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January 19, 2011

COGCC Underground Injection Control and Seismicity in Colorado

Colorado's earliest documented earthquake occurred on December 7, 1870. The *Colorado Transcript* stated, ``A careful observer at Fort Reynolds, 20 miles east of Pueblo, noted that bottles standing 1 inch apart were knocked together violently." Many earthquakes have occurred throughout Colorado since that time and continue to occur today. Earthquakes are vibrations created when large blocks of the Earth's crust move with respect to one another along a fault plane. The Colorado Earthquake Hazard Mitigation Council published a map in 2008 of earthquakes and faults in Colorado. The map can be obtained at the Colorado Geological Survey (CGS). The United States Geological Survey (USGS) maintains a database of Colorado earthquakes at the National Earthquake Information Center (NEIC) in Golden.

Most earthquakes or seismicity occur as a result of naturally-occurring geologic phenomena. However, there have been some cases where seismicity was suspected to have been triggered by injection of fluids into the subsurface. The term "Induced Seismicity" has been used to describe man-made earthquakes of this type. The most notable case in Colorado was at the Rocky Mountain Arsenal (the "Arsenal") near Denver. Earthquakes began after a 12,000-foot injection well was drilled at the Arsenal for the disposal of waste fluids. Injection commenced in March 1962. Shortly thereafter, an unusually frequent series of earthquakes occurred during the period from January 1963 to August 1967. In 1968 injection stopped, and the Army began removing fluid from the Arsenal well at a very slow rate in an effort to reduce earthquake activity. In Nicholson, 1990, *Earthquake Hazard Associated with Deep Well Injection- A Report to the U.S. E.P.A.*[5] injection volumes were related to earthquake events, demonstrating that these earthquakes were induced by fluid injection at the Arsenal.

COGCC, in accordance with federal law and COGCC's rules and policies, believes safeguards are in place to reduce the likelihood of induced seismicity. The current safeguards defined by COGCC permit process are injection volume; pressure below the fracture gradient; and, input from the Colorado Division of Water Resources (CDWR) and CGS to reduce the potential for induced seismicity related to UIC Class II wells.

The federal Underground Injection Control (UIC) program began on December 1974 with the creation of the Safe Drinking Water Act (SDWA). The SDWA established the UIC Program, administered by the United States Environmental Protection Agency (EPA), to protect Underground Sources of Drinking Water (USDW's) from impacts related to underground fluid injection practices. The EPA delegated primacy for regulation of Class II UIC wells to the State of Colorado for underground injection of oil and gas exploration and production waste on April 2, 1984. Colorado has administered the UIC program in accordance with federal regulations (40 CFR, Parts 144, 145, 146, and 147) since that time, providing the EPA with semi-annual reports, http://water.epa.gov/type/groundwater/uic/index.cfm.

The Colorado Oil and Gas Conservation Commission (COGCC) is the State regulatory agency that permits Class II UIC wells for injection of oil and gas exploration and production waste and enhanced recovery wells. The COGCC Class II UIC permit review process is defined by COGCC Rule 303 Permit to Drill, Rule 324B Exempt Aquifers, Rule 325 Underground Disposal of Water, Rule 326 Mechanical Integrity Testing, and Rules 706, 707, and 712, which identify Financial Assurance requirements. The permit process involves the review and approval of Form 21, Mechanical Integrity Test, Form 26, Source of Produced Water for Disposal, Form 31 Underground Injection Formation Permit Application, and Form 33 Injection Well Permit Application. Information included with these forms and required supplementary documentation describe well construction, ground water and injection zone isolation, fracture gradient, maximum injection rate, maximum injection volume, maximum injection pressure, injection zone water quality, and potential seismicity associated with fluid injection.

Injection wells must utilize a well construction method of cemented surface casing and production casing, which isolate and prevent fluid flow between injection zones and USDWs. To verify isolation, the COGCC UIC engineer reviews all relevant information, including: hydrogeologic studies, Colorado Division of Water Resources (CDWR) water well information, and COGCC's geophysical well log database. This information is used in conjunction with specific formation and well construction data submitted by the injection well operator, including resistivity and cement bond geophysical logs to verify that: 1) the surface casing is set below all fresh water zones used as a water supply, and 2) production casing cement placement and quality allows for adequate isolation of the injection zone and USDWs, including fresh water zones that are not currently being used as a water supply. Further, the geophysical logs are used to determine the injection zone thickness and porosity, and the logs are used to verify that the bounding shale zones are thick enough to provide zonal isolation. The COGCC UIC engineer calculates a maximum injection volume, based on thickness and porosity from the log data. By COGCC policy, the injection volume is restricted to a one-quarter mile radial volume. The restriction is intended to constrain the total volume of injected fluids during the life of the injection well.

After a well has been drilled and completed into the injection zone, an injection zone water sample test must be submitted. The sample is required to meet EPA-defined levels for total dissolved solids (TDS). COGCC Rule 324B Aquifer Exemption is required, if the sample has a TDS below 10,000 milligrams per liter and above 3,000 milligrams per liter. Water zones containing TDS of less than 3,000 milligrams per liter cannot be exempted and used for injection, because they are considered to be USDW's suitable for possible future use as treatable water supplies. COGCC solicits written opinion from the CDWR regarding the occurrence of surface and subsurface fresh water sources in the vicinity of the injection well and the suitability of the injection well's proposed casing and cement configuration to protect those resources.

Maximum surface injection pressure is calculated based on a default fracture pressure gradient of 0.6 psi per foot of depth. The operator may elect to conduct a Step Rate Injection Test to define whether a higher injection zone fracture gradient exists. From the resulting fracture gradient, the COGCC UIC engineer designates a maximum surface injection pressure at the operator's requested injection rate as a condition of permit approval. COGCC's policy is to keep injection pressures below the fracture gradient, which is defined uniquely for each injection well, minimizing the potential for seismic events related to fluid injection. Some injection wells do not need to inject under pressure because the formation will take water on a vacuum. Beginning in September of 2011, the COGCC UIC permit review process was expanded to include a review

for seismicity by the CGS. CGS uses their geologic maps, the USGS earthquake database, and area-specific knowledge to provide an opinion of seismic potential. If historical seismicity has been identified in the vicinity of a proposed Class II UIC well, COGCC requires an operator to define the seismicity potential and the proximity to faults through geologic and geophysical data prior to any permit approval.

COGCC has had recent discussions with operators, EPA and the USGS regarding induced seismicity. The USGS earthquake specialists visited the COGCC and CGS in January 2012. Discussions related to providing technical expertise regarding seismicity and possible relationships to Class II UIC wells.

COGCC believes safeguards are in place, in accordance with federal law and COGCC's rules and policies, but we will continue to review induced seismicity findings in other parts of the country with interest. The current safeguards defined by COGCC permit process are injection volume; pressure below the fracture gradient; and, input from the CDWR and CGS to reduce the potential for induced seismicity related to UIC Class II wells. COGCC strives to continually improve our evaluation methods, and the effectiveness of regulations, rules policies and procedures.

References:

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What is a Class II Underground Injection Control (UIC) well?
Class II UIC wells inject fluids associated with oil and natural gas production. Most of the injected fluid is salt water (brine), which is brought to the surface in the process of producing (extracting) oil and gas. In some oil fields, brine and other fluids are injected to enhance (improve) oil and gas production by using an enhanced recovery method known as "water flooding." There are approximately 885 active Class II UIC wells in Colorado, with 297 operating as exploration and production (E&P) waste disposal wells and 588 enhanced recovery wells. The waste disposal wells inject approximately 355,000 barrels of brine per day.

What are the types of Class II UIC wells?
There are three types of Class II injection wells associated with oil and natural gas production.

1. **Enhanced Oil Recovery Wells** (EOR) inject brine, water, steam, polymers, natural gas and/or carbon dioxide into oil-bearing formations to recover residual oil. This is also known as secondary or tertiary recovery. The injected fluid thins (decreases the viscosity) or displaces the residual oil and gas after primary production, which is then available for recovery. In a simple configuration, a single injection well is surrounded by multiple production wells. Production wells bring oil and gas to the surface; the UIC Program does not regulate production wells. Enhanced recovery wells are the most numerous type of Class II wells, representing as much as 60 percent of the Class II UIC wells in Colorado. There are currently 588 permitted EOR wells in Colorado.
2. **Disposal Wells** inject brines and other E&P waste fluids associated with the production of oil and natural gas operations. When oil and gas are produced, brine is also brought to the surface. The brine is segregated from the oil and gas by surface production facilities. It is then injected into the same deep underground formation or a similar formation specifically permitted for disposal. Class II disposal wells can only be used to dispose of fluids associated with oil and gas production. Disposal wells represent about 30 percent of Colorado's Class II UIC wells. There are 885 total UIC Class II wells with 297 operating as E&P waste disposal wells in Colorado.
3. **Hydrocarbon Storage Wells** inject liquid hydrocarbons in underground formations (such as salt caverns or abandoned hydrocarbon fields) where they are stored, generally, as part of the U.S. Strategic Petroleum Reserve.

Is UIC Class II Exploration and Production Disposal the same as hydraulic fracturing?
No. Injection well operations are not hydraulic fracturing. Hydraulic fracturing and underground injection are not related activities. Class II waste disposal is conducted below rock fracture gradient so as not to create new fractures. Class II waste disposal occurs over a long period of time, typically many years during the life of a UIC well. On the other hand, hydraulic fracturing is performed over a short period of time, typically hours, with "flowback" occurring over the course of several days or weeks. By definition, pressures used for hydraulic fracturing are above the fracture gradient, with the intent of inducing new fractures within a hydrocarbon extraction zone and does not include the permanent emplacement of fluids.

What are the requirements for Class II wells?
A state has the option of requesting primacy for Class II wells under section 1422 of the Safe Drinking Water Act:

Section 1422 requires states to meet EPA's minimum requirements for UIC programs. Programs authorized under section 1422 must include construction, operating, monitoring and testing, reporting, and closure requirements for well owners or operators. Enhanced oil and gas recovery wells may either be issued permits or be authorized by rule. Disposal wells are issued

permits. The owners or operators of the wells must meet all applicable requirements, including strict construction and conversion standards and regular testing and inspection.

Are there other types of underground injection wells?
Yes, there are six injection well types, which are designated based on the different types of waste injected into the wells. COGCC has primacy to administer EPA's requirements for Class II UIC wells.

- Industrial & Municipal Waste Disposal Wells (Class I) – There are 13 Class I wells in Colorado.
- Oil and Gas Related Wells (Class II) – There are 885 Class II wells in Colorado.
- Solution Mining Wells (Class III) – There are 37 Class III wells in Colorado.
- Shallow Hazardous and Radioactive Injection Wells (Class IV) – There are no permitted Class IV wells in Colorado.
- Shallow Non-Hazardous Injection Wells (Class V) – There are 1759 Class V wells in Colorado.
- Geologic Sequestration Wells (Class VI) – There are no Class VI wells in Colorado.