

Oklahoma Stopped Its Earthquakes by Shrinking Its Plumbing. Now It Needs the Pipes Back.

Statewide wastewater injection is down about 40% from its 2015 peak, and effectively the whole of that cut came out of the deep Arbuckle. With gas demand pulling new drilling into the Anadarko Basin, the binding limit on Oklahoma's next production cycle is not the rock. It is how many barrels of water an acre is allowed to dispose of, and who controls that permission.

The Arbuckle Ceiling: Disposal Capacity, Induced Seismicity, and the Water-Handling Constraint on Oklahoma Oil and Gas Production

40% STATEWIDE INJECTION DOWN SINCE 2015	2:1 BARRELS REINJECTED PER BARREL SOLD	2.88 Tcf MARKETED GAS IN 2025 A SIX-YEAR HIGH	6 MILES SHUT-IN RADIUS AFTER ONE M4.0 EVENT
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AUTONOMOUS MEASUREMENT FOR THE OILFIELD
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WHAT THIS PAPER FINDS

4×

THE PROGRAM WORKED, AND THAT IS THE PROBLEM

Plug-backs out of basement rock combined with volume reductions cut Oklahoma earthquake rates by roughly a factor of four. The capacity withdrawn to achieve that has not come back, and nothing in the current framework returns it.

1/2

OF THE DEEP DISPOSAL ZONE IS GONE

Injection into Ordovician-age zones — the Arbuckle among them — has fallen by about half since 2015, while shallower Pennsylvanian injection stayed roughly flat. The deep zone absorbed the entire statewide reduction.

54

WELLS PLACED UNDER ORDER BY A SINGLE EARTHQUAKE

The 2016 Cushing response shut in 7 Arbuckle disposal wells within 6 miles, cut 16 more by a quarter at 10 miles, and held 31 to their last 30-day average at 15 miles — with compliance due inside two weeks.

\$34

ADDED COST PER BARREL OF OIL WHEN THE PIPE IS LOST

At a documented Oklahoma water-to-oil ratio of 20:1, moving a barrel of water from a \$0.30 pipeline to \$2.00 trucking adds roughly \$34 to the cost of every barrel of oil produced — enough to strand a field with no change in commodity price.

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EXECUTIVE SUMMARY

Oklahoma solved an earthquake crisis by shrinking its disposal capacity. Statewide Class II injection has fallen about 40% from its 2015 peak, and the state still puts roughly twice as much fluid back into the ground as it produces for sale. The intervention worked: researchers credit the Corporation Commission's volume reductions and forced plug-backs out of basement rock, across 33 directives, with cutting earthquake rates by roughly a factor of four. The cost of that success is a permanent reduction in the cheapest disposal capacity the state has. Ordovician-age injection, which includes the Arbuckle, is down about half since 2015 while shallower Pennsylvanian injection stayed roughly flat — the deep zone absorbed effectively the entire statewide cut.¹

Demand is pulling the other way and the obvious escape valve has closed. Oklahoma marketed 2.88 trillion cubic feet of gas in 2025, the highest annual total since 2019, while roughly 18 Bcf/d of new pipeline capacity across Texas, Louisiana and Oklahoma was targeted for completion in 2026 to serve LNG and data center load. Texas, meanwhile, rewrote Permian disposal permitting effective June 1, 2025, replacing a framework largely unchanged since 1982.²

The thesis in one line: in Oklahoma, the binding question for the next decade is not how much hydrocarbon sits in the rock, but how many barrels of water a given acre is legally and physically allowed to dispose of — and who controls that permission.

1 THE TRADE OKLAHOMA MADE

1.1 How the constraint was built

Injection into the lower Arbuckle peaked in March 2015 at roughly 16 million cubic meters in a single month, after some 340 million cubic meters had gone into the Arbuckle's basement since 1995. Seismicity peaked about three months behind injection — a lag that matters enormously for regulatory design, because by the time the earthquakes arrive the pressure that caused them is already in the rock. The response escalated quickly. A March 2015 directive covered more than 300 disposal wells; by that July the Area of Interest had grown to 21 of Oklahoma's 77 counties, a further 211 wells had been brought under directive, and 124 Arbuckle wells had already plugged back out of the basement.³

¹ Oklahoma Geological Survey, *Class II Saltwater Disposal for 2011–2025 at the Monthly-, State-, and County-Scales by Geologic Zones of Completion, Oklahoma*, Open-File Report OF1-2026, by Benjamin Allen; OK Energy Today, “Study confirms Corporation Commission's earthquake program is working”, November 21, 2024.

² United States Energy Information Administration, *Oklahoma Natural Gas Marketed Production*, annual series, million cubic feet; Morningstar DBRS, *Natural Gas Demand Sparks the Largest U.S. Pipeline Build-Out Since 2008*, January 12, 2026; Railroad Commission of Texas, “Notice to Operators: New Guidelines for Permitting Saltwater Disposal Wells in the Permian Basin”, May 15, 2025; B3 Insight, “New RRC Guidelines Reshape SWD Permitting in the Permian”, May 30, 2025, by Campbell Gough.

³ OK Energy Today, Study confirms the earthquake program is working; Oklahoma Geological Survey, *Open-File Report OF1-2026*; Oklahoma Secretary of Energy and Environment, “Gov. Fallin Applauds Oklahoma Corporation Commission for Regulations Addressing Seismic Activity”, July 17, 2015.

Date	Action	Scope as stated by the issuing body
March 2015	First broad Arbuckle directive	More than 300 disposal wells across the Area of Interest
July 2015	Area of Interest expanded	211 more wells; 124 already plugged back; AOI reaches 21 of 77 counties
November 2016	Cushing plan, after an M5.0 event	7 wells shut in at 6 miles; 16 cut 25% at 10 miles; 31 capped at 15 miles
February 2017	Forward caps on new volume	Limits set to the lesser of a stated threshold or the rolling 30-day average
May 2023	Carney directive, after an M4.0 event	23 wells; shut-in inside 6 miles; those above 500 bbl/d at 6–10 miles halved

Sources: Oklahoma Secretary of Energy and Environment; Oklahoma Corporation Commission; Oklahoma Corporation Commission; Oklahoma Corporation Commission.⁴ Scope figures are as stated in each directive or advisory.

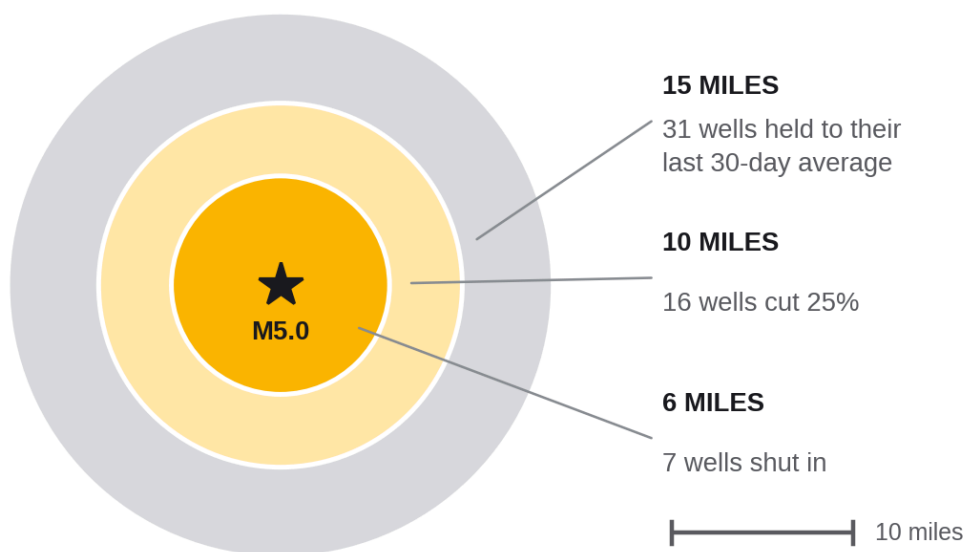


FIGURE 1 What one earthquake costs. The Corporation Commission's November 2016 Cushing plan, drawn to scale: three concentric tiers at 6, 10 and 15 miles from the epicentre, placing 54 Arbuckle disposal wells under order with compliance due within two weeks.

1.2 The ratchet nobody discusses

The February 2017 action is the most consequential and the least discussed. It did not reduce volumes then in use — the division director said it “will not reduce current volumes, but will keep future volume increases in check” — but it pegged allowable disposal to the lesser of a stated threshold or a rolling 30-day average of actual injection. The effect is structural. A disposal permit in the Area of Interest stopped being an option on future growth and became a ratchet that only tightens: a well that curtails for any reason resets its own ceiling downward. Permitted paper

⁴ Oklahoma Secretary of Energy and Environment, Gov. Fallin Applauds Oklahoma Corporation Commission; Oklahoma Corporation Commission, *Advisory 4 — Cushing*, Oil and Gas Division, November 8, 2016; Oklahoma Corporation Commission, *Review of Area of Interest (AOI) for Triggered Seismicity*, Oil and Gas Conservation Division directive, February 22, 2017; Oklahoma Corporation Commission, “Directive Reducing Disposal Volumes in Carney Area”, May 11, 2023.

capacity therefore overstates usable capacity, and any model built on permitted volumes is measuring the wrong thing.⁵

2 WHERE THE CAPACITY WENT

2.1 The volume picture

The Oklahoma Geological Survey's 2026 analysis of Class II injection across 2011–2025 gives the clearest available quantification. Statewide injection is down about 40% from the 2015 peak. Ordovician-age injection peaked in 2015 and has since fallen by roughly a factor of two, which the survey attributes to the daily monitoring regime imposed on Arbuckle wells, while Pennsylvanian-age injection has been roughly constant across 2011–2024. Together the two account for approximately 90% of injection in the state. One encouraging trend runs alongside: injection into wells whose completion zone was unknown peaked at 2.2 million barrels per month in December 2013 and had fallen to just over 0.5 million by late 2024.⁶

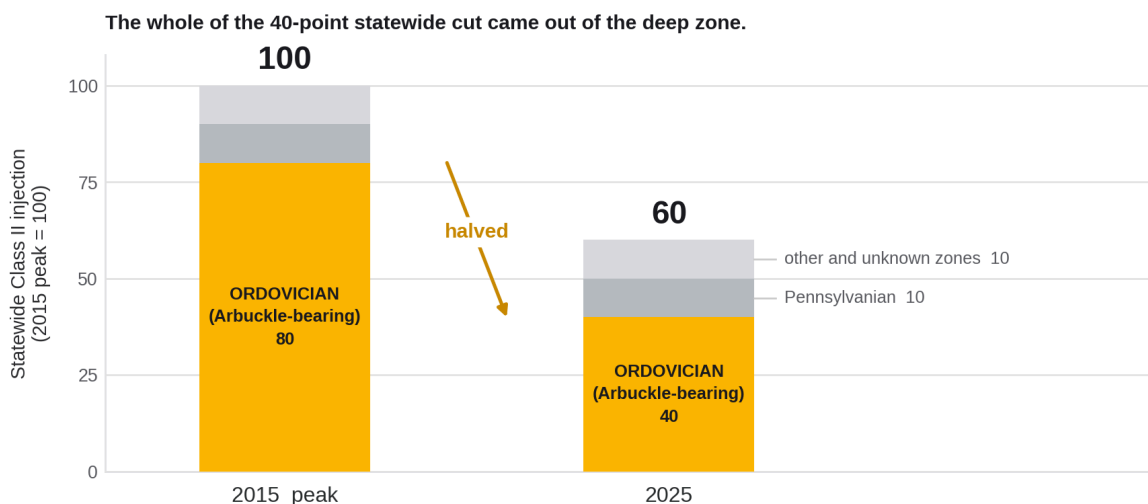


FIGURE 2 Where the 40-point cut came from. Statewide Class II injection indexed to the 2015 peak. Shares are derived from the ratios the Oklahoma Geological Survey reports — statewide down about 40%, Ordovician halved, Pennsylvanian roughly flat, the two together about 90% of statewide injection — and are shown as a scale indicator, not as a reported split.

Two readings deserve separating. The optimistic one is that Oklahoma displaced a large share of its deep Arbuckle load into shallower zones and recycling without collapsing production. The pessimistic one is that shallower zones are lower-permeability and more expensive per barrel, and that limited headroom is being reported as stability.⁷

⁵ Oklahoma Corporation Commission, *Area of Interest* review.

⁶ Oklahoma Geological Survey, *Open-File Report OF1-2026*.

⁷ Oklahoma Geological Survey, *Open-File Report OF1-2026*.

2.2 The residual seismicity that keeps taking capacity back

Activity is far below the 2015 peak but has not ended, and the residual rate is the mechanism through which capacity keeps being withdrawn. The Geological Survey recorded 270 located events in October 2025 alone; none reached magnitude 3.0 that month, but the geography is the point — Lincoln County led the state with 55 events, ahead of Grady with 40 and Canadian with 38. Oklahoma runs a stoplight procedure that curtails or shuts injection near earthquakes above roughly magnitude 2.5, and the commercial translation is blunt. Every M4.0-class event inside a producing fairway is a potential indefinite shut-in within 6 miles and a halving of volumes for the larger wells between 6 and 10 miles, as the Carney directive demonstrated across 23 Arbuckle wells in 2023. No operator can underwrite a well on disposal capacity that a future earthquake can revoke.⁸

3 WHAT THE CONSTRAINT COSTS

3.1 Disposal logistics as the swing variable

Handling route	Indicative cost per barrel of water
Pipeline to an operator's own disposal well	\$0.30
Trucking to a disposal site, Permian Basin	\$2.00
Deep Arbuckle injection, Oklahoma	\$0.20–\$2.00
Oklahoma sourcing and disposal, average	\$1.09
Treatment for oil and gas reuse	\$0.57

Sources: Texas Alliance of Energy Producers; Lexology; Oklahoma Water Resources Board.⁹ Indicative published ranges, not current contract pricing. The first two rows are Permian Basin figures published in 2019, used for the relative spread between routes rather than as Oklahoma quotes.

Run the sensitivity. Oklahoma's produced water challenge has been characterised by the state's own water agency at a water-to-oil ratio of 20:1, so every \$1.00 per barrel of water carries \$20 of cost per barrel of oil. Moving a barrel off a \$0.30 pipeline and onto \$2.00 trucking adds roughly \$34 per barrel of oil in water handling alone — enough to move a marginal field from developable to stranded with no change in commodity price or reservoir quality. That is the quantitative core of the argument: in water-heavy Oklahoma plays, disposal logistics can dominate oil price as the swing variable. Regulators do not set commodity prices, but through the stoplight system they effectively set a large component of operating cost.¹⁰

⁸ Oklahoma Geological Survey, *Oklahoma Seismicity Bulletin, October 2025*; Oklahoma Geological Survey, *Open-File Report OF1-2026*; Oklahoma Corporation Commission, Carney area directive.

⁹ Texas Alliance of Energy Producers, *Sustainable Produced Water Policy, Regulatory Framework, and Management in the Texas Oil and Natural Gas Industry: 2019 and Beyond*, with the Independent Petroleum Association of America, 2019 (industry pricing reference); Lexology, [commentary on Oklahoma disposal volumes and per-barrel injection costs], publisher's own title could not be confirmed (industry pricing reference); Oklahoma Water Resources Board, *Oklahoma Water for 2060: Produced Water Reuse and Recycling*, April 26, 2017.

¹⁰ Oklahoma Water Resources Board, *Oklahoma Water / Energy Nexus*, presentation by Owen Mills to the Oklahoma Geological Survey workshop, November 16, 2022; Texas Alliance of Energy Producers, *Sustainable Produced Water Policy* (industry pricing reference).

3.2 The liability channel

Liability has begun to settle rather than merely threaten. In November 2025 three Oklahoma producers — Spess Oil, Circle 9 Resources and Culbreath Oil & Gas — agreed to pay a combined \$555,000 to resolve claims tied to the magnitude 5.1 earthquake near Prague on February 2, 2024, covering property owners across nine counties. The absolute dollars are small; the precedent is not. For anyone buying operated saltwater infrastructure, seismicity liability is now a quantifiable diligence item rather than a theoretical tail risk.¹¹

4 DEMAND PULLS ONE WAY, REGULATION THE OTHER

4.1 The growth is real and it is gas

Oklahoma is not in decline, which is what makes the constraint live rather than academic. Marketed gas production reached 2.88 trillion cubic feet in 2025, up from 2.75 Tcf in 2024 and the highest annual total since 2019, with gross withdrawals still running ahead of the prior year into 2026. Crude is the flatter line: 147.9 million barrels in 2025 against 146.2 million in 2024. Drilling has concentrated accordingly — 44 rigs statewide at the end of March 2026, the gas-weighted Cana Woodford leading at 23.¹²

The pull is national. Morningstar DBRS counted 12 new and expanded pipeline projects across Texas, Louisiana and Oklahoma set for completion in 2026, adding roughly 18 Bcf/d — the largest build-out since 2008 — driven by LNG exporters and data centers. The collision is straightforward: incremental Anadarko gas drilling brings incremental produced water into a basin whose deep disposal capacity was deliberately cut roughly in half, and whose remaining capacity can be curtailed on two weeks' notice by an earthquake nobody can schedule.¹³

4.2 Texas closed the escape valve

Effective June 1, 2025, the Railroad Commission of Texas began evaluating new and amended Permian saltwater disposal permits under new guidelines, and the operational detail is more severe than the announcement suggests. The area of review was extended from 0.25 miles to a dual buffer at 0.5 and 2 miles across Districts 7C, 8 and 8A. Applications must demonstrate that injection will not drive formation pressures beyond the fracture gradient of the confining strata. Where cement or logging records inside the area of review are incomplete, the Commission presumes containment risk. Daily volumes are tiered by reservoir pressure, with zones at or above 0.7 psi/ft potentially limited to 10,000 barrels per day. The framework this replaced had been largely unchanged since 1982.¹⁴

¹¹ Lawyer Monthly, “\$550K Oklahoma Earthquake Settlement: File Claims Now”, November 12, 2025.

¹² United States Energy Information Administration, *Oklahoma Natural Gas Marketed Production*; Oklahoma Employment Security Commission, *Oklahoma Economic Indicators*, July 2026 edition; OK Energy Today, “Where they’re drilling in Oklahoma”, March 30, 2026.

¹³ Morningstar DBRS, *Largest U.S. Pipeline Build-Out Since 2008*; Oklahoma Geological Survey, *Open-File Report OF1-2026*; Oklahoma Corporation Commission, *Advisory 4 — Cushing*.

¹⁴ Railroad Commission of Texas, Notice to Operators, Permian saltwater disposal; B3 Insight, New RRC Guidelines Reshape SWD Permitting.

This matters twice over. It removes the option of moving water to a friendlier jurisdiction, and it signals where the model is heading: pressure-based, containment-based permitting is becoming the default, and Oklahoma's reactive stoplight regime is the older, blunter version of the same instinct.¹⁵

5 THE RELEASE VALVES, AND WHAT THEY DO NOT SOLVE

1. **Recycling and reuse, limited by geography rather than chemistry.** Oklahoma's own water agency mapped the problem a decade ago: the Mississippi Lime produces high volumes of water per well with little local reuse demand, while the STACK area around Blaine County needs water and has wells not projected to produce enough of it. Relief depends on moving water between areas — on midstream capital — not on treatment technology alone.¹⁶
2. **Mineral extraction, real but early.** The Oklahoma Brine Development Act, SB1930, passed the Senate 45-0 and cleared House Energy 11-0 in 2026, with iodine recovery the key target. Commercial momentum is genuine: Select Water Solutions and ISE Chemicals signed a definitive agreement in June 2026 under which ISE funds, builds and operates iodine facilities on produced water across Texas, New Mexico and Oklahoma while Select supplies the water and infrastructure and takes royalties — first commissioning targeted for 2027, roughly 3,000 tonnes per year by end-2030. The caveat is arithmetic: extraction changes the value of a barrel, but the barrel still needs a home.¹⁷
3. **Shallower and smarter injection, which is what already happened.** The migration from Ordovician to Pennsylvanian zones, with plug-backs above basement, is the playbook that cut earthquake rates roughly fourfold. It is not a future option; it is the thing already spent, and it consumed the shallow zones' headroom.¹⁸

One composition effect deserves naming, because it is the strongest counterargument to this paper. Oklahoma absorbed a 40% injection cut without losing production — but the Commission's own 2016 assessment observed that where the Mississippian Limestone play had produced an unprecedented amount of saltwater, “the SCOOP and STACK plays have very small amounts of produced water.” The state did not prove it can dispose of more water. It proved it could produce a drier barrel mix.¹⁹

¹⁵ B3 Insight, New RRC Guidelines Reshape SWD Permitting.

¹⁶ Oklahoma Water Resources Board, *Oklahoma Water for 2060*.

¹⁷ OK Energy Today, “Brine act gets House committee support”, April 2, 2026; Select Water Solutions, “Select Water Solutions Announces Definitive Agreement with ISE Chemicals Corporation Providing for the Development of Commercial Iodine Production Facilities Utilizing Produced Water Infrastructure Across Texas, New Mexico and Oklahoma”, press release, June 25, 2026.

¹⁸ Oklahoma Geological Survey, *Open-File Report OF1-2026*; OK Energy Today, Study confirms the earthquake program is working.

¹⁹ Oklahoma Corporation Commission, “New Year, New Plays, New Plans”, Oil and Gas Conservation Division, December 20, 2016; Oklahoma Geological Survey, *Open-File Report OF1-2026*.

6 WHAT THIS MEANS FOR OPERATORS, BUYERS AND INVESTORS

- **Underwrite water egress, not just reserves.** For any Oklahoma acquisition, ask how many barrels per day of disposal the asset can access, at what cost, under what permit, and at what distance from the nearest Area of Interest boundary and recent epicentre. Permitted capacity is a ceiling the Commission has already reset to trailing actuals once. Compliant, non-AOI, pipeline-connected capacity is correspondingly scarce and appreciating — and the same characteristics make it a litigation target.²⁰
- **Price the shut-in tail risk, and instrument the constraint rather than reacting to it.** Model a scenario in which an M4.0 event within 6 miles shuts the primary outlet while alternates are curtailed and trucking bridges the gap; the Cushing and Carney orders give the shape and the timetable. If that scenario breaks the investment, redundancy is the deal rather than an add-on. Disposal is administered against reported volumes on a rolling 30-day basis and enforced against seismic events that lag the injection causing them by about three months, so an operator tracking its own rolling averages against the ceilings those averages create is managing a known regulatory function; most of the underlying series are published. Assay the brine while you are at it — iodine and lithium content plus proximity to an aggregating network can convert a disposal liability into a royalty stream.²¹

LIMITATIONS

- The zone-by-zone split in Figure 2 is derived arithmetically from the ratios the Geological Survey reports, not from a published breakdown, and assumes injection outside the Pennsylvanian and Ordovician held roughly steady. It is a scale indicator.²²
- Per-barrel costs are published ranges rather than current Oklahoma contract pricing, and the pipeline-versus-trucking spread is drawn from 2019 Permian Basin data. Refresh both with operator quotes before using them in an investment model.²³
- The 20:1 water-to-oil ratio is presented by the Oklahoma Water Resources Board as a produced water challenge for the state, not as a formation-specific figure, so sensitivities built on it are directional. The count of 33 induced-seismicity directives is as of late 2024, and SB1930's final enacted text was not confirmed — the bill was still subject to amendment when it cleared committee.²⁴

²⁰ Oklahoma Corporation Commission, *Area of Interest review*; Lawyer Monthly, \$550K Oklahoma Earthquake Settlement.

²¹ Oklahoma Corporation Commission, *Advisory 4 — Cushing*; Oklahoma Corporation Commission, Carney area directive; Oklahoma Corporation Commission, *Area of Interest review*; Select Water Solutions, Definitive agreement with ISE Chemicals.

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²³ Texas Alliance of Energy Producers, *Sustainable Produced Water Policy* (industry pricing reference).

²⁴ Oklahoma Water Resources Board, *Oklahoma Water / Energy Nexus*; OK Energy Today, Study confirms the earthquake program is working; OK Energy Today, Brine act gets House committee support.

CONCLUSION

Oklahoma's induced-seismicity program deserves the credit it receives. It cut earthquake rates by roughly a factor of four through plug-backs and volume reductions, without shutting down the state's oil and gas industry. The cost of that success is a permanent reduction in the state's cheapest disposal capacity, administered through a reactive system that can revoke water egress on weeks of notice anywhere near the Area of Interest. With roughly two barrels of fluid reinjected for every barrel sold, and gas demand pulling new drilling into the Anadarko Basin, the binding constraint on Oklahoma's next production cycle is water logistics.²⁵

The investable conclusion follows directly. In Oklahoma the scarce asset is not acreage. It is permitted, compliant, pipeline-connected, low-seismic-risk disposal and recycling capacity, together with the brine chemistry that can turn a disposal cost into a mineral revenue line. Whoever controls water egress controls which barrels get produced.

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