

AP - 078

**STAGE 1
WORKPLAN**

4/11/2008

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2008 APR 15 PM 4 00

April 7, 2008



**Reserve Pit #15
Pride Energy -
South Four Lakes Unit**

Investigation and Remediation Plan

R.T. Hicks Consultants, Ltd.

901 Rio Grande Blvd. NW, Suite F-142
Albuquerque, NM 87104

R. T. HICKS CONSULTANTS, LTD.

901 Rio Grande Blvd NW ▲ Suite F-142 ▲ Albuquerque, NM 87104 ▲ 505.266.5004 ▲ Fax: 505.266-0745

RECEIVED

2008 APR 15 PM 4 00

April 11, 2008

Mr. Glenn von Gonten
New Mexico Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

RE: Pride Energy South Four Lakes #15 Reserve Pit – AP 078

Dear Mr. von Gonten:

Please accept the previously submitted Investigation and Remediation Plan for the above-referenced site as fulfillment of Pride Energy's mandate to submit an Abatement Plan. Also, note that the CD copy of the Abatement Plan contains a comprehensive record of well logs in Appendix A than enclosed in the hard copy. As we discussed yesterday, please accept the following amendment to the submission:

Pride will submit a proposal to close the open excavations in the near future. This submission will be a complete vadose zone remedy consistent with the requirements of Rule 19. If necessary, the remedy can address questions or concerns of NMOCD regarding the deep trench burial of reserve pit material at this site.

The schedule calls for a drilling rig to commence characterization activities as early as late April. By June, the results of the proposed characterization program will permit the design of a ground water remedy for the site. A second submission to NMOCD describing the proposed remedy should be ready by August. Because Rule 19 requires public notice within 15-days after the Division determines the plan is administratively complete, we ask that the Division withhold such a determination until your review of the second planned submission. This protocol will allow Pride to implement a single public notice for a Stage 1 & 2 Abatement plan. Your thoughts on this idea are appreciated.

Sincerely,
R.T. Hicks Consultants, Ltd.



Randall T. Hicks
Principal

Copy: Pride Energy
NMOCD District II
New Mexico State Land Office

R. T. HICKS CONSULTANTS, LTD.

901 Rio Grande Blvd NW ▲ Suite F-142 ▲ Albuquerque, NM 87104 ▲ 505.266.5004 ▲ Fax: 505.266-0745

April 7, 2008

Mr. Glenn von Gonten
New Mexico Oil Conservation Division
1220 South St. Francis Drive
Santa Fe, New Mexico 87505

RE: Pride Energy South Four Lakes #15 Reserve Pit - AP 078
Request for and Extension to Submit Abatement Plans for Five Other Pride Reserve Pit Sites

Dear Mr. von Gonten:

This letter is in response to the February 12, 2008 NMOCD requirement for Pride Energy's submittal of an Abatement Plan under Rule 19 for the #15 Reserve Pit site including other Pride Energy reserve pit sites. We respectfully request that NMOCD accept the attached submittal (containing the elements required of a Stage 1 & 2 Abatement Plan) and allow us to complete the proposed work herein.

Given what is known of the site, the proposed 3-month source removal pumping effort combined with natural restoration may result in the compliance of ground water standards within one year of the requirement date possibly exempting the site from Rule 19. Site conditions may be favorable for rapid removal of the chloride mass, however the response of the site will be known only after implementation of the proposed program. Compliance with standards must be apparent before 2009 in order to qualify for an exemption under Rule 19. An extension would allow us to maintain an aggressive schedule seeing as a drilling rig is scheduled for installation of the proposed monitoring/recovery well before the end of April.

We plan to use the data collected from the proposed activities for the South Four Lakes #15 site to assist in the preparation of appropriate responses to NMOCD's requests for Abatement Plans at the following sites:

- Pride Energy State X #1 Workover Pit
- Pride Energy State QE 13 #1 Workover Pit
- Pride Energy South Four Lakes #14 Drilling Pit
- Pride Energy South Four Lake #13 Drilling Pit

Therefore, we respectfully request a 60-day extension of time to file responses to the NMOCD requests relative to the above-referenced sites as well as a response for a newly-discovered ground water impairment site, Pride Energy State 36 #2. We ask that NMOCD rapidly review the attached submission and provide comments that will guide us in our preparation of the five forthcoming plans. Approval from the Environmental Bureau of the proposed reserve pit closure protocol would be greatly appreciated since we would prefer to install a monitoring well after the earthmoving equipment has completed their site work.

We believe implementation of emergency actions at the #15 site and the need to collect additional data at the above-referenced sites provides "good cause" for an extension of the mid-April deadline for submission of Abatement Plans or Remediation Plans under Rule 116, if appropriate. It is possible that after we collect data a plan will be submitted for emergency source removal pumping or other response

April 7, 2008
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at these other sites which may result in compliance with the standards by February 2009.

The source removal protocols outlined herein are similar to the ongoing program at the nearby Samson BD-04 site. At the BD-04 site, NMOCD did not object to our proceeding on an emergency basis where we are implementing the ground water remedy under NMOCD Rule 116. Please contact me if you have any questions or concerns about our moving forward on an emergency basis.

Sincerely,
R.T. Hicks Consultants, Ltd.

A handwritten signature in black ink, appearing to read "Randall T. Hicks". The signature is stylized with a large, looped "R" and a cursive "H".

Randall T. Hicks
Principal

Copy: Pride Energy
NMOCD District II

April 7, 2008

**Reserve Pit #15
Pride Energy -
South Four Lakes Unit**

Investigation and Remediation Plan

**prepared for :
New Mexico Oil Conservation Division**

**1220 South St. Francis Drive
Santa Fe, NM 87505**

R.T. Hicks Consultants, Ltd.

**901 Rio Grande Blvd. NW, Suite F-142
Albuquerque, NM 87104**

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Appendix A: OSE well locations within ½ mile; OSE well logs

Appendix B: Laboratory Certificate of Analysis

Appendix C: Chloride Conceptual Model

Appendix D: Quality Assurance Protocols

Plate 1: Regional Location Map

Plate 2: Aerial Photograph showing

Plate 3: Geologic Map

Plate 4: USGS Water Table Map

Plate 5: Local Water Table Map

Plate 6: Soil Sampling Map

Plate 7: Proposed Boring Location Map

1.0 Description of the Site

1.1 Location

Plate 1 shows the location of the South Four Lakes #15 reserve pit site relative to four additional Pride Energy Company sites and Tatum, New Mexico. Plate 2 is a 2004 aerial photograph showing the general area of the site. The site is in T12S R34E Section 2 Unit Letter G (N 33° 18' 30.5", W 103° 28' 48.2", API # 30-025-36882). To access the site:

1. Drive west on Highway 380 ten miles from the intersection of Highway 380 and Highway 206 in Tatum, New Mexico
2. Drive north 0.38 miles on the dirt access road
3. The location is on the west side of the access road

Figure 1 shows a photograph of the site and the general area near South Four Lakes Well #15. The photograph shows monitoring and recovery wells associated with the Phillips Petroleum South Four Lakes Unit ground water remediation system in the foreground and the #15 reserve pit behind the pick-up truck.



Figure 1: View northeast from South Four Lakes Tank Battery to Well #15

1.2 Site History

| Date | Description |
|-------------------|---|
| November 9, 2004 | Pride submits APD (C-101) for South Four Lakes Unit #15 |
| January 3, 2005 | C-101 amends proposed total depth to 16,000 feet |
| November 8, 2004 | Well spudded |
| February 11, 2005 | Released drill rig |
| March 14, 2005 | Perforate Devonian |

| | |
|-------------------|---|
| March 18, 2005 | Complete well |
| August 21, 2007 | C-144 Pit Closure Form submitted to NMOCD |
| December 10, 2007 | Revised C-144 submitted by Elke Environmental |
| January 30, 2008 | C-141 submitted by Elke Environmental |
| February 12, 2008 | NMOCD requires submission of Abatement Plan |

2.0 Site Investigation Results

2.1 Inventory of Water Wells

See Appendix A for a map and table showing the water wells within one mile of the South Four Lakes sites. Copies of driller's logs of wells near the site are also included in Appendix A.

2.2 Site Geology

The South Four Lakes Unit and associated State lease areas are located in the High Plains portion of the Great Plains physiographic province where flat-laying sedimentary rocks, ranging in age from Permian to Miocene exist. The majority of the area is covered with a shallow soil horizon (Kimbrough-Lea Complex; sandy loams overlying caliche) and sparsely vegetated with grasses, and brush. Plate 3 depicts a geologic map that shows the Ogallala Formation is present throughout much of the area. The Ogallala Formation is underlain by the Triassic Dockum Group red beds. The uppermost unit of the Dockum Group is the Chinle Formation which consists of a thick sequence of red clays and is not water-bearing (aquiclude).

The sediments which form the Ogallala Formation were carried eastward from the Southern Rocky Mountains as braided fluvial deposits which consist of clays, very fine-grained sands, some gravels and occasional lenses of calcite-cemented sands and clays. The Ogallala Formation is generally coarser-grained in the lower portion of the unit with a basal conglomerate present at some locations. Finer-grained sand and caliche are common in the upper portion of the Ogallala Formation. The base of the Ogallala Formation and top of the Chinle Formation is estimated between 90 to 110 feet over the area of concern.

2.3 Site Ground Water Hydrology

This section provides an estimate of subsurface hydraulic characteristics and an estimate of the rate and direction of contaminant migration as required by Rule 19.

Depth to ground water in the area ranges from approximately 24 ft to 38 ft below ground surface (bgs). Based on driller logs of area water wells permitted by the New Mexico Office of the State Engineer (OSE), the saturated thickness of the Ogallala Formation is estimated at approximately 65 to 80 ft.

A regional potentiometric surface map created using 1996 water level data obtained from the USGS database indicates that ground water in the area is flowing in a southeast direction (see Plate 4) with a hydraulic gradient of approximately 0.003 ft/ft. Plate 5 depicts the local potentiometric surface map based on local monitoring well data at the South Four Lakes tank battery. The local ground water gradient flows to the southeast with a gradient of approximately 0.002 ft/ft. This is consistent with the prevailing regional characteristics.

Site-specific values for hydraulic conductivity of the Ogallala Formation range between 0.5 ft/day to 50 ft/day based on published information (Nicholson and Clebsch, 1961; Ash, 1963; McAda

and Hart, 1985; Secor, 1995; and Musharrafieh, 1999). Experience in determining hydraulic conductivity values from aquifer tests of the uppermost portion of the Ogallala Aquifer in Lea County, suggests a value between 3 ft/day to 10 ft/day for the portion of the saturated zone most likely impacted by the release.

Application of Darcy's Law with the aforementioned estimates suggests a ground water velocity rate ranging from 9 ft/yr to 90 ft/yr. An aquifer test is necessary to quantify hydraulic conductivity values, ground water velocity rates, specific capacity, well yields, and other parameters at the site.

Chloride migration rate from a source approximates the ground water velocity.

2.4 Vertical and Horizontal Extent and Magnitude of Vadose-Zone Impairment

Plate 6 is a reproduction of the field map created by Elke Environmental showing the locations of the five sample borings within the former pit. The chloride concentrations with depth were derived from data in NMOCD on-line files for Case #AP-078.

Based upon these data and experience at similar sites, brine from the pit probably migrated through the vadose zone to ground water via saturated flow during operation of the drilling pit or sometime during the drying process. The uniform decline of chloride concentrations observed from about 20 feet below grade to the water table is due to dilution of the migrating brine by less saline ground water residing within the capillary fringe. Low porosity in the "chert" logged by the driller at these depths could also contribute to lower chloride measurements because the "chert" would retain a smaller mass of brine relative to caliche, which should exhibit a higher porosity.

The Laws of Fluid Dynamics, the Law of Gravity, the lithology of the unsaturated zone and years of experience characterizing releases from pits, ponds, lagoons, pipeline releases and tanks allow us to conclude with a very high degree of scientific certainty that the migration of brine released from the former reserve pit migrated vertically and horizontal dispersion in the vadose zone of a few feet is expected.

2.5 Surface-Water Hydrology

There are no surface water bodies within a mile of any of the subject sites with the exception of a windmill pond located approximately 1,500 ft northwest (up-gradient) from the South Four Lakes #15 well site. A recent water quality analysis from this windmill indicates concentrations of constituents of concern (chlorides - 167 mg/L, sulfate - 218 mg/L, TDS - 1,210 mg/L, and BTEX - <0.001 mg/L) are near or below WQCC standards.

3.0 Define Vertical and Horizontal Extent and Magnitude of Ground-Water above WQCC Standards

3.1 Evaluation of Existing Data

At the South Four Lakes #15 site, the January 21st ground water sample from Monitoring Well #1 shows a chloride concentration of 3,930 mg/L and the March 13th sampling event shows a

chloride concentration of 4,150 mg/L. The total dissolved solids analyses of the March sample from the well is 9,820 mg/L.

On March 27th, Hicks Consultants performed a conductivity profile of the screened interval at MW-1 to determine if any chemical stratification in the uppermost saturated zone is present. First, we obtained a sample from the un-purged well by slowly lowering a bailer (to minimize mixing within the well) into the upper 3-feet of the water table to retrieve a sample for chloride, TDS, and specific conductivity analysis. We then slowly lowered the bailer to the base of the well and obtained a sample from a depth of 20-feet below the water table. In theory the flow-through bailer with a ball seal should capture a discrete sample from the base of the well, provided the ball valve does not leak and disturbance in the well is minimal. In addition, the well was purged of more than 3 wells volumes (12 gallons) by hand bailing and a third sample was collected for the same suite of analyses. The results of these procedures are as follows:

| Sample Interval | Specific Conductance | Chloride | TDS |
|------------------------------|----------------------|----------|-------|
| | mS/cm | mg/L | mg/L |
| 0-3 feet below water table | 3.72 | 1,100 | 2,200 |
| 17-20 feet below water table | 9.33 | 3,100 | 5,400 |
| After purging | 13.3 | 4,700 | 8,100 |

These data suggest that chemical stratification of the uppermost ground water zone is present. The uppermost portion of the aquifer is moderately impacted by the release from the reserve pit. The observation that the "discrete" sample from the lower 3-feet of the well exhibits a lower chloride concentration than the sample after purging may indicate that the center of mass of released brine is present between the upper 3-feet of the aquifer and the 17-20 foot depth of the lower "discrete" sample. Additional testing is necessary to confirm these initial findings.

Laboratory analytical reports, chains of custody, and well sampling data forms are included in Appendix B.

Based on the estimates of ground water velocity (Section 2.3), ground water is migrating relatively slow at this site and the short-term consistency of the chloride content in MW-1 is, therefore, not surprising. Assuming that the release of brine occurred soon after drilling was completed at South Four Lakes #15 (March 2005), then the down gradient extent of ground water impairment should be less than 30 to 90 ft downgradient of the pit.

3.2 Proposed Characterization Program

Appendix C presents a conceptual model of chloride fate and transport in an aquifer below a reserve pit release. The following phased-approach is based upon the conceptual model and is intended (i) to quantify the volume and geometry of ground water impairment caused by the release from the former reserve pit and (ii) to collect data necessary for developing an appropriate ground water restoration strategy. The characterization program will commence immediately after completion of the vadose zone remedy (see Section 4.1) and will include:

- 1. Install Boring/Temporary Monitoring Wells** Using a hollow stem auger, drill one boring about 25 feet due east of the eastern edge of the former pit, a second boring about 25 feet due south of the former pit, and a third boring approximately 60 feet southeast (downgradient) of existing MW-1 as shown (See B-1, B-2 and B-3) on

Plate 7. During this activity this plan calls for:

- a. Collect samples of the vadose zone at 5-foot intervals to determine chloride concentration;
 - b. Collect a ground water grab sample through the drill pipe after penetration of the upper 5-feet of the saturated zone. Field determination of specific conductance will be performed at 10-foot intervals starting at 5-feet into the saturated zone until the on-site hydrogeologist is satisfied that the vertical extent of ground water impairment is sufficiently defined, or until the Red Beds of the Dockum group is encountered;
 - c. The boring program will terminate when the on-site hydrogeologist is satisfied that the vertical and horizontal extent of ground water impairment is sufficiently defined;
 - d. If data suggest that a boring penetrates a zone of the aquifer in which the TDS exceeds 5,000 mg/L (a salinity that may be acceptable to mature livestock according to NMSU Guide M-112, 1995) the boring will be offset 30 to 50 feet down gradient and the field program will repeat the chemical sounding of the upper aquifer described above;
 - e. Based upon the results of ground water sampling program described above, the on-site hydrogeologist may elect to install a temporary ground water monitoring well (or well cluster) at a boring location to confirm the findings through the collection of a sample consistent with standard industry methods (see Appendix D).
 - f. After consideration of maintaining integrity of oil field equipment, access to the producing well, and other technical factors, the on site hydrogeologist may elect to convert a temporary well to a permanent down gradient monitoring well.
2. **Install Monitor/Recovery Well(s)** After the boring and sampling program described above defines the approximate geometry of the zone of aquifer impairment, this plan proposes to drill a 4-inch monitor/recovery well about 25 to 30 feet distant from a permanent monitoring well; at a point where highest chloride mass can be expected.
- a. The construction of this well will be determined on-site and based upon the results of the boring characterization. This well construction will allow the collection of representative samples from the ground water depth zone exhibiting the highest impact (as measured by specific conductance) as well as recovery pumping from this zone.
 - b. If data suggest that downward vertical migration of released brine may continue within the aquifer, the on-site hydrogeologist may install a recovery well with two screened intervals permitting focused recovery pumping via well packers or a second recovery well completed in a deeper horizon.
3. **Evaluation of Well Boring Data** The on-site geologist will create a lithologic log of the soil borings and refine the geologic and hydrologic characteristics.
4. **Source Removal and Testing** After drilling is complete, this plan proposes a 3-month source removal and test pumping program. The purpose of this pumping program is to determine if ground water may be restored prior to February 2009 and to assist in the evaluation of ground water abatement alternatives. Water from the recovery well will flow to the produced water storage tanks and thence to the nearby

disposal well. Experience at similar sites suggests a pumping rate of 2 to 10 gallons per minute is possible. The proposed testing program consists of:

- a. Measurement of water levels in the recovery well and monitoring well(s)
 - i. On a daily/hourly basis for the first two days of pumping
 - ii. On a weekly basis for the first month of pumping and
 - iii. On a monthly basis for the next five months
 - iv. On a daily/hourly basis after cessation of pumping (after at least 2-days of pumping) to collect recovery data for calculation of hydrologic parameters.
- b. Collection of ground water samples for chloride and TDS analysis on a monthly basis from the recovery well
- c. Measurements of the flow rate and total flow from the recovery well at each site visit
- d. Collection of ground water samples from all monitor wells before and after the 3-month pumping program.

4.0 Assessment of Restoration Options

4.1 Vadose Zone Remedy

To prevent infiltration of precipitation through the impacted vadose zone below the former pit and the attendant flux of chloride to ground water, this plan proposes the NMOCD-approved design installed at South Four Lakes #16 (See NMOCD Case # 1RP-1805-0). Elke Environmental will install the vadose zone remedy as soon as possible in accordance with the plan recently approved by NMOCD for the #16 well site, which exhibits a similar chloride load in the vadose zone.

4.2 Ground Water Remedy

The preliminary evaluation of alternatives rejected any program that treats ground water and creates a waste (e.g. brine) that must be managed. This analysis suggests that creation of a brine waste and the management of the waste and treatment system results in less benefit to the environment by creating more contamination (i.e. air pollution, dust, energy consumption) than it cures.

A strategy of pump-and-use without treatment provides the highest environmental benefit if a bona fide use presently exists for the ground water. The proposed source removal pumping/testing program will collect the data to permit determination of how and if ground water pumped from the site could replace existing uses of fresh water in the area. In the absence of a bona fide use for this ground water (e.g. future oil well drilling in the immediate area), a pump-and-use strategy does not create the highest environmental benefit.

If a pump-and-use ground water restoration program is not possible and pump-and-dispose provides little benefit, the evaluation of alternatives suggests that natural restoration provides the highest environmental benefit. A combination of natural restoration and pump-and-use will likely be employed at this site.

5.0 Report to NMOCD

After 3-months of source removal pumping, a report will evaluate the data collected and prepare a report that:

1. Identifies the location of any additional monitoring wells necessary to define the extent and magnitude of ground water impairment to the extent necessary for completing a ground water restoration program,
2. Recommends:
 - a. Continuation of the pump-and-dispose source removal program for an additional 3-months,
 - b. Implementation of a pump-and-use ground water restoration program, or
 - c. Implementation of a natural restoration strategy.
3. Provides a description, justification and design of the preferred ground water restoration strategy
4. Provides a long-term monitoring program.

5.1 Quality Assurance Plan

The quality protocols proposed for this program are presented in Appendix D

5.2 Order of Activities

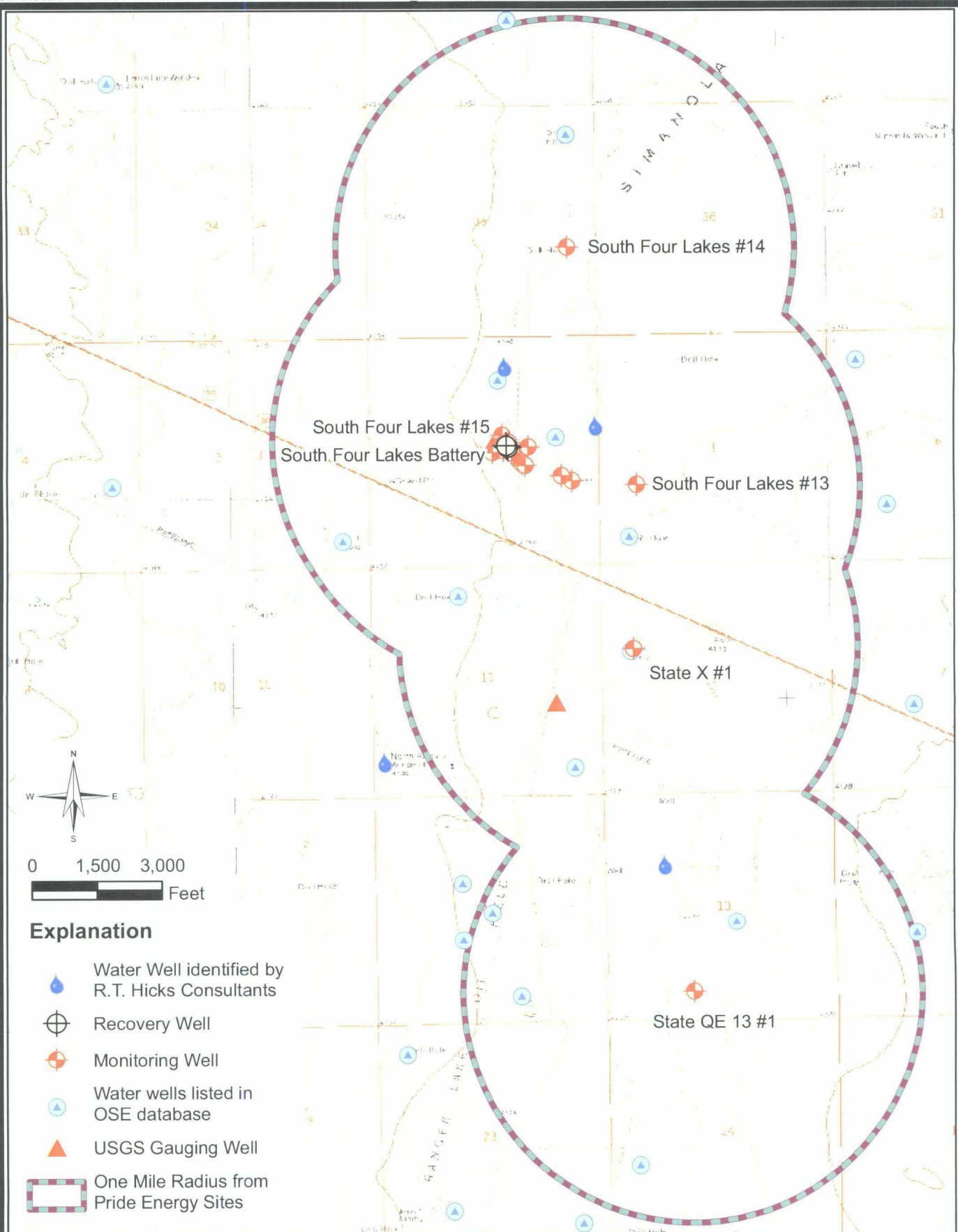
1. Submit proposal to NMOCD
2. Complete closure of reserve pit
3. Conduct characterization program
4. Commence source removal pumping and testing program
5. Submit report to NMOCD
6. Implement NMOCD-approved ground water remedy and begin long-term monitoring

Appendix A

**OSE well locations within 1/2 mile;
OSE well logs**

R.T. Hicks Consultants, Ltd.

901 Rio Grande Blvd. NW, Suite F-142
Albuquerque, NM 87104



R.T. Hicks Consultants, Ltd
 901 Rio Grande Blvd NW Suite F-142
 Albuquerque, NM 87104
 Ph: 505.266.5004

**Topographic Map Showing Water Wells Within
 One Mile of Pride Energy Sites**

Pride Energy: Abatement Plan

Draft

March 2008

Table A-1:
OSE Wells within one mile of Pride Energy Sites

| Well Name | File Number | USE | Start Date | Finish Date | Well Depth | Water Depth | TWS | RNG | SEC | O | O2 | O3 | EASTING | NORTHING | X COORD | Y COORD |
|---------------|-------------|-----|------------|-------------|------------|-------------|-------|-----|-----|----|----|----|---------|----------|---------|---------|
| L 00654 DCL | L 00654 | STK | | | 0 | 0 | 012S | 35E | | 18 | 3 | 2 | 644464 | 3682854 | 644413 | 3683058 |
| L 00655 DCL | L 00655 | STK | | | 0 | 0 | 012S | 35E | | 7 | 3 | 2 | 644440 | 3684458 | 644389 | 3684662 |
| L 00656 DCL | L 00656 | STK | | | 0 | 0 | 012S | 34E | | 1 | 3 | 3 | 642442 | 3685633 | 642391 | 3685837 |
| L 02732 | L 02732 | PRO | 1/5/1955 | 1/5/1955 | 155 | 155 | 4812S | 35E | | 6 | 1 | 1 | 644036 | 3688864 | 643985 | 3687068 |
| L 02732 APPRO | L 02732 | PRO | 1/5/1955 | 1/5/1955 | 155 | 155 | 4812S | 35E | | 6 | 1 | 1 | 644036 | 3688864 | 643985 | 3687068 |
| L 03005 | L 03005 | PRO | | | 0 | 0 | 012S | 34E | | 2 | 2 | 1 | 641520 | 3686724 | 641469 | 3686928 |
| L 03005 (1) | L 03005 (1) | PRO | | | 0 | 0 | 012S | 34E | | 2 | 2 | 4 | 641520 | 3686724 | 641469 | 3686928 |
| L 03200 | L 03200 | PRO | 5/14/1956 | 5/15/1956 | 128 | 128 | 5012S | 34E | | 23 | 4 | 4 | 642120 | 3680809 | 642069 | 3681013 |
| L 03200 APPRO | L 03200 | PRO | 5/14/1956 | 5/15/1956 | 128 | 128 | 5012S | 34E | | 23 | 4 | 4 | 642120 | 3680809 | 642069 | 3681013 |
| L 03244 | L 03244 | DOM | 8/1/1956 | 8/2/1956 | 75 | 75 | 4012S | 34E | | 23 | 3 | 4 | 641212 | 3680893 | 641161 | 3681097 |
| L 03244 APPRO | L 03244 | DOM | 8/1/1956 | 8/2/1956 | 75 | 75 | 4012S | 34E | | 23 | 3 | 4 | 641212 | 3680893 | 641161 | 3681097 |
| L 03360 | L 03360 | PRO | 11/6/1956 | 11/6/1956 | 110 | 110 | 3612S | 34E | | 12 | 1 | 3 | 642453 | 3684830 | 642402 | 3685034 |
| L 03360 APPRO | L 03360 | PRO | 11/6/1956 | 11/7/1956 | 110 | 110 | 3612S | 34E | | 12 | 1 | 3 | 642453 | 3684830 | 642402 | 3685034 |
| L 03371 | L 03371 | PRO | 11/27/1956 | 11/28/1956 | 120 | 120 | 3512S | 34E | | 24 | 3 | 1 | 642518 | 3681217 | 642467 | 3681421 |
| L 03371 APPRO | L 03371 | PRO | 11/27/1956 | 11/28/1956 | 120 | 120 | 3512S | 34E | | 24 | 3 | 1 | 642518 | 3681217 | 642467 | 3681421 |
| L 03696 | L 03696 | PRO | 9/21/1957 | 9/21/1957 | 112 | 112 | 4312S | 34E | | 3 | 4 | 4 | 640430 | 3685602 | 640379 | 3685806 |
| L 03696 APPRO | L 03696 | PRO | 9/21/1957 | 9/21/1957 | 112 | 112 | 4312S | 34E | | 3 | 4 | 4 | 640430 | 3685602 | 640379 | 3685806 |
| L 04146 | L 04146 | PRO | 5/21/1959 | 5/22/1959 | 105 | 105 | 4012S | 34E | | 15 | 0 | 0 | 639873 | 3682970 | 639822 | 3683174 |
| L 04146 APPRO | L 04146 | PRO | 5/21/1959 | 5/22/1959 | 105 | 105 | 4012S | 34E | | 15 | 0 | 0 | 639873 | 3682970 | 639822 | 3683174 |
| L 04183 | L 04183 | PRO | 6/10/1959 | 6/11/1959 | 135 | 135 | 4512S | 34E | | 23 | 1 | 1 | 640885 | 3681991 | 640834 | 3682195 |
| L 04183 APPRO | L 04183 | PRO | 6/10/1959 | 6/11/1959 | 135 | 135 | 4512S | 34E | | 23 | 1 | 1 | 640885 | 3681991 | 640834 | 3682195 |
| L 04326 | L 04326 | PRO | 11/17/1959 | 11/18/1959 | 85 | 85 | 3512S | 34E | | 11 | 1 | 2 | 641241 | 3685213 | 641190 | 3685417 |
| L 04326 APPRO | L 04326 | PRO | 11/17/1959 | 11/18/1959 | 85 | 85 | 3512S | 34E | | 11 | 1 | 2 | 641241 | 3685213 | 641190 | 3685417 |
| L 04540 | L 04540 | PRO | | | 0 | 0 | 012S | 34E | | 14 | 0 | 0 | 641480 | 3682995 | 641429 | 3683199 |
| L 04540 APPRO | L 04540 | PRO | | | 0 | 0 | 012S | 34E | | 14 | 0 | 0 | 641480 | 3682995 | 641429 | 3683199 |
| L 05636 EXP | L 05636 | STK | | | 0 | 0 | 012S | 35E | | 6 | 3 | 0 | 644255 | 3685859 | 644204 | 3686063 |
| L 05811 | L 05811 | PRO | 11/10/1965 | 11/11/1965 | 114 | 114 | 4312S | 34E | | 14 | 1 | 4 | 641270 | 3683203 | 641219 | 3683407 |
| L 05983 | L 05983 | PRO | 7/6/1966 | 7/6/1966 | 94 | 94 | 4712S | 34E | | 14 | 3 | 2 | 641277 | 3682801 | 641226 | 3683005 |
| L 06239 | L 06239 | PRO | 12/1/1967 | 12/1/1967 | 72 | 72 | 2511S | 34E | | 35 | 2 | 2 | 642001 | 3688442 | 641950 | 3688646 |
| L 06305 EXP | L 06305 | PRO | | | 0 | 0 | 012S | 34E | | 4 | 4 | 2 | 638812 | 3685981 | 638761 | 3686185 |
| L 06620 EXP | L 06620 | STK | | | 0 | 0 | 012S | 34E | | 14 | 4 | 3 | 641689 | 3682405 | 641638 | 3682609 |
| L 09870 EXP | L 09870 | PRO | | | 0 | 0 | 012S | 34E | | 11 | 4 | 4 | 642062 | 3684020 | 642011 | 3684224 |
| L 09884 | L 09884 | PRO | 11/28/1986 | 11/28/1986 | 132 | 132 | 4012S | 34E | | 13 | 4 | 1 | 643192 | 3682933 | 643141 | 3683137 |
| L 10197 | L 10197 | STK | | | 50 | 50 | 011S | 34E | | 26 | 4 | 1 | 641588 | 3689243 | 641537 | 3689447 |
| L 10202 | L 10202 | STK | 1/1/1939 | 1/1/1939 | 70 | 70 | 011S | 34E | | 28 | 4 | 4 | 638774 | 3688804 | 638723 | 3689008 |

WELL RECORD *Southern Petroleum Lease*

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

| | | | |
|--|--|--|--|
| | | | |
| | | | |
| | | | |
| | | | |

(A) Owner of well J. C. Crain Drilling Co.
Street and Number Box 176
City Runice State New Mexico
Well was drilled under Permit No. _____ and is located in the
1/4 SE 1/4 SE 1/4 of Section 3 Twp. 12 S Rge. 34 E
(B) Drilling Contractor Ed. Burke License No. WD-111
Street and Number Box 306
City Hobbs State New Mexico
Drilling was commenced Sept. 21 1957
Drilling was completed Sept. 21 1957

(Plat of 640 acres)

Elevation at top of casing in feet above sea level _____ Total depth of well 112
State whether well is shallow or artesian Shallow Depth to water upon completion 43

Section 2

PRINCIPAL WATER-BEARING STRATA

| No. | Depth in Feet | | Thickness in Feet | Description of Water-Bearing Formation |
|-----|---------------|----|-------------------|--|
| | From | To | | |
| 1 | 43 | 62 | 19 | Water Sand |
| 2 | 81 | 97 | 16 | Water Sand |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |

Section 3

RECORD OF CASING

| Dia in. | Pounds ft. | Threads in | Depth | | Feet | Type Shoe | Perforations | |
|---------|------------|------------|-------|--------|------|-----------|--------------|----|
| | | | Top | Bottom | | | From | To |
| 7 | 20 | 8 | 0 | 97 | 97 | none | 66 | 97 |
| | | | | | | | | |
| | | | | | | | | |

Section 4

RECORD OF MUDDING AND CEMENTING

| Depth in Feet | | Diameter Hole in in. | Tons Clay | No. Sacks of Cement | Methods Used |
|---------------|----|----------------------|-----------|---------------------|--------------|
| From | To | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Section 5

PLUGGING RECORD

Name of Plugging Contractor _____ License No. _____
Street and Number _____ City _____ State _____
Tons of Clay used _____ Tons of Roughage used _____ Type of roughage _____
Plugging method used _____ Date Plugged _____ 19 _____
Plugging approved by: _____

Cement Plugs were placed as follows:

| No. | Depth of Plug | | No. of Sacks Used |
|-----|---------------|----|-------------------|
| | From | To | |
| | | | |
| | | | |
| | | | |

| | |
|--------------------------------|-------------------------|
| FOR USE OF STATE ENGINEER ONLY | Basin Supervisor |
| | <u>Oct 2 1957</u> |
| Date Received _____ | OFFICE |
| | GROUND WATER SUPERVISOR |
| | ROSWELL, NEW MEXICO |

File No. L-3696 Use Oil Location No. 12.34.3.440 443223

FIELD ENGR. LOG

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

| | | | |
|--|--|--|--|
| | | | |
| | | | |
| | | | |
| | | | |

(A) Owner of well Moran Oil Producing and Drilling Corp.Street and Number P. O. Box 1919City Hobbs State New Mexico

Well was drilled under Permit No. _____ and is located in the

1/4 SE 1/4 NW 1/4 of Section 14 Twp. 12 S Rge. 34 E(B) Drilling Contractor Ed R. Furke License No. WD 111Street and Number P. O. Box 306City Hobbs State New MexicoDrilling was commenced November 10 1965Drilling was completed November 11 1965

(Plat of 640 acres)

Elevation at top of casing in feet above sea level _____ Total depth of well 114State whether well is shallow or artesian shallow Depth to water upon completion 43

Section 2

PRINCIPAL WATER-BEARING STRATA

| No. | Depth in Feet | | Thickness in Feet | Description of Water-Bearing Formation |
|-----|---------------|-----|-------------------|--|
| | From | To | | |
| 1 | 47 | 60 | 13 | sand, water |
| 2 | 62 | 102 | 20 | sand, water |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |

Section 3

RECORD OF CASING

| Dia in. | Pounds ft. | Threads in | Depth | | Feet | Type Shoe | Perforations | |
|---------|------------|------------|-------|--------|-------|-----------|--------------|-----|
| | | | Top | Bottom | | | From | To |
| 7 | 20 | 10 | 0 | 109.1 | 109.1 | open | 66 | 106 |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

Section 4

RECORD OF MUDDING AND CEMENTING

| Depth in Feet | | Diameter Hole in in. | Tons Clay | No. Sacks of Cement | Methods Used |
|---------------|----|----------------------|-----------|---------------------|--------------|
| From | To | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Section 5

PLUGGING RECORD

Name of Plugging Contractor _____ License No. _____

Street and Number _____ City _____ State _____

Tons of Clay used _____ Tons of Roughage used _____ Type of roughage _____

Plugging method used _____ Date Plugged _____ 1965

Plugging approved by: _____

Cement Plugs were placed as follows:

| No. | Depth of Plug | | No. of Sacks Used |
|-----|---------------|----|-------------------|
| | From | To | |
| | | | |
| | | | |
| | | | |
| | | | |

Basin Supervisor _____

FOR USE OF STATE ENGINEER ONLY

Date Received _____

02:18 AM 24 NOV 1965

File No. L-5811Use OWDLocation No. 12.34.14.140

LOG OF WELL

The undersigned hereby certifies that, to the best of his knowledge and belief, the foregoing is a true and correct record of the above described well.

Well Driller

2-5811

12-34, 14, 140

FIELD ENGR. LOG

WELL RECORD

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the nearest district office of the State Engineer. All sections, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1A and Section 5 need be completed.

Section 1

| | | | |
|--|--|--|---|
| | | | 0 |
| | | | |
| | | | |
| | | | |

(A) Owner of well MORAN OIL PRODUCING & DRILLING CORP.Street and Number P.O. Box 1919
City Hobbs 88240 State New MexicoWell was drilled under Permit No. L-6239 and is located in the
1/4 NE 1/4 NE 1/4 of Section 35 Twp. 11 S Rge. 34 E(B) Drilling Contractor Abbott Brothers License No. WD-46Street and Number P.O. Box 637
City Hobbs 88240 State New MexicoDrilling was commenced December 1 19 67Drilling was completed December 1 19 67

(Plat of 640 acres)

Elevation at top of casing in feet above sea level _____ Total depth of well 72State whether well is shallow or artesian shallow Depth to water upon completion 25

Section 2

PRINCIPAL WATER-BEARING STRATA

| No. | Depth in Feet | | Thickness in Feet | Description of Water-Bearing Formation |
|-----|---------------|----|-------------------|--|
| | From | To | | |
| 1 | 25 | 32 | 7 | red sand |
| 2 | 50 | 59 | 9 | water sand |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |

Section 3

RECORD OF CASING

| Dia in. | Pounds ft. | Threads in | Depth | | Feet | Type Shoe | Perforations | |
|---------|------------|------------|-------|--------|------|-----------|------------------|----|
| | | | Top | Bottom | | | From | To |
| 7 | 18 | 10 | 0 | 72 | 72 | open | 30 | 72 |
| | | | | | | | 4 rows 1/8 X 12" | |
| | | | | | | | | |
| | | | | | | | | |

Section 4

RECORD OF MUDDING AND CEMENTING

| Depth in Feet | | Diameter Hole in in. | Tons Clay | No. Sacks of Cement | Methods Used |
|---------------|----|----------------------|-----------|---------------------|--------------|
| From | To | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Section 5

PLUGGING RECORD

Name of Plugging Contractor _____ License No. _____

Street and Number _____ City _____ State _____

Tons of Clay used _____ Tons of Roughage used _____ Type of roughage _____

Plugging method used _____ Date Plugged _____ 19 _____

Plugging approved by: _____

Cement Plugs were placed as follows:

| No. | Depth of Plug | | No. of Sacks Used |
|-----|---------------|----|-------------------|
| | From | To | |
| | | | |
| | | | |
| | | | |
| | | | |

Basin Supervisor _____

FOR USE OF STATE ENGINEER ONLY

Date Received _____

1967 DEC 27 PM 3:11

File No. L-6239 Use O.W.D. Location No. 11.34.35.220

LOG OF WELL

LS Elev _____
Depth to K _____ Trc _____
Elev of K _____ Trc _____

Hydro. Survey _____ Field Check _____

Interpolated from Topo. Sheet _____
Determined by Inst. Leveling _____
Other _____

Murrell Abbott
Well Driller

11.34.35.220

STATE ENGINEER OFFICE
WELL RECORD

Section 1. GENERAL INFORMATION

(A) Owner of well Norton Drilling Owner's Well No. _____
Street or Post Office Address c/o Glenn's Water Well Service, Inc.
City and State Box 692 Tatum, N.M. 88267

Well was drilled under Permit No. L-9884 and is located in the:

a. $\frac{1}{4}$ W₂ $\frac{1}{4}$ NW $\frac{1}{4}$ SE $\frac{1}{4}$ of Section 13 Township 12-S. Range 34-E. N.M.P.M.

b. Tract No. _____ of Map No. _____ of the _____

c. Lot No. _____ of Block No. _____ of the _____
Subdivision, recorded in _____ County.

d. X= _____ feet, Y= _____ feet, N.M. Coordinate System _____ Zone in
the _____ Grant.

(B) Drilling Contractor Glenn's Water Well Service, Inc. License No. _____

Address Box 692 Tatum, N.M. 88267

Drilling Began 11/28/86 Completed 11/28/86 Type tools Rotary Size of hole 9 7/8 in.

Elevation of land surface or _____ at well is _____ ft. Total depth of well 132 ft.

Completed well is ☒ shallow ☐ artesian. Depth to water upon completion of well 40 ft.

Section 2. PRINCIPAL WATER-BEARING STRATA

| Depth in Feet | | Thickness in Feet | Description of Water-Bearing Formation | Estimated Yield (gallons per minute) |
|---------------|-----|----------------------|--|---|
| From | To | | | |
| 84 | 126 | 42 | sand and gravel | 100 |
| 40 | 84 | 44 | sand | 20 |
| | | | | |
| | | | | |

Section 3. RECORD OF CASING

| Diameter (inches) | Pounds per foot | Threads per in. | Depth in Feet | | Length (feet) | Type of Shoe | Perforations | |
|----------------------|--------------------|--------------------|---------------|--------|------------------|--------------|--------------|-----|
| | | | Top | Bottom | | | From | To |
| 6 5/8 | .156 | | | | 132 | | 40 | 126 |
| | | | | | | | | |
| | | | | | | | | |

Section 4. RECORD OF MUDDING AND CEMENTING

| Depth in Feet | | Hole Diameter | Sacks of Mud | Cubic Feet of Cement | Method of Placement |
|---------------|----|------------------|-----------------|-------------------------|---------------------|
| From | To | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Section 5. PLUGGING RECORD

Plugging Contractor _____
Address _____
Plugging Method _____
Date Well Plugged _____
Plugging approved by: _____

State Engineer Representative

| No. | Depth in Feet | | Cubic Feet of Cement |
|-----|---------------|--------|-------------------------|
| | Top | Bottom | |
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |

FOR USE OF STATE ENGINEER ONLY

Date Received December 4, 1986

Quad _____ FWL _____ FSL _____

Well No. L-9884 Use OWD Location No. 12.34.13.41322

12.34.13.41322

[illegible]

100

12.34.13.41322

Carly B. Brown
Driller

INSTRUCTIONS: This form should be executed in triplicate, preferably typewritten, and submitted to the appropriate district office of the State Engineer. All questions, except Section 5, shall be answered as completely and accurately as possible when any well is drilled, repaired or deepened. When this form is used as a plugging record, only Section 1(a) and Section 5 need be completed.

Appendix B

Laboratory Certificate of Analysis

R.T. Hicks Consultants, Ltd.

901 Rio Grande Blvd. NW, Suite F-142
Albuquerque, NM 87104

COVER LETTER

Friday, April 04, 2008

Andrew Parker
R.T. Hicks Consultants, LTD
901 Rio Grande Blvd. NW
Suite F-142
Albuquerque, NM 87104

TEL: (505) 266-5004

FAX (505) 266-0745

RE: South Four Lakes #15

Order No.: 0803291

Dear Andrew Parker:

Hall Environmental Analysis Laboratory, Inc. received 3 sample(s) on 3/28/2008 for the analyses presented in the following report.

These were analyzed according to EPA procedures or equivalent.

Reporting limits are determined by EPA methodology. No determination of compounds below these (denoted by the ND or < sign) has been made.

Please don't hesitate to contact HEAL for any additional information or clarifications.

Sincerely,



Andy Freeman, Business Manager
Nancy McDuffie, Laboratory Manager

NM Lab # NM9425
AZ license # AZ0682
ORELAP Lab # NM100001



Hall Environmental Analysis Laboratory, Inc.

Date: 04-Apr-08

CLIENT: R.T. Hicks Consultants, LTD**Client Sample ID:** MW-01 BOTTOM**Lab Order:** 0803291**Collection Date:** 3/27/2008 5:10:00 PM**Project:** South Four Lakes #15**Date Received:** 3/28/2008**Lab ID:** 0803291-01**Matrix:** AQUEOUS

| Analyses | Result | PQL | Qual | Units | DF | Date Analyzed |
|---------------------------------|--------|-----|------|-------|-----|----------------------|
| EPA METHOD 300.0: ANIONS | | | | | | Analyst: SLB |
| Chloride | 3100 | 10 | | mg/L | 100 | 4/1/2008 10:20:24 AM |
| SM 2540C: TDS | | | | | | Analyst: TAF |
| Total Dissolved Solids | 5400 | 20 | | mg/L | 1 | 4/2/2008 |

Qualifiers:

- * Value exceeds Maximum Contaminant Level
- E Value above quantitation range
- J Analyte detected below quantitation limits
- ND Not Detected at the Reporting Limit
- S Spike recovery outside accepted recovery limits

- B Analyte detected in the associated Method Blank
- H Holding times for preparation or analysis exceeded
- MCL Maximum Contaminant Level
- RL Reporting Limit

Hall Environmental Analysis Laboratory, Inc.

Date: 04-Apr-08

CLIENT: R.T. Hicks Consultants, LTD

Client Sample ID: MW-01 TOP

Lab Order: 0803291

Collection Date: 3/27/2008 5:00:00 PM

Project: South Four Lakes #15

Date Received: 3/28/2008

Lab ID: 0803291-02

Matrix: AQUEOUS

| Analyses | Result | PQL | Qual | Units | DF | Date Analyzed |
|--------------------------|--------|-----|------|-------|----|----------------------|
| EPA METHOD 300.0: ANIONS | | | | | | Analyst: SLB |
| Chloride | 1100 | 5.0 | | mg/L | 50 | 4/1/2008 10:37:48 AM |
| SM 2540C: TDS | | | | | | Analyst: TAF |
| Total Dissolved Solids | 2200 | 20 | | mg/L | 1 | 4/2/2008 |

Qualifiers: * Value exceeds Maximum Contaminant Level
E Value above quantitation range
J Analyte detected below quantitation limits
ND Not Detected at the Reporting Limit
S Spike recovery outside accepted recovery limits

B Analyte detected in the associated Method Blank
H Holding times for preparation or analysis exceeded
MCL Maximum Contaminant Level
RL Reporting Limit

Hall Environmental Analysis Laboratory, Inc.

Date: 04-Apr-08

CLIENT: R.T. Hicks Consultants, LTD
Lab Order: 0803291
Project: South Four Lakes #15
Lab ID: 0803291-03

Client Sample ID: MW-01
Collection Date: 3/27/2008 5:30:00 PM
Date Received: 3/28/2008
Matrix: AQUEOUS

| Analyses | Result | PQL | Qual | Units | DF | Date Analyzed |
|---------------------------------|--------|-----|------|-------|-----|----------------------|
| EPA METHOD 300.0: ANIONS | | | | | | Analyst: SLB |
| Chloride | 4700 | 20 | | mg/L | 200 | 4/1/2008 12:39:39 PM |
| SM 2540C: TDS | | | | | | Analyst: TAF |
| Total Dissolved Solids | 8100 | 20 | | mg/L | 1 | 4/2/2008 |

Qualifiers:

- * Value exceeds Maximum Contaminant Level
- E Value above quantitation range
- J Analyte detected below quantitation limits
- ND Not Detected at the Reporting Limit
- S Spike recovery outside accepted recovery limits

- B Analyte detected in the associated Method Blank
- H Holding times for preparation or analysis exceeded
- MCL Maximum Contaminant Level
- RL Reporting Limit

QA/QC SUMMARY REPORT

Client: R.T. Hicks Consultants, LTD

Project: South Four Lakes #15

Work Order: 0803291

| Analyte | Result | Units | PQL | %Rec | LowLimit | HighLimit | %RPD | RPDLimit | Qual |
|----------------------------------|--------|-------|------|------|----------|-----------|-------|----------|-------------------------------------|
| Method: EPA Method 300.0: Anions | | | | | | | | | |
| Sample ID: MB | | MBLK | | | | | | | |
| Chloride | ND | mg/L | 0.10 | | | | | | |
| Batch ID: R27910 | | | | | | | | | Analysis Date: 3/28/2008 8:06:09 AM |
| Sample ID: MB | | MBLK | | | | | | | |
| Chloride | ND | mg/L | 0.10 | | | | | | |
| Batch ID: R27942 | | | | | | | | | Analysis Date: 4/1/2008 9:10:46 AM |
| Sample ID: LCS | | LCS | | | | | | | |
| Chloride | 5.272 | mg/L | 0.10 | 105 | 90 | 110 | | | |
| Batch ID: R27910 | | | | | | | | | Analysis Date: 3/28/2008 8:23:33 AM |
| Sample ID: LCS | | LCS | | | | | | | |
| Chloride | 5.118 | mg/L | 0.10 | 102 | 90 | 110 | | | |
| Batch ID: R27942 | | | | | | | | | Analysis Date: 4/1/2008 9:28:10 AM |
| Method: SM 2540C: TDS | | | | | | | | | |
| Sample ID: 0803291-02A MSD | | MSD | | | | | | | |
| Total Dissolved Solids | 3264 | mg/L | 20 | 101 | 80 | 120 | 0.738 | 20 | |
| Batch ID: 15527 | | | | | | | | | Analysis Date: 4/2/2008 |
| Sample ID: MB-15527 | | MBLK | | | | | | | |
| Total Dissolved Solids | ND | mg/L | 20 | | | | | | |
| Batch ID: 15527 | | | | | | | | | Analysis Date: 4/2/2008 |
| Sample ID: LCS-15527 | | LCS | | | | | | | |
| Total Dissolved Solids | 1007 | mg/L | 20 | 100 | 80 | 120 | | | |
| Batch ID: 15527 | | | | | | | | | Analysis Date: 4/2/2008 |
| Sample ID: 0803291-02A MS | | MS | | | | | | | |
| Total Dissolved Solids | 3240 | mg/L | 20 | 99.0 | 80 | 120 | | | |

Qualifiers:

| | | | |
|---|--|----|--|
| E | Value above quantitation range | H | Holding times for preparation or analysis exceeded |
| J | Analyte detected below quantitation limits | ND | Not Detected at the Reporting Limit |
| R | RPD outside accepted recovery limits | S | Spike recovery outside accepted recovery limits |

Hall Environmental Analysis Laboratory, Inc.

Sample Receipt Checklist

Client Name RT HICKS

Date Received:

3/28/2008

Work Order Number 0803291

Received by: TLS

Sample ID labels checked by:

AS

Initials

Checklist completed by:

Jane Shomin

Signature

3/28/08

Date

Matrix:

Carrier name Client drop-off

Shipping container/cooler in good condition?

Yes ☒

No ☐

Not Present ☐

Custody seals intact on shipping container/cooler?

Yes ☐

No ☐

Not Present ☐

Not Shipped ☒

Custody seals intact on sample bottles?

Yes ☐

No ☐

N/A ☒

Chain of custody present?

Yes ☒

No ☐

Chain of custody signed when relinquished and received?

Yes ☒

No ☐

Chain of custody agrees with sample labels?

Yes ☒

No ☐

Samples in proper container/bottle?

Yes ☒

No ☐

Sample containers intact?

Yes ☒

No ☐

Sufficient sample volume for indicated test?

Yes ☒

No ☐

All samples received within holding time?

Yes ☒

No ☐

Water - VOA vials have zero headspace?

No VOA vials submitted ☒

Yes ☐

No ☐

Water - Preservation labels on bottle and cap match?

Yes ☐

No ☐

N/A ☒

Water - pH acceptable upon receipt?

Yes ☐

No ☐

N/A ☒

Container/Temp Blank temperature?

2°

<6° C Acceptable

If given sufficient time to cool.

COMMENTS:

Client contacted

Date contacted:

Person contacted

Contacted by:

Regarding:

Comments:

Corrective Action

Appendix C

Chloride Conceptual Model

R.T. Hicks Consultants, Ltd.

901 Rio Grande Blvd. NW, Suite F-142
Albuquerque, NM 87104

Appendix C: Conceptual Model of Chloride Fate and Transport in an Aquifer Underlying a Reserve Pit Release

The conceptual model considers the following factors:

1. A release of chloride-rich drilling fluid occurred during the operation of the pit or during the drying process when the pit held fluid, creating saturated flow between the pit and ground water.
2. Unsaturated transport of chloride from the residual pit material through the vadose zone to ground water after the pit dried is insignificant relative to transport via saturated flow described above.
3. The fluid released from the pit was saturated brine or brine diluted with residual water from the fresh water drilling pit. Saturated brine has a significantly higher density than the fresh water in the aquifer. Saturated brine weighs almost 11 pounds/gallon. Fresh water weight approximately 8.3 pounds/gallon.
4. Saturated brine released from a drilling pit can:
 - a. Move through the vadose zone via preferential pathways of saturated flow (e.g. through fractures) at the point of release, or
 - b. Move in the voids between the liner and earth material then through preferential pathways of saturated flow
5. When saturated brine enters the aquifer it will behave like a dense non-aqueous phase liquid (DNAPL) until diffusion, dilution and dispersion in the aquifer reduces the density of the brine and creates a mixed solution of brine and ground water.
6. The depth of penetration of brine as a DNAPL depends upon many factors including:
 - a. the total volume of brine released from the pit;
 - b. the density of the brine when it enters the aquifer;
 - c. the flux of brine into the aquifer through each preferential pathway;
 - d. the vertical hydraulic conductivity, hydraulic gradient, porosity, aquifer thickness, and the longitudinal, transverse, and vertical dispersivities;
 - e. the presence or absence of vertical pathways for DNAPL flow.

Figure C-1 illustrates a possible result where a relatively minor brine release enters an aquifer with a relatively high ground water flux. The mass of chloride released from the reserve pit is quickly dispersed and diluted, resulting in short-term minor impairment of ground water quality.

Figure C-2 shows a possible result of a relatively large brine release to an aquifer with a ground water flux that is equal to or less than the first example. Note that Time 6 is 3-4 years after the release, not 2-3 years as in the first example. Chloride concentrations in the monitoring well are higher due to the larger flux of brine into the aquifer.

Figure C-3 shows a possible result where a relatively large brine release flows through a limited number of preferential pathways, causing a focused impact to a thin, fine-grained aquifer with a relatively low ground water flux. Because of these conditions, the depth of DNAPL penetration is greater than the previous examples. The brine DNAPL flows to the bottom of the aquifer and "settles" on the underlying aquiclude.

Each brine release site will exhibit a unique set of conditions that will create a unique geometry of the impacted aquifer. These conceptual models of various brine release scenarios can assist in guiding the characterization effort at a given site. For example, deep ground water sampling points may not be necessary for the conditions described by Figure C-1. The conditions presented in Figure C-3 not only require monitoring of ground water at the base of the aquifer but may allow for cost-effective ground water restoration using a pumping well that focuses pumping at the base of the aquifer.

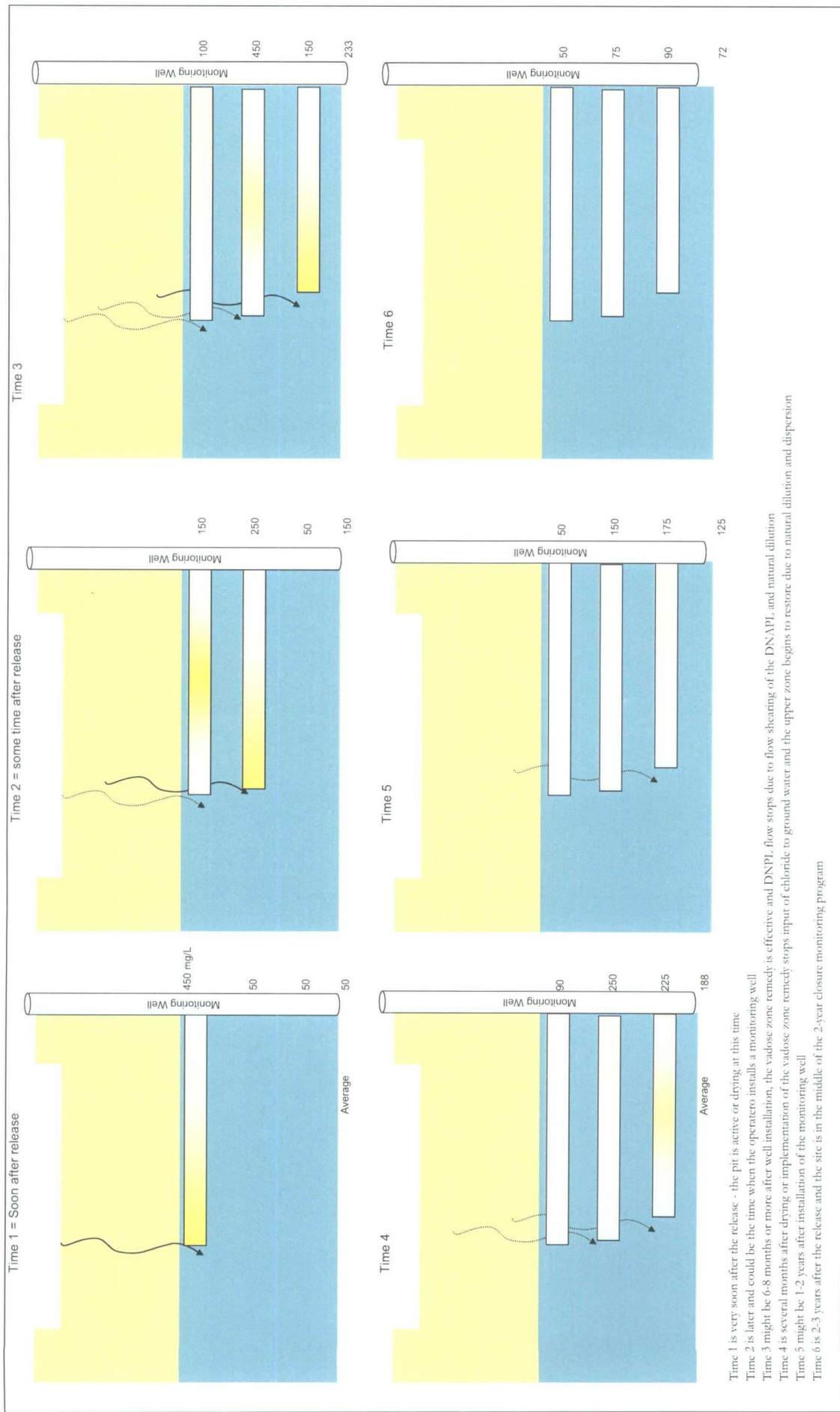
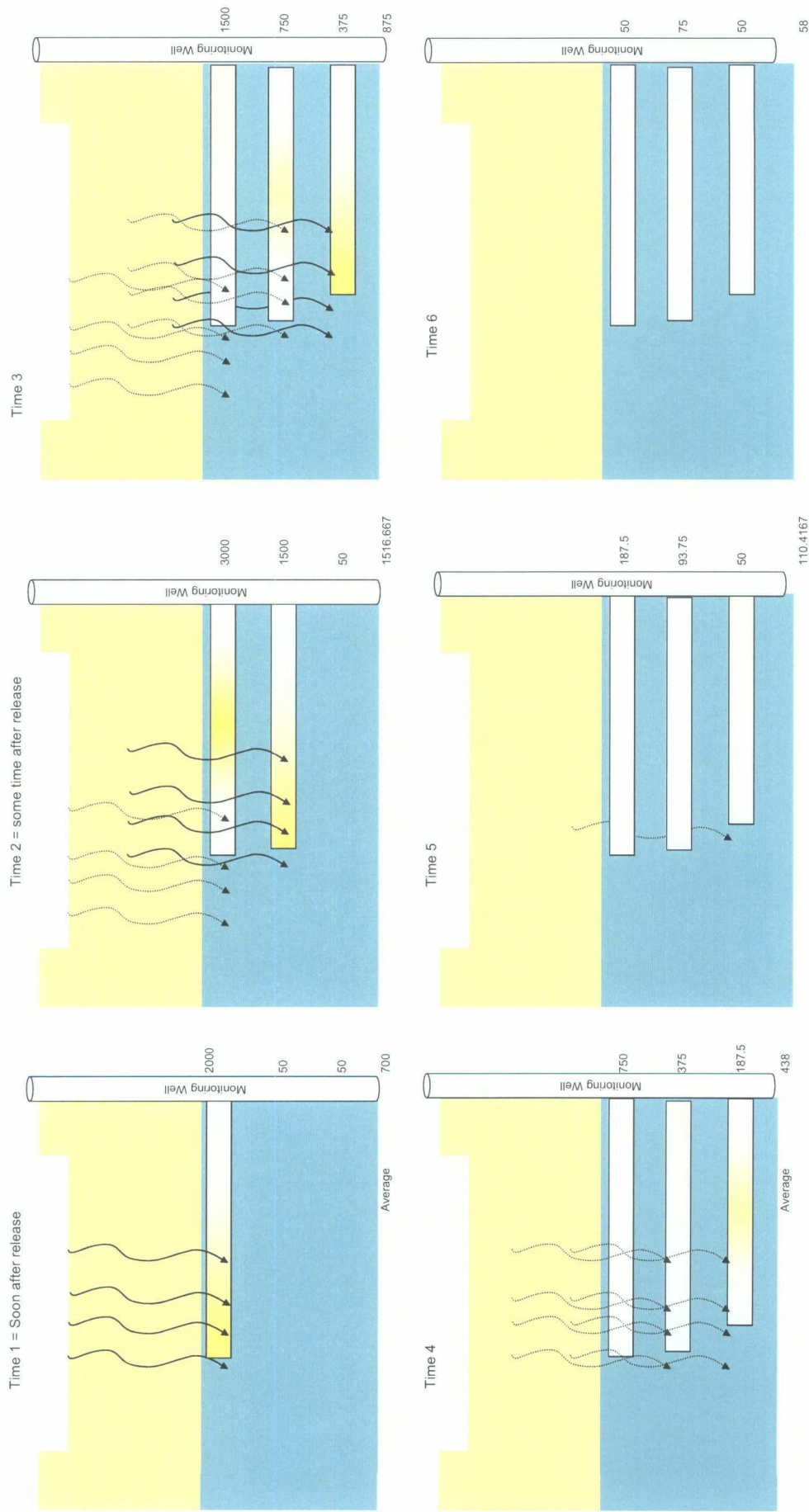
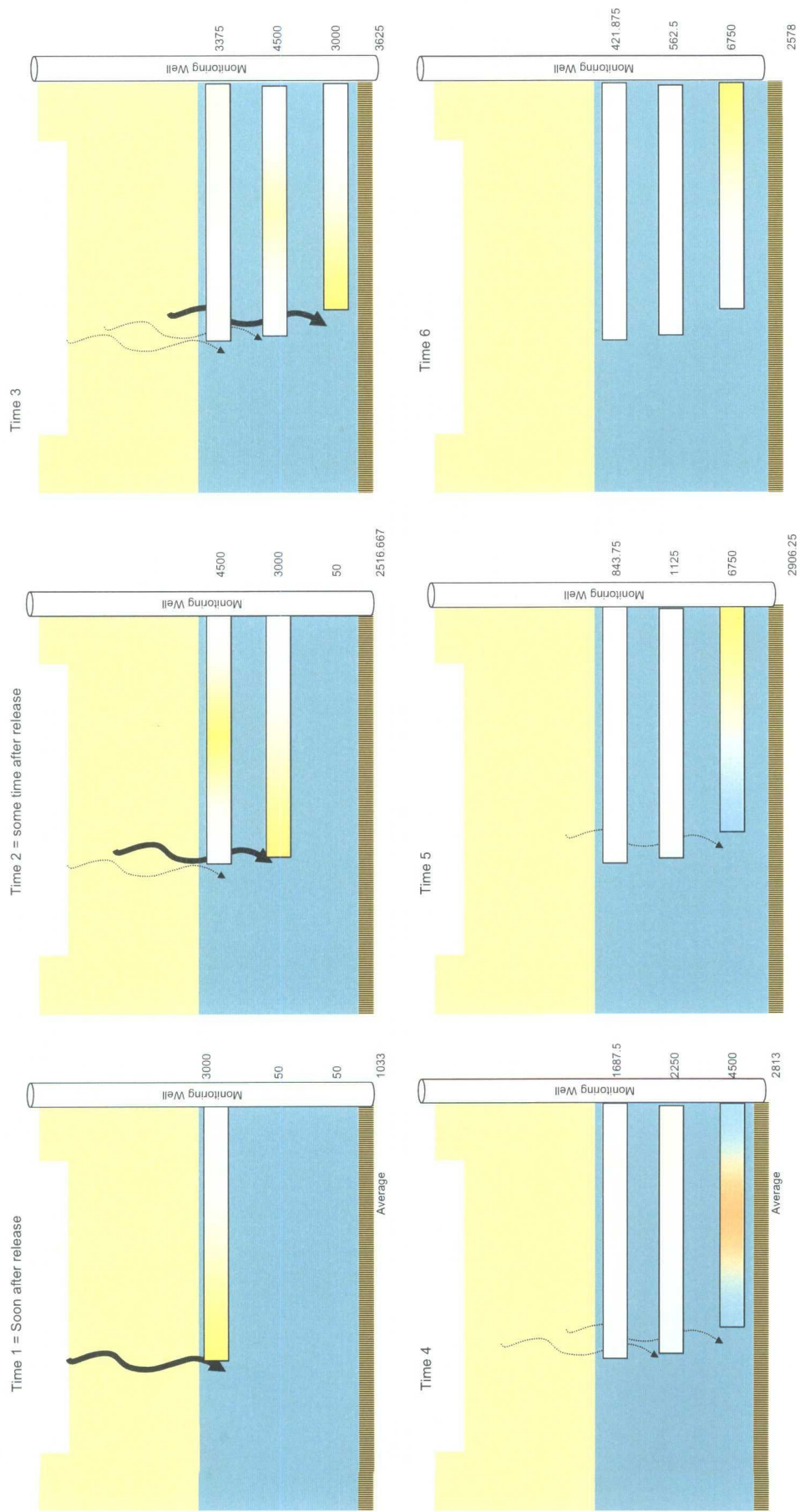


Figure C-1: Conceptual model of a minor release to a "high ground water flux" aquifer



Time 1 is very soon after the release - the pit is active or drying at this time
 Time 2 is later and could be the time when the operator installs a monitoring well
 Time 3 might be 6-8 months or more after well installation; the vadose zone remedy is effective and DNAPL flow stops due to flow shearing of the DNAPL and natural dilution
 Time 4 is several months after drying or implementation of the vadose zone remedy stops input of chloride to ground water and the upper zone begins to restore due to natural dilution and dispersion
 Time 5 might be 1-3 years after installation of the monitoring well
 Time 6 is 3-4 years after the release and the site is in the middle of the 2-year closure monitoring program

Figure C-2: Conceptual model of a relatively large brine release to an aquifer with a moderate ground water flux.



Time 1 is very soon after the release - the pit is active or drying at this time
 Time 2 is later and could be the time when the operator installs a monitoring well
 Time 3 might be 6-8 months or more after well installation, the vadose zone remedy is effective and DNAPL flow stops due to flow shearing of the DNAPL and natural dilution
 Time 4 is several months after drying or implementation of the vadose zone remedy stops input of chloride to ground water and the upper zone begins to restore due to natural dilution and dispersion
 Time 5 might be 2-4 years after installation of the monitoring well
 Time 6 is 4-5 years after the release and the site is in the middle of the 2-year closure monitoring program

Figure C-3: Brine release to a thin fine-grained aquifer

Appendix D

Quality Assurance Protocols

R.T. Hicks Consultants, Ltd.

901 Rio Grande Blvd. NW, Suite F-142
Albuquerque, NM 87104



Standard Guide for Sampling Ground-Water Monitoring Wells¹

This standard is issued under the fixed designation D 4448; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers sampling equipment and procedures and "in the field" preservation, and it does not include well location, depth, well development, design and construction, screening, or analytical procedures that also have a significant bearing on sampling results. This guide is intended to assist a knowledgeable professional in the selection of equipment for obtaining representative samples from ground-water monitoring wells that are compatible with the formations being sampled, the site hydrogeology, and the end use of the data.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for collecting ground-water quality samples from monitoring wells and is not intended to serve as a ground-water monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are provided for information only.

1.4 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)²

D 5088 Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites²

D 5792 Practice for Generation of Environmental Data Related to Waste Management Activities; Development of

Data Quality Objectives³

D 5903 Guide for Planning and Preparing a Ground-Water Sampling Event⁴

D 6089 Guide for Documenting a Ground-Water Sampling Event⁴

D 6452 Guide for Purging Methods for Wells Used for Ground-Water Quality Investigations⁴

D 6517 Guide for Field Preservation of Ground-Water Samples⁴

2.2 EPA Standards:

EPA Method 9020A

EPA Method 9022

3. Terminology

3.1 Definitions:

3.1.1 *low-flow sampling*—a ground water sampling technique where the purge and sampling rates do not result in significant changes in formation seepage velocity.

3.1.2 *minimal purge sampling*—the collection of ground water that is representative of the formation by purging only the volume of water contained by the sampling equipment (that is, tubing, pump bladder).

3.1.2.1 *Discussion*—This sampling method should be considered in situations where very low yield is a consideration and results from this sampling method should be scrutinized to confirm that they meet data quality objectives (DQOs) and the work plan objectives.

3.1.3 *passive sampling*—the collection of ground-water quality data so as to induce no hydraulic stress on the aquifer.

3.1.4 *water quality indicator parameters*—refer to field monitoring parameters that include but are not limited to pH, specific conductance, dissolved oxygen, oxidation-reduction potential, temperature, and turbidity that are used to monitor the completeness of purging.

4. Summary of Guide

4.1 The equipment and procedures used for sampling a monitoring well depend on many factors. These include, but are not limited to: the design and construction of the well, rate of ground-water flow, and the chemical species of interest. Sampling procedures may be different if analyses for trace organics, volatiles, oxidizable species, or trace metals are

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² Annual Book of ASTM Standards, Vol 04.08.

³ Annual Book of ASTM Standards, Vol 11.04.

⁴ Annual Book of ASTM Standards, Vol 04.09.

needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well purging, sample withdrawal, and field preparation of samples. Certain sampling protocols eliminate the first step.

4.2 The sampling must be well planned and all sample containers must be prepared prior to going to the field. These procedures should be incorporated in the approved work plan that should accompany the sampling crew so that they may refer to it for guidance on sampling procedures and analytes to be sampled (see Guide D 5903).

4.3 Monitoring wells must be either purged to remove stagnant water in the well casing or steps must be taken to ensure that only water meeting the DQOs and the work plan objectives is withdrawn during sampling (see Practice D 5792). When well purging is performed, it is accomplished by either removing a predetermined number of well volumes or by the removal of ground water until stable water quality parameters have been obtained. Ideally this purging is performed with minimal well drawdown and minimal mixing of the formation water with the stagnant water above the screened interval in the casing. Passive sampling and the minimal purge methods do not attempt to purge the water present in the monitoring well prior to sampling (1).⁵ The minimal purge method attempts to purge only the sampling equipment. Each of these methods is discussed in greater detail in Section 6.

4.4 The types of chemical species that are to be sampled as well as the reporting limits are prime factors for selecting sampling devices (2, 3). The sampling device and all materials and devices the water contacts must be constructed of materials that will not introduce contaminants or alter the analytes of concern in any way. Material compatibility is further discussed in Section 8.

4.5 The method of sample collection can vary with the parameters of interest. The ideal sampling scheme employs a completely inert material, does not subject the sample to pressure change, does not expose the sample to the atmosphere, or any other gaseous atmosphere before conveying it to the sample container or flow cell for on-site analysis. Since these ideals are not always obtainable, compromises must be made by the knowledgeable individual designing the sampling program. These concerns should be documented in the data quality objectives (DQOs) of the sampling plan (see Practice D 5792) (4).

4.6 The degree and type of effort and care that goes into a sampling program is always dependent on the chemicals of concern and their reporting levels as documented in the project's DQOs. As the reporting level of the chemical species of analytical interest decreases, the precautions necessary for sampling generally increase. Therefore, the sampling objective must clearly be defined ahead of time in the DQOs. The specific precautions to be taken in preparing to sample for trace organics are different from those to be taken in sampling for trace metals. A draft U.S. EPA guidance document (5) concern-

ing monitoring well sampling, including considerations for trace organics, is available to provide additional guidance.

4.7 Care must be taken not to contaminate samples or monitoring wells. All samples, sampling devices, and containers must be protected from possible sources of contamination when not in use. Water level measurements should be made according to Test Method D 4750 before placing, purging, or sampling equipment in the well. Redox potential, turbidity, pH, specific conductance, DO (dissolved oxygen), and temperature measurements should all be performed on the sample in the field, if possible, since these parameters change too rapidly to be conducted by a fixed laboratory under most circumstances. Field meter(s) or sondes equipped with flow-through cells are available that are capable of continuously monitoring these parameters during purging if they are being used as water quality indicator parameters. These devices prevent the mixing of oxygen with the sample and provide a means of determining when the parameters have stabilized. Certain measurements that are used as indicators of biological activity, such as ferrous iron, nitrite, and sulfite, may also be conducted in the field since they rapidly oxidize. All temperature measurements must be done prior to any significant atmospheric exposure.

5. Significance and Use

5.1 The quality of ground water has become an issue of national concern. Ground-water monitoring wells are one of the more important tools for evaluating the quality of ground water, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

5.2 The goal in sampling ground-water monitoring wells is to obtain samples that meet the DQOs. This guide discusses the advantages and disadvantages of various well sampling methods, equipment, and sample preservation techniques. It reviews the variables that need to be considered in developing a valid sampling plan.

6. Well Purging

6.1 Water that stands within a monitoring well for a long period of time may become unrepresentative of formation water because chemical or biochemical change may alter water quality or because the formation water quality may change over time (see Guide D 6452). Even if it is unchanged from the time it entered the well, the stagnant water may not be representative of formation water at the time of sampling. There are two approaches to purging that reflect two differing viewpoints: to purge a large volume of ground water and to purge a minimum of, or no ground water before collecting a sample. The approach most often applied is to purge a sufficient volume of standing water from the casing, along with sufficient formation water to ensure that the water being withdrawn at the time of sampling is representative of the formation water. Typically, three to five well volumes are used. An alternative method that is gaining acceptance is to minimize purging and to conduct purging at a low flow rate or to eliminate purging entirely.

6.2 In any purging approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns

⁵ The boldface numbers in parentheses refer to a list of references at the end of this guide.

around the well. Two potential negative effects are the introduction of ground water that is not representative of water quality immediately around the monitoring well and artificially high velocities entering the well resulting in elevated turbidity and analytical data that reflects the absorption of contaminants to physical particles rather than soluble concentrations in ground water. It may also result in cascading water from the top of the screen that can result in changes in dissolved gasses, redox state, and ultimately affect the concentration of the analytes of interest through the oxidation of dissolved metals and possible loss of volatile organic compounds (VOCs). There may also be a lingering effect on the dissolved gas levels and redox state from air being introduced and trapped in the sandpack. In no instance shall a well be purged dry. If available, the field notes or purge logs generated during previous sampling or development of the well as well as construction logs should be reviewed to assist in the selection of the most appropriate sampling method.

6.3 The most often applied purging method has an objective to remove a predetermined volume of stagnant water from the casing prior to sampling. The volume of stagnant water can either be defined as the volume of water contained within the casing and screen, or to include the well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out. Research with a tracer in a full scale model 2-in. polyvinyl chloride (PVC) well (6) indicates that pumping 5 to 10 times the volume of the well via an inlet near the free water surface is sufficient to remove all the stagnant water in the casing. This approach (with three to five casing volumes purged) was suggested by the U.S. EPA (7).

6.4 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some point well below the water surface, purge only the volume below that point then withdraw the sample from a deeper level. Research indicates this approach should avoid most contamination associated with stagnant water (6, 8). Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stagnant water from above. But the packer must be above the top of the screened zone, or stagnant water from above the packer may flow into the purged zone through the well's gravel/sand pack.

6.5 An alternate method is based on research by Barcelona, Wehmann, and Varlien (1) and Puls and Powell (2). Their research suggests that purging at rates less than 1 L/min (approximately 0.25 gal/min) provides more reproducible VOCs and metals analytical results than purging at high rates. This method is based on the premise that at very low pumping rates, there is little mixing of the water column and laminar ground-water flow through the screen provides a more consistent sample. This sampling method also produces less turbid samples that may eliminate the need for filtration when collecting metals. This method is commonly referred to as low-flow sampling.

6.6 The low-flow sampling approach is most applicable to wells capable of sustaining a yield approximately equal to the pumping rate. A monitoring well with a very low yield may not be applicable to this technique since it may be difficult to

reduce the pumping rate sufficiently to prevent mixing of the water column in the well casing in such a well. The water level in the well being sampled should be continuously monitored using an electronic water-level indicator during low-flow sampling. Such a water-level indicator could be set below the water surface after sufficient water has been withdrawn to fill the pump, tubing, and flow cell. The water-level indicator would then produce a continuous signal indicating submersion. When the well is purged, if the water level falls below the water-level indicator probe, the signal indicates that the water level has fallen below the maximum allowable drawdown and the pumping rate should be decreased. Pumping is started at approximately 100 mL/min discharge rate and gradually adjusted to match the well's recharge rate. The selection of the type of pump is dependent on site-specific conditions and DQOs. The bladder pump design is most commonly used in this sampling method, however, the depth limitation of this pump may necessitate the use of a gas-driven piston pump in some instances.

6.7 A variation on the above purging approaches is to monitor one or more indicator parameters until stabilization of the selected parameter(s) has been achieved. Stabilization is considered achieved when measurements are within a pre-defined range. This range has been suggested to be approximately 10 % over two successive measurements made 3 min apart by the U.S. EPA (4). More recent documents (9) have suggested ranges $\pm 0.2^\circ\text{C}$ for temperature, ± 0.1 standard units for pH, $\pm 3\%$ for specific conductance, $\pm 10\%$ for DO, and ± 10 mV for redox potential. A disadvantage of the stabilization approach is that there is no assurance in all situations that the stabilized parameters represent formation water. These criteria should therefore be set on a site by site basis since if set too stringent, large volumes of contaminated purge water may be generated without ensuring that the samples are any more representative. In a low yielding formation, this could result in the well being emptied before the parameters stabilize. Also, if significant drawdown has occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. If these criteria are properly selected, the volume of investigative derived waste water may be reduced.

6.8 The indicator parameters that may be monitored include pH, temperature, specific conductance, turbidity, redox potential, and DO. A combination of a pump and field meter(s) or sondes equipped with a flow-through cell is ideal for this purpose since it allows the monitoring of one or more of these parameters on a continuous basis without exposure to the atmosphere. A typical flow-through cell application is shown in Fig. 1. The pump used in this technique may be any pump capable of producing a steady flow such as a peristaltic or bladder pump. If a submersible pump is used, the hydraulic pressure developed in the flow-through cell may be sufficient to force the probes out of their position. This problem may be eliminated by installing a tee connector in the discharge line to allow only a portion of the flow to enter the flow-through cell. Another concern with the low-flow sampling method is sorption onto the tubing. Studies have indicated that at flow rates of 0.1 L/min (0.026 gal/min), low-density polyethylene (LDPE)

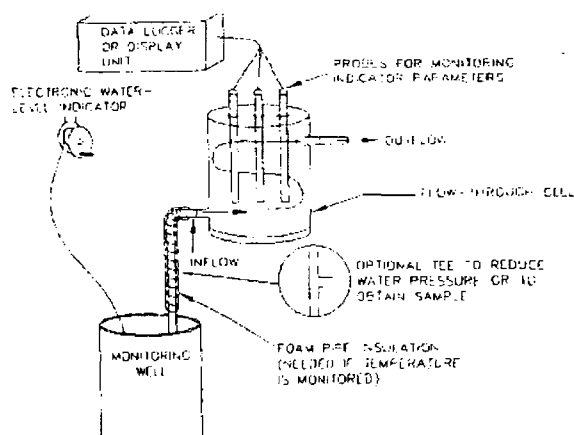


FIG. 1 Flow-Through Cell

and plasticized polypropylene tubings are prone to sorption and TFE-fluorocarbon should be used. This is especially a concern if tubing lengths of 15 m (50 ft) or longer are used (10).

6.9 Gibb and Schuller (11) have described a time-drawdown approach using knowledge of the well hydraulics to predict the percentage of stagnant water entering a pump inlet near the top of the screen at any time after flushing begins. Samples are collected when the percentage is acceptably low. As before, the advantage is that well volume has no direct effect on the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stagnant water due to effects other than drawdown (for example, density differences) is not accounted for in this approach.

6.10 An alternative to purging a well before sampling is to collect a water sample within the screened zone without purging. These techniques are based on studies that under certain conditions, natural ground-water flow is laminar and horizontal with little or no mixing within the well screen (12, 13). To properly use these sampling techniques, a water sample must be collected within the screened interval with little or no mixing of the water column within the casing. Examples of these techniques include minimal purge sampling which uses a dedicated sampling pump capable of pumping rates of less than 0.1 L/min, discrete depth sampling using a bailer that allows ground water entry at a controlled depth, (for example, differential pressure bailer (14)), or diffusion sampling. These sampling techniques are discussed in 8.1.10.

7. Materials and Manufacture

7.1 The choice of materials used in the construction of sampling devices should be based upon knowledge of what compounds may be present in the sampling environment and how the sample materials may interact via leaching, adsorption, or catalysis. A second concern is that corrosion or degradation may compromise the structural integrity of the sampling device. In some situations, PVC or other plastic may be sufficient. In others, an all TFE-fluorocarbon apparatus may be necessary. The potential presence of nonaqueous phase liquid (NAPL) should also be a consideration since its presence

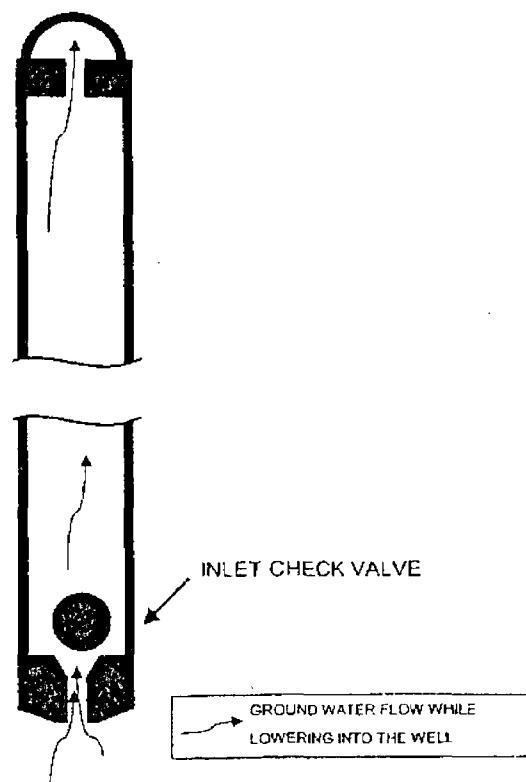


FIG. 2 Single Check Valve Bailer

would expose the sampling equipment to high concentrations of potential solvents. No one material is ideal in that each material will to some degree absorb or leach chemicals or may degrade on exposure to a chemical.

7.2 The advantages and disadvantages of these materials for sampling equipment are summarized in Table 1.

7.3 PVC:

7.3.1 If adhesives are avoided, PVC is acceptable in many cases although their use may still lead to some problems if trace organics are of concern or NAPL is present (15). At present, interactions occurring between PVC and ground water are not well understood. Tin, in the form of an organotin stabilizer added to PVC, may enter samples taken from PVC (16).

7.3.2 The structural integrity concerns with PVC increase with the concentration of PVC solvents in ground water. As such, NAPLs that are PVC solvents are a primary concern. Potential NAPLs that are of a concern for PVC and other commonly used plastics are listed in Table 2. Degradation of these materials is primarily by solvation, which is the penetration of the material by the solvent that ultimately causes softening and swelling that can lead to failure. Even in lower concentrations, however, PVC solvents may deteriorate PVC. Methylene chloride, which is a very effective PVC solvent, will soften PVC at one tenth its solubility limit while trichloroethylene, which is a less effective solvent, will begin to soften PVC at six tenths its solubility limit (17).

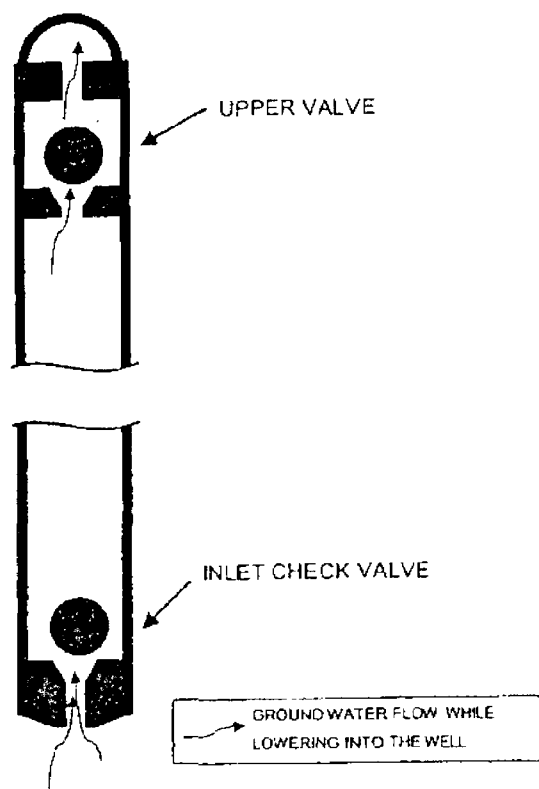


FIG. 3 Double Check Valve Bailer

7.4 TFE-Fluorocarbon Resins:

7.4.1 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices. Molded parts are exposed to high temperature during fabrication that destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point. Relative to PVC and stainless steel, TFE-fluorocarbon is less sorptive of cations (18).

7.4.2 Extruded TFE-fluorocarbon tubing may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once removed by flushing, should not affect the sample. TFE-fluorocarbon fluorinated ethylene propylene (FEP) and TFE-fluorocarbon perfluoroalkoxy (PFA) resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

7.5 Glass and Stainless Steel:

7.5.1 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is generally not used, however, because of difficulties in handling and fabrication. Stainless steel is strong and easily machined to fabricate equipment. It is, however, not totally immune to corrosion that could release metallic contaminants (see Table 1). Stainless steel contains various alloying metals, some of

these (that is, Nickel) may catalyze reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on ground-water quality and the constituents of interest.

7.5.2 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be able to be cleaned of trace organics, and must be cleaned between each monitoring well use to avoid cross-contamination of wells and samples. Decontamination of equipment PVC and stainless steel constructed sampling equipment exposed to organic chemicals, pesticides or nitroaromatic compounds generally can be successfully accomplished using a hot detergent solution followed by a hot water rinse. Equipment constructed of LDPE and TFE-fluorocarbon should also be hot air dried or oven dried at approximately 105°C to remove residual pesticides and organic contaminants, respectively (19, 20). A common method to verify that the device is "clean" and acceptable is to analyze a sample (equipment blank) that has been soaked in or passed through the sampling device, or both, to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples that represent the sampling equipment blank, in addition to other blanks (field blank and trip blank). Decontamination procedures are further discussed in Practice D 5088.

7.6 Additional samples are often collected in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chemical Society's committee on environmental improvement has published guidelines for data acquisition and data evaluation, which should be useful in such environmental evaluations (21).

8. Sampling Equipment

8.1 The choice of sampling technique must be based on an understanding of the hydrogeology of the site under investigation and the end use of the data. Since each technique has its advantages and disadvantages, no one technique can be chosen as the best overall technique. Since different techniques will likely yield different results, it is best to be consistent throughout an investigation to facilitate the comparison of data values over time. There is a fairly large choice of equipment presently available for ground-water sampling. The sampling devices can be categorized into the following nine basic types as described in the following sections:

8.1.1 Down-Hole Collection Devices:

8.1.1.1 Bailers, messenger bailers, or thief (22, 23) are examples of down-hole collection devices. They are not practical for removal of large volumes of water but are relatively inexpensive permitting their dedicated use and are widely used. These devices can be constructed in various shapes and sizes from a variety of materials. They do not subject the sample to pressure extremes.

8.1.1.2 A schematic of a single check valve unit is illustrated in Fig. 2. The bailer may be threaded in the middle so that additional lengths of blank casing may be added to

TABLE 1 Material Considerations In Selection Of Sampling Equipment (76)

| Material | Considerations |
|-------------------------|--|
| Polytetrafluoroethylene | <ul style="list-style-type: none"> • Virgin PTFE readily sorbs some organic solutes (17) • Ideal material in corrosive environments where inorganic compounds are of interest • Useful where pure product (organic compound) or high concentrations of PVC solvents exist • Potential structural problems because of its low tensile and compressive strengths, low wear resistance, and the extreme flexibility of the casing string as compared to other engineering plastics (40, 70, 71) • Potential problems with obtaining a seat between the casing and the annular sealant because of PTFE's low coefficient of friction and antistick properties as compared to other plastics (71) • Maximum string length of 2-in. (5-cm) diameter schedule PTFE casing should not exceed about 375 ft (~115 m) (72) • Expensive |
| Polyvinylchloride | <ul style="list-style-type: none"> • Leaching of compounds of tin or antimony, which are contained in original heat stabilizers during polymer formulation, could occur after long exposure • When used in conjunction with glued joints, leaching of volatile organic compounds from PVC primer and glues, such as THF (tetrahydrofuran), MEK (methyl ethyl ketone), MIBK (methyl isobutyl ketone) and cyclohexanone could leach into ground water. Therefore, threaded joints below the water table, sealed with O-rings or Teflon tape, are preferred • Cannot be used where pure product or high concentrations of a PVC solvent exist • There is conflicting data regarding the resistance of PVC to deterioration in the presence of gasoline (73) • Maximum string length of 2-in. (5-cm) diameter threaded PVC casing should not exceed 2000 ft (~610 m) (72) • PVC can warp and melt if heat cement (cement and water) is used as an annular or surface seal because of heat of hydration (74, 40) • PVC can volatilize CFCs into the atmosphere within the unsaturated zone, which can be a potential problem for studies of gas and moisture transport through the unsaturated zone • Easy to cut, assemble, and place in the borehole • Inexpensive |
| Stainless steel | <ul style="list-style-type: none"> • Generally has high corrosion resistance, which differs with type • Corrosion can occur under acidic and oxidizing conditions • Corrosion products are mostly iron compounds, with some trace elements • Primarily two common types: <ul style="list-style-type: none"> (1) Type 304 Stainless Steel: Iron alloyed with the following elements (percentages): Chromium (18-20 %), Nickel (8-11 %), Manganese (2 %), Silicon (0.75 %), Carbon (0.08 %), Phosphorus (0.04 %), Sulfur (0.03 %) (2) SS 316: Iron alloyed with the following elements (in percentages): Chromium (16-18 %), Nickel (11-14 %), Manganese (2 %), Molybdenum (2-3 %), Silicon (0.75 %), Carbon (0.08 %), Phosphorus (0.04 %), Sulfur (0.03 %) • Corrosion resistance is good for Type 304 stainless steel under aerobic conditions. Type 316 stainless steel has improved corrosion resistance over Type 304 under reducing conditions (75) • Expensive |
| Galvanized steel | <ul style="list-style-type: none"> • Less corrosion resistance than stainless steel and more resistance to corrosion than carbon steel (see Carbon steel entry) • Oxide coating could dissolve under chemically reduced conditions and release zinc and cadmium, and raise pH • Weathered or corroded surfaces present active adsorption sites for organic and inorganic constituents • Inexpensive |
| Carbon steel | <ul style="list-style-type: none"> • Corrosion products can occur (for example, iron and manganese oxides, metal sulfides, and dissolved metal species) • Sorption of organic compounds onto metal corrosion products is possible • Weathered surfaces present active adsorption sites for organic and inorganic constituents • Inexpensive |

increase the sampling volume. TFE-fluorocarbon, stainless steel, and PVC are the most common materials used for construction (24).

8.1.1.3 In operation, the single check valve bailer is gently lowered into the well to a depth just below the water surface, water enters the chamber through the bottom, and the weight of the water column closes the check valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check valve seat during chamber filling. Upon bailer withdrawal, the ball will immediately seat without sample loss through the check valve.

8.1.1.4 A double check valve bailer allows point source sampling at a specific depth (25, 26). The double check valve bailer is also effective at collecting dense, non-aqueous phase liquid (DNAPL) from the bottom of a monitoring well. An example is shown in Fig. 3. In this double check valve design, water flows through the sample chamber as the unit is lowered.

A venturi tapered inlet and outlet ensures that water passes through the unit with limited restriction. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation.

8.1.1.5 A top-filling bailer is a closed bottom tubular device, opened on top and provided with a loop or other fixture to attach to the drop line. The top-filling bailer is gently lowered below the water surface in the well and water pours into the bailer from the top. Although this variation on the bailer design results in greater agitation of the sample, it may be used to collect a sample of light, non-aqueous phase liquid (LNAPL) by lowering it just below the surface of the LNAPL and

TABLE 2 Chemical Compatibility Table For Selected NAPL (78)

| Chemical | PTFE (Teflon) | PP (Polypropylene) | PVC (Type I) | PVC (Type II) | 304 Stainless | 316 Stainless | Carbon Steel |
|---------------------------|---------------|--------------------|--------------|---------------|---------------|---------------|--------------|
| Benzene | R | X | U | U | G | G | G |
| Carbon Tetrachloride | R | U | X | U | E | E | G |
| Dichlorobenzene | R | R | U | U | ... | G | ... |
| Dichloroethane (DCA) | R | X | U | U | G | G | G |
| Dichloroethylene (DCE) | R | R | U | U | G | G | ... |
| Diesel Fuel | R | R | R | ... | E | E | G |
| Ethyl Benzene | R | U | U | U | S | G | U |
| Gasoline | R | X | R | ... | G | G | G |
| Hydraulic Oil (petro.) | R | X | R | ... | R | R | ... |
| Hydraulic Oil (synthetic) | R | X | R | ... | R | R | ... |
| Jet Fuels | R | X | R | R | G | G | G |
| Kerosene | R | R | R | R | G | G | G |
| Motor Oil | R | X | R | R | G | G | G |
| Naphthalene | R | R | U | U | E | E | G |
| Tetrachloroethylene (PCE) | R | U | U | U | E | E | G |
| Toluene | R | R | U | U | E | E | E |
| Trichloroethylene (TEC) | R | R | U | U | G | G | G |
| Xylenes | R | R | U | U | G | G | G |

For Metals

E < 2 mils Penetration/Year

G < 20 mils Penetration/Year

S < 50 mils Penetration/Year

U > 50 mils Penetration/Year

(1 mil = 0.001 in.)

R = Resistant (No corrosion rate reported)

For All Non-Metals

R = Resistant

U = Unsatisfactory

X = Conflicting Data, at least one reference reported unsatisfactory

allowing the bailer to skim the LNAPL from the surface of the water column.

8.1.1.6 The differential pressure bailer is a sealed canister body with two small diameter tubes of different heights built into its removable top (14). The bailer is usually constructed of stainless steel to provide sufficient weight to allow it to sink relatively quickly to the desired sampling depth. Once the bailer's downward progress is stopped, differences in hydrostatic pressure between the two tubes allows the bailer to fill through the lower tube as air is displaced through the upper tube. This type of bailer minimizes the exposure of the sample to air especially if fitted with internal 40 mL vials for direct sample bottle filling.

8.1.1.7 Special care must be taken to minimize exposing the sample to the atmosphere during the transfer of the sample from the bailer to the sample bottle. There are several approaches to overcome this issue. Bottom-emptying bailers used for sampling of VOCs, for example, should have an insertable sample cock or draft valve cock (often referred to as a bottom or bailer emptying device) in or near the bottom of the sampler allowing withdrawal of a sample from the bailer with minimal atmosphere exposure.

8.1.1.8 Suspension lines for bailers and other samplers should be kept off the ground and free of other contaminating materials that could be carried into the well. A plastic sheet may be spread out on the ground around the monitoring well for this purpose. Disposable TFE-fluorocarbon, PVC, polyethylene, and polypropylene bailers are available which offer time savings and all but eliminates the potential for cross contamination during sampling.

8.1.1.9 Sample oxidation is a concern with single check valve and top filling bailers. Sample oxidation might occur

during the extended time it takes to bail a sample if water levels are a great depth below the ground surface or if there is a delay in the transfer of the sample from the bailer to the sample bottles. Using point source bailers, however, minimizes the oxidation problem.

8.1.1.10 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber (27). Foerst, Kemmerer, and Bacon samplers are of this variety (23, 24, 26). A number of thief or messenger devices are available in various materials and shapes. Differential pressure bailers (14) also provide a point source sample but do not require manual tripping.

8.1.2 Bladder Pumps:

8.1.2.1 Bladder pumps consist of a flexible membrane enclosed by a rigid housing. Water enters the pump cavity through an inlet, usually located on the bottom of the pump. Compressed gas either from a compressor or air cylinder is injected into a bladder within the pump cavity forcing the check valve on the inlet to close and the sample up through a second check valve at the top of the pump and into a discharge line (Fig. 4). Water is prevented from re-entering the bladder by the top check valve. The bladder is then depressurized, allowing the pump to refill. The process is repeated to cycle the water to the surface. Samples taken from depths of 122 m (400 ft) have been reported.

8.1.2.2 A variety of design modifications and materials are available (29, 30) however, TFE-fluorocarbon bladders, either PVC, TFE-fluorocarbon resin or stainless steel bodies and fittings are most common. An automated controller system is

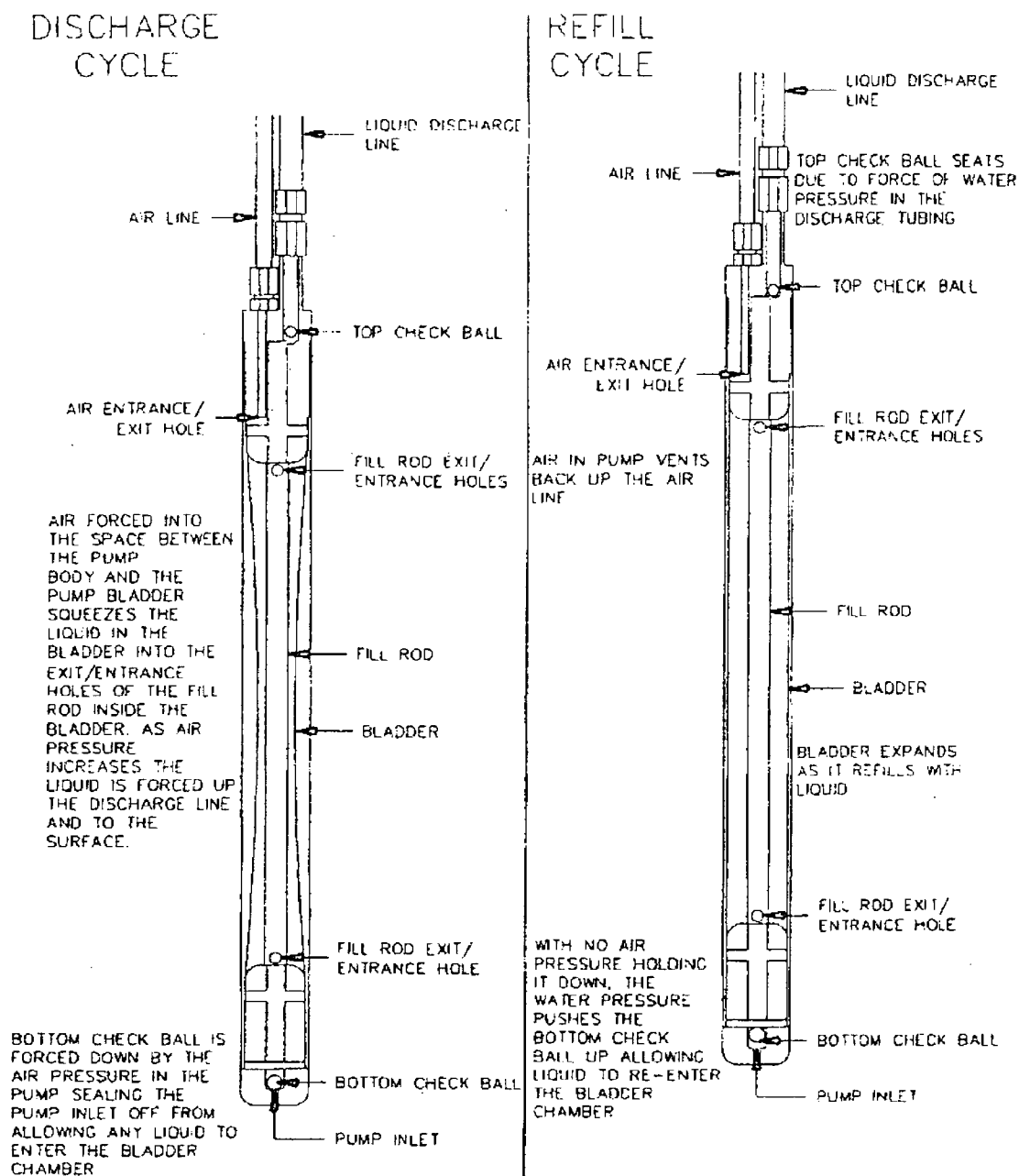


FIG. 4 Squeeze Type Bladder Pump

used to control the time between pressurization cycles and regulate pressure.

8.1.2.3 Bladder pumps have a distinct advantage over gas displacement pumps in that there is no contact with the driving gas. Disadvantages include the large gas volumes required, and difficulty in decontaminating the pump. This pump design is most applicable to dedicated well installations and where low pump rate or flow rate (less than 0.5 L/min) are required. The flow rate from a bladder pump is dependent on the dimensions of the bladder pump, controller settings, gas pressure, and total dynamic head.

8.1.3 Suction Lift Pumps:

8.1.3.1 Three types of suction lift pumps are the direct line, centrifugal, and peristaltic. A major disadvantage of any suction pump is that it is limited in its ability to raise water by the head available from atmospheric pressure. The theoretical suction limit is about 10.4 m (34 ft), but most suction pumps are capable of maintaining a water lift of only 7.6 m (25 ft) (31).

8.1.3.2 Many suction pumps draw water through a volute in which impellers, pistons, or other devices operate to induce a vacuum. Such pumps are probably unacceptable for most sampling purposes because they are usually constructed of non-inert materials such as brass or mild steel and may expose samples to lubricants. They often induce very low pressures around rotating vanes or other such parts such that degassing or potentially cavitation may occur. They can mix air with the sample via small leaks in the casing, and they are difficult to adequately clean between uses. Such pumps may be acceptable for purging of wells, but should not generally be used for sampling.

8.1.3.3 An exception to the above statements is a peristaltic pump (also known as a rotary peristaltic pump). A peristaltic pump is a self-priming, low-volume suction pump that consists of a rotor with rollers (32). Flexible tubing is inserted around the pump rotor and squeezed by rollers as they rotate. One end of the tubing is placed into the well (a weighted end may be used) while the other is connected directly to a receiving vessel. As the rotor moves, reduced pressure is created in the well tubing and an increased pressure on the tube leaving the rotor head. Pumping rates may be controlled by varying the speed of the rotor or by changing the size of the pump head, which contains the pump rotor.

8.1.3.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may be degassed (cavitation is unlikely), but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pump head itself. A section of silicone tubing is commonly used within the peristaltic pump head, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement (33) recommends using medical grade silicone tubing for VOC sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Various manufacturers offer

tubing lined with TFE-fluorocarbon or Viton[®] for use with their pumps. Plasticized polypropylene tubings and LDPE should be avoided if flow rates less than 0.1 L/min (0.025 g/min) are used (10). The extraction rate with this method can range from 0.04 to 30 L/min (0.01 to 8 gal/min) (34).

8.1.3.5 There is disagreement on the applicability of peristaltic pumps for the collection of groundwater samples. Research by Tai, et al (35) has shown that peristaltic pumps provide adequate recovery of VOCs. The U.S. EPA (4) does not recommend its use because of studies that suggest that VOCs may be lost during sampling (36).

8.1.3.6 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two-way stopper bottle and a hand held or mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism (37, 38).

8.1.3.7 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement (37, 38, 39).

8.1.3.8 Suction pump approaches offer a simple sample retrieval method for shallow monitoring wells. The direct line method is portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151 L/min (5 to 40 gal/min) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two pumps, as discussed in 8.1.3.4.

8.1.3.9 All three systems can be specially designed so that the water sample contacts only the TFE-fluorocarbon or silicone tubing prior to sample bottle entry. Dedicated tubing is recommended for each well or piezometer sampled. Each of these methods that rely on suction can change solution chemistry by causing degassing which may result in loss of volatile compounds and dissolved gasses and this should be a consideration in their application (34).

8.1.4 Electric Submersible Pumps:

8.1.4.1 A submersible pump consists of a sealed electric motor that powers a piston, impeller, or helical single thread worm. Water is brought to the surface through a discharge tube. Similar pumps are commonly used in the water well industry and many designs exist (40).

8.1.4.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 L/min (1.2 gal/min) flow rate at 33.5 m (110 ft) has been developed (41). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 L/min (14 gal/min) depending upon the depth of the total dynamic head (42).

[®] Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.

8.1.4.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the discharge tube during sampling. The possibility of introducing trace metals into the sample from pump materials also exists; however, submersible pumps designed specifically for environmental work do exist. These pumps are constructed of relatively inert materials such as stainless steel, TFE-fluorocarbons and Viton. Decontamination procedures are discussed in Practice D 5088. Recent research, however, has suggested that steam cleaning followed by rinsing with unchlorinated, deionized water should be used between samplings when analysis for VOCs is required (43). Complete decontamination of submersible pumps is difficult and should be confirmed by the collection of equipment blanks.

8.1.4.4 Submersible pumps have several disadvantages that should be considered. The silt and fine sand commonly present in monitoring wells may cause excessive wear to internal impellers and stators. These pumps also commonly require a high-amperage 120/220-V power source and a reel and winch system that limit their mobility. Submersible pumps may also not be suitable for collecting liquids containing VOCs or dissolved gasses because of their potential to degas the sample.

8.1.5 Gas-Lift Pumps:

8.1.5.1 Gas-lift pumps use compressed air to bring a water sample to the surface. Water is forced up an eductor pipe that may be the outer casing or a smaller diameter pipe inserted into the well annulus below the water (44, 45).

8.1.5.2 A similar principle is used for a unit that consists of a small diameter plastic tube perforated in the lower end. This tube is placed within another tube of slightly larger diameter. Compressed air is injected into the inner tube; the air bubbles through the perforations, thereby lifting the water sample via the annulus between the outer and inner tubing (45). In practice, the eductor line should be submerged to a depth equal to 60 % of the total submerged eductor length during pumping (40). A 60 % ratio is considered optimal although a 30 % submergence ratio is adequate.

8.1.5.3 The source of compressed gas may be a hand pump for depths generally less than 7.6 m (25 ft). For greater depths, air compressors, and pressurized air cylinders have been used. When air compressors are used, an air-oil filter must be installed to minimize the introduction of oil to the well.

8.1.5.4 As already mentioned, gas-lift methods result in considerable sample agitation and mixing within the well, and cannot be used for samples which will be tested for VOCs or dissolved gasses (for example, DO, methane). The eductor pipe or weighted plastic tubing is a potential source of sample contamination. In addition, Gibb (11) expressed concerns in sampling for inorganics. These concerns were attributed to changes in redox, pH, and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.

8.1.6 Gas Displacement Pumps:

8.1.6.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment.

The principle is shown schematically in Fig. 5. Water fills the chamber. A positive pressure is applied to the gas line closing the sampler check valve and forcing water up the sample line. The cycle is repeated by removing the pressure. Vacuum can also be used in conjunction with the gas (46). The device can be permanently installed in the well (47, 48, 49) or lowered into the well (50, 51).

8.1.6.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed (52, 53). The unit was designed specifically for sample testing for trace level organics. Continuous flow rates of up to 38 L/min (10 gal/min) are possible.

8.1.6.3 Gas displacement pumps offer reasonable potential for preserving sample integrity because little driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses and contamination from the driving gas and the housing materials.

8.1.7 Gas Driven Piston Pumps:

8.1.7.1 A double piston pump powered by compressed air is illustrated in Fig. 6. Pressurized gas enters the chamber between the pistons; the alternating chamber pressurization activates the piston that allows water entry during the suction stroke of the piston and forces the sample to the surface during the pressure stroke (54). Pumping rates between 0.16 and 0.51 L/min (0.04 and 0.13 gal/min) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

8.1.7.2 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from

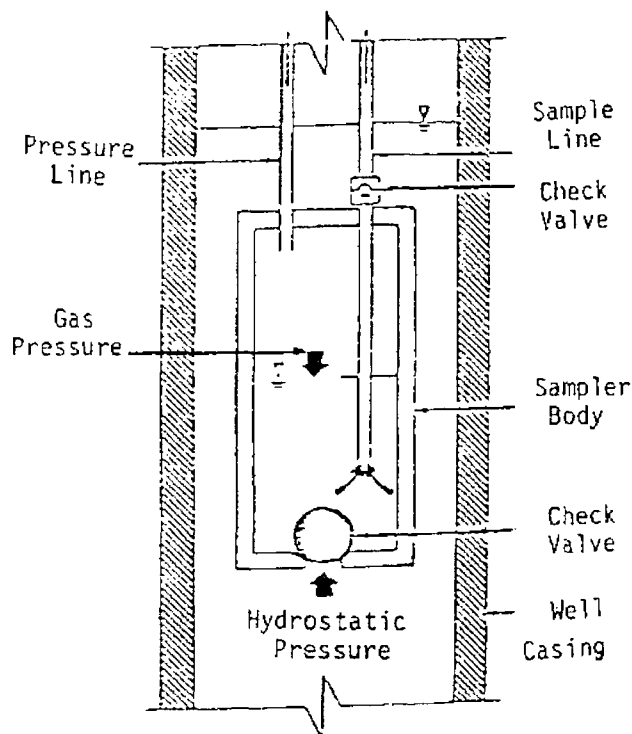


FIG. 5 The Principle of Gas Displacement Pumping

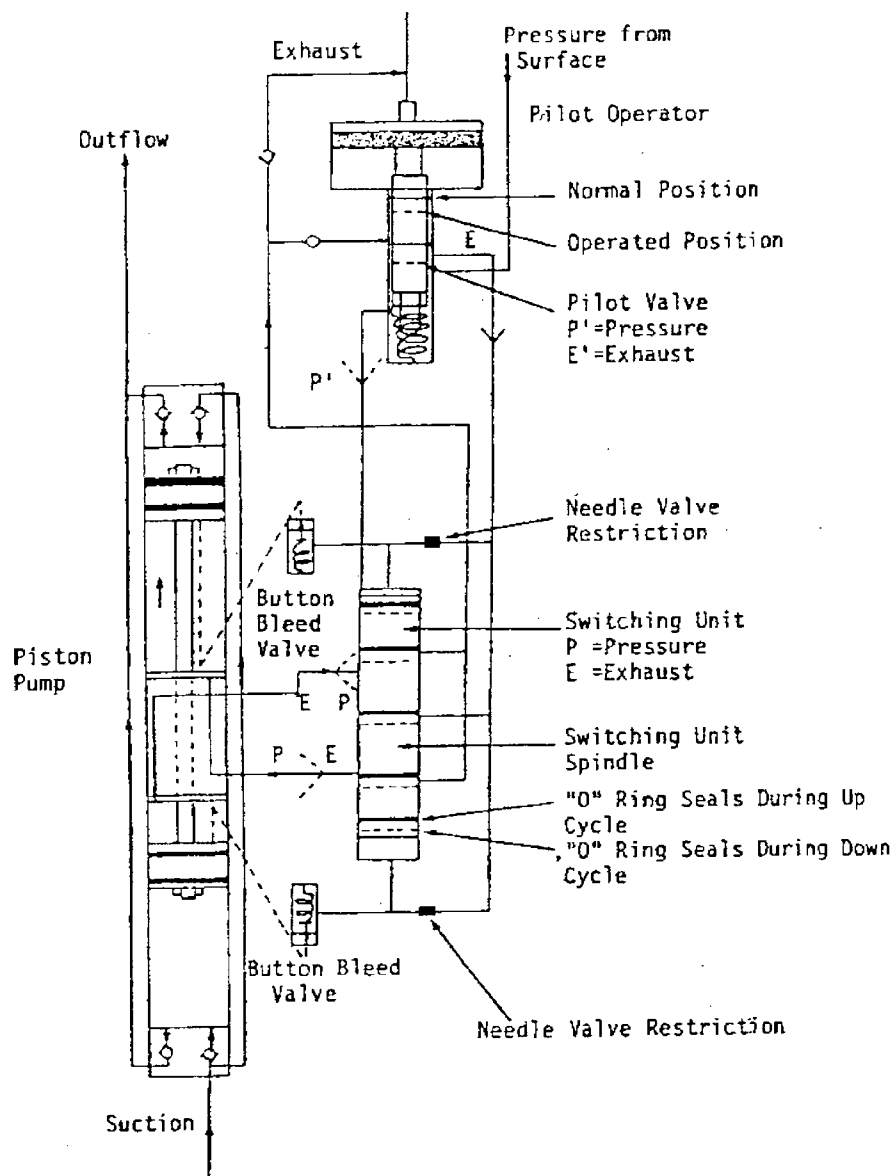


FIG. 6 Gas-Driven Piston Pump

the stainless steel and brass is a potential problem and the quantity of gas used is significant.

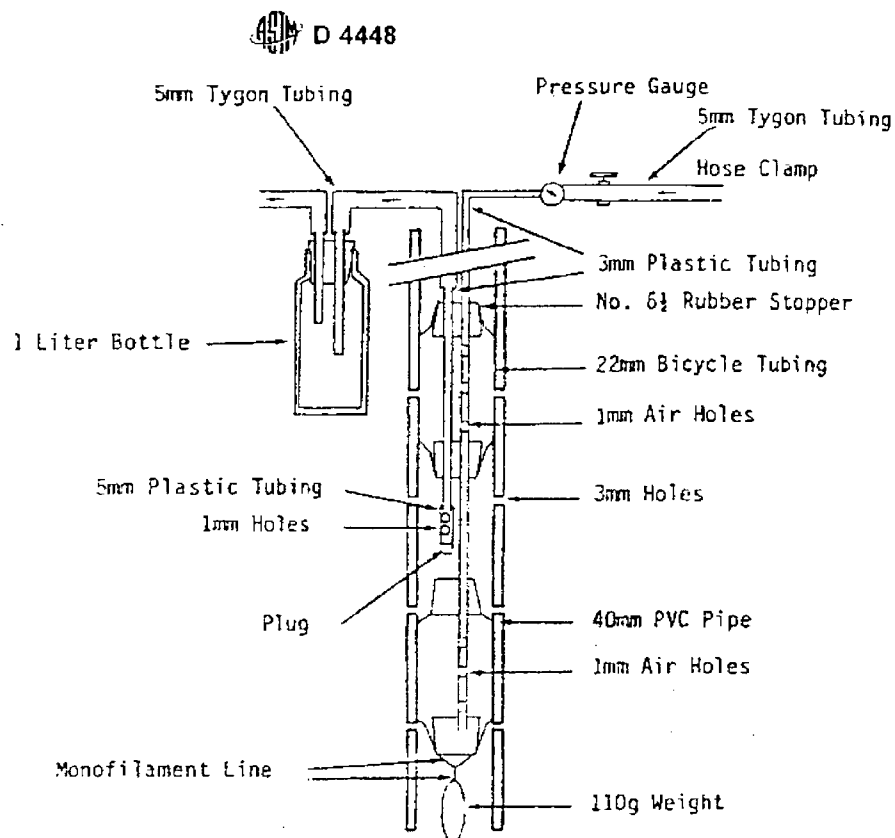
8.1.8 Packer Pump Arrangement:

8.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between packers within a well. Since the hydraulic or pneumatic activated packers are pressed against the casing wall, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed of a rubber compound (54-57). A packer pump unit consisting of a vacuum sampler positioned between packers is illustrated in Fig. 7 (58).

8.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Because access to the interval between packers is blocked once the packers are inflated, the selection of sampling devices is limited to sampling pumps. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

8.1.9 Inertial-Lift Pumps:

8.1.9.1 The inertial-lift pump consists of a foot valve at the



Taken from Ref (79)

FIG. 7 Packer Pump Arrangement

end of a flexible tube. The tube and foot valve is inserted into the well with one end of the tube remaining at the surface. The tube is then rapidly moved in a continuous up-and-down motion. Each upward stroke lifts the water column in the tubing a distance equal to the stroke length. At the end of the upstroke, the water continues to move slightly upward by inertia. On the down stroke, the foot valve opens allowing fresh water to enter the tube. This process continues resulting in a flow to the surface.

8.1.9.2 The inertial-lift pump is capable of operating efficiently at depths to 30 m (100 ft). It is effective in small diameter wells or direct-push technology probes which are typically 12.5 mm (1/2-in.) diameter. The pumping rate ranges from 0 to 7.6 L/min (0 to 2 gal/min) (34), depending on the rate of the up and down pumping stroke and the tube diameter. The equipment used in this pump is inexpensive enough to be dedicated to a well with the exception of the pump handle or motor drive that do not contact the sample.

8.1.9.3 The inertial-lift pump, however, has several disadvantages. It is difficult to operate in deep, large diameter wells. Although a motor drive can overcome this limitation, the incorporation of a motor drive limits the portability of the equipment. The foot valve must be selected to match the casing material since it will tend to ride against the casing and potentially will either damage the casing or wear out. The discharge tubing must be stiff for the pump to operate properly. This makes the tubing awkward to install and remove from a monitoring well.

8.1.10 *Minimal Purge, Discrete Depth, and Passive Sampling*—Sampling techniques that do not rely on, or require only minimal purging may be used if a particular zone within a screened interval is to be sampled or if a well is not capable of yielding sufficient ground water for purging. These techniques include minimal purge, discrete depth sampling, and passive sampling.

8.1.10.1 A dedicated pump is used for minimal purge sampling so that only enough water is purged through the pump so that the volume of water contained by the pump and discharge tube is removed before sampling. No attempt is made to purge the casing, screen, or formation. This volume should be minimized by the selection of small diameter tubing and the smallest possible pump chamber. This initial volume of discharged water is discarded since it had prolonged contact with the sampling device.

8.1.10.2 The discrete depth sampler is often non-dedicated. It is lowered very slowly to the depth of the screen where a water sample is drawn into the sampling chamber. This is accomplished either manually by using a triggering mechanism such as a cable or automatically such as with a differential pressure bailer (14). Discrete depth samplers, however, must be used with great caution because of the potential of mixing of the water column in the well casing while lowering the sampler to its sampling depth.

8.1.10.3 Passive sampling, using diffusion samplers (a water-filled membrane), is based on the principle of molecular diffusion of VOCs from the ground water into the sampler.

(Research is currently being conducted by the U. S. Geological Survey to evaluate diffusion samplers for the collection of non-VOC parameters, however, study results have not been published.) The samplers must remain in the borehole for an adequate time for the water initially within the sampler to equilibrate with that in the borehole. The diffusion sampler typically consists of water-filled, low-density polyethylene tubing, which acts as a semi-permeable membrane. The sampler is attached to a weighted line, and lowered to a predetermined depth within the screened interval. Since the sample is depth specific, multiple samplers may be strung together to provide samples from different depths within the well. After adequate residence time has elapsed, the sampler(s) are removed from the well, punctured and the sample transferred into sample bottles. The samples are preserved and submitted to the laboratory for analysis. In a study of this technique, a minimum of 11 days was required to achieve equilibration (59, 60). Concerns about the applicability of this sampling method to specific VOCs have been raised, however, no detailed evaluation of this issue has been published. In a comparison of sampling techniques, samples collected by the diffusion method were found to be biased lower than samples collected using a low-flow method (61), however, this difference was attributed to issues with the laboratory or to the depth-specific nature of diffusion samplers.

9. Sample Containers and Preservation

9.1 The order of sample container filling, method of filling, selection of sample container type, and preservation method should be provided in the sampling and analysis plan. Generally, the order of sample container filling should proceed from most volatile to least volatile compound.

9.2 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the foremost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard chemical reactions and complexes, and reduce the volatilization of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration, and freezing. For water samples, immediate refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be special cases where it might be prudent to include the temperature to which the samples were exposed. Inexpensive devices for this purpose, such as a recording thermometer, are available for this purpose. A water-filled bottle may be included in the sample-shipping container for temperature measurement by the laboratory receiving the samples.

9.3 All bottles and containers must be specially pre-cleaned, and organized in ice chests (isolating samples and sampling equipment from the environment) before one goes into the field. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting

samples, not on labeling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Examples of detailed plans and documentation procedures have been published (23, 62, see Guide D 6089).

9.4 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, the individual laboratory protocols, and the required QC samples. Since a well may not be capable of yielding adequate sample volume, a minimum required sample volume should be provided to the sample crew. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the laboratory coordinator beforehand. This is especially the case since some analyses and preservation measures must be performed at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

9.5 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils (22, 23, 29, 58, 63-65). Some of this information is summarized in Table XI.1 and Guide D 6517, however, different regulatory programs have specific requirements that must be met.

9.6 Sample containers for VOC samples require special cleaning and handling considerations (66). The sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-fluorocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring a sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on independently preserved samples. The sampling program for VOCs should include at a minimum trip blanks. Trip blanks and field spikes should also be considered for low level analysis.

9.7 The laboratory must analyze the purgeable samples within 14 days after collection. For samples for solvent extractions (extractable organics-base neutrals, acids, pesticides, herbicides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been pre-cleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note 1). Samples for organic extraction must be extracted within 7 days and analyzed within 40 days after extraction.

Note 1 -When collecting samples, the bottles should not be overfilled or prerinse with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

9.8 For a number of ground-water parameters, the most

meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well (see Test Method D 4750) and parameters that can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication (67) and detailed procedures are outlined in a U.S. Geological Survey publication (68, 69). Although a discussion of water level measuring techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made either before a well is purged or after it has had sufficient time to recover. Parameters that can change rapidly with storage include pH, turbidity, redox potential, DO, and temperature. Specific conductance, although most accurately determined in a laboratory setting, often is measured in the field where it is used as an indicator parameter to determine the completeness of purging. For some of the other parameters, the emphasis in ground-water monitoring is on the concentration of each specific dissolved component, not the total concentration of each. Samples for these types of measurements should be filtered through 0.45 μ m membrane filters ideally in the field or possibly at an on-site laboratory as soon as possible. Analyses often requiring filtered samples include metals, radioactivity parameters, dissolved organic carbon, dissolved orthophosphate, and total dissolved phosphorous (22, 23). If metals are to be analyzed, filter the sample prior to acid preservation. If concerns related to the loss of mobile colloidal material by filtering is a consideration, sampling protocol should be modified to limit sample turbidity during collection so that filtering is not necessary. This is often done by using very low purge and sample flow rates. For total organic carbon (TOC), the filter material should be tested to assure that it does not contribute to the TOC. The type or size of the filter to be used is not well determined. However, if results of metal, TOC

or other parameters that could be affected by solids are to be compared, the same filtering procedure must be used in each case. Repeated analytical results should state whether the samples were filtered and how they were filtered.

9.9 Shipment and receipt of samples must be coordinated with the laboratory to minimize time in transit or weekend delivery receipt. All samples for organic analysis (and many other parameters), should be maintained at 4°C ($\pm 2^\circ$ C) (65) during storage and shipping and should arrive at the laboratory within one day after shipment. Sample receipt should be verified to provide an opportunity to trace a lost shipment or to resample if breakage occurs during shipment.

9.10 A commonly used shipping container is an insulated ice chest (cooler) equipped with bottle dividers. An overnight courier service is recommended, if personal delivery service is not practical. Care must be taken in packaging the ice so that no leakage occurs. Such leakage may damage sample labels or, if it escapes the sample cooler, may be misconstrued to be hazardous liquid by the courier. Sample paperwork, including the chain-of-custody, should be enclosed in a sealed plastic bag and taped to the inside lid of the shipping container to protect it from water. Sample containers may be sealed in plastic bags to protect sample labels from water damage from melting ice or sample leakage from other bottles.

9.11 Many courier services have strict shipping requirements for samples that are "hazardous." The courier service should be contacted prior to field activities if there is a concern about how to ship a sample.

10. Keywords

10.1 diffusion sampling; ground water; low flow; low stress; minimal purge; monitoring; purge; sampling; stabilization; well

APPENDIX

(Nonmandatory Information)

X1. SAMPLE HANDLING PROCEDURES FOR GROUND WATER MONITORING PARAMETERS

X1.1 See Table X1.1 for procedures for handling samples.

TABLE X1.1 Sample Handling Procedures For Ground Water Monitoring Parameters (77)

| Parameter ^A | Bottle Type ^A | Preservative | Volume Required for Analysis, min (mL) ^B | Storage Time ^C (with Preservation, where applicable), max |
|---|----------------------------|---|---|--|
| pH | P,G | None, analyze immediately for field measurement | 25 | ASAP (≤ 48 h) for lab measurement |
| Specific Conductance | P,G | Cool (4°C) | 100 | 28 days |
| Alkalinity and Bicarbonate | P,G | Cool (4°C) | 100 | 14 days |
| COD | P,G | Analyze ASAP (≤ 48 h) or add H_2SO_4 to pH<2; cool (4°C) | 100 | 28 days |
| - TDS | P,G | Cool (4°C) | 100 | 7 days |
| TSS | P,G | Cool (4°C) | 100 | 7 days |
| Chloride | P,G | None | 50 | 28 days |
| Fluoride | P | None | 300 | 28 days |
| Nitrate | P,G | Analyze ASAP (≤ 48 h) or add H_2SO_4 to pH<2; cool (4°C) | 100 | 28 days |
| Sulfate | P,G | Cool (4°C) | 50 | 28 days |
| Ammonia | P,G | Analyze ASAP (≤ 48 h) or add H_2SO_4 to pH<2; cool (4°C) | 500 | 28 days |
| Mercury | P,G | HNO_3 to pH<2 | 100 | 28 days |
| Metals, Dissolved (Including Ca, Mg, K, Na) | P,G | Filter on site; HNO_3 to pH<2 | 200 | 6 months |
| Metals, Total (Including Ca, Mg, K, Na) | P,G | HNO_3 to pH<2 | 100 | 6 months |
| Phenols | P,G | Add H_2SO_4 pH<2; cool (4°C) | 500 | 28 days |
| Hardness | P,G | HNO_3 to pH<2 | 100 | 6 months |
| Volatile Organic Compounds (VOC) | G, TFE-lined cap | Add HCL to pH<2; cool (4°C) | 2 x 40 ml | 14 days |
| Total Organic Carbon (TOC) | G, TFE-lined cap | Add H_2SO_4 or HCL to pH<2; cool (4°C) | 40 | 28 days |
| Total Organic Halogen (TOH) | Amber glass, TFE-lined cap | H_2SO_4 to pH<2 and cool (4°C) for EPA 9020A; cool (4°C) for EPA 9022 | 250 | 28 days |
| Turbidity | P, borosilicate glass | Cool (4°C) | 100 | 48 h |

^A P = Plastic (polyethylene or equivalent); G = Glass; G, TFE-lined cap = Glass screw-cap vials sealed with Teflon-faced silicone septa.

^B Individual laboratories may request more than the minimum volume.

^C ASAP = As soon as possible.

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Standard Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices¹

This standard is issued under the fixed designation D 5784; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers how hollow-stem auger-drilling systems may be used for geoenvironmental exploration and installation of subsurface water-quality monitoring devices.

1.2 Hollow-stem auger drilling for geoenvironmental exploration and monitoring device installations often involves safety planning, administration, and documentation. This guide does not purport to specifically address exploration and site safety.

NOTE 1—This guide does not include considerations for geotechnical site that are addressed in a separate Guide.

1.3 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

1.4 This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1.5 This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

2. Referenced Documents

2.1 ASTM Standards:

D 653 Terminology Relating to Soil, Rock, and Contained Fluids²

D 1452 Practice for Soil Investigation and Sampling by Auger Borings²

¹ This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

Current edition approved Oct. 10, 1995. Published December 1995.

² Annual Book of ASTM Standards, Vol 04.08.

D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils²

D 1587 Test Method for Thin-Walled Tube Sampling of Soils²

D 2113 Test Method for Diamond Core Drilling for Site Investigation²

D 2487 Test Method for Classification of Soils for Engineering Purposes²

D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)²

D 3550 Practice for Ring-Lined Barrel Sampling of Soils²

D 4220 Practices for Preserving and Transporting Soil Samples²

D 4428/D4428M Test Methods for Crosshole Seismic Testing²

D 4700 Guide for Soil Sampling from the Vadose Zone²

D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)²

D 5079 Practices for Preserving and Transporting of Rock Core Samples³

D 5088 Practice for Decontamination of Field Equipment Used at Non-Radioactive Waste Sites³

D 5092 Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers³

D 5099 Test Method for Rubber—Measurement of Processing Properties Using Capillary Rheometry⁴

D 5254 Practice for Minimum Set of Data Elements to Identify a Ground-Water Site³

3. Terminology

3.1 Definitions:

3.1.1 Terminology used within this guide is in accordance with Terminology D 653. Definitions of additional terms may be found in Terminology D 653.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 bentonite—the common name for drilling fluid additives and well-construction products consisting mostly of naturally occurring montmorillonite. Some bentonite products have chemical additives that may affect water-quality analyses.

³ Annual Book of ASTM Standards, Vol 04.09.

⁴ Annual Book of ASTM Standards, Vol 09.01.

3.2.2 *bentonite granules and chips*—irregularly shaped particles of bentonite (free from additives) that have been dried and separated into a specific size range.

3.2.3 *bentonite pellets*—roughly spherical- or disk-shaped units of compressed bentonite powder (some pellet manufacturers coat the bentonite with chemicals that may affect the water-quality analysis).

3.2.4 *coefficient of uniformity*— $C_u (D)$, the ratio D_{60}/D_{10} , where D_{60} is the particle diameter corresponding to 60 % finer on the cumulative particle-size distribution curve, and D_{10} is the particle diameter corresponding to 10 % finer on the cumulative particle-size distribution curve.

3.2.5 *continuous-sampling devices*—barrel-type samplers that fit within the lead auger of the hollow-auger column. The sampler barrel fills with material as the augers advance.

3.2.6 *drill hole*—a cylindrical hole advanced into the subsurface by mechanical means. Also known as borehole or boring.

3.2.7 *drawworks*—a power-driven winch, or several winches, usually equipped with a clutch and brake system(s) for hoisting or lowering a drilling string.

3.2.8 *filter pack*—also known as a gravel pack or a primary filter pack in the practice of monitoring-well installations. The gravel pack is usually granular material, having specified grain-size characteristics, that is placed between a monitoring device and the borehole wall. The basic purpose of the filter pack or gravel envelope is to act as: (1) a nonclogging filter when the aquifer is not suited to natural development or, (2) act as a formation stabilizer when the aquifer is suitable for natural development.

3.2.8.1 *Discussion*—Under most circumstances a clean, quartz sand or gravel should be used. In some cases a pre-packed screen may be used.

3.2.9 *fluid-injection devices*—usually consist of various auger components or drill-rig attachments that may be used to inject a fluid within a hollow-auger column during drilling.

3.2.10 *grout packer*—an inflatable or expandable annular plug that is attached to a tremie pipe, usually positioned immediately above the discharge end of the pipe.

3.2.11 *grout shoe*—a drillable plug containing a check valve that is positioned within the lowermost section of a casing column. Grout is injected through the check valve to fill the annular space between the casing and the borehole wall or another casing.

3.2.11.1 *Discussion*—The composition of the drillable plug should be known and documented.

3.2.12 *hoisting line*—or drilling line, is wire rope used on the drawworks to hoist and lower the drill string.

3.2.13 *in situ testing devices*—sensors or probes, used to obtain mechanical or chemical-test data, that are typically pushed, rotated, or driven below the bottom of a borehole following completion of an increment of drilling. However, some in situ testing devices (such as electronic pressure transducers, gas-lift samplers, tensiometers, and so forth) may require lowering and setting of the device(s) in a preexisting borehole by means of a suspension line or a string of lowering rods or pipe. Centralizers may be required to correctly position the device(s) in the borehole.

3.2.14 *intermittent-sampling devices*—usually barrel-type samplers that may be rotated, driven, or pushed below the bottom of a borehole with drill rods or with a wireline system to lower, drive, and retrieve the sampler following completion of an increment of drilling. The user is referred to the following ASTM standards relating to suggested sampling methods and procedures: Practice D 1452, Test Method D 1586, Practice D 3550, and Practice D 1587.

3.2.15 *mast*—or derrick, on a drilling rig is used for supporting the crown block, top drive, pulldown chains, hoisting lines, and so forth. It must be constructed to safely carry the expected loads encountered in drilling and completion of wells of the diameter and depth for which the rig manufacturer specifies the equipment.

3.2.16 *Discussion*—To allow for contingencies, it is recommended that the rated capacity of the mast should be at least twice the anticipated weight load or normal pulling load.

3.2.17 *piezometer*—an instrument for measuring pressure head.

3.2.18 *subsurface water-quality monitoring device*—an instrument placed below ground surface to obtain a sample for analyses of the chemical, biological, or radiological characteristics of subsurface pore water or to make in-situ measurements.

4. Significance and Use

4.1 Hollow-stem auger drilling may be used in support of geoenvironmental exploration (Practice D 3550, Test Method D 4428) and for installation of subsurface water-quality monitoring devices in unconsolidated materials. Hollow-stem auger drilling may be selected over other methods based on the advantages over other methods. These advantages include: the ability to drill without the addition of drilling fluid(s) to the subsurface, and hole stability for sampling purposes (see Test Methods D 1586, D 1587, D 2487, and D 2488) and monitoring-well construction in unconsolidated to poorly indurated materials. This drilling method is generally restricted to the drilling of shallow, unconsolidated materials or softer rocks. The hollow-stem drilling method is a favorable method to be used for obtaining cores and samples and for the installation of monitoring devices in many, but not all geologic environments.

NOTE 2—In many geologic environments the hollow-stem auger drilling method can be used for drilling, sampling, and monitoring-device installations without the addition of fluids to the borehole. However, in cases where heaving water-bearing sands or silts are encountered, the addition of water or drilling mud to the hollow-auger column may become necessary to inhibit the piping of these fluid-like materials into the augers. These drilling conditions, if encountered, should be documented.

4.1.1 The application of hollow-stem augers to geoenvironmental exploration may involve ground water and soil sampling, in-situ or pore-fluid testing, or utilization of the hollow-auger column as a casing for subsequent drilling activities in unconsolidated or consolidated materials (Test Method D 2113).

NOTE 3—The user may install a monitoring device within the same auger borehole wherein sampling or in-situ or pore-fluid testing was performed.

4.1.2 The hollow-stem auger column may be used as a temporary casing for installation of a subsurface water-quality

monitoring device. The monitoring device is usually installed as the hollow-auger column is removed from the borehole.

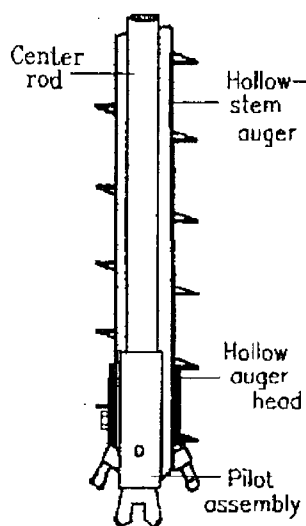
4.2 The subsurface water-quality monitoring devices that are addressed in this guide consist generally of a screened or porous intake device and riser pipe(s) that are usually installed with a filter pack to enhance the longevity of the intake unit, and with isolation seals and low-permeability backfill to deter the movement of fluids or infiltration of surface water between hydrologic units penetrated by the borehole (see Practice D 5092). Inasmuch as a piezometer is primarily a device used for measuring subsurface hydraulic heads, the conversion of a piezometer to a water-quality monitoring device should be made only after consideration of the overall quality and integrity of the installation, to include the quality of materials that will contact sampled water or gas.

NOTE 4—Both water-quality monitoring devices and piezometers should have adequate casing seals, annular isolation seals, and backfills to deter the movement of fluids between hydrologic units.

5. Apparatus

5.1 Each auger section of the hollow-stem auger-column assembly consists of a cylindrical tube with continuous helical flighting rigidly attached to the outer surface of the tube (see Fig. 1). The hollow-auger section has a coupling at each end for attachment of a hollow-auger head to the bottom end of the lead auger section and for attachment of additional auger sections at the top end to make up the articulated hollow-stem auger column.

NOTE 5—The inside diameter of the hollow-stem auger column is usually selected to provide an opening large enough for insertion of monitoring-device components such as the screened intake and filter pack and installation devices such as a tremie pipe. When media sampling is required, the optimum opening should permit easy insertion and retraction of a sampler or core barrel. When a monitoring device is installed, the annular opening should provide easy insertion of a pipe with an inside diameter large enough for placing completion materials adjacent to the riser.



NOTE 1—Various pilot assemblies not shown here may vary.

FIG. 1 Sketch Showing Basic Hollow-Stem Auger Components

5.1.1 *Hollow-Auger Head*, attached to the lead auger of the hollow-auger column and usually contains replaceable, abrasion-resistant cutters or teeth (see Fig. 1). As the hollow-auger head is rotated, it cuts and directs the cuttings to the auger flights which convey the cuttings to the surface.

5.1.2 *Auger-Drive Assembly*, attaches to the uppermost hollow-auger section and transfers rotary power and axial force from the drill rig to the auger-column assembly.

5.1.3 *Pilot Assembly*, may consist of: (1) an auger head aperture-plugging device with or without a center cutting head, or (2) a sampling device that is used to sample simultaneously with advancement of the auger column.

5.1.4 *Auxiliary Components of a Hollow-Auger Drilling System*, consist of various devices such as auger-connector wrenches, auger forks, hoisting hooks, and fluid-injection swivels or adapters.

5.2 *Drill Rig*, used to rotate and advance the auger column. The drill rig should be capable of applying the rated power at a rotary velocity of 50 to 100 r/min. The drill rig should have a feed stroke of at least the effective length of the auger sections plus the effective length of the auger couplings plus about 100 mm (4 in.).

6. Drilling Procedures

6.1 As a prelude to and throughout the drilling process stabilize the drill rig and raise the drill-rig mast. Attach an initial assembly of hollow-auger components (see Fig. 1) to the rotary drive of the drill rig.

NOTE 6—The drill rig, drilling and sampling tools, the rotary gear or chain case, the spindle, and all components of the rotary drive above the auger column should be cleaned and decontaminated prior to drilling according to Practice D 5088. All lubricated rotary gear or chain cases should be monitored for leaks during drilling. Any lubricants used should be documented. Lubricants with organic or metallic constituents that could be interpreted as contaminants if detected in a soil or water sample should not be used on auger couplings. Any instances of possible contamination should be documented.

6.2 Push the auger-column assembly below the ground surface and initiate rotation at a low velocity.

NOTE 7—If surface contamination is suspected, special drilling procedures may be required to deter transport of contaminated materials downhole. For example, the augers and auger head may be removed and cleaned according to Practice D 5088 following drilling of the initial increments. Complete removal of the augers from a boring may allow caving and cross contamination of materials (especially below the water table). When augers are reinserted, attempts should be made to note if caving or sloughing, or both, has occurred in the borehole and the information documented.

6.3 Then continue drilling, usually at a rotary velocity of about 50 to 100 r/min, and to a depth where intermittent sampling or in situ testing is required, or until the drive assembly is advanced to within about 0.15 to 0.45 m (6 to 18 in.) of the ground surface. Soil sampling is usually accomplished by either of two methods: (1) removing the pilot assembly, if being used, and inserting and driving a sampler through the hollow stem of the auger column, or (2) using a continuous sampling device within the lead auger section. In the latter case the sampler barrel fills with material as the hollow-auger column is advanced. It should be noted that the pilot assembly and any sampling devices should be cleaned and

decontaminated according to Practice D 5088 after each use and prior to reinsertion in the hollow-auger column. Water sampling can also be done through the hollow-stem augers when using augers with watertight connections to prevent fluid leakage from occurring at the connections: (1) by allowing the auger column to fill with water through the use of a screened lead auger section; (2) by allowing the auger column to fill from the bottom; (3) by using a soil-penetrating water sampling device that can be lowered into the hollow-auger column and either driven, rotated, or pushed out through the bottom or lead auger into the undisturbed material below the auger head.

NOTE 8 - Under some circumstances it may be effective to drill without using a pilot assembly. If a pilot assembly is not used, however, and water is not injected into the auger column simultaneously with advancement, material will often enter the hollow stem of the auger column. The addition of water to the auger column during drilling may deter material entrance but, on the other hand, may also affect both the mechanical and chemical characteristics of soil samples and the quality of water samples. Therefore, if water is added and the chemistry determined, the approximate volume(s) added over specific intervals and the water chemistry should be documented.

6.4 Accomplish drilling at greater depths by attaching additional hollow-auger sections to the top of the previously advanced hollow-auger column assembly.

NOTE 9—Cuttings are removed periodically from around the top of the auger column. Soil cuttings above the ground water may be representative of deposits being penetrated if proper cuttings-return rates are maintained. Cuttings from below the ground water surface are likely to be mixed from varying formations in the hole and are usually not representative of deposits at the end of the auger if cuttings are sampled for classification (see Practice D 2488) and relation to lithology report and document the intervals sampled. If drilling is performed in contaminated soil and

cuttings control is required, drilling through a hole in a sheet of plywood or similar material held securely above the borehole by the stabilizing jacks of the drill rig will usually facilitate cuttings control. Containment and disposal of contaminated and potentially contaminated drilling fluids and associated cuttings should be in accordance with applicable regulations.

6.5 When drilling must progress through material suspected of being contaminated, installation of single or multiple (nested) casings may be required to isolate zones of suspected contamination. Install isolation casings in a predrilled borehole or by using a casing advancement method. However, when attempting to auger inside the casing, the column of cuttings return may cause the augers to bind in the casing. Then install a grout seal usually by applying the grout at the bottom of the annulus with the aid of a tremie pipe, and a grout shoe or a grout packer. Allow the grout to set before drilling activities are continued.

7. Installation of Monitoring Devices

7.1 Subsurface water-quality monitoring devices are generally installed using hollow-stem augers following the three-step procedure shown in Fig. 2. The three steps are: (1) drilling, with or without sampling, (2) removal of the pilot assembly, if being used, and insertion of the monitoring device, and (3) incremental removal of the hollow-auger column as completion materials such as filter pack, annular seals, and backfill are installed as required.

NOTE 10—Removal of the pilot assembly following an increment of drilling or prior to installation of a monitoring device should be performed so that the entrance of material into the bottom of the hollow-auger stem is minimized. The efficacy of pilot assembly removal will depend upon several principal factors: (1) the character of the soil at the auger head, (2)

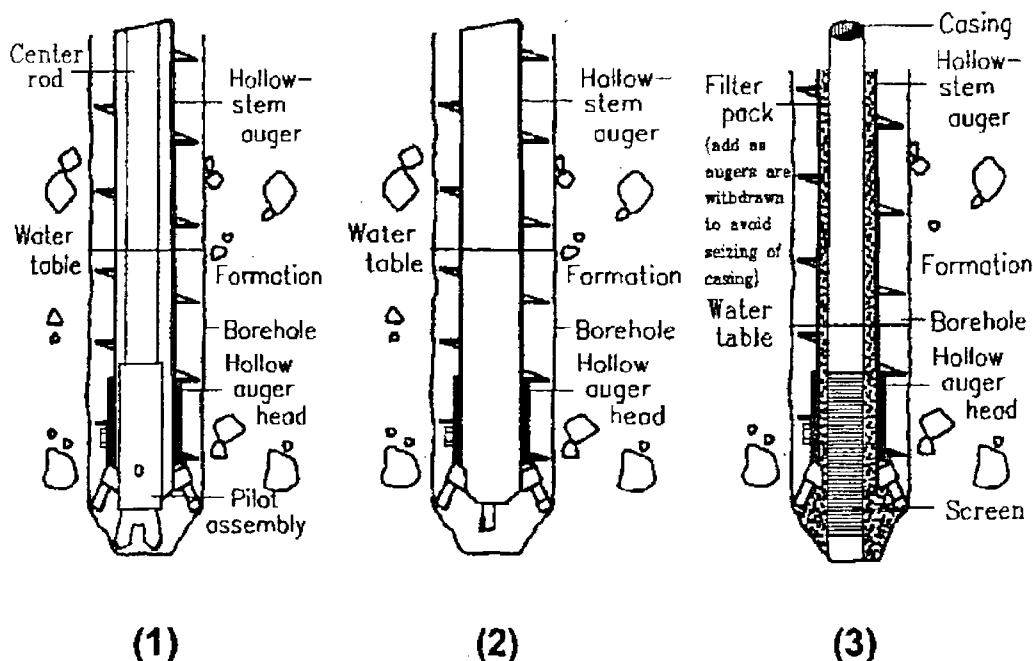


FIG. 2 Sketch Showing Basic Three-Step Procedure for Installation of Subsurface Water-Quality Monitoring Device Using the Hollow-Stem Auger Drilling Method

the water levels inside and outside the auger prior to removal of the pilot assembly, (3) the type of pilot assembly used (special designs of pilot assemblies can be used to reduce the suction effect of removing the pilot bit), and (4) the speed of removal. As drilling progresses in saturated, granular materials, it usually becomes progressively more difficult to maintain the stability of the material below the auger column because of unbalanced hydraulic heads. The stability of the material below the auger head may be enhanced by using special pilot assemblies or injecting water of known chemistry into the hollow auger during drilling. The injection of water into a borehole usually requires consideration and documentation of the effects of injected water on (1) quality of subsequent chemical analyses of sampled water, and (2) the possible addition of moisture or contaminants to sampled materials.

7.1.1 If materials enter the bottom of the auger hollow stem during removal of the pilot assembly, remove it with a bailer, drive sampler, or other device.

NOTE 11—If heaving occurs, the amount of material entering the hollow-stem auger column should be documented. The effective use of a bailer may require the addition of a fluid to the auger stem.

7.1.2 If sampling or in situ testing is not required during drilling for installation of a monitoring device, advance the boring (for some geologic conditions) by using an expendable knockout plate or plug of known chemistry instead of a pilot assembly.

NOTE 12—Knockout plates or plugs usually remain in the ground close to the monitoring device. Therefore, the material components for knockout plates or plugs should be selected based on their possible effects on subsequent measurements or analyses and the information documented. It may be necessary to fill or partially fill the auger stem with water of known chemistry to prevent blow-in, piping, or sanding in at the time of the plate or plug removal. Refer to Note 7 for considerations regarding adding water to the hollow-auger stem.

7.1.3 Use an auger head with an integral, hinged aperture cover to deter entrance of materials into the auger stem.

7.2 Assemble water-quality monitoring devices, with attached fluid conductors (risers), and suspend in tension prior to placement of filter pack and during placement of filter pack in the borehole (with the least possible addition of contaminants).

7.2.1 Some materials, such as screens and risers, may require cleaning or decontamination, or both, at the job site (see Practice D 5088).

7.2.2 Prior to installation, store all monitoring device materials under cover and place upwind and well away from the drill rig and other sources of potential contamination such as electrical generators, air compressors, or industrial machinery.

7.2.3 Clean hoisting tools, particularly wire rope and hoisting swivels, and decontaminate according to Practice D 5088 before using.

7.3 Select filter materials, bentonite pellets, granules and chips, and grouts and install to specific subsurface monitoring requirements. The thickness of the emplaced materials and extension of the materials above the top of the screen should be sufficient to adequately seal the well and monitoring device(s) against contamination effects of fluid movement between hydrologic units and infiltration of surface contaminants.

7.3.1 Filter packs for monitoring devices are typically installed by withdrawing the hollow augers in small increments, while simultaneously adding small increments of filter material. Record the total volume of filter materials installed and the depth to the upper surface of the filter pack and

compare to calculated volumes of material required for completion. Consider any discrepancies occurring between the actual volume of material used and the calculated volume required prior to proceeding to ensure proper completion. If filter material bridges within the hollow auger-riser annulus during installation, use tamping rods or other tamping devices to dislodge the bridge.

NOTE 13—Filter packs for monitoring devices installed in a saturated zone are typically selected on the basis of the grain size characteristics of the hydrologic unit adjacent to the screened intake (screen size should be less than the grain size of the formation adjacent to the screened intake). Filter-pack material is often inserted from above ground surface within the annulus of the hollow auger and the riser and is distributed by gravity around the screened intake. Filter-pack material with a uniformity coefficient of less than 2.5 is ordinarily selected to minimize in-place segregation of grain sizes. For some circumstances, such as installations under water in uniform, fine to very fine sand soils, the filter should be installed with a tremie pipe to minimize segregation of particle sizes. Filter packs for vadose-zone monitoring devices may be predominantly silt sized. These filter materials are often mixed with water of known quality, inserted through a tremie pipe, and tamped into place around the device.

NOTE 14 Effective installation of the filter pack, the seal above the filter pack, and the grout above the seal may be difficult to achieve. Consideration should be given to allow for sufficient annular space between the monitoring device and the hollow-stem auger to accommodate the tremie pipe. Under some circumstances, the filter pack may be more successfully installed by injecting or inserting water of known chemistry into the hollow-auger annulus either before or during incremental pull-back of the auger column. Enough water should be injected to both fill the space previously occupied by the auger flights and to maintain or slightly increase the head within the auger-hollow stem. This additional head within the auger-hollow stem provides an outward seepage force on the wall of the borehole as the augers are retracted. The additional head deters caving prior to installation of filter or seal materials. Approximate volumes of water used and water losses should be documented.

7.4 Usually place sealing materials consisting of either bentonite pellets, chips, or granules directly above the filter pack.

NOTE 15—It may be effective, when granular filters are used, to install a thin, fine sand, secondary filter either below the annular seal or both above and below the seal. These secondary filters are installed to protect the monitoring device, primary filter pack, and seal from intrusion of grout installed above the seal.

NOTE 16—A measured volume of water of known chemistry is often placed in the annulus on top of a dry bentonite seal to initiate hydration; however, hydration of a seal may require from 6 to 24 h.

7.5 The backfill that is placed above the annular seal is usually a bentonite- or cement-base grout.

NOTE 17—Grouts should be designed and installed in consideration of the ambient hydrogeologic conditions. The constituents should be selected and documented according to specific performance requirements. Typical grout mixtures are given in Practice D 5092 and Test Method D 4428.

NOTE 18—Grouting equipment and pipes should be cleaned and decontaminated according to Practice D 5088 prior to use and should be constructed of materials that do not "leach" significant amounts of contaminants to the grout.

7.5.1 When a tremie pipe is used, control its initial position and grouting pressures to prevent materials from being jetted into underlying seal(s) and filter(s) (use of a tremie pipe having a plugged bottom and side-discharge ports should be considered to minimize bottom-jetting problems).

7.5.2 After placement of the initial 1.5 to 3 m (5 to 10 ft) of grout above the underlying filter or seal, discharge additional grout at a depth of about 1.5 to 3 m below the grout surface.

NOTE 19—The need for chemical analysis of samples of each grout component and the final mixture should be considered and documented.

7.5.3 Install the grout from the bottom of the borehole to the top of the borehole so as to displace fluids in the borehole.

8. Development

8.1 Most monitoring device installations should be developed to remove suspended solids from disturbance of geologic materials during installation and to improve the hydraulic characteristics of the filter pack and the hydrologic unit adjacent to the intake. The method(s) selected and time expended to develop the installation and changes in quality of water discharged at the surface should be observed and recorded.

NOTE 20—Under most circumstances, development should be initiated as soon as possible following grouting and well completion operations. For suggested well-development methods and techniques, the user is referred to Test Method D 5099. However, time should be allowed for setting of grout.

9. Field Report and Project Control

9.1 The field report should include information recommended under Guide D 5434, and identified as necessary and pertinent to the needs of the exploration program.

9.2 Other information in addition to Guide D 5434 should be considered if deemed appropriate and necessary to the

requirements of the exploration program. Additional information should be considered as follows:

9.2.1 Drilling Methods:

9.2.1.1 Description of the hollow-stem auger system,

9.2.1.2 Type, quantities, and locations in the borehole of use of water or additives added,

9.2.1.3 Description of cuttings return, including quantities, and

9.2.1.4 Descriptions of drilling conditions related to rotation rates, and general ease of drilling as related to subsurface materials encountered.

9.2.2 Sampling—Document conditions of the bottom of the borehole prior to sampling and report any slough or cuttings present in the recovered sample.

9.2.3 In Situ Testing:

9.2.3.1 For devices inserted below the bottom of the borehole, document the depths below the bottom of the hole and any unusual conditions during testing, and

9.2.3.2 For devices testing or seating at the borehole wall, report any unusual conditions of the borehole wall.

9.2.4 Installations—A description of well-completion materials and placement methods, approximate volumes placed, depth intervals of placement, methods of confirming placement, and areas of difficulty of material placement or unusual occurrences.

10. Keywords

10.1 drilling; geoenvironmental exploration; ground water; vadose zone

APPENDIX

(Nonmandatory Information)

X1. ADDITIONAL REFERENCES

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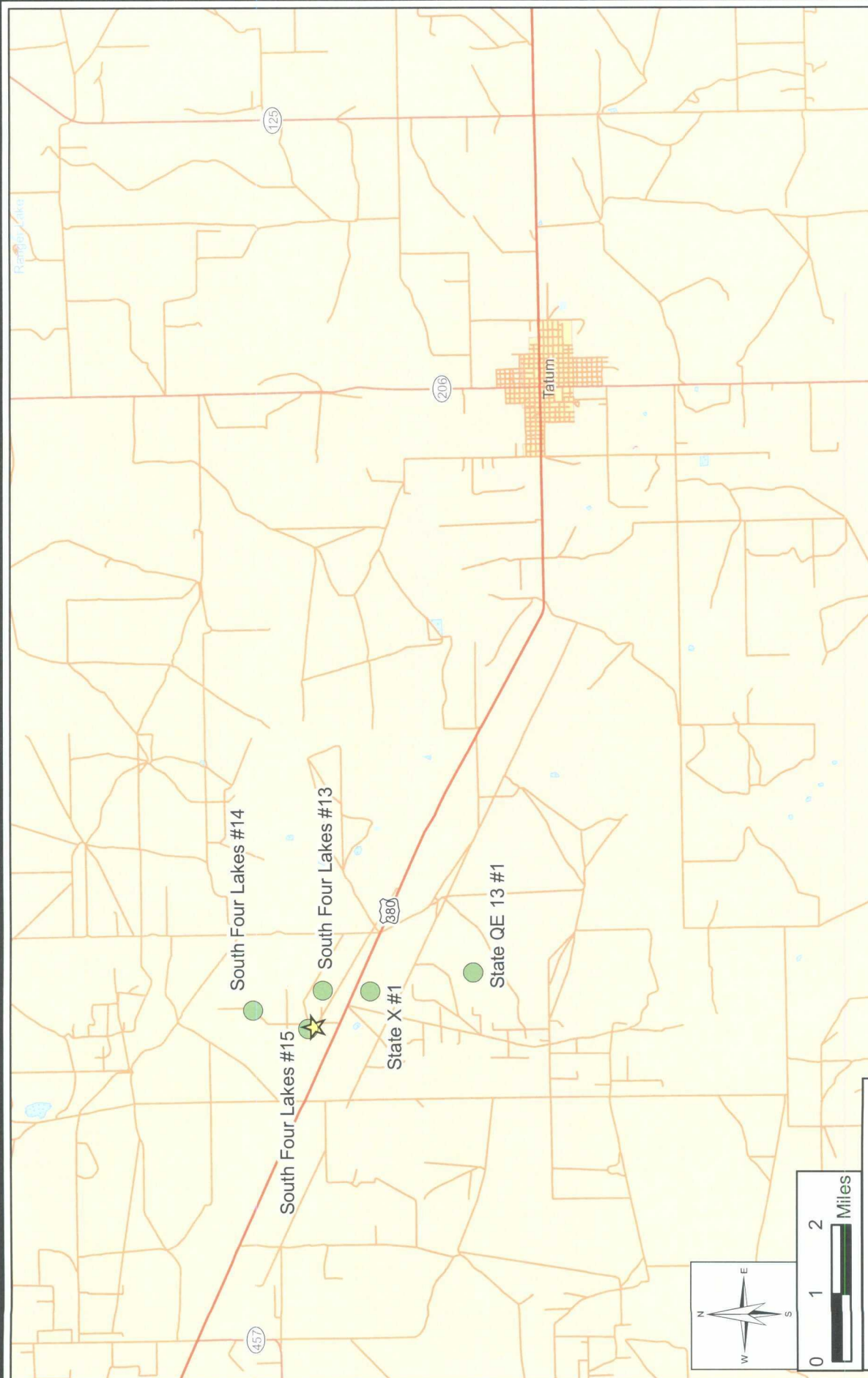
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Plates

R.T. Hicks Consultants, Ltd.

901 Rio Grande Blvd. NW, Suite F-142
Albuquerque, NM 87104



Explanation

- ★ South Four Lakes Tank Battery
- Pride Energy Site

R.T. Hicks Consultants, Ltd
 901 Rio Grande Blvd NW Suite F-142
 Albuquerque, NM 87104
 Ph: 505.266.5004

Region Location Map Relative to Tatum, NM

Pride Energy Company: South Four Lakes #15
 Abatement Plan

Plate 1

April 2008



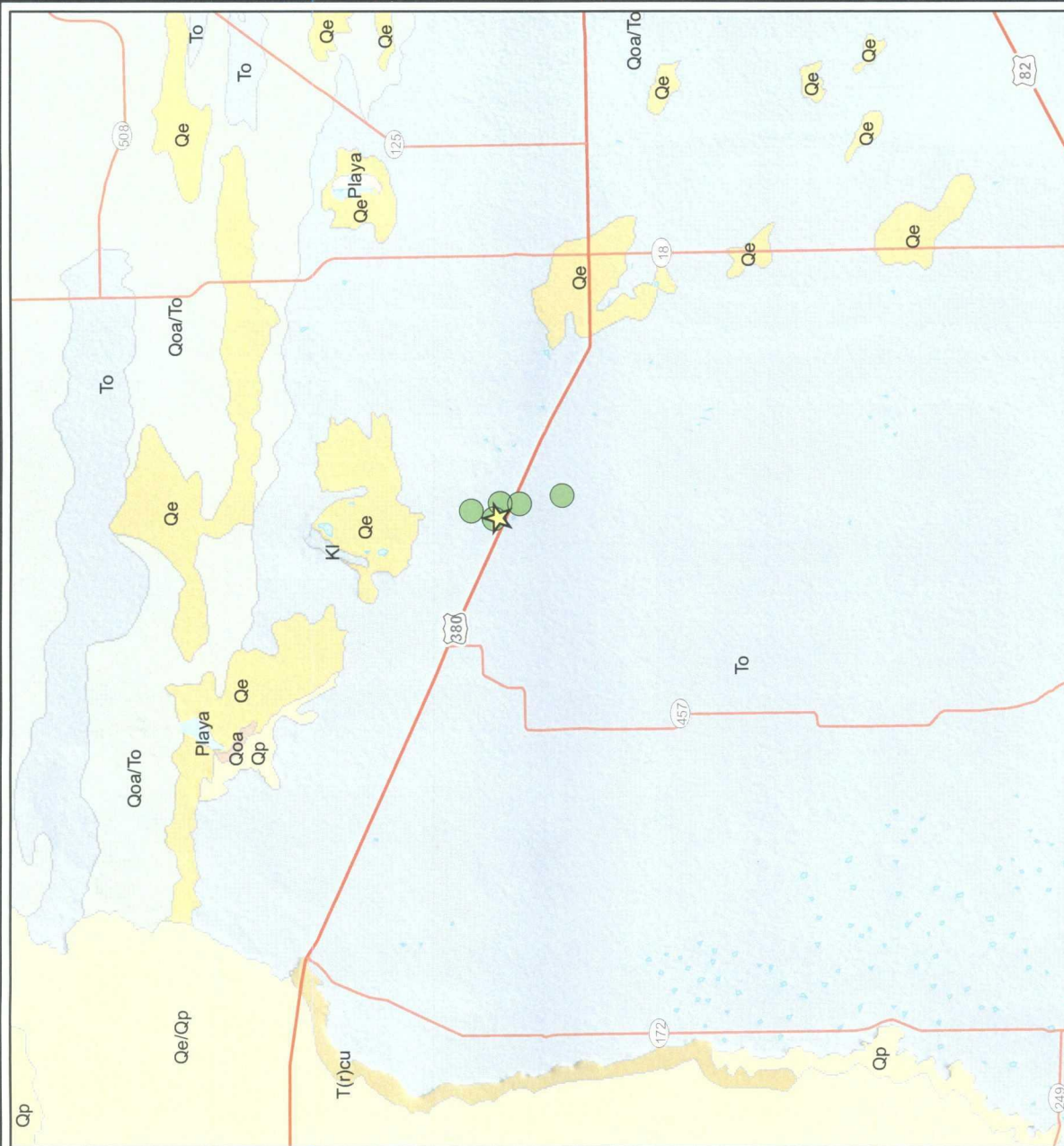
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 901 Rio Grande Blvd NW Suite F-142
 Albuquerque, NM 87104
 Ph: 505.266.5004

2004 Aerial of Site and Environs

Plate 2

Pride Energy Company: South Four Lakes #15
 Abatement Plan

April 2008



Explanation

- Pride Energy Site
- ★ South Four Lakes Tank Battery

Geologic Map

Map Unit, Description

- Kl, Lower Cretaceous, undivided
- Playa, Playa Deposits
- Qe, Quaternary-Eolian Deposits
- Qe/Qp, Quaternary-Eolian Piedmont Deposits
- Qoa, Quaternary-Older Alluvial Deposits
- Qoa/To, Quaternary-Older Alluvial Deposits/Ogalalla
- Qp, Quaternary-Piedmont Alluvial Deposits
- T(r)cu, Triassic-Upper Chinle Group
- To, Tertiary-Ogallala Formation



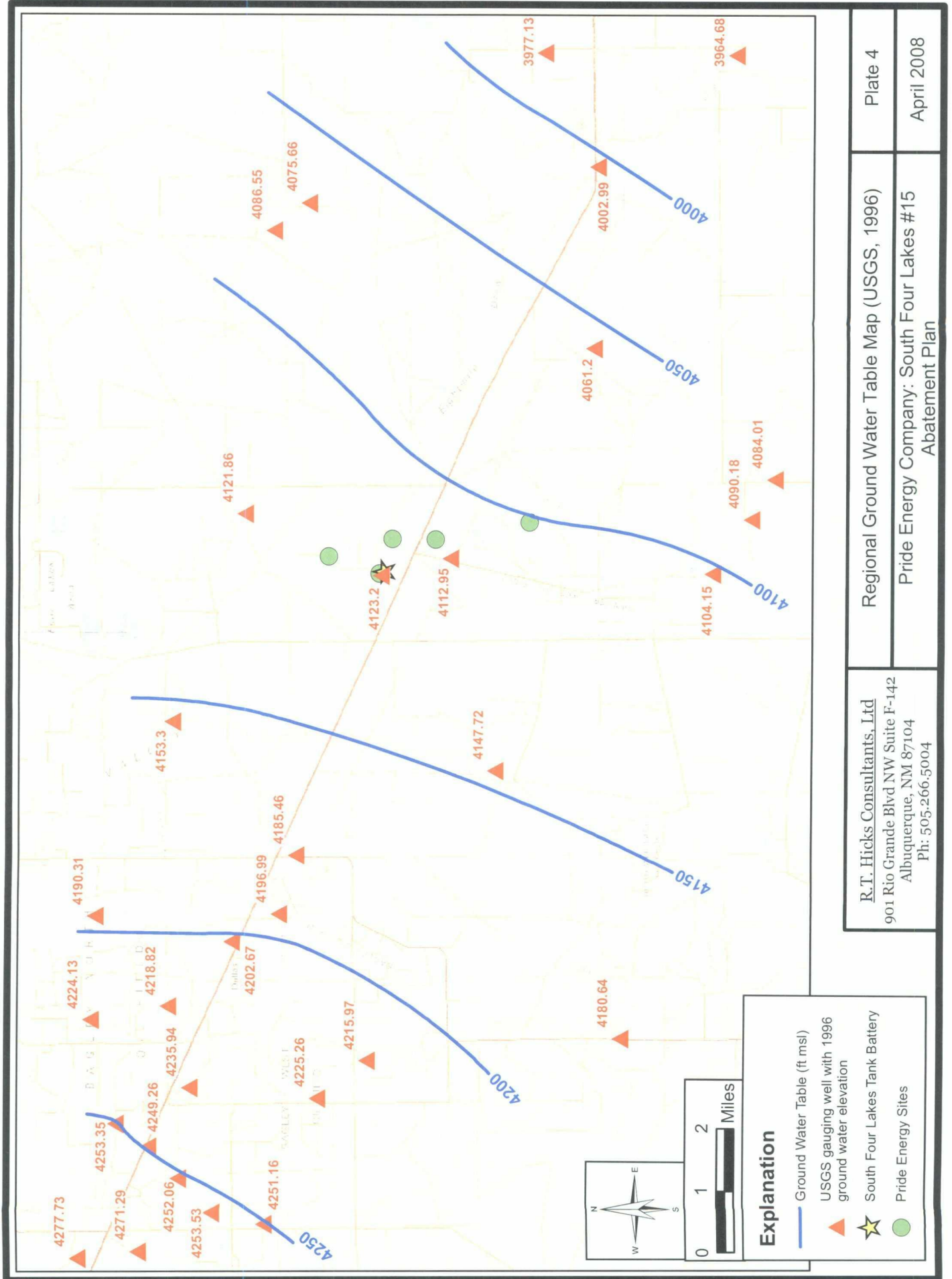
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Albuquerque, NM 87104
Ph: 505.266.5004

Geologic Map

Pride Energy Company: South Four Lakes #15
Abatement Plan

Plate 3

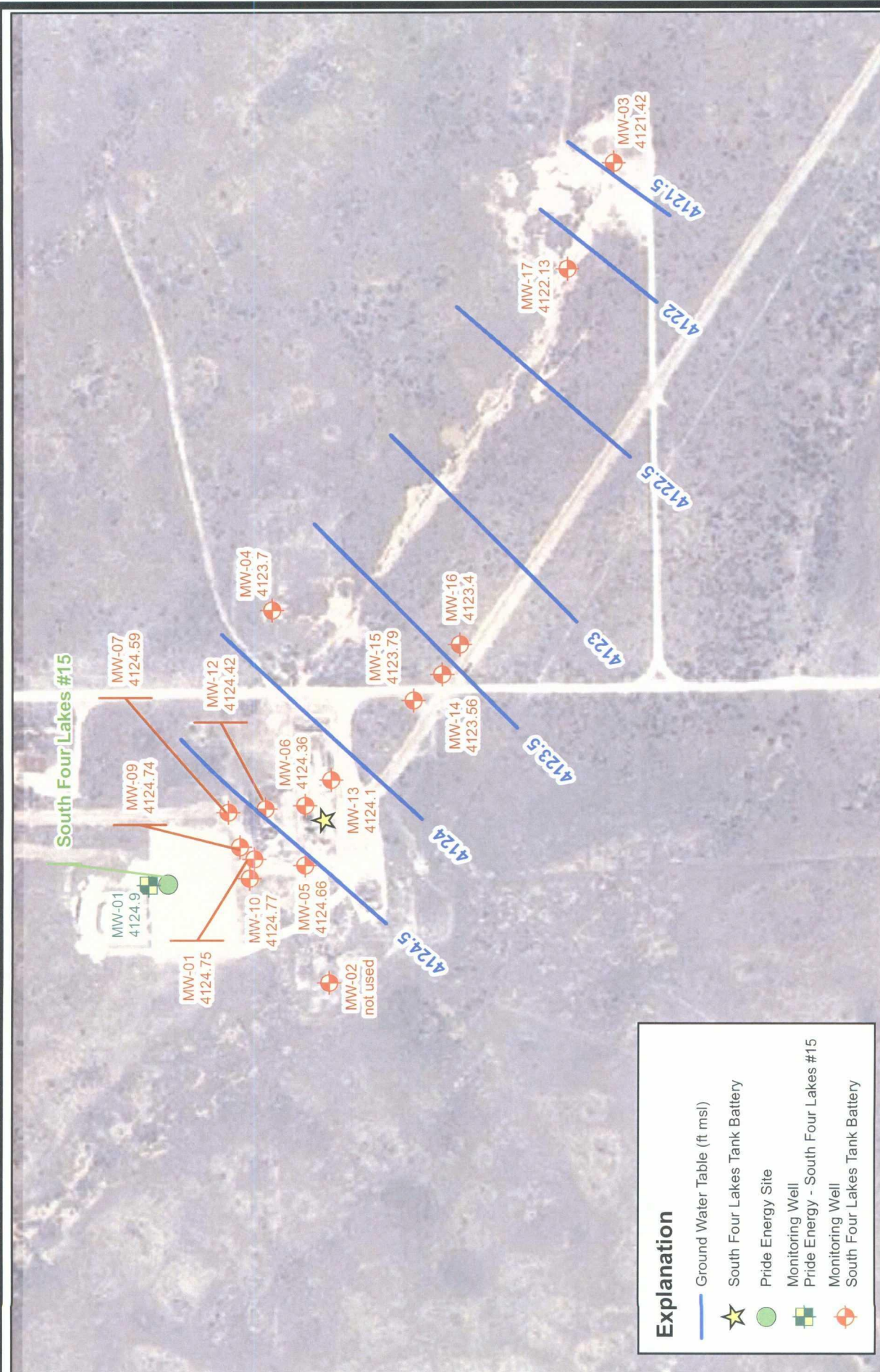
April 2008



Explanation

- Ground Water Table (ft msl)
- USGS gauging well with 1996 ground water elevation
- South Four Lakes Tank Battery
- Pride Energy Sites

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| R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004 | Regional Ground Water Table Map (USGS, 1996) | Plate 4 |
| | Pride Energy Company: South Four Lakes #15 Abatement Plan | April 2008 |

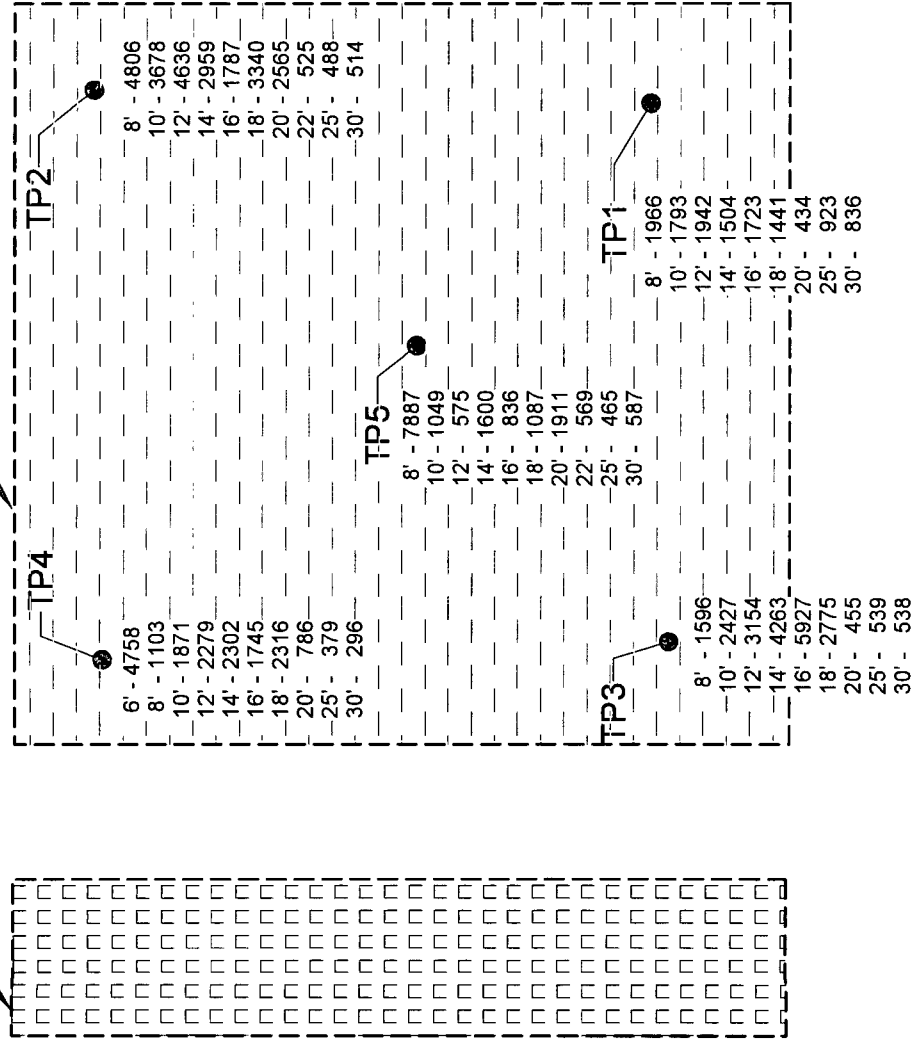


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| R.T. Hicks Consultants, Ltd 901 Rio Grande Blvd NW Suite F-142 Albuquerque, NM 87104 Ph: 505.266.5004 | Local Ground Water Table (03/13/2008) | Plate 5 |
| | Pride Energy Company: South Four Lakes #15 Abatement Plan | |



Burial Pit

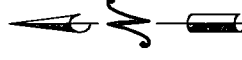
Former Drilling Pit



Wellhead

Legend

- TP1 Initial Soil Sample Location
- Field Chloride Results in ppm at depths (Ft) below ground surface
- All data is based on field testing performed by Elke Environmental.
- MW-1 Monitoring Well (No soil samples)



R.T. Hicks Consultants, Ltd.

901 Rio Grande Blvd NW Suite F-142

Albuquerque, NM 87104

PRIDE ENERGY COMPANY
SOUTH FOUR LAKES #15
T12S - R34E - Section - Unit J
Lea County, New Mexico

Plate 6

SOIL SAMPLING MAP
January 2008

