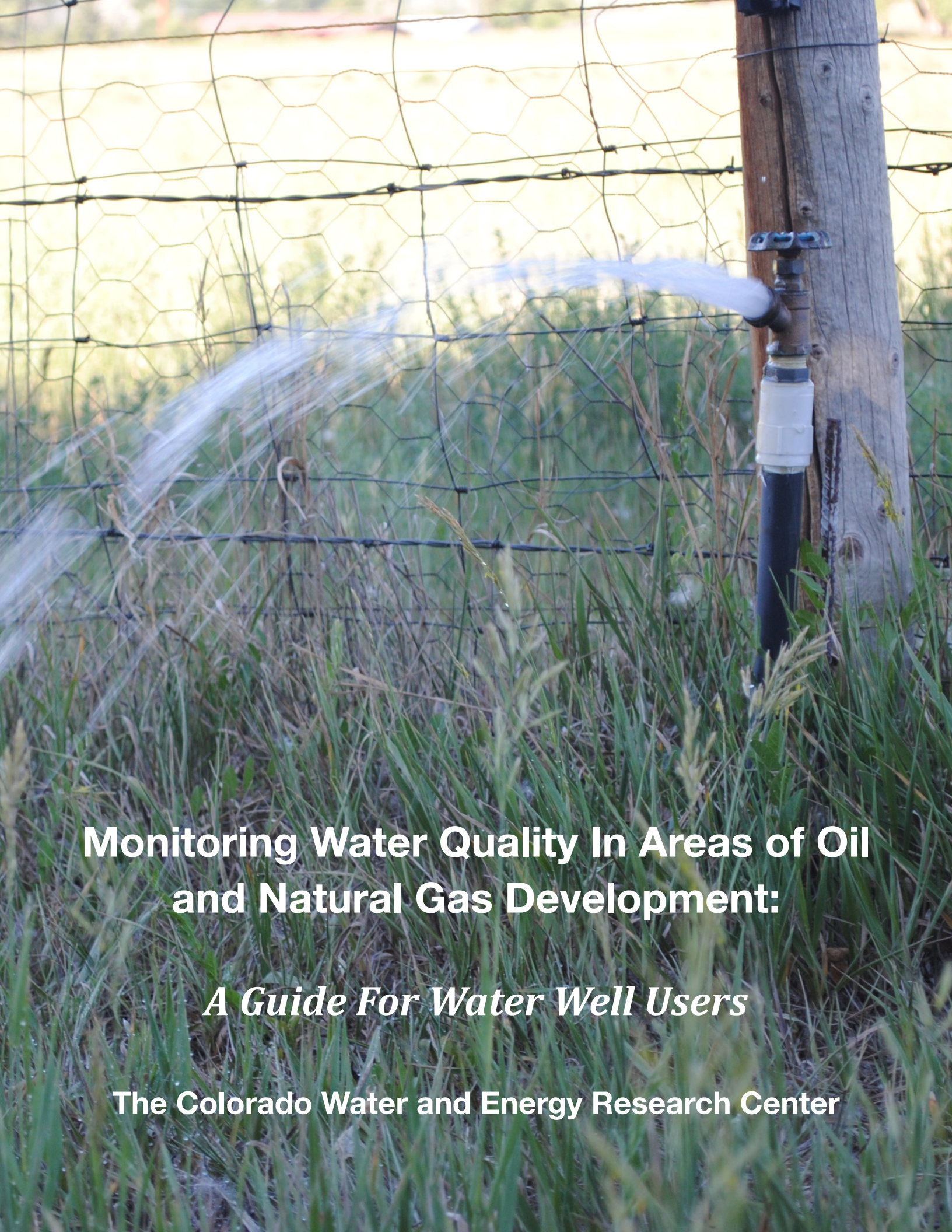


Monitoring Water Quality In Areas of Oil and Natural Gas Development:

A Guide For Water Well Users

The Colorado Water and Energy Research Center

Purpose of this Guide

Colorado is currently experiencing an **upswing in oil and gas extraction activity**, as are other states in the West and across the country. This jump in production is being spurred by the national demand for cheap domestic energy and by the proliferation of drilling technologies that have made it possible for operators to tap previously inaccessible or uneconomic oil and gas deposits. The production boom that has ensued is having two major effects on the ground: it is boosting the intensity of extraction in places where residents are already familiar with the oil and gas industry and it is also bringing drilling rigs to communities that have no experience (or sometimes no *recent* experience) with energy development.

As Colorado's oil and gas well count has risen, and as the industry has extended its geographic reach, public apprehension about the environmental impacts of oil and gas extraction has escalated as well. Much of this concern has been centered on aquifer protection, particularly in communities that depend heavily on groundwater. In Colorado, as elsewhere, some residents are alarmed about the possibility of groundwater contamination from an extraction technique called **hydraulic fracturing**. Coloradoans have also expressed worry about the possibility of **surface spills** of drilling waste and the potential for gas extraction-related **groundwater pumping** to reduce water levels in areas of coalbed methane development. This alarm has been exacerbated by a number of confounding factors, including a polarization of the public discussion of energy development and an absence of unbiased and intelligible information on these and other groundwater-related topics.

The Colorado Water and Energy Research Center (CWERC) aims to at least partially address that information deficit here, by providing guidance for water well owners who want to learn to about their groundwater resources and monitor them over time. CWERC seeks to provide helpful, independent, scientifically sound, and politically neutral information about energy and water resources in Colorado. This guide was developed after it became clear that Colorado water well users want to better understand their groundwater resources, and further, that they want help gauging if, and/or how, energy extraction might impact those groundwater resources.

To be clear, CWERC does not intend to imply that energy extraction is the sole source of all groundwater problems in Colorado. Nor does it claim that oil and gas operations will contaminate or deplete the groundwater systems in their vicinity. Aquifers can be contaminated or drawn down by countless natural factors and human activities. By and large, oil and gas operators take great care not to be among them. Still, water well users want to make sure that their groundwater resources are not compromised by energy extraction efforts in their proximity. In Colorado and across the country, individual water well users and watershed groups are seeking reassurance and security in data – specifically in **baseline data** and **long-term monitoring data**. Regulators and the oil and gas industry have been doing the same. The Colorado Oil and Gas Conservation Commission (COGCC) began enforcing a new set of statewide groundwater monitoring rules for oil and gas operators in May of 2013. Universities across the country have been playing important roles in the process as well – providing guidance on groundwater sampling, collecting baseline groundwater samples, and compiling and analyzing large sets of baseline groundwater quality data. It is CWERC's hope that these combined efforts will help shift the public debate over oil and gas extraction from a tangle of misinformation and uncertainty to a productive, transparent, and evidence-based conversation.

Baseline data is important because, in its purest form, it documents groundwater quality and quantity *before* energy extraction begins. Once a baseline has been established, it can be monitored for changes over time. This guide walks water well users through the process of measuring **baseline groundwater quality** and **quantity**. It also includes information on how best to monitor that baseline in order to develop a long-term record of groundwater conditions for the duration of oil and gas development near you. (A note about baselines: The best baselines are pre-drilling baselines, but any baseline measure is better than no baseline measure. If energy extraction has already begun near you, it isn't too late to start monitoring your groundwater. Please read on.)

Colorado Water & Energy
RESEARCH CENTER

About the Colorado Water and Energy Research Center:

Colorado's water and energy resources are tightly linked. The Colorado Water and Energy Research Center (CWERC) at the University of Colorado Boulder studies the connections between water and energy resources and the trade-offs that may be involved in their use. CWERC seeks to engage the general public and policymakers, serving as a neutral broker of scientifically-based information on even the most contentious "energy-water nexus" debates.

Since CWERC's launch in 2011, public interest and pressing scientific questions have steered the Center's work specifically toward oil and gas extraction, groundwater resources, and the importance of baseline water quality and quantity data.

Colorado Water and Energy Research Center Mission:

- Provide neutral, scientific information on important energy and water resources issues for the general public and policymakers.
- Facilitate the exchange of information and expertise among researchers and regulators working on energy and water resources problems.
- Assist citizen scientists in environmental monitoring efforts, particularly as they relate to the collection of baseline groundwater quality and quantity data.

How CWERC Developed this Guide:

This monitoring guide was written after extensive review of similar guides published by universities and watershed groups across the country and close study of the latest independent, peer-reviewed scientific literature on the topics discussed here. The guide has also benefitted from careful analysis of COGCC regulations and practices, including Colorado's new groundwater monitoring rules. COGCC staff also made themselves available to the authors for questions and comments on multiple occasions. Improvements can also be credited to several water well owners, a few Colorado-based hydrogeologists, environmental groups active on oil and gas issues in Colorado, local government officials in Boulder County, and commercial laboratory employees with experience in oil and gas operations – all of whom provided thoughtful input on the guide.

Authors of this Guide:

Adrianne Kroepsch, MA, Environmental Studies
Mark W. Williams, PhD, Geography and Institute of Arctic and Alpine Research

#ÏÎôÁÃôɖ

/ ² 9w/ ϫ Ŏ2ƒ2ǋl·Ř2ɸŜŘdz

Institute of Arctic and Alpine Research
UNIVERSITY OF COLORADO BOULDER

Learn More About Climate
Office for University Outreach
UNIVERSITY OF COLORADO BOULDER

Contents

Who is this Guide for?

If you **live in an area of oil or gas extraction**, have a **water well** on your property, and are **concerned about the integrity of your groundwater supply**, then this guide is for you. While documented groundwater impacts from oil and gas activities are rare, it is reasonable to be concerned about your own groundwater resource to verify its quality on the basis of carefully collected evidence. The information provided here is useful for:

- Water well users who want to set up their own groundwater monitoring program.
- Water well users who want to supplement testing already performed by an oil or gas operator.
- Water well users who do not want to test their own water, but who want information that will help them negotiate a monitoring plan as part of a surface use agreement with a natural gas operator.
- Watershed groups who are considering setting up regional groundwater monitoring programs.

Why Monitor Groundwater?

1. **It's your responsibility.** Water well users are responsible for monitoring the quality of their water and maintaining the structural health and cleanliness of their well. Groundwater quality varies from place to place for many natural and human-related reasons (see #2), which is why public health officials urge water well users to monitor their water quality no matter where they live. At a minimum, the Colorado Department of Public Health and Environment (CDPHE) recommends that water well users test their water once a year for coliform bacteria, lead, nitrate, and nitrite. CDPHE also advises testing for arsenic, calcium, copper, fluoride, iron, and uranium – all of which are common in groundwater or household plumbing and can be dangerous in high concentrations. You may want to perform some of these tests in addition to the oil-and gas-related tests recommended here.

2. **Groundwater quality can change naturally, and as a result of human activity.** Groundwater quality can vary at different times of year, since hydrologic conditions change with wet and dry seasons, even underground. It is important to find out how much your water quality tends to vary on its own so that you know the signs of unnatural changes when you see them. This can only be accomplished with consistent sampling over time, as described in the coming pages. Furthermore, groundwater may contain contaminants or pathogens that have nothing to do with human activity, such as uranium from eroding granite deposits or bacteria from the natural environment. That said, humans and animals are capable of contaminating groundwater in countless ways. Common sources of human and animal contaminants include **fertilizers, animal manure, herbicides, insecticides, pesticides, septic systems, leaking storage tanks and pipes, storm-water runoff, hazardous waste, and chemical spills**. These sources are often more likely to contaminate groundwater than energy extraction activities. You should consider all of the land uses near you when developing a monitoring strategy. Also consider the depth of your water well, since depth can diminish seasonal changes. A shallow well drilled into an unconfined riverbed (alluvial) aquifer will be more affected by seasonal shifts in hydrology or flooding than a deep well drilled into a bedrock aquifer that may have a clay "confining" layer above, separating it from surface water and other groundwater systems. (See the section on **well information** for guidance on determining your well's depth and the aquifer(s) from which it draws.)

3. **Oil and gas extraction activities have the potential to contaminate groundwater.** Oil and gas operators take great care to isolate extraction activities and byproducts from the environment. Nevertheless, energy development is an industrial activity conducted by human beings in all the complexity, contingency, and uncertainty of the real world. Despite industry's best efforts toward forestalling risks, and regulators' best efforts in oversight, energy extraction still has the potential to contaminate groundwater. Mistakes and mishaps can introduce contaminants into groundwater systems or mobilize gases and contaminants from elsewhere in the subsurface. The fluids involved in gas extraction – be they introduced fluids, such as those used for hydraulic fracturing, or produced fluids, such as those drawn from deep underground – typically contain salts, metals, and other potential toxins in concentrations that may be harmful to humans. For more information on these fluids, please refer to CWERC's **Groundwater Quality Interpretation Guide** on the CWERC website (CWERC.colorado.edu).

4. **"Before" and "after" information is essential for understanding changes to groundwater.** Baseline data are essential for understanding shifts in groundwater quality or quantity. If your water were to change as a result of oil and gas operations, it would be difficult to pinpoint the cause without information from both before and after operations began. Baseline testing can be used as a point of reference in the future. Also, baseline sampling can reveal an existing problem of some other kind (such as those described in #2) and put you in a position to correctly identify and address that problem.

5. **Long-term groundwater monitoring is important.** The entire life cycle of an oil or gas well should be considered in the context of groundwater monitoring. That life cycle might begin with seismic testing and end with well plugging and reclamation activities several decades later. Oil and gas extraction is a long-term process that merits long-term monitoring. Furthermore, groundwater moves very slowly in most places, meaning that pollutants may not be detected in a water well for several years after a contamination incident. In addition to gathering baseline information before oil or gas extraction begins, it is important to track water quality over time with a long-term monitoring strategy.

6. **Many groundwater contaminants cannot be detected by humans.** Some potential groundwater contaminants cannot be seen, smelled, or tasted – including several of those associated with oil and gas extraction and other enterprises. Some heavy metals, toxic organic compounds, and chemicals can only be detected through laboratory analysis. (Note: Other contaminants are easily detectible by smell, taste, or sight – particularly by discerning water well owners. For information on the perceptible indicators of a groundwater problem, please consult CWERC's **Groundwater Quality Interpretation Guide** on CWERC's website (CWERC.colorado.edu).)

In sum, there is quite a bit to pay attention to when it comes to groundwater, and it is your responsibility to educate yourself. Oil and gas extraction activity is but one factor in a long list of potential hazards, and must be understood in a larger context of land use activities and seasonal changes in the water cycle. Groundwater monitoring must also be considered in a broader context – one that includes a few legal and regulatory topics. In the next few sections, this guide will address the most important of these: the monitoring programs that could be available to water well users for free in Colorado, the legal admissibility of baseline data, and the ownership of mineral rights.

Do I Have to Spend My Own Money to Monitor My Groundwater, or Will Somebody Do it For Free?

Water well users might be able to receive free baseline water quality testing from natural gas operators under the regulations of the Colorado Oil and Gas Conservation Commission (COGCC). In May of 2013, the COGCC began enforcing a new set of statewide groundwater monitoring rules that require operators to test **up to four water wells** within one-half mile of a new oil or gas well. Because it is time consuming and expensive to monitor groundwater (**$500-700** for the Full Index of analytes and **$180-210** for the indicator analytes, described below), and because the COGCC requires operators to run water quality tests similar to many of those included in this guide, you may want to inquire with the operator drilling in your proximity as to whether they will test your well for free under these regulations. The new rules do not apply in three places that already had their own specific groundwater monitoring regulations in effect: the San Juan Basin near Durango, Raton Basin near Trinidad, and the Wattenburg Field in and around Weld County. In those locations, operators will continue to test one or two wells within one-half mile of a new oil or gas well under the previous rules. If you live in Weld County, the county Department of Public Health & Environment is offering testing for Volatile Organic Compounds at no cost to residents with domestic wells (call 970-304-6415 for more information). For more details on groundwater monitoring regulations, please consult the **Opportunities for Free Baseline Water Quality Testing** document on the CWERC website (CWERC.colorado.edu).

What Legal Considerations Should I Keep In Mind When Testing My Water?

This guide is not intended to serve as legal advice. For legal advice, please consult an attorney. The admissibility of scientific evidence in legal proceedings can be an important issue for people conducting groundwater monitoring. If legal use of groundwater monitoring data is intended, the only way to reliably expect admissibility is to hire a third party, such as a consultant or a laboratory technician, to sample your groundwater using a scientific protocol such as this one or COGCC's Model Sampling and Analysis Plan. COGCC's Model Sampling and Analysis Plan can be found on COGCC's home page, under "Hot Topics." (http://cogcc.state.co.us/RR_HF2012/Groundwater/FinalRules/ModelSAP_05012013.pdf) Water samples must also have been collected and analyzed following documented scientific protocols if they are to be imported into COGCC's statewide groundwater quality database.

What Information Should I Have About My Well and My Mineral Rights?

Lots of people purchase homes with water wells without checking the details of their water well permits or the status of their mineral rights. Homeowners concerned about oil and gas production would be wise to look into both of these. The physical structure of your well and your subsurface rights could be considered physical and legal aspects of your groundwater "baseline," respectively. By understanding your well's construction and your mineral rights, you should be better prepared to anticipate, and respond to, oil and gas drilling in your vicinity.

Well Permits: To look up well permit records online, visit the website for the Colorado Division of Water Resources Well Permit Search database (www.dwr.state.co.us/WellPermitSearch/). From these records, you should be able to find important details about your well, such as its **depth**. The permit may also include information about the construction of your well, such as what your well **casing** is made from, whether your well is **screened** and with what material, and if the annular space in your wellbore is **packed** with a material such as sand or gravel. The permit may also mention the aquifer(s) from which your well draws water. Enter all of this information on the **Well Sampling Worksheet** at the end of this guide.

Mineral Rights: A surface owner does not automatically own rights to the fossil fuels and minerals beneath their land because federal law sometimes divides surface and subsurface rights between different owners (this is called a "split estate"). If you do not own the mineral rights beneath your land, you have less control over drilling

operations on your property, but you do have the power to negotiate a Surface Use Agreement with an operator, as granted by the state of Colorado. To find out if you own your mineral rights, visit your **county clerk's office** and look up the tax identification number for your property (it will have remained consistent over time, despite changes to street names and addresses). Perform a property title search at your **county courthouse** using this tax identification number. Mineral rights information will be included in the property title.

What Should I Test My Water For?

Developing a groundwater monitoring program requires careful consideration of what to test, as well as the timing and frequency of sampling. Below is a suggested program that takes all of these aspects of monitoring into account. It is devised around two lists of analytes. (An *analyte* is a substance or an aspect of water quality that is the subject of *analysis*. To find out more about the analytes on these lists, please refer to the **Groundwater Quality Interpretation Guide** on CWERC's website (CWERC.colorado.edu).)

1. The long list of analytes is called the "**Full Index**." The Full Index lists **26** analytes that CWERC considers important for capturing a comprehensive picture of your groundwater conditions based on CWERC's water quality monitoring experience, review of the scientific literature on this subject, and COGCC's groundwater monitoring regulations, as well as discussions with commercial laboratories that run water quality tests for well users, the oil and gas industry, and regulators.
2. The second list of analytes is called the "**Indicators**." The Indicators list is an abbreviated (and therefore less expensive) version of the Full Index. It is composed of **nine** key analytes that would likely be the first to change in the event of an oil or gas-related impact to a groundwater supply (water well).

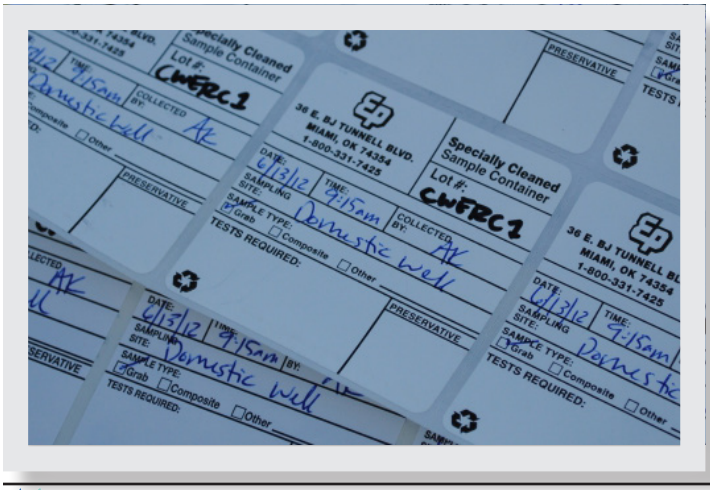


Table 1. Full Index of 26 analytes.

FULL INDEX ($500-700, depending on lab)	
GENERAL WATER QUALITY	Alkalinity Conductance pH Dissolved Organic Carbon (or Total Organic Carbon)
MAJOR IONS	Calcium Chloride Fluoride Magnesium Potassium Sodium Sulfate Nitrate + Nitrite (total)
METALS	Arsenic Barium Boron Chromium Copper Iron Lead Manganese Selenium Strontium
VOLATILE ORGANIC COMPOUNDS	Methane BTEX compounds (Benzene, Toluene, Ethylbenzene, Xylene)
OTHER	Water Level Stable isotopes of water (Oxygen-18 and Deuterium)

Table 2. List of 9 Indicator analytes

INDICATORS ($180-210, depending on lab)	
GENERAL WATER QUALITY	Conductance pH Dissolved Organic Carbon (or Total Organic Carbon)
MAJOR IONS	Chloride Potassium Sodium Sulfate
METALS	Barium
VOLATILE ORGANIC COMPOUNDS	Methane

How Often Should I Test My Water, and When Should I Do It?

Test your water twice each year, in fall (dry season) and spring (wet season), and shortly after any major oil or gas extraction event, such as drilling or hydraulic fracturing that occurs within one-half mile of your well. Alternate between testing for the Full Index and the Indicator analytes, as described below. Test the Full Index to capture the "**big picture**" of your water quality, and switch to the Indicators when you just need a "**snapshot**" to look for changes. CWERC's recommended sampling strategy:

1. **Before drilling begins** near you (if possible), test for the Full Index of analytes twice in one year – once in the spring (April-June) and once in the fall (Sept-Nov). Sampling in each of these seasons will document any natural changes in your water quality that might occur because of seasonal shifts in the water cycle. Groundwater quality can vary between wet and dry seasons of the year by dilution or concentration, particularly in shallow and unconfined riverbed (alluvial) aquifers. Understanding those seasonal differences (or a lack thereof) will be important as you interpret your groundwater quality results in the years to come.
    - **If you have multiple years before drilling begins,** test for the Full Index of analytes twice in the first year. After that, test only the Indicator analytes once per year until drilling begins. Schedule your Indicator sampling for the same season each year.
    - **If drilling has already begun near you** test for the Full Index of analytes twice in your first year of monitoring anyway (spring and fall), then test the Indicator analytes once per year after that, preferably in the same season. Your "baseline" will not be a pre-drilling baseline, which is ideal, but it will be better than having no baseline at all. While it isn't a perfect "before" sample, a post-drilling baseline can still be monitored for changes over time.

2. **After drilling begins**, test the Full Index analytes at **one, three, six**, and **nine** years. Try to schedule your Full Index sampling for the same season each time. You may continue testing further into the future if you wish (say, year twelve, year fifteen, etc.). CWERC considers one, three, six, and nine years to be an appropriate *minimum* timespan for long-term monitoring.

3. If a **major event**, such as the initiation of drilling or a hydraulic fracturing operation, occurs within one-half mile of your well, CWERC recommends testing for the Indicator analytes between 6 and 12 months after the event. If any of the Indicator analytes are present in more than a trace amount, and jump 20 percent or more from the highest recorded result, call the oil or gas operator and COGCC to report the groundwater quality shift. The COGCC will investigate any suspected oil-or-gas related changes to groundwater. COGCC staff will likely re-sample your groundwater and run similar tests to those included in the Full Index. For a list of the analytes that COGCC would test, visit the **Opportunities for Free Baseline Water Quality Testing** document on the CWERC website (CWERC.colorado.edu). You may decide that these tests are sufficient or you may prefer to conduct your own round of Full Index tests. **COGCC's complaint hotline number is 1-888-235-1101**.

4. Carefully consider any changes to the Indicators and Full Index analytes using the **Groundwater Quality Interpretation Guide** found on CWERC's website. As mentioned in #3, if one or more of the Indicator analytes is present in more than a trace amount, and falls significantly outside the normal seasonal range of variation that has been established from previous tests (i.e., if it has increased by 20 percent or more from the highest recorded result), call the natural gas operator and COGCC to report the change, which they will investigate. You may rely on the results of the COGCC analysis or follow up by testing the Full Index of analytes.

5. CWERC advises measuring the **depth to water** in your well when you perform your first Full Index test. If possible, measure your water level annually, and at the same time each year. If your well is shallow and draws water from an unconfined riverbed

(alluvial) aquifer, it will likely be at its lowest in the fall (dry season); this is an ideal time to measure the depth to water. If your well is deep and draws water from a confined bedrock aquifer, the season you choose matters less. If you pump groundwater heavily to irrigate crops or your landscaping, CWERC recommends measuring your water level outside of irrigation season. You will need a licensed well contractor to perform this test. For more information, refer to the section on measuring water level below.

How Do I Collect Water Samples from my Well, and Where Should I Send Them?

Among the first steps in setting up a monitoring program for groundwater quality should be to **choose** and **contact** a **laboratory**. Collect water samples using that laboratory's sampling bottles and instructions. Choose a laboratory that has been certified nationally by the National Environmental Laboratory Accreditation Program/NELAP, and which is willing to accept water samples from individual water well users. At the end of this guide, CWERC has included a short list of laboratories that meet those standards. The laboratories on this short list are capable of performing most of the tests recommended in this guide. Because laboratories specialize in different tests, however, you may need to use more than one lab to test all of the suggested analytes. When you contact the laboratory, let its staff know that you are a well user using the CWERC monitoring guide, and that you would like to run the CWERC analytes. The laboratory should be aware of CWERC's analyte list, but if for some reason they are not, you can always send it to them. Send the Full Index if that's what you are sampling, or the Indicator analytes if you are only checking the short list.

The laboratory will send you sampling bottles and instructions (also known as protocols). **Confirm with the laboratory that sampling protocols will be provided and then follow them very carefully.** The protocols will cover the collection of samples, as well as their storage and shipping. **All aspects of the protocols are essential to producing reliable results.** You will collect multiple bottles of water for different tests, and sampling and storage instructions will vary for each bottle. If you would rather not worry about performing proper sampling protocols yourself, consider hiring a third party to collect samples for you. Laboratories or water well drillers can usually recommend local water quality consultants with experience in water sampling.

For a photo tutorial of water sampling and shipping, refer to the **slideshow** titled **Collect Your Samples** on CWERC's website (CWERC.colorado.edu).

Because some laboratories may provide less guidance than others, here is a general list of sampling pointers. To gather a good water sample, CWERC recommends that you:

- Use certified clean bottles provided by the laboratory. Fill them according to laboratory specifications. Some will need to be rinsed with the water you're sampling, while others should not be rinsed because they contain special preservatives. Some will need to be filled until there is zero airspace left in the bottle; others will not.
- Collect the sample as far "upstream" in the system as possible – preferably straight from the well pump or an outdoor tap, instead of from a cistern or an indoor faucet. If this is not possible, select a leak-free, cold-water faucet, remove its aerator or strainer, and make note of any upstream water treatment mechanisms, such as water softeners.
- Samples collected for dissolved gas (i.e., methane) analysis may require special procedures that prevent gas from escaping. The simplest method requires that you slowly fill a glass vial containing a preservative until there is no airspace left in the bottle and a bump (a "positive meniscus") develops at the top. A more complicated technique requires that you submerge the empty sampling bottle upside down in a bucket full of well water so that it can be filled via a clean hose while it is underwater. Ask your laboratory for clear directions about which method you should use and how, exactly, to do it.
- Samples must be stored and shipped at a specific temperature. Laboratories often provide coolers and ice packs to assist with temperature regulation. CWERC recommends that you have a pre-cooled cooler with you when you take samples so that you can immediately transfer your samples to a temperature-controlled environment.

- Transport your samples to the laboratory for analysis immediately. If the laboratory is not within driving distance, you may need to ship the samples overnight. Send your samples on a Monday or a Tuesday so the lab can adequately perform tests with short hold-times. Make sure all ice is enclosed in plastic bags. FedEx and UPS will return coolers that leak.

For more details on any aspect of sampling, please see COGCC's Model Sampling and Analysis Plan (SAP),which describes best practices for collecting groundwater samples under the agency's new statewide groundwater monitoring rules. The Model SAP can be found on COGCC's home page, under "Hot Topics." http://cogcc.state.co.us/RR_HF2012/Groundwater/FinalRules/ModelSAP_05012013.pdf

How Do I Purge My Well?

It is important that you purge your well prior to sampling in order to collect fresh water rather than stagnant water from your pipes or the well column. **Purging and collecting samples should not directly follow a period of extended pumping because it could reduce water yield.** When you purge your well, **make a note of your well use in the 24 hours prior to sampling**. To purge, simply run the pump and allow water to flow through the system and out of the tap where you will collect your sample. (Feel free to use the purged water for some other use. You don't have to waste it!) The amount of time needed to purge "old" water depends on the rate at which your well flows, its depth, and the characteristics of your aquifer, such as whether it yields water quickly or slowly.

Two standard procedures exist for well purging. Either purge a calculated volume of water, or purge water until one or more of its parameters stabilize – for example, temperature, pH, or specific conductance. (For definitions of these parameters, please refer to the **Groundwater Quality Interpretation Guide** on the CWERC website (CWERC.colorado.edu). To understand specific conductance in particular, please read on.)

High-Yield Wells

When well yield is not a concern, standard COGCC, Environmental Protection Agency (EPA), and U.S. Geological Survey (USGS) protocols recommend purging **three well volumes** of water. For help calculating the **volume** of your well, your well's **flow rate**, and the amount of **time** it will take you to purge three well volumes, please refer to the Well Sampling Worksheet at the end of the guide.

Low-Yield Wells

If your well yields little water and recharges slowly, it could take several hours or several days to purge three well volumes of water. Such a lengthy timespan is unreasonable. Moreover, purging your well for that long could drain your well completely and result in a turbid sample or one that isn't representative of the aquifer because it has been drawn primarily from your well's casing. To gather a good sample from a low-yield well, COGCC, EPA, and USGS recommend a low-flow/low-volume purging technique, which requires that you purge your well at a low flow rate and only until your water's chemistry and physical characteristics stabilize. To do this, you need an electronic device that measures one or more parameters of your water, such as its pH, specific conductance, turbidity, temperature, or dissolved oxygen content. **Specific conductance** meters outperform pH meters, and some are relatively inexpensive, at about $50 online. Specific conductance is a measure of water's ability to conduct an electrical current. It is a proxy for the amount of inorganic dissolved solids in water; as dissolved substances increase, so does conductance. Measure specific conductance, or another parameter of your choice, every 30 seconds until it holds steady (i.e., it varies less than ±10%, or 0.2 for pH, over three consecutive measurements). Note the length of time it took for the parameter to stabilize in order to follow it in the future, then collect your water sample.

How Do I Measure the Water Level in My Well?

CWERC recommends you hire a licensed water well contractor to **measure the depth to water in your well once per year**, preferably when you collect water samples in the fall.

Monitoring the depth of your groundwater will allow you to watch for water level declines that could be caused by groundwater withdrawals associated with energy extraction or by some other cause. A number of factors can lower groundwater levels, such as drought, your own well pumping, or your neighbors' well pumping. These are typically more common than groundwater reductions due to oil and gas activity. It is also worth remembering here, as always, that subsurface environments are complicated and that each well is different. For example, if your well draws from a shallow, unconfined alluvial aquifer in a river valley, it will be more sensitive to changes in surface water hydrology. If your well draws from a deep, confined aquifer, it will be more sensitive to changes in deep subsurface hydrology. For more information on different types of aquifers and other groundwater basics, refer to "How Well Do You Know Your Water Well?," a booklet for water well users published by Colorado's water, public health, and oil and gas regulators. It is available in the Library section of the COGCC's website (cogcc.state.co.us/Library/WaterWellBooklet.pdf).

If you plan to test depth-to-water in your well, **pay close attention to the timing of the test in order to get an accurate measurement**. You want to make sure that you haven't drawn down your well in advance of the water level test. Turn off your well pump for *at least* two hours before taking a measurement (longer if you know that your well recharges slowly). If you measure water level on the same day you collect water samples, measure the water level *before* purging your well.

Licensed well contractors have different tools for measuring water level. Some use a special measuring tape with an electrode on the end (often called an electronic sounder), while others use a device that sends sound waves into the ground (often called a sonic water level meter). CWERC recommends you hire a contractor with a **sonic water level meter**, if possible, because it is a less invasive instrument that does not have to be lowered down the well column. If you choose a contractor with an electronic sounder that must be inserted into your well, verify that the tape has been sterilized beforehand and chlorinate your well after the measurement. To find a licensed contractor near you, visit the groundwater page at the Colorado Division of Water Resources' website (http://water.state.co.us/groundwater/BOE/Pages/LicensedContractors.aspx).

This is particularly important for people who live in areas of coalbed methane production. In Colorado, coalbed methane production is limited to the San Juan Basin near Durango and the Raton Basin near Trinidad. Extracting coalbed methane from coal deposits typically involves removing the groundwater that saturates those deposits, often with unknown effects to the regional groundwater system.

How Do I Find a Laboratory ?

Finding a properly certified laboratory that accepts samples from individuals and is capable of testing for all of the analytes CWERC recommends can be complicated. Here is a short list of **regional laboratories** that meet those requirements.

Accutest Mountain States[2]
www.accutest.com
303-425-6021
Wheat Ridge, CO

ACZ Laboratories[2]
www.acz.com
970-879-6950
Steamboat, CO

ALS Environmental[2]
www.alsglobal.com
970-490-1511
Fort Collins, CO

American West Analytical Laboratories[1,2]
www.awal-labs.com
801-263-8686
Salt Lake City, UT

Energy Laboratories
www.energylab.com
888-235-0515
Casper, WY

Green Analytical[1,2]
www.greenanalytical.com
970-247-4220
Durango, CO

TestAmerica[2]
www.testamericainc.com
303-736-0100
Arvada, CO

Isotech Laboratories[1*]
www.isotechlabs.com
887-362-4190
Champaign, IL

**Isotech specializes in analyzing stable isotopes of water, and it is one of the few labs capable of doing so. Because Isotech specializes in isotopes, they often provide the best price on this analysis.*

[1] Does not perform dissolved methane analysis at this time.
[2] Does not perform stable isotopes of water analyses at this time (see Isotech for this analysis).

How do I Make Sense of the Water Chemistry Results the Laboratory Sends Back?

Water quality information is only useful if you can understand and accurately appraise it. When you receive water quality results from your laboratory, ask if the laboratory has somebody on staff that can assist you with interpretation. If the laboratory cannot provide you with interpretive help, and/or if you would simply like more information, see the **Groundwater Quality Interpretation Guide** found on CWERC's website (CWERC.colorado.edu).

What Other Well Maintenance Should I Be Doing?

Water wells require regular maintenance. A neglected well can be more vulnerable to changing conditions around it – from natural events such as flooding or drought to human activities such as energy extraction. In addition to water quality testing, you should keep an eye on your well's structural components and periodically disinfect it to keep it free of bacteria and in good working order.

For more detailed information on water well maintenance visit the National Ground Water Association's website for water well users (wellowner.org).

Would you like to add your data to COGCC's public database?

Your baseline data is even more useful if it can be aggregated with other baseline data from across the state. To that end, COGCC recommends that all baseline water quality data be sent to the COGCC's public database so that it can be added to a statewide map. Ask your lab to send your data to the COGCC database manager at Arthur.Koepsell@state.co.us in COGCC Electronic Data Deliverable format (either Excel or XML). Your name and address will be stripped from the data before it is uploaded, but you must include your well's location in **latitude** and **longitude**, as pinpointed by a GPS device.

We Want to Hear From You!

If you have questions about using this guide or the resources referenced here, please email CWERC at cwerc@colorado.edu. CWERC wants feedback from water well users who use this guide, or simply consider using it. CWERC would also like to keep track of the areas where it is being used. Please contact us at cwerc@colorado.edu.

Acknowledgements:

Several individuals and organizations generously contributed their time and expertise to this project. The authors would like to acknowledge the director of the Colorado Oil and Gas Conservation Commission, Matt Lepore, as well as several COGCC environmental specialists for their thoughtful comments on the monitoring guide. The commercial labs referenced in this document were an important source of insight, as were several water well owners, hydrologists from the Colorado Water Resources Institute at Colorado State University, commenters from a few Colorado-based environmental groups, and local government officials in Boulder County. This project was made possible by funding from the University of Colorado Office for University Outreach, and benefited significantly from the time and energy of several of its staff members, including Wynn Martens, Linda Molner Kelley, Jeanne McDonald, Sophia Roudane, and Benjamin Martin. The project has also been supported by the AirWaterGas Sustainability Research Network, funded by the National Science Foundation under Grant No. CBET-1240584. Any opinion, findings, and conclusions or recommendations expressed in this monitoring guide are those of the authors and do not necessarily reflect the views of the National Science Foundation. Any errors or inconsistencies are the responsibility of the authors.

Where Can I Find the Resources Mentioned?

Colorado Department of Public Health and Environment Water and Environmental Testing Advice
http://www.colorado.gov/cs/Satellite/CDPHE-Lab/CBON/1251594505186

Colorado Division of Water Resources Well Permit Search
http://www.dwr.state.co.us/WellPermitSearch/default.aspx

Colorado Division of Water Resources list of Licensed Well Contractors
http://water.state.co.us/groundwater/BOE/Pages/LicensedContractors.aspx

Colorado Oil and Gas Association Model Sampling and Analysis Plan
http://cogcc.state.co.us /RR_HF2012/Groundwater/FinalRules/Model_SAP_05012013.pdf

Colorado Water and Energy Research Center
http://cwerc.colorado.edu

"How Well Do You Know Your Water Well?" Booklet
http://cogcc.state.co.us/Library/WaterWellBooklet.pdf

National Ground Water Association well maintenance advice
http://www.wellowner.org /water-well-maintenance/

Well Sampling Worksheet

Well Permit Information

Searchable at the Colorado Division of Water Resources www.dwr.state. co.us/WellPermitSearch/default.aspx.

Permit Number _____

Receipt Number _____

Date Well Drilled _____

Date Pump Installed _____

Total Well Depth _____

Well Diameter _____

Well Volume _____

Tip: To calculate the volume of your well, consult your well permit records for the **height of standing water** in your well and your well's **diameter**. Divide the diameter by two to find the **radius**. Once you know the height of water and the radius, use the following equation to find the volume: **well volume = π x radius^2 x height**. If you're measuring the radius in inches, this will give you the well volume in cubic inches, so to convert the volume to gallons, divide by 231 in^3/gallon. If you can't determine the height of standing water in your well, substitute the entire depth of your well, which is a more conservative measure.

Static Water Level (Depth-to-Water) at Time your Well was Drilled _____

Flow Rate at Time your Well was Drilled _____

Casing Height _____

Casing Type/Material _____

Notes on Structural Condition of Well and All Land Uses Nearby _____

_____

Sampling Information

Date of Sample _____

Number of Sample in Monitoring Program

(if you have collected baseline samples in previous seasons or years) _____

Name of Sample Collector _____

Names of Any Other People Present _____

Location/Type of Sample Site

(at pump, outdoor tap, well house, kitchen faucet, spring, seep, etc.) _____

_____

Description of Sample Site (note any upstream treatment mechanisms) _____

_____

Are you sampling for the Full Index or Indicators? _____

How much have you used your well in the 24 hours prior to sampling? _____

Purging, Flow, and Depth-to-Water Information

Ideal purge volume _____

Tip: Multiply the well volume calculated above by three to estimate the ideal amount of water for purging, though you may be required to purge less if your well recharges slowly. If you have a low-yield well, follow the USGS low-flow/low-volume purging guidelines described in this guide. If you must collect your sample from an indoor faucet, consider purging more than three well volumes in order to flush your pipes.

Flow rate _____

Tip: Find an empty five-gallon bucket and a watch that measures time to the second. Take a time measurement each time water reaches the top of a five-gallon bucket. To come up with a flow rate in gallons per minute (gpm), divide five gallons by the time measurement. For example, if it takes 2 minutes to fill the five-gallon bucket, then the flow rate is 5 gal/2 min, or 2.5 gal/min.

Calculated purge time_____

Tip: To estimate the proper purge time for three well volumes of water, you will need to know your flow rate (calculated above) and your ideal purge volume (also calculated above). Divide your ideal purge volume by your flow rate. For example, if you need to purge 25 gallons of water and your flow rate is 2.5 gal/min, then your purge time should be 10min (or 25 gallons divided by 2.5 gal/min).

Actual purge time_____

Actual purge volume_____

Tip: To calculate the actual purge volume, keep track of the number of 5 gallon buckets you fill during purging and add them up at the end. (Alternatively, track the total time spent purging and multiply it by the flow rate.)

Notes on appearance, smell, and taste of water, as well as any effervescence _____

_____

_____

Depth-to-Water in your well _____

Tip: Hire a certified well contractor to measure this before you draw your water level down by purging and collecting samples. If you cannot make this measurement on the same day you collect samples, do it within a few days of sample collection, also at a time when your well hasn't been pumped very much and has had the opportunity to recharge. Record your well use in the 24 hours prior to the measurement. CWERC recommends hiring a contractor with a sonic water level meter so that you do not have to open your well cap and risk tangling an electronic sounding tape in your well.

Name of Laboratory Used for Analysis _____

Notes on Laboratory Sampling Protocols or Packaging and Shipping _____

_____

_____

_____

Notes on Data Delivery to COGCC Database

Your laboratory should know how to send your results to COGCC in the proper Electronic Data Deliverable (EDD) format, which should either by in Excel or XML.

Database Contact: Arthur Koepsel, at Arthur.Koepsell@state.co.us

---

Latitude & Longitude of your well_____

This information may be on your well permit. Well owners can also use GPS, an iPhone application or other means for accurately getting this information.

References

AMEC Geomatrix, Inc. (2011). *Updated Trend and Data Analysis, San Juan Basin Water Quality Analysis Project, San Juan Basin, Colorado, Project No. 15244*. Retrieved from http://cogcc.state.co.us

American Society for Testing and Materials (ASTM). (2012). *Standard Guide for Purging Methods For Wells Used for Groundwater Quality Investigations* (D6452-99). Retrieved from http://www.astm.org/Standards/D6452.htm

Colorado Department of Public Health and Environment. (2002). *Drinking Water from Household Wells*. Denver, CO: CDPHE. Retrieved from http://www.cdphe.state.co.us/lr/water.htm

Colorado Oil and Gas Association. (2011). *Voluntary Baseline Groundwater Quality Sampling Program: Example Sampling and Analysis Plan*. Retrieved from http://www.coga.org/pdfs_facts/COGA-sample-analysis-Plan.pdf

Colorado Oil and Gas Conservation Commission. (2013). *Model Sampling and Analysis Plan, Version 1, for Rules 609 and 318.e(4)*. Retrieved from http://cogcc.state.co.us

Colorado Oil and Gas Conservation Commission. (2006). *Oil and Gas Well Notification, Consultation, and Reclamation Rules: Information for Oil and Gas Operators, Surface Owners, and Surface Tenants*. Retrieved from http://cogcc.state.co.us

Dahm, K.G., Guerra, K.L., Xu, P., & Drewes, J. E. (2011). "A Composite Geochemical Database for Coalbed Methane Produced Water Quality in the Rocky Mountain Region." *Environmental Science & Technology*. Retrieved from http://pubs.acs.org/doi/abs/10.1021/es201021n?mi=rs384g&af=R&pageSize=20&abstract=drinking+water

Harvard Law School. (2011). *An Ohio Landowner's Guide to Hydraulic Fracturing: Addressing Environmental and Health Issues in Natural Gas Leases.* Cambridge, MA: Emmet Environmental Law and Policy Clinic. Retrieved from http://blogs.law.harvard.edu/environmentallawprogram/files/2013/01/elpc-ohio-leasing-guide-v2-june-2011-web.pdf

Keith, K., Sessoms, H., Neibauer, M. Skinner, Q., Bauder, J. Waskom, R. Mesner, N. (2005). *Land and Water Inventory Guide for Landowners in Areas of Coal Bed Methane Development.* Montana State University Extension Service. Retrieved from http://waterquality.montana.edu/docs/Publications/CBM_Manual.shtml

New York State Department of Environmental Conservation (2011). *Revised Draft SGEIS on the Oil, Gas and Solution Mining Regulatory Program.* Retrieved from http://www.dec.ny.gov/energy/75370.html

New York State Water Resources Institute. (2011). *Private Water Well Testing in Areas Impacted by Marcellus Shale Gas Drilling*. Ithaca, NY: Cornell University, Department of Earth and Atmospheric Sciences. Retrieved from http://wri.eas.cornell.edu/index_9_1489175471.pdf

Osborn, S.G., Vengosh, A., Warner, N., & Jackson, R.B. (2011). Methane contamination of drinking water accompanying gas-well drilling and hydraulic fracturing. *Proceedings of the National Academy of Sciences, 108(20)*, 8172-8176. Retrieved from http://www.pnas.org/content/108/20/8172.short

Paschke, S. (2011, September). *Potential Environmental Impacts of Hydraulic Fracturing and Directly Linked Activities: Water Quality and Water Supply Concerns*. Presented at Hydraulic Fracturing: A Wyoming Energy Forum, Laramie, WY.

San Juan Public Lands Center. (2006). *Final Environmental Impact Statement: Northern San Juan Coal Bed Methane Project*. Durango, CO: San Juan Public Lands Center.

Sonnenberg & Associates and URS Corp. *Geologic and Modeling Analysis for Determining Nontributary Ground Water, Sussex & Shannon Sandstones, Western Denver-Julesburg Basin*. Denver, CO: Stephen Sonnenberg & Associates and URS Corp., prepared for Encana Oil & Gas, Inc. http://water.state.co.us/DWRIPub/Produced%20Nontributary%20Ground%20Water/EncanaFinalReport.pdf

S.S. Papadopulos & Associates, Inc. (2012). *Baseline Water Quality Review – Elbert County, Colorado*. Boulder, CO: S.S. Papadopulos & Associates, Inc., prepared for COGCC. Retrieved from http://cogcc.state.co.us/Library/DenverBasin/ElbertCountyBaselineWQ.pdf

Topper, R., Spray, K.S., Bellis, W.H., Hamilton, J.L. and Barkmann, P.E. (2003). *Ground Water Atlas of Colorado*, Special Publication 53. Denver, CO: Colorado Geological Survey. Retrieved from http://geosurvey.state.co.us/WATER/GROUNDWATERATLAS/Pages/GroundwaterAtlasofColorado.aspx

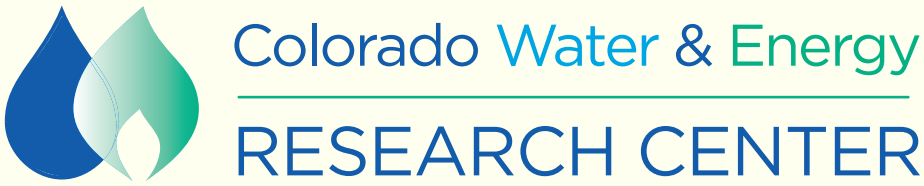
U.S. Environmental Protection Agency. (2004). *Field Sampling Guidance Document #1220: Groundwater Well Sampling*. Richmond, CA: U.S. EPA Region 9 Laboratory. Retrieved from http://www.epa.gov/region6/qa/qadevtools/mod5_sops/groundwater/sampling/r9_gw_gui.pdf

U.S. Environmental Protection Agency. (2011). *Draft Report: Investigation of Ground Water Contamination near Pavillion, Wyoming*. Retrieved from http://www.epa.gov/region8/superfund/wy/pavillion/

U.S. Geological Survey. (2006). "Chapter A4. Collection of Water Samples" in *National Field Manual for the Collection of Water Quality Data, Book 9: Handbooks for Water-Resources Investigations*. Reston, VA: Office of Water Quality. Retrieved from http://water.usgs.gov/owq/FieldManual/chapter4/pdf/Chap4_v2.pdf

Van Voast, W.A. (2003). "Goechemical signature of formation waters associated with coalbed methane." *AAPG Bulletin*, 87, 667-676.

Watts, K. R. (2006). *Separation between Production Intervals of Coalbed-Methane Wells and Water-Supply Wells in the Raton Basin, Huerfano and Las Animas Counties, Colorado, 1999*. Retrieved from http://ntis.library.gatech.edu/handle/123456789/2421


Colorado Water & Energy
RESEARCH CENTER