MONTGOMERY WATSON

September 10, 1999

(Via: FedEx)

New Mexico Environmental Department (NMED)
Hazardous and Radioactive Materials Bureau
2044 Galisteo
P.O. Box 26110
Sante Fe, New Mexico 87502

Attn: Mr. Steve Pullen

**Re:** *Final* Report for 1999 Stratigraphic and Groundwater Characterization Program
Triassic Park Waste Disposal Facility

Dear Mr. Pullen:

On behalf of Gandy Marley Incorporated (GMI), Montgomery Watson (MW) is pleased to submit two (2) copies of the above referenced final report. We have incorporated the comments we received on the draft report and included the remaining logs and the structural contour map in this final report.

If you have any questions concerning this report, please contact us.

Sincerely,

Montgomery Watson

David Ulrich for

Patrick G. Corser, P.E.
Principal

Enclosure

cc: Dale Gandy (1)
Ken Schultz (1)
Trey Greenwood (1)
Jim Bonner (1)
Montgomery Watson (2)

*Prepared for:*

TRIASSIC PARK WASTE DISPOSAL FACILITY
**Gandy Marley, Inc.**
Post Office Box 827
1109 East Broadway
Tatum, New Mexico 88267

# FINAL REPORT

# FOR

# 1999 STRATIGRAPHIC AND GROUNDWATER CHARACTERIZATION PROGRAM TRIASSIC PARK WASTE DISPOSAL FACILITY

*September 1999*

*Prepared by:*

**Montgomery Watson**
P.O. Box 774018
Steamboat Springs, Colorado 80477
(970) 879-6260

**InfiMedia Inc.**
1717 Louisiana Boulevard N.E.
Suite 209
Albuquerque, New Mexico 87110

# TABLE OF CONTENTS



# LIST OF TABLES



# LIST OF FIGURES



# LIST OF APPENDICES

# 1.0 INTRODUCTION

At the request of the New Mexico Environmental Department, Hazardous and Radioactive Material Bureau (HRMB), on August 3-5 1999, a drilling program was conducted by Gandy Marley, Inc. (GMI) at the proposed Triassic Park Disposal Facility. This drilling further clarified the subsurface stratigraphy and groundwater conditions underlying and adjacent to the proposed site. A total of ten (10) drill holes were completed as part of this program. All drilling activities were performed in accordance with the Final Work Plan for 1999 Stratigraphic and Groundwater Characterization Program dated July 28, 1999 and conditionally approved by the HRMB on July 30, 1999 (see Appendix A). Minor modifications of the Work Plan were required during implementation of the drilling program. These were generally reviewed with the HRMB onsite staff. The changes are discussed and documented in this report.

HRMB staff was onsite periodically to observe the drilling operations. Specifically, staff was onsite on August 3 and August 5, 1999.

## 2.0 PURPOSE

The primary purpose of this drilling was to provide additional definition to the character of the Upper Dockum sediments and their contact with the Lower Dockum mudstones. At the same time, this drilling was to supply more information on the saturation conditions of the Upper Dockum sediments. Additional details on the purpose of the drilling program are discussed in the Work Plan which is presented in Appendix A.

# 3.0 RESULTS OF STRATIGRAPHIC CHARACTERIZATION PROGRAM

Drilling commenced on August 3, 1999 and continued through the morning of August 5, 1999. Nine additional stratigraphic holes were drilled in the northern portion of the proposed site (see Figure 1). Due to the sandy, inaccessible nature of the area, a Caterpillar tractor (supplied by GMI) was used to build roads into each location. This equipment was also used throughout the drilling program to pull equipment into and out of each drill hole location.

Key Drilling of Roswell, New Mexico performed the work using a Portadrill, air rotary rig. The driller used a 6¾-inch drill bit and collected drill cuttings at 5-foot intervals. A registered professional geologist logged these cuttings, and a geophysical log was run on each drill hole. Southwest Geophysical Services, Inc., of Farmington, New Mexico prepared geophysical logs. Atkins Environmental of Roswell, New Mexico plugged each drill hole with a cement and bentonite grout. A trimie line was used and all holes were plugged from the "bottom up". The stratigraphic logs are presented in Appendix B and the geophysical logs for these holes are also presented in Appendix B.

Table 1, Summary of Stratigraphic Drilling Results, presents a summary of the 1999 stratigraphic drilling:

**TABLE 1**
**SUMMARY OF STRATIGRAPHIC DRILLING RESULTS**

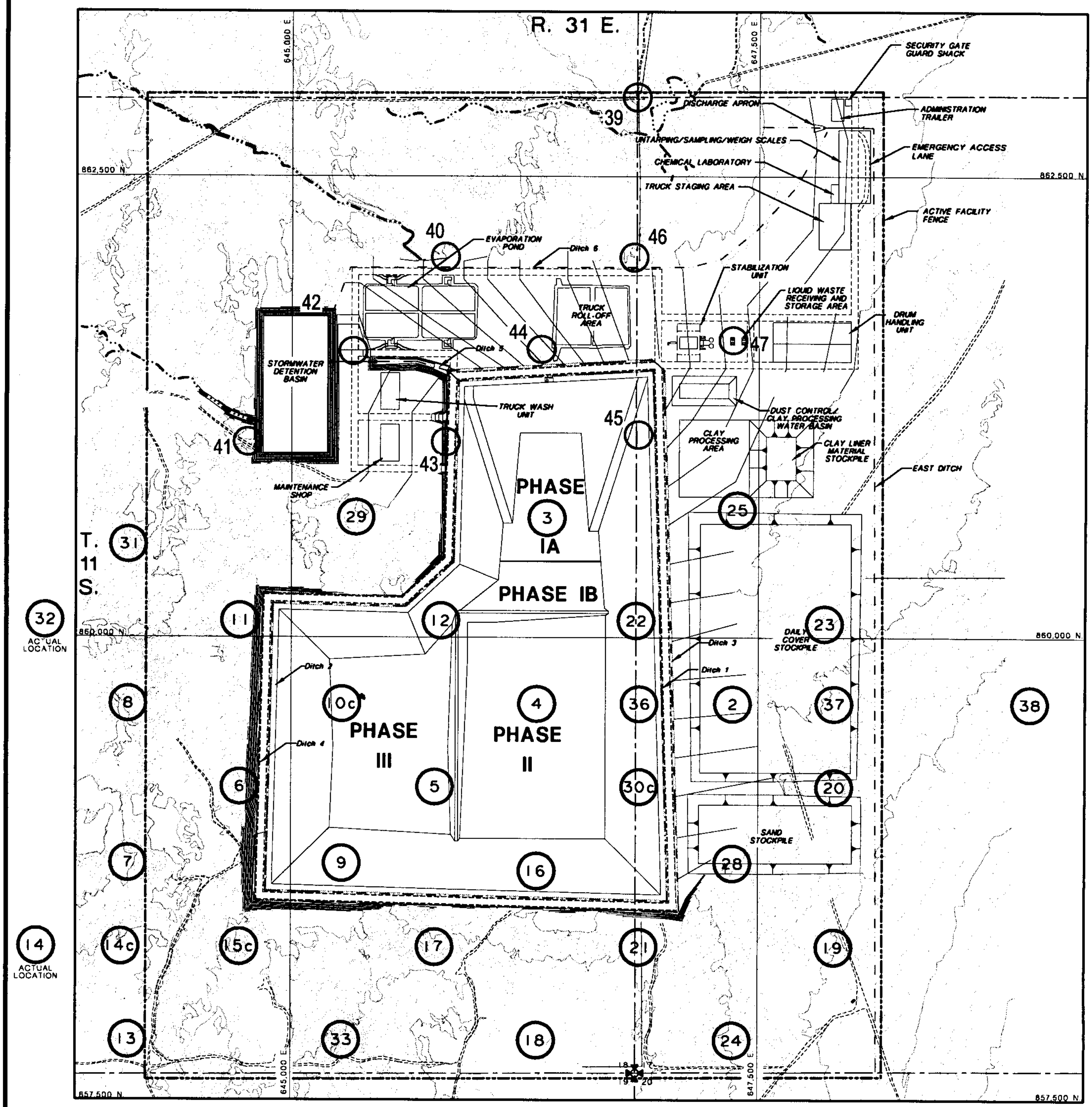
| Hole No | Depth | Depth to Contact[1] | Depth of Lower Dockum Penetrated |
|---|---|---|---|
| PB-39 | 120 ft | 96 ft | 24ft |
| PB-40 | 90 ft | 68 ft | 22 ft |
| PB-41 | 75 ft | 55 ft | 20 ft |
| PB-42 | 90 ft | 62 ft | 28 ft |
| PB-43 | 100 ft | 74 ft | 26 ft |
| PB-44 | 110 ft | 78 ft | 32 ft |
| PB-45 | 120 ft | 100 ft | 20 ft |
| PB-46 | 120 ft | 89 ft | 31 ft |
| PB-47 | 130 ft | 108 ft | 22 ft |

[1]Contact between upper and lower Dockum, based on visual logging of cuttings and geophysical log.

The nine stratigraphic holes drilled as part of this study are shown in Figure 1. To provide a complete picture of the drilling completed at the site, the historic holes are also shown. The northernmost drill hole is PB-39, which is located at the section corner for Sections 7, 8, 17 and 18; T11S; R31E. In order to fit the three north-south drill holes (PB-39, PB-46 and PB-47) within the site boundary, the north-south dimension of the drill hole grid was slightly compressed. This resulted in a drill hole spacing of approximately 900 feet between the lines of east-west drill holes. The spacing between holes along the east-west lines is still 1000 feet.

The same suite of geophysical logs (thermal neutron, gamma and caliper) was run on the 1999 drill holes. It should be noted that the 6¾-inch hole has some effect on the thermal neutron count rates. The character of the logs remains the same, although due to neutron flux, the actual count rate has increased. For example, with a 4¾-inch drill hole, the thermal neutron count rates for the Upper Dockum siltstones averaged approximately 3200 counts per second. With a 6¾-inch hole, this same lithology is averaging approximately 4200 counts per second.

As a matter of practice, the probe operator for Southwest Geophysical, Inc. on this program would "power-up" the down-hole geophysical equipment while the probe was resting at the bottom of the




## LEGEND

(21) LOCATION & NUMBER OF EXISTING HOLES

40 ◯ LOCATION & NUMBER OF 1999 STRATIGRAPHIC CHARCTERIZATION HOLES

NOTE: Holes 14 & 32 Are Shown At Actual Locatiion, But Just Fall Outside Of Mapped Area

| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 1 | Issued for Report | 9/7/99 | P.Corser | K.Conrath | P.Corser |
| 0 | Issued For Report | 8/19/99 | P.Corser | M.Mathisen | P.Corser |

MONTGOMERY WATSON

PROJECT No.: 1342602.02190200
AutoCAD FILE: P-Stratigraphic-Holes
SCALE: See Scale Bar
FIGURE No: 1

*Gandy Marley, Inc. - Triassic Park*
*1999 Characterization Program*

**LOCATION OF STRATIGRAPHIC CHARACTERIZATION HOLES**

hole. It would remain on the bottom of the hole for approximately two minutes while he was readying all the instrumentation for the logging of the hole. The thermal neutron (which is located at the bottom of the probe unit) was picking up counts during this two-minute period. This resulted in a false high-count rate at the bottom of each hole. This was particularly apparent in those holes that experienced some "caving in" of the loose surface sands. The probe operator suggested that the first two feet of the thermal neutron log be disregarded and to mark the logs accordingly.

In the past drilling, there has been some natural radioactivity observed scattered within the Upper Dockum sediments that was consistent with past movement and precipitation of uranium-bearing solutions. Geologically, this is not unusual, as this unit is equivalent to the Chinle Formation that hosts many uranium deposits in the Colorado Plateau region. The 1999 drilling encountered more concentrated occurrences of this natural radioactivity, particularly holes PB-43, PB-45, PB-46 and PB-47, where the gamma log had to be rerun in order to record maximum counts. These radioactive anomalies may be of "geologic interest" but will have no impact on the proposed facilities.

All holes penetrated the entire existing Upper Dockum section and were bottomed in the Lower Dockum mudstones. Accordingly, the contact between these two units was identified in both cuttings and geophysical logs. The Work Plan stated that approximately thirty (30) feet of Lower Dockum mudstones would be displayed at the bottom of each drill hole. An average of 25 feet of mudstone was displayed at the bottom of the 1999 drill holes. The driller was using 15-foot lengths of drill pipe, and if at least 20 feet of Lower Dockum mudstones were apparent in the drill cuttings, the field decision was made not to make the driller add another length of drill pipe.

No groundwater was encountered within the Upper Dockum or Lower Dockum sediments in the 1999 drilling. Drill hole PB-39, however, was filled with surface water from a nearby gravel pit. This gravel pit, located approximately 120 feet from the drill hole, was terminated in the clay of the Upper Dockum. As a result, the pit filled with water due to the heavy precipitation in the area this year. This surface water was estimated to be infiltrating into the hole through the alluvial deposits at a depth of fifteen feet. In order to confirm that this water was from surface water, the following steps were taken to resolve the source of the water:

1. The hole was completed at approximately 10:00 AM, 08/03/99. There was fifteen feet of surface alluvium at the top of the hole.

2. On exiting the drill hole, the driller observed the bottom two lengths of drill pipe (30 ft) were wet (water in the hole at a depth of 90 feet).

3. The geophysical logging truck arrived on the site the next day and a log was obtained at approximately 9:30 AM, 08/04/99. The depth of the water was 64 feet. It has risen 26 feet since the time it was drilled. (If the source of water were the Upper Dockum, it would have had an unexpected artesian head).

4. A second measurement was taken at 12:20 PM, 08/04/99 and the water level had risen to a depth of 32 feet.

5. A third water measurement was taken at 3:20 PM, 08/04/99 and the water level had risen to a depth of 22 feet.

6. The HRMB was called and it was suggested that a 30-foot deep offset hole be drilled. This offset hole would penetrate the 15-foot thick alluvium sequence and bottom in a 15-foot sequence of mudstone. If this offset filled with water, it would be evidence of surface water movement in these sediments. The HRMB agreed.

7. At approximately 5:00 PM, 08/04/99 a 30-foot deep offset hole to PB-39 was drilled. This hole was drilled 20 feet east of PB-39, between it and the gravel pit. The bit got stuck in the hole in the top 15 feet of drilling and water was observed on the drill pipe.

8. At 8:00 AM, 08/05/99 water levels were measured in both PB-39 and the offset hole. The water had now dropped to a depth of 47 feet in PB-39 and it stood at 12 feet in the offset hole.

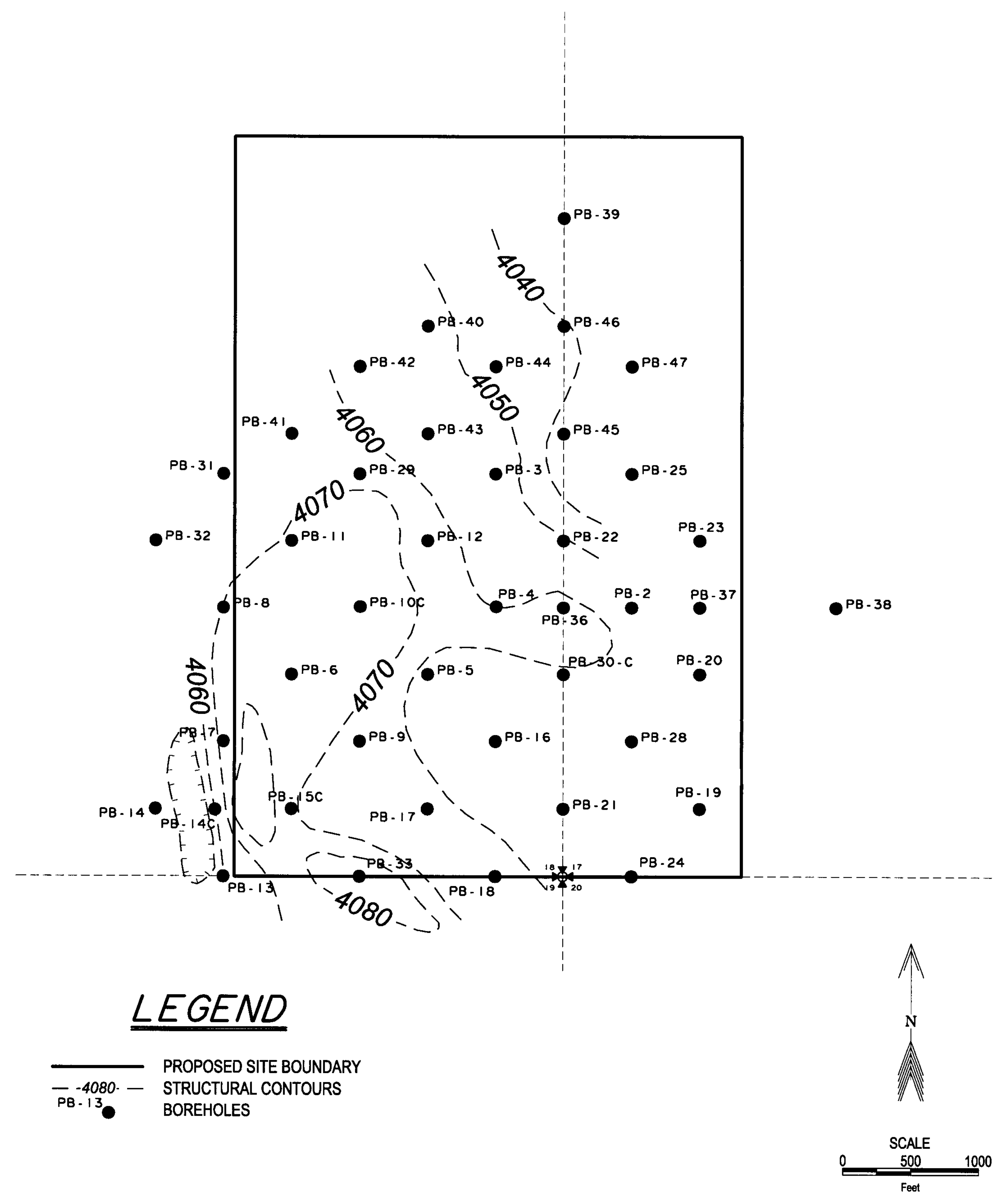
9. The water level in the gravel pit (120 feet from the hole) was noticeably lower. Moss that had been floating on top of the water was now draped over approximately five feet of mud.

10. During the day, two other water levels were taken on the holes. Water levels remained at 47 feet (PB-39) and 12 feet (offset hole).

11. With the concurrence of the HRMB representative, both holes were plugged the afternoon of 08/05/99.

The phenomena of impounded surface water migrating through alluvial sediments will have no impact on the proposed development activities. All water tanks or gravel pits existing within or adjacent to the landfill will be lined or filled. In addition, the Facility's perimeter ditches, designed for surface water control, will divert any surface water within these alluvial sediments.

Based on the results of the stratigraphic drilling program, we have updated the contour map indicating the contact between the Upper and Lower Dockum units. Figure 2 presents the structural contour map which is based on all drilling performed at the site. This indicates that the contact underlying the proposed Facility is a gently rolling surface with no indications of features that would "stratigraphically" trap groundwater.




| | | | | | |
|---|---|---|---|---|---|
| 0 | Issued for Submittal | 9/10/99 | J.Bonner | K.Conrath | D.Ellerbroek |
| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |

MONTGOMERY WATSON

PROJECT No.: 1342602.02190200
AutoCAD FILE: Gand-struc.dwg
SCALE: 1":1000'
FIGURE No. 2

*Gandy Marley, Inc. - Triassic Park*
*1999 Characterization Program*

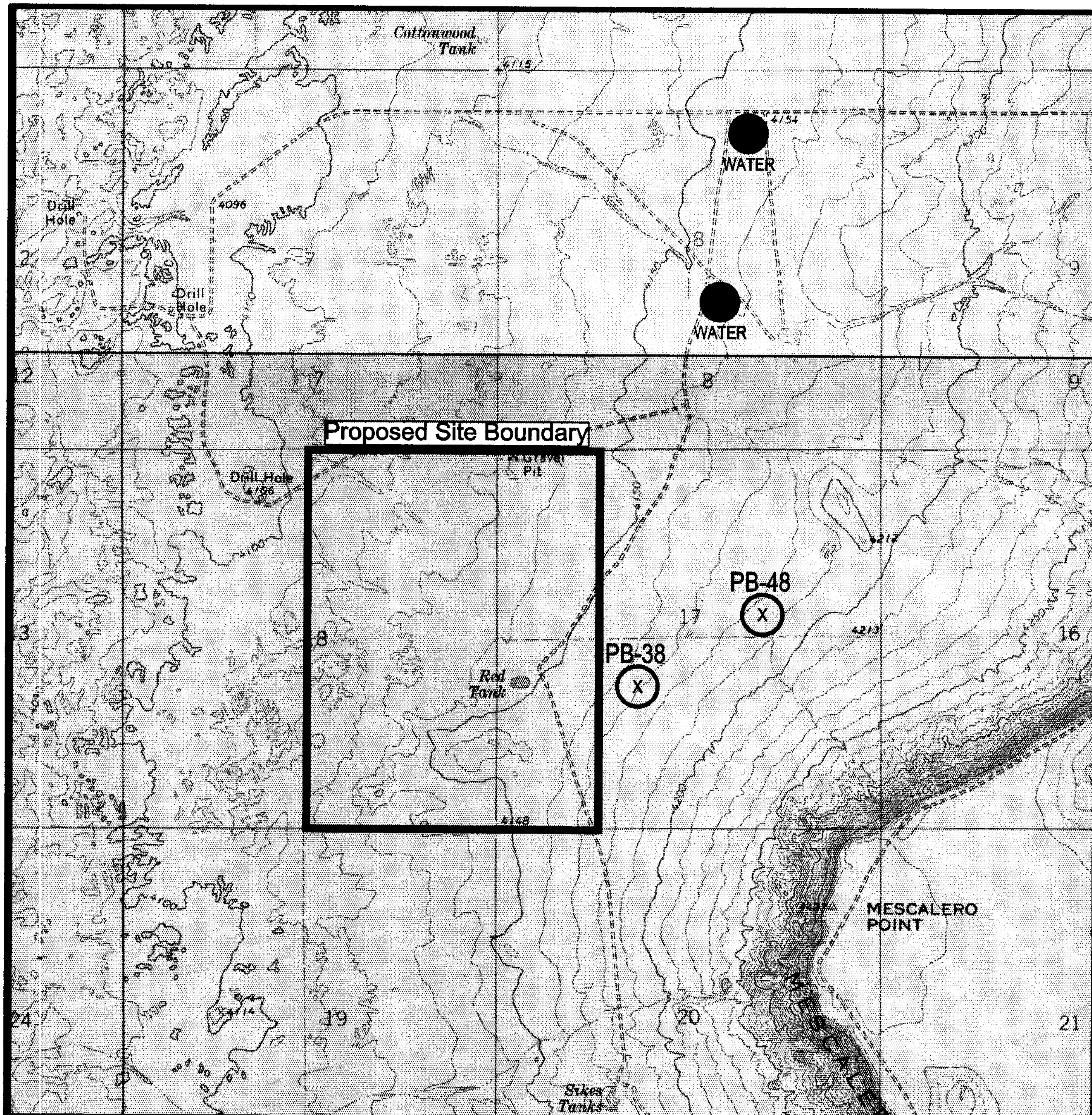
**STRUCTURE CONTOUR MAP**
**TOP OF LOWER DOCKUM**

# 4.0 RESULTS OF GROUNDWATER CHARACTERIZATION PROGRAM

The groundwater characterization program consisted of the drilling of one drill hole (PB-48) on the afternoon of August 5, 1999, east of the proposed site in an attempt to locate saturation within the Upper Dockum sediments. This drill hole was located 1000 feet north and 2000 feet east of drill hole PB-38, approximately ¾ of a mile from the proposed Phase I Landfill (see Figure 3). According to the Work Plan, had this hole encountered groundwater, it was to have been cased as a potential downgradient monitoring well.

Key Drilling completed this hole, using a 6¾-inch drill bit. Prior to drilling, the bottom 50 feet of drill pipe was steam cleaned and a vegetable-based lubricant was used during the drilling operations. The contact between the Upper Dockum and Lower Dockum sediments was encountered at a depth of 165 feet. The hole was completed to a depth of 210 feet. There was no saturation observed in the drill cuttings or on the geophysical log. Stratigraphic and geophysical logs for this hole are presented in Appendix C.

Atkins Environmental was on stand-by to complete the drill hole as a monitor well, if necessary. The morning of August 6, 1999, Atkins plugged this drill hole in the same manner in which they had plugged all stratigraphic holes. Prior to plugging, an electronic water finder was run down the hole and no saturation was encountered.




## LEGEND

● EXISTING HOLES WITH GROUNDWATER

PB-38 (X) EXISTING HOLE WITHOUT GROUNDWATER

N

SCALE
0 1000' 2000'
Feet

| REV. No | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 1 | Issued for Report | 9/7/99 | P.Corser | K.Conrath | P.Corser |
| 0 | Issued For Report | 8/19/99 | P.Corser | M.Mathisen | P.Corser |

MONTGOMERY WATSON

PROJECT No.: 1342602.02190200
AutoCAD FILE: PROPOSED-E-HOLES
SCALE: See Scale Bar
FIGURE No: 3

*Gandy Marley, Inc. - Triassic Park*
*1999 Characterization Program*

**LOCATION OF GROUNDWATER CHARACTERIZATION HOLE**

# 5.0 SUMMARY

1999 stratigraphic drilling results demonstrated that the subsurface stratigraphy underlying the proposed site is both continuous with and predictable from previous drilling results. There were no unexplainable features within the depositional environment. In all cases, the depth of the contact between the Upper Dockum and the Lower Dockum sediments was encountered where it was estimated to be. There was no groundwater within these sediments.

The groundwater characterization drilling demonstrated that there is even less groundwater in the vicinity of the site than originally thought. The limited saturation encountered one mile northeast of the site in the Upper Dockum now appears to be an isolated occurrence of perched groundwater. Upper Dockum sediments underlying the site and extending ¾ mile downgradient have been examined by over 40 drill holes and found to be unsaturated.

# Appendix A

MONTGOMERY WATSON

# APPENDIX A

## HRMB CONDITIONAL APPROVAL LETTER
## DATED JULY 30, 1999

## AND

## FINAL WORK PLAN
## DATED JULY 28, 1999

*State of New Mexico*
*ENVIRONMENT DEPARTMENT*
*Hazardous & Radioactive Materials Bureau*
*2044 Galisteo Street*
*P.O. Box 26110*
*Santa Fe, New Mexico 87502*
*(505) 827-1557*
*Fax (505) 827-1544*

GARY E. JOHNSON
GOVERNOR

PETER MAGGIORE
SECRETARY

DRAFT

July 30, 1999

Mr. Dale Gandy
Gandy Marley, Inc.
Post Office Box 827
1109 East Broadway
Tatum, New Mexico 88267

**RE: Conditional Approval for Work Plan for Stratigraphic and Groundwater Characterization Program, Proposed Triassic Park Waste Disposal Facility, Chaves County, New Mexico.**

Dear Mr. Gandy:

The New Mexico Environment Department (NMED) Hazardous and Radioactive Materials Bureau (HRMB) has completed its review of the Gandy Marley, Inc. "Work Plan for 1999 Stratigraphic and Groundwater Characterization Program" dated July 28, 1999. NMED approves the work plan with the following conditions:

1. Page 5, Section 2.5, Paragraph 1. Add the following sentence at the end of the paragraph, "Each borehole will be checked for the presence of groundwater prior to abandonment".

2. Page 9 Section 3.7.1 line 9. "Samples will be collected for metals analysis...." Change to "Samples will be collected for dissolved metals analyses...

3. Page 9 Section 3.7.1 line 10. Add the following sentence "Groundwater samples also will be collected for total metals analyses."

4. Page A-6, Section 3.4, Paragraph 7, Line 8. "Centralizers will be attached immediately above the well screen and at 20-foot intervals...." Change to "Centralizers will be attached at the base of and immediately above the well screen and at 50-foot

DRAFT



Please call Mr. Steve Pullen of this office at (505) 827-1561 if you have questions with regarding the conditions for approval listed above.

Sincerely,

James P. Bearzi
Chief
Hazardous and Radioactive Materials Bureau

cc: Stephanie Kruse
Steve Pullen

*Prepared for:*

TRIASSIC PARK WASTE DISPOSAL FACILITY
**Gandy Marley, Inc.**
Post Office Box 827
1109 East Broadway
Tatum, New Mexico 88267

# WORK PLAN

# FOR

# 1999 STRATIGRAPHIC AND GROUNDWATER CHARACTERIZATION PROGRAM

*Draft*

*July 1999*

*Prepared by:*

**Montgomery Watson**
P.O. Box 774018
Steamboat Springs, Colorado 80477
(970) 879-6260

**InfiMedia Inc.**
1717 Louisiana Boulevard N.E.
Suite 209
Albuquerque, New Mexico 87110

## TABLE OF CONTENTS



## LIST OF FIGURES

# 1.0 INTRODUCTION

The Hazardous and Radioactive Materials Bureau (HRMB) of the New Mexico Environment Department (NMED) requested that additional data be acquired on the subsurface stratigraphy and groundwater in the vicinity of the Triassic Park Waste Disposal Facility (Facility). This work plan will describe the procedures to be used to evaluate hydrostratigraphic conditions and provide a means of achieving consensus between the HRMB and Gandy Marley, Inc. (GMI) on the conduct of these programs. Results of this field work will be incorporated into the existing Facility Permit application.

# 2.0 STRATIGRAPHIC CHARACTERIZATION PROGRAM

## 2.1 PURPOSE

To date, all characterization drilling has been completed in the southern and central portions of the proposed site. The HRMB has requested that additional characterization drilling be completed in the northern portion of the site in order to assess the character of the subsurface relative to planned operational facilities in this area. The HRMB has also requested that GMI use the same drilling and evaluation techniques during this additional drilling as were used during earlier drilling programs.

The primary purpose of this drilling will be to provide additional definition to the character of the Upper Dockum sediments and their contact with the Lower Dockum mudstones. At the same time, this drilling will supply more information on the saturation conditions of the Upper Dockum sediments onsite and to the east of the site. These data will be used to site possible Vadose Zone Monitoring Wells, which may be used during the operation of the Facility.

## 2.2 APPROACH

GMI proposes the drilling of nine (9) additional stratigraphic holes in the northern portion of the proposed site (see Figure 1). The holes are to be located along a continuation of a survey grid used for all earlier drilling. A licensed, professional land surveyor established this grid. As shown on Figure 1, these additional holes will have the same area of influence (drill hole density) as the earlier characterization holes.

All additional drill holes will be completed thirty (30) feet into the Lower Dockum mudstones. Estimated depths are also shown on Figure 1. The increase in drill hole depth from west to east is due to both the eastward dip of the Triassic sediments and a gradual increase in surface elevation to the east.

## 2.3 DRILLING EQUIPMENT

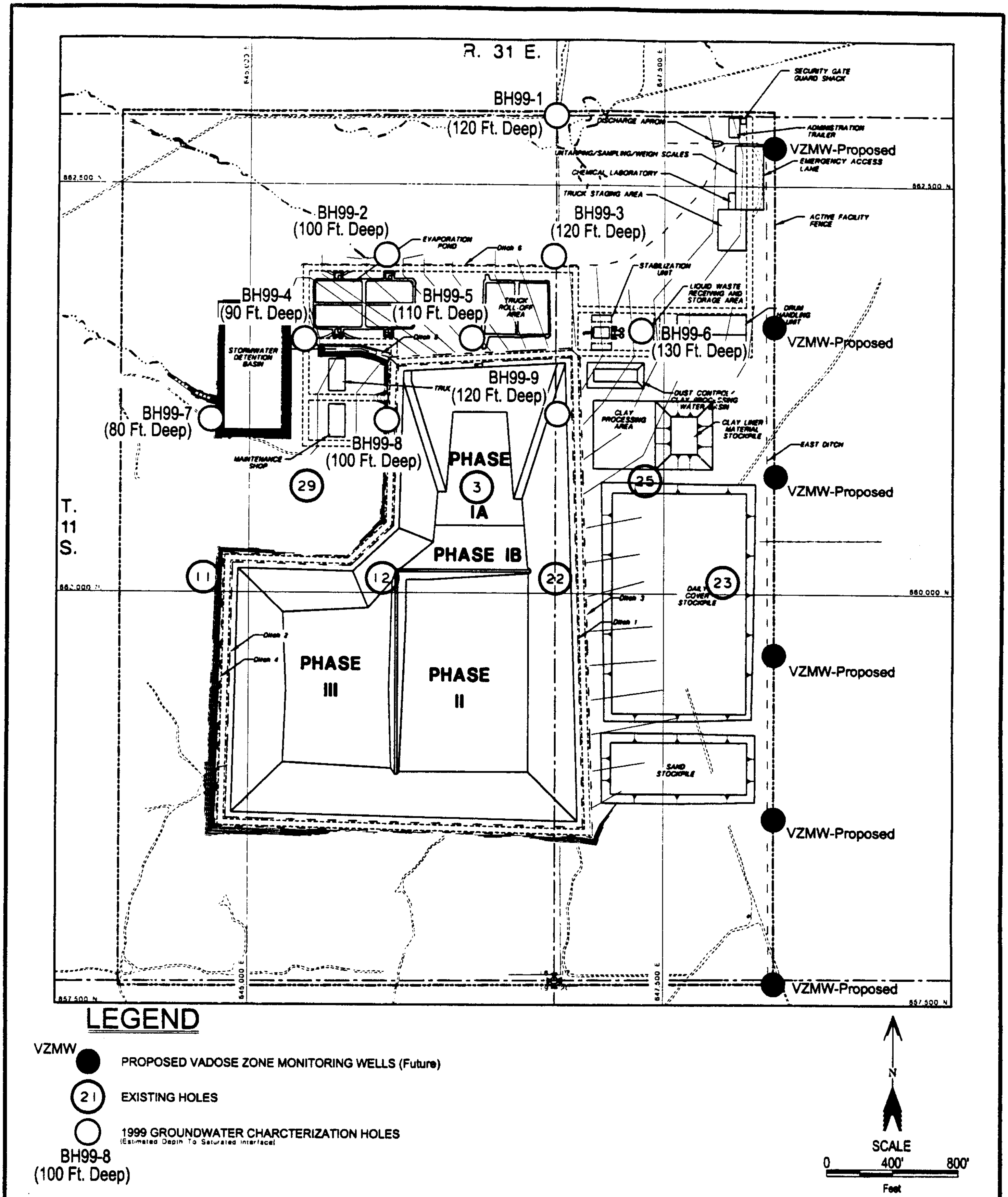
A rotary air rig will be used to drill these holes. Drilling with air provides clean cutting samples without the introduction of water into the subsurface. Therefore, should any water be observed, its source would be from sediments in the subsurface. A 4- to 6-inch hole will be drilled for the stratigraphic characterization holes. It is expected to take 2-3 days to complete this drilling program.

## 2.4 LOGGING

This program will use the identical visual and geophysical logging techniques as were used in previous drilling programs.

### 2.4.1 Geophysical

Southwest Geophysical Services, Inc. of Farmington, New Mexico will be the geophysical logging contractor. A suite of thermal neutron, gamma ray, and caliper logs will be run. The thermal neutron log will provide lithologic characterization of the sediments, as well as detect the presence of any subsurface water. The gamma ray log will help to define lithology and



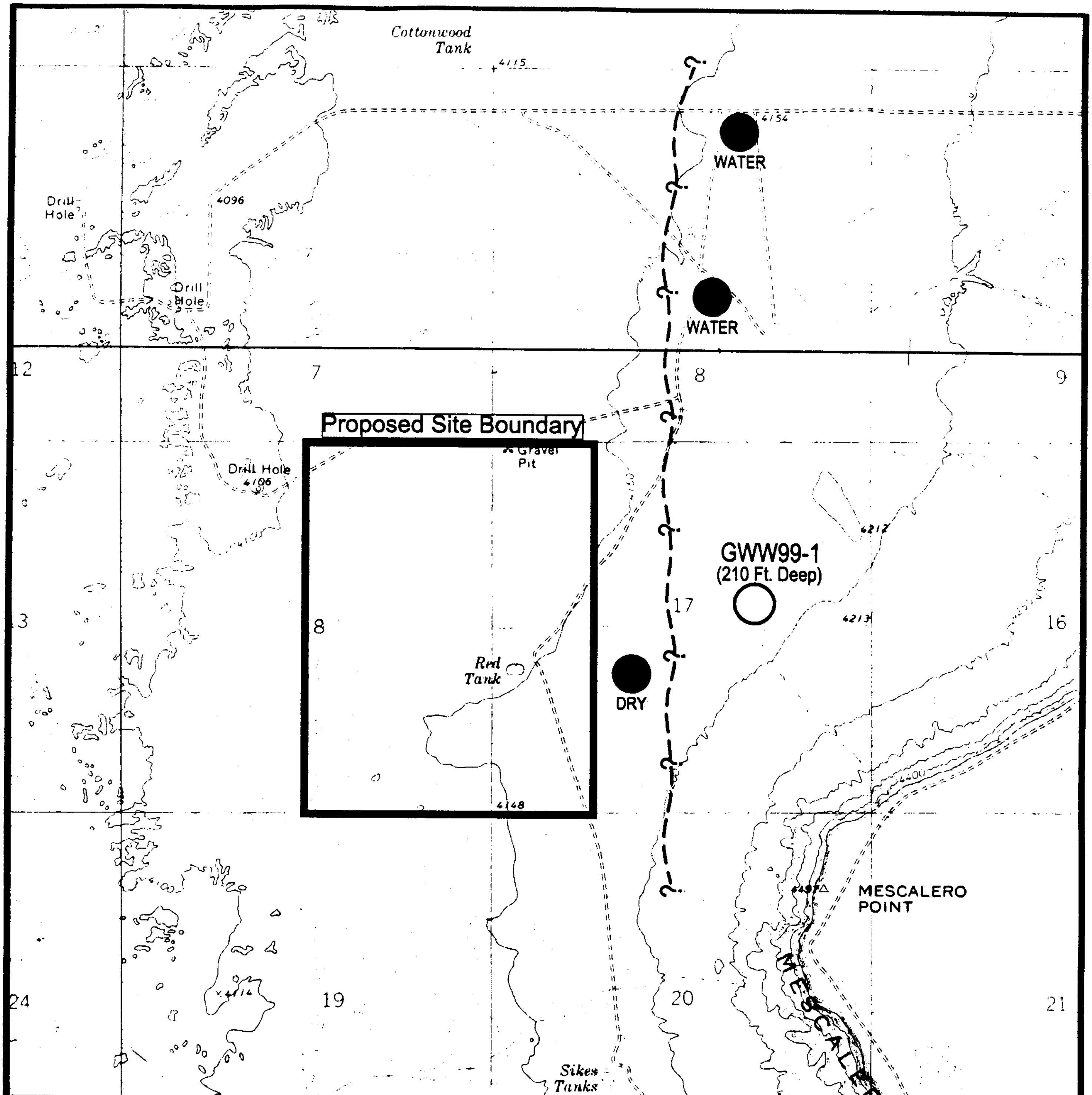

| REV No | REVISIONS | REV DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 0 | Issued For Report | 07/22/99 | P.Corser | M.Mathisen | P.Corser |

MONTGOMERY WATSON

PROJECT No. 1342602.02190200
AutoCAD FILE P-Stratigraphic-Holes
SCALE See Scale Bar
FIGURE No. 1

*Gandy-Marley, Inc. - Triassic Park Facility*
*1999 Groundwater Characterization Program*

**PROPOSED STRATIGRAPHIC HOLES**




## LEGEND

● EXISTING HOLES WITH GROUNDWATER

(210 Ft. Deep) ○ PROPOSED LOCATION FOR NEW GROUNDWATER CHARACTERIZATION WELL (Estimated Depth To Saturated Interface)

—?— —?— —?— APPROX. SATURATION INTERFACE

SCALE
0 1000' 2000'
Feet

N

| | | | | | |
|---|---|---|---|---|---|
| 0 | Issued For Report | 07/22/99 | P Corser | M Mathisen | P Corser |
| REV No | REVISIONS | REV DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |

MONTGOMERY WATSON

PROJECT No 1342602 02190200
AutoCAD FILE PROPOSED-E-HOLES
SCALE: See Scale Bar
FIGURE No: 2

*Gandy-Marley, Inc. - Triassic Park Facility*
*1999 Groundwater Characterization Program*

**PROPOSED EXPLORATORY HOLE**

indicate the presence of any naturally occurring radioactive minerals. The caliper log will record the width of the drill hole.

### 2.4.2 Lithologic

The drilling crew will catch and lay out samples of drill hole cuttings at five-foot intervals. This will provide a physical description of the subsurface sediments. A geologist will examine and describe the samples, as discussed in Appendix A. It is important to remember that there is some "lag time" associated with these cuttings samples. This is due to the time it takes the drilling medium to transport the cuttings to the surface. For this reason, the precise depths of lithologic contacts are best measured from geophysical logs.

## 2.5 HOLE ABANDONMENT

After the hole has been logged, the driller will mix a bentonite-cement grout (as described in Appendix A) and inject it into the bottom of the hole through the drill pipe or a tremie pipe. The hole will be filled with bentonite from the bottom to the top. A surface plug of cement will be placed on the top to keep surface waters from contaminating the hole.

# 3.0 GROUNDWATER CHARACTERIZATION PROGRAM

## 3.1 PURPOSE

Both the HRMB and GMI consider the saturation in the Upper Dockum to be the "uppermost aquifer" for the purpose of the Facility Permit application. However, drilling to date has encountered no saturation in the Upper Dockum sediments underlying the proposed site.

Saturated Upper Dockum sediments have been encountered ½ mile and one mile northeast of the proposed site. An inferred saturation interface is projected to be approximately fifteen hundred (1500) feet east of the site boundary. The HRMB has requested that GMI drill one exploratory hole east of the proposed site in order to determine the presence (or absence) of saturation within the Upper Dockum sediments.

Should GMI encounter saturation, the hole will be completed as a groundwater characterization well and the hydraulic characteristics of the saturated zone will be determined. The aquifer characterization test will include a slug test. The procedures for the slug test are described in Appendix B. Additionally, the groundwater will be sampled and chemically characterized. In this event, there would be no groundwater monitoring waiver as part of the Facility Permit application.

In the event that no groundwater is encountered, the Facility Permit application must be changed to designate the Lower Dockum (Santa Rosa Sandstone) as the "uppermost" aquifer. A groundwater monitoring waiver must also be incorporated into the Facility Permit application. The HRMB has already determined that monitoring the Santa Rosa Sandstone would not be protective of human health and the environment (letter dated June 25, 1999).

## 3.2 APPROACH

At the present time, there is one drill hole located immediately east of the proposed site boundary. This hole, PB-38, located approximately 800 feet east of the boundary, encountered no saturation within the Upper Dockum sediments. As shown in Figure 2, GMI proposes the drilling of one exploratory hole 1000 feet north of PB-38 and approximately 1800 feet east of PB-38. The hole should be on the "saturated" side of a projected saturation interface and located directly downgradient from the proposed Phase I Landfill.

The eastern extent of the hole location will be dependent upon topography. There is a steep drainage in the area of the proposed hole location. The hole will be drilled on the western edge of this drainage, avoiding the added cost of road construction. The drill hole will be completed thirty (30) feet into the underlying Lower Dockum at a depth of approximately 210 feet.

## 3.3 DRILLING EQUIPMENT

An air rotary rig will be used to drill these holes.

## 3.4 LOGGING

The program will use the same logging techniques as were used in characterization drilling program.

### 3.4.1 Geophysical

Southwest Geophysical Services, Inc. ill also be the geophysical logging contractor for the Groundwater Characterization Program. A suite of thermal neutron, gamma ray, and caliper logs will be run. The thermal neutron log will provide lithologic characterization of the sediments, as well as detect the presence of any subsurface water. The gamma ray log will help to define lithology and indicate the presence of any naturally occurring radioactive minerals. The caliper log will record the width of the drill hole.

### 3.4.2 Lithologic

The drilling crew will catch and lay out samples of drill hole cuttings at five-foot intervals. This will provide a physical description of the subsurface sediments. A geologist will examine and describe the samples, as discussed in Appendix A. It is important to remember that there is some "lag time" associated with these cuttings samples. This is due to the time it takes the drilling medium to transport the cuttings to the surface. For this reason, the precise depths of lithologic contacts are best measured from geophysical logs.

## 3.5 GROUNDWATER WELL DESIGN AND INSTALLATION

As discussed above, a groundwater well will be installed if groundwater is encountered in the Upper Dockum unit. It is anticipated that if groundwater is encountered, it will be due to perching along the contact between the Upper and Lower Dockum units. The contact between the Upper and Lower Dockum units will be difficult to detect on the basis of rock chips (drill cuttings) alone, and therefore will be substantiated using the results of the geophysical logging. Consequently, it will be necessary to drill the borehole, conduct the geophysical logging, and then determine the depth of the contact from the borehole and geophysical logging prior to installing the well.

If a well is installed, it will be done so using the procedures described in Appendix A. The location of the proposed well is shown in Figure 2. In general, the well will be installed using 2- to 4-inch diameter, schedule 80 PVC and a 20-foot screened interval, although a shorter or longer screened interval may be used if conditions warrant. A 4-inch diameter well will be installed, if possible. However, the allowable well diameter will be dependent on the available drilling equipment (i.e., the diameter of the borehole) and the requirement of a minimum of a 1½-inch annulus. Both the 20-foot screened interval and the 2-inch annulus are requirements of the NMED, HRMB.

If groundwater is not encountered in the borehole, it will be abandoned as a borehole in accordance with the procedures described in Appendix A.

The groundwater well will be fully developed before any use will take place. The procedures for well development are included in Appendix A.

## 3.6 SLUG TESTING

Subsequent to well installation and development, a slug test will be performed using the procedures explained in Appendix B. Slug tests are considered applicable for formations with low to moderate transmissivities, and therefore should be useful in the Dockum units based on their relatively low permeability. The test will be conducted using both the rising head and falling head approaches. The falling head approach will only be used to calculate aquifer parameters if the water is above the top of the screened interval (Fetter, 1994). Additionally, it will only be performed if there is at least five feet of water in the well. The results of the test will provide an order-of-magnitude estimate for hydraulic conductivity and transmissivity.

## 3.7 SAMPLING

The water level will be measured and groundwater samples will be collected from the new groundwater well on a biannual basis (i.e., spring and fall). The procedures for conducting these tasks are included in Appendix C. The first of the groundwater samples will not be collected until at least one (1) week after well development. A description of the proposed scope of work is included in the following sections.

### 3.7.1 Well Purging and Sampling Procedures

Prior to collecting groundwater samples for chemical analysis, the well will be purged by bailing or pumping, as described in Appendix C. The purpose of the purging will be to obtain a groundwater sample that is representative of the overall groundwater quality in the target aquifer. Non-representative conditions can be encountered, especially for major ions. This can be a result of the possible presence of drilling materials near the well, or because important environmental conditions, such as the reduction-oxidation (redox) potential, may differ drastically near the well from the conditions in the surrounding water-bearing materials. Subsequent to purging, groundwater samples will then be collected according to the procedures outlined in Appendix C. Samples collected for metals analysis (see Section 3.7.3) will be field filtered, as described in Appendix C.

### 3.7.2 Analytical Parameters, Sample Volumes, and Holding Times

During purging, the parameters pH, temperature, and conductivity will be measured in the field. These measurements will be taken a minimum of four times (see Appendix C) with the last measurement being taken just prior to sample collection. Additionally, groundwater samples will be analyzed in a laboratory for the parameters listed below.

- Calcium, magnesium, sodium, and total iron (dissolved) by EPA Method 200.7/6010
- Chloride and sulfate by EPA Method 300.0
- Alkalinity by EPA Method 310.1

Samples will be shipped to ACZ Laboratories, Inc., a certified chemical laboratory in Steamboat Springs, Colorado, for analysis. The necessary volume, container type, preservation, and maximum holding times for sample analysis are shown below.

| SAMPLE SPECIFICATIONS | | | | |
|---|---|---|---|---|
| **Name** | **Container** | **Preservation** | **Sample Volume** | **Holding Time** |
| Dissolved Metals | Plastic or Glass | $HNO_3$ to pH <2, 4 C | 500 ml | 180 days |
| Chloride and Sulfate | Plastic or Glass | None | 50 ml | 28 days |
| Alkalinity | Plastic or Glass | 4 C | 50 ml | 14 days |

### 3.7.3 Sample Labeling, Chains-of-Custody, and Shipping

The procedures for the documentation and handling of the samples are included in Appendix D. All samples will be shipped under proper custody to ACZ Laboratories, Inc. in Steamboat Springs, Colorado.

# 4.0 APPROVALS

The Hazardous and Radioactive Materials Bureau (HRMB) of the New Mexico Environment Department is in agreement with the proposed Scope of Work and its proposed implementation, as described in this Work Plan.

______________________________

James P. Bearzi
Chief, HRMB

# APPENDICES

# APPENDIX A

# DRILLING AND WELL INSTALLATION PLAN

# TABLE OF CONTENTS

Section No. Page No.



# LIST OF ATTACHMENTS

# 1.0 INTRODUCTION

This Drilling and Well Installation Plan (DWIP) has been prepared to augment the Work Plan. All of the procedures included in the DWIP are in accordance with the New Mexico Environmental Department's requirements.

This DWIP describes procedures for conducting the tasks listed below.

- Borehole logging
- Well design and construction
- Well development
- Borehole and well abandonment
- Equipment decontamination

Procedures for slug testing and groundwater sampling are included in Appendices B and C, respectively.

# 2.0 BOREHOLE LOGGING

It is anticipated that only bedrock will be encountered during drilling. Standard rock logging procedures should be used, as described below. However, since no coring will be conducted and only rock chips will be available for logging, the Unified Soils Classification System (USCS) can be used to provide additional information or if soils are encountered. All logging will be recoreded on the soil boring log form shown in Attachment A.

## 2.1 ROCK TYPE

The rock type should be described in terms of lithologic units rather than on a sample-by-sample basis. Thus, a single description may cover several sample intervals, or conversely, several rock types may occur within a single sample interval.

**Depth:** The depth below ground surface of all boundaries between lithologic units (rock types) should be included. Boundaries should be plotted at scaled depths. Identification/recording of boundaries between lithologic units is one of the **primary responsibilities** of the logger.

**Description:** A complete description of each lithologic unit encountered by the drill hole should be included. Soil, if included in the rock log or soil infillings, should also be described.

Contacts between rock types should be represented as listed below.

- Sharp - solid, horizontal line at contact location
- Gradational - solid, slanted line from start of gradational change to end of gradational change
- Inferred contact - dashed, slanted line extending over depth range of inferred contact
- Erosional - solid, wavy line at contact location (depth)
- Fault - heavy, solid horizontal line at contact location (depth)

The description should include the items shown in the following list.

- Rock type (e.g., basalt)
- Formation name, if known
- Modifiers (e.g., shaly, calcareous, silcieous, micaceous, vesicular)
- Bedding characteristics (e.g., laminated, thin bedded, massive)
- Color (based on USGS Rock Color Chart)
- Hardness (soft, very hard)
- Degree of cementation (poorly cemented, well cemented)
- Texture (dense, fine-, medium-,or coarse-grained; glassy; porphyritic; crystalline)
- Solution or void conditions (solid, cavernous, vuggy with partial infilling by clay)
- Primary and secondary permeability

## 2.2 STRENGTH DATA

**Weathering Index:** The Weathering Index should be recorded based on a standard weathering and intact rock strength classification, as shown in

Attachment B. Changes in the Weathering Index are indicated by a solid, horizontal line at the point of change for an abrupt change, or a solid slanting line covering the range of weathering change.

**Strength Index:** The Strength Index should be recorded based on a standard strength classification for rock, as shown in Attachment B. Any change in the Strength Index should be indicated by a solid horizontal line at the point of change.

## 2.3 WATER NOTES

Any observations related to groundwater conditions in the hole should be noted (e.g., "hole made water at 19 meters [62 ft],"). The color of groundwater discharge, particularly changes in color, should be noted.

## 2.4 MOISTURE

Describe the moisture condition of the cuttings, if possible, as dry (absence of moisture, dusty, dry to the touch), moist (damp but no visible water) or wet (visible free water, saturated).

## 2.5 ADDITIONAL COMMENTS

Additional comments may include the presence of, staining, mottling, or oxidation; difficulty in drilling and caving or sloughing of the borehole walls. Also, when drilling in an area known or suspected to contain imported fill material, every effort should be made to identify the contact between fill and native materials. If a soil is suspected to be fill, it should be clearly indicated on the log following the description. Stratigraphic units and their contacts should be noted wherever possible.

## 2.6 ADDITIONAL BORING LOG INFORMATION

In addition to rock descriptions, there are several other items that should be included on all boring log forms. Information in the log heading should be complete and accurate. The information listed below should be included, at a minimum.

- Boring or groundwater well number
- Project name and job number
- Site name
- Name of individual who logged the boring
- Drilling contractor
- Drill rig type and method of drilling (for example, "CME 75, hollow stem auger")
- Name of drilling company
- Name of driller and helper
- Borehole diameter and drill bit type
- Type of sampler, if any
- Time and date that drilling started and finished
- Time and date that the well was completed or the boring backfilled, as appropriate
- Method of borehole abandonment, if applicable
- Sketch map of boring or well location with estimated distances to major site features such as property lines or buildings and north arrow

If groundwater is encountered during drilling, the depth to water and the time and date of the observation should be recorded. If the first water encountered is a perched zone, the depth, time and date that any additional groundwater zones are encountered should also be recorded. Depth to water after drilling, the measuring point and the date and time of the measurement(s) must be noted. Additional measurements of depth to groundwater, including depth and time, may be beneficial.

# 3.0 GROUNDWATER WELL DESIGN AND INSTALLATION

The procedures described here are applicable to the design and installation of permanent groundwater wells and are in accordance with regulations set forth by the New Mexico Environmental Department (NMED). During all phases of well design, attention must be given to clear documentation of the basis for design decisions, the details of well construction and the materials to be used.

## 3.1 CASING DIAMETER AND SCREEN LENGTH

Groundwater well casing diameter is dependent on the purpose of the well and the amount and size of downhole equipment that must be accommodated. The groundwater well to be installed at the site will be designed as a 2- or 4-inch diameter wells, depending on available drilling equipment. Every attempt will be made to install a 4-inch diameter well to accommodate a greater variety of potential future uses of the well. Future uses could include such activities as conducting a long-term pumping test, which might require a pump larger than would fit in a 2-inch diameter well. However, it will be necessary to drill a borehole that will accommodate a minimum of a 2-inch annulus and so if the chosen drilling rig can only drill a maximum 6-inch diameter well, it will be necessary to install a 2-inch diameter well.

The well will be installed with a 20-foot long screened interval with 5 feet above the water table, as required by the NMED. However, if less than 15 feet of water are encountered above the contact between the Upper and Lower Dockum, a shorter screen will be used. Consideration should be given to seasonal fluctuations in water levels when locating the well screen across the top of the water table.

## 3.2 CASING AND SCREEN MATERIALS

The groundwater well casing and screen will be constructed of Schedule 80, polyvinyl chloride (PVC). The hydraulic efficiency of a well screen depends primarily upon the amount of open area available per unit length of screen. The two screen types commonly used for groundwater wells are machine-slotted and continuous-slot wire-wound. The groundwater well installed at the site will be constructed with machine-slotted PVC screens.

Additional construction specifications are listed below.

- Threaded, flush-joint casing
- Well caps that are vented to prevent the accumulation of gases and to allow water levels in the well to respond to barometric and hydraulic pressure changes
- Threaded end-caps

## 3.3 DECONTAMINATION OF CASING AND SCREEN MATERIALS

During the production of PVC casing, a wax layer can develop on the inner wall of the casing; protective coatings may also be added to enhance casing durability. All of these represent potential sources of chemical interference and must be removed with either a laboratory-grade non-phosphate solution or by steam cleaning prior to installation. Factory cleaning of casing and screen in a controlled environment by standard detergent washing, rinsing and air-drying procedures is superior to any cleaning efforts attempted in the field. Factory cleaned and sealed casing and screen that is certified by the supplier will be used, if available.

### 3.4 FILTER PACK AND WELL SCREEN DESIGN

A properly designed groundwater well requires that a well screen be placed opposite the zone to be monitored and be surrounded by materials that are coarser and of greater hydraulic conductivity than the natural formation material. Filter packs are installed to create a permeable envelope around the well screen. The selection of the filter pack grain size should be based on the grain size of the finest layer to be screened.

The typical well construction for a groundwater well in average formation materials includes filter pack on the order of #3 Monterey sand size and 0.020 inch slotted screen. A configuration similar to this will be used, unless the materials encountered are radically different than expected.

If conditions warrant, filter pack grain size and well screen slot size should be determined by the grain size distribution of the formation material. The filter pack should be designed first. It is recommended to use a filter pack grain size that is three to five times the average (D50) size of the formation materials. D50 will be estimated based on the lithologic description made by the site geologist or hydrogeologist. However, this method may be misleading in coarse, well graded formation materials. Another way to determine filter pack grain size is to take the D30 grain size of the formation materials and multiplying it by a factor of between 3 and 6, with 3 used if the formation is fine and uniform and 6 used if the formation is coarse and non-uniform. For both methods, the uniformity coefficient of the filter pack materials should be as close to 1.0 as possible to minimize particle size segregation during filter pack installation.

The filter pack will extend from the bottom of the well screen to a minimum of 2 feet above the top of the screen to account for settlement of the pack material during development and to act as a buffer between the well screen and the annular seal. Filter pack thickness must be sufficient to surround the well screen but thin enough to minimize resistance to the flow of fine-grained formation material and water into the well during development. Consequently, a filter pack thickness of approximately 2 inches will be used.

The materials comprising the filter pack should be as chemically inert as possible. It should be comprised of clean quartz sand or glass beads. Filter-pack materials usually come in 100-pound bags; these materials are washed, dried and factory packaged.

The size of well intake openings can only be selected after the filter-pack grain size is specified. The slot size should be such that 90 percent to 100 percent of the filter-pack material is held back by the well screen.

The casing string should be installed in the center of the borehole. This will allow the filter-pack materials to evenly fill the annular space around the screen and ensure that annular seal materials fill the annular space evenly around the casing. Where a dual-tube rig is used, the inner tube of the dual tube will adequately centralize the casing string. For other types of drilling, centralizers will be used to ensure the casing string is positioned in the center of the borehole. Centralizers are typically expandable metal or plastic that attach to the outside of the casing and are adjustable along the length of the casing. Centralizers will be attached immediately above the well screen and at 20-foot intervals along the casing to the surface.

Methods for filter pack emplacement normally used for groundwater wells include: 1) gravity (free-fall); and 2) tremie pipe. Gravity emplacement is only possible in relatively shallow wells (less than ~50 feet) with an annular space of more than 2 inches where the potential occurrence of bridging is minimized. Bridging can result in the occurrence of large unfilled voids in the filter pack or the failure of filter pack materials to reach their intended depth. Gravity emplacement may also cause filter pack gradation. Additionally, formation materials from the borehole wall can become incorporated into the filter pack, potentially contaminating it.

With the tremie emplacement method, the filter pack is poured or slurried into the annular space adjacent to the well screen through a rigid pipe, usually 1.5 inches in diameter. Initially the pipe is positioned so that its end is at the bottom of the annulus. If the filter pack is being installed in a temporarily cased borehole (e.g., dual-tube percussion) the temporary casing is pulled to expose the screen as the filter-pack material builds up around the well screen. In unconsolidated formations the temporary casing should only be pulled out 1 to 2 feet at a time to prevent caving. In consolidated or well-cemented formations or in cohesive unconsolidated formations, the temporary casing may be raised well above the bottom of the borehole prior to filter pack emplacement. For deep wells and/or nonuniform filter pack materials, the filter pack may be pressure fed through a tremie pipe with a pump. Emplacement will be continuously monitored with a weighted measuring tape accurate to the nearest 0.1 foot to determine when the filter pack has reached the desired height.

## 3.5 ANNULAR SEAL

Proper annular seal formulation and placement results in the complete filling of the annular space and envelopes the entire length of the well casing to ensure that no vertical migration can occur within the borehole.

Annular seal materials will include bentonite and neat cement grout. A bentonite seal at least 2 feet thick will be emplaced immediately above the filter pack using tremie pipe. The use of bentonite as a sealing material depends on its efficient hydration following emplacement. Expansion of bentonite in water can be on the order of 8 to 10 times the volume of dry bentonite. This expansion causes the bentonite to provide a tight seal between the casing and the adjacent formation. Bentonite pellets, granules, or chip will be used for this seal. Bentonite pellets expand in water at relatively slow rates, thus reducing the potential for bridging compared to chips, chunks, or granules. If the bentonite seal will be above the saturated zone, several gallons of clean distilled water will be poured down the annulus to begin the hydration process. A minimum of 20 minutes should pass to allow for hydration before additional annular seal materials are placed above the bentonite.

The remainder of the annulus, up to within 10 feet of the ground surface, can be filled with drill cuttings, clean, sandy soil, or tighter soil. An alternative is to use a high solids bentonite grout or slurry (e.g., Aquaguard) for the remainder of the annulus. The slurry will be mechanically blended in an aboveground rigid container and pumped through a tremie pipe to within a few inches of the bottom of the space to be sealed. This allows the slurry to displace groundwater and loose formation materials up the hole. The end of the tremie pipe should always remain in the grout without allowing air spaces. After emplacement, the tremie pipe should be removed immediately. The slurry should be emplaced in one continuous mass before initial setting of the cement or before the mixture loses its fluidity. The upper 10 feet of the annulus will be filled with a bentonite-cement grout with 2-8% bentonite by weight.

## 3.6 SURFACE COMPLETIONS

An aboveground completion with at least three guard posts (bollards) will be used, if practical, otherwise a flush-mounted completion will be used. The primary purpose of either type of completion is to prevent surface runoff from entering and infiltrating down the annulus of the well and to protect the well from accidental damage or vandalism. The surface seal may be an extension of the annular seal installed above the filter pack, or a separate seal emplaced atop the annular seal.

For aboveground completions, a protective steel casing fitted with a locking cover will be set into the uncured cement surface seal. Three (3) guard posts (bollards) will be spaced around the well with above ground completions to afford additional protection.

In a flush-mount surface completion, a watertight groundwater well Christy box or its equivalent will be set into the cement surface seal before it has cured. A locking well cap will be used to secure the inner well casing.

## 3.7 SUMMARY OF WELL DESIGN

In summary, the filter pack and well design criteria are listed below.

- PVC screen and casing
- Schedule 80 casing
- 0.020-inch machine slotted screen
- 2- to 4-inch diameter casing
- Threaded flush joint casing and end-caps
- #3 Monterey sand or equivalent for filter packs up to a minimum of 2 feet above the top of the screened interval
- Bentonite plug at least 2 feet thick on top of filter pack
- Annular seal to the surface to consist of neat cement
- Both filter pack and annular seal are to be emplaced using a tremie pipe
- Surface completions will be aboveground stand-pipes with bollards

All well completion information will be recorded on the well construction diagram shown in Attachment C.

# 4.0 WELL DEVELOPMENT

The goal of well development is to remove fines and drilling fluid residue from the gravel pack and the natural formation in the vicinity of the screened interval, this will assure good communication between the aquifer and the well. The result of well development is assurance that a sample collected will be a true representative of the quality of water moving through the formation.

The well development process is composed of: (1) the application of sufficient energy in a groundwater well to create groundwater flow reversals (surging) in and out of the well and the gravel pack to release and draw fines into the well; and (2) pumping or bailing to draw drilling fluids out of the borehole and adjacent natural formation along with fines that have been surged into the well.

## 4.1 GENERAL

The following general guidelines are applicable to well development regardless of method.

### 4.1.1 Decontamination

It is essential that every effort be made to avoid outside contamination and the cross-contamination of groundwater wells. This can best be done by ensuring that all equipment to be introduced into a well is clean. Before use and between each site, all equipment and other non-sampling equipment will be decontaminated with high-pressure steam or scrubbed with a non-phosphate detergent and rinsed with water from an approved water source. If appropriate, equipment will be covered in plastic to protect it from the elements.

### 4.1.2 Documentation

A critical part of groundwater well development is recording of significant details and events. Listed are some important details to document.

- Well identification number
- Installation date
- Date and time of development
- Quantity of drilling fluid lost during well installation
- Measured well depth (pre-development and post-development)
- Water level
- Height of water column
- Pumping rate and water level draw down (if applicable)
- Recharge rate (poor, good, excellent)
- Periodic parameter readings
- Sample observations
- Type of equipment used
- Total amount of water removed
- Completion time

### 4.1.3 Well Purging

The total volume of water purged during the development process will be based on two factors: (1) indicator parameters and (2) minimum purge volume.

#### 4.1.3.1 Indicator Parameters

During the development process, the indicator parameters pH, temperature, electrical conductivity and turbidity will be measured. The parameters pH, temperature and electrical conductivity will be measured with a field meter, while turbidity will be described qualitatively. Other observations of the water, such as color and odor, will also be recorded. Measurement of the indicator parameters will be taken at the beginning and end of the development process and at least once every ½-casing-volume; with a minimum of 4 measurements. Once the minimum required volume is reached, as described in Section 4.1.3.2, purging will continue until three consecutive measurements of the stabilization parameters meet the stabilization requirements shown below.

| | | |
|---|---|---|
| pH | ± 0.1 units | |
| Conductivity | ± 3 % of span | (i.e. ± 0.03 for span of 0 to 1 mS/cm) |
| Temperature | ± 1 °C | |

However, if the indicator parameters have stabilized, but there are still significant changes in color or some other qualitative characteristic, purging will continue until it has stabilized, if practical.

#### 4.1.3.2 Purge Volume

Before the development process begins, the minimum number of gallons to be removed will be calculated. The minimum number of gallons to purge will be equal to three casing volumes or one purge volume (described below), whichever is larger.

Information needed to calculate purge volume is listed below.

1. Total depth of well (TD)
2. Measured static water level (WL)
3. Screen length (SL)
4. Well casing inner diameter (ID)
5. Borehole Diameter (BD)
6. Number of gallons of water used during well drilling/construction
7. If the standing water column (SC) is longer then the screen length, you will need to note how many feet of filter pack was installed above the screen.

**Calculating one well volume:**

- To calculate standing water column (SC), TD - WL = SC
- Use a well volume chart to find a multiplier in the "gallons per foot" column that coincides with the wells ID
- SC x ID multiplier = gallons of water in one well volume

**Calculating one annulus volume (2 Options):**

## Option 1, if SC is shorter then the screen length

- Portion of saturated annulus = SC
- Use a volume chart to find a multiplier in the "Gallons per foot" column that coincides with the wells BD
- BD multiplier - ID multiplier = annulus multiplier
- Feet of saturated annulus x annulus multiplier x 30% (assumed porosity) = gallons of water in one annulus volume

## Option 2, if SC is longer then the screen length

- Portion of saturated annulus is = to the screen length + the number of feet of sand above the top of the screen
- Use a volume chart to find a multiplier in the "Gallons per foot" column that coincides with the wells BD
- BD multiplier - ID multiplier = annulus multiplier
- Feet of saturated annulus x annulus multiplier x 30% (assumed porosity) = gallons of water in one annulus volume

Calculating the minimum gallons to be removed: well volume + annulus volume + number of gallons lost during well drilling/construction = one purge volume

## Example:

You are to develop a 4-inch well. From the Well Construction Diagram you note the borehole diameter was 11 inches, the screen is 15 feet long and the driller used 75 gallons of water during well construction. With a water level indicator you measure the static water level at 59.45 feet and with a well tagger you measure the well depth at 71.21 feet.

Record in log book: TD = 71.25'
WL = 59.45'

TD -WL = SC
Log book: SC = 11.8'

From a Volume chart, the "gallons per foot" multiplier for a 4-inch well is 0.653 and 11.8 x 0.653 = 7.71 (gallons of water in one well volume).

Log book, One well vol. = 7.71 gallons

From a Volume chart, the "gallons per foot" for an 11-inch borehole is 4.937. Therefore, 4.937(BD multiplier) - 0.653(ID multiplier) = 4.284(annulus multiplier). And, 11.8 x 4.284 x 30% = 15.17 (gallons of water in one annulus volume).

Log book, One annulus vol. = 15.17 gallons
Drilling fluid lost = 75 gallons

7.71(one well volume) + 15.17(one annulus volume) + 75(fluid lost) = 97.88 gallons (one purge volume). A minimum of 3 well volumes must be removed during development. Additional water may need to be purged to allow the parameters to stabilize and the water to clear up.

Log book, One purge vol. = 97.88 gallons
97.88 x 3 = 293.64 (minimum number of gallons to be purged)
Log book, Minimum gallons to be purged = 293.64 gallons

## 4.2 WELL DEVELOPMENT

Development will be accomplished using surge and bail/pump. In relatively clean, permeable formations where water flows freely into the borehole, bailing, surging and pumping is an effective development technique. First, the bottom of well will be tagged to measure the amount of sand/silt before and after surging that may be present at the bottom of the well. Then a bailer will be lowered down the well to clean out any fines that have settled on the bottom of the well. Then a surge block, slightly smaller than the inside diameter of the well casing, will be used to agitate the water, causing it to move in and out of the screen, thus drawing in fines from the gravel pack and surrounding formation and breaking up any bridges that may have occurred during the placement of the gravel pack. After surging for a few minutes (depending on the height of the water column and length of screen), the bailer will then be lowered again to clean out any fines that were drawn into the casing as a result of surging. This surge/bail technique will continue until minimal fines are being pulled out with the bailer. A submersible pump will then be lowered down the well. Pumping will begin at the top of the saturated portion of the screened interval to prevent sand locking of the pump. The pump will be lowered at intervals of 5 feet or less until the pump is resting approximately 1 foot off the bottom of the casing. The water level will be monitored continuously during the first few minutes of pumping so as not to draw the water level below the pump intake and break the suction. The discharge flow rate will be increased (if possible) until the well is pumping at its maximum yield without draw down beneath the pump.

Developing low-yield wells is a very lengthy process. If development exceeds five hours, the remaining development will be done in stages (demobilize and remobilize), not to exceed three casing volumes or two return trips to the well. For wells installed in clay or fine-grained silt, the method of development will be bailing only. Surging of such wells has been found to substantially increase the turbidity of the water and does not significantly improve hydraulic well response. These wells will be bailed dry and a record kept on the time it takes for the well to recharge 80 percent.

# 5.0 BOREHOLE ABANDONMENT

A borehole that will not be converted into a well (e.g., soil borings, test holes and/or pilot holes) will be properly plugged and abandoned. The borehole will be abandoned by pumping grout to the bottom of the borehole through a tremie pipe until the borehole is filled to the ground surface with undiluted grout. Dry holes less than 15 feet deep can be filled with grout poured from the surface. After 24 hours, the abandoned borehole will be checked for grout settlement. Any settlement will be filled in with grout, using a tremie pipe if it is deeper than 15 feet. This process will be continued until firm grout remains at the ground surface.

Close attention will be paid to the mixture of the grout that is placed into a borehole or grout-filled well. The recommended mixture will consist of one sack (94 pounds) of Type I or II Portland cement (or equivalent) mixed with 7.2 to 8.5 gallons of clean water and 3 to 4 percent of bentonite powder (by weight). The optimum mix results in a volume of 1.5 to 1.6 cubic feet of slurry per sack of cement. The grout will be mixed to a smooth, uniform consistency with no lumps or balls present. It is best if the bentonite is mixed first, before adding the cement, to ensure that the bentonite is fully hydrated.

Once abandonment of a borehole is complete, the abandonment procedure will be documented. The documentation will include, at a minimum, the items listed below.

- Project name
- Dates of grouting
- Well or borehole designation
- Location of well or borehole by ¼, ¼ section (Township and Range)
- Depth of well, borehole or annulus prior to grouting
- Casing or items left in borehole
- Copy of boring log and well construction diagram
- Reason for abandonment
- Description and total quantity of grout used
- Disposition of materials removed from boring, if any
- Depth below ground surface of water or mud prior to grouting
- Method of placing the grout

# 6.0 DRILLING EQUIPMENT DECONTAMINATION

The purpose of decontamination and cleaning procedures during drilling and well installation is to prevent contamination of the samples and cross-contamination between sites. The decontamination area will be large enough to accommodate equipment to be used for invasive work and that will allow decontamination rinsate to be pumped off for temporary storage and subsequent disposal. Before use and prior to drilling of the borehole intended for the conversion to a groundwater well, all equipment will be decontaminated with high-pressure steam, or scrubbed with a non-phosphate detergent and rinsed with water from an approved water source. If appropriate, equipment will be covered in plastic to protect it from the elements.

All equipment that may directly contact samples, such as split-spoon samples or core barrels, will be decontaminated on-site. The following sampling-specific decontamination procedures will be utilized.

- Wash and scrub with detergent (laboratory grade, non-phosphate detergent)
- Rinse with tap water
- Rinse with deionized water
- Rinse with another batch of deionized water
- Air dry
- Protect from fugitive dust and vapors

# 7.0 REFERENCES

Aller, L., Bennett, T.W., Hackett, G., Petty, R.J., Lehr, J.H., Sedoris, H. and Nielsen, D.M., 1989. Handbook of suggested practices for the design and installation of groundwater monitoring wells, National Water Well Association, Dublin, Ohio, 397 pp.

ASTM, 1990, Standard D 2488-90, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).

Driscoll, F.G., 1987. Groundwater and wells; Johnson Division; St. Paul, Minnesota, 1089 pp.

Fetter, C.W., Jr., 1980. Applied Hydrogeology, Charles Merrill Publishing, Columbus, Ohio.

Freeze, R.A. and J.A. Cherry, 1979. Groundwater, Prentice-Hall, Inc., Englewood Cliffs, N.J.

Lohman, S.W., 1979. Ground-Water Hydraulics, USGS Prof. Paper 708. Available through the USGS "Books and Open-File Reports Section, Federal Center, Box 25425 Denver, Colorado 80225.

Nielsen, D. ed., 1991. Ground-water monitoring; Lewis Publishers, Chelsea, Michigan, 717 pp.

## ATTACHMENTS

# ATTACHMENT A

# SOIL BORING LOG FORM

BORING LOG NUMBER:

SHEET OF

LOC. ID: ELEVATION: DATUM:

PROJECT NAME: DRILL DATE:

INCLINATION: AZIMUTH: HAMMER WEIGHT: DATE FINISHED:

LOCATION SKETCH

| | | SOIL PROFILE | | SAMPLES | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| DEPTH | BORING METHOD | SOIL DESCRIPTION | GRAPHIC LOG | USCS | NUMBER | TYPE | BLOW COUNT/6" | RECOVERY | ADDITIONAL COMMENTS |
| | | | | | | | | | |

DEPTH UNITS: ______________ LOGGED BY: ______________

DRILLING CONTRACTOR: ______________ CHECKED BY: ______________

DRILLER: ______________

| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |

MONTGOMERY WATSON

PROJECT No.:

AutoCAD FILE:

SCALE: FIGURE No:

*SOIL BORING LOG FORM*

# ATTACHMENT B

# WEATHERING AND INTACT ROCK STRENGTH CLASSIFICATION

| WEATHERING CLASSIFICATION | | |
|---|---|---|
| TERM | DESCRIPTION | SYMBOL |
| Fresh | No visible sign of rock material weathering; perhaps slight discoloration on major discontinuity surfaces. | W1 |
| Slightly Weathered | Discoloration indicates weathering of rock material on discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker than in its fresh condition | W2 |
| Moderately Weathered | Less than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones. | W3 |
| Highly Weathered | More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones. | W4 |
| Completely Weathered | All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact. | W5 |

| INTACT ROCK STRENGTH CLASSIFICATION | | |
|---|---|---|
| TERM | DESCRIPTION | SYMBOL |
| Extremely Weak Rock | Indented by thumbnail | R0 |
| Very Weak Rock | Crumbles under firm blows with point of geological hammer, can be peeled by a pocket knife. | R1 |
| Weak Rock | Can be peeled by a pocket knife with difficulty, shallow indentations made by firm blow with point of geological hammer | R2 |
| Medium Strong Rock | Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single firm blow of geological hammer to fracture it. | R3 |
| Strong Rock | Specimen requires more than one blow of geological hammer to fracture it. | R4 |
| Very Strong Rock | Specimen requires many blows of geological hammer to fracture it. | R5 |
| Extremely Strong Rock | Specimen can only be chipped with geological hammer. | R6 |

# ATTACHMENT C

# WELL CONSTRUCTION DIAGRAM

Facility/Project Name: ______________ Well Number: ______________

Date Well Installed: From ________ To ________

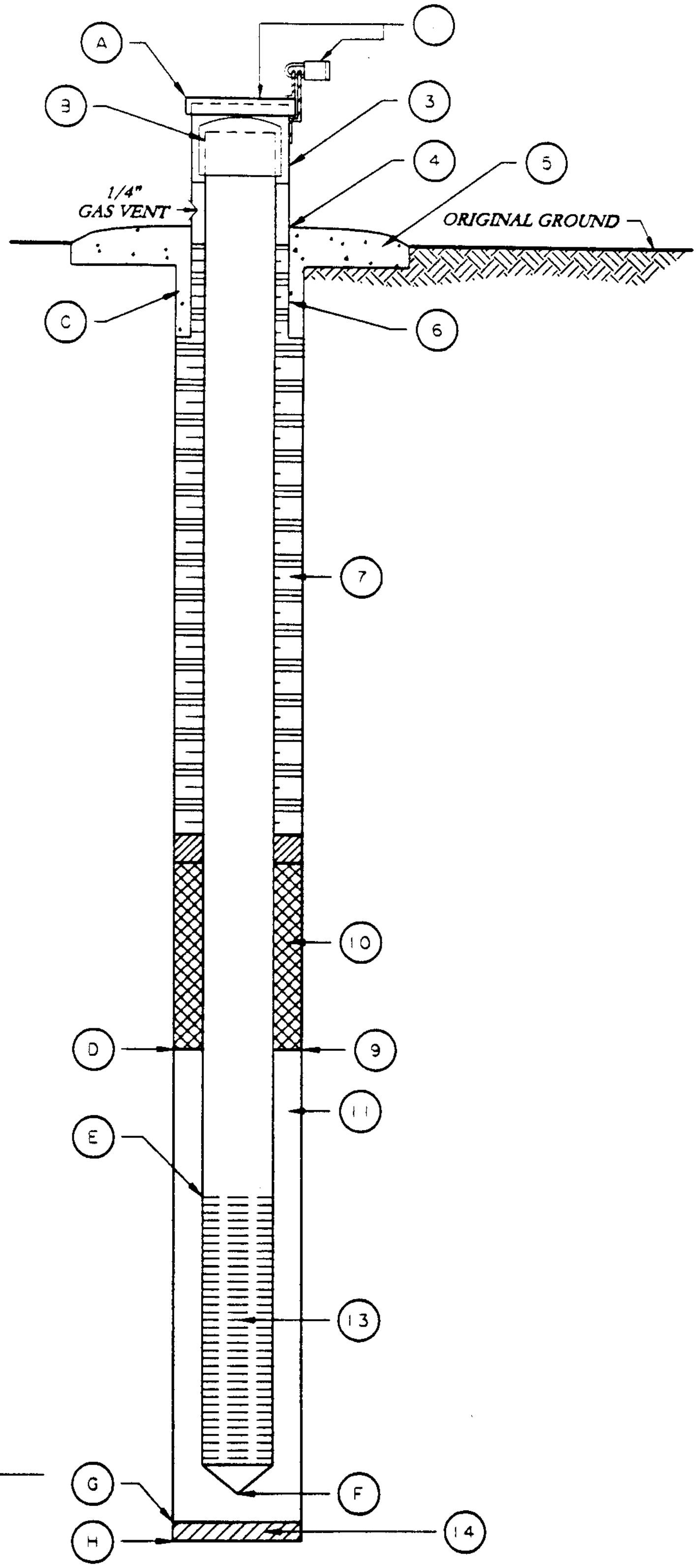
Well Installed By (Person's Name & Firm) ______________

Type of Protective Cover: Above-Gound ☐ Flush-To-Ground ☐

NOTE: Use top of casing (TOC) for all depth measurements

- (A) - Protective casing ________ ft. TOC
- (B) - Well casing ________ ft. TOC
- (C) - Surface seal, bottom ________ ft. TOC
- (D) - Primary filter, top ________ ft. TOC
- (E) - Screen joint, top ________ ft. TOC
- (F) - Well bottom ________ ft. TOC
- (G) - Filter pack, bottom ________ ft. TOC
- (H) - Borehole, bottom ________ ft. TOC
- (I) - Borehole, diameter ________ in. TOC
- (J) - O.D. well casing ________ in. TOC
- (K) - I.D. well casing ________ in. TOC
- (L) - 24hr. water level after completion ________ ft. TOC

- (1) - Cap and Lock? Yes ☐ No ☐
- (2) - Protective posts? Yes ☐ No ☐ No. ________
- (3) - Protective casing:
  - a. Inside diameter: Inches: ________
  - b. depth: Feet: ________
- (4) - Drainage port (s)? Yes ☐ No ☐
- (5) - Surface seal a. Cap? ________ b. Annular space seal? ________
- (6) - Material between well casing and protective casing: ________
- (7) - Annular space seal: Mix: ________
- (  ) - How installed: Tremie ☐ Tremie pumped ☐ Gravity ☐
- (8) - Centralizers Yes ☐ No ☐
- (9) - Bentonite seal:
  - a. Bentonite granules ☐ b. 1/4in. ☐ 3/8in. ☐ 1/2in. ☐ Bentonite pellets ☐
  - c. ________ ☐ other
- (10) - Secondary Filter Yes ☐ No ☐
  - a. Volume added ________ ft/3 ________ Bags/Size
  - b. Material ________
- (  ) - Filter pack material: Manufacturer, product name, & mesh size
  - a. ________
  - b. Volume added ________ ft/3 ________ Bags/Size
- (12) - Well casing: Flush threaded PVC schedule 40 ☐
  - Flush threaded PVC schedule 80 ☐
  - ________ Other ☐
- (13) - Screen material: ________
  - a. Screen type: ________
  - Factory cut ☐ Continuous slot ☐ Other ☐ ________
  - b: Manufacturer ________
  - c: Slot size: ________
  - d: Slotted length: ________
- (14) - Backfill material (below filter pack): None ☐
  - ________ Other ☐
- (15) - USCS classification of soil near screen None ☐
  - GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐ Bedrock ☐
  - SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
- (16) - Sieve analysis attached? Yes ☐ No ☐
- (17) - Drilling method used: Rotary ☐ Hollow Stem Auger ☐ Other ☐ ________
- (18) - Drilling fluid used: Water ☐ Air ☐ Drilling Mud ☐ None ☐
- (19) - Drilling additives used? Yes ☐ No ☐
  - Describe: ________




| | | | | | |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| 0 | Issued For Draft - Management Plan | 4/30/99 | T Leeson | M Mathisen | T Leeson |
| REV No | REVISIONS | REV DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |

MONTGOMERY WATSON

PROJECT No 1227010 121806

AutoCAD FILE TYPICAL WELL-MOSES

SCALE Not To Scale

FIGURE No

# WELL CONSTRUCTION DIAGRAM

# Appendix B

MONTGOMERY WATSON

# APPENDIX B

# STANDARD OPERATING PROCEDURES

# SLUG TESTING METHODS

# TABLE OF CONTENTS

# 1.0 INTRODUCTION

Determining the hydraulic properties of an aquifer is a fundamental component of the site characterization process. This Standard Operating Procedure (SOP) details methods for conducting a slug test. Slug tests are useful in low to moderate permeability materials and provide an order of magnitude estimate of hydraulic conductivity.

# 2.0 SLUG TESTING

## 2.1 THE PRINCIPLE - SLUG TESTING

Slug testing involves introducing or removing a "slug" of known volume into a well and recording the water level changes that result from either the instantaneous insertion or instantaneous withdrawal of the slug. The rate of recovery observed in the well is a function of the hydraulic properties of the aquifer and of the well itself. The transmissivity of the aquifer can then be estimated using appropriate well-flow equations.

## 2.2 ASSUMPTIONS AND LIMITATIONS OF SLUG TESTING

Slug tests stress only a small portion of the aquifer adjacent to the well, and therefore, slug tests are incapable of evaluating hydrogeologic boundary conditions, hydraulic anisotropy, storage coefficients, and pumping characteristics of the well. However, slug tests commonly provide a cost-effective means of gathering "point" transmissivities across a large area. Slug tests are commonly considered as a first step in characterizing an aquifer because of the relative low cost and effort requirements. Additionally, slug tests do not generate large volumes of groundwater, and therefore the method is often used to initially characterize water-bearing zones beneath hazardous waste sites, where disposal options of contaminated groundwater may be limited or costly.

## 2.3 SLUG INSERTION (FALLING HEAD) APPROACH

If a slug is rapidly inserted into the water column in a well, it will instantaneously raise the water column in the well. The amount of head change is defined as the instantaneous head ($H_O$). The water column will then "fall" to the static water level at a rate that is controlled by the hydraulic characteristics of the water-bearing formation and of the well itself. The slug insertion method is also known as a "falling head" test for this reason.

## 2.4 SLUG WITHDRAWAL (RISING HEAD) APPROACH

A second approach, the slug withdrawal method requires submersing the slug in the water column within a well, and allowing the water level to stabilize to static conditions. The slug is then rapidly withdrawn from the well. After the slug is withdrawn from the well, the instantaneous water level will be at a level that is lower than the static water level. The rate at which the water levels recover to static water levels is a function of the aquifer properties and of the well itself. This method is also known as a "rising head" test.

Both methods can be used in series during a slug testing program. The slug insertion method may be followed by the slug withdrawal with relative ease. However, if a slug insertion method is chosen for unconfined aquifers, groundwater will be displaced above the water table and into the unsaturated sand filter pack of the well and the formation itself. It is noted that the hydraulic conductivity of the soils overlying the water-bearing zone may differ from those of the aquifer. Additionally, hydraulic conductivity of unsaturated soils varies as a function of moisture content. For these reasons, a slug withdrawal method is generally considered advantageous to slug insertion in unconfined or semi-confined aquifers due to two-phase (air and water) flow. A good rule-of-thumb is if the static water level is within the screened interval of the well that is being tested, a slug withdrawal method should be chosen for aquifer analysis.

## 2.5 SELECTION OF THE SLUG

Several different types of slugs may be used for the test, including:

- Solid (blank) PVC pipe filled with sand and fitted with an eye bolt at one end to affix a bailing line

- Stainless steel or teflon bailers

- A slug of water of known volume

Introduction of a slug of water (usually distilled, organic-free water) may not be feasible due to regulatory restrictions. In addition, it is generally considered infeasible to "instantaneously" withdraw a slug of water using a pump. The withdrawal of a slug of water is limited to the use of bailers. The most common slug test involves the use of solid pipes (either slug insertion or withdrawal methods) or use of bailers (slug withdrawal only).

An additional slug testing method involves applying a pressure or vacuum to the well head and measuring changes in water levels that result following the removal of the pressure. This method requires specialized well fittings, generators, and compressors. A detailing of the method is provided in Kruseman and de Ridder (1991) (Oscillation Method, p.238), and will not be included in this SOP.

The remainder of this SOP will focus on slug tests conducted using a solid slug, although the general methods for slug tests analyses do not vary significantly if other types of slugs are used for the test.

A large slug will stress the aquifer to a greater degree than a small slug, and therefore the size of the slug should be maximized based on field conditions. Three-foot teflon bailers or sections of solid pipe can be threaded together to optimize slug volume. The size of the slug is limited only by the standing water column in the well and physical limitations in one's ability to instantaneously insert or withdraw the slug.

## 2.6 REQUIRED EQUIPMENT

<u>Slug</u>: solid pipe may be used for slug insertion or withdrawal. Bailers may be used for slug withdrawal only. The slug volume should be maximized based on field conditions. Different length slugs capable of threading together should be brought to the field to provide flexibility to the program. A typical slug used for a 2-inch-diameter groundwater well may be 1.5 inches in diameter and 6 to 10 feet in length. The volume of the slug used for each test must be recorded in the field notes.

<u>Bailing Line</u>: used for rapidly lowering and raising the slug into the water column. Deep wells may require the use of the winch on a smeal rig.

<u>Water Level Indicator</u>: to be used for measuring static water levels. A conductivity-based water level indicator capable of measuring to 0.01-foot accuracy is required.

## 2.7 PERSONNEL REQUIREMENTS

Slug testing requires a minimum of two-person team. One person is required to rapidly insert or withdraw the slug. The second person must simultaneously trigger the field instruments.

## 2.8 TEST METHODS

### 2.8.1 Slug Insertion Test Methods

1. Remove the well head expansion cap and allow the well to equilibrate to atmospheric conditions.

2. Record the static water level using a conductivity-based water level indicator. Sound the well. Note potential sediment at bottom.

3. Water levels should be measured from the top of casing (TOC). Water levels above static water levels will be recorded as positive, and water levels below static will be recorded as negative values. The slug test requires only measuring the change in head associated with slug insertion or withdrawal. TOC refers to measuring the absolute value (i.e., total head) of the water level relative to the TOC datum. This is an unnecessary step that may introduce error in the field, and is therefore not recommended for slug testing. An accurate record of all input parameters and field observations must be included in a field log.

4. Confirm static water levels.

5. Affix a bailing line to the slug. To accurately complete the test, the slug will require complete submersion in the well. Record the volume of the slug in the field log. Determine the total depth required to submerse the slug. A piece of duct tape may be used to identify the desired length. One person should handle the slug, and one person should handle the water level meter. The slug should be lowered to a "ready" position immediately above the static water level. The slug must not be tangled with the water level indicator.

6. ***This is the critical step.*** On a pre-determined count, one person must rapidly (but gently) ***lower*** the slug to total submersion while the second person begins measuring water levels. Wells screened within low to moderately transmissive aquifers may require from 30 seconds to several minutes or even hours to recover to static water levels. If the well recovers within a few seconds, it is likely that the well is screened within a moderate to high transmissivity zone, and therefore the slug test method is likely not an appropriate test method for determination of aquifer properties.

7. The slug injection test is completed when the water level recovers to static water levels. In many instances, the final few tenths of a foot of recovery may require a significant amount of time (hours). The field team should use their best judgement regarding when to terminate the test. It should be noted that for nearly all methods of data analysis, the last data points are equally significant as the initial data points. The validity of the tests should not be compromised due to impatience of field team members. In many cases, the team can be setting up the next test on a different well while the previous well completes its recovery.

8. Once the well has equilibrated to 100 percent (or nearly 100 percent) of static water level, the test can be terminated by stopping the data logger. However, at this time, it would be advantageous to initiate a slug withdrawal test (see item #4 below).

### 2.8.2 Slug Withdrawal Test Methods

1. Remove the well head expansion cap and allow the well to equilibrate to atmospheric conditions.

2. Record the static water level using a conductivity-based water level indicator. Sound the well. Note potential sediment at bottom.

3. Lower the slug into the water column so the slug is fully submerged. For this test, tie the slug bailing line to an immovable object and allow slug to remain motionless in the well. Ensure that the slug is not entangled with the water level indicator.

4. Allow the well to equilibrate to the static water level. The well will recover most quickly if a bailer is used for the slug. A solid pipe slug will require a longer period of time to recover. Verify that the well has equilibrated to static water level with a water level indicator.

5. *This is the critical step.* On a pre-determined count, one person must rapidly (but gently) *retrieve* the slug from the well while the second person simultaneously begins measuring water levels. Wells screened within low to moderately transmissive aquifers may require from 30 seconds to several minutes or hours to recover to static water levels. If the well recovers within a few seconds, it is likely that the well is screened within a moderate to high transmissivity zone, and therefore the slug test method is likely not an appropriate test method for determination of aquifer properties.

It is recommended that two slug tests be conducted for each well for data verification purposes.

The initial head values ($H_O$) which results from instantaneous withdrawal or injection of the slug should be evaluated against the maximum theoretical drawdown. This can easily be completed by calculating the volume of the slug and converting volume of the slug to volume of water in a well. The well volume can then be converted to feet of water in the well column. An example calculation is provided below:

Hypothetical slug size:

1.5-inch outer diameter (OD) x 120-inch length = 212.1 in.$^3$

Conversion to gallons:

212.1 in.$^3$ x (0.004329 gallons/in.$^3$) = 0.92 gallons

Conversion to feet (assumes a 2-inch inner diameter (ID) well):

0.92 gallons x (1 foot/0.16 gallons) = 5.75 feet

Therefore, using a slug that is 1.5 inches in diameter and 120 inches (10 feet) in length, the maximum anticipated change in water level with respect to static levels ($H_O$) would be 5.75 feet. This should be evaluated against the maximum head change observed in the field. Significantly different (greater than 20-30 percent) values may indicate that the transducers or data loggers are not functioning properly. Other possibilities are that the slug is not being inserted or withdrawn rapidly enough, or that the timing between the "trigger" operator and the "slug" operator is off. These factors should be evaluated and resolved prior to conducting additional slug tests.

# 3.0 REFERENCES

Bouwer, H. and Rice, R.C., 1976. A slug test method for determining the hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Cooper, H.H., and Jacob, C.E., 1946. A generalized graphical method for evaluating formation constants and summarizing well field history, Am. Geophys. Union Trans. vol 27, pp. 526-534.

Cooper, H.H., Bredehoeft, J.D., and Papadopulos, S.S., 1967. Response of a finite-diameter well to an instantaneous charge of water, Water Resources Research, vol. 3, no. 1, pp. 263-269.

Driscoll, F.G., 1986. Groundwater and Wells. 2nd Ed., Johnson Division of Wells, St. Paul, Minnesota.

Fetter, C.W., Jr., 1980. Applied Hydrogeology, Charles Merrill Publishing, Columbus, Ohio.

Freeze, R.A., and J.A. Cherry, 1979. Groundwater, Prentice-Hall, Inc., Englewood Cliffs, N.J.

# 3.0 REFERENCES


Bouwer, H. and Rice, R.C., 1976. A slug test method for determining the hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Cooper, H.H., and Jacob, C.E., 1946. A generalized graphical method for evaluating formation constants and summarizing well field history, Am. Geophys. Union Trans. vol 27, pp. 526-534.

Cooper, H.H., Bredehoeft, J.D., and Papadopulos, S.S., 1967. Response of a finite-diameter well to an instantaneous charge of water, Water Resources Research, vol. 3, no. 1, pp. 263-269.

Driscoll, F.G., 1986. Groundwater and Wells. 2nd Ed., Johnson Division of Wells, St. Paul, Minnesota.

Fetter, C.W., Jr., 1980. Applied Hydrogeology, Charles Merrill Publishing, Columbus, Ohio.

Freeze, R.A., and J.A. Cherry, 1979. Groundwater, Prentice-Hall, Inc., Englewood Cliffs, N.J.

# APPENDIX C

# STANDARD OPERATING PROCEDURES

# GROUNDWATER SAMPLING AND FIELD MEASUREMENTS

# APPENDIX B

# STRATIGRAPHIC CHARACTERIZATION LOGS

# Southwest Geophysical Services, Inc.

| GEOPHYSICAL WELL LOG: | PERM. DATUM: GROUND LEVEL | OTHER SERVICES: |
|---|---|---|
| GAMMA RAY<br>CALIPER<br>NEUTRON | LOG MEASURED FROM: G. L.<br>ELEVATION: | NONE |

COMPANY: GANDY–MARLEY INC.
PROJECT/FIELD: TRIASSIC PARK
WELL: PB–39
LOCATION: SEC: T: R:
NORTH– EAST–
COUNTY: CHAVES STATE: NEW MEXICO

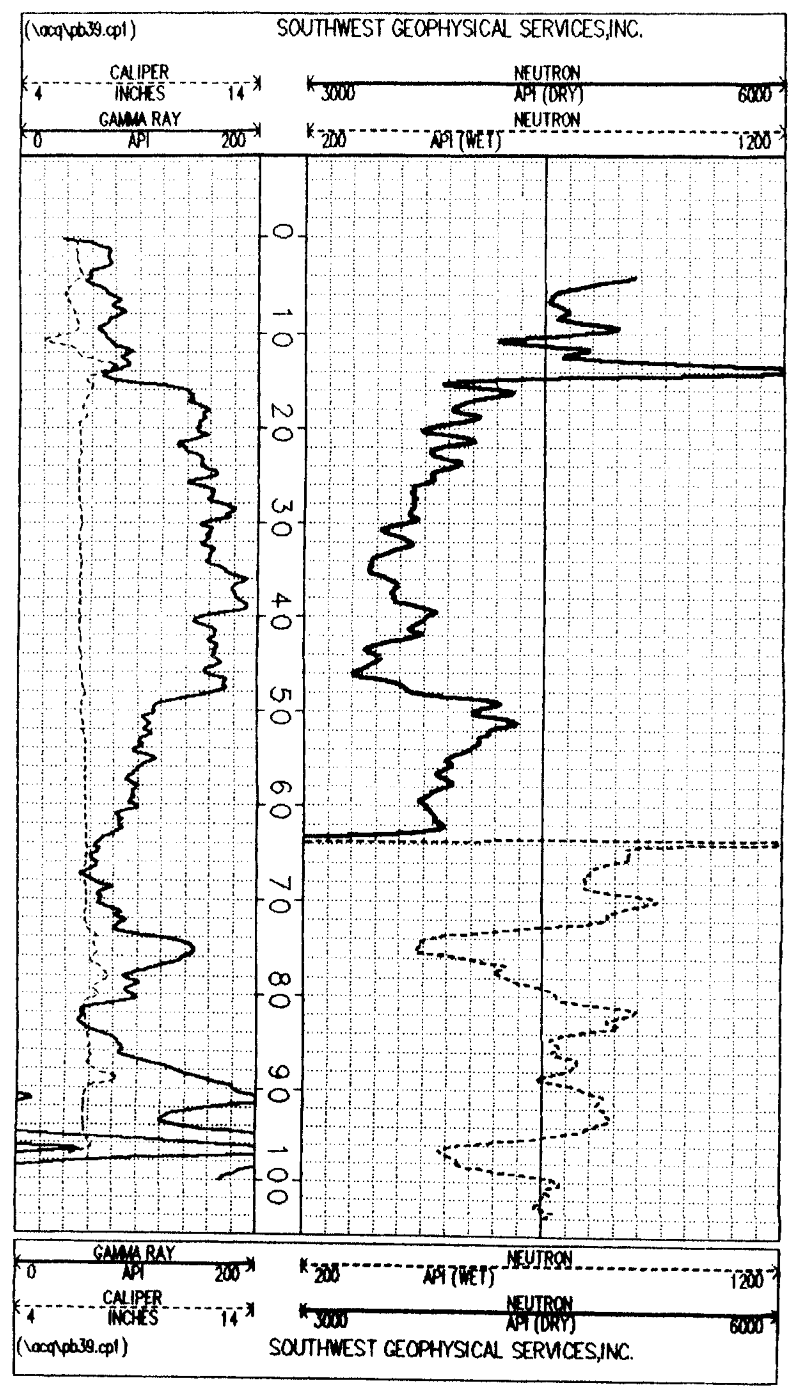
ELEVATION KB:
DF:
GL:

COMPANY: GANDY–MARLEY INC.
WELL: PB–39

| | RUN NO. 1 | | RUN NO. 1 |
|---|---|---|---|
| DATE | 8/4/99 | FLUID LEVEL | 64 FT. |
| DEPTH DRILLER | 120 FT | FLUID NATURE | |
| DEPTH LOGGER | 104 FT | FLUID VISCOSITY | |
| BOTTOM LOGGED | 104 FT | FL. RESISTIVITY | |
| TOP LOGGED INT. | SURFACE | FL. RES. @ B.H.T. | |
| CASING LEVEL | NONE | CIRCULATION TEMP. | |
| CASING SIZE | | BOT HOLE TEMP. | |
| CASING SIZE | | TOOL # | COMBO |
| BIT SIZE | 7 IN. | LOGGED BY: | D.DUCOTE |
| BIT SIZE | | WITNESSED BY: | J.BONNER |

REMARKS: NONE

THANK YOU



# Southwest Geophysical Services, Inc.

| GEOPHYSICAL WELL LOG: | PERM. DATUM: GROUND LEVEL | OTHER SERVICES: |
|---|---|---|
| GAMMA RAY<br>CALIPER<br>NEUTRON | LOG MEASURED FROM: G. L.<br>ELEVATION: | NONE |

**COMPANY:** GANDY–MARLEY INC.
**PROJECT/FIELD:** TRIASSIC PARK
**WELL:** PB–40
**LOCATION: SEC:** T: R:
NORTH– EAST–
**COUNTY:** CHAVES **STATE:** NEW MEXICO

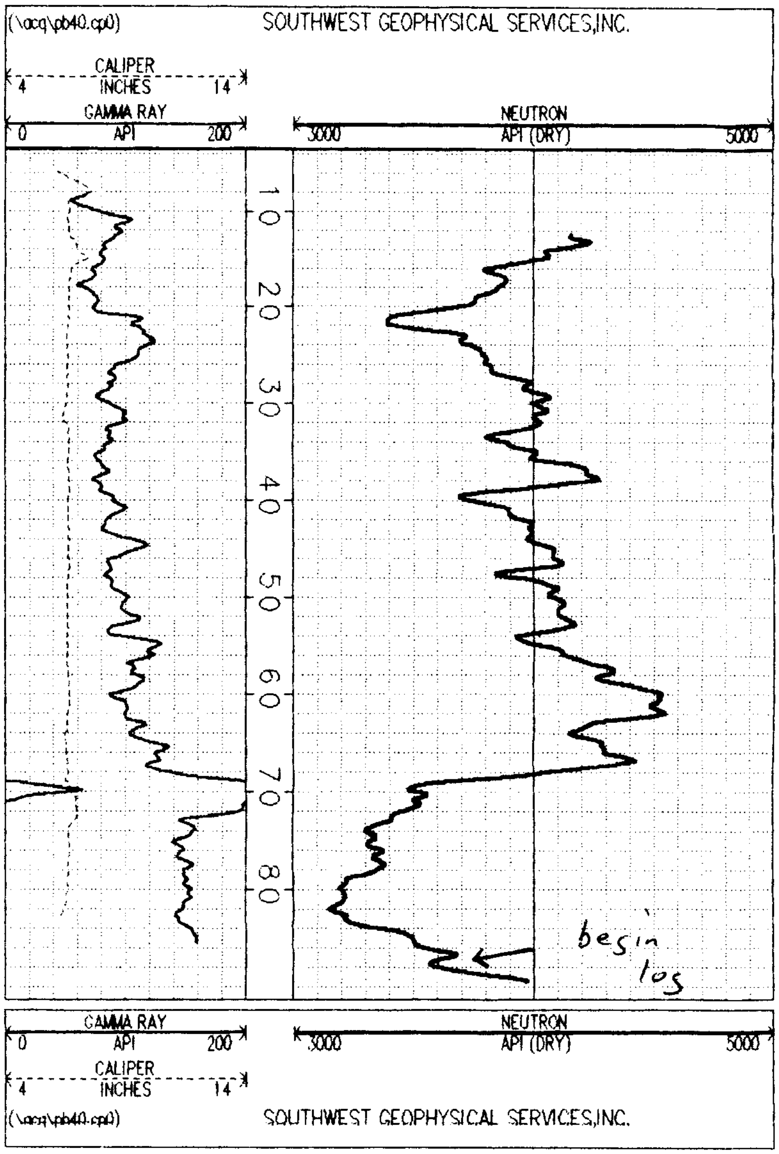
**ELEVATION** KB: DF: GL:

COMPANY: GANDY–MARLEY INC.
WELL: PB–40

| | RUN NO. 1 | | RUN NO. 1 |
|---|---|---|---|
| DATE | 8/4/99 | FLUID LEVEL | NONE |
| DEPTH DRILLER | 90 FT | FLUID NATURE | |
| DEPTH LOGGER | 90 FT | FLUID VISCOSITY | |
| BOTTOM LOGGED | 90 FT | FL. RESISTIVITY | |
| TOP LOGGED INT. | SURFACE | FL. RES. ● B.H.T. | |
| CASING LEVEL | NONE | CIRCULATION TEMP. | |
| CASING SIZE | | BOT HOLE TEMP. | |
| CASING SIZE | | TOOL # | COMBO |
| BIT SIZE | 7 IN. | LOGGED BY: | D.DUCOTE |
| BIT SIZE | | WITNESSED BY: | J.BONNER |

**REMARKS:** NONE

THANK YOU



**Southwest Geophysical Services, Inc.**

**GEOPHYSICAL WELL LOG:** GAMMA RAY, CALIPER, NEUTRON

**PERM. DATUM:** GROUND LEVEL
**LOG MEASURED FROM:** G. L.
**ELEVATION:**

**OTHER SERVICES:** NONE

**COMPANY:** GANDY–MARLEY INC.
**PROJECT/FIELD:** TRIASSIC PARK
**WELL:** PB–41
**LOCATION: SEC:** **T:** **R:**
**NORTH–** **EAST–**
**COUNTY:** CHAVES **STATE:** NEW MEXICO

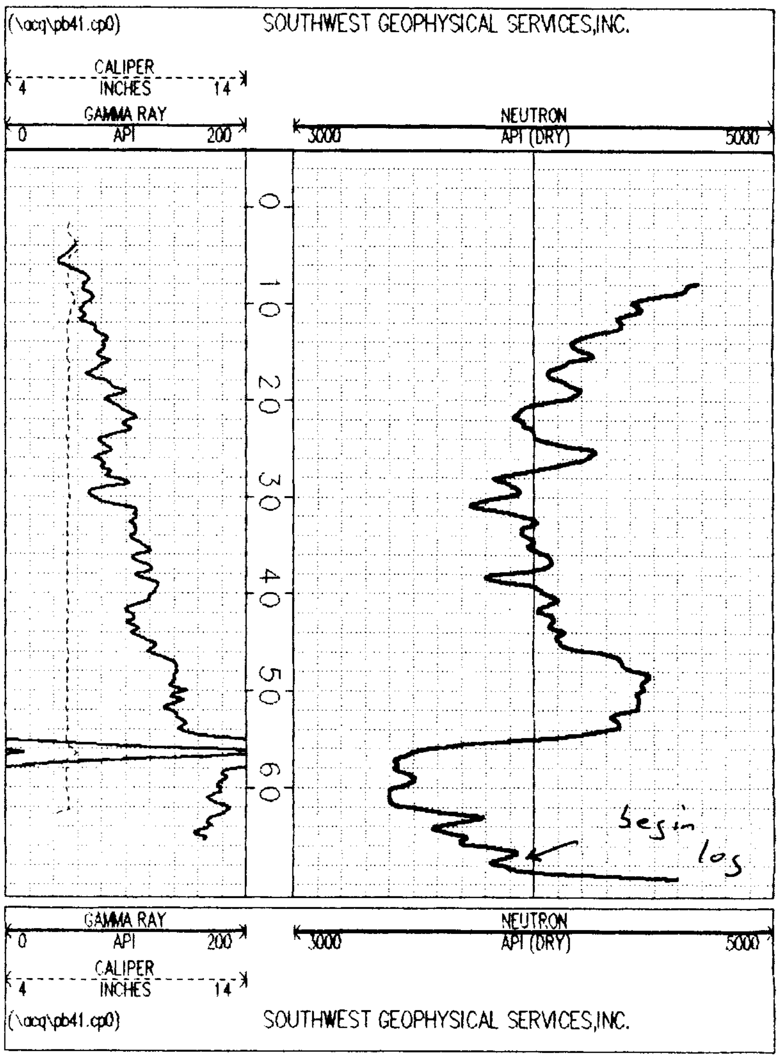
**ELEVATION KB:**
**DF:**
**GL:**

**COMPANY:** GANDY–MARLEY INC.
**WELL:** PB–41

| | RUN NO. 1 | | RUN NO. 1 |
|---|---|---|---|
| DATE | 8/4/99 | FLUID LEVEL | NONE |
| DEPTH DRILLER | 75 FT | FLUID NATURE | |
| DEPTH LOGGER | 70 FT | FLUID VISCOSITY | |
| BOTTOM LOGGED | 70 FT | FL. RESISTIVITY | |
| TOP LOGGED INT. | SURFACE | FL. RES. @ B.H.T. | |
| CASING LEVEL | NONE | CIRCULATION TEMP. | |
| CASING SIZE | | BOT HOLE TEMP. | |
| CASING SIZE | | TOOL # | COMBO |
| BIT SIZE | 7 IN. | LOGGED BY: | D.DUCOTE |
| BIT SIZE | | WITNESSED BY: | J.BONNER |

**REMARKS:** NONE

THANK YOU



# Southwest Geophysical Services, Inc.

| GEOPHYSICAL WELL LOG: | PERM. DATUM: GROUND LEVEL | OTHER SERVICES: |
|---|---|---|
| GAMMA RAY<br>CALIPER<br>NEUTRON | LOG MEASURED FROM: G. L.<br>ELEVATION: | NONE |

COMPANY: GANDY–MARLEY INC.
PROJECT/FIELD: TRIASSIC PARK
WELL: PB–42
LOCATION: SEC: T: R:
NORTH– EAST–
COUNTY: CHAVES STATE: NEW MEXICO

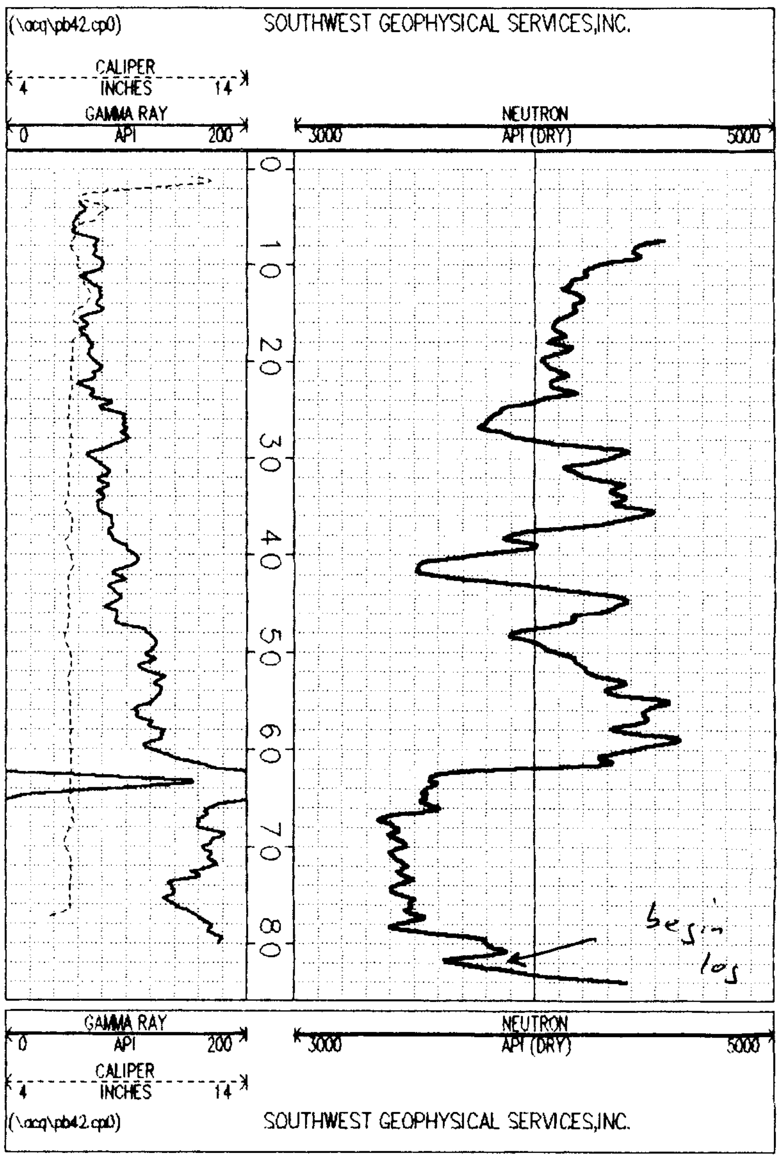
ELEVATION KB:
DF:
GL:

COMPANY: GANDY–MARLEY INC.
WELL: PB–42

| | RUN NO. 1 | | RUN NO. 1 |
|---|---|---|---|
| DATE | 8/4/99 | FLUID LEVEL | NONE |
| DEPTH DRILLER | 85 FT | FLUID NATURE | |
| DEPTH LOGGER | 84 FT | FLUID VISCOSITY | |
| BOTTOM LOGGED | 84 FT | FL. RESISTIVITY | |
| TOP LOGGED INT. | SURFACE | FL. RES. @ B.H.T. | |
| CASING LEVEL | NONE | CIRCULATION TEMP. | |
| CASING SIZE | | BOT HOLE TEMP. | |
| CASING SIZE | | TOOL # | COMBO |
| BIT SIZE | 7 IN. | LOGGED BY: | D.DUCOTE |
| BIT SIZE | | WITNESSED BY: | J.BONNER |

REMARKS: NONE

THANK YOU



**Southwest Geophysical Services, Inc.**

| | | |
|---|---|---|
| **GEOPHYSICAL WELL LOG:** GAMMA RAY CALIPER NEUTRON | **PERM. DATUM:** GROUND LEVEL<br>**LOG MEASURED FROM:** G. L.<br>**ELEVATION:** | **OTHER SERVICES:** NONE |

**COMPANY:** GANDY–MARLEY INC.
**PROJECT/FIELD:** TRIASSIC PARK
**WELL:** PB–43
**LOCATION: SEC:** T: R:
NORTH– EAST–
**COUNTY:** CHAVES **STATE:** NEW MEXICO

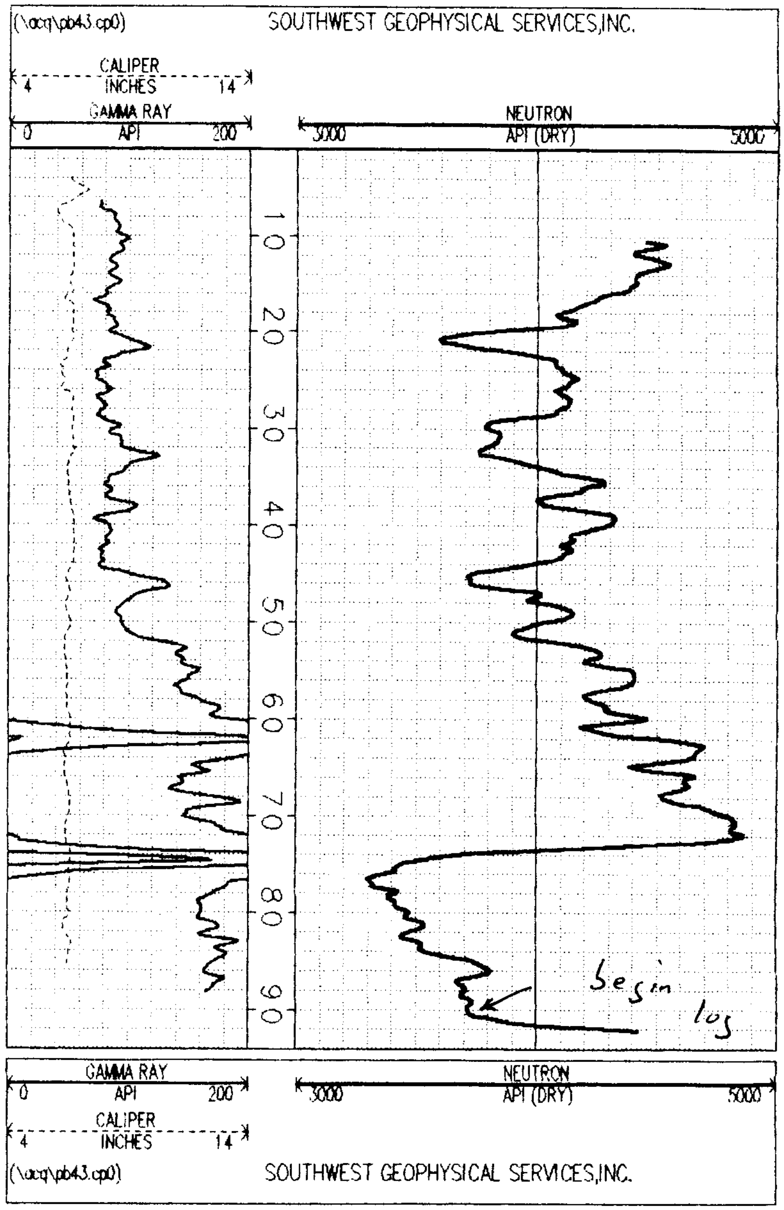
**ELEVATION KB:**
**DF:**
**GL:**

**COMPANY:** GANDY–MARLEY INC.
**WELL:** PB–43

| | RUN NO. 1 | | RUN NO. 1 |
|---|---|---|---|
| DATE | 8/4/99 | FLUID LEVEL | NONE |
| DEPTH DRILLER | 100 FT | FLUID NATURE | |
| DEPTH LOGGER | 93 FT | FLUID VISCOSITY | |
| BOTTOM LOGGED | 93 FT | FL. RESISTIVITY | |
| TOP LOGGED INT. | SURFACE | FL. RES. @ B.H.T. | |
| CASING LEVEL | NONE | CIRCULATION TEMP | |
| CASING SIZE | | BOT HOLE TEMP. | |
| CASING SIZE | | TOOL # | COMBO |
| BIT SIZE | 7 IN. | LOGGED BY: | D.DUCOTE |
| BIT SIZE | | WITNESSED BY: | J.BONNER |

**REMARKS:** NONE

THANK YOU



# Southwest Geophysical Services, Inc.

| GEOPHYSICAL WELL LOG: | PERM. DATUM: GROUND LEVEL | OTHER SERVICES: |
|---|---|---|
| GAMMA RAY | LOG MEASURED FROM: G. L. | NONE |
| CALIPER | ELEVATION: | |
| NEUTRON | | |

COMPANY: GANDY–MARLEY INC.
PROJECT/FIELD: TRIASSIC PARK
WELL: PB–44
LOCATION: SEC: T: R:
NORTH– EAST–
COUNTY: CHAVES STATE: NEW MEXICO

ELEVATION KB:
DF:
GL:

| | RUN NO. 1 | | RUN NO. 1 |
|---|---|---|---|
| DATE | 8/4/99 | FLUID LEVEL | NONE |
| DEPTH DRILLER | 110 FT | FLUID NATURE | |
| DEPTH LOGGER | 105 FT | FLUID VISCOSITY | |
| BOTTOM LOGGED | 105 FT | FL. RESISTIVITY | |
| TOP LOGGED INT. | SURFACE | FL. RES. @ B.H.T. | |
| CASING LEVEL | NONE | CIRCULATION TEMP. | |
| CASING SIZE | | BOT HOLE TEMP. | |
| CASING SIZE | | TOOL # | COMBO |
| BIT SIZE | 7 IN. | LOGGED BY: | D.DUCOTE |
| BIT SIZE | | WITNESSED BY: | J.BONNER |

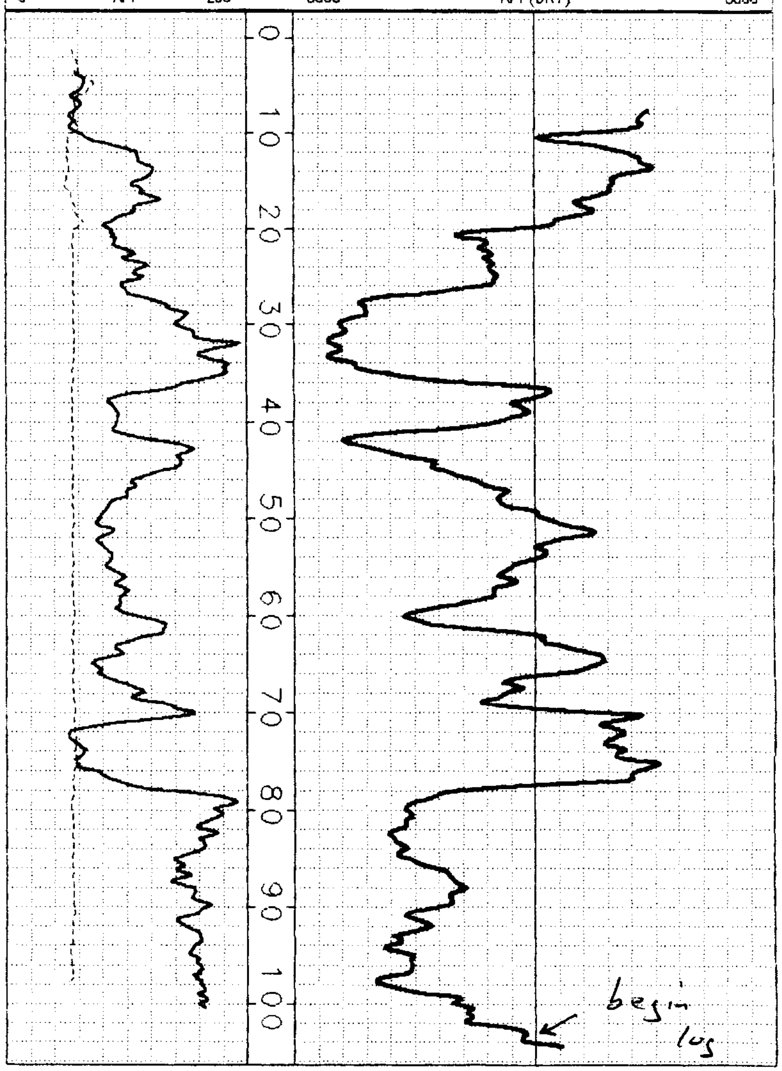
REMARKS: NONE

THANK YOU

COMPANY: GANDY–MARLEY INC.
WELL: PB–44

(\acq\pb44.cp0) SOUTHWEST GEOPHYSICAL SERVICES,INC.

CALIPER INCHES 4 – 14
GAMMA RAY API 0 – 200
NEUTRON API (DRY) 3000 – 5000




GAMMA RAY API 0 – 200
NEUTRON API (DRY) 3000 – 5000
CALIPER INCHES 4 – 14
(\acq\pb44.cp0) SOUTHWEST GEOPHYSICAL SERVICES,INC.

**Southwest Geophysical Services, Inc.**

| GEOPHYSICAL WELL LOG: | PERM. DATUM: GROUND LEVEL | OTHER SERVICES: |
|---|---|---|
| GAMMA RAY<br>CALIPER<br>NEUTRON | LOG MEASURED FROM: G. L.<br>ELEVATION: | NONE |

**COMPANY:** GANDY—MARLEY INC.
**PROJECT/FIELD:** TRIASSIC PARK
**WELL:** PB—45
**LOCATION: SEC:** T: R:
NORTH— EAST—
**COUNTY:** CHAVES **STATE:** NEW MEXICO

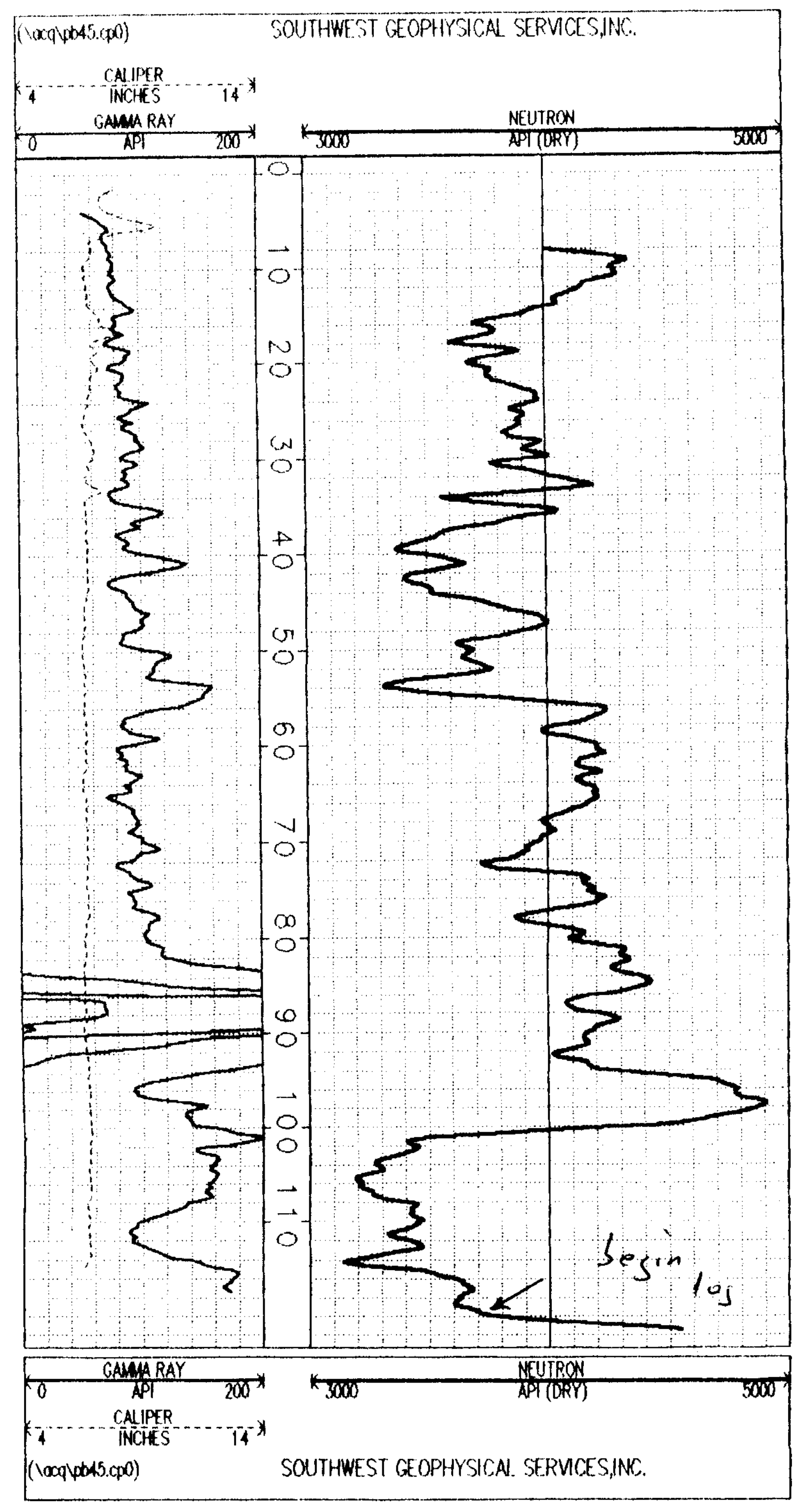
**ELEVATION KB:**
**DF:**
**GL:**

**COMPANY:** GANDY—MARLEY INC.
**WELL:** PB—45

| | RUN NO. 1 | | RUN NO. 1 |
|---|---|---|---|
| DATE | 8/4/99 | FLUID LEVEL | NONE |
| DEPTH DRILLER | 125 FT | FLUID NATURE | |
| DEPTH LOGGER | 122 FT | FLUID VISCOSITY | |
| BOTTOM LOGGED | 122 FT | FL. RESISTIVITY | |
| TOP LOGGED INT. | SURFACE | FL. RES. @ B.H.T. | |
| CASING LEVEL | NONE | CIRCULATION TEMP. | |
| CASING SIZE | | BOT HOLE TEMP. | |
| CASING SIZE | | TOOL # | COMBO |
| BIT SIZE | 7 IN. | LOGGED BY: | D.DUCOTE |
| BIT SIZE | | WITNESSED BY: | J.BONNER |

**REMARKS:** NONE

THANK YOU



# Southwest Geophysical Services, Inc.

| | | |
|---|---|---|
| **GEOPHYSICAL WELL LOG:** GAMMA RAY, CALIPER, NEUTRON | **PERM. DATUM:** GROUND LEVEL<br>**LOG MEASURED FROM:** G. L.<br>**ELEVATION:** | **OTHER SERVICES:** NONE |

**COMPANY:** GANDY--MARLEY INC.
**PROJECT/FIELD:** TRIASSIC PARK
**WELL:** PB--46
**LOCATION: SEC:** **T:** **R:**
**NORTH--** **EAST--**
**COUNTY:** CHAVES **STATE:** NEW MEXICO

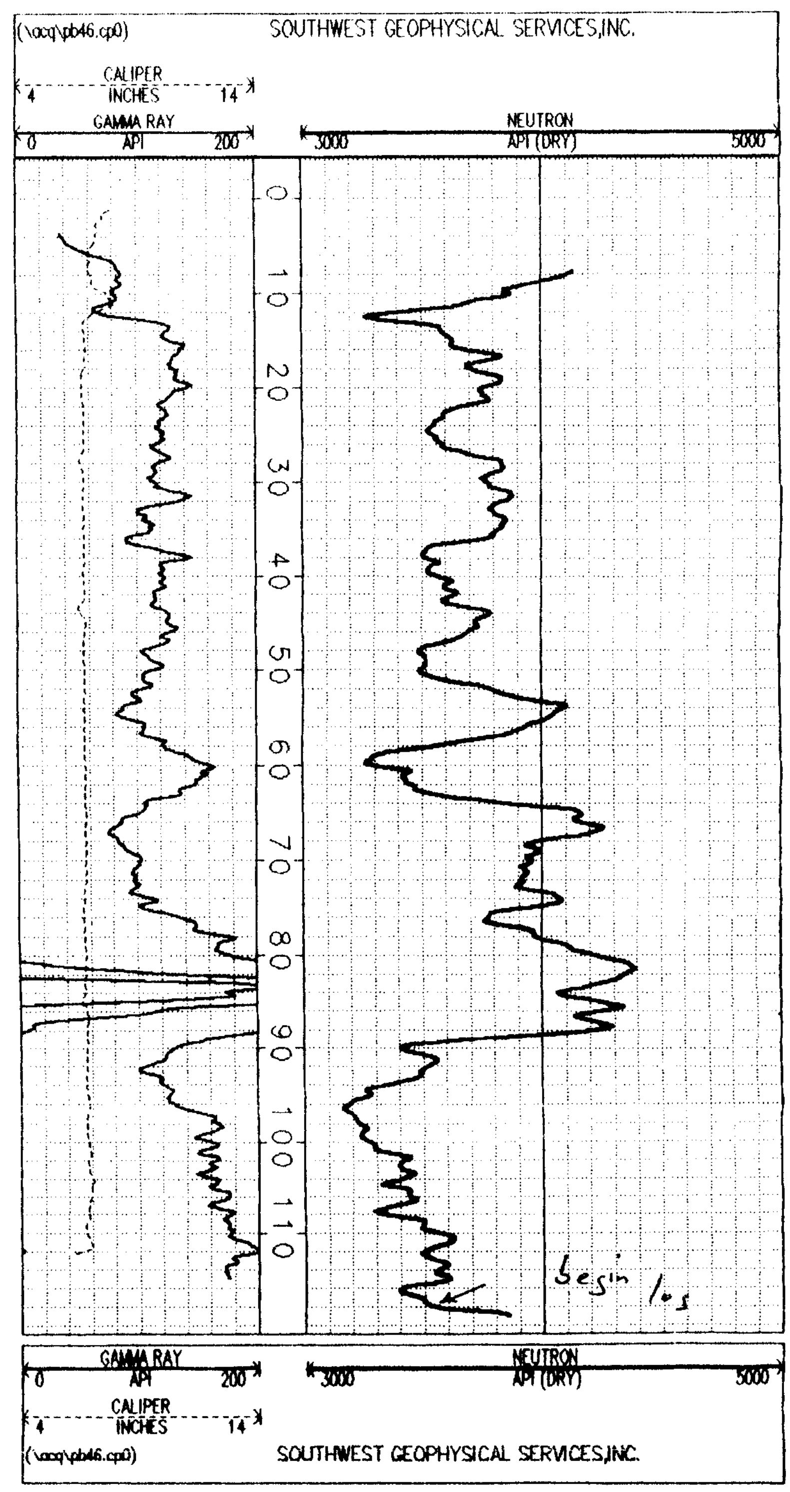
**ELEVATION KB:**
**DF:**
**GL:**

**COMPANY:** GANDY—MARLEY INC.
**WELL:** PB—46

| | RUN NO. 1 | | RUN NO. 1 |
|---|---|---|---|
| DATE | 8/4/99 | FLUID LEVEL | NONE |
| DEPTH DRILLER | 120 FT | FLUID NATURE | |
| DEPTH LOGGER | 119 FT | FLUID VISCOSITY | |
| BOTTOM LOGGED | 119 FT | FL. RESISTIVITY | |
| TOP LOGGED INT. | SURFACE | FL. RES. @ B.H.T. | |
| CASING LEVEL | NONE | CIRCULATION TEMP. | |
| CASING SIZE | | BOT HOLE TEMP. | |
| CASING SIZE | | TOOL # | COMBO |
| BIT SIZE | 7 IN. | LOGGED BY: | D.DUCOTE |
| BIT SIZE | | WITNESSED BY: | J.BONNER |

**REMARKS:** NONE

THANK YOU



# Southwest Geophysical Services, Inc.

| GEOPHYSICAL WELL LOG: GAMMA RAY, CALIPER, NEUTRON | PERM. DATUM: GROUND LEVEL<br>LOG MEASURED FROM: G. L.<br>ELEVATION: | OTHER SERVICES: NONE |
|---|---|---|

COMPANY: GANDY–MARLEY INC.
PROJECT/FIELD: TRIASSIC PARK
WELL: PB–47
LOCATION: SEC: T: R:
NORTH– EAST–
COUNTY: CHAVES STATE: NEW MEXICO

ELEVATION KB:
DF:
GL:

COMPANY: GANDY–MARLEY INC.
WELL: PB–47

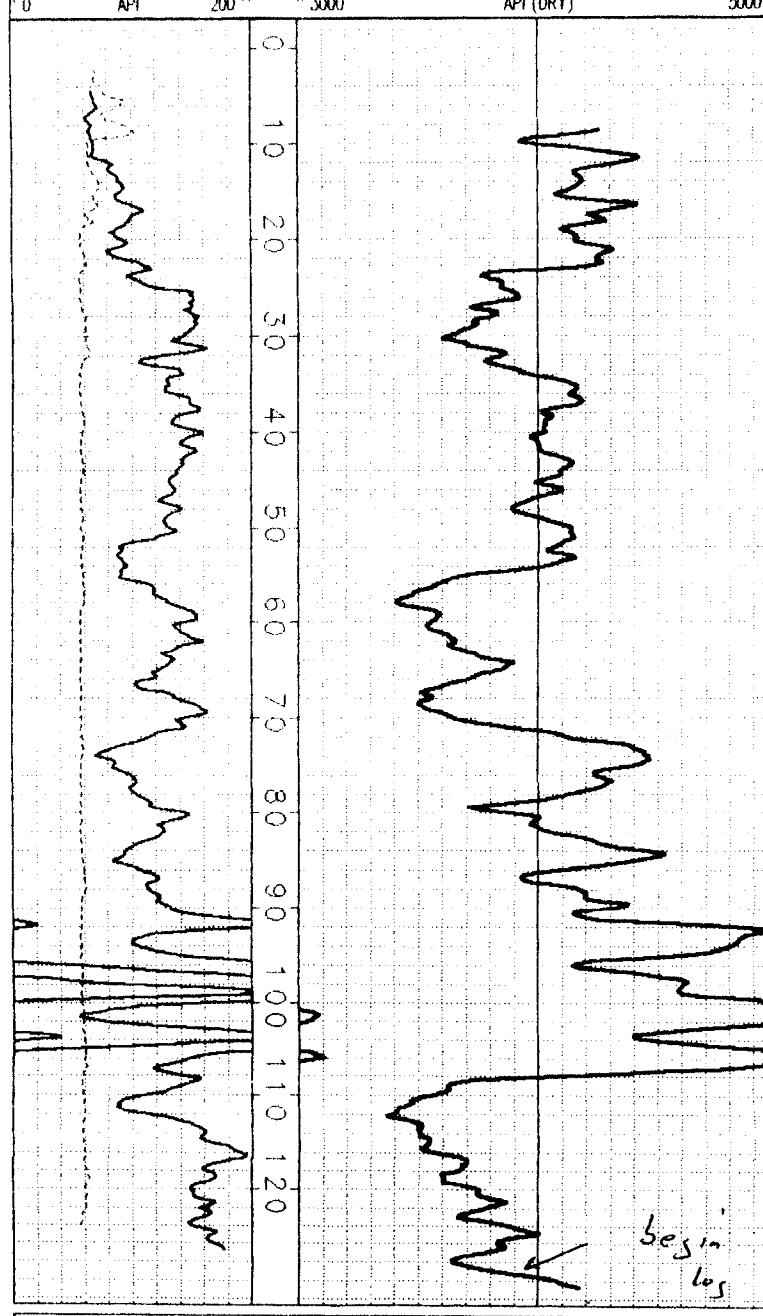
| | RUN NO. 1 | | RUN NO. 1 |
|---|---|---|---|
| DATE | 8/5/99 | FLUID LEVEL | NONE |
| DEPTH DRILLER | 130 FT | FLUID NATURE | |
| DEPTH LOGGER | 131 FT | FLUID VISCOSITY | |
| BOTTOM LOGGED | 131 FT | FL. RESISTIVITY | |
| TOP LOGGED INT. | SURFACE | FL. RES. @ B.H.T. | |
| CASING LEVEL | NONE | CIRCULATION TEMP. | |
| CASING SIZE | | BOT HOLE TEMP. | |
| CASING SIZE | | TOOL # | COMBO |
| BIT SIZE | 7 IN. | LOGGED BY: | D.DUCOTE |
| BIT SIZE | | WITNESSED BY: | J.BONNER |

REMARKS: NONE

THANK YOU

(\acq\pb47.cp0) SOUTHWEST GEOPHYSICAL SERVICES,INC.

CALIPER INCHES 4 – 14
GAMMA RAY API 0 – 200
NEUTRON API (DRY) 3000 – 5000




GAMMA RAY API 0 – 200
CALIPER INCHES 4 – 14
NEUTRON API (DRY) 3000 – 5000

(\acq\pb47.cp0) SOUTHWEST GEOPHYSICAL SERVICES,INC.

# Southwest Geophysical Services, Inc.

| GEOPHYSICAL WELL LOG: | PERM. DATUM: GROUND LEVEL | OTHER SERVICES: |
|---|---|---|
| GAMMA RAY<br>CALIPER<br>NEUTRON | LOG MEASURED FROM: G. L.<br>ELEVATION: | NONE |

COMPANY: GANDY–MARLEY INC.
PROJECT/FIELD: TRIASSIC PARK
WELL: PB–48
LOCATION: SEC: T: R:
NORTH– EAST–
COUNTY: CHAVES STATE: NEW MEXICO

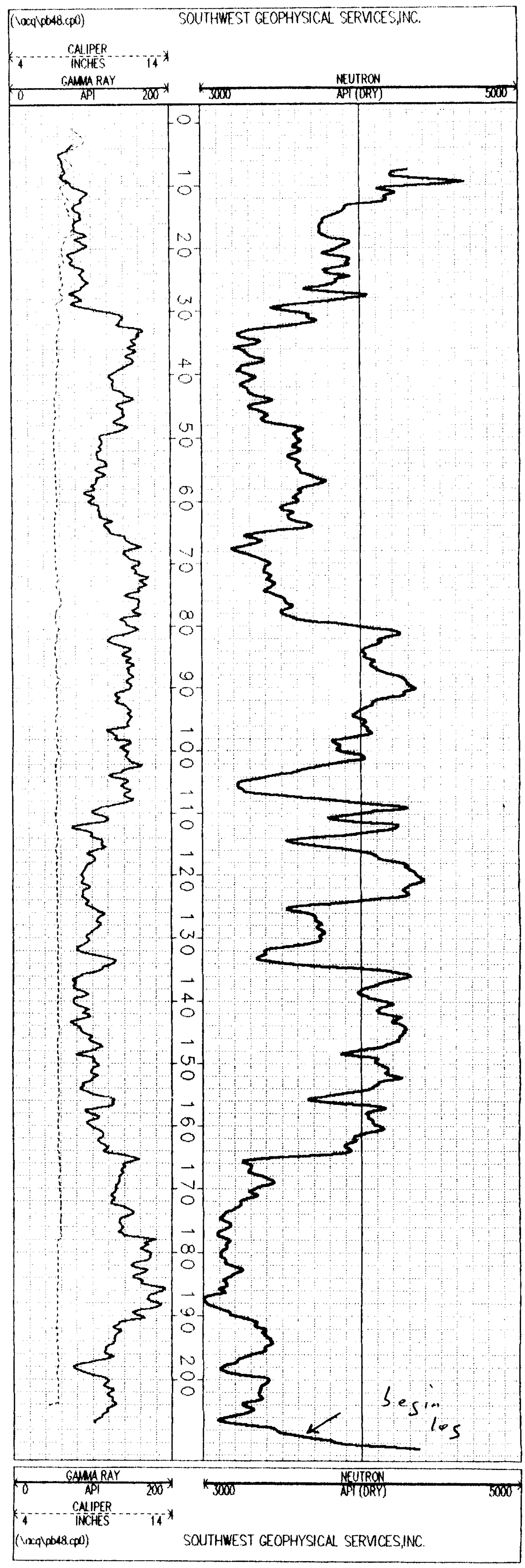
ELEVATION KB:
DF:
GL:

COMPANY: GANDY–MARLEY INC.
WELL: PB–48

| | RUN NO. 1 | | RUN NO. 1 |
|---|---|---|---|
| DATE | 8/5/99 | FLUID LEVEL | NONE |
| DEPTH DRILLER | 210 FT | FLUID NATURE | |
| DEPTH LOGGER | 211 FT | FLUID VISCOSITY | |
| BOTTOM LOGGED | 211 FT | FL. RESISTIVITY | |
| TOP LOGGED INT. | SURFACE | FL. RES. @ B.H.T. | |
| CASING LEVEL | NONE | CIRCULATION TEMP. | |
| CASING SIZE | | BOT HOLE TEMP. | |
| CASING SIZE | | TOOL # | COMBO |
| BIT SIZE | 7 IN. | LOGGED BY: | D.DUCOTE |
| BIT SIZE | | WITNESSED BY: | J.BONNER |

REMARKS: NONE

THANK YOU



BORING LOG NUMBER: **PB-39** SHEET 1 OF 1

| | |
|---|---|
| LOC. ID: | ELEVATION: 4130 | DATUM: MSL |
| PROJECT NAME: GANDY-MARLEY | DRILL DATE: 8/3/99 |
| INCLINATION: | AZIMUTH: | HAMMER WEIGHT: N/A | DATE FINISHED: 8/3/99 |

LOCATION SKETCH

NORTH EDGE OF SITE ON SECTION CORNER (SEE LOCATION MAP)

| DEPTH (UNITS) | BORING METHOD | SOIL PROFILE – SOIL DESCRIPTION | GRAPHIC LOG | USCS | NUMBER | TYPE | BLOW COUNT/6" | RECOVERY |
|---|---|---|---|---|---|---|---|---|
| | AIR ROTARY WITH 6 3/4 INCH BIT | | | | | SEE ADDITIONAL COMMENTS | N/A | N/A |
| 0 | | Fine surface sand, brown clay with PreCambrian cobbles | | | | | | |
| | | Red-brown claystone | | | | | | |
| 25 | | Yellow brown claystone | | | | | | |
| 50 | | Red grey siltstone with red grey claystone @ 75' | | | | | | |
| 75 | | | | | | | | |
| 100 | | Moderate red brown mudstone - damp @ top | | | | | | |
| 125 | | TD=120 FT. | | | | | | |
| 150 | | | | | | | | |
| 175 | | | | | | | | |
| 200 | | | | | | | | |
| 225 | | | | | | | | |

## ADDITIONAL COMMENTS

### GROUNDWATER

Bottom two joints wet where hole finished. Hole logged 9:30 8/4/99 water level @ 64.0'

Water measurement taken 12:20 8/4/99 @ 32.0'

Water measurement taken 3:20 8/4/99 @ 22.0'

Water measurement taken 8:00 8/5/99 @ 47.0'

### DESCRIPTIONS

All descriptions based on Air Rotary. Cutting samples obtained every 5 ft.

### GEOPHYSICAL LOGS

- Thermal Neutron
- Gamma
- Caliper

Logs are attached

### PLUGGING

Holes plugged with cement-bentonite grout by Atkins Environmental. Plugged from bottom up with trim line.
Due to presence of water, an additional hole was drilled @ 30 ft. offset.

Water in 30 ft. offset was at 12.0' @8:00 8/5/99

DEPTH UNITS: 120 FT.
DRILLING CONTRACTOR: KEY DRILLING
DRILLER: JUSTIN BOWMAN

LOGGED BY: JAB
CHECKED BY:

| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 0 | Issued for Review | 9/2/99 | J.Bonner | K.Conrath | P.Corser |

MONTGOMERY WATSON

PROJECT No.: 1342602.02190200
AutoCAD FILE: SLPB39.DWG
SCALE: N/A
FIGURE No:

GANDY-MARLEY, INC.

**SOIL BORING LOG FORM**

BORING LOG NUMBER: PB-40

SHEET 1 OF 1

LOCATION SKETCH

NORTH OF PROPOSED EVAPORATION PONDS (SEE LOCATION MAP)

| | |
|---|---|
| LOC. ID: | ELEVATION: 4121 |
| DATUM: MSL | |
| PROJECT NAME: GANDY-MARLEY | DRILL DATE: 8/3/99 |
| INCLINATION: VERTICAL | AZIMUTH: N/A |
| HAMMER WEIGHT: N/A | DATE FINISHED: 8/3/99 |

| DEPTH (UNITS) | BORING METHOD | SOIL PROFILE / SOIL DESCRIPTION | GRAPHIC LOG | USCS | NUMBER | TYPE | BLOW COUNT/6" | RECOVERY |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | N/A | N/A |
| 0 | AIR ROTARY WITH 6 3/4 INCH BIT | Fine surface sand, brown clay with PreCambrian cobbles | | | | SEE ADDITIONAL COMMENTS | | |
| | | Red grey siltstone | | | | | | |
| 25 | | | | | | | | |
| 50 | | | | | | | | |
| 75 | | Moderate red brown mudstone | | | | | | |
| | | TD=90 FT. | | | | | | |
| 100 | | | | | | | | |
| 125 | | | | | | | | |
| 150 | | | | | | | | |
| 175 | | | | | | | | |
| 200 | | | | | | | | |
| 225 | | | | | | | | |

ADDITIONAL COMMENTS

**DESCRIPTIONS**

All descriptions based on Air Rotary. Cutting samples obtained every 5 ft.

**GEOPHYSICAL LOGS**

- Thermal Neutron
- Gamma
- Caliper

Logs are attached

**PLUGGING**

Holes plugged with cement-bentonite grout by Atkins Environmental. Plugged from bottom up with trim line.
Due to presence of water, an additional hole was drilled @ 30 ft. offset.

DEPTH UNITS: 90 FT.
DRILLING CONTRACTOR: KEY DRILLING
DRILLER: JUSTIN BOWMAN

LOGGED BY: JAB
CHECKED BY:

| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 0 | Issued for Review | 9/2/99 | J.Bonner | K.Conrath | P.Corser |

MONTGOMERY WATSON

PROJECT No.: 1342602.02190200
AutoCAD FILE: SLPB40.DWG
SCALE: N/A
FIGURE No:

GANDY-MARLEY, INC.

SOIL BORING LOG FORM

BORING LOG NUMBER:

# PB-41

SHEET 1 OF 1

| | |
|---|---|
| LOC. ID: | ELEVATION: 4118 |
| DATUM: MSL | |
| PROJECT NAME: GANDY-MARLEY | DRILL DATE: 8/3/99 |
| INCLINATION: VERTICAL | AZIMUTH: N/A |
| HAMMER WEIGHT: N/A | DATE FINISHED: 8/3/99 |

LOCATION SKETCH

GRID LOCATION BH99-7

| DEPTH (UNITS) | BORING METHOD | SOIL PROFILE – SOIL DESCRIPTION | GRAPHIC LOG | SAMPLES – USCS | SAMPLES – NUMBER | SAMPLES – TYPE | SAMPLES – BLOW COUNT/6" | SAMPLES – RECOVERY |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | N/A | N/A |
| 0 | AIR ROTARY WITH 6 3/4 INCH BIT | Fine surface sand, brown clay with caliche stains, rocks and PreCambrian cobbles | | | | SEE ADDITIONAL COMMENTS | | |
| 25 | | Red grey siltstone | | | | | | |
| 50 | | Moderate red brown mudstone | | | | | | |
| 75 | | TD=75 FT. | | | | | | |
| 100 | | | | | | | | |
| 125 | | | | | | | | |
| 150 | | | | | | | | |
| 175 | | | | | | | | |
| 200 | | | | | | | | |
| 225 | | | | | | | | |

## ADDITIONAL COMMENTS

### DESCRIPTIONS

All descriptions based on Air Rotary. Cutting samples obtained every 5 ft.

### GEOPHYSICAL LOGS

- Thermal Neutron
- Gamma
- Caliper

Logs are attached

### PLUGGING

Holes plugged with cement-bentonite grout by Atkins Environmental. Plugged from bottom up with trim line.
Due to presence of water, an additional hole was drilled @ 30 ft. offset.

DEPTH UNITS: 75 FT.
DRILLING CONTRACTOR: KEY DRILLING
DRILLER: JUSTIN BOWMAN

LOGGED BY: JAB
CHECKED BY:

| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 0 | Issued for Review | 9/2/99 | J.Bonner | K.Conrath | P.Corser |

GANDY-MARLEY, INC.

MONTGOMERY WATSON

PROJECT No.: 1342602.02190200
AutoCAD FILE: SLPB-41DWG
SCALE: N/A
FIGURE No:

**SOIL BORING LOG FORM**

BORING LOG NUMBER:

**PB-42**

SHEET 1 OF 1

LOC. ID: | ELEVATION: 4121 | DATUM: MSL

PROJECT NAME.: GANDY-MARLEY | DRILL DATE: 8/3/99

INCLINATION: VERTICAL | AZIMUTH: N/A | HAMMER WEIGHT: N/A | DATE FINISHED: 8/3/99

LOCATION SKETCH

GRID LOCATION BH99-4

| DEPTH (UNITS) | BORING METHOD | SOIL PROFILE – SOIL DESCRIPTION | GRAPHIC LOG | SAMPLES – USCS | NUMBER | TYPE | BLOW COUNT/6" | RECOVERY |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | N/A | N/A |
| 0 | AIR ROTARY WITH 6 3/4 INCH BIT | Fine surface sandstone, brown clay & PreCambrian cobbles (caliche) | | | | SEE ADDITIONAL COMMENTS | ↓ | ↓ |
| | | Red grey silt with grey red clays @ 40' | | | | | | |
| 25 | | | | | | | | |
| 50 | | | | | | | | |
| | | Moderate red brown mudstone | | | | | | |
| 75 | | | | | | | | |
| | | TD=90 FT. | | | | | | |
| 100 | | | | | | | | |
| 125 | | | | | | | | |
| 150 | | | | | | | | |
| 175 | | | | | | | | |
| 200 | | | | | | | | |
| 225 | | | | | | | | |

ADDITIONAL COMMENTS

**DESCRIPTIONS**

All descriptions based on Air Rotary. Cutting samples obtained every 5 ft.

**GEOPHYSICAL LOGS**

- Thermal Neutron
- Gamma
- Caliper

Logs are attached

**PLUGGING**

Holes plugged with cement-bentonite grout by Atkins Environmental. Plugged from bottom up with trim line.
Due to presence of water, an additional hole was drilled @ 30 ft. offset.

Water in 30 ft. offset was at 12.0' @8:00 8/5/99

DEPTH UNITS: 90 FT.
DRILLING CONTRACTOR: KEY DRILLING
DRILLER: JUSTIN BOWMAN

LOGGED BY: JAB
CHECKED BY:

| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 0 | Issued for Review | 9/2/99 | J.Bonner | K.Conrath | P.Corser |

MONTGOMERY WATSON

PROJECT No: 1342602.02190200
AutoCAD FILE: SLPB-42.DWG
SCALE: N/A
FIGURE No:

GANDY-MARLEY, INC.

**SOIL BORING LOG FORM**

BORING LOG NUMBER: PB-43

SHEET 1 OF 1

LOCATION SKETCH

GRID LOCATION BH99-8

| | | | |
|---|---|---|---|
| LOC. ID: | ELEVATION: 4130 | DATUM: MSL | |
| PROJECT NAME: GANDY-MARLEY | | DRILL DATE: 8/4/99 | |
| INCLINATION: VERTICAL | AZIMUTH: N/A | HAMMER WEIGHT: N/A | DATE FINISHED: 8/4/99 |

| DEPTH (UNITS) | BORING METHOD | SOIL PROFILE – SOIL DESCRIPTION | GRAPHIC LOG | SAMPLES – USCS | SAMPLES – NUMBER | SAMPLES – TYPE | SAMPLES – BLOW COUNT/6" | SAMPLES – RECOVERY |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | N/A | N/A |
| 0 | AIR ROTARY WITH 6 3/4 INCH BIT | Fine surface sandstone, brown clay and cobbles | | | | SEE ADDITIONAL COMMENTS | | |
| | | Brown clay with caliche stained cobbles | | | | | | |
| 25 | | Red grey siltstone | | | | | | |
| 50 | | Light grey to light red grey siltstone | | | | | | |
| 75 | | Moderate red brown mudstone | | | | | | |
| 100 | | TD=100 FT. | | | | | | |
| 125 | | | | | | | | |
| 150 | | | | | | | | |
| 175 | | | | | | | | |
| 200 | | | | | | | | |
| 225 | | | | | | | | |

## ADDITIONAL COMMENTS

### DESCRIPTIONS

All descriptions based on Air Rotary. Cutting samples obtained every 5 ft.

### GEOPHYSICAL LOGS

- Thermal Neutron
- Gamma
- Caliper

Logs are attached

### PLUGGING

Holes plugged with cement-bentonite grout by Atkins Environmental. Plugged from bottom up with trim line.
Due to presence of water, an additional hole was drilled @ 30 ft. offset.

Water in 30 ft. offset was at 12.0' @8:00 8/5/99

DEPTH UNITS: 100 FT.
DRILLING CONTRACTOR: KEY DRILLING
DRILLER: JUSTIN BOWMAN

LOGGED BY: JAB
CHECKED BY:

| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 0 | Issued for Review | 9/2/99 | J.Bonner | K.Conrath | P.Corser |

MONTGOMERY WATSON

PROJECT No.: 1342602.02190200
AutoCAD FILE: SLPB43.DWG
SCALE: N/A
FIGURE No:

GANDY-MARLEY, INC.

**SOIL BORING LOG FORM**

BORING LOG NUMBER:

# PB-44

SHEET 1 OF 1

LOC. ID: | ELEVATION: 4128 | DATUM: MSL

PROJECT NAME.: GANDY-MARLEY | DRILL DATE: 8/4/99

INCLINATION: VERTICAL | AZIMUTH: N/A | HAMMER WEIGHT: N/A | DATE FINISHED: 8/4/99

LOCATION SKETCH

| DEPTH (UNITS) | BORING METHOD | SOIL PROFILE / SOIL DESCRIPTION | GRAPHIC LOG | USCS | NUMBER | TYPE | BLOW COUNT/6" | RECOVERY |
|---|---|---|---|---|---|---|---|---|
| | AIR ROTARY WITH 6 3/4 INCH BIT | | | | | SEE ADDITIONAL COMMENTS | N/A | N/A |
| 0 | | Fine surface sand with brown clay and caliche stained cobbles | | | | | | |
| 25 | | Brown clay | | | | | | |
| | | Yellow-brown clay | | | | | | |
| 50 | | Red grey siltstone with red brown clays @ 50' & 70'. Light grey siltstone @ bottom | | | | | | |
| 75 | | Moderate red brown mudstone | | | | | | |
| 100 | | TD=110 FT. | | | | | | |
| 125 | | | | | | | | |
| 150 | | | | | | | | |
| 175 | | | | | | | | |
| 200 | | | | | | | | |
| 225 | | | | | | | | |

## ADDITIONAL COMMENTS

### DESCRIPTIONS

All descriptions based on Air Rotary. Cutting samples obtained every 5 ft.

### GEOPHYSICAL LOGS

- Thermal Neutron
- Gamma
- Caliper

Logs are attached

### PLUGGING

Holes plugged with cement-bentonite grout by Atkins Environmental. Plugged from bottom up with trim line.
Due to presence of water, an additional hole was drilled @ 30 ft. offset.

DEPTH UNITS: 110 FT.
DRILLING CONTRACTOR: KEY DRILLING
DRILLER: JUSTIN BOWMAN

LOGGED BY: JAB
CHECKED BY:

| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 0 | Issued for Review | 9/2/99 | J.Bonner | K.Conrath | P.Corser |

MONTGOMERY WATSON

PROJECT No: 1342602.02190200
AutoCAD FILE: SLPB45.DWG
SCALE: N/A
FIGURE No:

GANDY - MARLEY, INC.

SOIL BORING LOG FORM

BORING LOG NUMBER: **PB-45**

SHEET 1 OF 1

LOC. ID: | ELEVATION: 4135 | DATUM: MSL

PROJECT NAME: GANDY-MARLEY | DRILL DATE: 8/4/99

INCLINATION: VERTICAL | AZIMUTH: N/A | HAMMER WEIGHT: N/A | DATE FINISHED: 8/4/99

LOCATION SKETCH

GRID LOCATION BH99-9

| DEPTH (UNITS) | BORING METHOD | SOIL PROFILE – SOIL DESCRIPTION | GRAPHIC LOG | USCS | NUMBER | TYPE | BLOW COUNT/6" | RECOVERY |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | N/A | N/A |
| 0 | AIR ROTARY WITH 6 3/4 INCH BIT | Fine surface sand and caliche stained pebbles | | | | SEE ADDITIONAL COMMENTS | | |
| | | Brown mudstones | | | | | | |
| 25 | | | | | | | | |
| | | Red brown mudstones with grey clay @ 45' | | | | | | |
| 50 | | | | | | | | |
| | | Red grey siltstone | | | | | | |
| 75 | | | | | | | | |
| | | Grey to light grey siltstone and fine sandstone | | | | | | |
| 100 | | | | | | | | |
| | | Moderate red brown mudstone | | | | | | |
| | | TD=120 FT. | | | | | | |
| 125 | | | | | | | | |
| 150 | | | | | | | | |
| 175 | | | | | | | | |
| 200 | | | | | | | | |
| 225 | | | | | | | | |

ADDITIONAL COMMENTS

**DESCRIPTIONS**

All descriptions based on Air Rotary. Cutting samples obtained every 5 ft.

**GEOPHYSICAL LOGS**

- Thermal Neutron
- Gamma
- Caliper

Logs are attached

**PLUGGING**

Holes plugged with cement-bentonite grout by Atkins Environmental. Plugged from bottom up with trim line.
Due to presence of water, an additional hole was drilled @ 30 ft. offset.

DEPTH UNITS: 120 FT.
DRILLING CONTRACTOR: KEY DRILLING
DRILLER: JUSTIN BOWMAN

LOGGED BY: JAB
CHECKED BY:

| REV No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 0 | Issued for Review | 9/2/99 | J.Bonner | K.Conrath | P.Corser |

MONTGOMERY WATSON

PROJECT No.: 1342602.02190200
AutoCAD FILE: SLPB45.DWG
SCALE: N/A
FIGURE No:

GANDY - MARLEY, INC.

SOIL BORING LOG FORM

BORING LOG NUMBER:

**PB-46**

SHEET 1 OF 1

LOCATION SKETCH

Grid location BH99-3

| | | | |
|---|---|---|---|
| LOC. ID: | | ELEVATION: 4130 | DATUM: MSL |
| PROJECT NAME.: GANDY-MARLEY | | | DRILL DATE: 8/4/99 |
| INCLINATION: VERTICAL | AZIMUTH: N/A | HAMMER WEIGHT: N/A | DATE FINISHED: 8/4/99 |

| DEPTH (UNITS) | BORING METHOD | SOIL PROFILE – SOIL DESCRIPTION | GRAPHIC LOG | SAMPLES: USCS | NUMBER | TYPE | BLOW COUNT/6" | RECOVERY |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | N/A | N/A |
| 0 | AIR ROTARY WITH 6 3/4 INCH BIT | Surface sandstone and caliche stained pebbles | | | | SEE ADDITIONAL COMMENTS | ↓ | ↓ |
| | | Red brown mudstone | | | | | | |
| 25 | | Brown mudstone | | | | | | |
| | | Red brown mudstone with grey red siltstone @ 55' | | | | | | |
| 50 | | | | | | | | |
| | | Red grey siltstone with grey clay | | | | | | |
| 75 | | Grey - light grey siltstone in fine sandstone | | | | | | |
| | | Red grey silty clay | | | | | | |
| 100 | | Moderate red brown mudstone | | | | | | |
| 125 | | TD=120 FT. | | | | | | |
| 150 | | | | | | | | |
| 175 | | | | | | | | |
| 200 | | | | | | | | |
| 225 | | | | | | | | |

ADDITIONAL COMMENTS

**DESCRIPTIONS**

All descriptions based on Air Rotary. Cutting samples obtained every 5 ft.

**GEOPHYSICAL LOGS**

- Thermal Neutron
- Gamma
- Caliper

Logs are attached

**PLUGGING**

Holes plugged with cement-bentonite grout by Atkins Environmental. Plugged from bottom up with trim line.
Due to presence of water, an additional hole was drilled @ 30 ft. offset.

DEPTH UNITS: 120 FT.
DRILLING CONTRACTOR: KEY DRILLING
DRILLER: JUSTIN BOWMAN

LOGGED BY: JAB
CHECKED BY:

| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 0 | Issued for Review | 9/2/99 | J.Bonner | K.Conrath | P.Corser |

MONTGOMERY WATSON

PROJECT No.: 1342602.02190200
AutoCAD FILE: SLPB-46.DWG
SCALE: N/A
FIGURE No:

GANDY - MARLEY, INC.

**SOIL BORING LOG FORM**

BORING LOG NUMBER: **PB-47**

SHEET 1 OF 1

| | |
|---|---|
| LOC. ID: | ELEVATION: 4139 |
| DATUM: MSL | |
| PROJECT NAME: GANDY-MARLEY | DRILL DATE: 8/5/99 |
| INCLINATION: VERTICAL | AZIMUTH: N/A |
| HAMMER WEIGHT: N/A | DATE FINISHED: 8/5/99 |

LOCATION SKETCH

GRID LOCATION
BH99-6

| DEPTH (UNITS) | BORING METHOD | SOIL PROFILE — SOIL DESCRIPTION | GRAPHIC LOG | USCS | NUMBER | TYPE | BLOW COUNT/6" | RECOVERY |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | N/A | N/A |
| 0 | AIR ROTARY WITH 6 3/4 INCH BIT | Fine surface sandstone, brown clay and cobbles | | | | SEE ADDITIONAL COMMENTS | | |
| 25 | | Red brown mudstone | | | | | | |
| | | Grey red clayey siltstone | | | | | | |
| 50 | | Yellow brown mudstone | | | | | | |
| 75 | | Red grey siltstone | | | | | | |
| | | Grey to dark grey siltstone with light grey clays | | | | | | |
| 100 | | Moderate red brown mudstone | | | | | | |
| 125 | | TD=130 FT. | | | | | | |
| 150 | | | | | | | | |
| 175 | | | | | | | | |
| 200 | | | | | | | | |
| 225 | | | | | | | | |

ADDITIONAL COMMENTS

**DESCRIPTIONS**

All descriptions based on Air Rotary. Cutting samples obtained every 5 ft.

**GEOPHYSICAL LOGS**

- Thermal Neutron
- Gamma
- Caliper

Logs are attached

**PLUGGING**

Holes plugged with cement-bentonite grout by Atkins Environmental. Plugged from bottom up with trim line.
Due to presence of water, an additional hole was drilled @ 30 ft. offset.

DEPTH UNITS: 130 FT.
DRILLING CONTRACTOR: KEY DRILLING
DRILLER: JUSTIN BOWMAN

LOGGED BY: JAB
CHECKED BY:

| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 0 | Issued for Review | 9/2/99 | J.Bonner | K.Conrath | P.Corser |

MONTGOMERY WATSON

PROJECT No.: 1342602.02190200
AutoCAD FILE: SLPB-47.DWG
SCALE: N/A
FIGURE No.:

GANDY - MARLEY, INC.

SOIL BORING LOG FORM

BORING LOG NUMBER: **PB-48** SHEET 1 OF 1

| | |
|---|---|
| LOC. ID: | ELEVATION: 4194 |
| DATUM: MSL | |
| PROJECT NAME: GANDY MARLEY | DRILL DATE: 8/5/99 |
| INCLINATION: VERTICAL | AZIMUTH: N/A |
| HAMMER WEIGHT: N/A | DATE FINISHED: 8/5/99 |

**LOCATION SKETCH**

1000 Ft. NORTH &
2000 Ft. EAST OF
1B-38

## SOIL PROFILE

Boring method: AIR ROTARY WITH 6 3/4 INCH BIT

Samples: Type — SEE ADDITIONAL COMMENTS; Blow Count/6" — N/A; Recovery — N/A

| Depth (ft) | Soil Description |
|---|---|
| 0 – ~30 | Fine surface sanstone and brown clays with caliche stained cobbles |
| ~30 – ~48 | Yellow brown mudstone |
| ~48 – ~60 | Red grey siltstone |
| ~60 – ~65 | Red brown clay |
| ~65 – ~80 | Red grey mudstone |
| ~80 – ~100 | Grey brown clayey siltstone |
| ~100 – ~110 | Red grey mudstone |
| ~110 – ~130 | Red grey siltstone |
| ~130 – ~140 | Red grey mudstone |
| ~140 – ~175 | Red grey clayey siltstone |
| ~175 – ~190 | Yellow brown mudstone |
| ~190 – 210 | Moderate red brown mudstone |
| 210 | TD=210 FT. |

## ADDITIONAL COMMENTS

Bottom 50 feet of drill pipe steam-cleaned prior to drilling. Wesson Oil used as "pipe dope".

Water level probe deconded and operational.

**DESCRIPTIONS**

All descriptions based on Air Rotary. Cutting samples obtained every 5 ft.

**GEOPHYSICAL LOGS**

- Thermal Neutron
- Gamma
- Caliper

Logs are attached

**PLUGGING**

Holes plugged with cement-bentonite grout by Atkins Environmental. Plugged from bottom up with trim line.
Due to presence of water, an additional hole was drilled @ 30 ft. offset.

DEPTH UNITS: 210 FT.
DRILLING CONTRACTOR: KEY DRILLING
DRILLER: JUSTIN BOWMAN
LOGGED BY: JAB
CHECKED BY:

| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| 0 | Issued for Review | 9/2/99 | J.Bonner | K.Conrath | P.Corser |

MONTGOMERY WATSON

PROJECT No.: 1342602.02190200
AutoCAD FILE: SLPB-48.DWG
SCALE: N/A
FIGURE No:

GANDY - MARLEY, INC.

**SOIL BORING LOG FORM**

# Appendix C

MONTGOMERY WATSON

# TABLE OF CONTENTS

Section No. Page No.

# 1.0 INTRODUCTION

This guideline is a general reference for the proper equipment and techniques for groundwater sampling. The purpose of these procedures is to enable the user to collect representative and defensible groundwater samples and to facilitate planning of the field sampling effort. These techniques should be followed whenever applicable, although site-specific conditions or project-specific plans may require adjustments in methodology.

To be valid, a groundwater sample must be representative of the particular zone of the water being sampled. The physical, chemical, and bacteriological integrity of the sample must be maintained from the time of collection to the time of analysis in order to minimize changes in water quality parameters. Acceptable equipment for withdrawing samples from completed wells includes bailers and various types of pumps. The primary considerations in obtaining a representative sample of the groundwater are to avoid collecting stagnant (standing) water in the well, to avoid physically or chemically altering the water due to improper sampling techniques, sample handling, or transport, and to document that proper sampling procedures have been followed.

This guideline describes suggested well evacuation methods, sample collection and handling, field measurement, decontamination and documentation procedures.

## 2.0 DEFINITIONS

Annular Space: The space between casing or well screen and the wall of the drilled hole, or between drill pipe and casing, or between two separate strings of casing. Also called annulus.

Aquifer: A geologic formation, group of formations, or part of a formation that is capable of yielding a significant amount of water to a well or spring.

Bailer: A long narrow tubular device with an open top and a check valve at the bottom that is used to remove water from a well during purging or sampling. Bailers may be made of Teflon, polyvinyl chloride (PVC), or stainless steel. Disposable bailers are available and are made of polycarbonate.

Bladder Pump: A pump consisting of flexible bladder usually made of Teflon contained within a rigid cylindrical body (commonly made of PVC). The lower end of the bladder is connected through a check valve to the intake port, while the upper end is connected to a sampling line that leads to the ground surface. A second line, the gas line, leads from the ground surface to the annular space between the bladder and the outer body of the pump. After filling, under hydrostatic pressure, application of gas pressure causes the bladder to collapse, closing the check valve and forcing the sample to ground surface through the sample line. Gas pressure is often provided by a compressed air tank, and commercial models generally include a control box that automatically switches the gas pressure off and on at appropriate intervals.

Centrifugal Pump: A pump that moves a liquid by accelerating it radically outward in an impeller to a surrounding spiral-shaped casing.

Chain of Custody: Method for documenting the history and possession of a sample from the time of its collection through its analysis and data reporting to its final disposition.

Check Valve: Ball and spring valves on core barrels, bailers, and sampling devices that are used to allow water to flow in one direction only.

Conductivity (electrical): A measure of the quantity of electricity transferred across a unit area, per unit potential gradient, per unit time. It is the reciprocal of resistivity.

Datum: An arbitrary surface (or plane) used in the measurement of heads (i.e., National Geodetic Vertical Datum [NGVD], commonly referred to as mean sea level [msl]).

Decontamination: A variety of processes used to clean equipment that contacted formation material or groundwater that is known to be or suspected of being contaminated.

Downgradient: In the direction of decreasing hydrostatic head.

Drawdown: The lowering of the potentiometric or piezometric surface in a well and aquifer due to the discharge of water from the well.

Electric Submersible Pump: A pump that consists of a rotor contained within a chamber and driven by an electric motor. The entire device is lowered into the well with the electrical cable and discharge tubing attached. A portable power source and control box remain at the surface.

Electrical submersible pumps used for groundwater sampling are constructed of inert materials such as stainless steel, and are well sealed to prevent sample contamination by lubricants.

**Filter Pack:** Sand or gravel that is generally uniform, clean, and well rounded that is placed in the annulus of the well between the borehole wall and the well screen to prevent formation material from entering through the well screen and to stabilize the adjacent formation.

**Headspace:** The empty volume in a sample container between the water level and the cap.

**HydroPunch:** An in situ groundwater sampling system in which a hollow steel rod is driven into the saturated zone and a groundwater sample is collected.

**In Situ:** In the natural or original position; in place.

**Groundwater Well:** A well that is constructed by one of a variety of techniques for the purpose of extracting groundwater for physical, chemical, or biological testing, or for measuring water levels.

**Packer:** A transient or dedicated device placed in a well or borehole that isolates or seals a portion of the well, well annulus, or borehole at a specific level.

**Peristaltic Pump:** A low-volume suction pump. The compression of a flexible tube by a rotor results in the development of suction.

**pH:** A measure of the acidity or alkalinity of a solution, numerically equal to 7 for neutral solutions, increasing with increasing alkalinity and decreasing with increasing acidity. (Original designation for potential of hydrogen.)

**Piezometer:** An instrument used to measure head at a point in the subsurface; a nonpumping well, generally of small diameter, that is used to measure the elevation of the water table or potentiometric surface.

**Preservative:** An additive (usually an acid or a base) used to protect a sample against decay or spoilage, or to extend the holding time for a sample.

**Static Water Level:** The elevation of the top of a column of water in a groundwater well or piezometer that is not influenced by pumping or conditions related to well installation, hydrologic testing, or nearby pumpage.

**Turbidity:** Cloudiness in water due to suspended and colloidal organic and inorganic material.

**Upgradient:** In the direction of increasing static head.

# 3.0 RESPONSIBILITIES

Project Manager: Selects site-specific water sampling methods, locations for groundwater well installations, groundwater wells to be sampled and analytes to be analyzed with input from the field team leader (FTL) and project geologist. Responsible for project quality control and field audits.

Field Team Leader: Implements water sampling program. Supervises project geologist/hydrogeologist and sampling technician. Insures that proper chain-of-custody procedures are observed and that samples are sampled, transported, packaged, and shipped in a correct and timely manner.

Project Geologist/Hydrogeologist: Insures proper collection, documentation, and storage of groundwater samples prior to shipment to the laboratory. Assists in packaging and shipment of samples.

Field Sampling Technician: Assists the project geologist/hydrogeologist in the completion of tasks and is responsible for the proper use, decontamination, and maintenance of groundwater sampling equipment.

# 4.0 WATER SAMPLING GUIDELINES

## 4.1 WELL EVACUATION AND SAMPLING EQUIPMENT

There are many methods available for well purging. A variety of issues must be considered when choosing evacuation and sample collection equipment including the depth and diameter of the well, the recharge capacity of the well, and the analytical parameters that will be tested. Few sampling devices are suitable for the complete range of groundwater parameters. For example, an open bailer is acceptable for collecting major ion and trace metal samples, but it may lead to erroneous analytical results if used for the collection of samples that are analyzed for volatile organics, dissolved gases, or even pH. Generally, the best pumps to use are positive displacement pumps, such as bladder and helical rotor pumps that minimize the aeration of the groundwater as it is sampled, and therefore yield the most representative groundwater samples. Although it is possible to use different equipment to evacuate the well and to sample the well, this is not recommended because of the increased decontamination requirements and possibilities for cross contamination. It is recommended that a flow rate as close to the actual groundwater flow rate should be employed to avoid further development, well damage, or the disturbance of accumulated corrosion or reaction products in the well (Puls and Barcelona, 1989).

Positive displacement pumps, such as bladder pumps, are generally recommended for both well evacuation and sample collection. Other types of sample collection, such as bailing or the use of gas lift pumps, should be avoided, especially when analyzing for sensitive parameters because of the geochemical changes that can occur due to the aeration of the water within the well. Also, the use of these sample devices may entrain suspended materials, such as fine clays and colloids which are not representative of mobile chemical constituents in the formation of interest (Puls and Barcelona, 1989).

Specific instructions for the use of several of the sampling devices are discussed in the next sections. All purging and sampling equipment should be decontaminated before beginning work and between wells in accordance with Section 4.4.

<u>Bailers</u>: Bailers represent the simplest and least expensive method of collecting the sample from a well. However, they may not be suitable for all analyses. For most applications, the bailer should be constructed of Teflon or stainless steel. Disposable bailers constructed of polyethylene may also be acceptable for some applications (e.g., sampling for petroleum hydrocarbons), and they represent a simple method of avoiding cross-contamination between samples without the time-consuming need for decontamination. The following issues should be considered when using bailers for sampling:

- Bailers should be decontaminated per Section 4.4 of these guidelines and then isolated from any type of contamination prior to use for purging or sampling. The bailer should be decontaminated prior to the first well and between each subsequent well.

- Stainless steel or Teflon-coated stainless steel wire is recommended for lowering and retrieving the bailer from the well. At no time should the bailer or the line touch the ground during the sampling process. This can be done by coiling the line in a bucket or on a sheet of polyethylene. Polypropylene line may be substituted for the stainless steel wire, but should be discarded after each use.

- When lowering the bailer into the well, care should be taken to minimize agitation in the well, such as when the bailer contacts the water-table surface. The bailer should be lowered beneath the top of the screened interval.

Peristaltic/Centrifugal Pumps: Peristaltic and centrifugal pumps are widely used for purging of wells with water levels close to the surface (less than 30 feet). They are reasonably portable, light, and easily adaptable to ground-level monitoring of field parameters by attaching a flow-through cell. These pumps require minimal downhole equipment, and they can easily be cleaned in the field, or the entire tubing assembly can be changed for each well. The following procedures should be considered when using these pumps:

- Prior to use, the exterior and interior of all intake tubing for use with the peristaltic/centrifugal pump should be thoroughly flushed with tap water and then double rinsed with distilled water. New tubing should be used at each well and then discarded. If a gas-powered generator is used, it should be downwind of the well.

- The intake of the suction tubing should be lowered to the midpoint of the well screen. Alternatives to this procedure may be necessary if the drawdown from the purging operations causes the water level to fall and begin to pump air. The suction line should be lowered slowly into the well until it pumps water continuously but not lower than 1 foot above the bottom of the well.

- If parameters are to be monitored continuously, connect the instrumentation header to the pump discharge and begin flushing the well. Continuously monitor the parameters (pH, Eh, temperature, and specific conductivity) and measure the volume of groundwater being pumped. Alternately, parameters may be monitored in a beaker filled from the pump discharge.

- After purging, remove the intake tubing from the well while the pump is still pumping to prevent backwash of water into the well. Stop the pump and disconnect the tubing from the pump for cleaning or disposal.

- If tubing is to be reused (not recommended), clean the interior of the tubing by flushing thoroughly with tap water. Double rinse the tubing with distilled water. Using Alconox and water, wash the exterior of the tubing, and then rinse with tap water and distilled water.

Gas-Lift Pumps: A pressure displacement system consists of a chamber equipped with a gas inlet line, a water discharge line and two check valves. When the chamber is lowered into the casing, water floods it from the bottom through the check valve. Once full, a gas (e.g., nitrogen or air) is forced into the top of the chamber in sufficient amounts to displace the water out the discharge tube. The check valve in the bottom prevents water from being forced back into the casing, and the upper check valve prevents water from flowing back into the chamber when the gas pressure is released. This cycle can be repeated, as necessary, until purging is complete. The pressure lift system is particularly useful when the well depth is beyond the capability of a peristaltic or centrifugal pump. The water is displaced up the discharge tube by the increased gas pressure above the water level. The potential for increased gas diffusion into the water makes this system unsuitable for sampling volatile organic or most pH critical parameters. The entire pump assembly and tubing should be decontaminated before beginning purging and between wells as described in Section 4.4. The following procedures should be considered when using these pumps:

- Determine depth to midpoint of screen or depth to well section open to the aquifer (consult driller's or well completion log).
- Lower displacement chamber until top is just below water level.
- Attach gas supply line to pressure adjustment valve on cap.
- Gradually increase gas pressure to maintain discharge flow rate.
- Measure rate of discharge frequently. A bucket and stopwatch are usually sufficient.
- Purge a minimum of five casing volumes or until discharge characteristics stabilize (see discussion on well purging).

**Submersible Pumps:** Submersible pumps take in water and push the sample up a sample tube to the surface. The power sources for these pumps may be compressed gas or electricity. The operation principles vary, and the displacement of the sample can be by an inflatable bladder, sliding piston, gas bubble, or impeller. Bladder or helical rotor pumps are recommended for sampling for sensitive parameters. Pumps are available for 2-inch-diameter wells and larger, and these pumps can lift water up to several hundred feet. The entire pump assembly and tubing should be decontaminated before beginning purging and between wells as described in Section 4.4.

Limitations of this class of pumps include:

- They may have low delivery rates.
- Many models of these pumps are expensive.
- Compressed gas or electricity is needed.
- Sediment in water may cause clogging of the valves or eroding the impellers with some of these pumps.
- Decontamination of internal components of some types is difficult and time consuming.
- Advantages of this class of pumps include:
- Delivery of low turbidity samples.
- Adjustable to very low flow rates.
- Some types (e.g., bladder pumps) are relatively inexpensive and easy to install as dedicated systems.
- Some types (e.g., bladder pumps) can be easily disassembled for decontamination.

## 4.2 WELL EVACUATION METHODS

### 4.2.1 Purging Requirements

To obtain a representative groundwater sample, it must be understood that the composition of the water within the well casing and in close proximity to the well is probably not representative of the overall groundwater quality in the target aquifer. This is due to the possible presence of drilling materials near the well and because important environmental conditions such as the oxidation-reduction (redox) potential may differ drastically near the well from the conditions in the surrounding water-bearing materials. For these reasons it is necessary to pump or bail the well until it is thoroughly flushed of standing water and contains fresh water from the aquifer. The recommended amount of purging before sampling is dependent on many factors including the characteristics of the well, the hydrogeological nature of the aquifer, the type of sampling equipment being used, and the parameters that are to be analyzed.

The number of casing volumes that should be removed prior to sample collection has been a matter of debate in the groundwater community for some time. The consensus seems to be that rather than relying on the removal of a specific volume of water (such as five casing volumes) prior to sample collection, physical parameters such as pH, specific conductivity, temperature, and possibly redox potential should be used to evaluate when enough water has been removed from the well to obtain a representative groundwater sample. However, it is recommended that where possible, a minimum of three casing volumes should be purged prior to sampling. The sensitivity of the above parameters to changes as a result of exposure of groundwater to surface level conditions (i.e., changes in the partial pressure of dissolved gases or the conditions of the purging system) make in situ monitoring desirable. An alternative to this would be to conduct these measurements in a closed cell attached to the discharge side of the pump system. Puls and Barcelona (1989) suggest that an initial estimate for the time of pumping necessary to collect representative water from a formation is around two times the time required to get plateau values for the above parameters. For example, the parameters may be considered stable when several consecutive measurements (collected at least one-half a casing volume apart) do not change by more than the following:

- Conductivity ±10 percent
- pH ±0.1 unit
- Temperature ±1°C

When evacuating low yield wells (wells that are incapable of yielding at least five casing volumes), the well should be evacuated to dryness once (USEPA, 1986). As soon as the well recovers sufficiently, the samples should be collected and containerized in the order of the parameter volatilization sensitivity. The samples should be retested for field parameters after sampling as a check on the stability of the water samples over time. Whenever full recovery exceeds two hours, the sample should be collected as soon as sufficient volume is available for a sample for each parameter. However, allowing a well to recover overnight is not acceptable. At no time should the well be pumped to dryness if the recharge rate causes the formation water to vigorously cascade down the sides of the screen and cause an accelerated loss of volatiles. In this case, samples should be collected at a rate slow enough to maintain the water level at or above the top of the screen to prevent cascading.

Other factors that will influence the amount of purging required before sampling include the pumping rate and the placement of the pumping equipment within the column of water in the well. For example, recent studies have shown that if a pump is lowered immediately to the bottom of a well before pumping, it may take some time for the column of water above it to be exchanged if the transmissivity of the aquifer is high and the well screen is at the bottom of the casing. In these cases, the pump will be drawing water primarily from the aquifer. Purging from higher in the well or just below the water surface provides a more complete removal of the casing water.

#### 4.2.2 Calculation of Casing Volume

To insure that an adequate volume of water has been removed from the well prior to sampling, it is first necessary to determine the volume of standing water in the well and the volume of water in the filter pack below the well seal. The volume can be easily calculated by the following method (calculations should be entered in the field logbook):

1. Obtain all available information on well construction (e.g., location, casing, screen, depth).

2. Determine well or casing diameter.

3. Measure and record static water level (depth below ground level or top of casing reference point) using one of the methods described in Section 2.3.1.

4. Determine depth of well by sounding using a clean, decontaminated weighted tape measure or an electronic water-level probe.
5. Calculate the volume of water in the casing using the following formula:

$$V = 7.481 (\pi r^2 h)$$

Where:

V = Casing Volume (gal)
r = Well radius (ft) = well diameter (ft)/2
h = Linear feet of water in well = total well depth (ft) - static water depth (ft)

Alternatively, the casing volume can be calculated by multiplying the linear feet of water in the well by the volume per linear feet taken from Attachment 1 or other similar tables. Always be sure that the units in your calculation are consistent. In the equation above, 7.481 is the conversion factor from cubic feet to gallons.

#### 4.2.3 Calculation of Annulus Volume

Some groundwater sampling protocol requires the evacuation of casing and annulus volumes prior to sampling. In these cases the volume of water contained in the annular space between the casing and the borehole wall is calculated by the following formula:

$$V^c = (C_b - C_c) \times (h) \times (0.30)$$

Where:

| | | |
|---|---|---|
| $C_b$ | = | Borehole Capacity (Volume in Gal./ft) |
| $C_c$ | = | Casing Capacity (Volume in Gal./ft) |
| h | = | Amount of standing water in the well |
| 0.30 | = | Average porosity of typical sand pack |

The annulus volume is added to the casing volume prior to multiplying by the number of volumes to be excavated.

## 4.3 SAMPLE COLLECTION METHODS

Prior to sampling, the sampling team will document any signs of tampering or well deterioration. All groundwater samples should be collected using a clean, dry decontaminated bailer made of either stainless steel or Teflon.

### 4.3.1 Sample Containers

A complete set of sample containers should be prepared by the laboratory prior to going into the field. The laboratory should provide the proper containers with the required preservatives. The laboratory's QA manual should provide a complete description of the procedures used to clean and prepare the containers. The containers should be labeled in the field with the date, well designation, project name, collectors' name, time of collection, parameters to be analyzed, and preservative. The sample containers should be kept in a cooler (at 4°C) until they are needed (i.e., not left in the sun during purging). One cooler should be used to store the unfilled bottles and another to store the samples.

Temperature, pH, and specific conductance should be measured and recorded in the field before and after sample collection to check on the stability of the water samples over time.

### 4.3.2 Field Filtration for Dissolved Metals

Filtering groundwater samples has been a subject of considerable debate in recent years. In many cases, samples passing a 0.45-micron ($\mu$m) filter were used to provide an indication of dissolved metals concentrations in groundwater. Puls and Barcelona (1989) report that the use of a 0.45-micron filter was not useful, appropriate, or reproducible in providing information on metals mobility in groundwater systems, nor was it appropriate for determination of truly "dissolved" constituents in groundwater. A dual sampling approach is recommended to collect both filtered and unfiltered samples.

Any filtration for estimates of dissolved species loads should be performed in the field with no air contact and immediate preservation and storage. In-line pressure filtration is best with as small a filter pore size as practically possible (e.g., 0.45, 0.10 micron). Disposable, in-line filters are recommended for convenience and avoiding cross-contamination. The filters should be pre-rinsed with distilled water; work by Jay (1985) showed that virtually all filters require pre-washing to avoid sample contamination.

In the absence of filters, sample turbidity can generally be reduced by using bladder pumps. USEPA (1986) recommends that the turbidity should be less than 5 nephelometric turbidity units (NTUs).

## 4.4 FIELD MEASUREMENTS

A variety of field measurements are commonly made during the sampling of groundwater including water level, pH, conductivity, and temperature. The accuracy, precision, and usefulness of these measurements is dependent on the proper use and care of the field instruments. Valid and useful data can only be collected if consistent practices (in accordance with recommended manufacturers instructions) are followed. The instruments should be handled carefully at the well site and during transportation to the field and between sampling sites.

### 4.4.1 Water Level

Water levels can be measured by several techniques, but the same steps should be followed in each case. The proper sequence is as follows:

1. Check operation of measurement equipment aboveground.
2. Record all information specified below on a sampling form or in the field notebook if a form is not available.
3. Record well number, top of casing elevation and surface elevation if available.
4. Measure and record static water level and total depth to the nearest 0.01 foot (0.3 cm) from the surveyed reference mark on the top edge of the inner well casing. If no reference mark is present, record in the logbook where the measurement was taken from (i.e., from the north side of the inner casing).
5. Record the time and day of the measurement.
6. Some water-level measuring devices have marked metal or plastic bands clamped at intervals along the measuring line used for reference points to obtain depth measurements. The spacing and accuracy of these bands should be checked before each round of measurements because they may loosen and slide up or down the line, resulting in inaccurate reference points.

Electric Water Level Indicators. These devices consist of a spool of small-diameter cable or tape and a weighted probe attached to the end. When the probe comes in contact with the water, an electrical circuit is closed and a meter, light, and/or buzzer attached to the spool will signal the contact. This is the recommended method for obtaining accurate water-level measurements.

There are a number of commercial electric sounders available, none of which is entirely reliable under all conditions likely to occur in a contaminated groundwater well. In conditions where there is oil on the water, groundwater with high specific conductance, water cascading into the well, or a turbulent water surface in the well, measuring with an electric sounder may be difficult.

For accurate readings, the probe should be lowered slowly into the well. The electric tape is marked at the measuring point where contact with the water surface was indicated. The distance from the mark to the nearest tape bank is measured using a ruler or steel tape and added to the band reading to obtain the depth to water. Band spacing should be checked periodically as described above.

Chalked Steel Tape. Water level is measured by chalking a weighted steel tape and lowering it a known distance (to any convenient whole-foot mark) into the well or borehole. The water level is determined by subtracting the wetted chalked mark from the total length lowered into the hole.

The tape should be withdrawn quickly from the well because water has a tendency to rise up the chalk due to capillary action. A paste called "National Water Finder" may be used in place of chalk. The paste is spread on the tape the same way as the chalk but the part that gets wet turns red. This paste is manufactured by the Metal Hose and Tubing Company, Dover, New Jersey.

Disadvantages to this method include depths are limited by the inconvenience of using heavier weights to properly tension longer tape lengths (typically, 100 foot tapes require a 10- to 12-pound weight to tension adequately); it is ineffective if borehole/well wall is wet or inflow is occurring above the static water level; chalking the tape is time consuming; and it is difficult to use in the rain. The water chemistry may also be modified somewhat by the addition of chalk or paste.

### 4.4.2. pH

The pH meters should be calibrated against two ASTM traceable standard pH solutions, either 4 and 7 or 7 and 10, depending on whether previous pH measurements have been less than or greater than 7, respectively. Calibration measurements will be recorded in the field logbook. The meter readings will be adjusted, and the probe should then be rinsed thoroughly with distilled water. The probe should then be immersed in the water sample, and the pH and temperature recorded in the field log or on the sampling form. Calibration standards will be measured again as a check after sample measurement and recorded in the field logbook. The manufacturer's directions for calibration, maintenance, and use should be read and closely followed. Any problems with the functioning of the meter should be noted in the field log and reported to the office equipment manager.

### 4.4.3. Conductivity

Specific conductivity meters should be standardized by immersing a decontaminated specific conductivity probe into an ASTM traceable standard solution of conductivity buffer. The conductivity of the standard solution should be within the same order of magnitude as anticipated for the water sample. Calibration results will be recorded in the field logbook. The meter reading will be adjusted to the buffer solution value, and the probe will then by thoroughly rinsed with distilled water. The probe should then be immersed in the well water sample, and the conductivity value recorded. Calibration standards will be measured again as a check after sample measurement and recorded in the field logbook. The manufacturer's directions for calibration, maintenance, and use should be read and closely followed. Calibrant solutions should be dated and discarded on their expiration date. Any problems with the functioning of the meter should be noted in the field log and reported to the office equipment manager.

#### 4.4.4. Temperature

Temperature measurements should be made with either a mercury or electronic thermometer capable of accurately reading to 0.1°C. The temperature reading should be recorded in the field log or on the sampling form.

### 4.5 DECONTAMINATION

The general decontamination procedure for all non-dedicated groundwater sampling equipment (bailers, pumps, water-level probes) consists of the following steps:

1. Scrub and wash with laboratory-grade detergent (such as Alconox) and tap water;

2. Rinse with reagent-grade isopropanol alcohol or methanol and allow to air dry; and

3. Triple rinse with deionized water.

If available, a steam cleaner can also be used for decontaminating sampling equipment. Steam cleaning is the desired method since it does not introduce any additional chemicals into the system. If a steam cleaner is available it should be used instead of any other type of decontamination procedure. As with other procedures documented in this SOP, decontamination procedures may be determined by the client or regulatory agency involved in the project.

# 5.0 REFERENCES

Jay, P.C., 1985. Anion Contamination of Environmental Water Samples Introduced by Filter Media. Analytical Chemistry 57(3): 780-782.

Nielson, D.M., 1991. Practical Handbook of Groundwater Monitoring, Lewis Publishers, Inc., Chelsea, MI.

Puls, R.W. and M.S. Barcelona, 1989. Ground Water Sampling for Metals Analyses, Superfund Ground Water Issue, EPA/540/4-89/001, March 1989.

U.S. Environmental Protection Agency (USEPA), 1986. RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1, September 1986.

# APPENDIX D

# STANDARD OPERATING PROCEDURES

# SAMPLE LABELING, CHAINS-OF-CUSTODY, AND SHIPPING

# TABLE OF CONTENTS

The documentation and handling procedures described in the following subsections will be used during collection, storage, packing and shipping of all environmental samples.

# 1.0 SAMPLE LABELING

Each sample collected will be assigned a unique alphanumeric identifier code by the field team to track samples through all phases of the project. The numbering system will allow project personnel to easily catalog all samples collected and will provide an accurate and efficient means for database manipulation after the field investigation is completed.

Sample identifiers are comprised of six elements (without dashes or spaces) as shown below.

- Two-digit year designation: e.g., 99.
- Three-letter project site designation: TP for Triassic Park.
- Three-digit sample numbers starting at 001
- Two-letter sample media designation: WP for water potable.
- Numeric location identifier: 01 for well GWW99-1.

The following examples illustrate the sample identifier scheme: sample 99TP001WP01 will be the first water sample collected from groundwater well GWW99-1 collected in 1999.

Samples will be tracked using a sample label that includes the information below.

- Project name and number
- Sample designation (number)
- Date and time of sample collection
- Initials of the sampler
- Analyses to be performed on the sample
- Preservative used, if any

Labels will be affixed to the sample containers and covered with clear tape to prevent removal, except for any samples to be analyzed for VOCs.

## 1.1 CHAINS-OF-CUSTODY

Sample custody is maintained by a chain-of-custody (CoC) record. The custody record is completed by the individual collecting the sample. CoC records will be completed for all samples.

### 1.1.1 Custody Procedures

- A sample will be considered under proper custody if the following conditions are met.
  - It is in actual possession of the responsible person
  - It is in view, following physical possession
  - It is in the possession of a responsible person and is locked or sealed to prevent tampering
  - It is in a secure area
- The CoC is a continuously maintained custody record that travels with the samples at all times.

- The CoC must be signed by each field person responsible for collecting, checking or otherwise handling the samples, or shipping the samples to an outside laboratory or other agency.
- The CoC must always include the following items.
  - Corporate name
  - Sampler name and signature
  - The site designation
  - Sample designations
  - Sampling date
  - Sample collection times
  - Analyses to be performed on the samples
  - Number of containers submitted for each sample set
- The person(s) collecting the samples must sign the CoC in the appropriate block at the end of the sampling day.
- At that time, labels on sample containers should be checked against the CoC to make sure there are no discrepancies. Errors should be immediately corrrected.
- When samples are held at the project site overnight or longer, the comparison check described above should be made again by the person responsible for shipping the samples.
- The person responsible for shipping the samples must perform the following tasks.
  - Sign the topmost "relinquished by" block
  - Fill in the shipping date and time
  - Tally the number of sample containers
  - Note the shipping bill number
  - Record the storage time and temperature (if applicable)
- A copy must be retained for return to the project office together with a copy of the shipping bill.
- The remainder of the form must be placed inside the shipping container prior to being sealed for shipment.

### 1.1.2 Sample Storage

- Samples should be placed in a cooler filled with ice. The ice should be packaged to minimize leakage into the cooler.
- Each ice chest should contain one clearly labeled temperature blank consisting of tap water in a small plastic bottle.
- A permanent record of the samples stored or shipped from the site should be kept in a field notebook.
- When preparing samples for shipment, record in the sample shipping notebook the following items.
  - Time
  - Date
  - Sample numbers
  - Laboratory to which they are being shipped
- Initial all notebook entries.
- When preparing stored samples for shipping, the cooler will be repacked with fresh ice.

## 1.2 SAMPLE SHIPPING

Samples will be packaged and shipped using procedures described below. To the extent practical, samples will be shipped to the laboratory the day after they are collected.

### 1.2.1 Shipping Supplies

The items listed below are needed for packing and shipping samples.

- Ice chest(s)
- 8 to 10 pounds of ice per chest
- Bubble wrap bags
- Packing material
- Address labels
- Strapping tape
- Temperature blank
- Shipping bill
- Custody seals
- Large zippered freezer bags

### 1.2.2 Sample Packing

- Check all container labels against the CoC to make sure there are no discrepancies and both the labels and the CoC are complete and legible
- Count the containers to make sure the number is recorded correctly on the CoC
- Make sure all bottle caps are tightly secured
- If any samples were handled or treated in an unusual manner, make sure this is noted on both the sample and the CoC
- Sample Placement
  - 500 ml bottles shall be placed upright in the ice chest, not stacked.
  - Plastic and glass bottles shall be alternated.
  - Place a temperature blank in each ice chest being shipped.
  - Place 8 to 10 pounds of completely frozen ice in each ice chest, distributing it evenly among the samples to insure an even temperature distribution. Dry ice should not be used because it can freeze samples. Gel ice (blue ice) should be used if practical, as water ice will melt during shipment and possibly contaminate samples.
  - Discard any ice that shows signs of leakage.
  - Fill all void spaces in the ice chests with clean packing material (styrofoam peanuts, bubble wrap or other approved wrapping material). Paper or cardboard should never be used as packing material.
- Complete the shipping bill with shippers' and receivers' addresses, if these are not already printed on the bill.
- Mark the airbill for overnight delivery.
- Note the airbill number in the appropriate box on the CoC.
- Next to each sample line on the CoC, note the number of the ice chest number in which the sample was placed.
- Retain a copy of the CoC.
- Put the CoC in a zippered freezer bag and tape to the inside lid of the corresponding ice chest.
- Remove old labels, tape, etc., from the ice chests.
- Attach the shipping bill to the top of the corresponding container.

### 1.2.3 Shipping Containers

- Attach address labels to all shipping containers.
- Make sure each container will close properly and that the drain is plugged.
- Seal each container with strapping tape in at least two places, and wrap the tape twice around the container at the hinge points.
- Attach custody seals across the ends of the tape.
- Place "up" arrow stickers on the sides of containers holding water samples.
- Transport the samples to the carrier's shipping location.
- Obtain a copy of the airbill from the carrier's representative.
- Staple the airbill copy to the retained copy of the CoC.
- Give both papers to the field team leader (FTL), or designee, who will circulate or file them as needed.
- The FTL will fax the CoC and airbill copy to the Project Chemist at the analytical laboratory to inform the laboratory of the anticipated arrival time of the samples at the local airport.

All samples will be shipped to:

ACZ Laboratories, Inc.
Attn: Sample Receiving
30400 Downhill Drive
Steamboat Springs, CO 80487
Phone: (800) 334-5493
Fax: (970) 879-2216

# APPENDIX C

# GROUNDWATER CHARACTERIZATION LOGS

BORING LOG NUMBER: PB-48

SHEET OF

LOC. ID:
ELEVATION:
DATUM:
PROJECT NAME:
DRILL DATE: 08/05/99
INCLINATION:
AZIMUTH:
HAMMER WEIGHT:
DATE FINISHED:

LOCATION SKETCH

1000 ft north & 2000 ft east of PB-38

| DEPTH | SOIL PROFILE — SOIL DESCRIPTION | GRAPHIC LOG | USCS | NUMBER | TYPE | BLOW COUNT/6" | RECOVERY |
|---|---|---|---|---|---|---|---|
| | fn surface ss and brn clays with caliche stained cols | | | | | | |
| | yell-brn mudstone | | | | | | |
| 50' | red-gray siltstone | | | | | | |
| | red-brn clay | | | | | | |
| | red-gray mudstone | | | | | | |
| | gray-brn clayey siltstone | | | | | | |
| 100' | red-gray mudstone | | | | | | |
| | red-gray siltstone | | | | | | |
| | red-gray mudstone | | | | | | |
| 150' | red-gray clayey siltstone | | | | | | |
| | yell-brn mudstone | | | | | | |
| 200' | med red-brn mudstone | | | | | | |
| | TD | | | | | | |

ADDITIONAL COMMENTS

Bottom 50 feet of drill pipe steam-cleaned prior to drilling. Wesson oil used as "pipe dope".

Probe ajusted "deconed" probe

DEPTH UNITS: 210 ft
DRILLING CONTRACTOR: Key Drilling
DRILLER: Jackie Bowman
LOGGED BY: JAB
CHECKED BY:

| REV. No. | REVISIONS | REV. DATE | DESIGN BY | DRAWN BY | REVIEWED AND SIGNED BY |
|---|---|---|---|---|---|
| | | | | | |

# SOIL BORING LOG FORM

MONTGOMERY WATSON

PROJECT No.
AutoCAD FILE
SCALE
FIGURE No.