Monitoring and Protecting Groundwater During Oil & Gas Development

Overview of Colorado Aquifer Systems

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Colorado Aquifer Systems

• Topics
  – Locations and occurrence of:
    • Aquifer systems
    • Oil & gas basins
  – Potential contamination events
    • What types of events are we monitoring for?
  – Travel times
  – Considerations with respect to rulemaking
Colorado Oil & Gas Basins

Source: COGCC GIS database
Colorado Aquifer Systems

• Interaction of aquifers and oil and gas drilling activities
  – Focus is on sedimentary aquifer systems
  – Sedimentary bedrock and alluvial aquifers typically overlay O&G formations
  – Other aquifer types exist, but typically do not interact with O&G formations
Figure 3-3. Schematic cross section of various types of aquifers.

Source: Ground Water Atlas of Colorado
Schematic Cross-Section of Aquifer Types in Colorado

Source: Ground Water Atlas of Colorado
Simple model, sometimes but not always true

Alluvial Deposits in Colorado
Source: Ground Water Atlas of Colorado
Northeastern CO, Alluvial Deposits and Oil and Gas Basins
Northwestern CO, Alluvial Deposits and Oil and Gas Basins
Sedimentary Bedrock Aquifer Systems in Colorado

Source: Ground Water Atlas of Colorado
Overlay of Bedrock Aquifers and Oil and Gas Basins
Denver Basin Example

Schematic geologic cross section of Denver Basin – Oil & Gas zones located in and below Pierre Shale

Source: Ground Water Atlas of Colorado
Dakota-Cheyenne Aquifer

Source: Ground Water Atlas of Colorado
Overlay of Dakota-Cheyenne Aquifer and Oil and Gas Basins
<table>
<thead>
<tr>
<th>Era</th>
<th>System</th>
<th>Series</th>
<th>Stratigraphic Unit</th>
<th>Unit Thickness (feet)</th>
<th>Physical Characteristics</th>
<th>Hydrogeologic Unit</th>
<th>Saturated Thickness (feet)</th>
<th>Hydrologic Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mesozoic</td>
<td>Cretaceous</td>
<td>Upper Cretaceous</td>
<td>Pierre Shale</td>
<td>0–4,000+</td>
<td>Black to dark-gray shale</td>
<td>Confining layer</td>
<td>Not known to yield water to wells</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Niobrara Formation</td>
<td>200+</td>
<td>Upper unit is yellowish chalk, lower unit is chalky limestone and marl</td>
<td>Fort Hayes Limestone</td>
<td>50–60</td>
<td>Yields water to stock wells and springs north of Arkansas River</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carlile Shale</td>
<td>200+</td>
<td>Upper unit is sandy shale; middle unit is black, fissile shale; lower unit is chalky shale</td>
<td>Codell Sandstone</td>
<td>20+</td>
<td>Yields water to a few stock wells</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Greenhorn Formation</td>
<td>65</td>
<td>Upper unit is chalky sandstone and thin limestone; lower unit is hard, crystalline limestone</td>
<td>Confining layer</td>
<td></td>
<td>Yields no water to wells</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Graneros Shale</td>
<td>85–100</td>
<td>Gray to black shale</td>
<td>Confining layer</td>
<td></td>
<td>Yields no water to wells</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lower Cretaceous</td>
<td>Dakota Sandstone</td>
<td>150–235</td>
<td>Fine-grained, thin-bedded to massive sandstone</td>
<td>Dakota Sandstone</td>
<td>150+</td>
<td>Yields sufficient for domestic and stock use; in some areas yields enough for municipal and industrial use</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Purgatoire Formation</td>
<td>60–350</td>
<td>Upper unit is gray to black clayey shale; lower unit is massive, fine-grained sandstone</td>
<td>Dakota-Cheyenne aquifer Cheyenne Sandstone Member</td>
<td>30–200</td>
<td>Yields sufficient for industrial, municipal, and irrigation use</td>
</tr>
<tr>
<td></td>
<td>Jurassic</td>
<td></td>
<td>Morrison Formation</td>
<td>20–240</td>
<td>Varicolored marl</td>
<td>Confining layer</td>
<td></td>
<td>Minimal yield to wells from sandstone lenses</td>
</tr>
</tbody>
</table>

Hydrogeologic Units in Eastern CO.
All of these units are also developed for Oil & Gas
In some locations
Source: Ground Water Atlas of Colorado
Example Well Depths

- Wattenberg area (DJ O&G Basin, Denver Basin aquifer system)
  - Alluvial water supply wells: 80 ft
  - LFH water supply wells: 890 ft
  - O&G wells (Niobrara): 8000 ft
  - Dakota Formation (not aquifer at this location): 8400 ft
Considerations re. Well Depths

• Locations other than eastern Colorado
  – Water supply wells vary in depth
  – O&G wells have variable depths
  – Water supply wells may be constructed in formations not typically considered to be aquifers
  – Geology and relationship between aquifers and O&G formations may be complex
Contamination Occurrences - During O&G Drilling and Fracking

- Cement seals in boreholes prevent interaction
  - Cement plugs may fail if not properly installed
- Fractures may create conduits between aquifers and O&G wells (fracked wells)
- Surface spills
- Unforeseen events
  - There are many unknowns
  - Impossible to fully understand subsurface fluid movement
Fluid flow mechanisms

- Fluids will not migrate from oil and gas formations to aquifers unless a conduit has been created
  - New fracture
  - Well borehole
- Surface spills can contaminate aquifers
  - Spills
  - Leaky surface pits
  - Contaminants can migrate through surface streams, through aquifers, or by overland flow
Aquifer Travel Times

• Variable based on site-specific conditions
• Alluvial aquifers
  – 0.05 to 10 feet per day (18 to 3,650 ft per year)
• Bedrock aquifers
  – 0.05 to 0.5 feet per day (18 to 182 ft per year)
• Groundwater moves very slowly
  – Monitoring may need to continue for long periods to identify contaminants
• Well pumping can impact travel times
Considerations Regarding Sampling points

• Need to define what the Rules are seeking to protect
  – Existing wells?
  – All aquifers?
  – Surface water?

• Use of existing wells only will protect just that, existing wells only

• Springs provide opportunity for groundwater discharge sample

• New wells provide opportunity to sample aquifers in which no local wells are constructed at strategic aquifer locations
Water Quality Samplings Parameters

- Parameters to be analyzed need to cover fluids introduced in borehole
- Hydrocarbon profile will help to identify O&G that may migrate from a new well
- Sampling of gas from wells is recommended if any evidence of gas in wells is present
Considerations for Rulemaking

• Contamination may occur to:
  – Shallow alluvial aquifers
  – Deeper bedrock aquifers
  – Surface water

• A single monitoring approach may not be appropriate for all situations

• Monitoring of existing wells may not be protective of all aquifer systems

• It will be cost prohibitive to construct new monitoring wells in some situations
Considerations for Rulemaking – cont.

- Contaminants may move very slowly
- Monitoring for extended time periods may be required in order to detect contaminants
- Horizontal location of O&G wells and orientation of fractures should be considered when developing monitoring strategy
- Draft rules require two samples. This may not adequately cover existing aquifers and stream systems if more than two aquifer systems and/or surface water is present.
Considerations for Rulemaking – cont.

• Monitoring program is protective for property / well owners as well as O&G operators

• Statewide consistent approach helps to streamline process and establish expectations

• Need flexibility to adjust requirements based on site-specific conditions
  – Single approach will not match all situations
Questions / Discussion

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