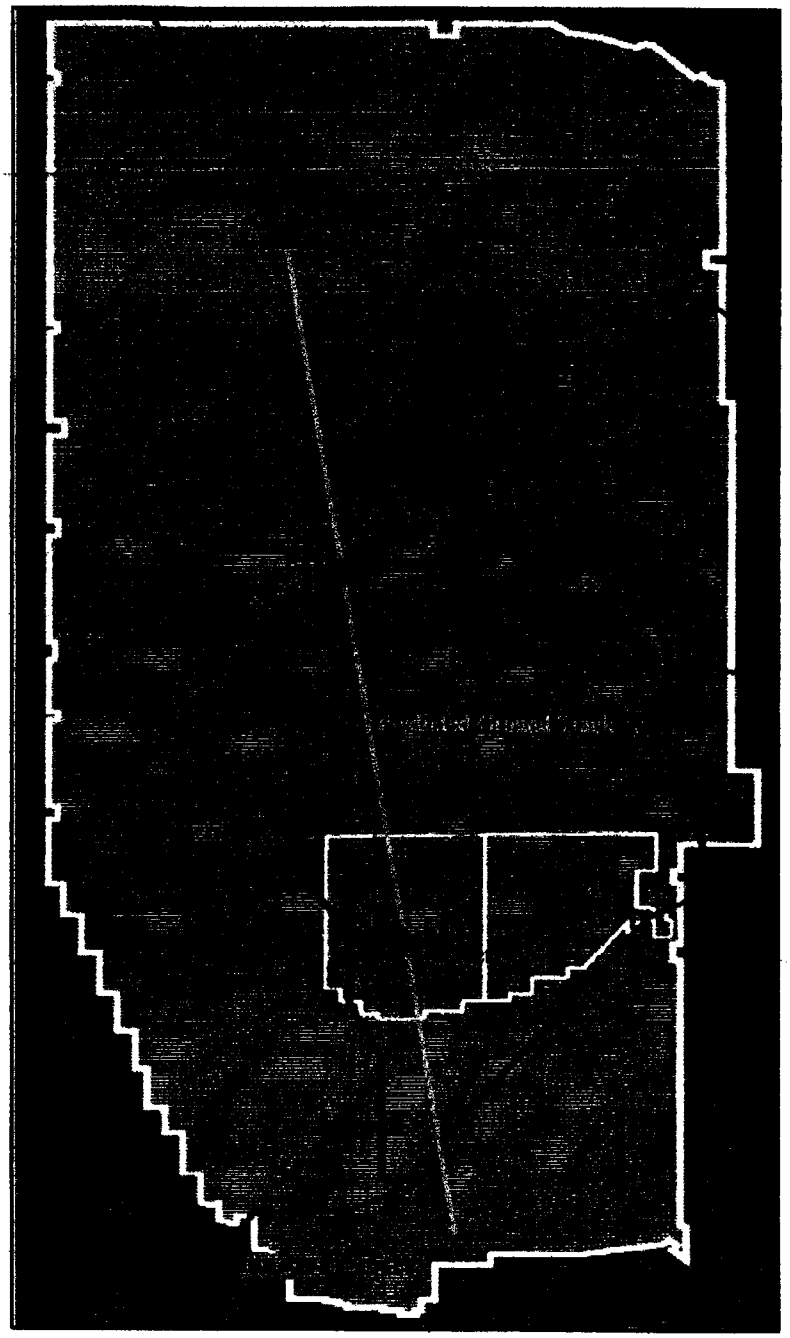
WGS84				NAD27			
Lat	33°	11.771'	E 363826 (m)	Lat	33°	11.765'	E 363876
Lon	106°	27.654'	N 3673987 (m)	Lon	106°	27.620'	N 3673783

LANCE MONOLITHIC IMPACT 14 DEC 99 SECOND MISSILE

WGS84				NAD27			
Lat	32°	44.767'	E 368925 (m)	Lat	33°	44.760'	E 368975
Lon	106°	23.945'	N 3624008 (m)	Lon	106°	23.911'	N 3623804



Lance Missile Impact Sites of 14 December 1999



Lance Missile Predicted Ground Track

CSTE-DTC-WS-MT-AA (70-10r) 14 Jan 00

MEMORANDUM FOR MT-MT, ATTN: Mr. Martinez

SUBJECT: Lance Propellants

1. In response to the verbal request of Ms. Wilson, MT-AW, the following information has been prepared by the MT-AA Chemistry Lab describe the Lance propellants, their hazards, their breakdown products and safety precautions.

2. The subject propellants are as follows:

a. Inhibited Red Fuming Nitric Acid (IRFNA)

(1) IRFNA is composed of Nitric Acid (81.6-84.8%) Nitrogen Dioxide (13-15%), Water (1.5-2.5%) and Hydrogen Fluoride Inhibitor (0.7%)

(2) IRFNA is a liquid propellant rocket engine oxidizer, orange-red in color, strongly fuming, and evolves nitric acid vapor and nitrogen oxides. IRFNA is a highly corrosive oxidizing agent which will vigorously attack most metals.

(3) IRFNA is highly corrosive to humans via direct contact, causing burns to all tissues and is highly toxic via ingestion and breathing.

b. Unsymmetrical-Dimethylhydrazine (UDMH)

(1) UDMH is a liquid propellant rocket engine fuel, clear in color with an ammonia-like, fishy odor. It is a flammable, hygroscopic, mobile liquid, which is miscible with water. UDMH is strongly basic, a powerful reducing agent and has a significant vapor pressure.

(2) UDMH is highly toxic to humans via contact, ingestion and breathing.

3. When IRFNA and UDMH come in contact, they ignite spontaneously with a very energetic reaction. In addition to the large amount of heat formed, the reaction products are water and hydrazine-nitrate salt. The reaction products are very finely divided and disperse rapidly in the air due to the heat of reaction and the rocket's motion through the atmosphere.

4. If a Lance happens to impact the ground while it still contains a significant amount of unreacted propellants, several scenarios are possible.

CSTE-DTC-WS-MT-AA
SUBJECT: Lance Propellants

a. The propellant tanks rupture upon impact, the IRFNA and UDMH react vigorously and the reaction products disperse in the environment. Only trace levels of the original propellants remain at the impact site. The hydrazine nitrate salt reaction product would slowly hydrolyze in the presence of water to form dilute ammonium and nitrate compounds.

b. One propellant tank ruptures, releasing either IRFNA or UDMH into the environment. If IRFNA is the one released, it would react with any oxidizable material present forming compounds. Any remaining IRFNA would dissipate through various mechanisms, e.g., dilution in water to form a weak acidic nitrate solution, evaporation to form nitric acid vapors which would quickly dissipate. If UDMH were the one released, it would most likely ignite due the heat of impact. In the absence of ignition, the UDMH would have a tendency to quickly evaporate and dissipate in the air. The UDMH would react with any reducible compounds present in the environment to form a hydrazine-type salt. Since UDMH is water soluble, it could also be expected to dilute if it comes in contact with water.

c. Neither tank ruptures on impact and the propellants are "safely" contained.

5. If personnel are required to cleanup/mitigate an impact area involving either or both unreacted propellants, approved full. body protection and supplied air are absolutely required due to corrosively, toxicity and reactivity considerations.

6. Point of contact is the undersigned at 678-2992.

Joseph E. Gomez
JOSEPH E. GOMEZ
Chemist

CF:
MT-AW (Ms. Wilson)
MT-MT (Mr. Casares)
ES-EC (Mr. Mendoza)

CSTE-DTC-WS-ES-EC (200-1) 20 January, 2000

MEMORANDUM FOR COMMANDER, WHITE SANDS TEST CENTER

SUBJECT: Remediation Actions for the Lance Missile Impact at White Sands National Monument

1. **Purpose:** Obtain approval of and direction to execute the decisions reached between the White Sands National Monument, the New Mexico Environment Department and White Sands Missile Range concerning, the remediation actions for the Lance missile that impacted the WSNM.

2. Discussion:

a. At the request of the New Mexico Environment Department (NMED) and the White Sands National Monument (WSNM), a meeting was held on 18 January to discuss the actions needed to remediate the Lance missile impact site in the WSNM. Attendees are identified at Enclosure 1.

b. The following decisions were reached by the attendees:

(1) The contaminant of concern for this incident is the UDMH (Hydrazine) fuel component of the missile. Based on information presented by WSMR (MT) all parties believe that the IRFNA (Nitric Acid) fuel component most probably vented to the atmosphere during missile flight due to a tank, piping, or motor failure. Any IFRNA remaining at the time of impact should have been neutralized through interaction (primary dilution) with the groundwater and gypsum soil base.

(2) No missile location or recovery effort will be required at this time. All parties agreed that there were most likely no issues or circumstances which would require the location and removal of the missile, given the isolated location of the impact site and the difficulties involved with locating and removing the missile or its remains.

(3) The impact crater will be left "as is" at this time. Any decision on its eradication will be deferred until further review by the WSNM staff and the Park Service has taken place. NMED and WSMR staff present at the meeting had no requirement to eliminate the crater.

(4) WSMR will re-sample the crater, the immediate area surrounding the crater, and the water in the crater-and provide the results to NMED and the WSNM as soon as they are available See Enclosure 2.

(5) WSMR will develop a monitoring program for the site and submit same as soon as possible to the WSMR and NMED for review and approval. Upon approval by both parties the program will then be executed. See Enclosure 3. Action at the site other than monitoring (i.e., active groundwater remediation to treat or remove the UDMH or its breakdown components) will be required only if the if the monitoring results indicated an adverse impact to the environment.

CSTE-DTC-WS-ES-EC
SUBJECT: Remediation Actions for the Lance Missile Impact at White Sands National

(6) WSNM agrees to allow a one-time ground access to the immediate area of the impact crater for instillation of the monitoring wells and equipment. To the maximum extent possible, existing tracks and trails will be utilized to gain access to the site. See Enclosure 4.

c. If approved, the decisions reached at this meeting will commit White Sands Missile Range to perform a series of tasks designed to demonstrate that any UDMH released by the missile be reduced to non-hazardous levels or breakdown components without adverse impact to the environment. The course of action developed during the meeting is supported by all three activities as being the most reasonable and economic means of accomplishing this goal.

d. This memorandum has been reviewed by and staffed with -NR, -MT, -SJA, -RM, and the WSNM. It was verbally coordinated with the NMED Hazardous and Radioactive Materials and Groundwater Bureaus.

3. Recommendation:

The Commander, White Sands Test Center, approve and direct the execution of the following:

a. MT to provide funding for execution of all remediation actions identified by this memorandum. Discussion on recovery of costs should take place between the customer, MT, and RM.

b. MT to provide technical support as needed to support successful execution of the remediation actions identified by this memorandum.

c. ES to reimbursably execute the tasks identified by Enclosures 2, 3, and 4.

d. NR (Flight Safety) to reimbursably develop the information described by Enclosure 5.

e. Army Air to reimbursably provide helicopter support (as available within military mission constraints) for the execution of the tasks described by the enclosures.

4. The point of contacts for further information on this action are Mr. Gene Forsythe, Chief, Environmental Compliance Division, Environment and Safety Directorate and Mr. Javier Mendoza, Environmental Engineer, Environmental Compliance Division. They may be reached at 678-2224.

Encls
as

THOMAS A. LADD
Director, Environment and Safety

Copy for: MT
NR
RM
SJA
IS

ATTENDENCE ROSTER
for the
LANCE MISSILE IMPACT MEETING
18 JANUARY 2000
WHITE SANDS NATIONAL MONUMENT

White Sands National Monument

Dennis Vasquez	Director
Bill Conrod	Resources Manager
Rick Huff	(USGS, representing WSNM)

New Mexico Environment Department

Robert Dinwiddie	HRMB
Barbara Toth	Toxicologist
Phillip Solano	HRMB
Loreen Lithgow	GWB
Julie Jacobs	GWB

White Sands Missile Range

Javier Mendoza	-ES
Andre Bullitt	-MT
Joseph Gomez	-MT
Roberto Casares	-MT
Robin Wilson	-MT
Don Williams	-MT
Gene Forsythe	-ES

RE-SAMPLING WORK TASK
for the
LANCE MISSILE IMPACT SITE
in the
WHITE SANDS NATIONAL MONUMENT

1. Perform re-sampling of the impact site as expeditiously as possible to confirm presence or absence of IRFNA (Nitric Acid Fuel), UDMH (Dimethyl Hydrazine fuel), and the two UDMH breakdown (components of concern; NDMA (Dimethyl Nitroamine), and DNM (Dimethyl Nitroamine).

2. Sample the water in the crater by taking a surface sample and a deep sample (preferably at the bottom of the crater).

3. Sample the crater by taking soil samples at two widely separated locations on the interior crater wall.

4. Sample the surrounding area (to establish baseline levels)by taking two surface soil samples which are on opposite sides of the crater and which are located between 100 and 150 feet from the crater.

5. All samples taken will be split samples. One set will be provided to the MT Chemistry Lab (Dr. Gomez) analysis. The second set will be provided to a commercial lab for analysis.

6. Per discussion with NMED HRMB (Mr. Solano) the analysis performed must be accomplished using analytical techniques 8070 or 607.

7. Select an area representative of the crater soil type, but outside of the SCBA limit. Using a hand auger and manual shovel-dug hole, excavate to a depth of 10 feet (auger) or 5 feet (manual), and take at least two un-compacted soil samples of a predetermined volume which can be used to determine soil density for an impact penetration calculation. The MT Chemistry Lab. should independently analyze the samples for density.

8. Entrance to and exit from the site will be via helicopter.

9. Operations within 100 feet of the crater require the use of full-face SCBA breathing apparatus.

10. Date an approximate time of the operation will be provided to Mr. Dennis Vasquez or Bill Conrod of the WSNM as soon as it is known. WSNM may participate as observers on this event by notifying Mr. Javier Mendoza or Mr. Gene Forsythe (678-2224).

11. Individual analysis reports will be provided to HRMB (Mr. Solano and Ms. Jacobs) and Mr. Vasquez within 1 week of receipt from each performing laboratory. These will be "Faxed" and then transmitted in hard copy and on floppy disk (Word format) via USPS certified mail.

12. All work will be documented via digital photography and field notes. A trip report will be filed with the Division Chief, -ES-EC within five working days of fieldwork completion. This will include copies of the photography as well as a detailed GIS-type map showing sites of work performed.

13. The North and South boundaries of the crater will be "GPS'd," with the actual location that the GPS data was collected for being documented via digital photography (put a stake with identifying markings in the ground at that point). All GPS data must be corrected.

14. POCs for further information on this Enclosure are Mr. Gene Forsythe or Mr. Javier Mendoza. They may be reached at 505-678-2224.

MONITORING PLAN WORK TASK
for the
LANCE MISSILE IMPACT SITE
in the
WHITE SANDS NATIONAL MONUMENT

1. WSMR, NMED, and WSNM agree that monitoring beyond that described by Enclosure 2 of this document that any UDMH released by the missile impact, will be reduced to non-hazardous levels or breakdown components without adverse impact to the environment. To that end WSMR will install groundwater monitoring wells in the vicinity of the impact site and perform recurring groundwater monitoring and data collection/ analysis until it can be demonstrated that non-hazardous levels of the LTDMH and its two breakdown components of concern have been achieved.

2. WSMR will design a data collection and groundwater monitoring system that will accomplish the following goals:

a. Identify and define vertical and horizontal water flow characteristics in the immediate area of the impact.

b. Allow for the recurring collection of groundwater samples for analysis for the contaminants of concern.

c. Perform recurring data collection of water flow characteristics and groundwater, with analysis of the later for the specified contaminants of concern.

d. Provide regular status reports, with reporting of water flow and contaminant data.

3. Once the design has been reviewed by NMED and WSNM, WSMR will execute the design and establish a groundwater monitoring program for the site. The reports will include tables providing the analytical result of groundwater for the reported quarter as well as cumulative and trend data analyses.

4. Specific requirements for this effort include, but are not limited to the following:

a. Due to the unknown situation with respect to current water table movement rates and directions, the amount of UDMN released into the water table (or its dispersion to date), at least two concentric rings of monitoring sites must be established in order to allow for the highest probability that any contaminant plume will be captured and tracked.

b. Assuming that the work effort described by Enclosure 2 of this document demonstrates no discernable health hazard from IRNA or UDHM (or its breakdown components) exists at the crater, an initial set of monitoring wells will be installed immediately outside the crater, and the first set or ring of monitoring will be established within 100 feet of the crater perimeter. If this is not the case, -ES will determine the closest safe distance to the crater that well installation will be allowed.

c. Additional sets or rings of monitoring sites will be established at scientifically pre-determined distances from the crater, based on the following assumptions:

(1) Analysis techniques 8070 or 806 will be used to identify the presence of contaminants.

(2) Between 100 and 500 pounds of UDMH are estimated to have been released by the missile, and this release was evenly distributed between the surface at impact and the resting depth of the missile warhead.

(3) The water table at the impact site begins at 4 feet below the surface and is continuous down to the resting continuous down to the resting depth of the missile warhead, Warhead resting depth calculations will be provided by -NI (Flight Safety) as soon as they are developed.

(4) Soil/water densities within the water table adjacent to the impact site are essentially and practically unchanged throughout the entire depth of the water table. Soil/water densities; will be provided by -MT (Chemical Laboratory) as soon as they are developed.

(5) Water flow within the aquifer across the impact site is assumed to be basically static or not more than *300 feet per year, thus defining the anticipated spread of the contaminants of concern.

(6) Detection of the contaminants of concern is **not** an issue after dilution and breakdown below the documented hazardous levels has been achieved. The outermost set or ring of groundwater monitoring sites will not be placed further from the impact site than the highest probability calculated for this distance during the design phase.

d. Monitoring wells at the groundwater monitoring sites will be installed using a small diameter Geo-probe type device mounted on a single vehicle or by manually operated hand auger, as appropriate to the conditions and well depth.

e. Due to the uncertainty about the release rate and depth of release at the impact site, and the actual resting depth of the missile warhead and its remains, groundwater monitoring for the presence of contaminants of concern at groundwater monitoring site must take place at three depths; 10 feet, 25 feet, and as close as possible to the calculated maximum resting depth of the missile warhead. These depths may be adjusted during the design phase based on validated changes to the initial working assumptions provided here.

f. Vertical water flow rates will be determined using a well developed at the mid-depth (25 feet) or as otherwise determined during the design phase.

g. If, during the installation phase of this effort, multiple water tables are detected, groundwater monitoring well depths will be adjusted to assure that each identified water table is sampled by each groundwater monitoring site. In this eventuality, it will be necessary to install additional wells to allow for the calculations of lateral water flow rates within each water table. Should this occur, vertical water flow rate detection will be eliminated to limit the number of wells installed at each groundwater monitoring site.

h. Upon completion and development of all wells, an initial set of samples will be taken. All wells will be re-sampled about 30 days after the initial sampling. After the second set of samples has been taken, five further sets samples will be taken at 60-day intervals. All sampling during this period will include groundwater flow data as well as contaminant analysis data. Results from this phase of the groundwater monitoring program will be used to determine if additional sampling or other remediation action is required. WSMR will provide NMED and WSNM a formal report within 90 days after the conclusion of this phase of the program which will summarize findings to date and make formal recommendations for further action or close-out of the monitoring program.

i. Should contaminant plumes be identified, the activity executing the groundwater monitoring program will prepare plume models or plume maps (as the data support) upon receipt of the results from each groundwater sampling event. A set of cumulative transport history (plume movements over time) maps will be prepared after each sampling event which shows both the plume front location (at each sampled depth) and the measured or calculated concentration of the contaminant at the leading edge of the plume. This data will be included in the quarterly reports.

j. All groundwater samples taken will be split samples. One set will be provided to the MT Chemistry Lab (Dr. Gomez) for analysis. The second set will be provided to a commercial lab for analysis.

k. Enclosures 2 and 4 of this document establish further performance and reporting requirements that apply to the execution of this Enclosure.

l. During the initial monitoring well installation effort all work performed will be documented viadigital photography and engineering field notes. The performing activity will file a formal trip report with the Division Chief,-ES-EC, within five working days of field work completion.. This will include copies of the photography as well as a detailed GIS-type map showing sites of work performed. All monitoring wells will have their geographical location determined via GPS which has been validated and corrected using the -ES base station located in bldg 163. Note that installation of "clusters" of monitoring wells located with 30 feet of each other need only to have their centroid located by GPS. Photography and mapping of individual well locations against the centroid location will be adequate to support well location during the monitoring program.

m. During the actual monitoring program, all work performed will be documented via digital photography if unusual or unexpected conditions are encountered. The performing activity will file a formal trip report with the Division Chief, -ES-EC, within five working days of field work completion.

5. POCs for further information on this Enclosure are Mr. Gene Forsythe or Mr. Javier Mendoza. They may be reached at 505-678-2224.

GROUND ACCESS RESTRICTIONS
for the
LANCE MISSILE IMPACT SITE
in the
WHITE SANDS NATIONAL MONUMENT

1. At this time the operative assumption is that one vehicle mounting a Geo-probe type device will be physically able to traverse the region from Range Road 7[1] across to the impact site by following old tracks and trails. If this is not true, alternative access methods will have to be developed.

2. WSNM has agreed to allow a single entry/exit maneuver to install the monitoring wells and devices. Prior to vehicle entry, personnel from the activity performing the work, WSNM, -ES, and –IS will perform a. helicopter reconnaissance to select the route to be followed. IS will mark the SWNM fence on Range Road 7[2] with WSNM concurrent and arrange to install temporary gate or other securable access through the fence, meeting WSNM requirements.

3. Although the actual number and depth of monitoring wells are unknown at this point, a working assumption is that the fieldwork will take from 3-7 days.

4. At the end of the first work day, exit from the site will be by Army Air helicopter-. The vehicle will be left in place at the site. Entry and exit for all additional workdays will also be by Army Air helicopter, and any additional supplies needed for the fieldwork will be transported to the site by Army Air helicopter. The activity performing the work will be required to pre-arrange entry and exit times (contingent upon range schedules and helicopter availability) and coordinate those with Army Air, -NR (range Scheduling), and –ES.

5. Delays in access to the site may be encountered due to range scheduling requirements.

6. This work is being performed at a remote site, with no reasonable road evacuation routes available. Because of this, the following requirements are imposed on the activity performing the work:

a. A portable toilet must be provided the activity performing the work and used during, on-site operations.

b. Both a WSMR radio and a backup cellular telephone must be on-site and operable during all operations. ES will coordinate the provision of the WSMR radio (radio net access to be determined), a battery charger, and a space battery set. The radio must be on and monitored during all on-site operations. Provision of the backup cellular telephone is the activity's responsibility.

c. All personnel present at the site must receive the WSMR UXO safety briefing; prior to entrance to the work site. This will be provided by –ES.

[1]Alternatively, access via the old North-East 30 site road may be used, depending on WSNM approval.
[2]See footnote 1.

d. A personnel listing of all personnel who will be present at the site must be provided to – ES prior to initial entrance to the work site, and as soon as any changes in personnel are identified.

7. POCs for further information on this Enclosure are Mr. Gene Forsythe or Mr. Javier Mendoza They may be reached at 505-678-2224.

DEVELOPMENT OF MISSILE DEPTH ESTIMATES
for the
LANCE MISSILE IMPACT SITE
in the
WHITE SANDS NATIONAL MONUMENT

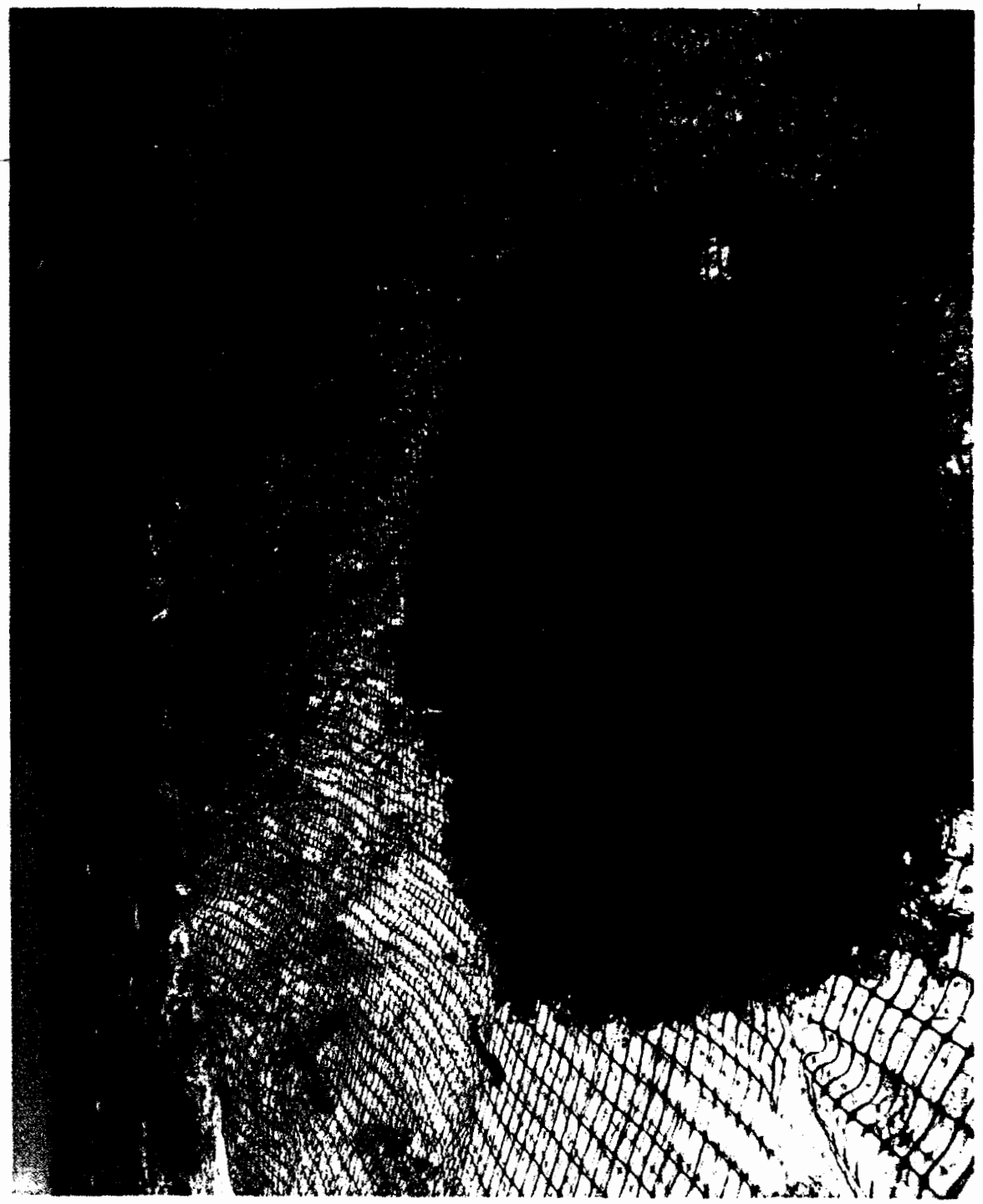
1. Anticipated terminal velocity (velocity at time of impact) and angle of impact for the missile, assuming zero thrust from the motor at and after apogee.

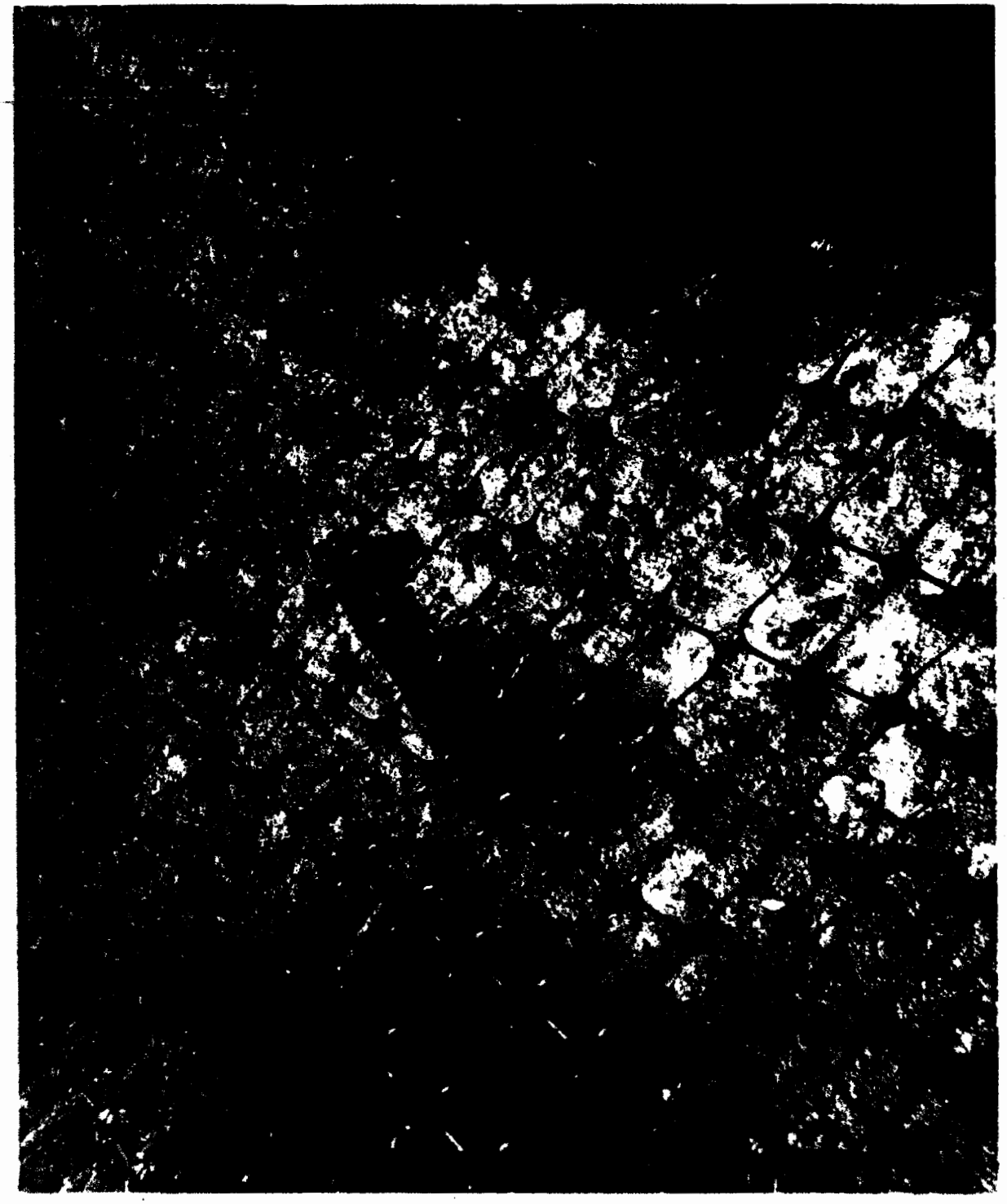
2. Ballistic, co-efficient of the 100 inch warhead section of the missile (weight and dimensions available from MT).

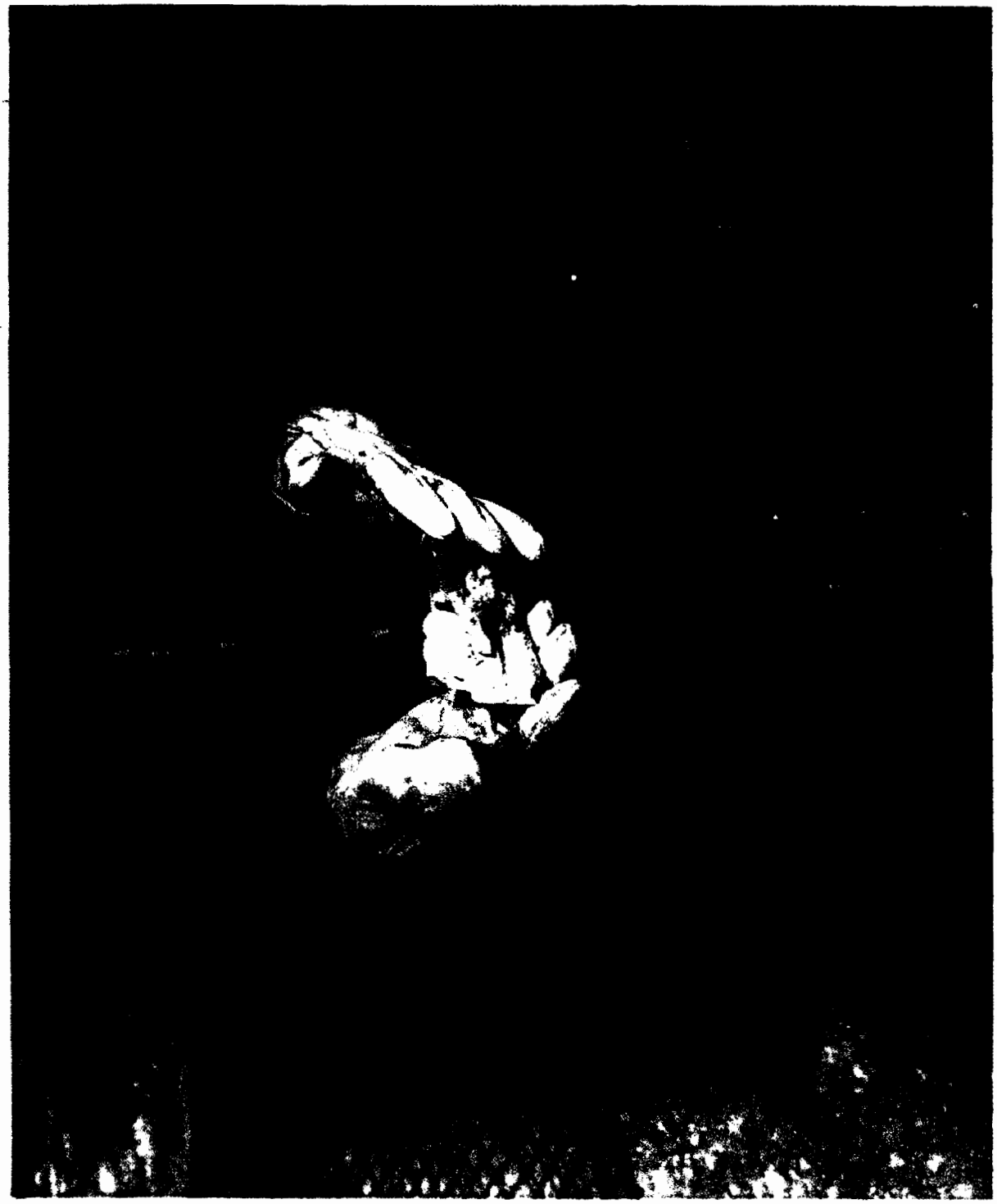
3. Calculated depth, assuming straight-line penetration at calculated angle of impact and intact warhead section, to which the warhead section could have penetrated after impact. ES will provide ground density data for this calculation if required. This may be presented as a range of depths and probabilities, if necessary.

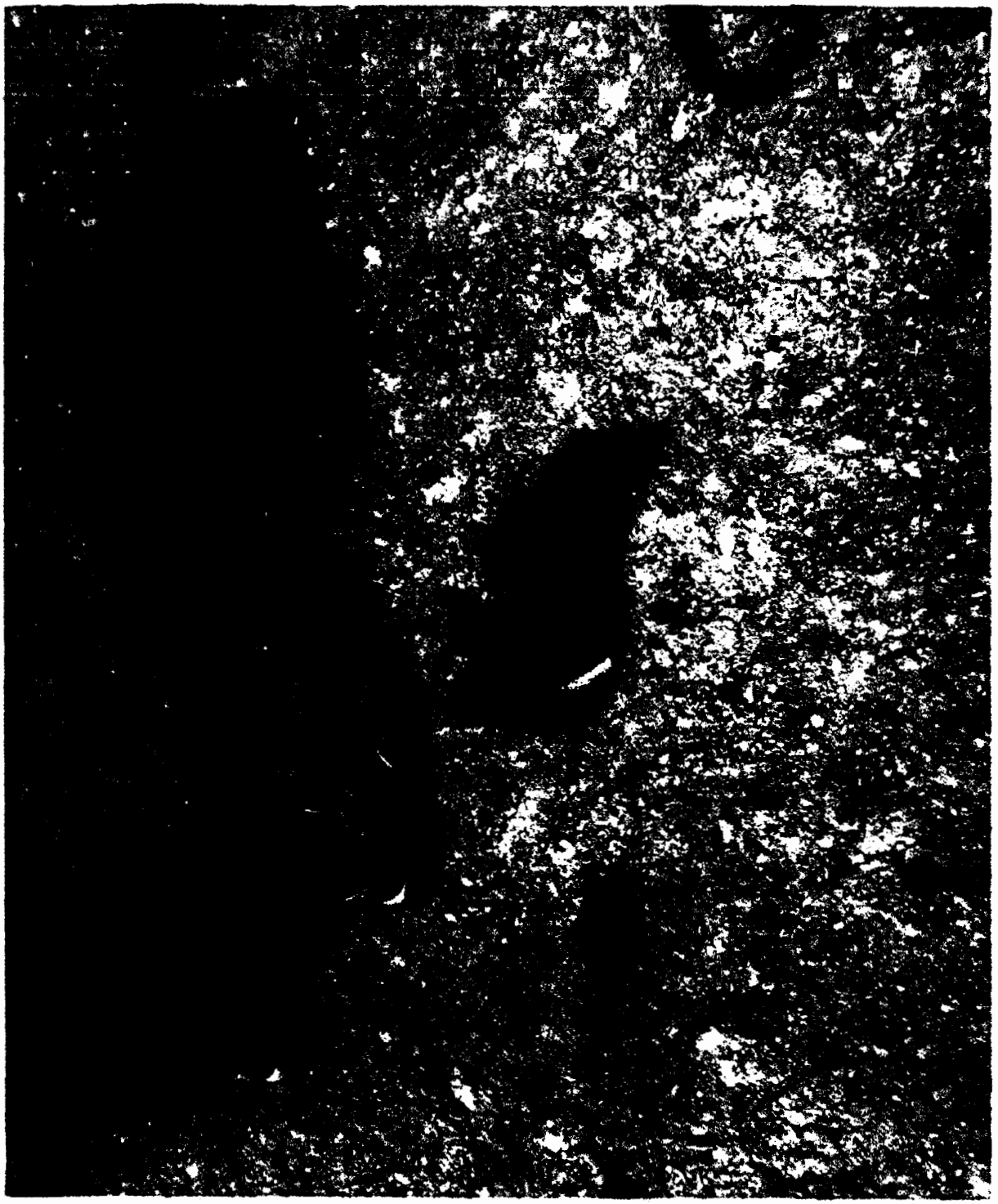
4. Analysis of total missile weight and construction parameters to determine if the depth calculated in item 3., above, would be significantly affected (and to what degree) by the remainder of the missile body after impact.

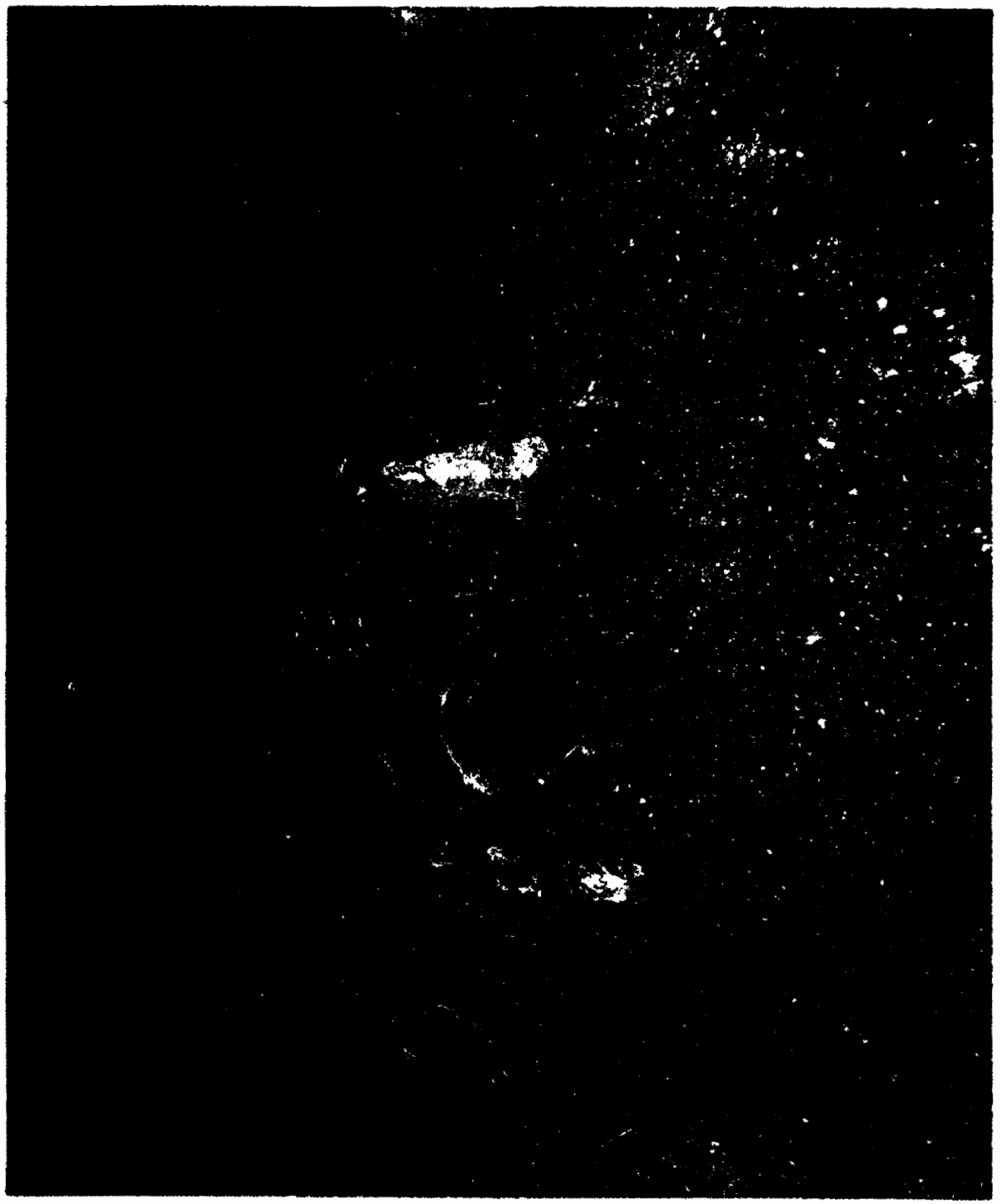
5. POCs for further information on this Enclosure are Mr. Gene Forsythe or Mr. Javier Mendoza. They may be reached at 505-678-2224.

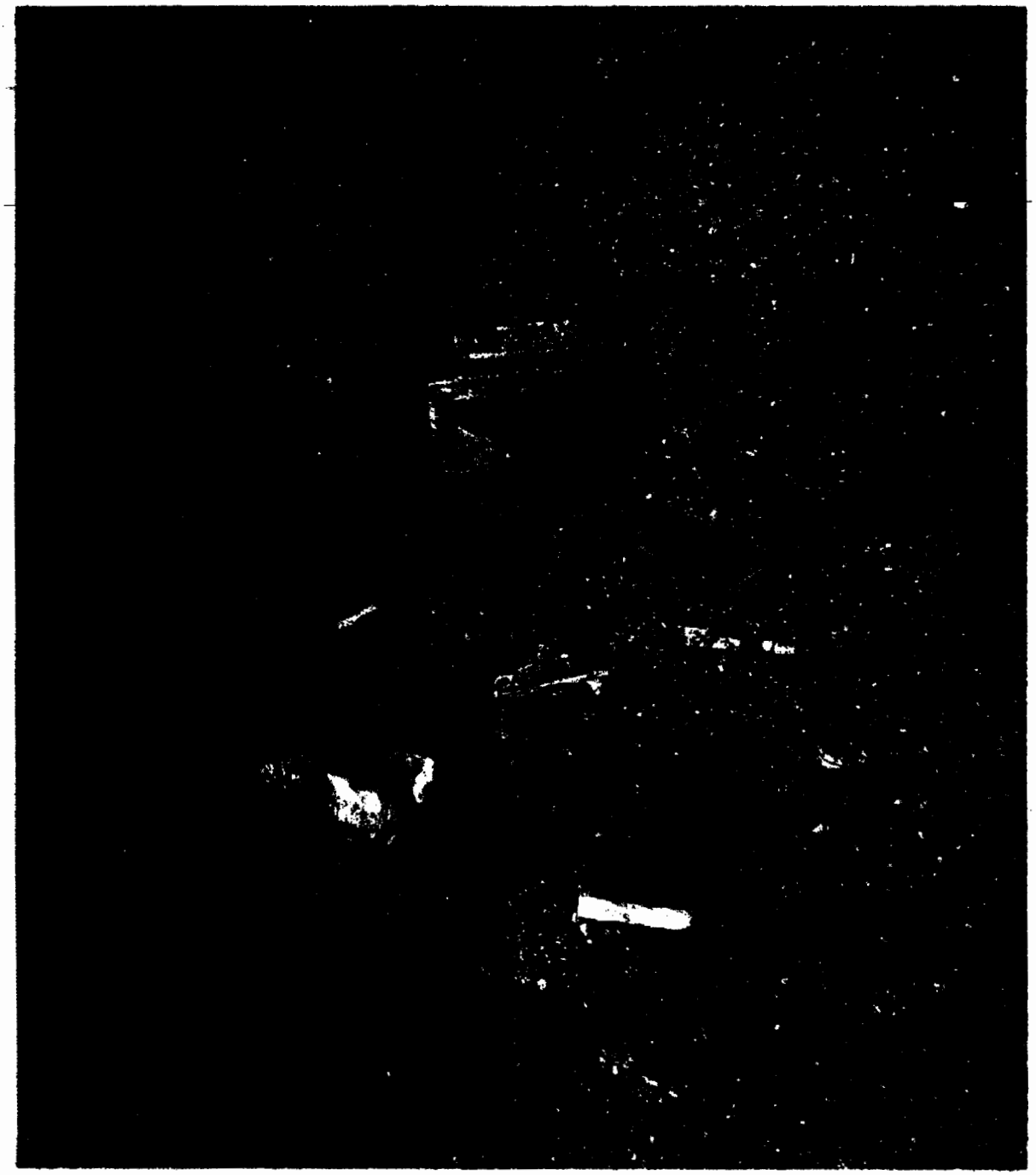












21 DEC 1999

CSTE-DTC-WS-MT-AA (70-10r)

MEMORANDUM FOR ES-EC, ATTN: Mr. Mendoza

SUBJECT: Analysis Support

1. In response to your verbal request, the Applied Environments Test Branch Chemistry Laboratory (MT-AA-E) analyzed six soil samples and one water sample for the presence of Inhibited Red Fuming Nitric Acid (IRFNA) and 1,1-Dimethylhydrazine (UDMH). Also, the Total Dissolved Solids were measured for the water..

2. Results. The results are presented in Table 1, Encl 1.

3. The samples were obtained by ES-EC personnel on 16 Dec 99 and were delivered to the laboratory on the same day. The analyses were completed on 20 Dec 99.

4. Low levels of the target compounds were detected in some of the soil samples and possibly in the water sample. Since no background water sample is provided, it is difficult to assess the significance of the data obtained for the crater water.

5. Please not that low part per million concentrations of Benzene, Toluene, Ethylbenzene and Xylenses were also detected in the soil and water samples. Further assessment of these chemicals would require fresh samples of the soil and water along with the required background samples.

6. Point of contact is Dr. Joseph E. Gomez, MT-AA-E, 678-2992.

for ANDRUS GARAY
Chief, Applied Envr Test Branch

Encl
as

CSTE-DTC-WS-MT-AA (70-10r)

07 FEB 2000

MEMORANDUM FOR ES-EC, ATTN: Mr. Mendoza

SUBJECT: Analysis Support

1. In response to your verbal request, the Applied Environments Test Branch Chemistry Laboratory (MT-AA-E) analyzed six soil samples and three water samples for the presence of Inhibited Red Fuming Nitric Acid (IRFNA) and 1,1-Dimethylhydrazine (UDMH). The water samples were also measured for Total Dissolved Solids and for pH and the soils were also measured for their density.

2. Results. The results are presented in Table 1, Encl 1.

3. The samples were obtained by ES-EC personnel on 26 Jan 00 and were delivered to the laboratory on the same day. They were completed on 3 Feb 00.

4. No evidence for the presence of UDMH in either the soil or water samples was detected. Only slightly elevated levels of Nitrate Ion were detected above background levels for all of samples..

5. Again, low part per million concentrations of Benzene, Toluene, Ethylbenzene and Xylenes were also detected in the soil and water samples.

6. Point of contact is Dr. Joseph E. Gomez, MT-AA-E, 678-2992.

ANDRUS GARAY
Chief, Applied Envr Test Branch

Encl
as

CF:
MT-MT (Mr. Martinez)
MT-MT (Mr. Casares)
MT-AW (Mr. Overley)

TABLE 1

A. Sample Identification

Chem Log 69 - Soil, Background #1, Crater Area, Lance
Chem Log 70 - Soil, Background #2, Crater Area, Lance
Chem Log 71 - Soil, North Edge of Crater, Lance
Chem Log 73 - Soil, West Edge of Crater, Lance
Chem Log 75 - Soil, South Edge of Crater, Lance
Chem Log 77 - Soil, East Edge of Crater, Lance
Chem Log 79 - Water, Background, Crater Area, Lance
Chem Log 80 - Water, Top Sample, Crater, Lance
Chem Log 81 - Water, Bottom Sample, Crater, Lance

B. UDIMH and IRFNA in Soil

Sample Identification	Concentration, parts per million UDMH(1)	IRFNA(2)
Chem Log 69	ND*	7.2
Chem Log 70	ND*	7.1
Chem Log 71	ND*	7.5
Chem Log 73	ND*	10.2
Chem Log 75	ND*	9.5
Chem Log 77	ND*	8.3

(1) These data were obtained by Purge and Trap Gas Chromatography/Mass Spectrometry. Freshly prepared standards of UDMH were used for calibration and quantitation.

(2) These data were obtained by Ion Chromatography. A freshly prepared reference standard was used for calibration and quantitation. The IRFNA was quantitated on the basis of Ion concentration levels.

* ND = None Detected - detection limit for UDMH in soil = 0.3ppm.

C. Soil Density

Sample Identification	Soil Density (grams/cubic centimeter)
Chem Log 69	1.20
Chem Log 70	1.14
Chem Log 71	1.09
Chem Log 73	1.05
Chem Log 75	1.31
Chem Log 77	1.19

D. UDMH and IRFNA in Water

Sample Identification	Concentration, parts per million UDMH(L)	IRFNA(2)
Chem Log 79	ND*	3.8
Chem Log 80	ND*	3.2
Chem Log 81	ND*	8.7

(1) These data were obtained by Purge and Trap Gas Chromatography/Mass Spectrometry. Freshly prepared standards of UDMH were used for calibration and quantitation.

(2) These data were obtained by Ion Chromatography. A freshly prepared reference standard was used for calibration and quantitation. The IRFNA was quantitated on the basis of Ion concentration levels.

* ND = None Detected - detection limit for UDMH in water = 0.1ppm

E. Total Dissolved Solids (TDS)

Sample Identification	TDS (milligrams/liter)
Chem Log 79	3,160
Chem Log 8 0	4,820
Chem Log 81	12,000

F. pH

Sample Identification	pH
Chem Log 79	7.0
Chem Log 80	7.2
Chem Log 81	7.8

DEPARTMENT OF THE ARMY
US ARMY WHITE SANDS MISSILIE RANGE
WHITE, SANDS MISSU RANGE, NEW MEXTCO 88002-

REPLY TO
ATTENTION OF

March 15, 2000

Environmental and Safety Directorate

Mr. James P. Bearzi
Chief, Hazardous and Radioactive Materials Bureau
P. O. Box 26110
2044 Galisteo
Santa Fe, New Mexico 87502

Dear Mr. Bearzi:

This letter is to formally update your office with the enclosed laboratory results as stated in our letter dated March 2, 2000 to your office. We will provide the remaining laboratory results as soon as they are provided to our office.

Any questions concerning this report should be addressed to Mr. Javier Mendoza, Environmental Compliance at (505) 678-2224.

Sincerely,

Thomas A. Ladd

Thomas A. Ladd
Director, Environment and Safety Directorate

Enclosure
NASA-WSTF
Analysis Report

Copy Furnished:
NMED Groundwater Bureau (Ms. Loreen Lithgow)

Preliminary Report of Analytical Results
from
soil and water samples collected
at the
Lance Missile Impact Site, White Sands National Monument, N.M.

MEVATEC has received results from two of the four laboratories engaged to analyze soil and water samples collected from the site of the Lance Missile impact at White Sands National Monument. The missile impacted within the boundaries of the National Monument on xx January; samples were collected by MEVATEC on 28 February 2000 and were received by the analytical laboratories on 29 February 2000.

Soil and water samples were collected from the site as follows:

- Soil samples were collected at the surface around the impact crater at the four compass points.
- Additional soil samples were collected at the surface approximately 150 feet (46 m) east and west of the impact crater.
- Water samples were collected from water standing in the impact crater. One sample of water was collected from the surface of the pool and one sample was collected from a depth of approximately four feet below the surface of the pool.
- An additional water sample was collected from a hand-augured boring of approximately 4 feet below ground surface 150 feet east of the impact crater. The sample collected from the hand-augered boring was collected to serve as a comparison for background water conditions.
- Five simple splits were collected; three of the splits were shipped to analytical laboratories, one split is being held for analysis by the WSMR Chemistry Laboratory (MT) pending repair of their instrument, one split was held in reserve in case of breakage of sample containers during shipping-

A sample split was delivered to NASA-WSTF for the analysis of UDMH; results were received today (3/15/2000) and were reported negative (less than the detection limit) for UDMH in all soil and water samples.

A sample split was shipped to Southwest Research Institute (SWRI) of San Antonio, TX and sample split was shipped to GPL Labs Gaithersburg, MD. These laboratories were contracted to provide analysis of N-Nitrodimethylamine and N-Nitrosodimethylamine, dissolved constituents, and water quality parameters. Results of analyses were received today (3/15/2000) from SWRI; GPL Labs has not yet returned their analyses.

SWRI reported concentrations of N-Nitrodimethylamine at 0.09 pg/L in the two water samples collected from the impact crater; all other samples were reported negative (less than the detection limit). No concentrations of N-Nitrosodimethylamine were reported.

Analysis of water quality parameters revealed no concentrations out of the ordinary, given the location of the shallow ground water in the center of a closed geomorphic basin with no through drainage.

Results received thus far are considered by MFVATFC to be those most likely representative of the true conditions at the impact site. These laboratories (NASA-WSTF and SWRI) are the laboratories that develop the methods for the analyses they were asked to perform.

ANALYTICAL REPORT
LWO# [illegible]

INTRODUCTION

The NASA White Sands Test Facility (WSTF) Chemistry and Metallurgy Laboratory was requested to analyze 6 soil and 3 water samples for unsymmetrydimethylhydrazine (UDMH). The samples were delivered to the laboratory on [illegible], inspected, and the custody form (attached) was signed. Samples were stored refrigerated until they were extracted and/or filtered, then analyzed by high performance liquid chromatography on [illegible]. One water sample was analyzed in duplicate, and one soil extract was spiked and analyzed. UDMH results are reported in units of mg/kg; results for soils are reported on a dry weight basis (Table 1). Quality control results are shown in Table 2.

ANALYTICAL RESULTS

Table 1. Analytical Results

Sample [illegible]	UDMH (mg/kg)	Reporting Limit (mg/kg)
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	ND	[illegible]

* ND means not detected at the indicated reporting limit.

QUALITY CONTROL RESULTS

Table 2. Quality Control Results

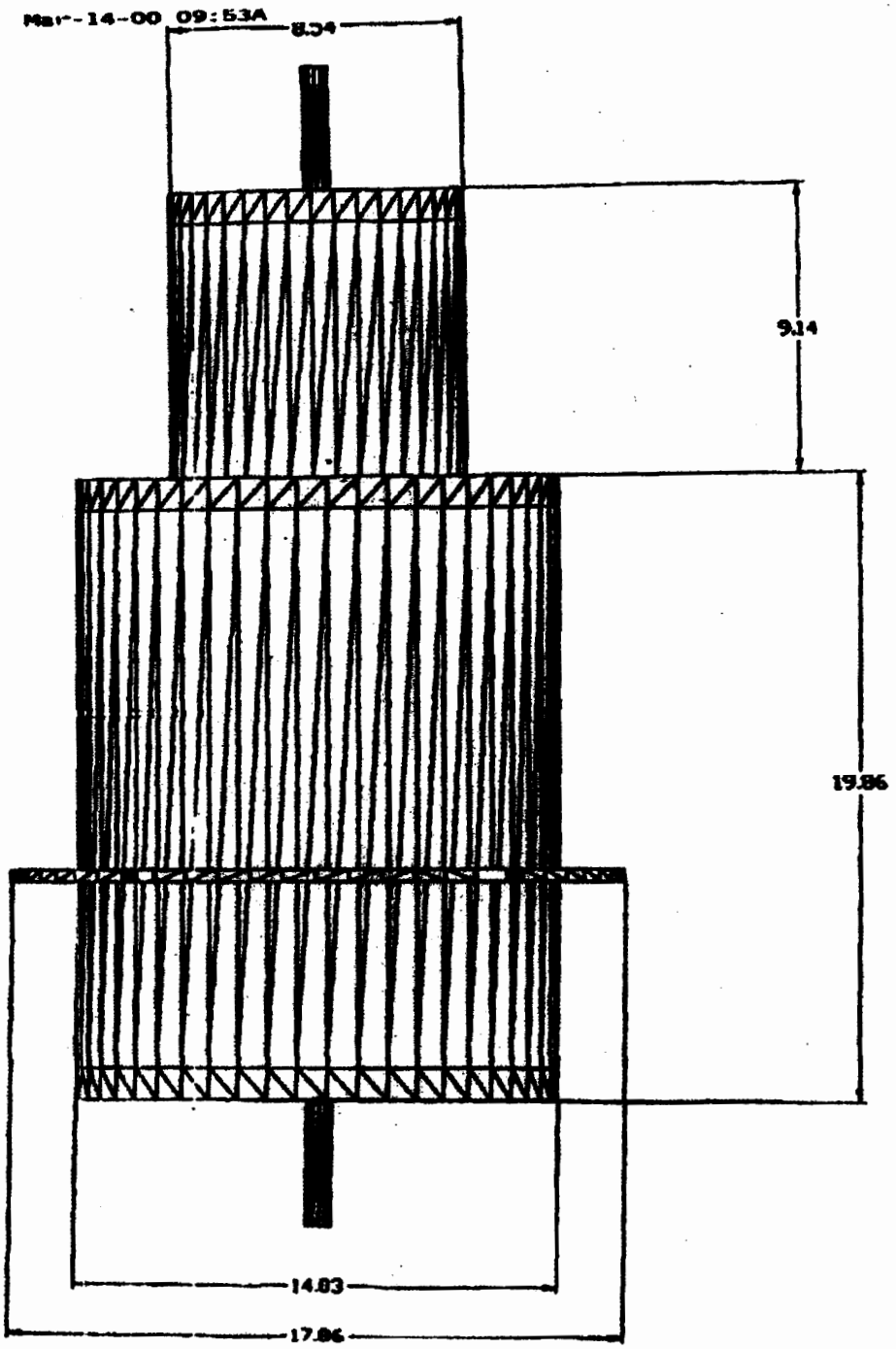
Control Type	UDMH Result (mg/kg)	Allowed Limits
[illegible]	[illegible]	[illegible] mg/kg
[illegible]	[illegible]	[illegible] mg/kg
[illegible]	[illegible]	< [illegible] mg/kg
[illegible]	ND	< [illegible] mg/kg
[illegible] spiked with [illegible] mg/kg (SOIL [illegible] - WATER [illegible])	[illegible]	[illegible] mg/kg
[illegible] duplicate ([illegible] - SOIL [illegible] - [illegible])	ND	<[illegible]% RPD**

* ND means not detected at the indicated reporting limit.
** RPD means relative percent difference

Prepared By: [illegible] Approved By: [illegible]

Date: 3/9/00 Date: 03/09/00

Lance Warhead Configuration



LANCE IMPACT

1. According to radar track, the Lance impacted at the following coordinates:

32.74583435 degrees (North)	[WSTMX: 479,810.54]
10.3989945 degrees (West)	[WSTMY: 310,711.40]

Radar data showed the flight path angle to be -70.71 degrees and the speed at impact to be 345.02 meters/second or 1131.94 feet/second. This impact is approximately 30 kilometers downrange on a nominal 130 km flight.

2. Weights for the given configuration are:

Empty (M252 warhead w NO Fuel)	1390.73 lbs
Maximum fuel (Unsymmetrical Dimethylhydrazine: UDMH)	375.5 lbs
Maximum oxidizer (Inhibited Red Fuming Nitric Acid: IRFNA)	1106.5 lbs
Nominal fuel and oxidizer at 30 km	470.80 lbs

3. An analysis of the recorded velocities from the radar track provides the following observations:

   a. The missile failed to achieve a nominal velocity profile. This results not only in reduced altitude and range; but also, since the booster motor is designed to cut out at a specified velocity, a longer burn time.

   b. The missile lost thrust after approximately 7 seconds compared to a nominal. cut off time of 5 seconds. This is consistent with a motor using fuel at the boost rate without cut off.

4. For purposes of determining depth penetration, it will be necessary to estimate the weight of the missile and remaining fuel at impact. A normally functioning LANCE missile at 30 km will weigh 1861.53 lbs. As previously noted, this wasn't a normally functioning missile; the low apogee, low velocity and short range would indicate that more than the usual amounts of fuel and/or oxidizer remained at impact. Lance Smith of MT-MT has hypothesized a constriction in the oxidizer (IRFNA) flow lines. If the flow of oxidizer were restricted, the thrust would be reduced without reducing the quantity of fuel used. This would be like running an automobile with the choke on. As such, there, would be a minimal amount of fuel and an unknown weight of oxidizer remaining at impact. A rough guess at the weight of unused oxidizer would proceed as follows:

   a. The ballistic range of a missile, that is, the range it will travel after thrust ceases is proportional to the initial velocity.

b. The velocity achieved is proportional to the weight of fuel burned

c. The fuel actually burned, not merely vented, is proportional to the amount of oxidizer present: halve the amount of oxidizer and only half the fuel will be burned; the other half will be vented.

d. Therefore, since the total range of the missile was reduced by 75% (130 km to 30km) a first approximation would indicate that the use of oxidizer would be reduced by 75% also. Normally, in the first 30 seconds of flight the missile uses 770 lbs of oxidizer. Twenty five percent of this weight is 192.5 lbs used with 914 1bs remaining at impact. The total missile impact weight would be 2204 lbs.

e. An observer in the launch crew reported a red plume after launch, since this was probably oxidizer, the actual weight of oxidizer remaining at impact was less than the amount stated.

6. A telephone call to Michele Crull (256-895-1653) of the U.S. Corps of Engineers in Huntsville, AL yielded the following penetration distances:

	sand	soil with vegetation	clay
a. Intact Missile	22.7 feet	29.9 feet	45.6 feet
b. Fuel Tank (Empty)	10.3 feet	13.6 feet	22.7 felt
c. Oxidizer Tank (Empty)	10.7 feet	14.1 feet	21.5 feet
d. Motor	10.5 feet	13.8 feet	21.0 feet

7. A telephone call to the Environmental Office at WSMR yielded the following information on the soils of the ALKALAI FLATS, the area in the vicinity of Lake Lucero where the impact occurred. The surface is gypsum to a depth of 5 feet over Alluvial Sediments (gypsum and sand) with caliche (clay).

8. On 16 March, Lance Smith (MT-MT), Andre Bullit (Lance Project Engineer), Robin Wilson (MT-AW). William Glaster (Lockheed-Martin Flight Services), Mike Smith (New Tec Photographer), and Lance Wheeler (NR-CF) inspected the impact site. They found:

a. The surface materials were powdery and easily compressed (foot pressure).

b. The water table was measured to lie approximately two (2) feet below the surface.

c. The missile impact caused a circular crater measuring 18 feet in diameter and a visible depth of approximately 5 feet in depth.

d. Many small pieces of missile debris were observed on the surface exterior to the crater and several pieces partially buried within the crater. An on-site inspection by William Glaster indicated that the debris came from different sections of the missile: warhead skin, fuel tanks, fins and motor mount assembly.

e. The presence of the debris over the surface of the impact site indicates that the missile blew apart on impact, possibly due to mixture of oxidizer with residual amounts of fuel.

9. If the vehicle fragmented on impact (as it appears to have done) as the result of an explosion or kinetic stresses, the penetration depths specified in the above paragraphs are not valid except as maxima. If either of the tanks survived the explosion, it is not buried beyond a depth of 23 feet.

10. The on-site inspection of the debris indicated that either the fuel tank, the oxidizer tank or both tanks ruptured on impact. The Flight Safety office recommends that an analysis of the debris be conducted to confirm that both the fuel and oxidizer tanks ruptured at impact. Referring to the enclosed memorandum from Mr. Gomez, Chemist, the reagents (IRFNA and UDMH) combine with each other or with ground water.

11. Water samples taken 6 weeks after the impact indicate no appreciable or reoccurring contamination such as would be the case if a buried tank were leaking fuel or oxidizer.

APPENDIX B

SPECIAL USE PERMIT ISSUED BY THE WSNM

Form 10-114
Rev. DEC. 99

UNITED STATES DEPARTMENT OF THE INTERIOR
National Park Service

Special Use Permit

Name of Use **Access; install & operate groundwater testing facilities**

Date Permit Reviewed 20__ _____
Reviewed 20 __ _____
Reviewed 20 __ _____
Expires **2002** __

Long Term ____

Short Term **X**

Permit # _____
Region Park Type No. #

Name of Area

Gene Forsythe
White Sands Missile Range of **White Sands Missile Range** **505-678-xxxx**
Name or Permittee Address Phone

is hereby authorized during the period from (Time **0001hrs** day __ Month __ 20**02**), through (Time **2359hrs** day __ Month __ 20**02**), to use the following described land or facilities in the above named area:

National Park Service lands immediately surrounding the Lance Missile impact site of December 1999. Approximate coordinates of site are (UTM) 368 928, 3624.01N.

For the purpose(s) of:

Access to install, connect, and operate subsurface drilling analysis and testing equipment, for the purpose of capturing and testing groundwater for possible contamination.

Authorizing legislation or other authority (CFR - DO 53): **16 U.S.C. 1 et seq.; 42 U.S.C. 9601 et seq.**

NEPA Compliance: CATEGORICALLY EXCLUDED **X** EA/FONSI ___ EIS ___ OTHER APPROVED PLANS ___

PERFORMANCE BOND: Required _____ Not Required **X** Amount $_____

LIABILITY INSURANCE: Required _____ Not Required ____ Amount $_____

ISSUANCE of this permit is subject to the conditions on the reverse hereof and appended pages and when appropriate to the payment to the U.S. Dept. of the Interior, National Park Service of the sum of $

The undersigned hereby accepts this permit subject to the terms, covenants, obligations, and reservations, expressed or implied herein.

PERMITTEE _____ _____
Signature Date

Authorizing Official _____, James A. Mack _____
Signature Superintendent Date

Additional Authorizing Official _____, _____ _____
(if Required) Signature Title Date

CONDITIONS OF THIS PERMIT

. The permittee shall exercise this privilege subject to the supervision of the Superintendent, and shall comply with all applicable laws and regulations of the area.

. The issuance of this permit will grant White Sands Missile Range (WSMR) access to National Park Service (NPS) property to conduct those activities necessary to perform the work set forth in the attached statement of work entitled "Work Plan".

. All personnel and equipment will be transported to the site by helicopter. Any vehicles brought to the site will be limited to traveling within the established work zone. The zone will be clearly delineated by an NPS representative prior to the commencement of work.

. WSMR will provide portable toilets for personnel assigned to the site.

. The NPS reserves the right to stop work being performed on NPS property should the NPS determine that such work has or will negatively impact any NPS resources.

. WSMR personnel and contractors must be apprised of, and be familiar with, the contents of this permit. A copy of this permit will be available on-site during all phases of the associated work.

. Any monitoring wells will be installed in accordance with industry standards and as approved by the NPS. The wells will be located with NPS approval: (a) so as not to negatively impact any NPS resources, including but not limited to natural, cultural, and infrastructure resources; (b) to most effectively delineate the contamination identified, in order to minimize the number of wells required to be installed on NPS property; and (c) in accordance with National Historical Preservation Act (NHPA), section 106 clearance.

Unless the NPS requires otherwise in writing, monitoring wells will be completed with metal locking covers. Covers and aprons will be painted desert tan. Duplicate keys will be provided to the NPS at time of installation. Each well will have a permanent label (beneath the cover) with well number and any other identifying information.

All wells will be located by UTM format to the nearest meter. The data will be provided in the final report.

All laboratory analytical data from sampling events conducted by WSMR on NPS lands will be provided to the NPS within 30 days after sample collection.

8. This permit does not authorize any use, activity, or purpose other than those expressly herein described.

9. Assignment - This permit may not be transferred or assigned without the consent of the Superintendent, in writing.

10. This permit does not grant any property rights, easements, rights-of-ways, etc.

11. PREVENTION OF DAMAGE AND RESTORATION OF SITE: WSMR shall take adequate measures as directed and approved by NPS to prevent or minimize damage to all Park resources during all activities including, but not limited to well installation and sampling. This may include but not be limited to restoration, soil conservation and erosion protection measures, landscaping, and repairing roads, trails, signs, etc. Any trees damaged or removed will be replanted as directed by NPS. All work on Park lands shall be completed to the satisfaction of NPS.

12. QUALITY CONTROL: An NPS representative will observe all activities on NPS property, or those activities that are or may be impacting NPS property and resources.

13. REIMBURSEMENT FOR NPS PERSONNEL: WSMR will compensate the NPS for all hours worked by NPS personnel under this Special Use Permit. NPS will provide WSMR a Bill for Collection for all associated costs.

14. REGULATORY REQUIREMENTS: All site work will be conducted and implemented in accordance with all Federal, state, and local regulations and requirements, including the Comprehensive Environmental Response, Compensation and Liability Act, CERCLA, 42 U.S.C sections 9601 et seq., and the National Oil and Hazardous Substances Pollution Contingency Plan, 40 C.F.R Part 300 et seq., and shall be consistent with the NPS mission (see e.g., 16 USC Sections 1 et. seq.).

15. WSMR shall make available to the NPS all information in its possession that is relevant to Site Work and all other related environmental work, in a timely fashion. Five copies of identified information will be delivered by WSMR to the NPS point of contact within 30 days of completion of the work.

16. SAFETY: All applicable Federal, state, and local health and safety regulations and standards, including those cited in 29 Code of Federal Regulations (CFR) 1910.120, will be adhered to while performing any work on NPS property.

17. Upon NPS request, WSMR will close all wells and restore the area in accordance with State, EPA, and NPS requirements.

18. Future access to NPS property or any modifications to this permit will require a written amendment issued by the NPS.

19. All work and investigations on NPS property requires a minimum 48-hour notice to the NPS point of contact.

20. The NPS point of contact for all aspects of this permit will be James A. Mack, Superintendent, White Sands National Monument. His alternate will be Bill Conrod, Chief of Resources Management, White Sands National Monument. Either can be contacted at (505) 679-2599, or by mail at P.O. Box 1086, Holloman AFB, NM 88330-1086.

21. Damages - The permittee shall pay the United States for any damage resulting from this use which would not reasonably be inherent in the use which the permittee is authorized to make of the land described in this permit.

22. Benefit - Neither Members of, nor Delegates to Congress, or Resident Commissioners shall be admitted to any share or part of this permit or derive, either directly or indirectly, any pecuniary benefits to arise therefrom: Provided, however, that nothing herein contained shall be construed to extend to any incorporated company, if the permit be for the benefit of such corporation.

23. Revocation - This permit may be terminated upon breach of any of the conditions herein or at the discretion of the Superintendent.

24. The permittee is prohibited from giving false information; to do so will be considered a breach of conditions and be grounds for revocation [Re: 36 CFR 2.32(a)(4)].

25. Permittee will comply with applicable public health and sanitation standards and codes.

26. This agreement is made upon the express condition that the United States, its agents and employees shall be free from all liabilities and claims for damages and/or suits for or by reason of any injury, or death to any person or property of the Permittee, its agents or employees, or third parties, from any cause or causes whatsoever while in or upon said premises or any part thereof during the term of this agreement or occasioned by any occupancy or use of said premises or any activity carried on by the Permittee in connection herewith, and the Permittee hereby covenants and agrees to indemnify, defend, save and hold harmless the United States, its agents and employees from all liabilities, charges, expenses and costs on account of or by reason of any such injuries, deaths, liabilities, claims, suits or losses however occurring or damages growing out of the same.

27. Permittee shall present to the National Park Service for review and approval any reports, studies, analyses or other deliverable derived in whole or in part from information or data gathered under this permit.

d. Many small pieces of missile debris were observed on the surface exterior to the crater and several pieces partially buried within the crater. An on-site inspection by William Glaster indicated that the debris came from different sections of the missile: warhead skin, fuel tanks, fins and motor mount assembly.

e. The presence of the debris over the surface of the impact site indicates that the missile blew apart on impact, possibly due to mixture of oxidizer with residual amounts of fuel.

9. If the vehicle fragmented on impact (as it appears to have done) as the result of an explosion or kinetic stresses, the penetration depths specified in the above paragraphs are not valid except as maxima. If either of the tanks survived the explosion, it is not buried beyond a depth of 23 feet.

10. The on-site inspection of the debris indicated that either the fuel tank, the oxidizer tank or both tanks ruptured on impact. The Flight Safety office recommends that an analysis of the debris be conducted to confirm that both the fuel and oxidizer tanks ruptured at impact. Referring to the enclosed memorandum from Mr. Gomez, Chemist, the reagents (IRFNA and UDMH) combine with each other or with ground water.

11. Water samples taken 6 weeks after the impact indicate no appreciable or reoccurring contamination such as would be the case if a buried tank were leaking fuel or oxidizer.

APPENDIX C

GEOPHYSICAL SURVEY AT THE WHITE SANDS NATIONAL MONUMENT WHITE SANDS MISSILE RANGE NEW MEXICO

GEOPHYSICAL SURVEYS AT THE WHITE SANDS NATIONAL MONUMENT WHITE SANDS MISSILE RANGE, NEW MEXICO

Blackhawk GeoSciences Project Number: 2715MVT

Prepared For:

MEVATEC CORPORATION
P.O. Box 399
Building 126, 3rd Floor
White Sands Missile Range, New Mexico 88002
505-678-3412 • Fax 505-678-6449

Prepared By:

BLACKHAWK GEOSCIENCES, INC.
301 Commercial Road, Suite B
Golden, Colorado 80401
303-278-8700 • Fax 303-278-0789

February 21, 2002

GEOPHYSICAL SURVEYS AT THE WHITE SANDS NATIONAL MONUMENT WHITE SANDS MISSILE RANGE NEW MEXICO

Blackhawk GeoScience Project Number 2715MVT

Prepared For:
MEVATEC CORPORATION

TABLE OF CONTENTS

1.0 **INTRODUCTION** ____ 3

2.0 **DATA ACQUISITION AND PROCESSING** ____ 4

2.1 GENERAL ____ 4

3.0 **INTERPRETATION AND RESULTS** ____ 6

3.1 DISCUSSION OF GEOPHYSICAL DATA ____ 6

3.1.1 EM61 DATA ____ 6

3.1.2 MAGNETOMETER DATA ____ 6

3.1.3 COMBINED INTERPRETATION ____ 7

4.0 **SUMMARY AND CONCLUSIONS** ____ 10

Appendix A - Technical Note

1.0 INTRODUCTION

This report contains the procedures and results of geophysical surveys conducted at the White Sands National Monument (WSNM) located within the White Sands Missile Range (WSMR), New Mexico. Blackhawk GeoSciences, Inc. (Blackhawk) performed the work for MEVATEC Corporation (MEVATEC) on February 4, 2002.

The objective of the geophysical surveys was to map the location of a buried Lance Missile and expected debris, which impacted the area. The Lance Missile is about 20 feet in length, 22 inches in diameter and carried a simulated warhead consisting of welded steel pipe. The surveys were undertaken to detect the metallic debris from the missile impact, which will aid in determining future borehole sampling locations on the site. To accomplish the survey objective, the following geophysical instruments were utilized:

- Geonics EM61-MK2 High Resolution Metal Detector
- Geometrics G858 Cesium Vapor Magnetometer

A brief description of the fundamentals and applications of these methods are given in Appendix A.

The Lance Missile Impact Site is located within the alkali flats area on the WSNM in Dona Ana County, New Mexico (Figure 1-1). The missile penetrated the ground surface and created an impact crater about 18 ft in diameter and 5 ft deep. The depth of burial of the missile is expected to be no more than 23 ft bgs. The site surrounding the impact crater is generally flat and the surface geology consists mainly of gypsum crystal fragments with some thin clay layers in the upper 10 to 25 ft. The surface vegetation consists of sparse clumps of grass with some small bushes. The impact site is located approximately 2.5 miles east of Range Road 7, as shown in Figure 1-2.

2.0 DATA ACQUISITION AND PROCESSING

2.1 General

The Lance Missile Impact site was accessed by helicopter supplied by MEVATEC. A helicopter was required since vehicle transport to the site was not allowed by WSNM. The main limitation caused by use of the helicopter was that the geophysical survey was restricted to one field day. Because of this limitation, Blackhawk could not survey the grid location with our Differential Global Positioning System (DGPS). Instead, the grid was surveyed by MEVATEC as described later in this section.

Blackhawk field personnel established a 100 ft by 100 ft survey grid centered on the Missile Impact Crater. Survey points were marked at each grid corner and at each end of a 5-ft line spacing grid with a wooden stake on the ground. The origin (0,0) of the geophysical survey grid was located in the southwest corner of the site. The geophysical data were collected along parallel south-north lines over the grid. Survey grid north was initially established by compass. To obtain complete data coverage over the impact crater, shoveling of the ground surface was necessary to taper the steep sides of the crater walls. Wooden planks were laid across the open crater pit such that an operator could use the plank to walk and also pull the instrument across the crater. Missile debris (i.e. fiberglass, metal parts) located on the ground surface and in portions of the impact crater was removed from the grid site prior to the geophysical survey so as to not interfere with the survey data.

The Geonics EM61-MK2 high-resolution metal detector was utilized to map both ferrous and non-ferrous (i.e. iron and aluminum) buried objects at the site. The instrument was used in trigger mode, where a wheel odometer triggered a measurement every 0.65 ft. The EM61 data was stored in a data logger. The data were taken on 5 ft line spacing oriented south-to-north across the survey grid. The EM61 instrument can detect very small metallic objects (i.e. pop can) and the occurrence of a large amount of surface metal debris will mask the response from deeper targets (i.e. missile parts). The typical response of the EM61 system is a "bull's-eye" located directly over a buried metallic object. The maximum exploration depth of the EM61 is about 10 feet for detecting a single 55-gallon metal drum.

Magnetometer measurements were taken at the site with the Geometrics G858 Cesium Vapor magnetometer to identify areas with ferrous (iron) metal. The magnetic data were stored in the Geometrics G858 data logger along survey lines that were 5 ft apart with a station spacing of approximately 0.5 ft. The exploration depth of the magnetometer is generally proportional to the amount of ferrous material in the buried object, and for a single metal drum the exploration depth is typically greater than 20 ft. The magnetometer is not as sensitive as the EM61 to very small near surface metallic items. The response of the magnetometer to buried metal objects can be complex and the lateral resolution is generally less than the EM61 system. The magnetometer data were corrected for diurnal drift using a moving linear filter.

The field data from each instrument were transferred from the data loggers to a PC and checked for completeness and accuracy. The coordinates of the four survey grid corners were acquired by MEVATEC with a Trimble Omni Star DGPS. The accuracy of the Omni Star DGPS receiver is expected to be sub-meter with post processing of the data. The GPS grid data were used to apply a positional warp to the geophysical sensor

data to translate the data into New Mexico State Plane (Central Zone) coordinates. The data files for each instrument were used to produce a combined grid file (instrument response and sensor position) that was imported into the Oasis mapping program, where gridding algorithms were used to create color contour maps for each method.

3.0 INTERPRETATIONS AND RESULTS

3.1 Discussion of Geophysical Data

3.1.1 EM61 Data

The results of the EM61-MK2 survey at the WSNM Lance Missile site are shown on Figure 3-1. This figure shows the color grid of Channel 1 (Bottom Coil), along with the surveyed outline of the impact crater and geophysical data lines overlain on the map. In the presence of metallic objects, the EM61 signal response increases and the unit of measurement is the millivolt (mV). The size and shape of the metallic objects and their depth of burial determine the magnitude of the EM61 signal. Generally, background EM61 responses have a value close to zero, and all anomalies on this color map with amplitudes greater than about 15 mV are expected to be caused by buried metallic objects, unless otherwise noted. In Figure 3-1, there is a significant increase in the recorded instrument response near the center of the survey grid, occurring both in and around the impact crater. This suggests that a large portion of the Lance missile is located within and slightly north of the impact crater. Several other areas of the grid also display higher EM61 values, which suggests that more metal parts of the missile (i.e. metal scrap) are present in these areas. The EM61 survey identified five areas of significant anomalous response not associated with surface metal debris. The five areas are identified by a letter (A through E), and are outlined on the map and discussed in Section 3.1.3.

3.1.2 Magnetometer Data

The magnetometer measures the presence of ferrous metal objects. The depth at which metal objects can be detected depends on their size. For example, a single metal drum may be detectable at a depth of about 20 feet, whereas larger metallic objects would be detected at deeper depths. The measurement unit for magnetic field intensity is the gamma (G). The earth's magnetic field induces a magnetic moment per unit volume in ferromagnetic material. The measured total magnetic field is the vector sum of the earth's magnetic field and any perturbations caused by local ferromagnetic objects along with the magnetic field of geologic materials. A total field magnetic anomaly usually contains both a magnetic high and an associated magnetic low response (dipolar). These dipolar responses can range from tens to hundreds of gammas, and can result in a significant anomaly associated with large ferromagnetic objects. Numerous metal objects in a limited area may distort the pairing of high and low anomalies, but the area containing the buried metal will be significantly different from background both in magnitude and variation.

For the Lance Missile site, the Magnetic data were processed first using the total magnetic field. A background level of 49,320 gammas was subtracted from the data points and a drift correction was applied, the resultant color plot is shown in Figure 3-2. This map shows the complicated total magnetic field results over the missile site. Next, the data were processed from the total magnetic field data to analytic signal in order to help simplify the anomaly shape. The analytic signal is derived from the square root of the sum of the squares of the three gradients of the magnetic field (gammas/m). Analytic signal anomalies therefore, have a peak response that is centered over the top of the source of the magnetic anomaly, which creates a simpler map than the total field map.

The results of the analytic signal are shown on Figure 3-3. Magnetic responses greater than about 5 gammas/m are expected to be caused by significant buried ferrous objects. A total of five magnetic anomalies (A through E) are outlined on the analytic signal color contour map and they are also described below.

3.1.3 Combined Interpretation

Anomalous areas in the EM61 and Magnetometer (analytic signal) data have been outlined on Figures 3-1 and 3-3, respectively. The locations of other surface metal debris are also shown on the figures. The EM61 data are most useful for defining the limits of the anomalous areas, because of the better lateral resolution with this method. A total of five anomalous areas (A through E) are detected in both the EM61 and Magnetometer data sets. Lists of the coordinate center (New Mexico Central Zone) of the anomalous areas for the EM61 and Magnetometer data are given in Table 3-1 and Table 3-2, respectively.

Table 3-1

EM Anomalies

Anomaly	State Plane (X)	State Plane (Y)	Comments
A	1594606.54	635029.49	Very large and significant anomaly. Likely comprised of several targets. Corresponds to Magnetic Anomaly A.
B	1594592.79	635019.04	Small confined target, May correspond with Magnetic Anomaly B.
C	1594588.71	635072.03	Isolated, small target. No corresponding Magnetic anomaly.
D	1594574.59	635002.05	Small confined target. No corresponding Magnetic anomaly.
E	1594640.50	635027.18	Isolated, small target. No corresponding Magnetic anomaly

Table 3-2 Magnetic Anomalies			
Anomaly	**State Plane (X)**	**State Plane (Y)**	**Comments**
A	1594610.92	635034.07	Very large magnetic anomaly. Likely comprised of several objects. Corresponds to EM Anomaly A.
B	1594590.21	635024.81	Weak anomaly. Likely corresponds to EM Anomaly B.
C	1594600.03	635050.64	Strong Magnetic Anomaly. No corresponding EM anomaly.
D	1594610.89	635004.38	Significant isolated anomaly. No corresponding EM anomaly.
E	1594625.05	635038.16	Weak anomaly. No corresponding EM anomaly.

Figure 3-4 shows an interpretation summary map of the anomalous areas from the two geophysical methods. The most significant feature on the summary map is the large anomaly (about 30 ft by 30 ft) associated with Area A in both the EM61 and Magnetic data. These anomalies are nearly coincident and are centered over the impact crater and extend about 10 feet north of the crater. This anomaly is expected to outline the bulk of the buried Lance missile. Most of the remaining anomalies are expected to be caused by relatively small metal pieces of the missile. Where the EM61 has detected an anomaly without a corresponding Magnetic anomaly (EM anomalies C,D and E), the object may be non-ferrous (i.e. aluminum). Where the Magnetometer has detected an anomaly without a corresponding EM anomaly (Magnetic anomalies C, D and E), the object is ferrous and likely deeper (or smaller) than the EM detection limits.

The Magnetic Analytic Signal data were modeled to estimate the approximate depth and location of the targets. The results of this modeling are also shown on the summary map. This figure shows the target identifications and locations. Table 3-3 lists the target parameters.

Table 3-3 Magnetic Data Model Results				
Anomaly ID	State Plane (X)	State Plane (Y)	Estimated Depth (ft)	Estimated Caliber Size (mm)
1	1594616.00	635037.70	1.9	155
2	1594610.00	635035.70	5.1	328
3	1594608.00	635025.90	9.7	420
4	1594606.00	635039.50	4.9	186
5	1594600.00	635050.90	1.6	110
6	1594625.00	635039.30	7.7	165
7	1594611.00	635004.00	8.0	215
8	1594590.00	635025.50	4.8	116

The magnetic modeling program uses an aspect ratio of 4.5 to 1 (target length to diameter (caliber)) in the calculation to obtain the approximate depth and caliber size of discrete targets. The modeling shows that several separate targets (Anomaly ID's 1,2,3 and 4) can be modeled within Magnetic Anomaly A. These targets range from a depth of about 2 to 10 feet, with the deepest target in the center of the crater. This result appears to indicate that the missile is fractured into several pieces at varying depths. However, due to the complexity of the Magnetic anomaly, it is equally likely that the missile is for the most part, intact but the shape is distorted.

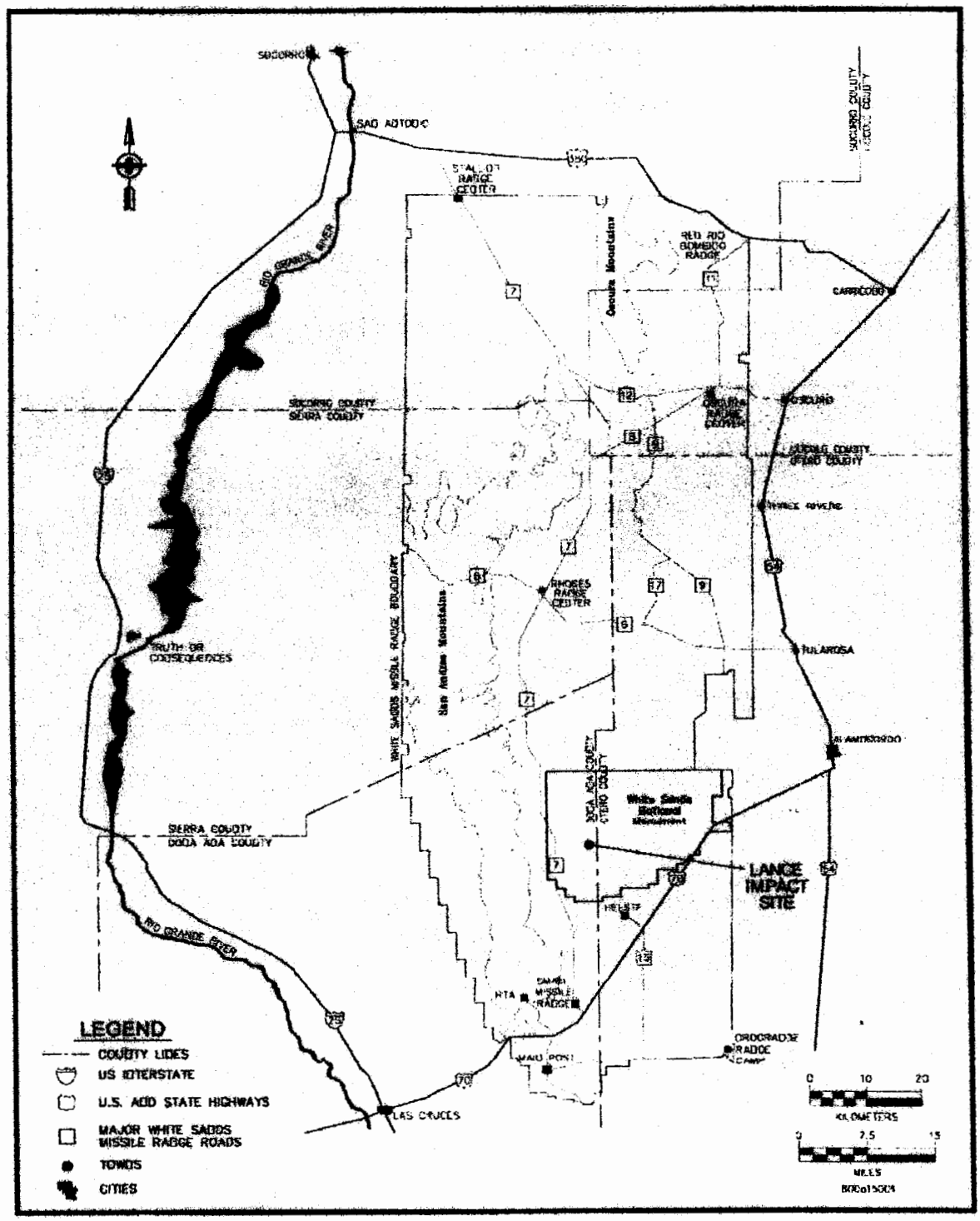
The coordinates of the center of the Lance Missile Impact Crater were surveyed with the Omni Star DGPS and they are 1594606.70, 635026.88.

4.0 SUMMARY AND CONCLUSIONS

EM61 and Magnetometer geophysical surveys were conducted at the White Sands National Monument (WSNM) site located in the White Sands Missile Range (WSMR), New Mexico to help define the location of a Lance Missile, which impacted the area. The survey site is located in the northwestern portion of the WSNM in the alkali flats region, which is located east of Lake Lucero, as shown in Figures 1-1 and 1-2.

The survey grid contained surface metal missile debris that was removed prior to the surveys so as not to interfere with the geophysical data results at the site. Five EM61 and Magnetic anomalies were identified at the survey site, which are interpreted to be caused by buried metallic pieces of the Lance missile. The most significant EM61 and Magnetic anomaly is large in areal extent (about 30 ft by 30 ft) and is located within the impact crater and somewhat north of the crater (Anomaly A in EM61 and Magnetic data, Figure 3-4). This anomaly is expected to outline the main mass of the missile. The modeled depth of discrete targets within this anomaly shows that most of the missile (or pieces of the missile) is buried at depths less than 10 feet.

The coordinates of the center (New Mexico State Plane) of the Lance Missile Impact Crater is located at 1594606.70, 635026.88.



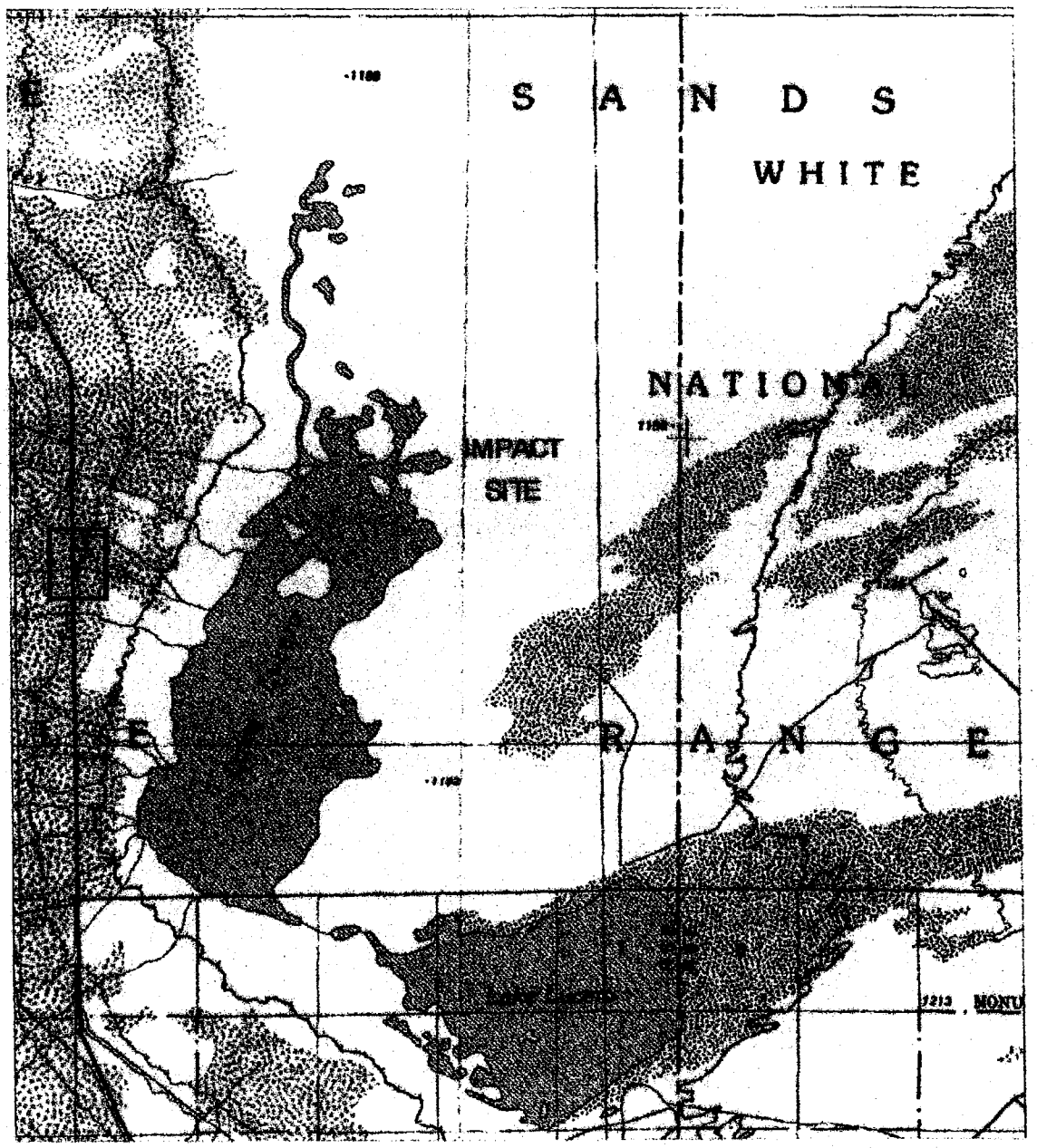
BLACKHAWK GeoSciences
a division of Blackhawk GeoServices

Location Map of
White Sands Missile Range,
White Sands National Monument,
and the Lance Missile Impact Site

Figure: 1-1

Project No. 2715MVT

Location1.cdr



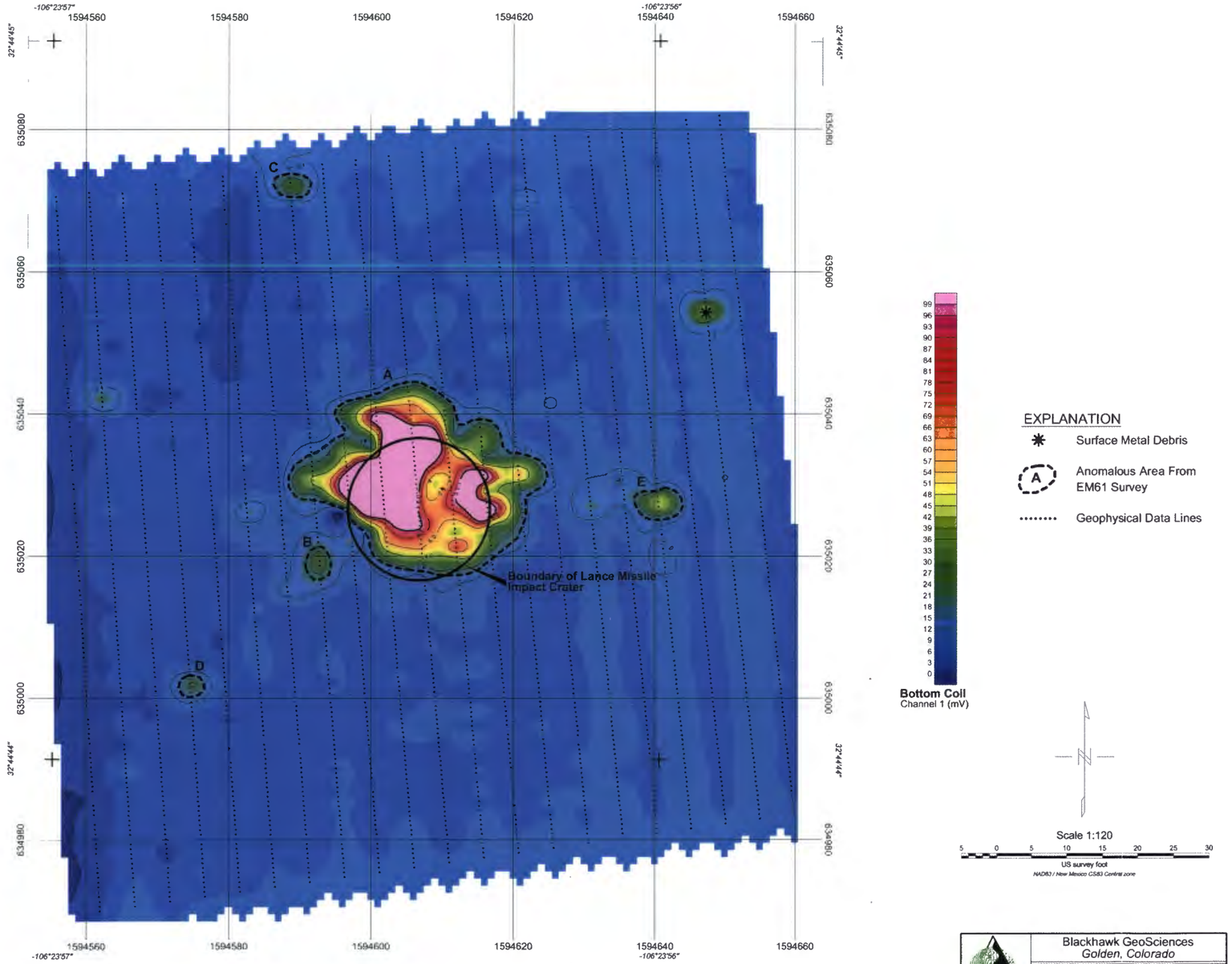
BLACKHAWK GeoSciences a division of Blackhawk GeoServices

Location Map of the Lance Missile Impact Site and Surrounding Area

Figure: 1-2

Project No. 2715MVT

Location2.cdr



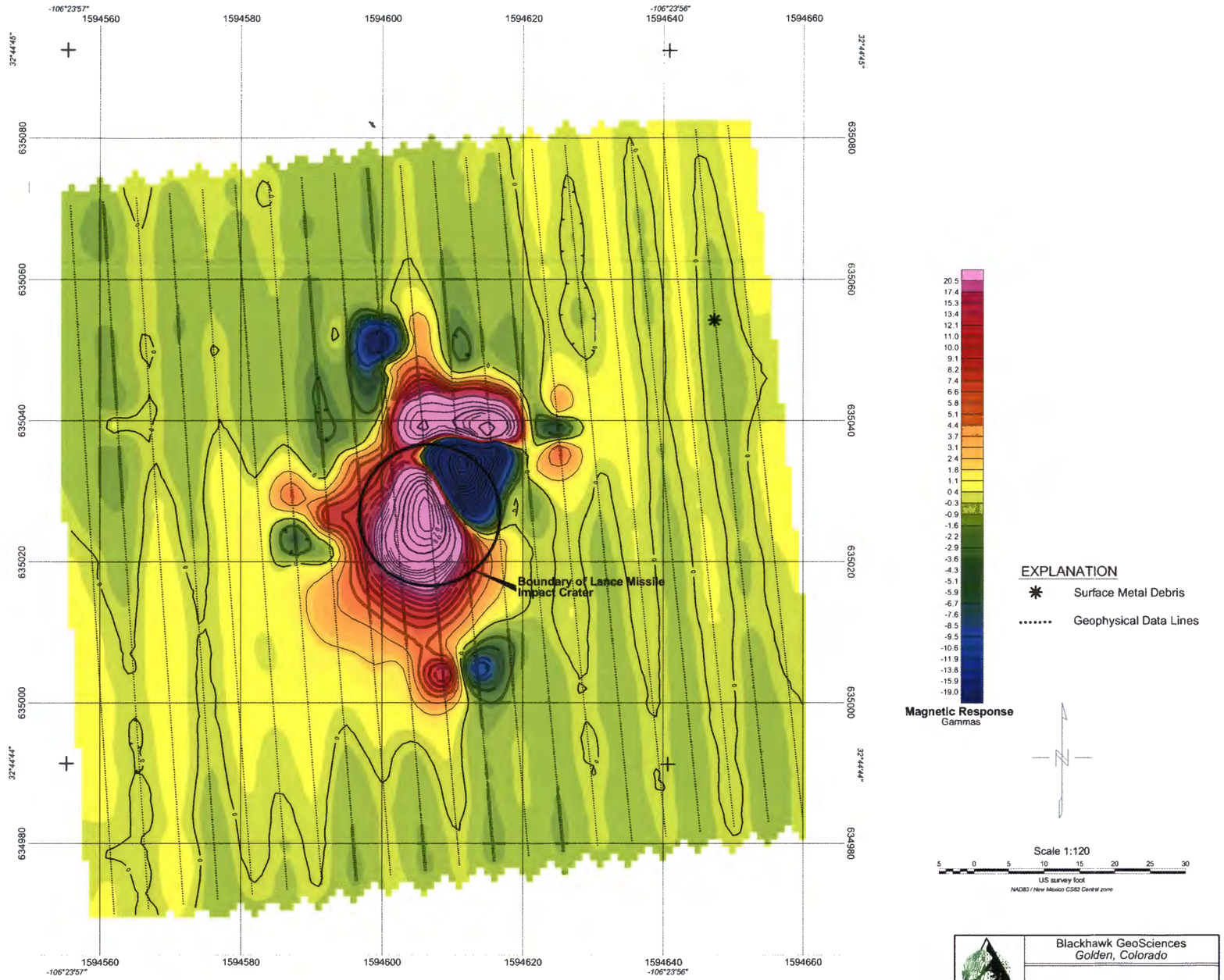
Blackhawk GeoSciences
Golden, Colorado

EM61 Survey Over
Lance Missile Crater
Bottom Coil-Channel 1

White Sands National Monument
New Mexico

MEVATEC Corporation

Figure No. 3-1
Project No. 2715MVT
File No. *wsmr_em61ch1_wrp.map*
Date: Feb. 2002



Blackhawk GeoSciences
Golden, Colorado

Figure No. 3-2

Project No. 2715MVT

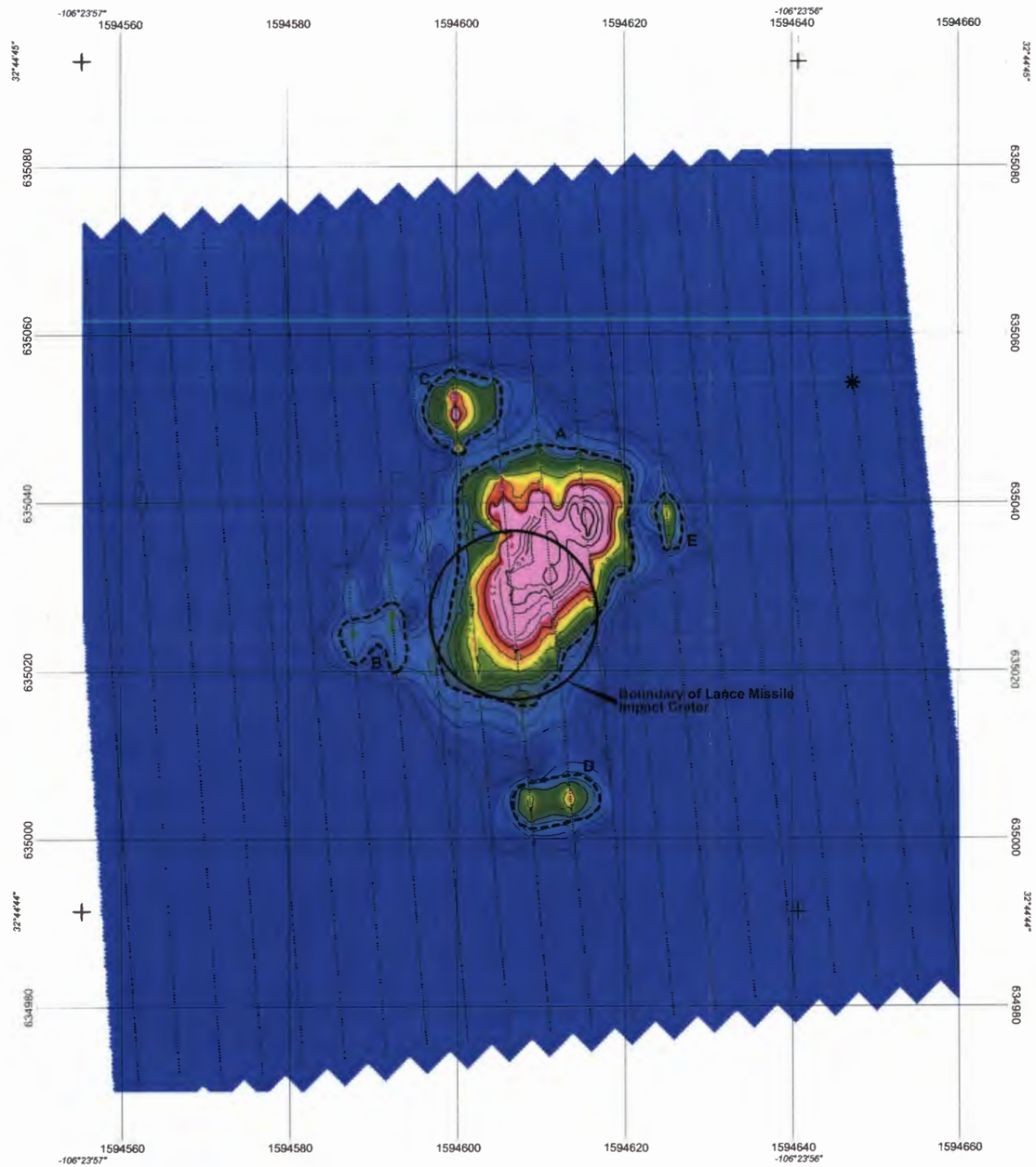
File No. ws: *magtotfd.map*

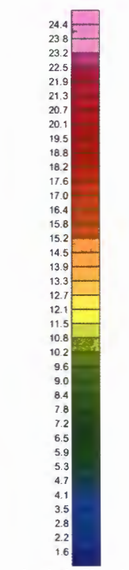
Date: Feb. 2002

Magnetic Survey Over
Lance Missile Crater
Total Magnetic Field

White Sands National Monument
New Mexico

MEVATEC Corporation





EXPLANATION

- Surface Metal Debris
- Anomalous Area From Magnetic Survey
- Geophysical Data Lines

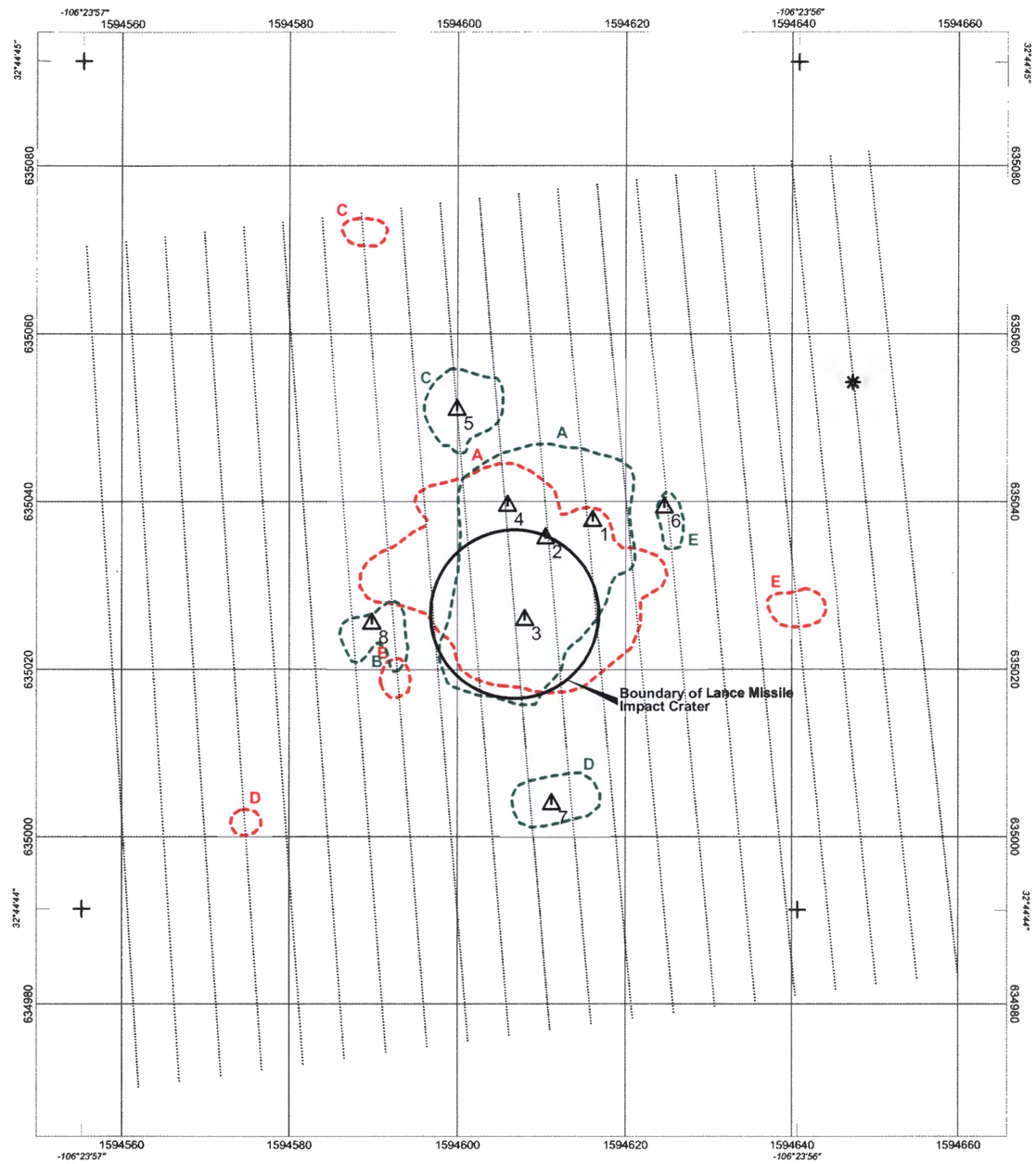
Scale 1:120

5 0 5 10 15 20 25 30

US survey foot

NAD83 / New Mexico CS83 Central zone

Figure No. 3-3	Blackhawk GeoSciences *Golden, Colorado*
Project No. 2715MVT	Magnetic Survey Over Lance Missile Crater Analytic Signal
File No. ws_ *maganalsig.map*	*White Sands National Monument New Mexico*
Date: Feb. 2002	MEVATEC Corporation



EXPLANATION

- Surface Metal Debris
- Target ID From Magnetic Modeling Results
- Anomalous Area From EM61 Survey
- Anomalous Area From Magnetic Survey
- Geophysical Data Lines

Scale 1:120

5 0 5 10 15 20 25 30

US survey foot

NAD83 / New Mexico CS83 Central zone

Blackhawk GeoSciences
Golden, Colorado

Figure No. 3-4

Project No. 2715MVT

File No. ws_ *maginterp.map*

Date: Feb. 2002

Interpretation Summary Map

White Sands National Monument
New Mexico

MEVATEC Corporation

APPENDIX D

MONITORING WELL COMPLETION DIAGRAMS

MONITORING WELL CONSTRUCTION DETAILS

WELL NUMBER: LMW-2

WELL NAME: _____

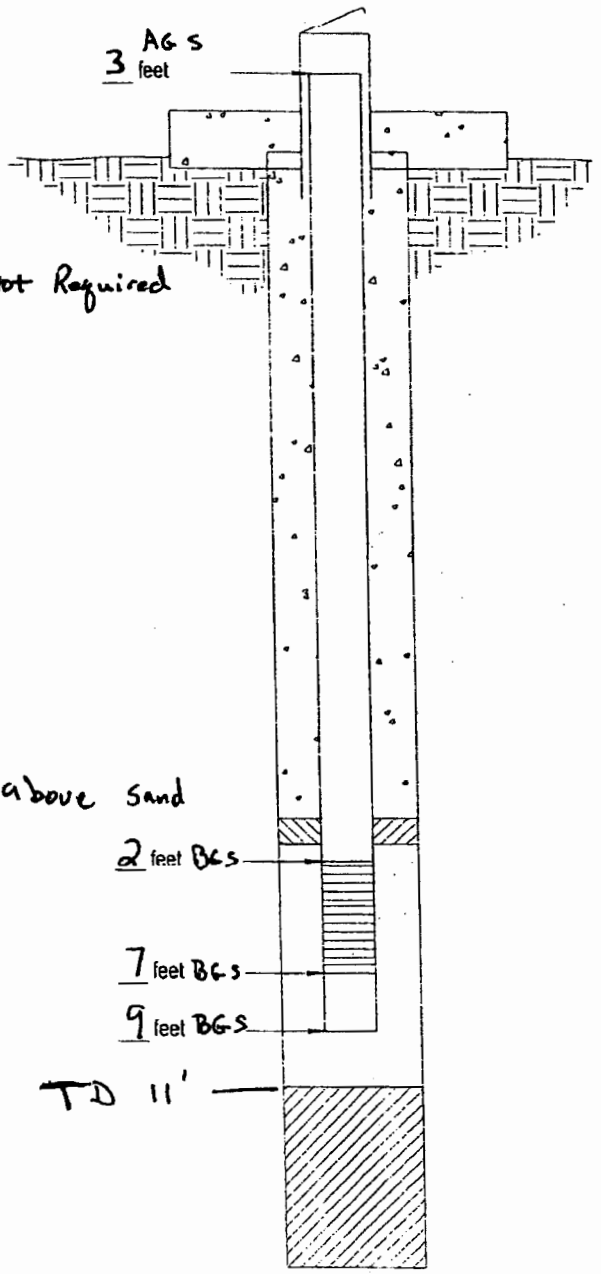
TD - 11'

KEYED NOTES:

1. CONCRETE PAD W/ EMBEDDED BRASS MARKER — Not Required
   ELEVATION _____ FEET (NAVD 1988).
   LAT. _____
   LONG. _____
2. TOP OF WELL CASING ELEVATION _____ Feet
3. TOTAL DEPTH (feet below top of casing) 12 Feet.
4. CASING DIAMETER 2 Inches.
5. SCREEN INTERVAL (feet below top of casing).
   5 Feet to 10 Feet.

4 bags Silica Sand

2' ft Bentonite hole plug above sand and screen.



GENERAL NOTES:

1. DRAWING NOT TO SCALE

500bb046

MONITORING WELL CONSTRUCTION DETAILS

WELL NUMBER: LMW-03

WELL NAME: _____

KEYED NOTES:

1 CONCRETE PAD W/ EMBEDDED BRASS MARKER
ELEVATION _____ FEET (NAVD 1988).
LAT. _____
LONG. _____

2. TOP OF WELL CASING ELEVATION _____ Feet.

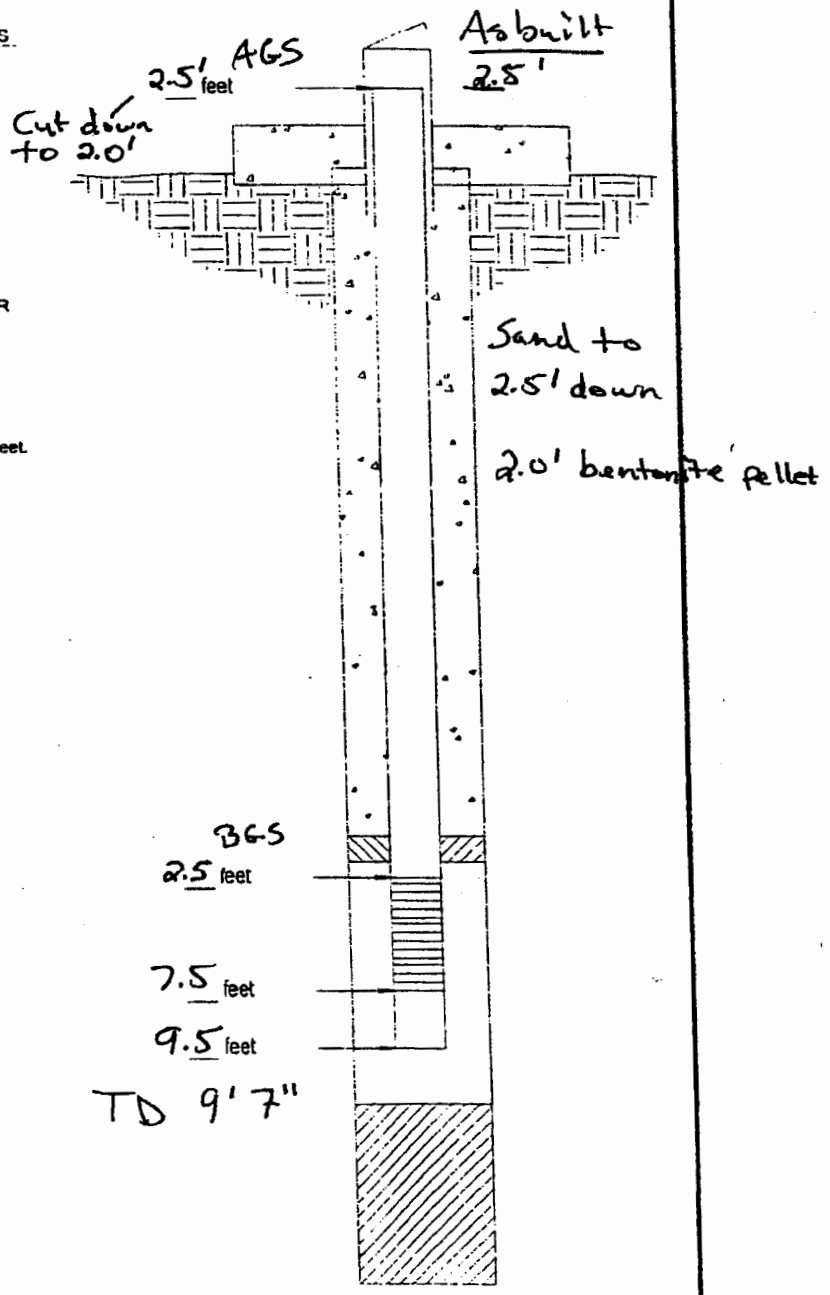
3. TOTAL DEPTH (feet below top of casing) _____ Feet.

4. CASING DIAMETER _____ Inches.

5. SCREEN INTERVAL (feet below top of casing):
_____ Feet to _____ Feet.

3.5
4 bags sand

1 bucket bentonite



GENERAL NOTES:

1. DRAWING NOT TO SCALE

500bb046

MONITORING WELL CONSTRUCTION DETAILS

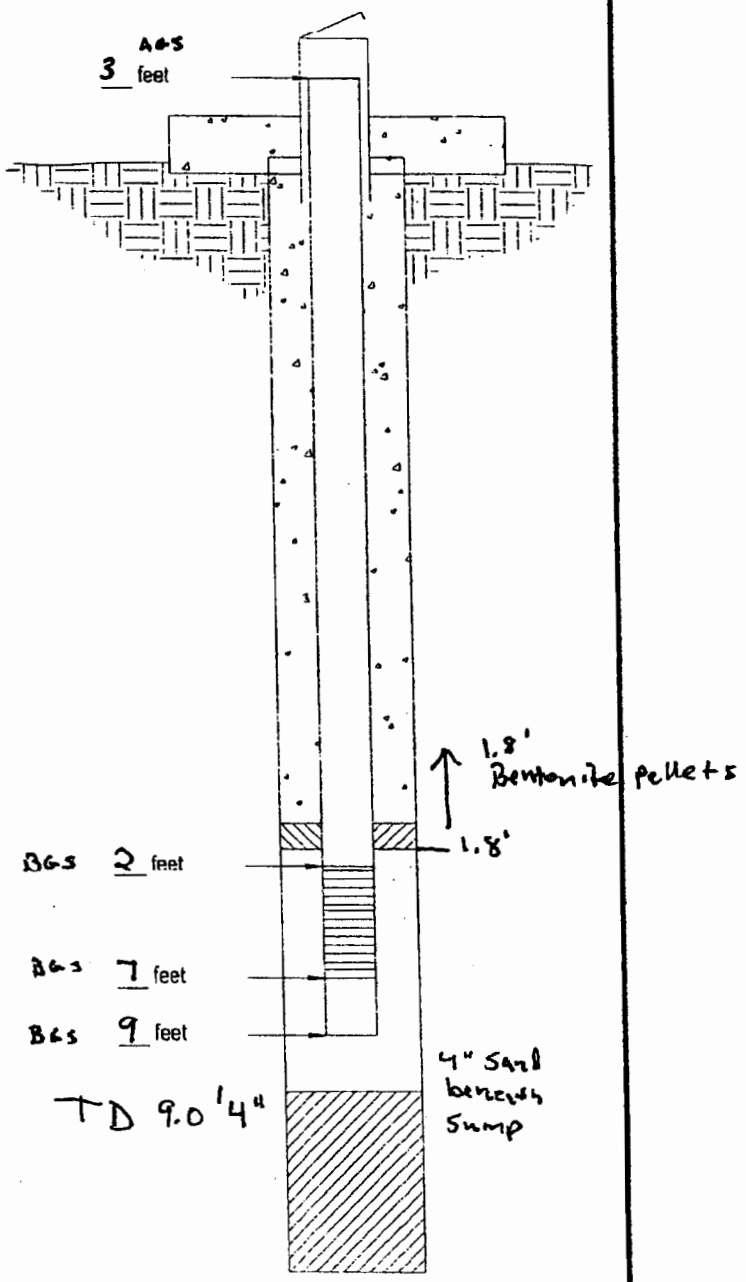
WELL NUMBER: LMW-04

WELL NAME: _____

KEYED NOTES:

1. CONCRETE PAD W/ EMBEDDED BRASS MARKER
   ELEVATION _____ FEET (NAVD 1988).
   LAT. _____
   LONG. _____
2. TOP OF WELL CASING ELEVATION _____ Feet
3. TOTAL DEPTH (feet below top of casing) _____ Feet.
4. CASING DIAMETER _____ Inches.
5. SCREEN INTERVAL (feet below top of casing).
   _____ Feet to _____ Feet.

Silica Sand 4 bags after we got casing to stay in hole.



GENERAL NOTES:

1. DRAWING NOT TO SCALE.

500bb046

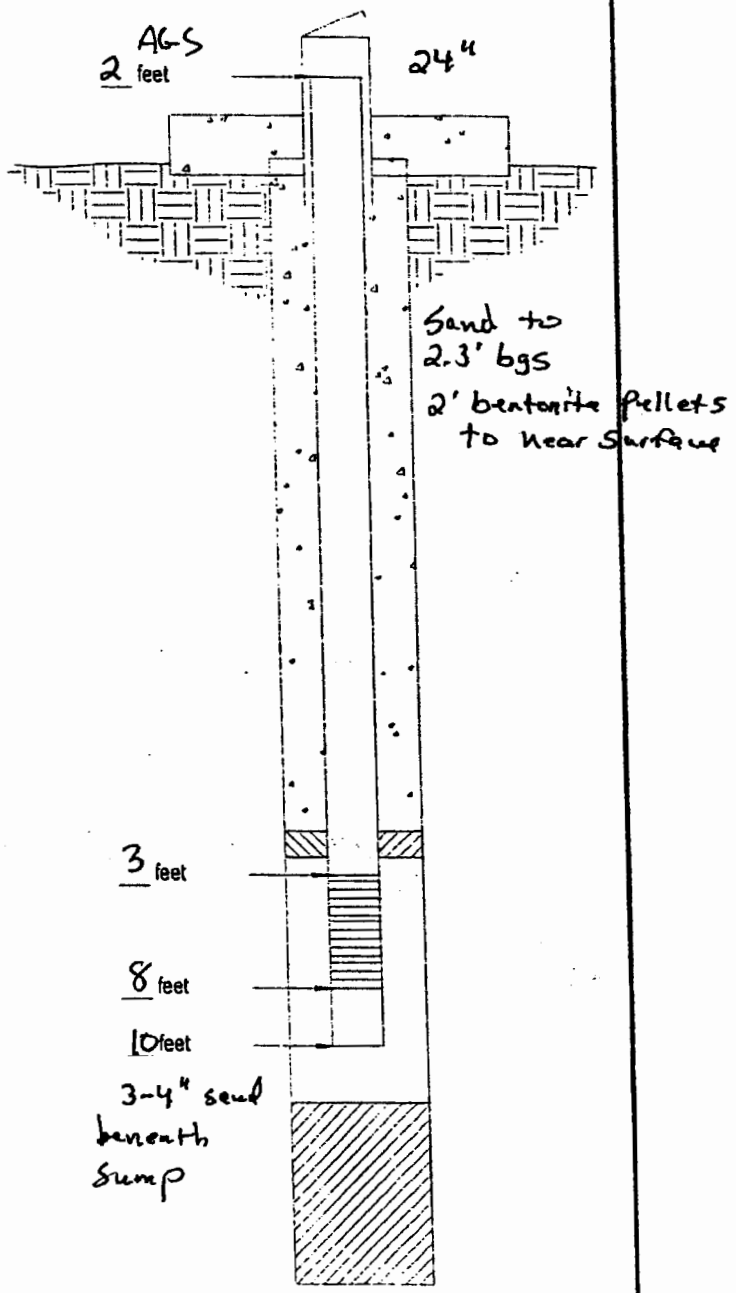
MONITORING WELL CONSTRUCTION DETAILS

WELL NUMBER: LMW-05

WELL NAME _____

KEYED NOTES:

1. CONCRETE PAD W/ EMBEDDED BRASS MARKER
   ELEVATION _____ FEET (NAVD 1988).
   LAT. _____
   LONG. _____
2. TOP OF WELL CASING ELEVATION _____ Feet.
3. TOTAL DEPTH (feet below top of casing) _____ Feet.
4. CASING DIAMETER _____ Inches.
5. SCREEN INTERVAL (feet below top of casing):
   _____ Feet to _____ Feet.



GENERAL NOTES:

1. DRAWING NOT TO SCALE.

500bb046

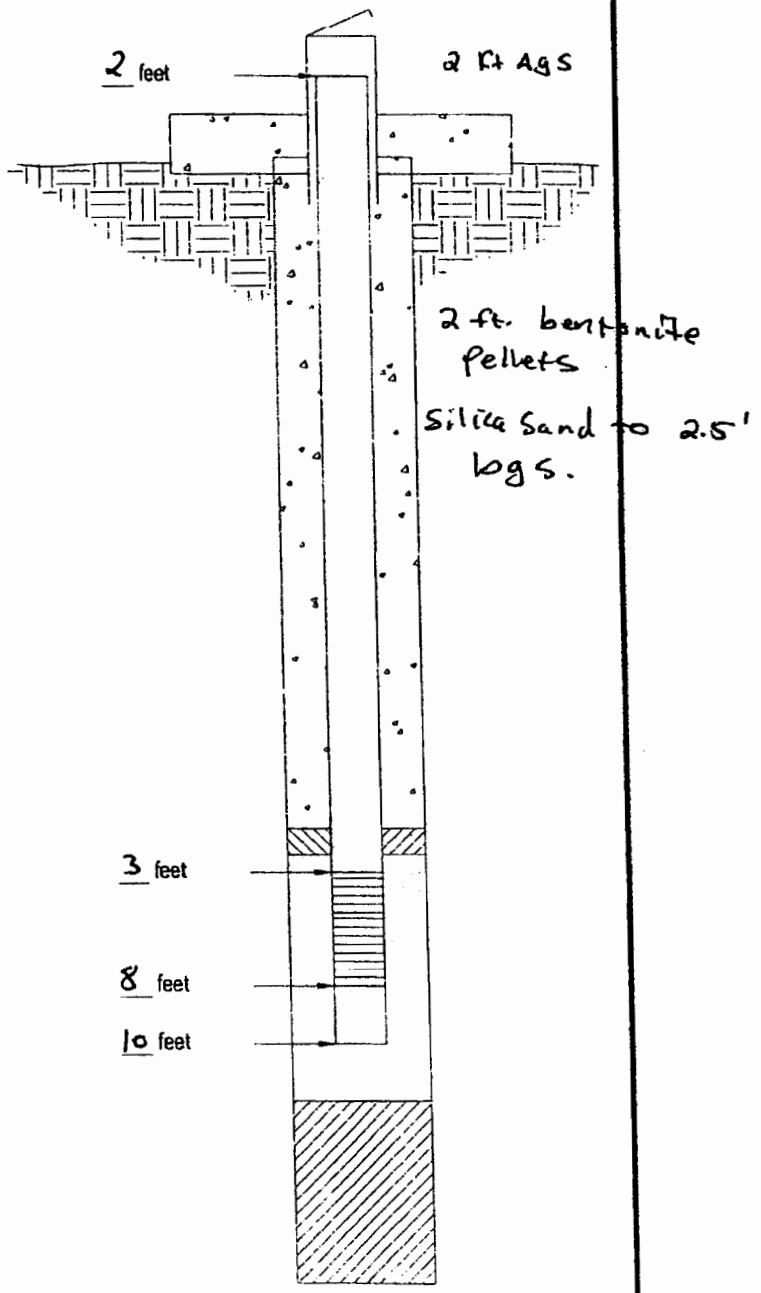
MONITORING WELL CONSTRUCTION DETAILS

WELL NUMBER: _____
WELL NAME: LMW-06

KEYED NOTES:

1. CONCRETE PAD W/ EMBEDDED BRASS MARKER
   ELEVATION _____ FEET (NAVD 1988).
   LAT. _____
   LONG. _____
2. TOP OF WELL CASING ELEVATION _____ Feet.
3. TOTAL DEPTH (feet below top of casing) _____ Feet.
4. CASING DIAMETER _____ Inches.
5. SCREEN INTERVAL (feet below top of casing):
   _____ Feet to _____ Feet.

4 bags Silica Sand
1 bucket bentonite



GENERAL NOTES:

1. DRAWING NOT TO SCALE.

500bb046

MONITORING WELL CONSTRUCTION DETAILS

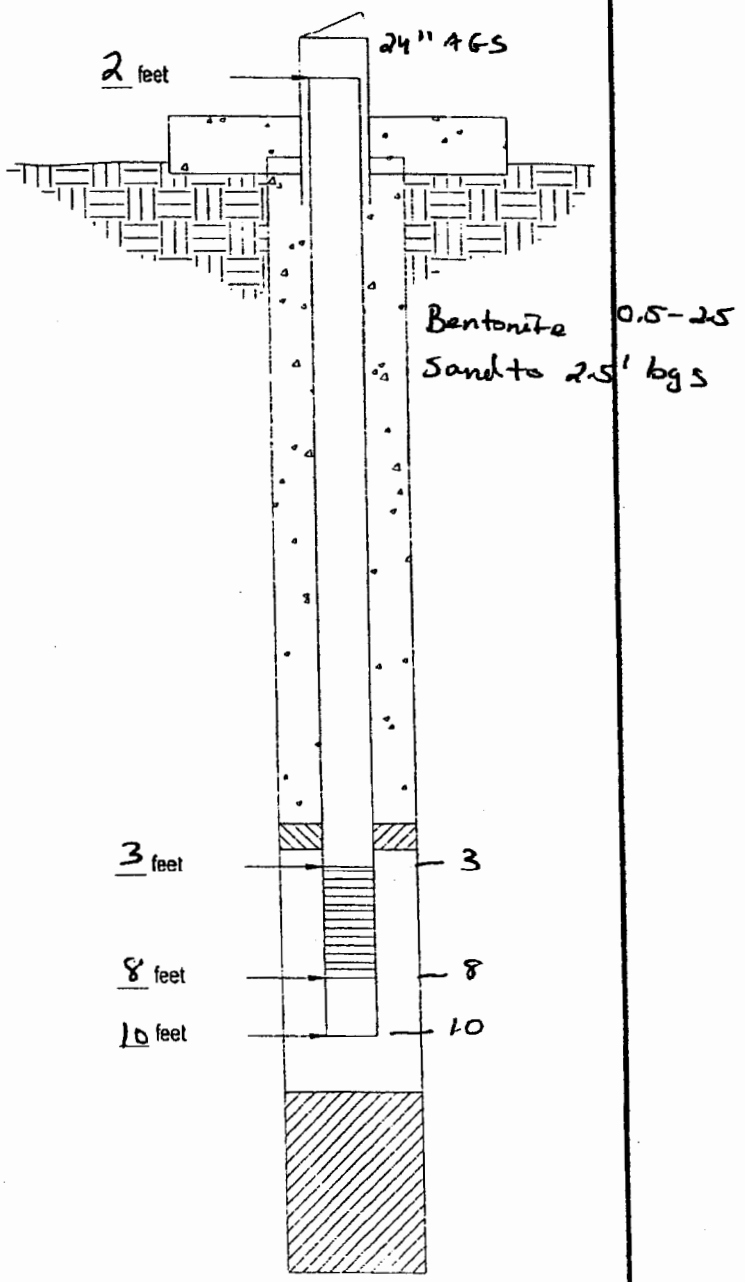
WELL NUMBER: LMW-07

WELL NAME: _____

KEYED NOTES:

1. CONCRETE PAD W/ EMBEDDED BRASS MARKER
   ELEVATION _____ FEET (NAVD 1988).
   LAT. _____
   LONG. _____
2. TOP OF WELL CASING ELEVATION _____ Feet
3. TOTAL DEPTH (feet below top of casing) _____ Feet.
4. CASING DIAMETER _____ Inches.
5. SCREEN INTERVAL (feet below top of casing).
   _____ Feet to _____ Feet.

≈ 1 bucket bentonite



GENERAL NOTES:

1. DRAWING NOT TO SCALE.

500bb046

MONITORING WELL CONSTRUCTION DETAILS

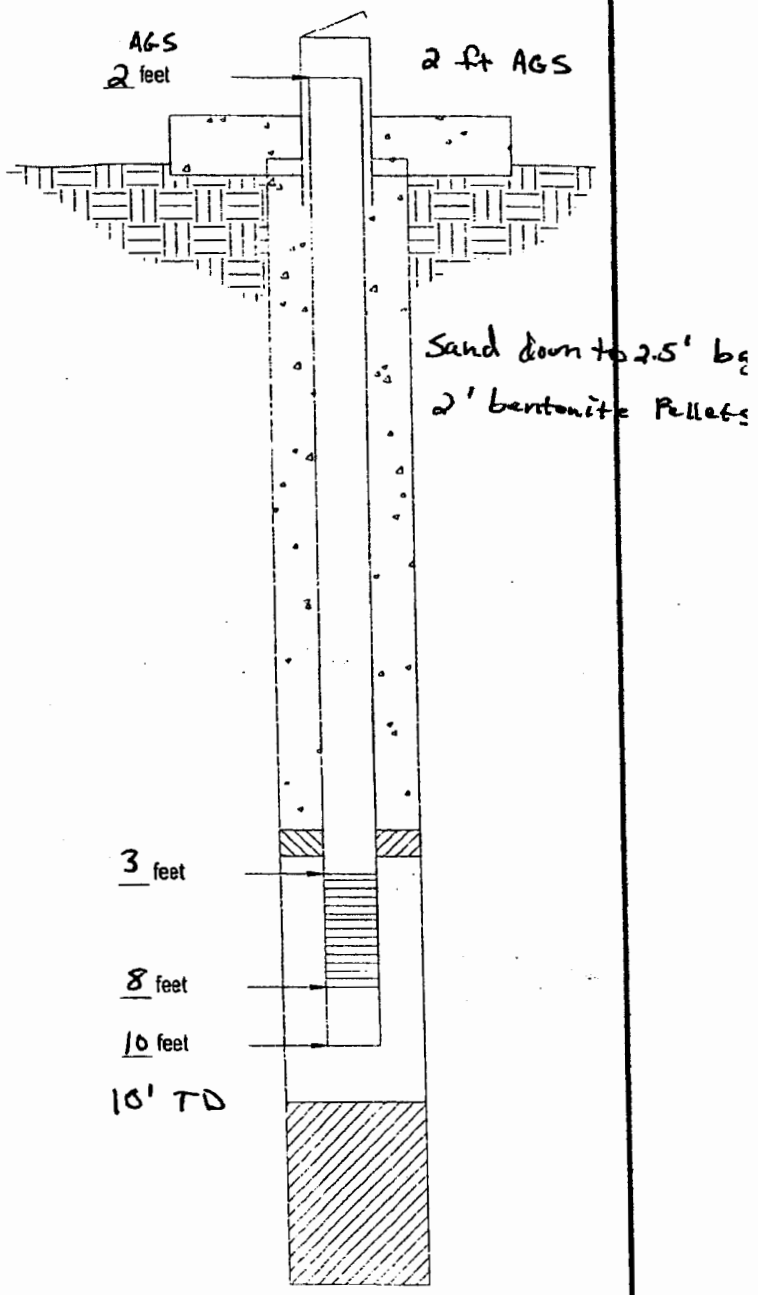
WELL NUMBER: LMW-08

WELL NAME: _____

KEYED NOTES:

1. CONCRETE PAD W/ EMBEDDED BRASS MARKER
   ELEVATION _____ FEET (NAVD 1988).
   LAT. _____
   LONG. _____
2. TOP OF WELL CASING ELEVATION _____ Feet.
3. TOTAL DEPTH (feet below top of casing) _____ Feet.
4. CASING DIAMETER _____ Inches.
5. SCREEN INTERVAL (feet below top of casing):
   _____ Feet to _____ Feet.

4 bags Silica Sand
1 bucket Pellets



GENERAL NOTES:

1. DRAWING NOT TO SCALE

500bb046

3-23-02

As built

MONITORING WELL CONSTRUCTION DETAILS

WELL NUMBER: LMW-09

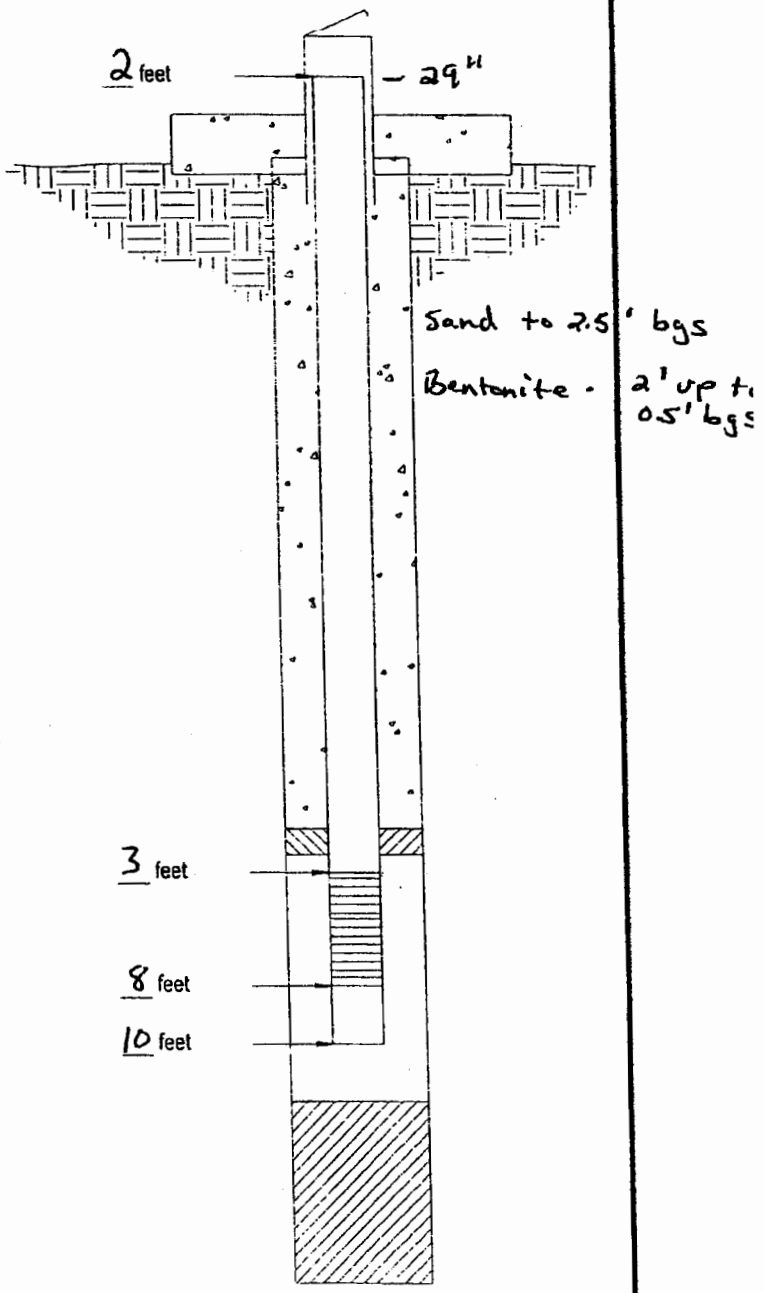
WELL NAME: _____

KEYED NOTES:

1. CONCRETE PAD W/ EMBEDDED BRASS MARKER
   ELEVATION _____ FEET (NAVD 1988).
   LAT. _____
   LONG. _____
2. TOP OF WELL CASING ELEVATION _____ Feet
3. TOTAL DEPTH (feet below top of casing) _____ Feet.
4. CASING DIAMETER _____ Inches.
5. SCREEN INTERVAL (feet below top of casing):
   _____ Feet to _____ Feet.

5-ft riser
5-ft screen
2-ft sump

Silica Sand .45-.48mm
54 bags
1 bucket pellets



GENERAL NOTES:

1. DRAWING NOT TO SCALE

500bb046

MONITORING WELL DEVELOPMENT RECORD

INSTALLATION	WELL ID		DATE	TIME
	LMW-02		3-25-02	
PERFORMED BY	WATER LEVEL		TOTAL DEPTH	
	INITIAL TOC 3.75'	FINAL TOC 4.10	INITIAL	FINAL TOC 10.90'
DEVELOPMENT METHOD		SURGE TECHNIQUE Bailer		
FIELD MEASUREMENTS				

Time	Cum. Volume (gal)	Water Quality				Comments
		Temp	pH	Cond	Turbidity	
0800	10 gal	55	8.51	>19,999	V. High	Grey water
0814	15 gal	55.1	8.20	>19,999	V. High	Grey water
0821	20 gal	55.8	8.37	>19,999	V. High	Grey water
0835	25 gal	57.5	8.14	>19,999	V. High	Grey water
0848	30 gal	57.4	8.19	>19,999	High	Grey water
0857	35 gal	58.[illegible]	8.31	>19,999	High	Grey water

TOTAL VOLUME REMOVED	COMMENTS
35 gal	
DEVELOPMENT TIME	
57 minutes	

MONITORING WELL DEVELOPMENT RECORD

INSTALLATION	WELL ID	DATE	TIME
	LMW - 3	3-25-02	0800

PERFORMED BY	WATER LEVEL		TOTAL DEPTH	
	INITIAL	FINAL	INITIAL	FINAL
	~~4.04~~	4.04'		11.81

DEVELOPMENT METHOD	SURGE TECHNIQUE
Hand Bail	Bailer.

FIELD MEASUREMENTS

Time	Cum. Volume (gal)	Water Quality				Comments
		Temp	pH	Cond	Turbidity	
0805	5	56.5	8.50	>19.999	V. High	Gray
0816	10	58.4	8.56	>19.999	Low	Cloudy - Gray
0821	15	58.8	8.56	>19.999	Low	Clear - Gray
0827	20	57.4	8.55	>19.999	Low	Clear - Sl. Gray
0836	25	57.2	8.55	>19.999	Low	Clear - Sl. Gray
0847	30	59.4	8.56	>19.999	-	Clear. Sl. Gray
0853	35	58.7	8.52	>19.999	-	Clear. - Sl. Gray

TOTAL VOLUME REMOVED 35 gal	COMMENTS
53 min. DEVELOPMENT TIME	

MONITORING WELL DEVELOPMENT RECORD

INSTALLATION	WELL ID		DATE	TIME
	LMW-04		3/25/02	
PERFORMED BY	WATER LEVEL		TOTAL DEPTH	
	INITIAL	FINAL	INITIAL	FINAL
	3.75' TOC	3.77	11.03	11.03 (TOC)
DEVELOPMENT METHOD		SURGE TECHNIQUE		

FIELD MEASUREMENTS

34% Rel. Humid

Time	Cum. Volume (gal)	Water Quality				Comments
		Temp	pH	Cond	Turbidity	
0900	Initial					
0912	5	59.1	8.35	>19.999	V. slight	Murky - Gray
0918	12	58.3	8.41	>19.999	"	" "
0920	15	58.3	8.46	>19.999	"	" "
0927	20	57.7	8.41	>19.999	Med.	Cloudy - Gray
0930	25	58.4	8.46	>19.999	"	Cloudy - Gray
0935	30	62.4	8.46	>19.999	Low	Cloudy (Gray)
0945	35	62.6	8.42	>19.999	"	Gray
0948	40	61.8	8.37	16.84		Clear Gray

TOTAL VOLUME REMOVED 40 gal	COMMENTS
48 min. DEVELOPMENT TIME	

MONITORING WELL DEVELOPMENT RECORD

INSTALLATION	WELL ID	DATE	TIME
	LMW-05	3-25-02	0903

PERFORMED BY	WATER LEVEL		TOTAL DEPTH	
	INITIAL Toc, 3.87	FINAL Toc 3.90	INITIAL	FINAL Toc 11.76

DEVELOPMENT METHOD	SURGE TECHNIQUE
Bailer	Bailer

FIELD MEASUREMENTS 63.° 0-5 mph wind from the North
34% Humidity

Time	Cum. Volume (gal)	Water Quality				Comments
		Temp	pH	Cond	Turbidity	
0906	8 gal	60.8	8.34	>19,999	V. High	DK Grey
0920	13 gal	59.8	8.30	>19,999	High	Grey
0930	18 gal	—	8.41	>19,999	Mod-High	Grey
0939	23 gal	61.8	8.37	>19,999	Mod-High	Grey
0949	28	62.8	8.31	>19,999	Mod-High	Grey
0952	32	63.9	8.32	>19,999	Mod-High	Grey
1000	35	63.3	8.27	>19,999	Mod	Grey

TOTAL VOLUME REMOVED 35 gal 54 min. DEVELOPMENT TIME	COMMENTS

TD → 11.84 TOC .16 8.38 gal H2O
Column Volume 1.34 gal

MONITORING WELL DEVELOPMENT RECORD

INSTALLATION	WELL ID		DATE	TIME
	LMW-06			
PERFORMED BY	WATER LEVEL		TOTAL DEPTH	
	INITIAL TOC 3.46'	FINAL TOC 3.48'	INITIAL TOC 11.84'	FINAL TOC 11.83'
DEVELOPMENT METHOD		SURGE TECHNIQUE		
FIELD MEASUREMENTS				

Time	Cum. Volume (gal)	Water Quality				Comments
		Temp	pH	Cond	Turbidity	
1015	5	65.5	8.18	>19,999	High	DK Grey
1018	10 gal	65.3	7.98	>19,999	High	DK Grey
1029	15 gal	69.0	8.04	>19,999	High	Grey
1037	20 gal	67.8	8.13	>19,999	High	LT Grey
1043	25 gal	68.9	8.39	>19,999	Mod	Lt Grey
1049	30 gal	67.4	8.42	>19,999	mod	LT Grey
1055	35 gal	68.8	8.48	>19,999	mod	Lt Grey

TOTAL VOLUME REMOVED 35 gal	COMMENTS
40 min DEVELOPMENT TIME	

TD 11.81 - TOC

MONITORING WELL DEVELOPMENT RECORD

INSTALLATION	WELL ID		DATE	TIME
	LMW-7			NA
PERFORMED BY	WATER LEVEL		TOTAL DEPTH	
	INITIAL TOC 3.92'	FINAL 4.11	INITIAL TOC 11.81'	FINAL 11.82'
DEVELOPMENT METHOD		SURGE TECHNIQUE		
FIELD MEASUREMENTS				

Time	Cum. Volume (gal)	Water Quality				Comments
		Temp	pH	Cond	Turbidity	
11:16	4 gal	69.6	8.29	>19.999	Mod	Grey
1126	5 gal	70.8	8.36	>19.999	Mod-High	DK Grey
1150	10 gal	71.9	8.35	>19.999	Mod High	DK Grey
1151	12.5 gal	69.5	8.37	>19.999	Mod High	DK Grey
1206	15 gal	72.5	8.00	>19.999	Mod High	Lt Grey
12:13	17.5 gal	71.3	8.42	>19.999	Mod High	Lt Grey
1221	20 gal	71.3	8.37	>19.999	Mod High	Lt. Grey
1236	25 gal	71.1	8.36	>19.999	Mod High	Lt Grey
1248	30 gal	70.3	8.32	>19.999	Mod High	clear
1256	35 gal	69.5	8.40	>19.999	Mod High	clear

TOTAL VOLUME REMOVED 35gal	COMMENTS Bailing Dry @ 1126 ≈ 5' in well after 20-25 gallons - started recharging much faster.
1 Hr 40 min DEVELOPMENT TIME	

11.90 TD TOC

MONITORING WELL DEVELOPMENT RECORD

INSTALLATION	WELL ID	DATE	TIME
	LMW-8	3/25/02	1047

PERFORMED BY	WATER LEVEL		TOTAL DEPTH	
	INITIAL TOC	FINAL	INITIAL	FINAL
	4.07	4.07	11.90' TOC	11.89'

DEVELOPMENT METHOD	SURGE TECHNIQUE

FIELD MEASUREMENTS

Time	Cum. Volume (gal)	Water Quality				Comments
		Temp	pH	Cond	Turbidity	
1048	Initial	61.4	8.54	>19.999	High	Murky - Gray
1053	5	61.3	8.49	>19.999	"	" "
1102	10	62.2	8.60	>19.999	"	" "
1109	15	61.8	8.39	~~17.54~~	"	" "
1115	20	59.7	8.40	18.85	"	" "
1122	25	57.4	8.25	16.77	Mod	Cloudy - Gray
1127	30	62.7	8.26	14.02	Low	Sl Cloudy - Gray
1131	35	62.1	8.27	14.27		Sl Cloudy - Gray

TOTAL VOLUME REMOVED 35 gal	COMMENTS
43 minutes DEVELOPMENT TIME	

11.46 TD TOC

MONITORING WELL DEVELOPMENT RECORD

INSTALLATION	WELL ID		DATE	TIME
	LMW-9			1000
PERFORMED BY	WATER LEVEL		TOTAL DEPTH	
	INITIAL	FINAL	INITIAL, TOC	FINAL
	4.02	4.02	11.46'	11.46'
DEVELOPMENT METHOD		SURGE TECHNIQUE		
Bailer		Bailer		

FIELD MEASUREMENTS

Time	Cum. Volume (gal)	Water Quality				Comments
		Temp	pH	Cond	Turbidity	
1000						
1004	5gal	64.9	7.56	>19.999	Med	Cloudy Gray
1009	10gal	59.8	8.28	>19.999	–	Cloudy Gray
1014	15	57.3	8.40	>19.85	–	" Gray
1018	20	57.4	8.22	14.60		Gray
1023	25	57.6	8.33	13.79		Clear, Gray
1028	30	59.9	8.38	15.99		Clear Gray
1032	35	59.7	8.33	14.85		Clear -Gray

TOTAL VOLUME REMOVED 35gal	COMMENTS
32 min. DEVELOPMENT TIME	

APPENDIX E

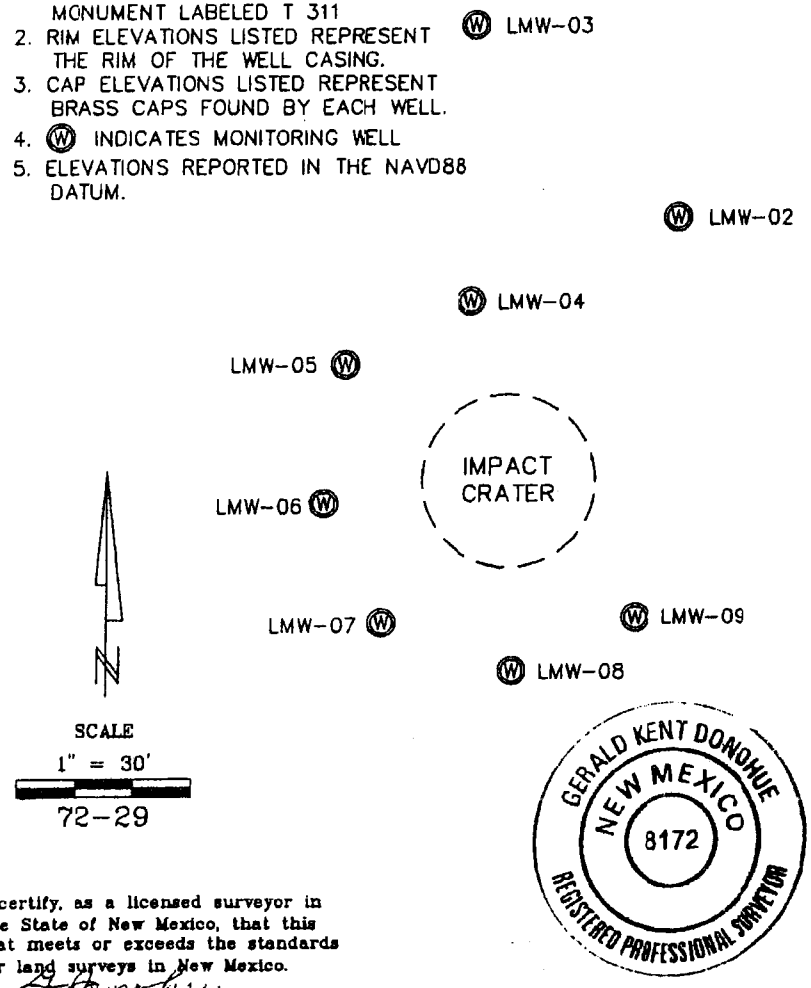
MONITORING WELL SURVEY

PLAT OF SURVEY SHOWING MONITORING WELL LOCATIONS AT THE LANCE MISSILE IMPACT SITE WITHIN THE WHITE SANDS NATIONAL MONUMENT NEAR LAKE LUCERO, DONA ANA COUNTY, NEW MEXICO

MAY 15, 2002

NOTES

1. ELEVATIONS BASED ON A DMA WSMR MONUMENT LABELED T 311
2. RIM ELEVATIONS LISTED REPRESENT THE RIM OF THE WELL CASING.
3. CAP ELEVATIONS LISTED REPRESENT BRASS CAPS FOUND BY EACH WELL.
4. (W) INDICATES MONITORING WELL
5. ELEVATIONS REPORTED IN THE NAVD88 DATUM.



WELL NO.	ELEVATION RIM	ELEVATION CAP
02	3895.02	3893.15
03	3895.36	3893.17
04	3894.72	3892.68
05	3894.80	3893.00
06	3894.41	3892.57
07	3894.89	3892.85
08	3895.03	3892.89
09	3894.98	3892.97

LATITUDES/LONGITUDES FOR THE BRASS CAPS

WELL NO.	LATITUDE	LONGITUDE
02	32°44'44.90084"N	106°23'55.91761"W
03	32°44'45.22757"N	106°23'56.32676"W
04	32°44'44.75731"N	106°23'56.33752"W
05	32°44'44.65130"N	106°23'56.59233"W
06	32°44'44.41342"N	106°23'56.63513"W
07	32°44'44.20582"N	106°23'56.51504"W
08	32°44'44.12466"N	106°23'56.24967"W
09	32°44'44.21190"N	106°23'56.00265"W

LATITUDE/LONGITUDE EQUATION FOR T 311

	LATITUDE	LONGITUDE
RECORD	32°45'10.24042"N	106°27'47.96810"W
FIELD	32°45'10.29231"N	106°27'47.82328"W

I certify, as a licensed surveyor in the State of New Mexico, that this plat meets or exceeds the standards for land surveys in New Mexico.

GERALD K. DONOHUE P.L.S. 8172

Donohue Land Surveys
3010 Bowman Avenue
P.O. Box 40
Mesilla Park, N.M. 88047
1-505-523-1114

APPENDIX F

FIELD LITHOLOGIC LOGS

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. LMW-1	SHEET No. 1 OF 1

1. PROJECT: Lance SWMU 168	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station): WSNM	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number): LMW-1 (Monitoring Well)	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER: Layne Geoconstruction	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE: [X] Vertical [ ] Inclined ____ Degrees from Vertical	16. DATE HOLE — STARTED: 3-19-02 — COMPLETED: 1630 — 1508
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE: 12.5' — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR: Brady T. Dan

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		Gypsum "Crust" on surface - 2-3" thick			
	5		mottled grey, black, white gypsum sand and silt Saturated from 2.5' → down to ≈ 7.0' - mottled black - organic material? - Core smelled putrid - from 5.0'-7.0' - Clay like dissolved gypsum?	80%		Lith Sample Collected 1535 Still Saturated tight material
	10		Mottled grey, black, white - gypsum sand - cemented - + Halite? - Compact 11.5-11.8 - 3"-4" - Saturated zone 12.0'-12.5' Solid crystalline gypsum (Halite)	95%		1630 - Samples Collected
			6" - gypsum/halite(?) Cemented - dk black brackish water			no lith collected Saturated
	15		— Auger Stuck — Abandon hole			
	20					

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. LMW-2	SHEET No. 1 OF

1. PROJECT: 168 Lane Impact	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number): LMW-2 - Monitoring Well	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER: Layne GeoConstruction	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE: [X] Vertical [ ] Inclined ____ Degrees from Vertical	16. DATE HOLE — STARTED: 3-21-02 0907 — COMPLETED: 1015
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE: 10' 11" — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR: Brady T. Dan

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5	X	Mottled grey, white, black gypsum sand & silt Saturated w/ water - fetid smell.	100%		0926 - Chem Sample Collected VOC - 0.0 LEL - 0 H_2S - 0
	10	X	Compact gypsum x-tals 200 blow counts for 11" - hit refusal	90%		1015 - Chemical Sample Collected
	15		TD 10' 11"			
	20					

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. LMW-03	SHEET No. 1 OF 1
1. PROJECT SWMU 168 Lance impact		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)		
2. LOCATION (Coordinates or Station)		12. MANUFACTURER'S DESIGNATION OF DRILL		
3. DRILLING AGENCY		13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN	DISTURBED	UNDISTURBED
4. HOLE No. (As shown on drawing title and file number) LMW-03		14. TOTAL NUMBER CORE BOXES		
5. NAME OF DRILLER Layne Geoconstruction		15. ELEVATION GROUND WATER		
6. DIRECTION OF HOLE ☒ Vertical ☐ Inclined ____ Degrees from Vertical		16. DATE HOLE 3-24-02	STARTED 1000	COMPLETED 1040
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE		
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING		
9. TOTAL DEPTH OF HOLE 9' 7"	10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR Brady T. Dan		

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5	☒	Mottled grey - Sandy Silty gypsum - wet fetid smell	95%		1015 collected Chem. Sample
	10	☒	Cemented, compact gypsum dark grey fetid smell -		Blow Counts 50/50 w/1"	1040 - Collected Chem + Lith Sample
			TD 9' 7"			

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. LMW-04	SHEET No. 1 OF 1

1. PROJECT SWMU 168 LMW-04	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number) LMW-04 Monitoring well	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER Lane Geoconstruction	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE [X] Vertical [ ] Inclined ____ Degrees from Vertical	16. DATE HOLE — STARTED 3-22-02 0755 — COMPLETED 0950
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 9'4" — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR Brad T. Da[illegible]

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		No Lith or chemical Samples collected			
	5		Did not collect split spoon.			
	10		TD 9'4"			
			Well Set @ 0950			

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. LMW-05	SHEET No. 1 OF 1

1. PROJECT: 0168 Lance Impact	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number): LMW-05	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER: Lafne Geoconstruction	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE: [X] Vertical [ ] Inclined ____ Degrees from Vertical	16. DATE HOLE: 3-24-02 — STARTED: 0834 — COMPLETED: 0850
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE: 10' — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR: Brad T. Dave

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX No. SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
			wet 2'-3.0' down			
	5					
			Harder Augering @ ≈ 8.0'			
	10					
			TD 10'			
			Will Set well Screen 3'-8'			

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. LMW-06	SHEET No. 1 OF 1

1. PROJECT 0168 Lance Site	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number) LMW-06	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER Layne	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE [X] Vertical [ ] Inclined ____ Degrees from Vertical	16. DATE HOLE — STARTED 0733 — COMPLETED 0748 — 3-29-02
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 10' — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR Brady T. Dan

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
			wet @ ≈ 3.0'			
	5					
			Harder Augering @ 7.0'			
	10					
			TD 10.0'			
			will set well			

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. LMW-07	SHEET No. 1 OF 1

1. PROJECT: SWMU 168 Lance impact	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number): LMW-07	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER: Layne GeoConstruction	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE: [X] Vertical [ ] Inclined ____ Degrees from Vertical	16. DATE HOLE — STARTED: 3-23-02 — COMPLETED: 1155 — 1115
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE: 10' — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR: Bradley T. Dana

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5		wet @ ≈ 3.0'			
			Harder Augering @ ≈ 8.0'			
	10		No Split Spoons or Samples collected will Screen from 3.0-8.0'			
			TD 10'			

DRILLING LOG	DIVISION	INSTALLATION	HOLE No LMW-08	SHEET No. 1 OF 1

1. PROJECT SWMU 168 Lance Impact	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number) LMW-08	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER Layne Geoconstruction	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE [X] Vertical [ ] Inclined ____ Degrees from Vertical	16. DATE HOLE — STARTED 3-23-02 1010 — COMPLETED 1040
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 10.0' — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR Brad T. Dan

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5		wet @ ≈ 3'			
	10		Harder Augering @ 8'			
			10' TD - No samples or Split Spoons.			
			Set well			

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. LMW-09	SHEET No. 1 OF 1

1. PROJECT: SWMU 168 Lance Impact	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number): LMW-09	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER: Layne Geoconstruction	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE: [X] Vertical [ ] Inclined ____ Degrees from Vertical	16. DATE HOLE — STARTED: 3-23-02 0810 — COMPLETED: 0835
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE: 10.0' — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR: Brady T. Davis

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5					
			≈ 3'-wet cuttings out of hole			
			compact @ 7.0' ↓			Harder Augering @ 7.0'-8.0'
	10					
						will Screen 3'-8'
			TD 10'			
			Completed well			

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. SB-01	SHEET No. 1 OF 1
1. PROJECT SWMU 168 LANCE impact		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)		
2. LOCATION (Coordinates or Station)		12. MANUFACTURER'S DESIGNATION OF DRILL		
3. DRILLING AGENCY		13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN	DISTURBED	UNDISTURBED
4. HOLE No. (As shown on drawing title and file number) SB-01 Soil Boring		14. TOTAL NUMBER CORE BOXES		
5. NAME OF DRILLER ~~Bo~~ Layne Geoconstruction		15. ELEVATION GROUND WATER		
6. DIRECTION OF HOLE [X] Vertical [ ] Inclined ____ Degrees from Vertical		16. DATE HOLE 3-21-02	STARTED 1203	COMPLETED 1255
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE		
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING		
9. TOTAL DEPTH OF HOLE 9' 8"	10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR Brady T. Davis		

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5	X	DK Grey - white / black mottled gypsum sand and silt w/ crystals saturated w/ H_2O			1215 - Chemical sample collected VOC 0.0 H_2O - 0
	10	X	Compact gypsum sand w/ gyp x-tals + silt - cemented		Blow Counts 22/50	- Hit refusal 1238 - Chem and lith sample collected. VOC 0.0 - H_2S 0 Down Hole
	15		9' 8" - TD			

Bentonite hole plug 3 Bags + ¼ bucket bentonite pellets

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. SB-02	SHEET No. 1 OF 1

1. PROJECT SWMU 0168 Lance Impact	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number) SB-02	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE ☒ Vertical ☐ Inclined ____ Degrees from Vertical	16. DATE HOLE 3-21-02 — STARTED 1525 — COMPLETED 1555
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE 9.5' — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR Bradley T. Davis

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5		Dk. Grey white/black Mottled gray gypsum and Silt - Saturated w/ H_2O			1530 chem. sample Collected
	10		Compact Gypsum Sand Cemented Dry			1555 9-11 ft sample Collected
	15		TD 9.5'			

3 Bags bentonite

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. SB-03	SHEET No. 1 OF 1

1. PROJECT: SWMU 168 Lance Impact	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number): SB-03	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER: Layne Geoconstruction	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE: [X] Vertical [ ] Inclined ____ Degrees from Vertical	16. DATE HOLE — STARTED: 3-21-02, 1345 — COMPLETED: 1410
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE: 8' 7" — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR: Brady T. Dear

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5		Mottled grey, white and black Gypsum Sand and silt Saturated w/ H_2O			1355 - Chemical Sample Collected QC Dup Collected
	10		mottled grey/white gypsum Sand, silt w/ crystals dry -			1410 - chemical Sample Collected
				Blow Counts 20/50		hit Refusal @ ~~8'~~ 8' 7"
	15					

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. SB-04	SHEET No. 1 OF 1

1. PROJECT: SWMU 168 Large Impact	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number): SB-04	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER: Layne Geo Construction	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE: [X] Vertical [ ] Inclined ____ Degrees from Vertical	16. DATE HOLE — STARTED: 3-24-02 1158 — COMPLETED: 1215
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE: 9' 8.5" — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR: Bradley T. Davis

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5		Mottled grey sandy silty gypsum —wet—			Chemical Sample Collected @ 1205
	10					1215 – Chemical Sample collected
			Dry @ bottom			Blow Counts 15-6" / 50-2.5"
			TD-9' 8.5"			

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. SB-05	SHEET No. 1 OF 1
1. PROJECT SWMU 168 Lance impact		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)		
2. LOCATION (Coordinates or Station)		12. MANUFACTURER'S DESIGNATION OF DRILL		
3. DRILLING AGENCY		13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN	DISTURBED	UNDISTURBED
4. HOLE No. (As shown on drawing title and file number) SB-05		14. TOTAL NUMBER CORE BOXES		
5. NAME OF DRILLER Layne Geoconstruction		15. ELEVATION GROUND WATER		
6. DIRECTION OF HOLE ☒ Vertical ☐ Inclined ____ Degrees from Vertical		16. DATE HOLE 3-22-02	STARTED 1505	COMPLETED 1535
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE		
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING		
9. TOTAL DEPTH OF HOLE 9.5'	10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR Bradley T. Dan		

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5		wet gypsum sand and silt Dark gray	90%		Chemical Sample Collected @ 1523
	10		Compact, cemented gypsum dry	95%		chemical Sample Collected @ 1535.
			Hit Refusal			
			60 blow counts for 6 inches			
			TD 9.5'			

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. SB-06	SHEET No. 1 OF 1
1. PROJECT SWMU 168		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)		
2. LOCATION (Coordinates or Station)		12. MANUFACTURER'S DESIGNATION OF DRILL		
3. DRILLING AGENCY		13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN	DISTURBED	UNDISTURBED
4. HOLE No. (As shown on drawing title and file number) SB-06 Soil Boring		14. TOTAL NUMBER CORE BOXES		
5. NAME OF DRILLER Layne GeoConstraction		15. ELEVATION GROUND WATER		
6. DIRECTION OF HOLE [X] Vertical [ ] Inclined ____ Degrees from Vertical		16. DATE HOLE 3-22-02	STARTED 1020	COMPLETED 1100
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE		
8. DEPTH DRILLED INTO ROCK		18. TOTAL CORE RECOVERY FOR BORING		
9. TOTAL DEPTH OF HOLE 9.5'	10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR Brad T. Dan		

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5	X	White to grey gypsum sand and silt - wet - not saturated. 95%			Chemical sample collected @ 1035 ~~Lith Sample Collected~~
	10	X	Compact - cemented gypsum - Dk. grey mottled + white. TD 9.5'		Blow Counts 60 for 6"	1100 - Chemical Sample Collected Lith Sample Collected

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. SB-07	SHEET No. 1 OF 1

1. PROJECT: SWMU 168 Lance	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number): SB-07	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER: Layne GeoConstruction	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE: ☒ Vertical ☐ Inclined ____ Degrees from Vertical	16. DATE HOLE — STARTED: 3-22-02, 1150 — COMPLETED: 1220
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE: 9.5' — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR: Brady T. Dau

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5	☒	Mottled gray - White Sand and Silt gypsum - Wet - [redacted] Saturated			1203 - Chem. Sample collected QC Sample Collected.
	10	☒	DK gray mottled Crystalline gypsum Cemented Compacted dry		Blow Counts 75 for 6"	1220 - Chem + lith Sample Collected
			TD 9.5'			
			Lost lead Auger down hole.			

DRILLING LOG	DIVISION	INSTALLATION	HOLE No. SB-08	SHEET No. 1 OF 1

1. PROJECT: SWMU 168	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
2. LOCATION (Coordinates or Station)	12. MANUFACTURER'S DESIGNATION OF DRILL
3. DRILLING AGENCY	13. TOTAL No. OF OVERBURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
4. HOLE No. (As shown on drawing title and file number): SB-08	14. TOTAL NUMBER CORE BOXES
5. NAME OF DRILLER: Layne Geoconstruction	15. ELEVATION GROUND WATER
6. DIRECTION OF HOLE: [X] Vertical [ ] Inclined ____ Degrees from Vertical	16. DATE HOLE — STARTED: 3-22-02 — COMPLETED: 1400 — 1445
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING
9. TOTAL DEPTH OF HOLE: 9'8" — 10. SIZE AND TYPE OF BIT	19. SIGNATURE OF INSPECTOR: Brady T. Dar

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (description) d	% CORE RECOVERY e	BOX OR SAMPLE NUMBER f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0					
	5		Wet sand and silt gypsum Dark gray mottled white, black.	25%		Poor recovery. Collected only 2-4oz, 1-2oz, and 40mL vile.
	10		Dark grey mottled gypsum compact cemented dry	75%		70 Blow counts for 8"
						Chem and lith Sample Collected @1445

APPENDIX G

EPA REGION IV RECOMMENDED ECOLOGICAL SCREENING VALUES

Recommended Ecological Screening Values (mg/kg) for Soil .

CONSTITUENT	Target Analyte List	Target Compound List	Screening Value	Source
Inorganics				
Aluminum	✓		50	[2]
Antimony	✓		3.5	[5]
Arsenic	✓		10	[2]
Barium	✓		165	[5]
Beryllium	✓		1.1	[5]
Boron			0.5	[2]
Cadmium	✓		1.6	[5]
Chromium	✓		0.4	[2,3]
Cobalt	✓		20	[1, 2, 4]
Copper	✓		40	[5]
Iron	✓		200	[2]
Lanathum			50	[2]
Lead	✓		50	[1, 2]
Lithium			2.0	[2]
Manganese	✓		100	[2]
Mercury (inorganic)	✓		0.1	[2]
Mercury (methyl)	✓		0.67	[5]
Molybdenum			2.0	[2]
Nickel	✓		30	[2]
Selenium	✓		0.81	[5]
Silver	✓		2.0	[2]
Technetium			0.2	[2]
Thallium			1.0	[2]
Tin			53	[5]
Titanium			1,000	[2]
Tungsten			400	[2]
Uranium			5.0	[2]
Vanadium	✓		2.0	[2]
Zinc	✓		50	[2]
Mineral Pollutants				
Bromine			10	[2]
Cyanide, free (total)	✓		0.9	[3]
Cyanide, comlex (total)	✓		5.0	[1]
Thiocyanates			2.0	[4]
Fluorene			30	[2]

Recommended Ecological Screening Values (mg/kg) for Soil (Continued).

CONSTITUENT	Target Analyte List	Target Compound List	Screening Value	Source
Iodine			4.0	[2]
Sulfur			2.0	[1]
Monocyclic Aromatic Hydrocarbons				
Benzene		✓	0.05	[4]
Biphenyl			60	[2]
Ethylbenzene		✓	0.05	[1,4]
Toluene		✓	0.05	[1,4]
Trichloroethylene		✓	0.001	[4]
Xylene		✓	0.05	[1,4]
Total MAH's			0.1	[1]
Phenolic Compounds				
Phenol		✓	0.05	[4]
Chlorophenol, 3-			7.0	[2]
Chlorophenols (each)		✓	0.01	[1]
Chlorophenols (total)		✓	0.01	[1]
Dichlorophenol, 3,4-			20	[2]
Dichlorophenols (total)			0.003	[4]
Dinitrophenol, 2,4-	✓		20	[2]
Monochlorophenols (total)			0.0025	[4]
Nitrophenol, 4-		✓	7.0	[2]
Pentachlorophenol		✓	0.002	[4]
Tetrachlorophenol, 2,3,4,5-			20	[2]
Tetrachlorophenols (total)			0.001	[4]
Trichlorophenol, 2,4,5-	✓		4.0	[2]
Trichlorophenol, 2,4,6-			10	[2]
Trichlorophenols (total)			0.001	[4]
Polycyclic Aromatic Hydrocarbons				
Acenapthene		✓	20	[2]
Anthracene		✓	0.1	[1]
Benzo(a)pyrene		✓	0.1	[1]
Chloronaphthalene		✓	1.0	[4]
Fluoranthene		✓	0.1	[1]
Naphthalene		✓	0.1	[1]
Phenanthrene		✓	0.1	[1]
Pyrene		✓	0.1	[1]
Total PAH's			1.0	[1,4]

Recommended Ecological Screening Values (mg/kg) for Soil (Continued).

CONSTITUENT	Target Analyte List	Target Compound List	Screening Value	Source
Chlorinated Hydrocarbons				
Aliphatic chlorinated hydrocarbons (each)			0.1	[1]
Aliphatic chlorinated hydrocarbons (total)			0.1	[1]
Carbon tetrachloride		✓	1,000	[2]
Chlorinated hydrocarbons (total)			0.1	[1]
Chloroacetamide			2.0	[2]
Chloroaniline, 3-			20	[2]
Chlorobenzene (each)		✓	0.05	[1]
Chlorobenzene (total)		✓	0.05	[1]
Cis-1,4-dichloro-2-butene			1,000	[2]
Dichloroaniline, 2,4-			100	[2]
Dichloroaniline, 3,4-			20	[2]
Dichlorobenzene			0.01	[4]
Dichloroethane, 1,2-		✓	0.4	[4]
Dichloromethane		✓	2.0	[4]
Dichloropropane, 1,2-			700	[2]
Hexachlorobenzene		✓	0.0025	[4]
Hexachlorocyclopentadiene		✓	10	[2]
Nitrobenzene		✓	40	[2]
Nitrosodiphenylamine, N-		✓	20	[2]
Pentachloroaniline			100	[2]
Pentachlorobenzene			0.0025	[4]
PCBs (total)		✓	0.02	[4]
Polycyclic chlorinated hydrocarbons (total)			0.1	[1]
Tetrachloroaniline, 2,3,5,6-			20	[2]
Tetrachlorobenzene			0.01	[4]
Tetrachloroethene			0.01	[4]
Tetrachloromethane			0.001	[4]
Trans-1,4-dichloro-2-butene			1,000	[2]
Trichloroaniline, 2,4,5-			20	[2]
Trichlorobenzene		✓	0.01	[4]
Trichloromethane (chloroform)			0.001	[4]
Vinyl chloride		✓	0.01	[4]
Pesticides				
Aldrin		✓	0.0025	[4]
Atrazine			0.00005	[4]
DDT/DDE/DDD (total)		✓	0.0025	[4]

Recommended Ecological Screening Values (mg/kg) for Soil (Continued).

CONSTITUENT	Target Analyte List	Target Compound List	Screening Value	Source
Dieldrin		✓	0.0005	[4]
Endrin		✓	0.001	[4]
Carbaryl			0.5	[4]
Carbofuran			0.2	[4]
HCH, a-			0.0025	[4]
HCH, b-			0.001	[4]
HCH, g- (Lindane)		✓	0.00005	[4]
Maneb			3.5	[4]
Organochlorinated (each)			0.1	[1]
Organochlorinated (total)			0.1	[1]
Total Pesticides			0.1	[1]
Other Pollutants				
Acrylonitrile			1,000	[2]
Catechol			20	[4]
Cresols			0.5	[4]
Cyclohexane			0.1	[1]
Cyclohexanon			0.1	[4]
Diethylphthalate		✓	100	[2]
Dimethylphthalate		✓	200	[2]
Di-n-butyl phthalate		✓	200	[2]
Ethylene glycol			97	[3]
Furan			600	[2]
Gasoline			20	[1]
Hydrochinon			1.0	[4]
Mineral Oils			50	[4]
Phthalates (total)			0.1	[4]
Pyridine			0.1	[1, 4]
Resorcinol			1.0	[4]
Styrene		✓	0.1	[1, 4]
Tetrahydrofuran			0.1	[1, 4]
Tetrahydrothiophene			0.1	[1, 4]

From: Friday, G. P. November 1998. Ecological Screening Values for Surface Water, Sediment, and Soil. Westinghouse Savannah River Company, Savannah River Technology Center, (WSRC-TR-98-00110), Aiken, SC 29808.

Source:

[1]Beyer (1990).

[2]Oak Ridge National Laboratory (Efroymson et al. 1997a,b).

[3]CCME (1997).

[4]Ministry of Housing, Spatial Planning and Environment (1994).

[5]Crommentuijn et al. (1997).