



ENGINEERING UNIT SEISMICITY REVIEW FOR CLASS II UNDERGROUND INJECTION CONTROL WELLS

The Underground Injection Control (UIC) program is a federal U.S. Environmental Protection Agency (EPA) regulatory program defined by the **Safe Drinking Water Act** of 1974. The EPA has delegated authority to the Colorado Oil and Gas Conservation Commission (COGCC) to regulate, permit, monitor and enforce on EPA Class II wells engaged in underground injection activities on non-tribal lands within Colorado. Class II underground injection is for disposal or recycling (in enhanced recovery operations) of Oil and Gas Exploration and Production Waste, generally referred to as produced water. Colorado was delegated authority over Class II injection wells in 1989.

Potential for Seismicity

UIC permit review includes a review for seismicity. The seismic review uses United States Geological Survey (USGS) geologic maps and an earthquake database, Colorado Geologic Survey (CGS), public literature, and area-specific knowledge provided by operators to assess seismic potential. If historic seismicity is identified in the vicinity of a proposed Class II UIC well, COGCC requires the operator to characterize the seismic potential with respect to the proximity of injection into basement rocks and known faults. This characterization uses geologic and geophysical data within COGCC's review prior to any permit approval.

The COGCC is engaging with the University of Colorado, Colorado School of Mines, Colorado State University, Mesa State University, Interstate Compact Commission, Ground Water Protection Council and the USGS as well as the EPA to understand induced seismicity.

Maximum Injection Pressure, Rate and Volume

In order to minimize the potential for seismic events related to fluid injection COGCC's policy is to keep injection pressures below the pressure at which rocks fracture in the subsurface. A fracture gradient in pounds per square inch per foot is uniquely calculated for each injection well. To determine fracture gradients in injection zones operators perform a step rate or passive injectivity test. From the resulting fracture gradients, the COGCC designates a maximum surface injection pressure and injection rate determined to minimize the potential for induced seismicity. Values for these parameters are specifically recorded in the injection well's permit to operate.

COGCC also calculates a maximum injection volume, based on injection zone thickness and porosity from geophysical well-log data. By COGCC's policy is to

calculate a gross injection volume over a one-quarter mile radius. The volume may be extended up to one-half mile with additional reviews. This restriction of the total volume of injected fluids is intended to constrain the life of the injection well.

Depth to Basement

The COGCC uses the available USGS and CGS geologic maps, public literature, COGCC well data and geophysical logs, and area-specific understand of basement depth and sealing zones. This allows COGCC to review an individual well for pressure and fluid containment to the injection zone.

Seismicity Monitoring

The COGCC uses the induced seismicity risk management “Traffic Light”¹ protocol as a guide to manage and monitor seismicity at injection wells. The protocol employs a combination of seismic observation methods that includes both qualitative and quantitative criteria to evaluate responses to seismic events. Because the USGS publishes 2.5 magnitude events, Commission staff uses the listed USGS events as a reference to monitor seismic activity.

COGCC by permit conditions requires operators of any new injection well intending to inject over 10,000 barrels of water per day to install seismic monitoring equipment.

Ultimately, COGCC’s permit review process incorporates multiple factors as safeguards in the prevention of induced seismicity.

- Review of well construction
- Review of seismic activity in USGS database
- Review of USGS geologic maps
- An understanding of known faults and basement
- Injection volume limit
- Injection pressure less than subsurface fracture pressure
- Daily injection rate
- Required seismic monitoring for commercial wells



Planning - Risk Management Plan: Traffic Lights

Green	Continue operations – no seismicity felt at surface (MMI I-II)* – Less than M2.5 within 2.5 Miles
Amber	Modify operations – seismicity felt at surface (MMI II-III+)* – Greater than M2.5 & Less than 4.4 within 2.5 Miles
Red	Suspend operations – seismicity felt at surface with distress and/or damage (MMI V+)* – Greater than M4.5 within 2.5 Miles

Perceived Shaking	Not Felt	Weak	Light	Moderate	Strong	Very Strong	Severe	Violent	Extreme
Potential Damage	none	none	none	Very Light	Light	Moderate	Moderate Heavy	Heavy	Very Heavy
Peak Acceleration (%g)	<0.17	0.17 to 1.4	1.4 to 3.9	3.9 to 9.2	9.2 to 18	18 to 34	34 to 65	65 to 124	>124
Peak Velocity (cm/s)	<0.1	0.1 to 1.1	1.1 to 3.4	3.4 to 8.1	8.1 to 16	13 to 31	31 to 60	60 to 116	>116
Magnitude	1 – 2.9	3 – 3.9	4 – 4.4	4.5 – 4.9	5 – 5.4	5.5 – 5.9	6 – 6.4	6.5 – 6.9	7.0+
Modified Mercalli	I	II to III	IV	V	VI	VII	VIII	IX	X+
Traffic Lights *	Green			Red					

Exhibit 1

* Established based upon local conditions, demographics and codes

AXPC / Industry induced
seismicity SME presentation

¹Modified from a talk given by Jeff Bull at the Groundwater Protection Council Meeting January 23, 2013, "Induced Seismicity and the O&G Industry"