Class II UIC Webinar No. 4: Area of Review (AOR) and Zone of Endangering Influence (ZOEI)

Class II UIC Program
Technical History &
Program Evolution
Webinar Series

GROUNDWATER PROTECTION COUNCIL

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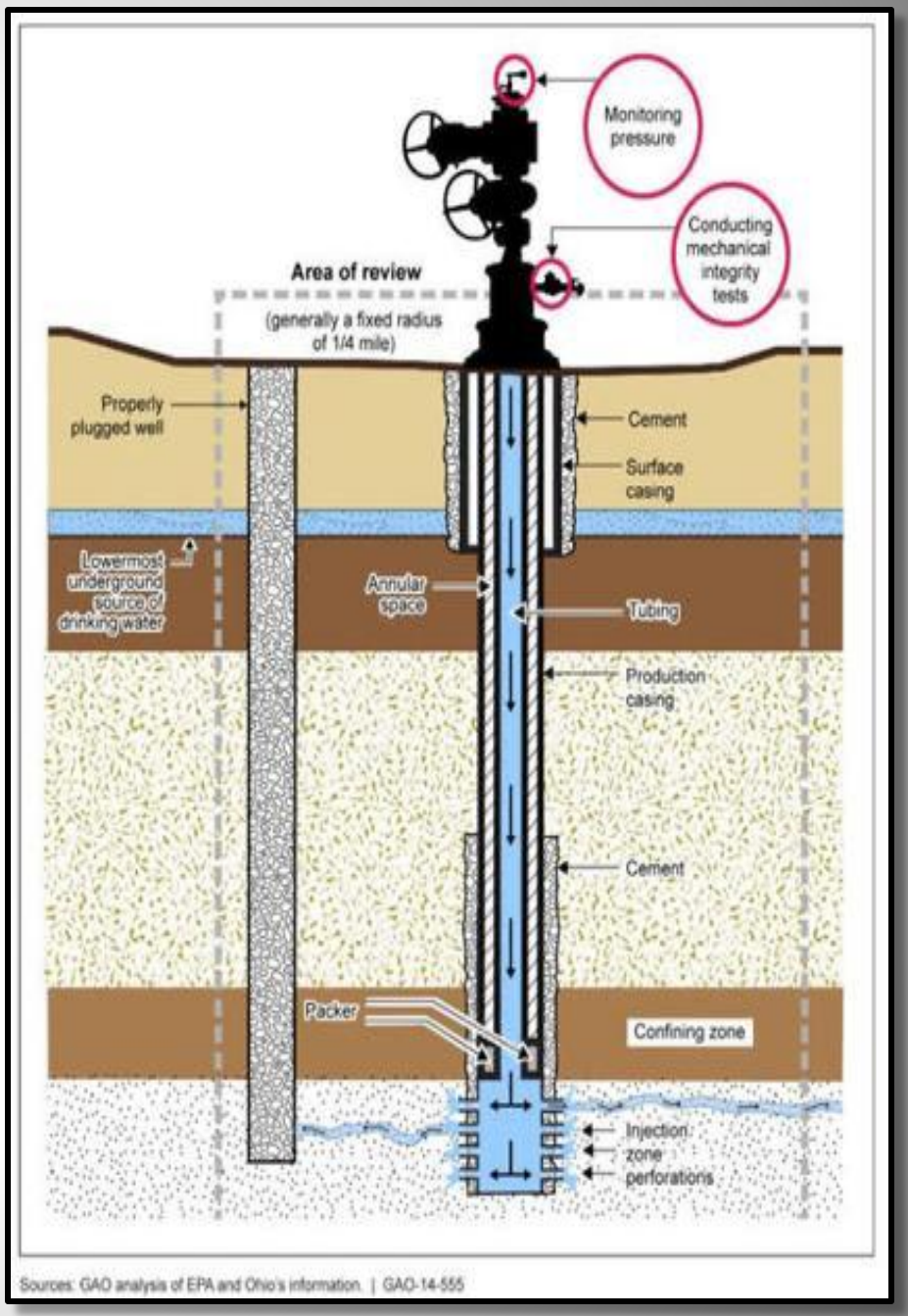
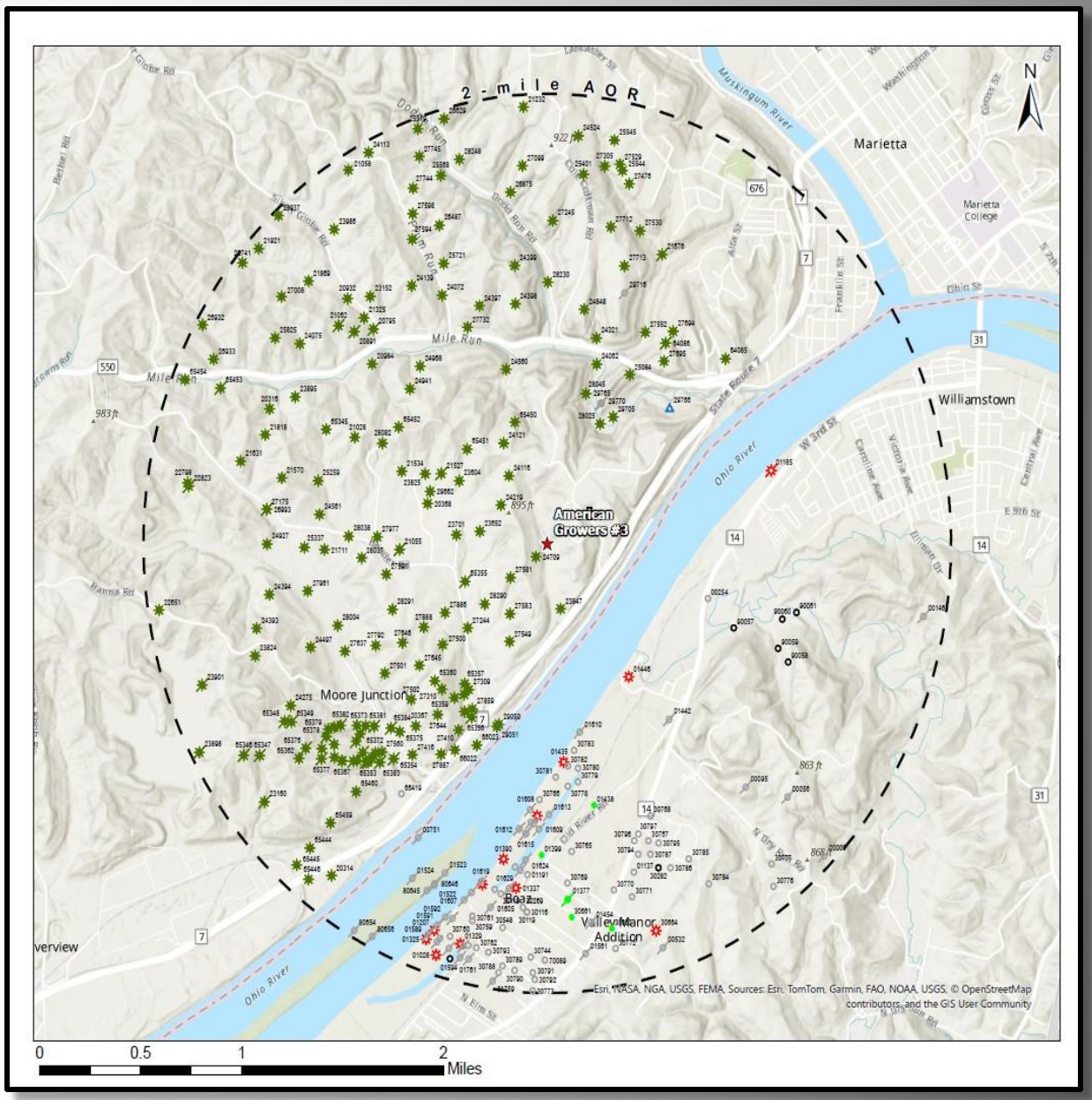


The Critical Nature of AOR and the Zone of Endangering Influence for the Protection of USDWs

- The basis of AOR and ZOEI are perhaps the most significant cornerstones of the UIC Program, for any class of injection well, especially Class II.
- AOR analysis is critical for assessing the feasibility, planning, designing, assessing potential corrective action, and ultimately assuring not only the protection of USDWs, but that injection activities will not affect other systems or activities (e.g., oil & gas production, gas storage, industrial waste injection, and more).
- Although things like well design, mechanical integrity, and other program areas are important, AOR and assessment of the ZOEI are CRITICAL!

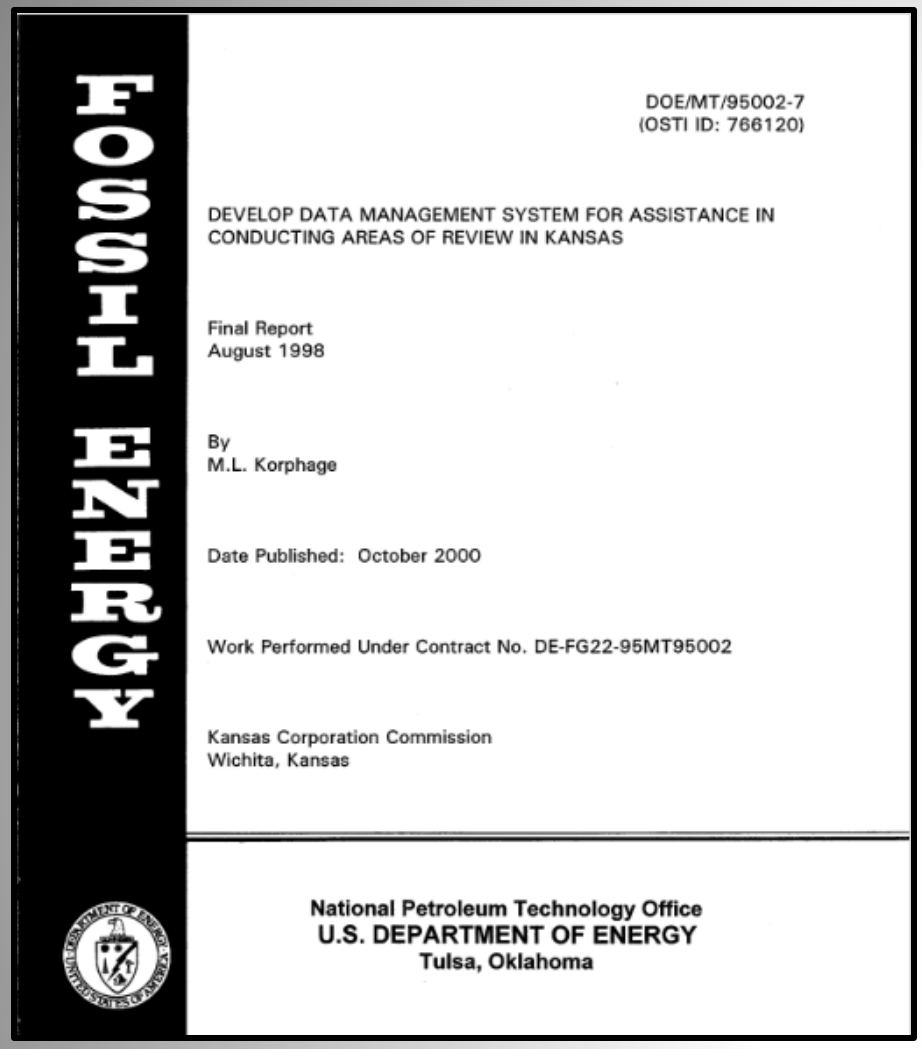


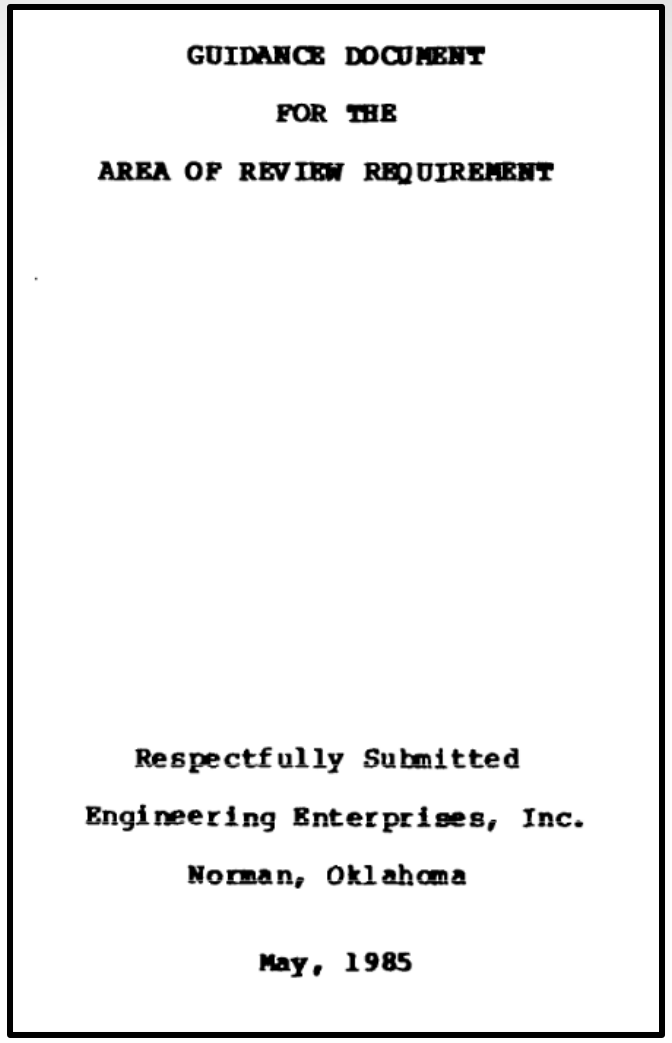
Source: ALL Consulting, 2024

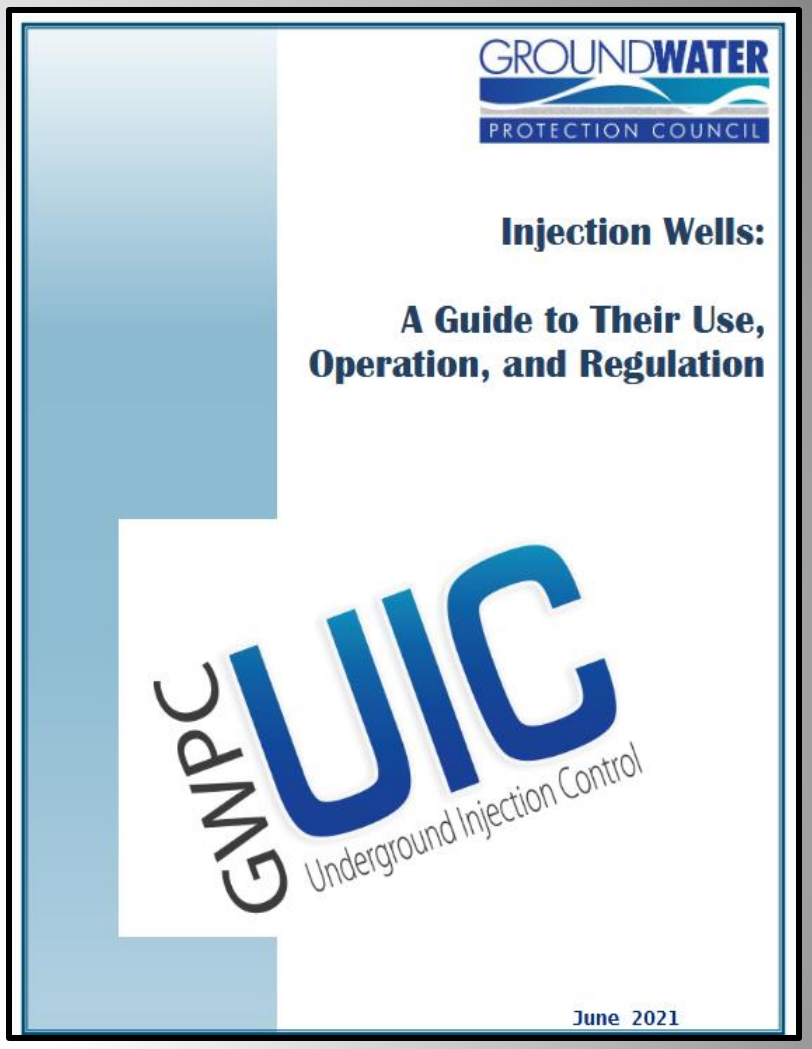
Common Challenges to AOR/ZOEI Assessment

- Incomplete Well Records: Abandoned wells may lack plugging or cementing data or have no records at all.
- High well density in mature fields can be problematic.
- Complex Geology: Faults or variable permeability can complicate ZOEI calculations, necessitating conservative assumptions.
- High Injection Volumes: Increased ZOEI and potentially greater number of corrective actions.
- Regulatory Scrutiny: Surface purges, fluid migration out of zone, or seismic events (New Mexico, Ohio, Oklahoma, and Texas) have heightened regulatory oversight, so robust AOR/ZOEI analyses are critical.
- Discrepancies between databases and finding records.

Source: Texas Monthly, 2022



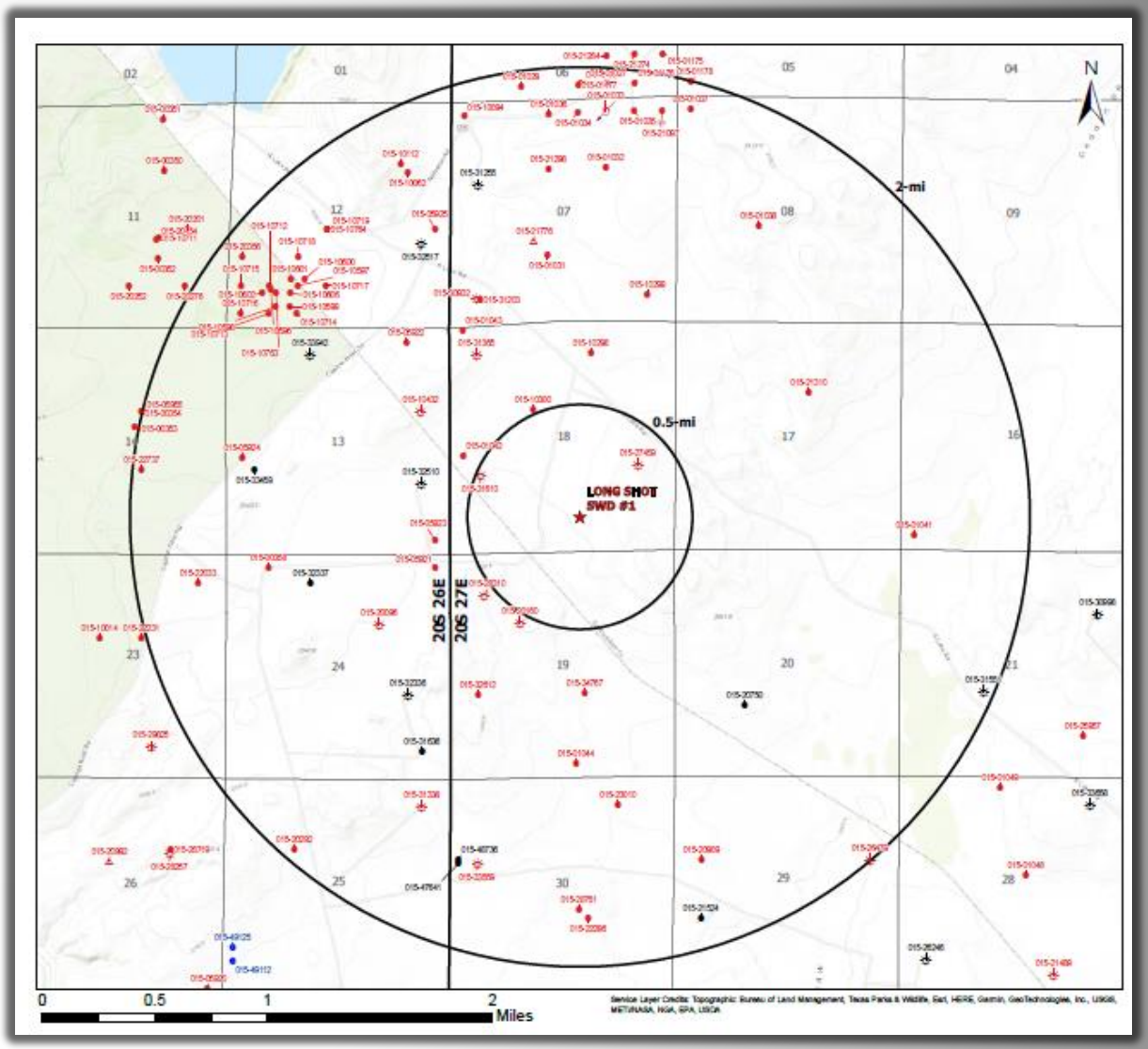




WHAT IS THE AREA OF REVIEW AND ZOEI

Area Of Review (AOR)

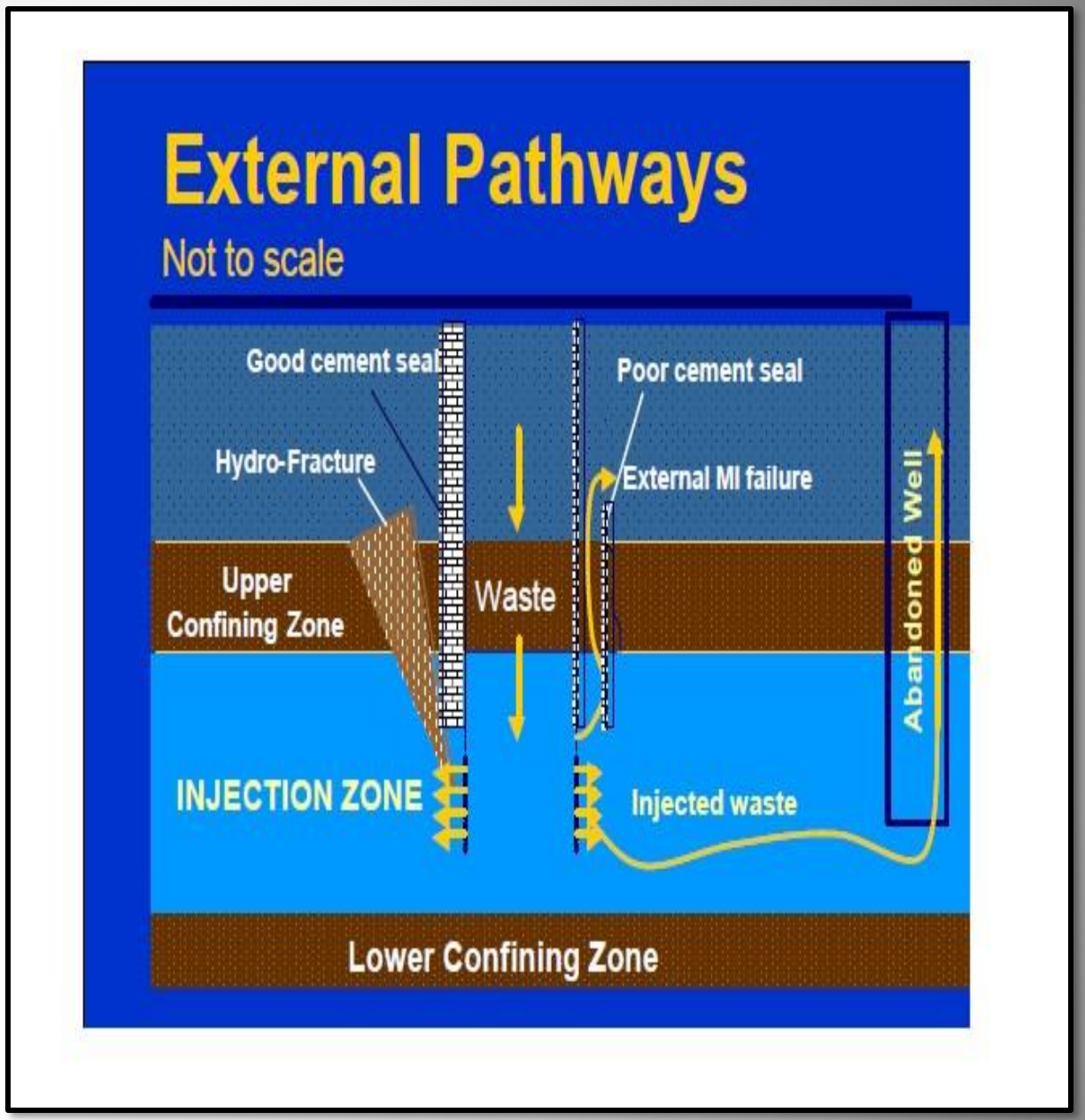
- All primacy states and EPA uses either a fixed radius or equation for calculating an AOR for a Class II disposal well.
- Fixed-radius AORs generally range from ~¼- to ~2-miles for Class II Wells.
- When calculated the AOR, the “zone of endangering influence” or ZOEI is the approved method.
- Some primacy states have allowed for variances to the area of review based on pressure and volumetric calculations to ensure unplugged or improperly plugged wells are not impacted.



Source: ALL Consulting 2022

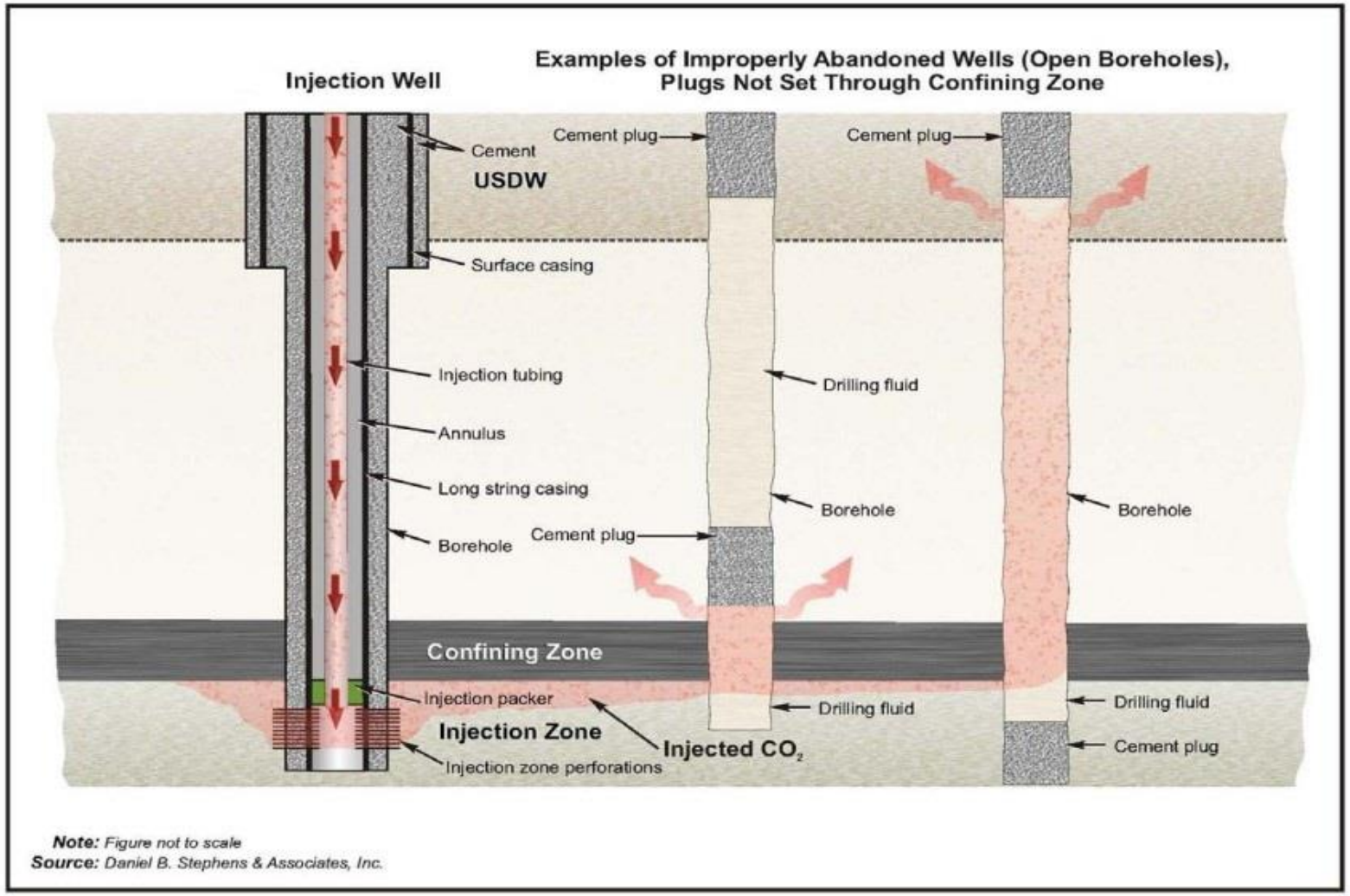
AOR Investigations

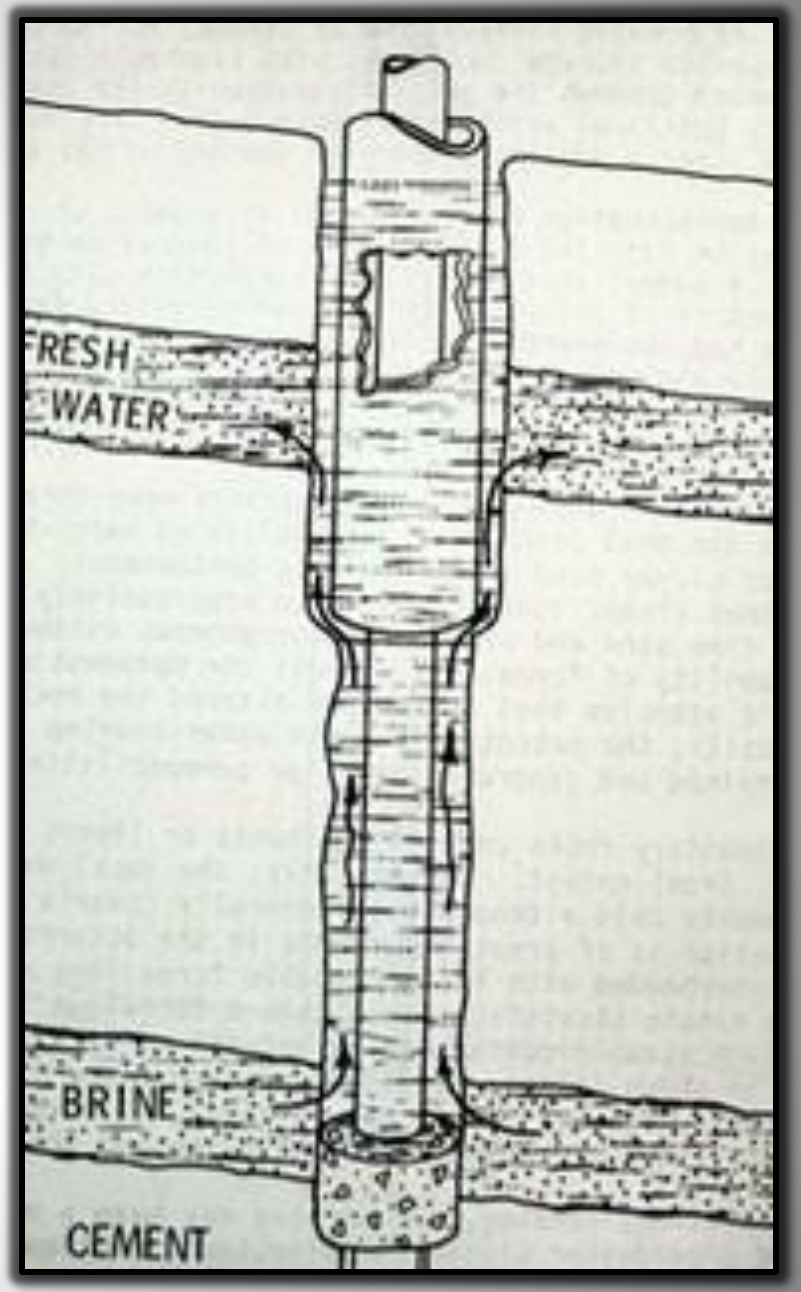
- Identify and evaluate wellbores and potential conduits into or through the proposed injection zone or into the proposed confining zone if required.
- Assess wellbores to determine if penetrations into or through the proposed injection zone are properly plugged and abandoned or have adequate cement behind the intermediate or production casing string to prevent vertical migration of injected fluids out of the injection zone.



Source: EPA, 2003

Potential Fluid Migration





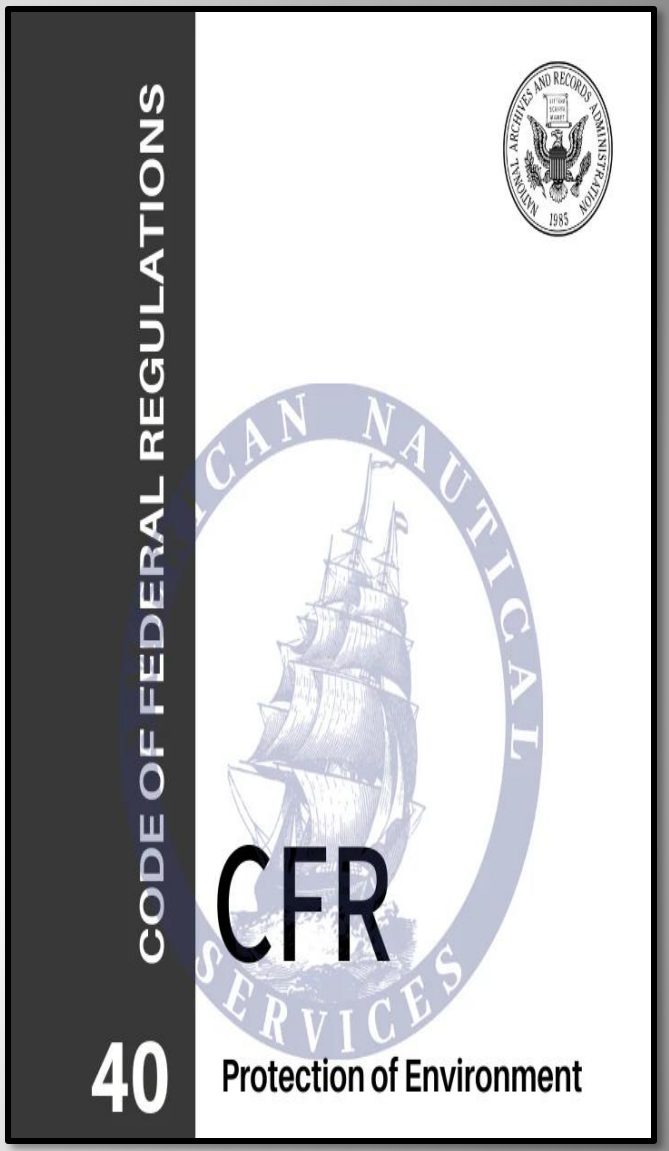
Source: TGS, Tulsa's Physical Environment, 1971

EPA Requirements

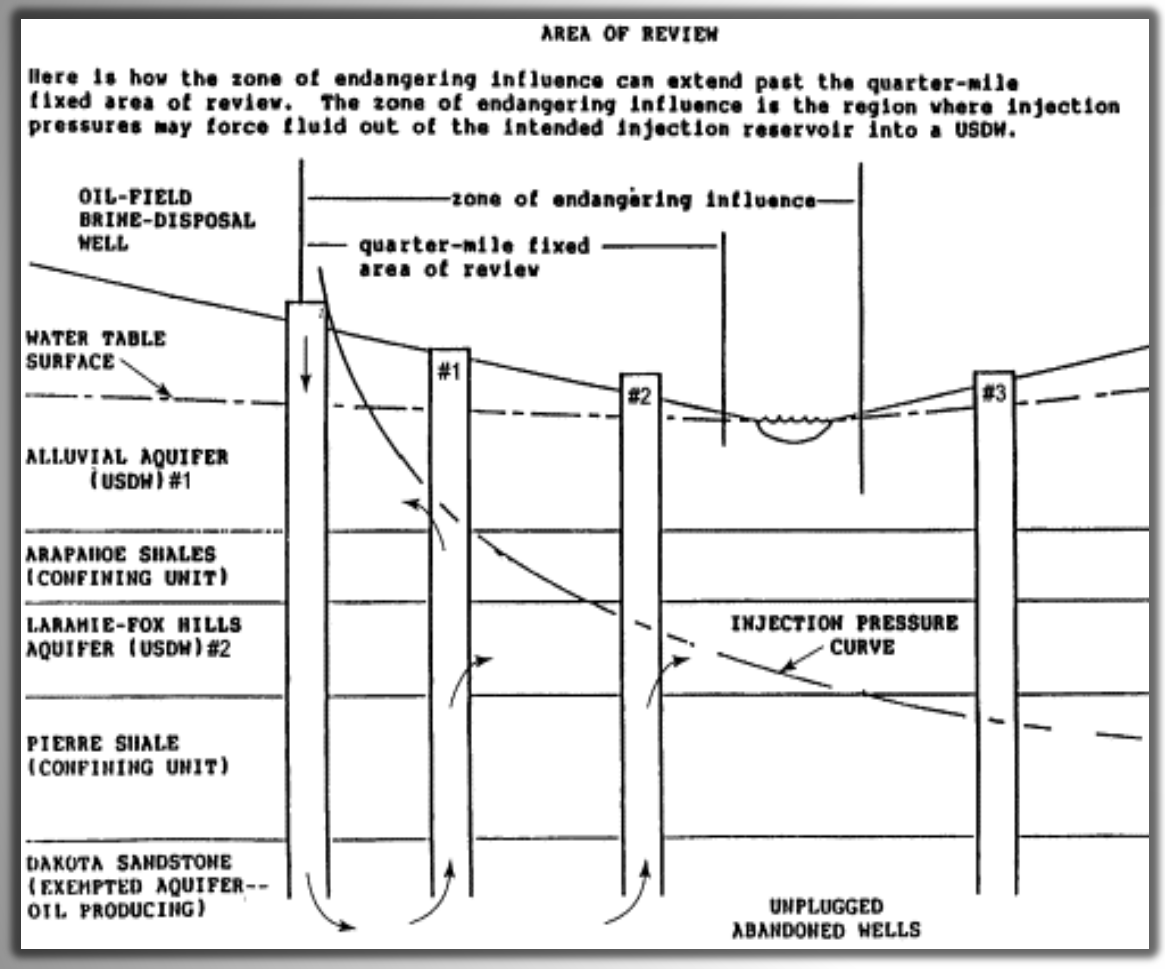
- 40 CFR Part 144, requires an AOR of at least ¼ mile (1,320 feet) around a Class II injection well, when using the fixed-radius approach.
- 40 CFR § 144.28(f) provides for the use of AOR Variances based on site-specific data, in conjunction with 40 CFR § 146.6.
- 40 CFR § 144.16 allows the EPA Administrator (or delegated state Director) to grant variances from certain UIC requirements for specific well classes or situations, provided USDWs are protected. While this section is not specific to AoR, it supports the broader regulatory framework for variances, including those for AOR under § 144.28(f).
- EPA allows primacy states to set stricter or tailored standards based on local conditions, that meet minimum requirements.
- States or EPA regions may require a larger radius (e.g., ½ mile or 1 mile) based on local geology or injection history.

History of the Area of Review Process

- Initial UIC rules in the 1980s favored fixed-radius Area of Review (AOR) due to limited data and computing power.
- Department of Energy early research explored pressure transients for enhanced oil recovery (EOR), laying groundwork for Zone of Endangering Influence (ZOEI) models. 40 CFR § 146.6 allowed flexibility for AOR determination and ZOEI modeling. In 1982, EPA began to delegate Class II primacy to states.
- In 1993, new UIC Class II regulations were being considered that would require AOR evaluations of at least some grandfathered older wells (pre-1982). These updated regulations would also provide the granting of variances if USDWs could be protected.
- A project administered by the *Underground Injection Practices Research Foundation* (UIPRF) with participation by the state UIC programs, the *American Petroleum Institute* (API), the EPA regions and EPA headquarters showed that AOR Variance Methodologies could save costs without compromising safety.
- Most grandfathered Class II injection wells have either been brought into compliance, plugged, or re-permitted under modern UIC standards.



Zone of Endangering Influence



Steve Platt & Dave Rectenwald, 2005

- The ZOEI is used by Class II regulatory agencies to calculate the potential for fluid migration out of the injection zone and into a USDW.
- ZOEI can be calculated from site-specific data using a modified *Theis* equation defined in EPA regulations.
- The ZOEI is the area with a radius of lateral distance in which the reservoir pressure within the injection zone may cause the migration of injected or native formation fluids into the USDW.
- Endangerment is defined as a pressure increase that has the potential to cause a column of formation fluid that would allow fluids to enter a USDW.

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- Endangerment is defined as a pressure increase that has the potential to cause a column of formation fluid in a conduit to extend above the level of the base of a USDW.

RITCHIE HUNTER #2 – TEN YEARS OF INJECTION - ZONE OF ENDANGERING INFLUENCE (ZEI) CALCULATIONS – JANUARY 1, 2016 TO JANUARY 1, 2026

Calculations are as follows:

$$r = \sqrt{\frac{2.25KHt}{S10^{x}}}$$

Where:

$$X = \frac{4\pi KH(hw - hbo)SpGb}{2.3Q}$$

And:

"K" hydraulic conductivity of the injection zone (length/time) = **2 x 10^{-3} ft/day**

"H" thickness of the injection zone (length) = **66 feet**

"t" time of injection (time) = January 1, 2016 to January 1, 2026 = **3,650 days**

"S" storage coefficient (dimensionless) = **4 x 10^{-3}**

"Q" injection rate (volume/time) = **3,100 barrels/day**

"h_{bo}" observed original hydrostatic head of the injection zone (length) = **6,000ft**

"h_w" hydrostatic head of underground source of drinking water (length) = **100ft**

"S_pG_g" specific gravity of fluid in the injection zone (dimensionless) = **1.1**

"pi" π (dimensionless) = **3.142**

With the following assumptions:

- Injection zone is homogeneous (uniform throughout) and isotropic (uniform in all directions).
- Injection zone has an infinite area extent.
- Injection well penetrates the entire thickness of the injection zone.
- The well diameter is infinitesimal compared to the radius of ZEI, "r", when injection time is longer than a few minutes.
- Emplacement of fluids into the injection zone creates an instantaneous increase in pressure.

Source: ALL Consulting, 2016

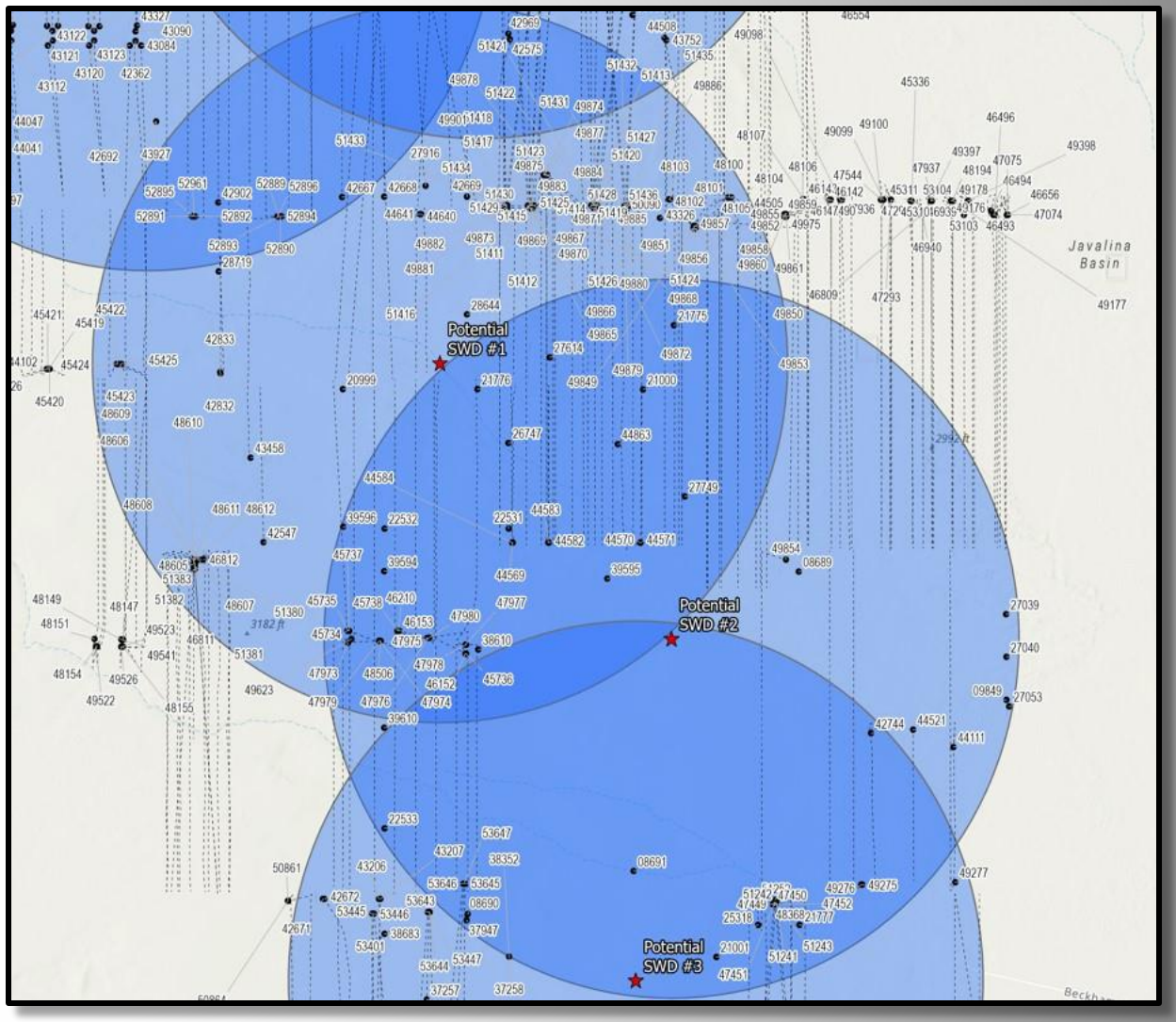
ZOEI Assumptions

- The ZOEI equation is based on the following assumptions:
  - (a) The injection zone is homogenous and isotropic;
  - (b) The injection zone has infinite area extent;
  - (c) The injection well penetrates the entire thickness of the injection zone;
  - (d) The well diameter is infinitesimal compared to “r” when injection time is longer than a few minutes; and
  - (e) The emplacement of fluid into the injection zone creates instantaneous increase in pressure.

REQUIREMENTS CAN VARY BY STATE OR REGIONAL AREA

State-Specific Area of Review Requirements

- Several primacy states have revised their rules or modified their Class II SWD AOR fixed radius requirements.
- This includes Kansas, New Mexico, Ohio, Oklahoma, and Texas which have stricter or have modified their Class II SWD AOR requirements.
- Additionally, Louisiana, North Dakota, and Wyoming have some variations to their AOR processes.
- Be aware of the variations!



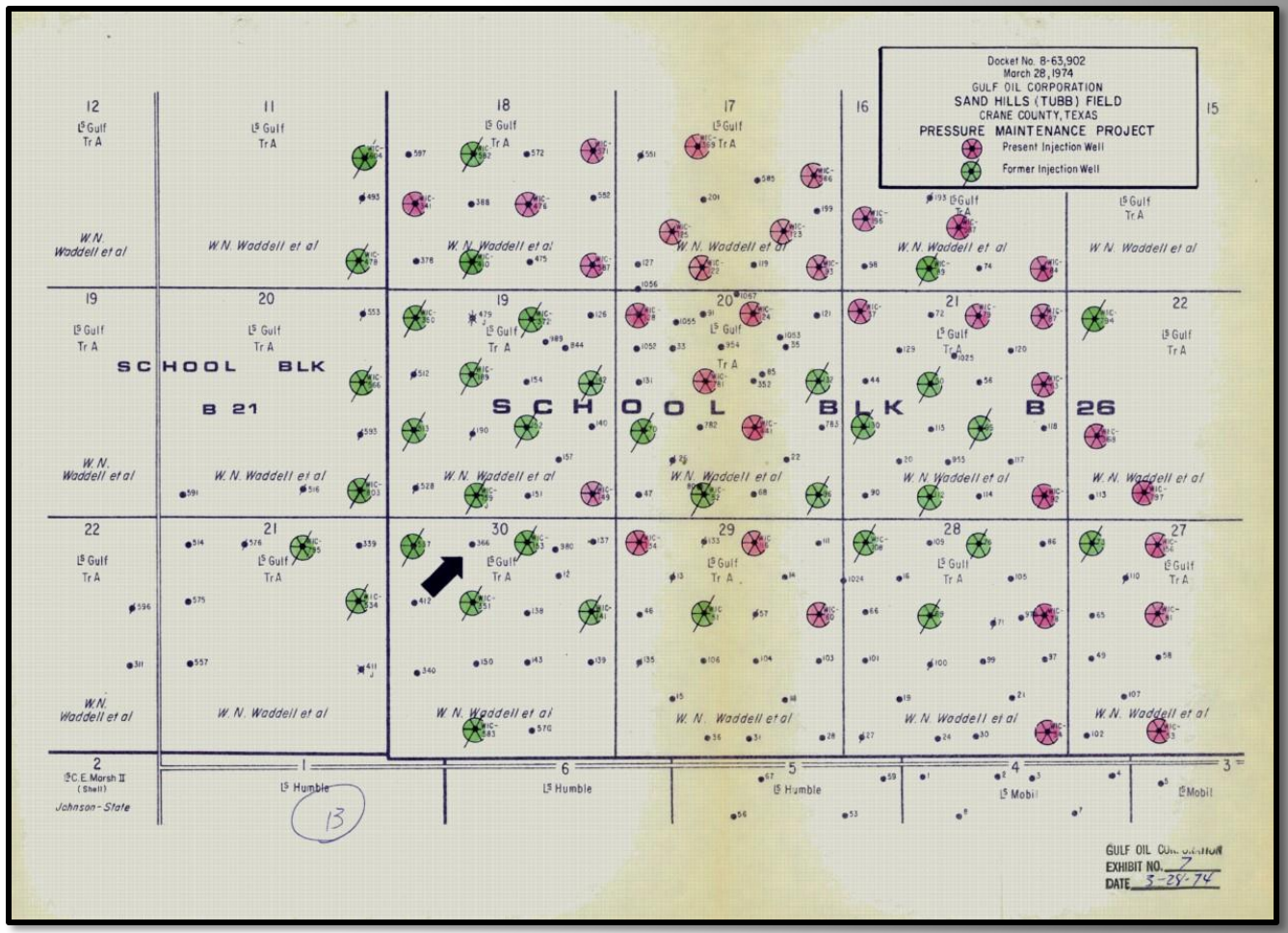
Source: ALL Consulting, 2025

Kansas Corporation Commission

- Fixed ¼ mile AOR but Operators required to submit information on wells that penetrate the injection zone within the ½ mile radius.
- Uses the ZOEI calculation only as a method to define the AOR only if it expands the ¼ mile radius.
- No ZOEI calculations resulting in an AOR of less than ¼ mile may be used.
- Kansas Corporation Commission has the authority to provide access to wells in an AOR even if they are on another lease or property for the purpose of completing corrective action.

Louisiana Office of Conservation, Injection and Mining Division

- Class II SWD AOR search must include:
  - Conducting a foot-search of the AOR to identify any wells in the field;
  - Searching SONRIS for wells in the DNR database; and
  - Researching field maps and company files.



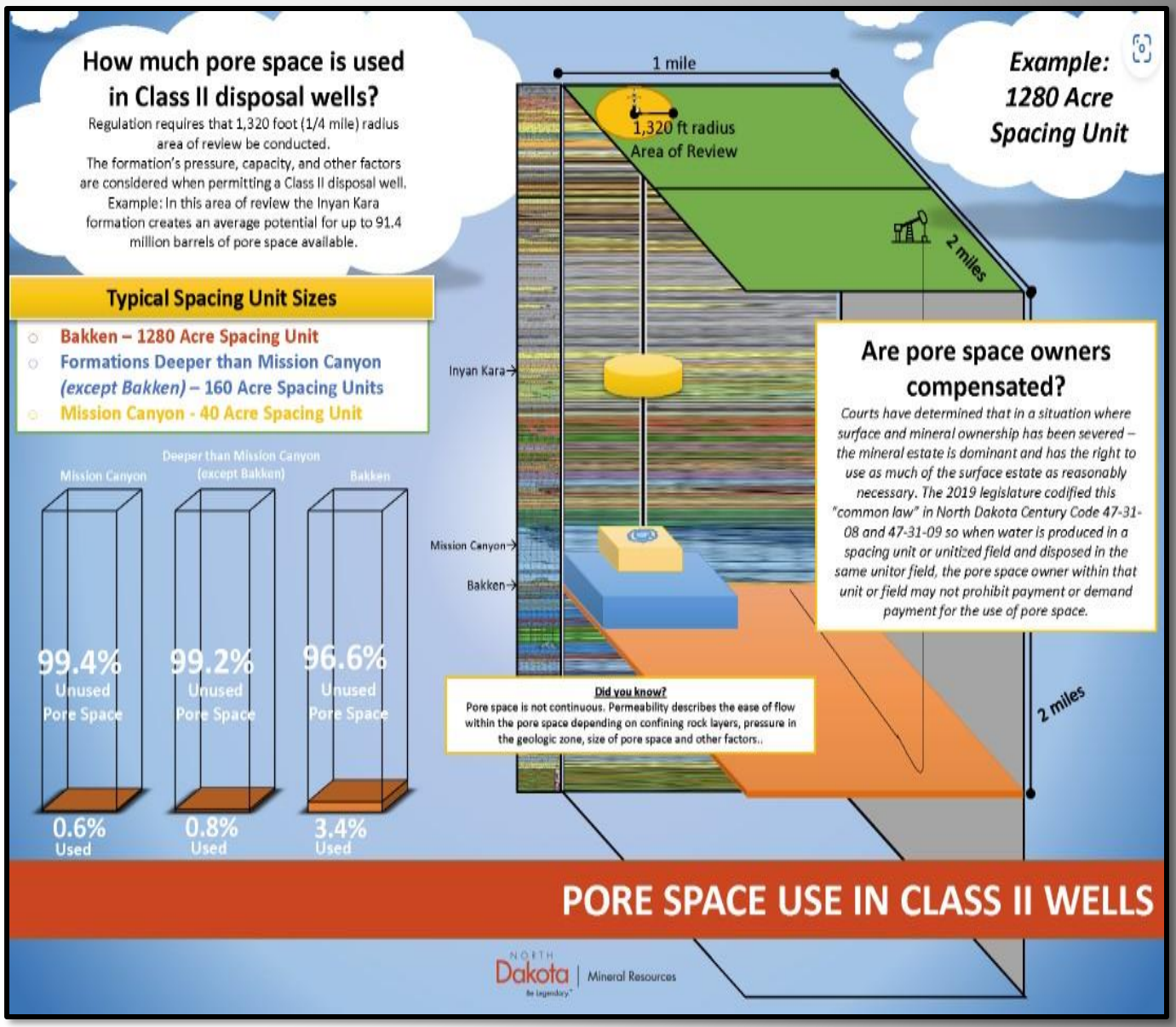
Source: Texas Railroad Commission, 1974

New Mexico Oil Conservation Division

- Changed their AOR requirements for deep SWDs (Woodford Shale and deeper wells) to a one- mile AOR due to induced seismicity concerns.
- Due to alleged impacts to horizontal well drilling operations in New Mexico in the Avalon Shale, Bone Spring, and Wolfcamp formations in the Delaware Basin, Delaware Mountain Group (DMG) SWDs now require a:
  - One-mile AOR; and
  - A two-mile separation between DMG SWDs.

North Dakota Industrial Commission (NDIC)

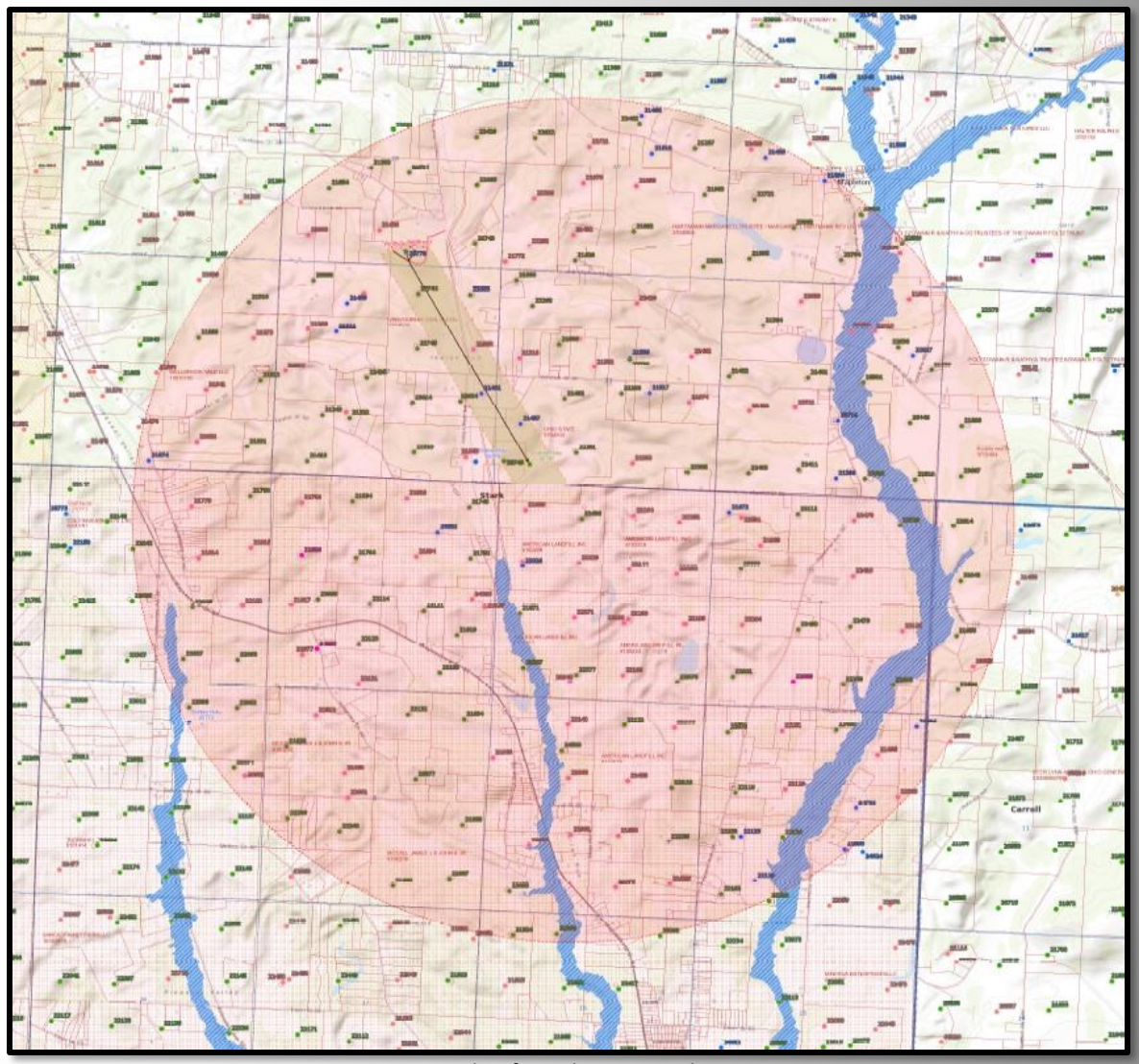
- Uses the standard ¼ mile AOR fixed radius but may extend the fixed radius to ½ mile for high-volume Bakken disposal wells.
- Depending on location, Aquifer Exemption & other requirements may also become an issue.



Source: North Dakota Mineral Resources, 2025

Ohio Department of Natural Resources

- Ohio Division of Oil and Gas Resources Management (DOGRM) passed new rules in January of 2022 for Class II saltwater disposal wells (SWDs).
- These new AOR rules were based on allegations of injection fluid migration beyond the existing ½ mile AOR.
- These new rules increased the AOR requirements for SWDs to the following:
  - Less than an average injection volume of 200 barrels of water per day (BWPD) per year = AOR of ½ mile
  - Between 200 but less than 1,000 BWPD per year = AOR of 1 mile
  - Greater than an average volume of 1,000 BWPD = AOR of 2 miles



Example of an Ohio Two-Mile AOR

Oklahoma Corporation Commission

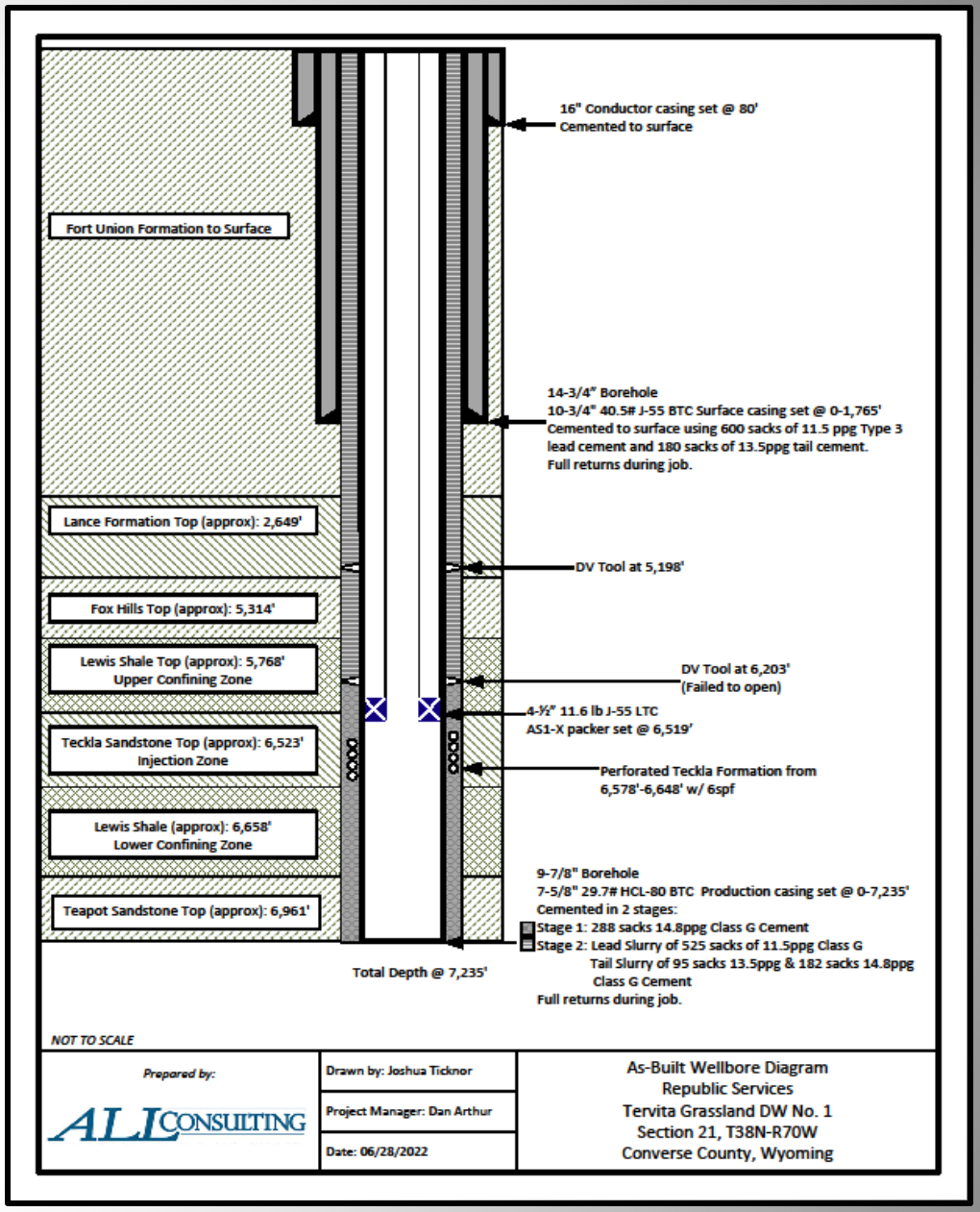
- *Oklahoma Administrative Code (OAC) 165:10, particularly 165:10-5 for injection and disposal wells.*
- *Typically, an AOR radius of ½-mile due to a history of induced seismicity and high injection volumes in formations like the Arbuckle Group.*
- *A variance to use a smaller AOR (e.g., ¼ mile) or a calculated ZOEI requires:*
- Robust hydrogeologic modeling demonstrating that the ZOEI is contained within a smaller area.
- Evidence that USDWs and surface waters are protected.
- Approval from OCC's Technical Services Division.
- In seismically sensitive areas (e.g., near the Oklahoma Fault Zone), the OCC may impose larger AOR radii (e.g., 1 mile) or additional monitoring requirements.

Texas Railroad Commission

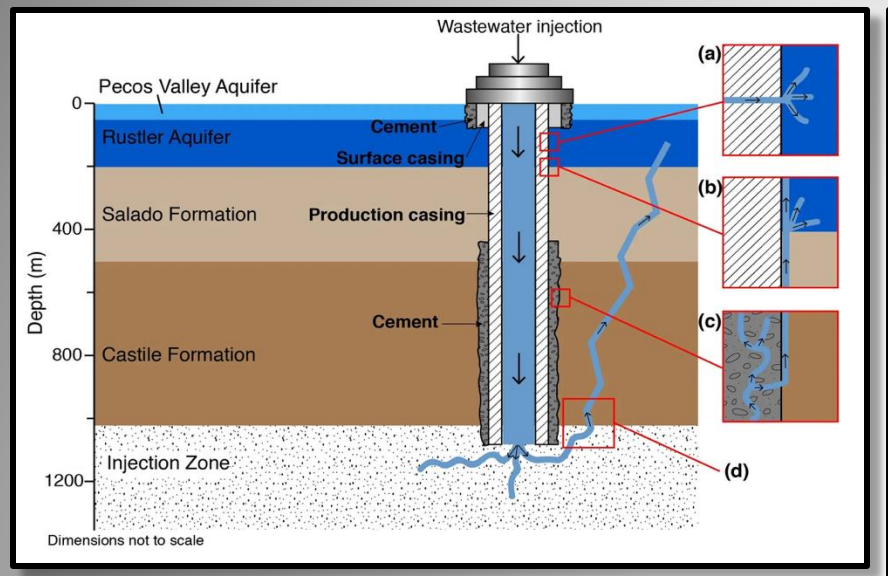
- All abandoned wells within the AOR must be plugged in a manner to prevent movement of fluids from one zone to another and protection of USDWs.
- Applicant can show by calculation that a lesser area will be affected by pressure increases to justify using a lesser area in lieu of the ¼ mile AOR.
- Calculations must be performed by and bear the seal of a professional engineer registered in the State of Texas.
- The AOR does not stop at the Texas state line. If an AOR extends into an adjoining state, UIC staff will require notification of adjoining state UIC program staff.
- ***PLEASE NOTE: As noted previously, things can change quickly, and Texas has not modified their requirements.***

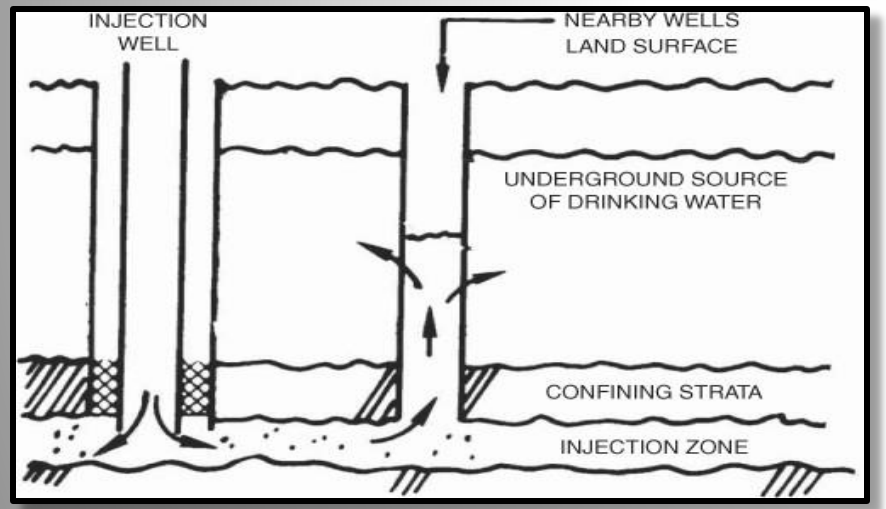
Wyoming Oil & Gas Conservation Commission

- Wyoming uses the standard ¼ mile fixed radius but emphasizes ZOEI calculations for deep disposal wells in tight formations.
- Previously, commercial Class II disposal wells in Wyoming were regulated as Class I non-hazardous and are now regulated by the Wyoming Oil and Gas Conservation Commission.



Source: ALL Consulting, 2022





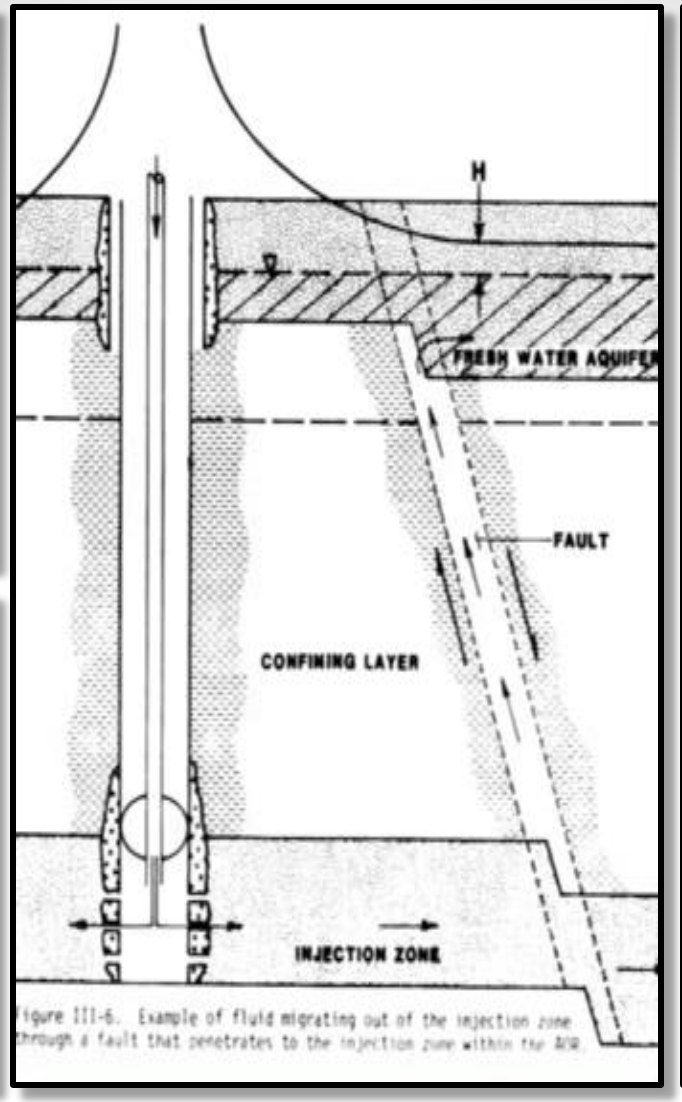


Figure III-6. Example of fluid migrating out of the injection zone through a fault that penetrates to the injection zone within the AOR

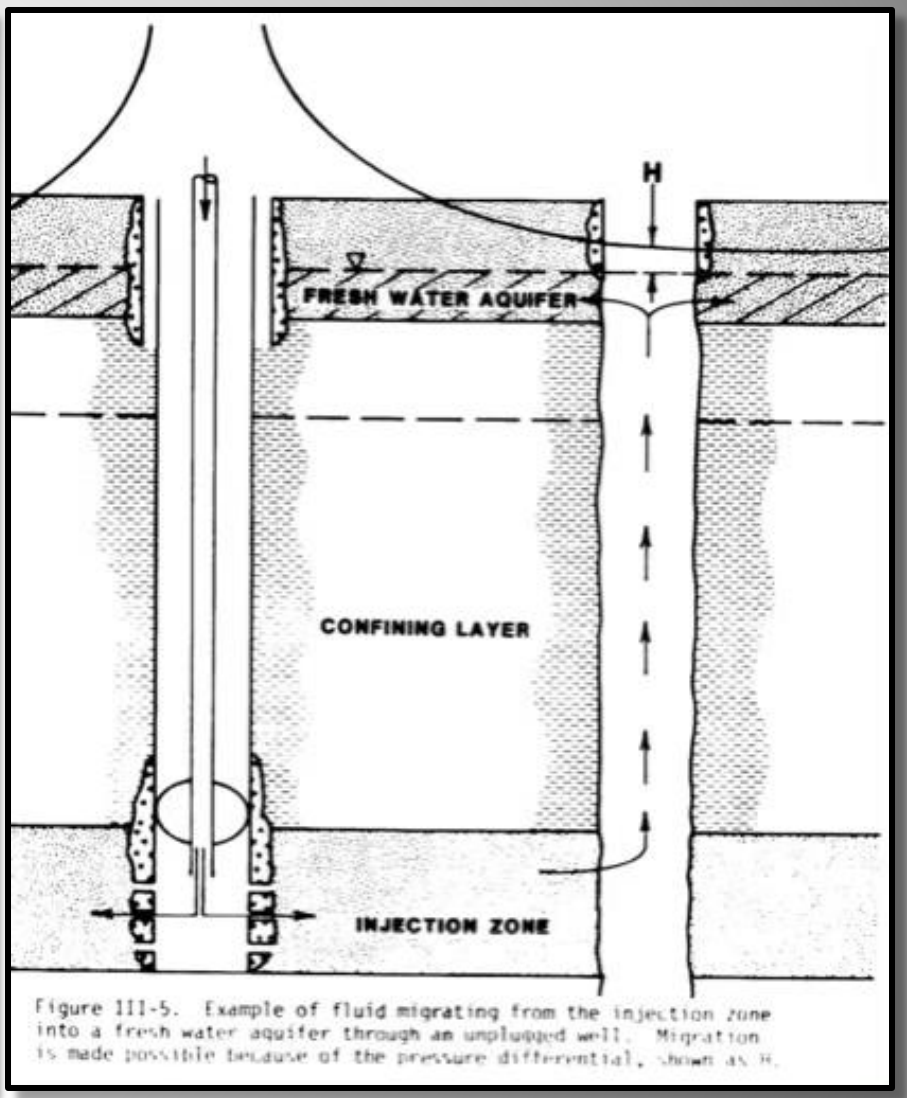


Figure III-5. Example of fluid migrating from the injection zone into a fresh water aquifer through an unplugged well. Migration is made possible because of the pressure differential, shown as H.

CORRECTIVE ACTION

Corrective Action

- Applicant must identify conduits and ensure proposed measures are adequate to protect USDWs
- May require:
  - Developing and submitting a Corrective Action (CA) Plan to monitor problem wells
  - Increase testing frequencies
  - Conduct visual observations
  - Implement remedial cementing
  - Plugging or re-opening and re-plugging of inadequately plugged wells,
  - Or moving or selection of a new well location if CA is not feasible

Source: DMRM, 2006

Identifying Wells in Need of Corrective Action

- Once well(s) are identified in need of CA, a plan is submitted to the regulatory agency for approval.
- The next step is typically a field survey in an effort to identify the well(s) in need of CA.
- If re-opening of a well is necessary, then development of a plan is undertaken.

Types of Corrective Action Planning

- CA of an existing and active well in an AOR that does not have isolation across the injection zone, may require remedial action to prevent potential migration of injected fluids into a USDW.
- CA of this type may require cement bond log of a well or remedial cementing to isolate the proposed injection zone in the SWD.
- If CA is required for an improperly plugged or an unplugged well(s) in the AOR, then a far more robust plan is developed.

Closing Thoughts

- Fully understanding AOR Analysis (including assessment of the ZOEI) is critical for the protection of USDWs.
- AOR and ZOEI can vary amongst Class II UIC Primacy States based on a variety of issues, so don't assume every state is the same!
- Locating old wells that penetrate into or through the proposed injection zone within the AOR or ZOEI can be challenging, and some states allow for variances to the AOR or ZOEI determinations.
- Corrective action can take a number of different approaches, but the development and submittal of a CA plan is the first step in addressing regulatory concerns.

Questions?

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Citation Information: J. Daniel Arthur and Tom Tomastik, ALL Consulting. "Class II Area of Review and Zone of Endangering Influence" Presented at the GWPC Class II UIC Webinar Series, July 8, 2025.