Appendix A

Garfield County Hydrogeologic Characterization Study – Phase II Field Sampling Plan for Task 1

Garfield County Hydrogeological Characterization Study- Phase II

FIELD SAMPLING PLAN

Prepared for:

Garfield County Board of County Commissioners
Garfield County Oil & Gas Auditor

Prepared by:

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1.0 PROJECT CONTACT INFORMATION AND DIRECTIONS

Emergency Information:

Police and Ambulance – 911

Hospitals (maps on next page):

Clagett Memorial Hospital – Rifle
707 East 5th St.
970-625-1510

Valley View Hospital – Glenwood Springs (32 miles east of Rifle)
1906 Blake Ave.
970-945-6535

Other Contacts

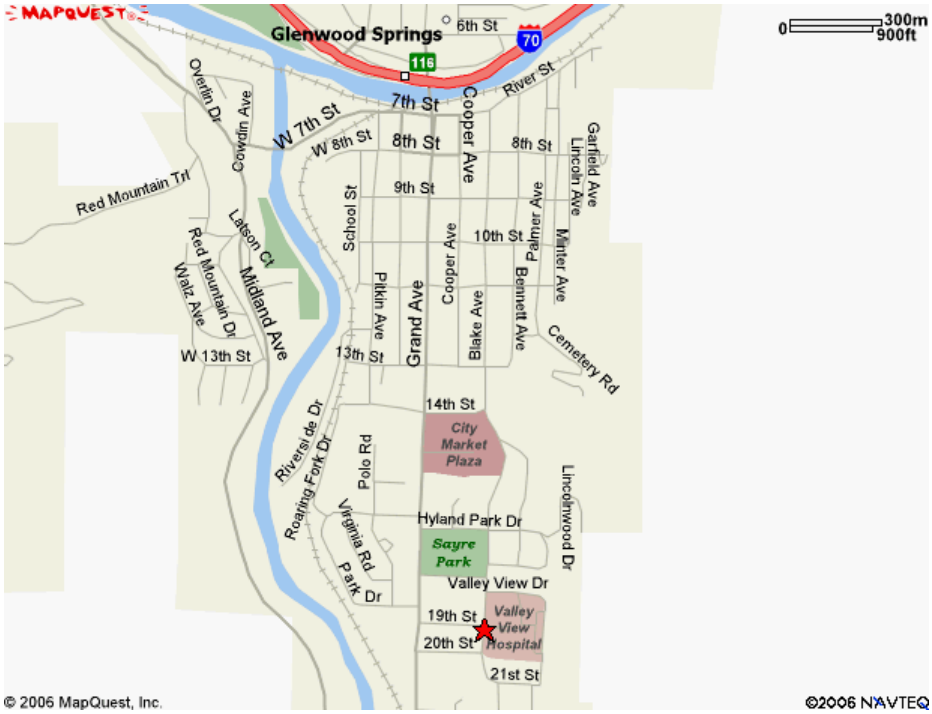
Field Environmental
800-393-4009
301 Brushton Ave., Suite A
Pittsburgh, PA 15221

ACZ laboratories
800-334-5493
970-879-6590
2773 Downhill Drive
Steamboat Springs, CO 80487

Isotech Laboratories, Inc
217-398-3490
1308 Parkland Court
Champaign, IL 61821

Clagett Memorial Hospital – Rifle. 707 East 5th St.

Valley View Hospital – Glenwood Springs (32 miles east of Rifle). 1906 Blake Ave.



2.0 INTRODUCTION

2.1. Project Background

The Mamm Creek field covers an area of approximately 110 square miles in western Colorado. Currently, gas wells are being drilled and completed in the Upper Cretaceous Williams Fork and the Tertiary Wasatch Formations along the I-70 corridor in Garfield County. This natural gas development has been accompanied by concern from local government and the public about the potential impacts to groundwater resources. To address these concerns, Garfield County Board of County Commissioners and Garfield County Oil & Gas Auditor is conducting Hydrogeological Characterization Part II. This study involves re-sampling of domestic water wells and springs that have been identified during past sampling events as having solutes of concern, saline water type, or methane. Once the results from the domestic water wells and springs are analyzed, producing natural gas wells located up gradient from domestic wells and springs will be identified and sampled to determine if chemical signatures of producing wells match domestic wells. The Mamm creek study area is located south of the towns of Rifle and Silt and include township ranges 6S92W, 6S93W, 7S92W, AND 7S93W. A map of this study area is shown in Figure 1.

S. S. Papadopulos & Associates, Inc. (SSPA) has been contracted by Garfield County Board of County Commissioners in conjunction with the Garfield County Oil & Gas Auditor to conduct sampling in the summer of 2007 of domestic water wells and springs in the Mamm Creek Study area. This Field Sampling Plan (FSP) has been prepared by SSPA as a tool to ensure that field sampling personnel conduct sampling and sample-related activities in a consistent, appropriate, and efficient manner. The document is designed as a field manual for use and reference as necessary during actual sampling activities.

2.2. Objectives

The objectives of the field sampling for the Phase II Hydrogeologic Characterization of the Mamm Creek Area are to:

- Task 1: Sample approximately 77 domestic water wells and springs that have been identified from the Colorado Oil & Gas Conservation Commission

(COGCC) database as having constituents of concern [Floride (F), Selenium (Se), and Total Nitrates (NO3)] greater than Colorado Basic Ground Water Standards (CBGWS; equivalent for these compounds to federal Maximum Contaminant Levels).

- Task 1: Sample approximately 28 wells identified from COGCC database as having methane concentrations above 2 mg/L and only sampled once or have never been sampled for isotopes analysis.
- Task 1: Sample approximately 21 wells that have been identified from the COGCC database as having saline waters.
- Task 2: Identify and sample producing wells located upgradient of domestic wells where CBGWS are not met or where high saline levels exist.

2.3. Hydrogeologic Setting

The Wasatch Formation consists of mudstone with intervening lenses of fine-grained sandstone. Porosity and hydraulic conductivity are low in the Wasatch and much of the groundwater produced from Wasatch wells is likely from flow through open fractures. Wasatch wells in the study area may be several hundred feet deep; well yield varies widely, but often is fairly low (5 or fewer gallons per minute [gpm]) and depth to water in the wells commonly exceeds 100 feet.

In areas near the major streams, particularly the Colorado River, groundwater is commonly pumped from the saturated alluvium that is present adjacent to and beneath the streams and that has sufficient thicknesses and hydraulic conductivities to produce water for domestic and/or agricultural uses. Most alluvial wells do not exceed 100 to 150 feet deep. Wells completed in alluvium produce primarily from unconsolidated sandy or gravelly units. Water levels are normally within a few tens of feet of the ground surface and well yield is often above 10 gpm.

Based on information provided in drillers logs it is not always clear whether a well produces water from the Wasatch Formation or from the alluvium.

2.4. Sampling Locations and Parameters

The target area for this sampling project is shown in Figure 1. The wells that will be sampled are being selected by SSPA, in consultation with the COGCC, based on data from previous water sampling events, and information contained in Phase 1 Hydrogeologic Characterization of the Mamm Creek Field Area in Garfield County (URS, 2006). Most of the wells are domestic water supply wells; a few of them provide water to more than one residence, and a few are springs. A complete of wells to be sampled is included in Figure 2

Water from all of the wells to be sampled will be analyzed in the laboratory for the water quality parameters listed below. All water quality parameters will be analyzed at ACZ laboratories in Steamboat Springs, CO.

- Major anions (Cl, SO4, CO3 , HCO3 , NO3, NO2)
- Major cations (Na, Ca, Mg, K, Fe)
- pH
- Total dissolved solids (TDS)

Water collected from approximately 77 wells that have been sampled previously and records indicate that water quality has not met CGBWS for Flouride (F), Nitrate (NO_3^-) or Selenium (Se) will be sampled for the water quality parameters listed above and the following:

- Halides (F and Se)

Water collected from approximately 21 wells that have been sampled previously and records indicate that water has been characterized as saline water associated with high TDS (>1000) will be sampled for the water quality parameters listed first and the following:

- Halides (F , Br, Se, B, and Sr)

Water collected from approximately 28 wells that have been previously sampled and records indicate that dissolved methane levels are greater than 2 mg/L will be sampled for the general water quality parameters and the following:

- Dissolved methane

The same 28 wells that have elevated methane levels will also be sampled for gas composition and stable isotopes. All gas composition and stable isotope analysis samples will be analyzed at the Isotech, Inc., laboratory in Champaign, Illinois, for the following parameters:

- Fixed Gas Chromatography: H_2, Ar, N_2, O_2, CO_2, H_2S
- Hydrocarbon Gas Chromatography: C1, C2, C3, iC4, nC4, iC5, nC5, and C6+
- Stable Isotopic Analysis: $\delta^{13}C$ of C1, δD of C1, $\delta^{13}C$ of CO_2, $\delta^{13}C$ of C2 and C3

Specifications for produced well samples will be provided in an addendum to this Field Sampling Plan after sampling of domestic wells is completed.

3.0 WATER AND GAS SAMPLING PROCEDURES

3.1. Field Sampling Forms and Logbook Procedures

Field sampling personnel will be responsible for collecting owner information, well characteristics, site location description, and purging/sampling information for each well sampled. This information will be recorded on the Well Data Collection Forms shown in Figure 3 and Figure 4. The information will be filled out as completely as possible for each well sampled. In addition, each field sampler will maintain a personal field logbook to document overall field activities.

3.2. Well and Sample Identification

Well/sample identification will be a unique identifier for each sample location. All field forms will include well and sample identifiers. Details for well and sample identification are provided below.

Well Identification: Locations will be identified using the facility identifier provided in the COGCC database. Each well facility number is unique to a sampling location regardless if there are more than one well at one owner location. Well permit numbers have been indicated in the COGCC database, where available, for individual facilities IDs.

Sample Identification: Samples collected and submitted for laboratory analysis will be identified in the field on sample bottles and on sampling Chain-of-Custody forms using the same facility identifier provided at each sampling site.

3.3. Water Level Measurements

Because of the complexities involved with measuring water levels in wells used to provide domestic water supply, it is anticipated that no water levels will be measured during this sampling event. However, for each well sampled, the well location and construction will be assessed and visually documented so that if, in the future, water levels are proposed to be collected, the field sampling personnel will have a good idea of the effort that will be required to collect water levels.

If the need does arise to measure one or more water levels during this sampling event, the following methodology will be adhered to:

1. No devices of any kind will be introduced into a water supply well, nor will water levels will be measured, with out the written permission of the well owner.
2. Prior to placing any water level measurement device into a well it will be sanitized with a chlorine bleach rinse.
3. After the water level measurement is completed any piece of equipment placed back into the well will be sanitized with a chlorine bleach rinse.

3.4. Sample Point Selection

Every effort should be taken to collect water samples from locations that are as close as possible to the well on the well discharge line. While it is preferred that a sampling point before the pressure tank on the well be chosen, it is most important that the sample point not be located after a holding tank (for samples where collection of methane, compositional gases, or isotopes are required), water softener or other water treatment or purifying device and that an aerator not be installed on the sample point. Samples should not be collected from points on hot water lines.

To collect a sample, first discuss with the well owner the operations of their water supply system. To ensure that a sample of treated or purified water is not being collected, it is generally a good idea to observe the plumbing system with the well owner if the sample is not being collected from a hydrant near the well or from the pressure tank for the well.

In the event that a sample of unheated, untreated, and/or non-aerated water cannot be collected, the well will not be sampled.

3.5. Groundwater Purging Protocols

Most standard environmental water well sampling protocols require purging a minimum of 3 well bore volumes of water prior to collecting water samples. For several reasons (e.g., unknown well construction, low yield, high frequency of pumping) it may not be practical, or necessary, to purge 3 or more well volumes from a water supply well to collect valid samples. For the Garfield County sampling, an alternative technique, based on low flow sampling techniques utilized in the environmental industry (Puls and Barcelona, 1996 and ASTM, 2002; etc.) will be employed. As with other low flow techniques, determining when a sample should

be collected will be based on field measurement of basic water quality parameters. Stabilization of those parameters, collected over a several minute period with continuous flow at a relatively low and sustainable rate, will be required before samples are collected.

To allow efficient and consistent sampling, and to avoid over pumping a well, the following groundwater purging protocols will be used.

1. Question the well owner about well yield prior to purging a well. If well yields are estimated to be less than 5 gpm, then the flow rate for purging should be kept well under 5 gpm. Estimate the initial purge rate using a 5-gallon bucket and adjust the flow as necessary. Use the following guidelines for setting purge flow rates:
   - Purge the well slowly at first, while water quality is observed. Purge rates should be slow enough to avoid turbulence in the well bore and pump tubing that may stir up sediments in the well casing.
   - If the water is clear and remains clear, increase the flow rate gradually to a maximum of 3 to 5 gpm (if appropriate based on estimated well yield) as long as no increase in entrained sediment is observed.
   - Throughout the purging period keep track of the approximate cumulative flow of water.
2. Let the water run for approximately 10 minutes. Listen at the wellhead or the pressure tank to determine when the pump is operating. Ideally during this time the well will operate for at least one cycle. If the well has not cycled on, let the water run until the pump turns on. Use this period to provide field observations of water quality. These observations should include the following:
   - Water color
   - Water clarity
   - Odors (if any)
   - Effervescence (if any)
   - Produced sediment (if any)
   - Evidence of bacterial fouling (bioslimes or biofilms)
3. After the water has run for approximately 10 minutes and the pump has cycled on at least once, begin measuring field parameters. The parameters that will be measured are pH, specific conductance (SC), temperature (T), and dissolved oxygen (DO). The parameters will be measured on a calibrated multi-parameter meter whose probes are connected to a flow-through cell that accommodates a continuous flow of water. Specifications for this instrument are located in Appendix B.

4. Record field parameter measurements at approximately 5-minute intervals. When 3 consecutive measurements indicate stabilization of all field parameters has occurred, the well can be sampled. Stabilization for each parameter will be determined as follows:
   - pH varies by less than 0.1 units between measurements,
   - T varies by less than 0.2°C,
   - SC varies by less than 5% for values < 100 microsiemens/centimeter (µS/cm) and by less than 3% for values > 100 µS/cm, and
   - DO varies by less than 0.3 mg/L.
5. If a well does not stabilize after 6 or more field measurements, reduce the system water flow rate to 1 gpm or less and collect two more sets of field parameter measurements prior to sampling. In addition to recording all field parameter measurements, also record that the flow rate was reduced due to the failure of the water quality to stabilize.

Sample all wells using the procedures described below.

3.6. Sampling Procedures

All samples will be collected at low flow rates between 0.1 gpm and 1 gpm. Collecting samples at low flow rates insures more representative measurements of dissolved gas and other volatile constituent concentrations. The flow-through cell used to determine field water quality parameters will be bypassed for sampling.

3.6.1. Water Sample Collection

This section pertains to the collection of samples for major anions and cations, metals, halides, pH. These samples will be collected into the following sample containers which will be provided by ACZ Laboratories, Inc. (ACZ). Information provided by ACZ on sampling procedures is included in Appendix C.

For each water sample location, there is a prepackaged sample kit that contains sample containers wrapped in a polyethylene bag provided by ACZ. Sample kits contain all bottles necessary for each type of sample at each location. A label with the task names is located on the outside of the sample kit; task names were determined by ACZ and do not necessarily match descriptions of the type sample at each location. Refer to Figure 6 to determine task names by sample types and how each sample type should be collected.

Each bottle contained in the sampling kit is marked with colored dots on the side of the bottle, if there is no colored dot then the sample bottle is a RAW unfiltered sample. Raw samples can be collected as described above. Do not rinse any sample bottle before collecting, sample bottles have been pre-cleaned and some contain preservatives.

White and green sample bottles should be filtered with a 0.45 micron filter. After the well has been flushed and reaches a steady state, attach a filter to a tube and let water flow through the filter before collecting it in a sample bottle. If there is not sufficient pressure to draw water through, a pump may be necessary and should be carried in the field.

Sampling of springs may require the use of a pump. If a pump is used, the pump should be cleaned according to specification in section 3.7, and the filter should be placed after the pump.

Yellow and green sample bottles contain sulfuric acid and nitric acid preservatives, respectively. Before collecting sample, check to ensure that preservative has not leaked, if leaking occurred contact ACZ for instructions. While filling these samples bottles wear proper protective equipment including rubber gloves, and be careful not to spill any of the preservative. Do not over fill samples, samples should be filled to the shoulder of the container.

The 40mL Volatile Organic Analysis (VOA) vials should be carefully and completely filled at a low flow rate. A positive meniscus should form on the top of the vial so that when it is capped there is no air bubbles trapped inside.

If the yellow or green sample bottles are not correctly filled, the sample container(s) should be discarded and new one(s) used because they contain preservatives. All containers should be capped tightly and cleaned of debris on the outside. A water proof marker should be used to label each sample with facility identifier, sample date and time, preservative (if appropriate), filtering, and project and sampling personnel identification using the labels provided by ACZ. All bottles for each bottle kit should be retuned to the polyethylene bag and cooled to 1ºC-6º C. After collection and prior to shipping, all samples should be stored securely

in a cooler on ice. Instructions for packaging and shipping the samples are provided in further detail in section 3.8.

3.6.2. Dissolved Methane Sample Collection

Because dissolved methane gas concentrations in well water can vary significantly over a very short period of time, it is important to maintain a consistent sampling protocol when collecting samples for dissolved methane analysis. Depending on whether or not the well water effervesces, there are two methods for collecting samples for dissolved methane analysis.

Dissolved Methane Sampling – Non-Effervescent Water: Use the following procedure to collect dissolved methane samples from wells with water that does not effervesce.

1. Use clear 3/8-inch or 1/2-inch outside diameter polyvinyl tubing for the discharge line from which the dissolved methane water sample will be collected.
2. Establish a flow of water through the line that is sufficiently low to ensure that laminar flow through the line is maintained—generally this will be less than 0.5 gpm.
3. Place the clear polyvinyl tubing into the bottom of a clean white 5-gallon bucket keeping the end of the tubing submerged in water to minimize the free gas space in the line.
4. Using gloved hands, lower a sealed Teflon-capped VOA vial with no preservative to near the bottom of the bucket. Uncap the vial under water allowing the vial to fill completely with water. No air should be allowed to remain in the vial or in the cap.
5. Invert the VOA vial and insert the tubing to flush the vial with the sample water. Allow enough water to flow through the vial to displace twice its volume. While keeping the VOA vial as near as possible to the bottom of the bucket, slowly remove the tubing from the vial and screw the Teflon cap on to the vial. (The advantage of using this method is that dissolved methane is trapped under the pressure of a head of water and the sample is less likely to degas.)
6. After the vial is capped, remove it from the bucket, turn it upside down, and inspect it to insure that there are no bubbles in the vial. If bubbles are visible, discard the water in the vial and repeat the sampling process as described above.

Dissolved Methane Sampling – Effervescent Water: If the water discharging from the sample line at the bottom of the 5-gallon bucket effervesces, then the following modified sampling process must be used.

1. Follow steps 1 through 4, above.
2. If following step 5, above, results in gas bubbles forming in the sealed VOA vial, or if it is clear from observing the water discharging from the sample line that this will occur, then after the inverted VOA vial has been filled with water from the discharge tubing, it will be necessary to remove the gas bubbles by tilting the vial under water.
3. To complete the sample collection, keeping fresh water flowing over the open end of the VOA vial, tilt it upward to release the gas bubbles. Seal the vial with the Teflon cap and remove it from the water and inspect it to make sure that no gas bubbles are present. If bubbles are present, discard the water and repeat the process.

In some cases when there is free gas in the aquifer, it may not be possible to obtain a sample that does not have bubbles. In these instances, any head space created by degassing water must be recorded on the field sampling form and in the field notes.

3.6.3. Gas Composition and Stable Isotope Sampling and Shipping

As with the collection of samples for dissolved methane, the method used to collect samples for gas composition and stable isotopes depends on whether or not the well water effervesces when it is discharged at the ground surface. For determining gas composition and stable isotopes, if dissolved gases are exsolving at a high rate and the water effervesces, a sample of gas is collected by displacing well water from a sample bottle while creating a gas headspace. Collection methods for the two situations are described below. In addition, shipping of these samples, which requires special care, is described below.

Gas Composition and Stable Isotope Sampling – Non-Effervescent Water: If the water being sampled is not effervescent or produces only a very small amount of gas when it discharges then the following sampling procedure is used.

1. Use clear 3/8-inch or 1/2-inch outside diameter polyvinyl tubing for the discharge line from which the gas and stable isotope sample will be collected. (This will be the same tubing used for the collection of the sample for dissolved methane and the other parameters.)
2. Establish a flow of water through the line that is sufficiently low to ensure that laminar flow through the line is maintained—generally this will be significantly less than 0.5 gpm. Fill a clean 5-gallon bucket most of the way full of water.

3. Remove the cap of one of the clear plastic 1-liter samples bottle provided by Isotech Laboratories, place the clear discharge tubing at the bottom of the bottle, and fill it with water. (The caps of the bottles provided by Isotech contain a bactericide capsule which must remain attached to the cap.)
4. Once the bottle is filled, using gloved hands, immerse the bottle in the 5 gallon bucket full of water, keeping the tubing at the bottom of the bottle. Place the bottle at the bottom of the bucket under a head of water and keep water flowing at a low rate until another 2 volumes of water have been displaced from the bottle. Then slowly lift the tubing out of the bottle and immediately cap it under water. No air should be allowed into the bottle and the cap should still contain the bactericide capsule.
5. After the bottle is capped, remove it from the bucket, turn it upside down, and inspect it to insure that there are no bubbles present. If bubbles are visible, collect another sample.
6. When finished, dry the bottle, tape the cap to the bottle around the neck with airproof and waterproof tape, and pack the bottle upside down in ice.

Gas Composition and Stable Isotope Sampling –Effervescent Water: If the water being sampled effervesces strongly or a gas-free water sample was not able to be collected using the method described immediately above, use the following procedure to collect a sample of gas from the water.

1. Follow steps 1 through 3, above.
2. Remove the discharge tubing from the sample bottle, and using gloved hands, submerge the bottle in the 5 gallon bucket full of water and invert it.
3. Insert the clear discharge tubing into the inverted bottle and increase the flow rate to 2 to 3 gpm. Allow the bubbling gases from the discharged water to displace the water in the sample bottle until 1/3 to 1/2 of the water in the bottle has been displaced.
4. Seal the sample bottle under water with the screw cap containing the bactericide capsule.
5. Remove the sealed bottle from the water, dry the bottle, tape the cap to the bottle around the neck with airproof and waterproof tape, and pack the bottle upside down in ice.

Gas Composition and Stable Isotope Sample Shipping: The gelatin capsule attached to the caps of the Isotech 1-liter sample bottles delivers bactericide to water in the bottle as long as the water is in contact with the capsule. For water treated in this method with bactericide, the component and isotopic composition of hydrocarbons in water samples will not change over a

period of a month. If there is no bactericide in the water sample, natural bacteria will begin consuming the enclosed dissolved methane and alter its constituent and stable isotopic composition. To ensure the validity of samples containing bactericide capsules, it is very important that the sample bottles be shipped to the analytical laboratory in an inverted position so that the water in the bottle remains in contact with the bactericide capsule attached to the cap.

Even with the bottles packed in an inverted position, all shipments should be via an overnight courier to minimize the amount of time in which the cooler containing the samples might be stored in a position other than right side up.

If no bactericide has been added to a sample being analyzed for gas composition and stable isotopes, the samples should be placed on ice and shipped to the analytical laboratory via overnight courier within 24 hours of collection. In addition the laboratory should be contacted and instructed to process the samples and remove dissolved gases from the water matrix as soon as the samples are received.

3.7. Equipment Decontamination

Any equipment, buckets, hoses, and probes that may come in contact with well water or surface sampling apparatus should be cleaned and disinfected not only to maintain sample integrity, but also to avoid contaminating water wells with bacteria. For the Garfield County sampling project, the sampling apparatus is constructed so that the only pieces of equipment requiring decontamination are the length of discharge tubing that connects to the well sample tap, the length of tubing that is used for sample collection (including the attached needle valve, and the 5-gallon bucket that is used to facilitate sampling under a head of water. All other parts of the apparatus, including the flow-through cell are beyond these pieces and do not require regular decontamination.

The pieces requiring decontamination will be cleaned using the following protocol:

1. Clean equipment as needed with a mild detergent solution (using TSP or Alconox) and triple rinse thoroughly with distilled water;
2. Allow to air dry.

3.8. Sample Handling, Packing, and Shipping

Prior to final packing and shipping of samples to the analytical laboratory, complete all Chain-of-Custody forms required to be shipped with the samples. (A copy of the style of Chain-of-Custody form to be used for the Garfield County sampling project is included as Figure 5.) Double check both the numbers and types of bottles against the Chain-of-Custody forms to ensure consistency in both quantities and labeling. Sign all Chain-of-Custody forms prior to sealing them in ziplock bags and placing the bags in the coolers for shipment. Every cooler containing samples for analysis should contain at least one Chain-of-Custody form.

Pack the sample bottles upright (or inverted for sample bottles containing bactericide capsules in the lid) in the cooler with at least 1 to 2 times as much ice as the total volume of samples. Glass containers should be separated with plastic containers, ice packs, or padding to minimize the potential for breakage during transport. Prior to sealing the sample coolers, confirm that fully completed and signed Chain-of-Custody forms (and other laboratory-required forms) are included and are stored in sealed ziplock bags. Seal the coolers shut securely with shipping tape and with laboratory-supplied custody seals, if appropriate.

Where possible, use overnight courier services (e.g., UPS) to ship samples so that they will be received by the laboratory within 24 hours of shipment. If necessary, contact the laboratory and arrange to have laboratory personnel available to take custody of and process shipments delivered on weekends or holidays.

4.0 WELL LOCATION DOCUMENTATION

For both COGCC database construction/maintenance and future field sampling purposes it is important that all wells sampled be fully described and precisely located. For the Garfield County sampling project the following protocols will be used.

4.1. Well Location Description and Photographic Documentation

At each location sampled, a well information form will be completed. A copy of the form to be used is shown in Figure 2. In addition to completing well owner and well construction information, the form contains an area for description of the location and area around the well. It is important that this information be completed to a degree sufficient to allow future sampling personnel to locate and identify the well in the field in a situation where no one—either sampler or future well owner—is familiar with previous sampling events. The description should include location relative to the nearest roads and buildings and any features or structures that may be housing or obscuring the well. In addition, the description should also include where the well was sampled and how that point is located relative to the well and/or the pressure tank or other significant features on the water supply system.

Each well sampled should be photographed by the sampler at the time of sampling. At a minimum the following photographs should be taken:

- Site locator photograph showing enough information for future sampling teams to positively identify the property being sampled.
- Well head photograph.
- Sampling location photograph.

Each photograph taken should be documented on the well information form or in the sampler's field notebook at the time the photograph is taken.

4.2. GPS Location Determination

A Differential GPS instrument is not required for mapping of wells in the project. All wells in this study have been sampled previously, which suggests that accurate GPS coordinates

were obtained in the past. Therefore a handheld GPS unit will be used to record the positions of wells.

For the wells sampled during the Garfield County study, a hand held Garmin eTrex GPS unit will be used. Operating instructions for the instrument are contained in the instrument carrying case and will be kept in the field at all times. Field personnel will collect measurements at the time of sampling activities and will write down the coordinate information on the Well Information Form.

5.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

5.1. Sample Chain of Custody

Chain-of-Custody forms similar to that shown in Figure 5 will be completed and provided with all samples submitted to analytical laboratories. A copy of each form will be retained by the field personnel who packages and relinquishes the sample coolers.

5.2. Field QA/QC

5.2.1. Field Equipment Calibration and Maintenance

Calibration of the water quality multi-parameter meter (measures, pH, T, SC, and DO) will be conducted at the beginning of each week of sampling and at other times if the field sampling personnel suspect that instrument errors are occurring. Calibration will be performed according to the instructions kept in the instrument carrying case.

5.2.2. Field Duplicates and Blanks

Equipment and trip blanks are not required for this project. Therefore, no Matrix Spike/Matrix Spike Duplicate field samples nor any other QA/QC samples will be collected or analyzed.

6.0 REFERENCES

ASTM International, 2002, Standard Practice for Low-Flow Purging and Sampling for Wells and Devices Used for Ground-Water Quality Investigations. American Society for Testing and Materials, D 6771-02.

Puls, R. W., and M. J. Barcelona, 1996, Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures. U. S. Environmental Protection Agency, Office of Research and Development, Publication No. EPA/540/5-95/504, 12 pp.

URS, 2006, Phase 1 Hydrogeologic Characterization of The Mamm Creek Field Area in Garfield County, URS Corporation, Denver, CO.

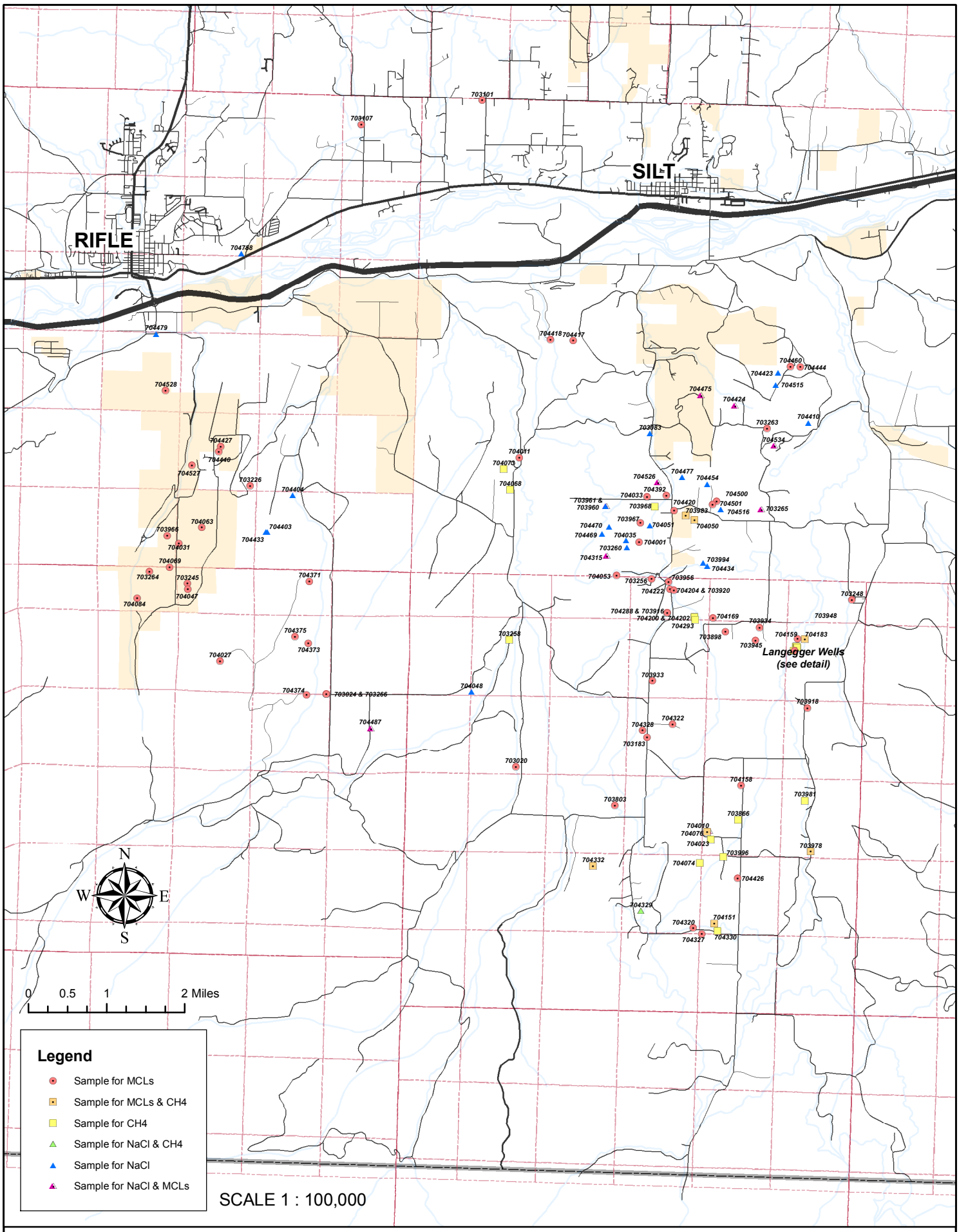


Figure 1. Task 1 Sampling Locations for Mamm Creek Phase II Study

Estimated Sample Numbers for Mamm Creek Phase II Study Proposal

Analytical parameters and common laboratory analytical methods	**Standard Inorganics[1]** Various	**Selenium** ICP-MS	**Strontium** ICP-MS	**Boron** ICP-MS	**Fluoride** 300.0	**Bromide** 300.0	**Dissolved Methane** RSK 175	**Gas Composition and Isotopes[5]**
Task 1: Domestic Wells with CH_4 > 2 mg/L [2]	20	0	0	0	0	0	20	20
Task 1: Domestic wells with Drinking Water Standards for NO_3^-, F, and/or Se exceeded	58	58	0	0	58	0	0	0
Task 1: Domestic wells with Drinking Water Standards for NO_3^-, F, and/or Se exceeded and Na-Cl Waters	10	10	10	10	10	10	0	0
Task 1: Domestic wells with Drinking Water Standards for NO_3^-, F, and/or Se exceeded and CH_4 elevated.	7	7	0	0	7	0	7	7
Task 1: Domestic Wells with Na-Cl Waters [3]	20	0	20	20	20	20	0	0
Task 1: Domestic Wells with Na-Cl Waters and >2 mg/L CH_4	1	0	1	1	1	1	1	1
Task 2: Gas Wells Near Domestic Wells with Primary Drinking Water Standards Exceeded[4]	20	20	0	0	20	0	0	0
Task 2: Gas Wells Pads or Produced Water Pits Near Domestic Wells with Na-Cl Water[4]	10	0	10	10	10	10	0	0
Totals:	**146**	**95**	**41**	**41**	**126**	**41**	**28**	**28**

1 For this study standard inorganics consist of:
- Major cations (dissolved metals): Na, Ca, K, Mg, plus Fe (all by method 200.7). Field filter and acidize.
- Major anions: Cl, SO_4 (both by method 300.0); CO_3/HCO_3 (alkalinity as $CaCO_3$ by std. method 2320B); and NO_3 as N (by method 300.0 or NO_3/NO_2 as N by EPA method 353.3)
- Total Dissolved Solids (by method 160.1)

2 RFP Question and Response Section Answer 50 approximates 20 wells with CH_4 > 2 mg/L with only one anlysis or no isotopic determination.

3 Na-Cl waters are previously sampled wells with >1000 TDS and > 500 Na

4 Total of 30 samples assumed, with 20 samples being to test similarity to domestic wells with Primary Drinking Water Standards exceeded and 10 to test similarity to domestic wells with Na-Cl waters.

5 Isotope analyses by Isotech Laboratories

Basic Well Information

Date: _____

Well Owner: _____ **Staff:** _____

Well Name: _____

Address: _____

Phone: _____

Well Location: _____ **Facility ID:**

Well Permit #: _____

Well Permit Name: _____

Water Well Conditions

Well Type: Domestic_____ Stock_____ Irrigation ____

Pump?: Yes____ No____ **Pump Type:** Submersible____ Other_____

Well Depth: _____ **Screened Interval(s):** _____

Casing Dimensions: _____ _____

Casing Material: Stainless Steel____ Carbon Steel____ Galvanized Steel____ PVC____ Other____

Formation: _____

Yield: _____ **Static Water Level (SWL):** _____

Test Date: _____ **SWL Date:** _____

Drawdown: _____

Typical Daily Water Use: _____

Location: Outdoor Tap _____ Pressure Tank_____ Pump _____

Tap before/on Pressure Tank? Yes_____ No_____ **Easily Accessible?**_____

Information Source: ____ Well Owner Interview
____ CO State Engineers Database
____ Well Completion & Pump Installation Report

Notes: _____

Photos: _____

Well Sampling Form Part I

Well Owner: **Date:** _____

Well Name: **Time:** _____

Well Location: **Staff:** _____

FACILITY ID: _____

Pre-Sampling Information

Water Color: _____

Water Clarity: _____

Odor: _____

Effervescence: _____

Produced Sediment: _____

Bacterial Fouling: _____

Notes: _____

_____

_____

Water Quality Sampling?: YES____ NO__ **# Samples:** _____

Dissolved Gas Sampling?: YES____ NO____

Well Purging and Water Quality Sampling

Low Flow?: YES_____ flow at low rate and monitor field parameters prior to collecting samples

NO _____ pump 3 well bore volumes and measure parameters prior to collecting samples

Approx. Purge Rate: _____

	Time	pH	Temp (C)	SC (t-uS/cm)	DO (mg/L)
Stabilization Limits	*5 - 10 min Interval*	*varies by < 0.1*	*varies by < 0.2*	*for < 100, < 5% for > 100, < 3%*	*varies by < 0.3*

Well Sampling Form Part II

Well Owner: _____ **Date:** _____

Well Name: _____ **Time:** _____

Facility ID: **Staff:**

Sampling for Dissolved Methane

If Water Effervesces During Sampling

Bubbles present in vial? _____

Head space created by degassing water? _____

If Water Does Not Effervesce

Samples collected: _____

Sampling for Chromatographic and Stable Isotopic Analysis of Free/Dissolved Gases

Effervescent Water:

Head Space: _____

Non Effervescent Water:

Sample as usual

Samples Collected:

Water Sample Check List

Wells not meeting MCL and/or Salt Signature

(1) 500 mL Raw Bottle	_____	**Completely fill**
(1) 250 mL White Bottle	_____	**Completely fill, 0.45 micron filter**
(1) 250 mL Yellow Bottle	_____	**Do not overfill, Sulfuric Acid**
(1) 250 mL Green PC Bottle	_____	**Do not overfill, Nitric Acid, 0.45 micron filter**

Wells > 2 mg/L Methane

(1) 500 mL Raw Bottle	_____	**Completely fill**
(1) 125 mL Green Bottle	_____	**Do not overfill, Nitric Acid, 0.45 micron filter**
(1) 250 mL White Bottle	_____	**Completely fill, 0.45 micron filter**
(1) 250 mL Yellow Bottle	_____	**Do not overfill, Sulfuric Acid**
(3) 40 mL vial up	_____	**Do not overfill, no bubbles**
(1) Isotech 1 Liter Bottles with Septa Cap	_____	**Completely fill, No bubbles**

Wells not meeting MCL or Salt Signature and >2 mg/L High Methane

(1) 500 mL Raw Bottle	_____	**Completely fill**
(1) 250 mL White Bottle	_____	**Completely fill, use 0.45 micron filter**
(1) 250 mL Yellow Bottle	_____	**Do not overfill, Sulfuric Acid**
(1) 250 mL Green PC Bottle	_____	**Do not overfill, Nitric Acid, 0.45 micron filter**
(3) 40 mL vial up	_____	**Do not overfill, no bubbles**
(1) Isotech 1 Liter Bottles with Septa Cap		**Completely fill, No bubbles**

Send Data and Invoice to

Name: _____

Company: _____

Address: _____

_____

Phone: _____

Fax: _____

Email: _____

Project: _____

Location: _____

Sampled by: _____

Circle one:

Standard

Priority

Rush

Analysis Package Codes on Back

ISOTECH®

Isotech Laboratories, Inc.

1308 Parkland Court

Champaign, IL 61821

Phone: 217-398-3490

Fax: 217-398-3493

www.isotechlabs.com

mail@isotechlabs.com

Sample Description

Container Number	Sample Identification	Date Sampled	Time	Analyses Requested			Comments

Chain-of-Custody Record

Signature	Company	Date	Time
Relinquished by			
Received by			
Relinquished by			
Received by			
Relinquished by			
Received by			

EXPLANATION OF ANALYSIS CODES

Natural Gas Characterization

NG-1; level 1 analysis - composition, $\delta^{13}C$ and δD of CH_4

NG-2; level 2 analysis - NG-1 plus $\delta^{13}C$ of C_2H_6, and C_3H_8

NG-3; level 3 analysis - NG-2 plus $\delta^{13}C$ of i-C_4H_{10}, and n-C_4H_{10}

Bacterial Gas Characterization

BG-1; level 1 analysis - composition, $\delta^{13}C$ of CH_4 and CO_2, δD of CH_4

BG-2; level 2 analysis - BG-1 plus ^{14}C in CH_4

BG-3; level 3 analysis - BG-2 plus ^{3}H in CH_4

Water Analysis

SIW; stable isotopes of water - δD and $\delta^{18}O$ of H_2O, and $\delta^{13}C$ of dissolved inorganic carbon (DIC)

RAG; radiocarbon analysis of groundwater - $\delta^{13}C$ and ^{14}C of dissolved inorganic carbon (DIC)

TAG; tritium analysis of groundwater - low-level ^{3}H in H_2O

ACZ Laboratories, Inc.

2773 Downhill Drive Steamboat Springs, CO 80487 (800) 334-5493

CHAIN of CUSTODY

Report to:

Name:	Address:
Company:	
E-mail:	Telephone:

Copy of Report to:

Name:	E-mail:
Company:	Telephone:

Invoice to:

Name:	Address:
Company:	
E-mail:	Telephone:

If sample(s) received past holding time (HT), or if insufficient HT remains to complete analysis before expiration, shall ACZ proceed with requested short HT analyses?

YES ☐ **NO** ☐

If "NO" then ACZ will contact client for further instruction. If neither "YES" nor "NO" is indicated, ACZ will proceed with the requested analyses, even if HT is expired, and data will be qualified.

PROJECT INFORMATION

Quote #:

Project/PO #:

Reporting state for compliance testing:

Sampler's Name:

Are any samples NRC licensable material?

ANALYSES REQUESTED *(attach list or use quote number)*

SAMPLE IDENTIFICATION	DATE:TIME	Matrix	# of Containers								

Matrix: SW (Surface Water) · GW (Ground Water) · WW (Waste Water) · DW (Drinking Water) · SL (Sludge) · SO (Soil) · OL (Oil) · Other (Specify)

REMARKS

Please refer to ACZ's terms & conditions located on the reverse side of this COC.

RELINQUISHED BY:	DATE:TIME	RECEIVED BY:	DATE:TIME

Figure 6: Sample Bottle Descriptions

Wells not meeting MCL and/or Salt Signature

Task	Well Test	Analysis	Bottle	Instructions
TASK-1-LONG-2	MCL	Wet Chemistry	(1) 500 mL Raw Bottle	Completely fill
TASK-1-NA-CL	NaCl	Wet Chemistry	(1) 250 mL White Bottle	Completely fill, 0.45 micron filter
TASK-LONG-3	NaCl and MCL	Total Wet Chemistry	(1) 250 mL Yellow Bottle	Do not overfill, Sulfuric Acid (H_2SO_4)
TASK-1-NACL-SE	NaCl and MCL	Metals	(1) 250 mL Green PC Bottle	Do not overfill, Nitric Acid (HNO_3^-), 0.45 micron filter

Wells with >2 mg/L Methane

Task		Analysis	Bottle	Instructions
TASK-1-CH4	CH_4	Wet Chemistry	(1) 500 mL Raw Bottle	Completely fill
		Metals	(1) 125 mL Green	Do not overfill, Nitric Acid (HNO_3^-), 0.45 micron filter
		Wet Chemistry	(1) 250 mL White Bottle	Completely fill, 0.45 micron filter
		Total Wet Chemistry	(1) 250 mL Yellow Bottle	Do not overfill, Sulfuric Acid (H_2SO_4)
		VOA	(3) 40 mL Vial Up	No bubbles

Wells not meeting MCL or Salt Signature and >2 mg/L

Task		Analysis	Bottle	Instructions
TASK-1-LONG TASK-1-NA-CL-CH4	MCL and CH_4 NaCl and CH_4	Wet Chemistry	(1) 500 mL Raw Bottle	Completely fill
		Wet Chemistry	(1) 250 mL White Bottle	Completely fill, use 0.45 micron filter
		Total Wet Chemistry	(1) 250 mL Yellow Bottle	Do not overfill, Sulfuric Acid
		Metals	(1) 250 mL Green PC bottle	Do not overfill, Nitric Acid (HNO_3^-), 0.45 micron filter
		VOA	(3) 40 mL Vial Up	No bubbles

Wells > 2 mg/L Methane Gas Collection

Task		Analysis	Bottle	Instructions
ISOTECH	all CH_4	Isotopes	(1) Isotech 1 Liter Bottles with Septa Cap	Completely fill, if effervescence fill 1/3-1/2 with air

Notes: Task names will be marked on pre-packaged bottle sets, choose the set according to the type of well to be sampled.

Appendix A

Piceance Creek Basin Water Quality Study IV Letter to Garfield County Residents

S. S. PAPADOPULOS & ASSOCIATES, INC.
ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS

S. S. PAPADOPULOS
S. P. LARSON
C. B. ANDREWS
D. L. HATHAWAY

June 1, 2007

Subject: **Water Sampling for Garfield County Hydrogeological Characterization Study Phase Two**

Dear Garfield County Resident:

S. S. Papadopulos & Associates, Inc. (SSPA) has been contracted by Garfield County Board of County Commissioners in conjunction with the Garfield County Oil & Gas Auditor to conduct sampling of water supply wells and springs in the Mamm Creek Study area. The purposes of this study are to collect groundwater quality information in the Mamm Creek area and to evaluate the information for potential impacts from natural gas development.

SSPA will be contacting you in the next few days or weeks regarding collecting water samples from your well or spring for laboratory analysis of various water quality parameters. Your cooperation is appreciated in granting access to sampling locations and providing information on your water system so that sampling can be conducted efficiently. Sample results will be provided to you and in the event that water quality standards are not met, you will be notified of that condition by Garfield County.

If you have additional questions about this project, please contact Jesse Smith, Assistant County Manager, at 970-625-0973 or Bryan Grigsby, SSPA Project Manager, at 303-939-8880.

Sincerely,

S. S. PAPADOPULOS & ASSOCIATES, INC.

Bryan Grigsby
Senior Project Hydrogeologist

cc: Jesse Smith – Garfield County

3100 ARAPAHOE AVENUE, SUITE 203, BOULDER, COLORADO 80303 • TEL: (303) 939-8880 FAX: (303) 939-8877
http://www.sspa.com • e-mail: boulder@sspa.com

Appendix B

Specification Sheets for Multiprobe and Filter

FIELD Environmental Instruments

Equipment Rental and Field Supplies

"Your Needs Are Our Business"

Toll-Free
800-393-4009

VOSS Technologies

Single Sample Disposable 0.45 Filter

The Single Sample® Groundwater Cartridge features 1/8" NPT threaded inlet and outlets with stepped hose adapter on the inlet side for in line filtering of pumped samples with up to 3/8 ID tubing.

An optional stepped barb can be threaded on each end for use of up to 1/2" tubing.

- A true membrane element.
- Certification for 67 metals and 2 anions.
- Completely inert components and assembly process.
- Ready to use.
- Individually sealed packaging.
- 1/8" NPT treaded ends with stepped hose adapter on inlet side.
- .45µm, 1µm and 5 µm elements available.

ORDERING INFORMATION

Field Environmental Instruments
99 Miller Avenue
Braddock, PA 15104

For Orders or Inquiries:
800-393-4009
Fax 412-271-5083

Visit us soon on the web
www.fieldenvironmental.com

Appendix C

ACZ Bottle Orders and Sampling Information

A C Z Laboratories, Inc.

2773 Downhill Drive Steamboat Springs, CO 80487 (800) 334-5493

Bottle Order Packing List

Account: S.S. Papaodopulos Assoc.
Bottle Order: BO17244
Internal Note:

Bill to Account: Bill to ACZ
Ship Date Requested: 05/31/2007
Request Placed at: 05/31/2007 09:06
Service Requested: UPS Ground

Sampling supplies

PACK	Qty	ACZ ID	Type	Description
	2	COC	Chain of Custody	Chain of Custody, 1 for 10 samples.
	2	SEAL	Custody Seal	Custody seals for cooler, two for each cooler.
	1	RETURN	Return Address	Return Address label, one for each cooler.
	150	LABELS	Sample Labels	ACZ supplied labels for sample containers

Quote number: GARFIELD-GW
Sample Quantity: 15

Garfield County: 70 groundwater wells July - August 2006

Client is responsible for necessary field filtering

PACK	Qty	Type	Size	Filter/Raw/Preserve	Instructions
	1	RAW	500 ML	Raw	Wet Chemistry (analyses that do not require preservative or filtration) - Completely fill container.
	1	WHITE	250 ML	Filtered	Wet chemistry (dissolved) - Filter sample with .45 micron filter. Completely fill container.
	1	RED PC	250 ML	Red pre-cleaned Raw/Nitric	Metals (total including ICPMS) - Do not overfill as there is Nitric Acid in the bottle.
	3	VIAL P	40 ML	Raw/HCl	VOA, BTEX, TVH - Do not overfill and make sure sample contains no bubbles.
	1	YELLOW	250 ML	Raw/Sulfuric	For total wet chemistry analyses. Do not overfill as there is Sulfuric Acid in the bottle.
	3	VIAL UP	40 ML	Raw	VOA & Radon - Do not overfill and make sure sample contains no bubbles.

A C Z **Laboratories, Inc.**
2773 Downhill Drive Steamboat Springs, CO 80487 (800) 334-5493

Bottle Order Packing List

Account: **S.S. Papaodopulos Assoc.**
Bottle Order: **BO17244**
Internal Note:

Bill to Account: **Bill to ACZ**
Ship Date Requested: **05/31/2007**
Request Placed at: **05/31/2007 09:06**
Service Requested: **UPS Ground**

General Sampling Techniques and Instructions

Inspect the sample containers provided in the sample kits. If any of the preservative has leaked notify your project manager or client services contact as soon as possible.

The sample containers are packaged in separate polyurethane bags or in bubble wrap for larger sample containers representing the total number of samples you need to collect. Ten bags of bottles equal 10 samples to be collected. Treat each sample container package as a set, sample from the same place and at the same time for all containers in the set.

The sample containers can be identified by the colored dot on the side of the container. A RED container type will have a red dot on its side. Raw/unpreserved container types do not have a colored dot.

Except for RAW container types, each container has a preservative specific to the analysis you have requested. Do not rinse any container and take care not to lose any of the preservative when filling containers with your sample.

Some samples collected for inorganic constituents should be field filtered. If you are unable to perform the filtration in the field please notify your project manager so the samples can be properly prepared when they arrive at the lab. The "Filter/Raw/Preserve" column above shows what containers should be field filtered. There are many techniques for field filtering, however, when using tubing or pumps, please ensure your equipment is as clean as possible to diminish contamination affects. The filter should typically be .45 um pore size unless otherwise stated in "Sampling Instruction Specifics" page of this packet. You may also send a "Field Blank" with your sample (using the same equipment for sample filtering) to determine any field contamination problems.

Completely fill containers with your sample to the shoulder of the container. All 40 mL vials require "Zero Headspace"; make sure no air is present in the container for these samples.

Make sure all caps are tight for shipment. Clean any debris from the outside of the containers. Label all containers with the provided labels for your sample. Use a waterproof marker to write on the label. For each label fill in at a minimum the Company, Sample ID, Sample Date and Time. Also check whether the sample was filtered or not.

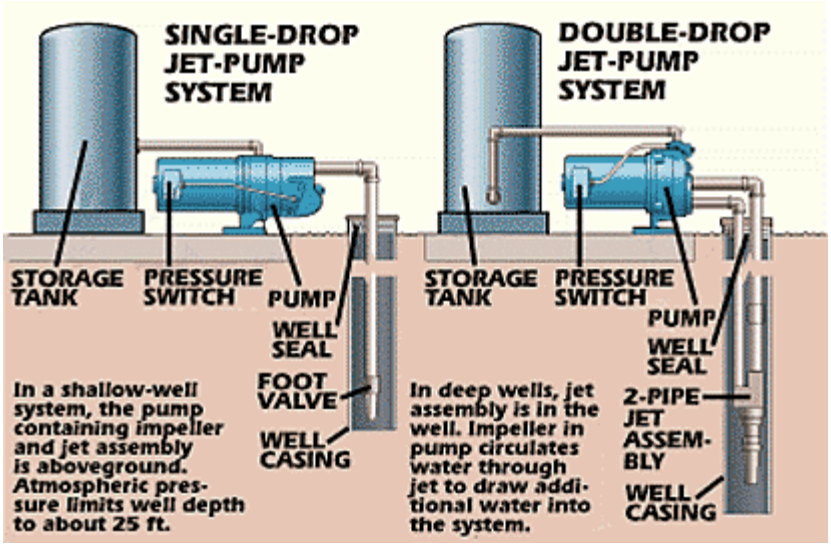
Place the entire sample set back into the original polyurethane bag. Cool the samples to 0ºC to 4ºC, place upright in a similar configuration within the cooler provided. Place the frozen ice packets around the samples and seal for return shipment. All samples other than Red, Green and Tan should be cooled to 0ºC to 6ºC for return shipment. For sample sets with short hold times please send the cooler via an overnight shipping company to ACZ.

In ACZ's ongoing effort to improve quality the use of custody seals (CS) has been implemented. For security purposes the CS should be applied to the sample cooler and cooler lid when samples are shipped back to ACZ. The condition of the seal, upon receipt, is indicative if the cooler has been tampered with during the time in transit. Apply the CS on the opening side of the container, sign and date the CS, and cover the CS with clear packing tape. Upon receipt of the container at the lab any damage will be reported to the QA/QC Officer.

Appendix D

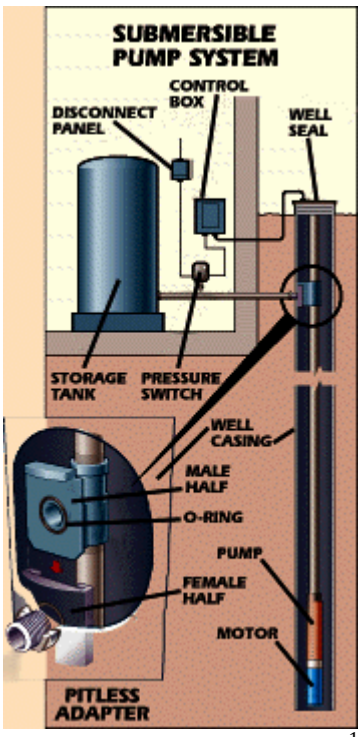
Simplified Domestic Well Water System Descriptions

Appendix D: Simplified Domestic Well Water System Descriptions



Jet Pump System[1]

Three types of pumps are common for domestic wells, Jet Pumps, submersible pumps, and suction pumps. A Jet Pump, works by creating suction above the well and drawing water up. Jet pumps are powered by an electrical motor that drives an impeller that moves water through a narrow passage similar to a nozzle forcing water through a constriction, causing a vacuum that brings more water up the well. Due to the suction, Jet pumps are limited to operation in wells shallower than 25 ft. In deeper wells, a double drop jet system is used and is characterized by the jet assembly being placed down in the water while the motor and impeller are located above the well.



Submersible Pump System[1]

A second common pump is a submersible pump which is characterized by long cylindrical shape that fits inside well casing. In this pump, impellers are stacked on top of a motor, so that the pump works by pushing water up the well instead of using suction. In previous studies of water wells in Garfield County, submersible pumps were the most commonly found.

A third type of pump is a simple suction pump that operated by creating a vacuum above a water surface. These pumps require power to account for vertical hydraulic head and friction losses. They are most commonly used in shallow wells.

While sampling domestic wells in Garfield County, the land owner should inform the sampler of the type of pump operating the well. If the land owner is not familiar with the pump system, and the pump is not visible, then the type of pump does not need to be specified on field forms.

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[1] http://www.popularmechanics.com/home_journal/how_your_house_works/1275136.html?page=3, accessed June 5, 2006