

Information supporting The Wabash County Carbon Capture Sequestration Ordinance

The material compiled in this binder, contains information in various forms, from a variety of sources, that in our opinion, help to support the valid need for the Carbon Capture Sequestration Ordinance, being voted on, August 3, 2026, by the Wabash County, IN Board of Commissioners.

This Binder was created by the Wabash County Environmental Protection Alliance (WCEPA) and provided to the Wabash County Board of Commissioners. Any opinions in this binder, stated by the WCEPA, are our opinions only, and may not reflect, or align, with those of the Wabash County Board of Commissioners.

Josh Leffel

Amy Lybarger

Brent Klutz

Ryan Hauptert

RECEIVED

AUG 17 2026

Shelly Bauso
WABASH CO AUDITOR

"THE IMPORTANCE OF TRUST"

The whole reason we are here today, the reason for this ordinance, is because POET Bioprocessing has proposed CCS in Wabash county.

CCS is a big deal. It's a big project. A highly controversial project that could affect alot of people, for a very long time.

A county government, as well as the citizens they represent, would need a certain amount of trust in a company proposing a project of this magnitude.

You see, a solid, foundation of trust is needed in every relationship, be it personal or business. Without it, you have nothing on which to further build, or grow that relationship from.

In my opinion, this company cannot be trusted, and I will give you some examples.

Reading through the POET Bioprocessing vs Wabash County Commissioners lawsuit papers, filed by POET's attorneys, it states that POET held several public meetings regarding their project. That's not true.

Small, invite only meetings, are not the same as open, PUBLIC meetings.

We were told there would be no pipeline associated with this project, however, in that same lawsuit, they mention pipeline language at least twice.

They told us in March 2025, that they needed to sequester CO2 so that they could manufacture low carbon fuel.

That's not true. It's widely known that they currently manufacture ZERO CARBON fuel for NASCAR as well as on a commercial scale.

They said in interviews pertaining to that, that they used the farmers low carbon practices, as well as their own regenerative method of dealing with CO2, combined with their capturing of some of it for industrial uses, etc, to achieve ZERO CARBON.

In POET's VOL 19, ISSUE 1 edition of their publication called VITAL, I read an article called YOU CANT BEAT ZERO, which highlights their zero carbon fuel partnership with NASCAR.

However, now their method of producing the fuel has changed, again. I will read you some language from that article;

"By combining regenerative ag practices with carbon capture, utilization, and SEQUESTRATION, and advanced biotechnology, POET's bioethanol achieves zero and beyond; in fact, some bioethanol achieved a CI score as low as -14.

Did you hear that one word... SEQUESTRATION?? Guess what? It's not true! Currently POET is NOT sequestering ANY CO2, at ANY of their locations across the US. In my opinion, the American public is being lied to.

This ordinance is NEEDED to protect this county from the effects of CCS.

In this specific instance, it is also needed to protect us from this company, a company that in my opinion, has not been truthful or transparent.

In my view, they cannot be trusted to oversee this project, our safety, our health, our land, our water, or our property rights.

Please do the right thing for Wabash County residents and landowners, by passing this ordinance today. Thank you for allowing me the opportunity to address my concerns.

Yahoo Mail: Search, Organize, Conquer

*Submitted by:
Josh Leftel 8/17/2024*



Wabash County Board of Commissioners,
Cheryl Ross
Tyler Niccum
Jeff Dawes

The Wabash County Environmental Protection Alliance (WCEPA) respectfully requests to have the following statement read into the record, during the Carbon Capture Sequestration (CCS) Ordinance portion of the August 3rd 2026, Wabash County Board of Commissioners meeting.

We would like to express our full support for the CCS Ordinance that is being voted on this day, August 3rd, 2026, by the Wabash County Board of Commissioners.

It is our belief that CCS projects pose the very real risk of negatively impacting properties and or residents located throughout the initial injection storage area, as well as the CCS project Area of Review (AOR) or even beyond it.

Several landowners and or residents of Wabash County Indiana, were unknowingly placed on an Area of Review list for the CCS project currently being proposed in Wabash County Indiana.

This AOR list was created sometime around the year 2020, (we know this by back dating the property ownership records and appears to have been sent to the Environmental Protection Agency (EPA) in or around, September 2024. There are approximately 118 properties on that list.

In the Wabash County CCS ordinance, there is a recommended two-mile setback from occupied structures. This measurement is taken from the center of the Carbon Dioxide injection well, outward in each direction. We would concur that this setback distance is a good place to start, because, that's relatively the same distance from the injection well, that was used to create the area of review.

Per the EPA's own definition of an AOR for a CCS project, the initial two-mile setback set forth in the Wabash County CCS ordinance, makes perfect sense. The EPA defines the Area of Review list as the properties that are at the highest risk of receiving ground or water contamination from the CO2 plume or the pressure front associated with it. Our very own Environmental Protection Agency is clearly admitting, that properties on a CCS AOR

list, are absolutely at risk from these projects.

If companies are allowed to inject pressurized Carbon Dioxide for LONGER than 12 years due to an extension of the tax credits being used to fund these projects, then it would stand to reason, that the AOR could grow larger. If that is the case, we would also support an increase of the current two-mile setback, in order to protect those properties that would be ADDED to the Area of Review.

We feel that this ordinance is also needed to protect property values in Wabash County. As mentioned previously, several properties are now on an AOR list for a CCS project being proposed in Wabash County. That fact alone, we can only surmise, could decrease the value of those properties. Certainly, if the CO2 plume or pressure front does cause damage to any of those properties, including ground or water contamination, that could also help to further decrease the value of the affected properties.

If companies are allowed to inject this pressurized CO2, and through testing, it is determined to have migrated onto a landowners property that did not already sign a CCS lease with a CCS operator, a few things will take place. The CCS operator is currently allowed, by Indiana State law, to use eminent domain, or forced Integration, against that property's owner, to integrate the affected property into the CCS project, even if the owner of that property, is completely against the idea of participating in the project.

Owners of these affected properties would lose certain rights that typically come with property ownership, as well as having to modify the deed to their land so that it reflects the fact that it now contains pressurized CO2 and is part of a CCS project. The fact that pressurized CO2 is being stored under the affected property, we feel, could decrease the property's value, making it harder to market in the future.

Because there are real risks to the people residing in the AOR, and because the EPA also states that CCS can cause an increase in seismic activity, otherwise known as earthquakes, and due to the fact that accidents have happened regarding pressurized CO2, such as the disaster in Satartia, Mississippi, we support, and see a valid need for, an aggressive, thorough, and well thought out safety plan. This ordinance is designed to provide that safety to residents being impacted by a CCS project.

It has been proven that just the noise, lighting, and aesthetics, of a project, can all negatively impact residents living in close proximity to them, as well as their property

values. We feel that this ordinance also addresses those issues quite fairly.

There has been confusion about whether or not the Wabash County Board of Commissioners actually have the authority to say where a CCS project can be built. There is language on The Indiana Department of Natural Resources website under the section titled Local Government and CCS that contains the following language pertaining to CCS projects in Indiana:

- "Local government says WHERE it can be done, and state / federal government says how it can be done."
- IC 14-39 does NOT preempt local units of government from adopting zoning ordinances regarding the siting of CCS projects.

According to this language, it is very clear that the local government of Wabash County Indiana, does indeed have the legal power and the full authority, to decide where a CCS project can operate within their jurisdiction.

Something we would also like to bring up is how disappointed several residents and owners of land in Wabash County are, in regards to how the 2d seismic testing was carried out. Several property owners, possibly all of them, along the seismic testing route, were NEVER notified in any way shape or form, that seismic testing was going to be taking place. A few residents mentioned concerns about damage that occurred to their property, that in their opinion, was caused by this seismic testing.

This seismic testing was performed from the surface of county roads but was being used to test the land BELOW it, that is owned by people that pay taxes on that private land. In the future, notification sent to all affected landowners, before seismic testing is to take place, is the least that should be done.

Better yet, since the landowners adjacent to the county roads, pay taxes on the land under, and to the center of those roads, we feel very strongly, that permission from those landowners should be required, prior to approving ANY seismic testing from the surface of Wabash County owned roads.

Before the conclusion of our statement, we would like to highlight CCS in Illinois. Archer Daniels Midland, (ADM) a company with an exceptionally long list of safety violations, including deaths of employees, is currently capturing and injecting CO2.

There was a period though, that CO2 injection at their site was paused. The EPA, the same organization that approved their CCS project in the first place, later had to order them to stop, after it was found to be leaking CO2. Further investigation showed several more locations that were believed to be at risk from leaks.

Changes were made to the project, and a few years later, they were allowed to start injecting again. However, all of that excitement obviously caught the attention of the Governor of Illinois, as he later signed a law, BANNING CCS anywhere near the Mahomet Aquifer, the sole source of clean drinking water for over one million Illinois residents. We would be wise to pay close attention to this. His decision to take action, should speak very loudly to all of us.

Several residents of Wabash County and owners of land there have been very vocal, concerning their opposition to CCS in Wabash County. Several signed CCS Letters of Opposition can support this claim. CCS projects being proposed in Wabash County, could affect a lot of property owners who just want to be able to live their lives without the dark cloud of the effects of CCS, looming over their heads.

This ordinance does a good job of giving them that piece of mind, as well as protecting their property they have worked so hard to acquire and maintain.

We urge you to please protect the land, water, property, and safety, of the current landowners and residents of Wabash County, as well as the future generations we will never meet, by signing this CCS ordinance into law.

Respectfully,

The WCEPA

Wabash County Environmental Protection Alliance

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Good morning Wabash County Board of Commissioners,

My name is Josh Leffel. I reside at 1412 east 900 north, North Manchester IN.

I was not able to attend this morning due to having to take one of our sons to Riley Children's hospital this morning, so I wanted to take the time to write down my thoughts and send them to you.

I'm just going to start right off by stating that I firmly believe that it is your moral obligation, to protect the citizens of Wabash county to the best of your ability,

I think it is your duty as commissioners, to whole heartedly, listen to their opinions and concerns on issues that come up in Wabash County. It is your responsibility to make good decisions based off of the feedback your constituents provide you with.

Let me give you a glimpse of what life has been like for the last couple of years for our family, as we have lived with the looming threat of this CCS project, that these two greed fueled companies are proposing.

A lot of you know why I got involved in this mess. I'm sorry you have had to hear this over and over, but I want those that have not heard it, to be able to.

Imagine being blessed with the gift of a brand new home, custom built for your two sons who suffer from Duchennes Muscular Dystrophy, a disease that has them confined to wheelchairs. That gift, that blessing, means more than words can express. It's a life changing situation for our whole family!

Land at that time was hard to find, but our family owned some, north east of our local POET Biorefining facility, which was fine with us, because we had not heard anything bad about POET for the most part. So, we agreed, this would be the location for our sons' new, custom built, fully handicap accessible home.

Fast forward a couple years and that dream becomes a reality as our children got to say goodbye to their old, restrictive, non handicap accessible home, and move into their new, custom built, just for them, fully handicap accessible one.

Our boys no longer needed our help to navigate their own home. For the very first time since losing their ability to walk and being placed in wheelchairs, they were able to go wherever they wanted, in their own house, all by themselves! They are mobile, they are free, they are happy and they are safe.

They were safe for about the first four years. That's when life at our property changed, and not in a good way.

I came home from work one day and noticed flags along our road. I noticed little boxes off to the side of the road in the ditch. No big deal I thought, probably running internet or something. Then, later I heard it. Boom! Boom! Boom!

I made my way down to see an odd looking vehicle making a lot of noise, by the time I got there, they were pretty well past our property. So I made my way to a neighbors house to see what was going on, and my oh my, did I get the education of a lifetime.

I found out, that POET had hired a seismic testing crew to perform seismic testing on several county roads, including the one that I own to the center of. They performed these tests without my knowledge or my consent. I pay taxes on the land under that road, to the center of that road, and they tested it. In my opinion, I feel like they trespassed on me.

Then he told me WHY, they were doing this. They were gathering data to help them obtain a permit so that they, and their partner, VAULT 44.01, could carry out a CCS operation across the field from our home.

A quick look into CCS led me down a rabbit hole that was very scary. There were so many risks associated with this project, and our home was now right in the crosshairs! What do we do? Do we just sit here and let the neighbors try to fight it? Do we let the county deal with it and hope they can win without any outside help? Do we sell our land and run away and keep our mouths shut to the new owners, or, do we stay and earn our new home, by fighting back against this project?

Your life, when being faced with these projects almost comes to a standstill. There's so many questions you have to start asking yourself. Do I upgrade this on our home or will it be a waste of time? Do I put in a bunch of landscaping, or will it not matter? Should I plant trees, or will I even be able to watch them grow?

My wife and I had to make the decision, that if this project is allowed to proceed, we cannot in good conscience, stay here with our family, knowing the very real risks associated with this project. We certainly do not want to have to modify our deed to reflect the fact that supercritical CO2 is on our property, and we dang sure don't want to deal with having eminent domain used against our property to forcefully integrate us into a project we do not want to be a part of!

Well, I think you all know which decision we decided to make. We are not leaving...not without putting up one heck of an effort to stop this project first.

So, a phone call is made to POET. The GM and myself have a talk, which wasn't that bad, and he agreed to take my contact info and add me to a list, so that when other meetings came up regarding CCS, I could at least be a part of the process, even if I was against it.

But the invites never came. My phone calls never happened. I was not kept in the loop from POET, at all. However, I did find out later, that I was added to a list. POET did keep their word on that, as I found out that our brand new home, built just for my boys, was placed on POET's AOR list or area of review, and sent in to the EPA in 2024!

That list contains our home and 117 other properties, that by definition of AOR, stand the highest probability of being impacted the heaviest, from either the CO2 plume, or pressure front associated with it! The best part, they NEVER told us about it, and had every chance to do it, BEFORE we ever built our home!

These two companies tell us they "need" to inject CO2 into the ground for 12 years, in order to be able to produce low carbon or ZERO carbon fuel..

That is a bold faced lie, and I know it is because POET has admitted it, not only on their very own website, but in several interviews and nearly every Sunday on NASCAR. Yes, NASCAR. POET supplies all the fuel, ZERO CARBON FUEL, for the race cars on the NASCAR circuit. Not only that, but they also produce ZERO CARBON FUEL on a commercial scale as well.

You know what technique they are NOT having to use right now, to produce that CO2? Carbon Capture Sequestration! That's right!

Actually they use totally regenerative processes, including, but not limited to, the Closed Carbon Cycle the North Manchester facility uses, as well as taking credit for low carbon methods their farming customers utilize, to obtain their goals. How do I know this? Again, as previously stated, it's all readily available, all over their very own website, as well as in several interviews they have given with several news outlets.

It's probably not something I would be doing, if I were trying to push a scam like CCS onto an American public that doesn't want it.....butPOET just operates, well, differently, I guess.

I'm sure there are members of the corn growers association, or economic development leaders, or ethanol producers association, or possibly the Farm Bureau, that will come up here this morning and tell you otherwise, and if they do, they are lying to you, because they too, in my opinion, will do anything to get their hands on that 45Q!

In my opinion, they simply want to inject this CO2 into the ground for 12 years, in order to be able to get filthy rich from the 45Q tax credits that they will be paid with, that are only valid for, you guessed it, 12 years. This injected CO2 will have the opportunity to migrate wherever it wants to, throughout the AOR, essentially turning our properties into their CO2 wasteland.

We get the risks, they get the rewards! Rewards worth about \$25,250,000 extra, every year, just from 45Q alone, that does not take in account for the money they will make off the 45Z credits!

Fighting back against these projects in order to keep your land, your water, your home, your family, your neighbors and community, safe, from a project like this, takes a lot out of you. There are so many meetings to attend. You must work tirelessly in order to unite your community, there are so many phone calls and constant research being done. There are zoom calls, there's public events, the list goes on and on.

All of this takes time away from your family. Precious time that you will NEVER get back! As a father, I do this because it's the right thing to do! My kids however, start to wonder if I've picked everyone else over them. My wife, she feels the same way a lot of times. To say this has stressed our marriage would be an understatement. At times, it has ripped it apart! All of these things are happening all the time, because we are trying so hard to keep our lives safe from CCS.

These companies pursuing these projects, RELY HEAVILY on communities getting worn down from fighting. They rely on neighbors starting to hate neighbors. They get joy out of hearing people like me talk about the stress of their project, ripping relationships apart. Everytime they hear stories like these, or see it happening with their own eyes, THEY SEE DOLLAR SIGNS. It's a sick, twisted, depraved mindset to have, but divide and conquer is the technique they depend on the most.

We want to live in peace. We want to know we are safe. We want to know that our water will remain clean and drinkable. They tell us they will install an RO system to take care of the CO2 if it leaks into our water.

However, that's been determined to be a lie, because we checked. RO systems are not used to treat CO2, but what would VAULT know about that? They have never completed a CCS project much less had to deal with the ramifications of one!

We would be their guinea pigs if they proceed with this project. That's not fair to my family and it's not fair to anyone else residing in Wabash county. Obviously I could go on and on about my disdain for this project and I've left ALOT out of this.

I'm asking you as a citizen of Wabash county, as a tax payer, as a husband to a wife who has put up with so much unfair stress due to my involvement with trying to push back against this project, and a father of two disabled kids who are depending on me, to keep them and their new home safe from this greedy project, please find it in your hearts to do everything within your power to help us.

Thank you for everything you have all done for this community up to this point. I for one have been so proud to be able to tell other communities how lucky we are, to have the tremendous board of commissioners we have!

You listen to us. You honestly seem to care. Your moral compasses have not been broken by greed or bribes. Show us all one more time that all of that is still true, by standing up for us today. Vote YES on this CCS ordinance, that so many tremendous individuals have spent so much time creating.

God Bless all of you, that have been involved in this process of trying to keep our community safe from this project, and God Bless our United States of America!

Sincerely,
Josh Leffel

CCS LETTER OF OPPOSITION

Wabash County Board of Commissioners
Cheryl Ross
Jeff Dawes
Tyler Niccum
One West Hill Street, Suite 102
Wabash, IN 46992

Dear Wabash County Indiana Board of Commissioners;

As a resident of Wabash County Indiana, and or, an owner of land therein, I oppose the Carbon Capture Sequestration project that POET and VAULT 44.01 have expressed interest of constructing, in Wabash County Indiana.

First, in my opinion, I do not feel like these two companies have acted in a very open, transparent or forthcoming manner with the general public, regarding the full details of their proposed CCS project.

In my opinion, the only people who will enjoy any economic benefit from this project are the two companies who stand to profit, in one way or another, from the government funded (taxpayer), 45Q carbon credits associated with CCS.

It is my understanding that this CO2 will be injected into Wabash County land for a period of 12 years, which happens to coincide with the same timeframe that these 45Q credits are valid for. What will be done with the CO2 after the 12-year injection period?

Currently POET uses a Regenerative Process to deal with their CO2, which introduces no new CO2 into our atmosphere, the details of which can be easily obtained on their website. I have some concerns about their new process (CCS) they want to advance with, which I would like to share with you.

The first is the fact that CCS activity can cause earthquakes. A quick online search will show you that as more companies inject into the Mount Simon Sandstone formation, the more frequent those earthquakes could become.

I am concerned with the contamination of our aquifer system / drinking water. I am worried that the highly pressurized CO2 could push up saltwater brine, lead, mercury, arsenic or other heavy metals, as well as the CO2 itself, into our drinking water.

I am concerned with how this could also potentially negatively affect our subsoils, and how that might impact crop production in the future. I understand that the CO2 could mix with the saltwater brine in the Mount Simon Sandstone formation to form carbonic acid, which could possibly corrode metals, as well as eat away at the very formation they are hoping will contain it safely, forever.

Another concern I have is the risk of asphyxiation of nearby residents, should a pipe burst, as has happened in other places in the past. I am also worried that property rights could be jeopardized during this project. Finally, I am worried about how this might negatively affect home and land prices for some residents in Wabash County if this project were allowed to proceed.

I understand that at some point after the injection is finished, that ALL liability from this CCS project will be shifted off of these two companies and onto the state of Indiana, releasing them from the responsibility of any negative consequences that may show up in the future, related to the previous CCS activity.

As a commissioner, you all play a very key role in this CCS project. Therefore, I am asking you, as Wabash County Commissioners, to please make the safety of the citizens of Wabash County your top priority concerning any decisions you make regarding this proposed CCS project.

You have the power, duty, and the responsibility to not only protect the current residents of Wabash County, but also the future generations to come, that you and I will never meet. By signing this letter, I am hereby stating my opposition to the aforementioned Carbon Capture Sequestration project in Wabash County Indiana.

Thank you for your thoughtful consideration of this very important matter.

Printed name:

Signature:

Date:

Address:

TALKING POINTS

This is a complicated issue and one that elicits strong emotions. A concern shared by many is that we are allowing something to happen that may negatively affect not only us, but future generations of Wabash County residents.

- **We are being asked to socialize the risks of a business venture while the profits are privatized.** POET and VAULT 44.01 as operator(s) of this project will receive federal subsidized payments in the form of 45Q carbon credits created by the Inflation Reduction Act, in the amount of \$85 per sequestered ton of CO₂, and that money is valid for a time period of 12 years after the injection project would begin.
- **Seismic Activity** (Tremors, Earthquakes) is projected to become stronger in the future should Carbon Capture Sequestration (CCS) be allowed on a more widespread basis, which is a real possibility especially if more companies are allowed to pursue it, especially with these companies all planning to use the same geological subsurface layer. This proposed area is called the Mount Simon Sandstone Formation (MSSF). This porous formation consists of a sedimentary rock varying in depths ranging from 2500-3500 feet and is filled with a salty watery brine mixture. This briny pore space is being targeted to permanently store the CO₂.
- **Inadequate Amounts of Research and Information have not been presented to citizens of Wabash County.** How much pressurized, supercritical CO₂ can the MSSF safely hold (as it has not been scientifically determined and reported to the public by any reputable academic source) under pressure, as POET and VAULT 44.01, are not the only companies in the United States hoping to be able to inject into this same subsurface formation? In addition, when mixing this highly pressurized CO₂ with the salt water brine in the MSSF, it will form carbonic acid, which can corrode any metal it comes into contact with, as well as eat away at the very rock formation it is supposed to be captured in forever.
- **Water Contamination** of our underground aquifers from substances such as the CO₂ gas itself, as well as lead, mercury, arsenic, and other heavy metals such as manganese, cobalt and nickel that are normally locked in the subsurface rock layer, are released into the water of the aquifer. CO₂ contamination is not treatable by a Reverse Osmosis system as presented by POET and VAULT 44.01 at a previous public meeting. "RO systems cannot effectively remove CO₂ from water. CO₂ is a gaseous component that slips through the semi-permeable membrane used in RO systems. While it won't affect the taste or smell of water, it remains intact in the purified water." (Water Safety Lab)
- **Asphyxiation of local residents** should a pipe rupture as has happened in other states already. (Satartia, Mississippi, Louisiana, Georgia, Texas, Pennsylvania, New Hampshire) CO₂ is an undetectable gas which can cause severe health issues and/or death to residents if not able to be treat in a timely manner. CO₂ has the ability to leak to the surface and into a basement or crawlspace of a home or inside a livestock facility. The CO₂ renders emergency responding vehicles and responders useless and creates enormous difficulties that our community is not equipped to deal with.
- **Negatively impact on values** of my home, and/or other citizens' properties in the community, and negatively affect land values and/or productivity due to potential soil contamination, thus rendering properties extremely difficult to sell in the future.
- **Soil Contamination** can occur when CO₂ diffuses up into our soil surface in high concentrations could potentially have profound negative effects on plant growth. Elevated levels of CO₂ above ground is actually good for plants, but elevated CO₂ levels below ground interfere with the plants' ability to take up nutrients and respire, thus rendering the soil unfit to grow crops in the future.
- **Future Liability** falls on to the State of Indiana and the taxpayers at a determined timeframe after the CO₂ injection is complete. At this time, ALL liability from any future potential issues caused by this process, are shifted from the operator(s) POET and VAULT 44.01, to the State of Indiana and its taxpayers. In addition, we have NOT been told what will happen to the CO₂ that POET will continue to produce after the 45Q payments stop, which leads me to believe that this entire project is designed to simply use my tax dollars to make the operator(s) of this project a lot of money over a 12 year period of time, while at the same time, potentially putting my family, my neighbors, the community around POET, and or the entire State of Indiana as a whole, at risk of the many potential side effects that CCS can cause.

Plan revision number: 1.0

Plan revision date: 12 September 2024

Parcel ID	Owner	Address	City	Zip
85-07-18-400-011.000-001	Arnett Kerne & Rhoda	331 E 950 N	North Manchester	46962
85-07-29-100-001.000-001	Beauchamp Homestead Properties LLC	1385 E 800 N	North Manchester	46962
85-07-30-200-003.000-001	Beauchamp Homestead Properties LLC	800 N	North Manchester	46962
85-07-20-100-002.000-001	Beery Leland H & Angilee M	E 850 N	North Manchester	46962
85-07-20-100-013.000-001	Beery Leland H & Angilee M	900 N	North Manchester	46962
85-07-19-100-001.000-001	Behny Ronald Gene & Lynne Carol	N State Road 13	North Manchester	46962
85-06-24-200-004.000-012	Behny Ronald Gene Trust	8902 N State Road 13	North Manchester	46962
85-06-24-200-005.000-012	Behny Ronald Gene Trust	8700 N St Rd 13	North Manchester	46962
85-07-18-300-028.000-001	Bennett William & Beccylyn	331 E 950 N Lot 249	North Manchester	46962
85-06-25-400-009.000-010	Biehl Eldon E & Martha J L / E 1 / 2 & Biehl Larry	72 W 700 N	North Manchester	46962
85-06-25-400-006.000-010	Biehl Family Farm LLC	348 W 700n	North Manchester	46962
85-07-29-200-006.000-001	Brubaker Alan L & Monica	1863 E 800 N	North Manchester	46962
85-07-29-200-007.000-001	Brubaker Alan L & Monica	800 N	North Manchester	46962
85-07-29-200-002.000-001	Brubaker Alan L & Monica A	800 N	North Manchester	46962
85-07-29-200-009.000-001	Brubaker Boyd & Brad Brubaker T/C	800 N	North Manchester	46962
85-07-19-200-013.000-001	Creekside Farms Inc	850 N	North Manchester	46962
85-07-30-300-004.000-001	Custer Kenneth E & Barbara R Rev Liv Trust 1/2 Ea	7257 N State Road 13	North Manchester	46962
85-07-30-400-007.000-001	Custer Kenneth Eugene	7257 N State Road 13	North Manchester	46962
85-06-25-100-001.000-010	Dale Farms Inc	800 W	North Manchester	46962
85-06-24-400-017.000-012	Dale Farms Inc	376 W 800 N	North Manchester	46962
85-06-25-400-010.000-010	Dale-Niccum Land Partnership	N State Road 13	North Manchester	46962
85-07-20-200-018.000-001	Dingess Oscar D & Kathy M	1633 E 900 N	North Manchester	46962
85-07-17-400-010.000-001	Dodson Devin & Amanda	1568 E 900 N	North Manchester	46962
85-06-24-400-010.000-012	Eaknight Kevin L & Courtney L	8370 N State Road 13	North Manchester	46962
85-06-13-400-013.000-012	Egner Isaac J	22 W 900 N	North Manchester	46962
85-07-19-300-008.000-001	Flora Shane M	8479 N State Road 13	North Manchester	46962

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Parcel ID	Owner	Address	City	Zip
85-07-28-100-009.000-001	Graves Tim & Shelley	7863 N 200 E	North Manchester	46962
85-07-20-300-016.000-001	Greer William Allen & Susan B	1329 E 850 N	North Manchester	46962
85-07-20-300-007.000-001	Grossman Rex E & Sheila M	E 850 N	North Manchester	46962
85-07-20-300-008.000-001	Grossman Rex E & Sheila M	E 850 N	North Manchester	46962
85-07-20-300-017.000-001	Grossman Steven Michael & Kassi Jo	E 850 N	North Manchester	46962
85-06-24-200-018.000-012	Harp Development LLC	8652 N State Rd 13	North Manchester	46962
85-07-19-300-019.000-001	Hauptert Daniel D & Roxanne	N State Road 13	North Manchester	46962
85-07-19-300-009.000-001	Hauptert Daniel D & Roxanne	State Road 13	North Manchester	46962
85-07-20-100-012.000-001	Hauptert Farms Inc	E 850 N	North Manchester	46962
85-07-18-400-012.000-001	Hauptert Farms Inc	E 900 N	North Manchester	46962
85-07-19-200-003.000-001	Hauptert Farms Inc	900 N	North Manchester	46962
85-06-25-200-003.000-010	Hauptert Farms Inc	N State Road 13	North Manchester	46962
85-07-30-100-001.000-001	Hauptert Farms Inc.	State Road 13	North Manchester	46962
85-06-24-400-008.000-012	Hauptert Livestock Enterprises	N State Road 13	North Manchester	46962
85-07-19-300-018.000-001	Hauptert Livestock Enterprises Inc	N State Road 13	North Manchester	46962
85-06-24-200-019.000-012	Hauptert Livestock Enterprises Inc	N State Road 13	North Manchester	46962
85-07-32-100-015.000-001	Hauptert Steven E	150 E	North Manchester	46962
85-07-19-300-020.000-001	Hauptert Steven E & Kathy J	N State Road 13	North Manchester	46962
85-07-19-400-016.000-001	Heartland Rural Electric Membership Corporation	E 850 N	North Manchester	46962
85-07-30-100-008.000-001	High View Farm	800 N	North Manchester	46962
85-07-19-300-016.000-001	Indiana State Of	N State Road 13	North Manchester	46962
85-07-19-300-017.000-001	Indiana State Of	N State Road 13	North Manchester	46962
85-07-30-400-008.000-001	Indiana State Of	State Road 13	North Manchester	46962
85-06-25-400-012.000-010	Indiana State Of	N State Road 13	North Manchester	46962
85-06-25-400-011.000-010	Indiana State Of	W 700 N	North Manchester	46962
85-06-24-400-019.000-012	Indiana State Of	N State Road 13	North Manchester	46962

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85-06-24-400-020.000-012	Indiana State Of	N State Road 13	North Manchester	46962
85-06-24-400-021.000-012	Indiana State Of	N State Road 13	North Manchester	46962
85-07-20-400-010.000-001	Isbell Ronald L & Carolyn A	8158 N 180 E	North Manchester	46962
85-07-17-300-032.000-001	Leffel Joshua T & Melissa S	1412 E 900 N	North Manchester	46962
85-07-19-400-011.000-001	Lewis Seth L & Laura D	8448 N 100 E	North Manchester	46962
85-07-20-400-009.000-001	Lewis Sharon	8461 N 180 E	North Manchester	46962
85-07-17-300-009.000-001	Lyons Family LP	E 900 N	North Manchester	46962
85-07-18-400-015.000-001	Lyons Family LP	E 900 N	North Manchester	46962
85-07-17-300-022.000-001	Lyons Family LP	E 950 N	North Manchester	46962
85-07-30-200-006.000-001	Manchester Veal LLC	437 E 800 N	North Manchester	46962
85-07-30-100-002.000-001	Manchester Veal LLC	State Road 13	North Manchester	46962
85-07-19-200-007.000-001	Marshall Allen Kent & Teresa	260 E 850 N	North Manchester	46962
85-07-19-300-021.000-001	Marshall Allen Kent & Teresa	N State Road 13	North Manchester	46962
85-06-24-400-011.000-012	Mc Nall Timmy C & Loretta D	8222 N State Road 13	North Manchester	46962
85-07-18-400-013.000-001	Meeks Cody L & Rileigh	331 E 900 N	North Manchester	46962
85-06-25-200-005.000-010	Nesler Joel C & Jennifer Ann	7806 N State Road 13	North Manchester	46962
85-06-25-200-006.000-010	Niccum Ryan	N State Road 13	North Manchester	46962
85-06-25-400-013.000-010	Niccum Ryan	N State Road 13	North Manchester	46962
85-06-25-400-007.000-010	Niccum Ryan & Stephanie L	7504 N State Road 13	North Manchester	46962
85-07-30-100-005.000-001	North Central Cooperative Inc	31 E 800 N	North Manchester	46962
85-07-20-100-015.000-001	North Manchester Ethanol LLC	1118 E 850 N	North Manchester	46962
85-07-19-200-005.000-001	North Manchester Ethanol LLC	544 E 850 N	North Manchester	46962
85-07-19-200-004.000-001	North Manchester Ethanol LLC	720 E 850 N	North Manchester	46962
85-07-21-300-009.000-001	Oldfather Family Revocable Trust	E 180 N	North Manchester	46962
85-07-20-400-011.000-001	Oldfather Family Revocable Trust	E 800 N	North Manchester	46962
85-07-21-300-010.000-001	Oldfather Family Revocable Trust	E 800 N	North Manchester	46962

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Parcel ID	Owner	Address	City	Zip
85-07-20-400-017.000-001	Oldfather Family Revocable Trust	N 180 E	North Manchester	46962
85-07-20-200-005.000-001	Perry Jeffrey L & Virginia	8829 N 180 E	North Manchester	46962
85-07-32-100-001.000-001	Personett & Sons Land Co Inc	E 700 N	North Manchester	46962
85-07-31-200-003.000-001	Personett & Sons Land Co Inc	700 N	North Manchester	46962
85-07-19-400-015.000-001	Poet Biorefining-North Manchester LLC	868 E 800 N	North Manchester	46962
85-07-19-200-002.000-001	Randall David A & Sally	601 E 900 N	North Manchester	46962
85-07-20-200-006.000-001	Reahard Alice	8653 N 180 E	North Manchester	46962
85-07-21-100-002.000-001	Reahard Alice	N 180 E	North Manchester	46962
85-07-20-200-003.000-001	Reed Credit Trust 1/2 Int Anderson Shirley A Trust	E 850 N	North Manchester	46962
85-07-20-200-004.000-001	Reed Michael J & J Edward T/C 1/2 & Anderson S Tru	E 900 N	North Manchester	46962
85-07-21-100-001.000-001	Reed Michael J & J Edward T/C 1/2 & Anderson S Tru	E 900 N	North Manchester	46962
85-07-17-400-016.000-001	Runkel Billy D & Jeanne L Trustees Family Trust	E 900 N	North Manchester	46962
85-07-17-400-018.000-001	Runkel Billy D & Jeanne L Trustees Family Trust	N 180 E	North Manchester	46962
85-07-29-400-004.000-001	Runkel Farms	1586 E 700 N	North Manchester	46962
85-07-29-300-003.000-001	Runkel Farms	E 700 N	North Manchester	46962
85-07-17-300-031.000-001	Runkel Farms	1152 E 900 N	North Manchester	46962
85-07-29-400-005.000-001	Runkel Farms	700 N	North Manchester	46962
85-07-32-200-016.000-001	Runkel Farms	700 N	North Manchester	46962
85-07-20-200-020.000-001	Runkel Farms Partnership In Partnership Gary L & S	180 E	North Manchester	46962
85-07-31-200-010.000-001	Runkel Richard	700 N	North Manchester	46962
85-07-31-200-002.000-001	Runkel Richard L & Carolyn	721 E 700 N Lot 1	North Manchester	46962
85-07-32-100-009.000-001	Sartl Benjamin J & Cecilia K	1123 E 700 N	North Manchester	46962
85-06-24-400-009.000-012	Schmalzried Eugene E	200 W 800 N	North Manchester	46962
85-07-20-200-019.000-001	Shepherd Jake & Virgie M	1579 E 900 N	North Manchester	46962
85-06-13-400-023.000-012	Singleton Tyler & Shalea	9124 N State Rd 13	North Manchester	46962
85-07-29-200-008.000-001	Southline LLC	7496 N 200 E	North Manchester	46962

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Parcel ID	Owner	Address	City	Zip
85-06-24-200-006.000-012	Speicher Bobbi & Melanie Macgregor T/C	State Road 13	North Manchester	46962
85-07-17-400-017.000-001	Stephan Wayne A & Diana	1852 E 900 N	North Manchester	46962
85-07-28-300-003.000-001	Vawter Ruth E L / Est Then: Angia & Jamie Vawter 1	200 E	North Manchester	46962
85-07-29-300-004.000-001	Vawter Zachary R	1128 E 700 N	North Manchester	46962
85-07-19-300-014.000-001	Vetor Larry & Marilyn	8181 N State Road 13	North Manchester	46962
85-07-30-100-009.000-001	Wabash County Commissioners	800 N	North Manchester	46962
85-07-19-300-015.000-001	Wabash County Commissioners	N State Road 13	North Manchester	46962
85-06-25-200-004.000-010	Wabash County Commissioners	800 N	North Manchester	46962
85-06-24-400-018.000-012	Wabash County Commissioners	W 800 N	North Manchester	46962
85-07-19-200-012.000-001	Warren Susan D	695 E 900 N	North Manchester	46962
85-07-28-100-001.000-001	Whitacre Family Farm LLC	200 E	North Manchester	46962
85-06-13-400-012.000-012	Winger Billy J	900 N	North Manchester	46962
85-07-18-300-010.000-001	Winger Billy Joe	N State Road 13	North Manchester	46962
85-07-31-100-001.000-001	Wolf Kelly L & Kaye Ellen Lauer Wolf	N State Road 13	North Manchester	46962

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UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF INDIANA
SOUTH BEND DIVISION

POET BIOREFINING – NORTH
MANCHESTER, LLC d/b/a POET
BIOPROCESSING – NORTH
MANCHESTER,

Plaintiff,

VS.

BOARD OF COMMISSIONERS
OF WABASH COUNTY, INDIANA,

Defendant.

CAUSE NO. _____

JURY TRIAL DEMANDED

COMPLAINT

Plaintiff POET Biorefining – North Manchester, LLC d/b/a POET Bioprocessing – North Manchester (“POET”), by and through counsel, brings this Complaint to enjoin and declare unenforceable a Wabash County ordinance that imposes an indefinite ban on issuing any local improvement location permits (“ILPs”) for “any structure related to any carbon sequestration project,” as the ordinance effects an unconstitutional taking, violates the Indiana Home Rule Act, and is preempted by Indiana’s carbon capture and sequestration statute. Recognizing the tremendous benefits carbon capture and sequestration provides to American farmers and industry, the federal and Indiana legislatures have enacted statutes specifically promoting, authorizing, and regulating carbon capture and sequestration projects. In 2019, Indiana’s legislature passed a law authorizing and supporting the development of carbon capture and sequestration projects across the state, the purpose of which was to help Indiana farmers gain access to premium markets for their corn, and to increase farm revenues and land values. Wabash County, however, has now passed a moratorium on carbon capture and sequestration

projects in Wabash County. The enacted moratorium serves only to hurt Indiana farmers, who are already suffering from oversupply and historically low prices. The central question in this case is whether Wabash County can frustrate those federal and state policies—and eviscerate the value of POET's property and interests in property, including but not limited to its property interests in pore space—by categorically prohibiting all carbon capture and sequestration projects in the county. Federal and state law provide a clear answer: The County cannot do so. Accordingly, this illegal moratorium must be struck down.

INTRODUCTION

1. Carbon capture and sequestration (“CCS”) is a technological process by which carbon dioxide emissions from power plants and other industrial sources are captured and injected thousands of feet below the earth's surface into subsurface geologic formations for permanent storage. This process enables industrial sources to continue to operate while emitting fewer greenhouse gases into the atmosphere.

2. At an ethanol facility such as POET's North Manchester plant in Wabash County, CCS typically entails three steps: CO₂ capture, transportation, and storage. Biogenic CO₂ is first captured during the fermentation process that transforms corn into alcohol. Once that CO₂ is captured, the second step compresses and deeply chills that CO₂ into a fluid and transports it to an appropriate storage site, usually by pipeline. In the third step, the CO₂ is injected into deep, underground geological formations, where it is stored long term, rather than being released into the atmosphere.

3. Federal law has long encouraged the development and deployment of CCS technology. In 2008, Congress created the 45Q tax credit program with bipartisan support,

which incentivizes investment in CCS by providing significant federal tax credits for each metric ton of CO₂ captured and sequestered.

4. In 2011, the Indiana General Assembly enacted Senate Bill 251, which created the Comprehensive Hoosier Option to Incentivize Cleaner Energy (“CHOICE”) program, setting a goal of 10 percent clean energy by the end of 2025. Senate Bill 251 also stated that it was in the public interest for the state to encourage the study, analysis, and development of CCS projects. Then, in 2019, Indiana adopted Senate Bill 442, codified at Ind. Code § 14-39-1-3, which expressly endorses and supports CCS as “a public use and service, in the public interest, and a benefit to the welfare and people of Indiana.”

5. In 2022, the Indiana Legislature enacted House Enrolled Act 1209, codified at Indiana Code Chapter 14-39-2, which creates a clear statewide regulatory framework for CCS, affirms that Indiana is open to CCS projects, and authorizes the Indiana Department of Natural Resources (“IDNR”) to regulate CCS projects. In accordance with this statute’s instruction to IDNR to create a permitting process for CCS projects, *see* Ind. Code § 14-39-2-5(d), IDNR has promulgated regulations setting out the process for obtaining a permit to undertake a CCS project, *see* 312 IAC 30-6-1.

6. In the third, “storage” step of the CCS process, the CO₂ is injected into a surface wellhead connected to an underground injection control (“UIC”) well leading to the subsurface geologic formations. These types of UIC wells are known as Class VI wells. Class VI wells are currently regulated in Indiana by the United States Environmental Protection Agency (“EPA”). EPA has a rigorous process for issuing permits for Class VI wells for CCS projects, which provides stringent safeguards to protect groundwater and local communities.

7. Indiana's CCS legislation reflects the State's recognition of the role that CCS projects play in Indiana's efforts to encourage economic growth while also reducing carbon emissions.

8. POET, a biofuel and bioprocessing company, plays a vital role in Indiana's farm economy. To produce its biofuel, POET purchases corn from local farmers. Across five bioprocessing facilities (including one in Wabash County), the company employs over 230 team members and produces 340 million gallons of bioethanol annually. POET purchases almost 120 million bushels of corn from over 3,400 Indiana farmers, representing a \$552 million corn-grind value and generating \$890 million in direct expenses that circulate through rural communities. POET's integration into these local communities has created jobs, strengthened local tax bases, and provided a dependable market for farmers in a time when stability is desperately needed.

9. In addition to purchasing hundreds of millions of dollars of corn-based feedstock from farmers annually to produce biofuel, for the last several years POET has been working on a CCS project in Wabash County that will provide further benefits to Hoosier farmers (the "CCS Project"). The CCS Project will involve the capture of CO₂ produced at POET's North Manchester facility in Wabash County and the storage of that CO₂ in pore space (*i.e.*, small cavities in soil, sediment, and rock) located thousands of feet below the surface, consistent with the three steps of CCS projects discussed above. Federal tax credits are available to POET for every metric ton of CO₂ captured and sequestered by the CCS Project. By storing CO₂ deep underground rather than emitting it into the atmosphere, the CCS Project will greatly reduce the carbon impact of POET's bioprocessing operations.

10. By providing a way to produce biofuels in a low-carbon manner, CCS provides POET and farmers access to low-carbon fuel markets, which represent the primary source of

growth for biofuels and, by extension, corn demand. Due to the increasing demand for low-carbon fuel across the world, a bioprocessing facility (such as POET's North Manchester facility) that can use CCS to produce low-carbon biofuel can obtain higher prices from customers (and, consequently, can pay farmers higher prices for feedstock).

11. While Congress and the Indiana General Assembly have sought to encourage CCS projects over the last two decades, other forces have imposed increasing pressures on Indiana's farmers. These forces include elevated input costs, decreasing prices (particularly for corn), and corn supply that continually outpaces demand. These conditions mean that access to new markets is not merely a long-term goal; it is an immediate necessity for Hoosier farmers. As the federal and Indiana governments have recognized, CCS projects are an important way farmers can access new markets.

12. For the CCS Project here, POET will both use its own pore space under its Wabash County facility and will pay surrounding landowners (many of whom are farmers) for the privilege of using their pore space for the CCS project. The CCS Project will therefore provide direct pecuniary benefits to POET and other landowners in Wabash County.

13. Notwithstanding these benefits, and contrary to the express findings and comprehensive regulatory framework enacted by the Indiana General Assembly, on June 2, 2025, the Board of Commissioners of Wabash County, Indiana (the "County") enacted an ordinance that bans the issuance of ILPs for "any structure related to any carbon sequestration project" (the "Moratorium Ordinance"). By its terms, this complete ban will exist for an indefinite time period, and it has already operated to thwart legal and authorized CCS development activities for a period of eight months.

14. Importantly, the Moratorium Ordinance was not passed until approximately *six years* after Indiana, via Senate Bill 442, expressly authorized CCS projects and found that such projects serve the public interest and the public welfare of Hoosiers.

15. The Moratorium Ordinance unlawfully prohibits the very CCS projects the State of Indiana has expressly authorized and deemed to be in the public interest. The Moratorium Ordinance also unlawfully usurps the power of IDNR, which is vested with regulatory authority to oversee CCS projects in the State of Indiana.

16. The Moratorium Ordinance provides no time limitation on the duration of the moratorium or any deadline by which the County is to enact a zoning ordinance regulating CCS projects. This makes the Moratorium Ordinance invalid and unlawful on its face under Indiana law.

17. In addition, the Moratorium Ordinance effects an uncompensated taking under the Fifth and Fourteenth Amendments of the U.S. Constitution because it destroys the value of the CCS project that POET has spent years developing. Prior to the Moratorium Ordinance being passed, POET took extensive action and invested significant funds and resources for its CCS Project in Wabash County. The Moratorium Ordinance operates to deprive POET of millions of dollars invested in POET's CCS Project. The Moratorium Ordinance also completely destroys all economically viable use of POET's pore space that would have been used for the CCS Project.

18. POET brings this action to challenge the Moratorium Ordinance as unconstitutional, as a violation of Indiana's Home Rule Act, and as preempted by Indiana's CCS statute. POET seeks damages, injunctive, declaratory and other relief.

PARTIES

19. POET is a biofuel and bioprocessing company with a facility located in North Manchester, Indiana, which is located in Wabash County. POET owns a large portion of the pore space beneath its facility's property, has tangible interests in the neighboring pore space, and is developing the CCS Project to capture and sequester biogenic CO₂ emitted from its North Manchester facility.

20. Wabash County, Indiana is a municipal corporation and a political subdivision under Indiana law.

21. The County's Board of Commissioners is the County's executive body.

JURISDICTION AND VENUE

22. POET brings this action based on a violation of the Takings Clause of the Fifth Amendment of the U.S. Constitution. The Defendant's violation of the Fifth Amendment is actionable under 42 U.S.C. § 1983. POET seeks recovery of damages and an award of attorneys' fees and costs under 42 U.S.C. § 1988.

23. POET also seeks a declaration under the Federal Declaratory Judgment Act, 28 U.S.C. § 2201, that the Moratorium Ordinance violates the U.S. Constitution and violates the Indiana Home Rule Act, Ind. Code § 36-1-3-1 *et seq.*, and that it is preempted by Indiana law. Additionally, POET seeks injunctive relief to support and effectuate that declaration.

24. The Court has original jurisdiction over this action under 28 U.S.C. §§ 1331 and 1343(3).

25. Additionally, the Court has supplemental jurisdiction over POET's state law claims under 28 U.S.C. § 1367(a).

26. Venue in this Court is proper under 28 U.S.C. §§ 1391(b)(1) and (2).

FACTS

27. Senate Bill 442, enacted in 2019, “declare[s] as a matter of legislative determination” that “the use of carbon dioxide transmission pipelines, including their routing, construction, maintenance, and operation, and the underground storage of carbon dioxide are . . . a public use and service, in the public interest, and a benefit to the welfare and people of Indiana.” Ind. Code § 14-39-1-3.

28. To that end, Indiana law “authorize[s]” “[c]arbon sequestration projects . . . in Indiana for the purposes of: (1) injecting carbon dioxide into the pore space of an underground storage facility through at least one (1) carbon dioxide injection well pursuant to a UIC Class VI permit; and (2) employing the underground storage of carbon dioxide.” Ind. Code § 14-39-2-5.¹

29. Indiana law designates IDNR as the state agency that regulates CCS projects. *See, e.g.*, Ind. Code § 14-39-2-5(d) (“A storage operator may not operate a carbon sequestration project in Indiana without: (1) a UIC Class VI permit; and (2) a valid permit issued by the department.”); Ind. Code § 14-39-2-6 (providing the procedures under which “[t]he department shall review an application submitted under section 5(d) of this chapter”).

30. Indiana law designates the Natural Resources Commission (“NRC”) as the state entity that exercises the authority to adopt rules that IDNR has the authority to adopt under Ind. Code § 4-22-2. Under Ind. Code § 14-10-2-4(c), whenever IDNR or its director has the authority to adopt rules under Ind. Code § 4-22-2, the NRC is required to exercise that authority in coordination with IDNR. The NRC has authority under Ind. Code § 14-10-2-6 to issue notices of violation for those that violate a law administered by IDNR.

¹ Indiana’s statutes regarding carbon sequestration were recently amended effective July 1, 2025. *See* 2025 Ind. Legis. Serv. P.L. 213-2025 (H.E.A. 1001).

31. The NRC has promulgated rules to permit and regulate CCS projects in Indiana. *See, e.g.*, 312 IAC 30-3 (providing for pore space agreements with pore space owners within a proposed storage facility); 312 IAC 30-5 (providing requirement to obtain a pipeline certificate of authority); 312 IAC 30-6 (providing framework to apply for and operate under a Carbon Sequestration Project Permit); 312 IAC 30-7 (providing ongoing responsibilities for storage operators).

32. In sum, Indiana's CCS statutes and IDNR regulations have established a comprehensive regulatory framework for permitting and regulating CCS projects in Indiana. *See* Ind. Code art. 14-39 (Title 14, Natural and Cultural Resources, Article 39, Carbon Dioxide); 312 IAC 30 *et seq.*

33. In reliance upon the Indiana law expressly authorizing, endorsing, and promoting CCS projects, POET has been developing the CCS Project in Wabash County for years prior to the adoption of the Moratorium Ordinance.

34. In particular, POET has contracted with Vault GSL CCS Holdings, LP ("Vault") in connection with the CCS Project.

35. Vault is a CCS project development company.

36. POET and Vault are working together to develop the CCS Project.

37. In October 2023, POET and Vault entered into an agreement (the "CCS Agreement"), which provides for POET and Vault to work together and which sets out responsibilities and obligations with respect to the CCS Project.

38. For example, among other things, POET is responsible for conducting preparation works, design, engineering, development, permitting, funding, constructing, maintaining

ownership, completing, commissioning, testing, placing into service, and operating certain POET-owned facilities to capture, compress, and process CO₂ for delivery to Vault.

39. Vault's obligations under the Agreement include, but are not limited to, the obligation to perform preparatory work, construct and develop facilities, obtain approvals, and secure rights to property and property rights to pore space and interests relating to pore space (such as options for pore space) for the sequestration facility.

40. The right to pore space and other real property interests and rights obtained by Vault may be unilaterally assigned to POET, and POET is expressly identified in Vault's agreements with the owners of pore space as a third-party beneficiary of those agreements.

41. As expressly authorized by Indiana law, CCS projects make use of pore space deep below the surface to store carbon. Ind. Code § 14-39-2-5. Not all properties have pore space, and not all subsurface cavities are suitable for use as pore space to store carbon as part of a CCS project.

42. Locating potentially suitable pore space, confirming the ability to use the pore space for CCS projects, and then acquiring the pore space all involve extensive efforts and activities—and require significant monetary investments.

43. When POET's and Vault's work on the CCS Project began, POET already owned and controlled a substantial volume of pore space. Since then, POET and Vault have acquired pore space from surrounding landowners, and they have now secured over 70% of the pore space needed for the CCS Project.

44. These actions have been taken with the reasonable expectation that such investments and property interests acquired and developed could be used for CCS projects, as expressly approved, endorsed, and supported by the State of Indiana. Ind. Code § 14-39-2-5.

45. Indiana law provides that IDNR may issue an order requiring owners of pore space to integrate their interests and develop the pore space as a proposed storage facility for CO₂ to serve the public interest, prevent waste, and facilitate the efficient and effective use of natural resources if, among other requirements, the storage facility operator has obtained consent of the owners of at least 70% of the surface area above the proposed storage facility. Ind. Code § 14-39-2-4.

46. POET has had many discussions about the CCS Project with County officials, including members of the Board of Commissioners.

47. Beginning in late 2023, and continuing through the end of 2025, multiple informational public meetings were held in Wabash County for POET and Vault to provide information and details about the CCS Project, answer questions, and gather input from the public. These meetings were open to anyone interested in learning about CCS and anyone who might want to ask questions about the CCS Project. Members of the public who attended the meetings included farmers, business owners, area residents, landowners, and interest groups. These meetings were in addition to the many meetings held during the same time among POET, Vault, and Wabash County representatives to resolve open issues about the CCS Project and the county's efforts to prevent it.

48. As provided for in the CCS Agreement, Vault has applied to the EPA for the Class VI UIC program permit necessary to support the CCS Project. Vault's application to EPA was first submitted on July 30, 2024, and deemed complete by EPA on October 30, 2024. The application and notice of completeness predate the passage of the Moratorium Ordinance.

49. The location of the wellhead for the Class VI injection well will be on POET's property in Wabash County. The CO₂ will be captured and compressed on POET's property and

transported on POET's property to this wellhead. There will be no pipeline that leaves the boundaries of POET's facility for this CCS project.

50. POET and Vault are also in the process of preparing the materials to support an application for state approval for the CCS Project by IDNR in accordance with state law.

51. On June 2, 2025 – approximately six years after Indiana enacted SB442 which expressly authorized, endorsed, and promoted CCS projects, and which expressly found such projects to be in the public interest and a benefit for the public in Indiana – the County enacted the Moratorium Ordinance (Ordinance No. 2025-85-07).

52. A true and accurate copy of the Moratorium Ordinance is attached hereto as **Exhibit 1**.

53. The Moratorium Ordinance is titled, "An Ordinance Imposing a Temporary Moratorium on the Issuance of Improvement Location Permits for Carbon Sequestration Projects." Ex. 1 at 1.

54. The ordinance imposes a "moratorium on the issuance of an improvement location permit for any structure related to any carbon sequestration project . . . pending adoption of an ordinance amending the Wabash County Zoning Ordinance to provide regulations related to carbon sequestration projects within Wabash County." Because the ordinance does not have an expiration date nor set any timeline for the amendment of the County's Zoning Ordinance, it is effectively indefinite.

55. No provision of the Moratorium Ordinance prevents the County from enforcing the moratorium indefinitely.

56. Under Indiana law, indefinite moratoriums, such as the one created by the Moratorium Ordinance, are unlawful and invalid.

57. The Moratorium Ordinance directly, completely, and indefinitely prevents POET's development of the CCS Project. The Moratorium Ordinance is a wholesale ban on all CCS activity, and it indefinitely precludes POET and its contract partner Vault from obtaining any ILPs needed to build any of the structures to support the CCS Project or take any significant, material action to implement or further the CCS Project. And the Moratorium Ordinance does so even where those structures satisfy all of the County's other land-use requirements.

58. The Moratorium Ordinance has caused POET to experience delays and also has forced POET to undertake unnecessary actions and efforts with respect to the CCS Project, including actions and efforts that POET would not have had to experience or undertake in the absence of the Moratorium Ordinance. This includes, but is not limited to, delayed testing that is needed with respect to the federal and state permitting processes for the CCS Project.

59. Vault has previously received IDNR permission to use an abandoned oil well to test the geology on property offsite. Vault also received IDNR permission to plug the well once testing was completed. The Moratorium Ordinance directly prohibits both activities, further delaying the CCS Project and prohibiting an activity that IDNR has granted express permission to perform.

60. Pore space suitable for carbon storage and interests in the rights to use pore space owned by others are significant, valuable, and compensable interests in property.

61. Pore space that can be used for a CCS project is an interest in property subject to a taking under the Fifth and Fourteenth Amendments to the U.S. Constitution, and any taking of pore space requires payment of just compensation. *See, e.g., Northwestern Landowners Assoc. v. North Dakota*, 25 N.W.3d 220 (N.D. 2025).

62. The ban on the issuance of ILPs for CCS projects imposed by the Moratorium Ordinance effectuates a total ban on CCS projects and prevents CCS projects from being developed indefinitely. This action by Wabash County destroys all or almost all of the value of the pore space and interests in pore space owned and acquired for the CCS Project and causes such pore space to have little or no value.

63. As a result, the County has effectuated a taking of the pore space and the interests in pore space owned and acquired for the CCS Project without just compensation in violation of the Takings Clause of the U.S. Constitution. The County has not provided compensation to POET or any other party for this taking.

64. Because the pore space to be utilized for the CCS Project has no economic use other than storing carbon as part of the CCS Project, the Moratorium Ordinance renders the pore space economically worthless despite Indiana's statutes which expressly authorize pore space to be used for CCS projects. As a result, the Moratorium Ordinance effectuates a complete taking of the CCS Project's pore space, without providing just compensation for that taking, as required by the Takings Clause.

65. Furthermore, the Moratorium Ordinance has interfered with POET's overall progress for the CCS Project and has impacted other reasonable and substantial investment-backed expectations relating to the CCS Project beyond the pore space, including the inability to have local permit applications processed, indeterminate delays in the ability to obtain other needed permits and perform work to develop the CCS Project, and by imposing increased uncertainty and additional unforeseen risks on the CCS Project.

66. The Plan Director of the Wabash County Plan Commission (“Plan Director”) has twice refused to process applications for special exceptions and ILPs for the CCS Project, relying on the ban imposed by Moratorium Ordinance.

67. In particular, POET submitted two special exception applications on November 19, 2025, and submitted two ILP applications on November 21, 2025 (collectively, the “Permit Applications”), for the CCS Project. These applications related to the proposed construction of gravel pads, fencing, and weather enclosures to support a Geological/Structure Test well on POET’s property at its North Manchester, Indiana bioprocessing facility.

68. In a letter dated December 18, 2025, the Plan Director for the Wabash County Plan Commission stated that the County would not process the Permit Applications because the Moratorium Ordinance prohibits issuance of ILPs for CCS projects within the County.

69. The Permit Applications were revised based on certain purported application deficiencies identified in the Plan Director’s December 18, 2025 letter and were resubmitted to the Plan Director within the thirty (30) day cure and resubmittal period provided to applicants under Ind. Code § 36-7-4-1109.4 on January 16, 2026.

70. In a letter dated February 5, 2026, the Plan Director again refused to process the Permit Applications. This refusal was silent as to the requested additional information provided on the Permit Applications but again expressly relied on the Moratorium Ordinance. The Plan Director stated: “The Applications will be processed after the expiration of the moratorium, subject to any regulations related to carbon sequestration projects adopted by Wabash County.” But there is, in fact, no expiration date in the Moratorium Ordinance. It is therefore clear that the County will simply not process the ILP applications related to CCS projects no matter their

contents. It has twice expressly confirmed that the Moratorium Ordinance bars any consideration or granting of any ILP applications for CCS projects while it is in effect.

71. The Moratorium Ordinance imposes a complete standstill of all work on the CCS Project and constitutes a complete taking of POET's ownership of the pore space and other property interests, as well as its other investments in the CCS Project.

72. Until the Moratorium Ordinance is invalidated, POET will continue to suffer ongoing harm to its property, property interests, investments, and the CCS Project in general.

COUNT I – UNCONSTITUTIONAL TAKING CLAIM

73. POET restates and incorporates by reference each of the foregoing paragraphs as if fully set forth herein.

74. Acting under the color of state law, the County passed the Moratorium Ordinance which has the effect of a complete and indefinite ban on the CCS Project and has been used to justify the County denying and refusing to process any applications for ILPs that are required for POET to move forward with the CCS Project.

75. As a result of the Moratorium Ordinance, POET is unable to proceed with the CCS Project in Wabash County.

76. The Moratorium Ordinance imposes an extreme, adverse economic impact on POET.

77. Pore space that can be used for a CCS project is an interest in property subject to a taking under the Fifth and Fourteenth Amendments to the U.S. Constitution, and any taking of pore space requires payment of just compensation.

78. The Moratorium Ordinance interferes with POET's reasonable and substantial investment-backed expectations with respect to the CCS Project, including but not limited to the

pore space it already owned and the interests in pore space it has since acquired for the CCS Project.

79. POET has no other economically viable use of the pore space. Therefore, the Moratorium Ordinance renders the pore space to be worthless, nullifying the significant investment made in acquiring and developing the pore space as well as the other significant financial investments in the CCS Project.

80. The Moratorium Ordinance has effectuated a taking of property, including but not limited to the pore space, the interests in pore space, and POET's investments in the CCS Project.

81. The County has failed to provide just compensation to POET for its taking.

82. The County has violated the Fifth Amendment and Fourteenth Amendment of the U.S. Constitution.

83. POET is entitled to just compensation for the unconstitutional taking of its property by the County.

84. POET brings this claim for the County's unlawful taking in violation of the U.S. Constitution pursuant to 42 U.S.C. § 1983, as specifically authorized by the United States Supreme Court in *Knick v. Township of Scott*, 588 U.S. 180 (2019).

85. The County has deprived POET of rights, privileges, and/or immunities secured by the U.S. Constitution. POET is therefore entitled to (1) just compensation from the County for an unconstitutional taking of its property and (2) equitable relief, including but not limited to an injunction of the Moratorium Ordinance. Additionally, POET is entitled to recover its attorneys' fees and costs pursuant to 42 U.S.C. § 1988.

COUNT II – VIOLATION OF INDIANA HOME RULE ACT

86. POET restates and incorporates by reference each of the foregoing paragraphs as if fully set forth herein

87. Indiana law specifically withholds from local “unit[s],” including the County, “[t]he power to regulate conduct that is regulated by a state agency, except as expressly granted by statute.” Ind. Code § 36-1-3-8(a)(7).

88. In addition, under Ind. Code § 36-1-3-5(a), the County may not exercise power that is “expressly granted to another entity.”

89. By statute, Indiana has “authorized” “[c]arbon sequestration projects . . . in Indiana for the purposes of: (1) injecting carbon dioxide into the pore space of an underground storage facility through at least one (1) carbon dioxide injection well pursuant to a UIC Class VI permit; and (2) employing the underground storage of carbon dioxide.” Ind. Code § 14-39-2-5.

90. Also, by statute, Indiana has designated IDNR as the entity to regulate CCS projects in the State. *See* Ind. Code § 14-39-1-1, § 14-39-2-1 *et seq.*

91. By rule, Indiana, through the NRC, has promulgated a framework to permit, construct, and operate CCS projects. *See* 312 IAC 30 *et seq.*

92. Indiana has not expressly granted local units like the County authority to regulate CCS projects in the State.

93. Through the Moratorium Ordinance, the County is prohibiting for an indefinite duration all CCS projects, which the State of Indiana expressly allows, and which are required to be regulated by IDNR, a state agency. The Moratorium Ordinance also imposes unreasonable burdens by preventing the progression of CCS projects, which is inconsistent with Indiana law and is upending reasonable investment-backed expectations.

94. The Moratorium Ordinance thus violates the Home Rule Act.

95. POET is entitled to (1) a declaration that the Moratorium Ordinance violates Indiana law and is void and without effect, and (2) an order enjoining enforcement of the Moratorium Ordinance.

96. POET respectfully requests that the Court conduct a speedy hearing of this claim and request for a declaratory judgment, as provided under Federal Rule of Civil Procedure 57.

COUNT III – STATE LAW PREEMPTION

97. POET restates and incorporates by reference each of the foregoing paragraphs as if fully set forth herein.

98. The Moratorium Ordinance directly conflicts with and is thus preempted by state law.

99. By statute, Indiana has “authorized” “[c]arbon sequestration projects . . . in Indiana for the purposes of: (1) injecting carbon dioxide into the pore space of an underground storage facility through at least one (1) carbon dioxide injection well pursuant to a UIC Class VI permit; and (2) employing the underground storage of carbon dioxide.” Ind. Code § 14-39-2-5.

100. Indiana statutes direct IDNR to “review” and “approve” “application[s]” for “carbon sequestration project permit[s].” Ind. Code §§ 14-39-2-5, -6, -7.

101. Under Indiana law, a storage operator is required to obtain a UIC Class VI permit and a valid permit issued by IDNR to operate a CCS project in Indiana. Ind. Code § 14-39-2-5(b).

102. The State of Indiana issues CCS project permits pursuant to 312 IAC 30, promulgated in September of 2025.

103. Through the Moratorium Ordinance, the County is prohibiting for an indefinite duration all CCS projects, which the State of Indiana expressly allows, and which are required to be regulated by IDNR, a state agency. The Moratorium Ordinance also imposes unreasonable burdens by preventing the progression of CCS projects, which is inconsistent with Indiana law and is upending reasonable investment-backed expectations.

104. The Moratorium Ordinance is therefore preempted because it directly conflicts with Indiana law, prohibits conduct that Indiana law expressly permits, and adds unreasonable burdens that are inconsistent with the express statutory intent and declarations.

105. POET is entitled to (1) a declaration that the Moratorium Ordinance is preempted and is void and without effect, and (2) an order enjoining enforcement of the Moratorium Ordinance.

106. POET respectfully requests that the Court conduct a speedy hearing of this claim and request for a declaratory judgment action, as provided under Federal Rule of Civil Procedure 57.

PRAYER FOR RELIEF AS TO ALL COUNTS

WHEREFORE, POET requests and prays that the Court provide the following:

- a. Conduct a speedy hearing of this declaratory judgment action under Federal Rule of Civil Procedure 57;
- b. Enter Judgment for POET and against Defendant;
- c. Award POET its damages and all other appropriate legal relief;
- d. Declare that the Moratorium Ordinance is unconstitutional, preempted by state law, void, and unenforceable;
- e. Enjoin the County from enforcing the Moratorium Ordinance against POET;
- f. Award POET reasonable attorneys' fees, costs, and expenses to the fullest extent permitted by law; and

g. Provide POET all other relief that the Court deems just and proper.

Respectfully submitted,

Dated: March 5, 2026

/s/ Bart A. Karwath

Joshua J. Minkler (No. 18483-49)

Kian Hudson (No. 32829-02)

Paul M. Drucker (No. 34304-49)

Bart A. Karwath (No. 16088-49)

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Bart.Karwath@btlaw.com

Sarah E. Brown (No. 35715-53)

BARNES & THORNBURG LLP

201 S. Main Street, Suite 400

South Bend, Indiana 46601

Phone: (574) 233-1171

Sarah.Brown@btlaw.com

*Attorneys for Plaintiff POET Biorefining – North
Manchester, LLC d/b/a POET Bioprocessing –
North Manchester*

EXHIBIT 1

BEFORE THE BOARD OF COMMISSIONERS OF WABASH COUNTY, INDIANA

ORDINANCE NO. 2025-85-07

**AN ORDINANCE IMPOSING A TEMPORARY MORATORIUM ON
THE ISSUANCE OF IMPROVEMENT LOCATION PERMITS FOR
CARBON SEQUESTRATION PROJECTS**

WHEREAS, on December 5, 2022, the Board of Commissioners of Wabash County adopted Ordinance No. 2022-85-14, a Zoning Ordinance for the Unincorporated Areas of Wabash County, Indiana, and the Towns of LaFontaine, Lagro, and Roann, Indiana ("Zoning Ordinance")

WHEREAS, on March 18, 2022, the Governor of Indiana signed Public Law 163 (HB 1209) into law, which added IC 14-39-2 to the Indiana Code as a new chapter, which provided an authorization framework for carbon sequestration projects within Indiana.

WHEREAS, the Zoning Ordinance currently fails to provide any regulations related to carbon sequestration projects within Wabash County, which omission constitutes a defect in the Zoning Ordinance that should be corrected before any improvement location permits for structures related to carbon sequestration projects in an any zoning district are issued.

WHEREAS, the Wabash County Plan Commission initiated a proposal to adopt an ordinance to impose a temporary moratorium on the issuance of improvement location permits for carbon sequestration projects, including any carbon dioxide transmission line, carbon dioxide injection well, storage facility, and all appurtenant facilities, in order to amend the Zoning Ordinance to address issues related to carbon sequestration projects.

WHEREAS, the Plan Commission timely gave notice to interested parties and held a public hearing in accordance with I.C. 36-7-4-604.

WHEREAS, the Plan Commission timely certified its recommendation on the proposal in accordance with I.C. 36-7-4-605, thereby recommending its adoption.

NOW, THEREFORE, IT IS ORDAINED AS FOLLOWS:

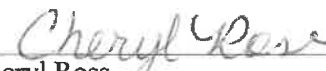
1. There is now imposed a temporary moratorium on the issuance of an improvement location permit for any structure related to any carbon sequestration project, including but not limited to any carbon dioxide transmission line, carbon dioxide injection well, storage facility, and all appurtenant facilities, in all zoning districts in the unincorporated areas of Wabash County, pending adoption of an ordinance amending the Wabash County Zoning Ordinance to provide regulations related to carbon sequestration projects within Wabash County.
2. This Ordinance shall be effective in the unincorporated areas of Wabash County upon its adoption. This Ordinance shall be effective in the incorporated areas of the Towns of LaFontaine, Lagro, and Roann, Indiana upon its adoption by the appropriate legislative body.

ADOPTED this 2 day of June, 2025.

BOARD OF COMMISSIONERS OF WABASH COUNTY



Jeff D. Daves, Chairman



Cheryl Ross



Tyler Niccum

ATTEST:



Shelly Baucce, Wabash County Auditor

Memorandum Prepared By: .

Vault GSL CCS LP
c/o Vault 44.01 Ltd.
Attn: Land
1125 17th Street, Suite 1275
Denver, Colorado 80202

After Recording Return To:

Vault GSL CCS LP
c/o Vault 44.01 LTD
Attn: Land
1125 17th Street, Suite 1275
Denver, Colorado 80202

IC 36-2-11-15 affirmation: I affirm under penalties of perjury, that I have taken reasonable care to redact each social security number in this document unless otherwise required by law.

Joseph Silipo

Joseph Silipo, Senior Landman

MEMORANDUM OF
PORE SPACE SEQUESTRATION EASEMENT

This Memorandum of Lease Agreement ("Memorandum") is made and effective as of the 4th day of April, 2025, (the "Effective Date") by and between: by and between Keystone Cooperative, Inc. fka Co-Alliance Cooperative, Inc., successor by merger with Ceres Solutions Cooperative, Inc., successor by merger with North Central Cooperative, Inc. ("Grantor"), whose address is PO Box 299 Wabash, IN 46992, and Vault GSL CCS LP ("Grantee") whose address is 1125 17th Street, Suite 1275, Denver, CO 80202.

WHEREAS, Grantor and Grantee have entered into a Pore Space Sequestration Easement ("Easement Agreement") as of the Effective Date pursuant to which Grantor did lease exclusively unto Grantee, that portion of the subsurface area of the property described in Exhibit A (the "Property") lying between three hundred (300) feet above the top of the Eau Claire formation and two hundred (200) feet below the base of the Mt. Simon formation ("Pore Space");

WHEREAS, Grantor and Grantee desire to execute this Memorandum in order to place of record in the Recorder's Offices of each county where the Property is located a summary of certain terms and conditions of the Easement. Agreement

NOW, THEREFORE, for the good and valuable consideration recited in the Easement Agreement, the receipt and sufficiency of which is acknowledged by each party, Grantor and Grantee state:

1. **Definitions.** Reference is made to the Easement Agreement itself for all pertinent terms. Among those pertinent terms are those set forth in this Memorandum.

In addition to terms elsewhere defined in this Memorandum and in the Easement Agreement, the following terms shall have the meaning set forth below:

- a. **"Carbon Dioxide"** shall mean all classifications and types of carbon dioxide, both in liquid and gaseous and supercritical forms, and incidental associated substances derived from the source materials and capture process and any substances added or used to enable or facilitate transport, injection, monitoring and sequestration including but not limited to the definition of "carbon dioxide" under Indiana Code section 14-39-1-1, but shall not include any Hazardous Materials as defined in the Easement Agreement.
 - c. **"Sequestration Operations"** means: (i) injecting and permanently storing, sequestering and monitoring Carbon Dioxide in the Pore Space and (ii) conducting any and all activities, operations and undertakings associated with or related to the injection and sequestration of Carbon Dioxide, including, without limitation, the following: (a) evaluating, developing, maintaining, operating, testing, and using any and all reservoirs for Sequestration Operations, (b) obtaining all regulatory approvals and permits for the injection, sequestration of Carbon Dioxide; (c) retaining title to all Carbon Dioxide injected and sequestered in the Pore Space; (d) transporting Carbon Dioxide for interchange, sequestration, or other services performed by the Grantee on or with respect to the Property or a Sequestration Unit (or acreage adjacent or in the vicinity).
 - d. **"Sequestration Unit"** shall mean one or more sequestration units formed by Grantee pursuant to its right, as set forth in the Easement Agreement, to combine, integrate, pool or unitize all or any portion of the Pore Space with any other pore space adjacent to or in the vicinity of the Property owned or controlled by Grantee.
2. Use. Grantor has granted and conveyed to Grantee (i) an exclusive easement and right to use the Pore Space underlying the Property for the purposes of permanently sequestering and monitoring Carbon Dioxide (the **"Pore Space Easement"**) and (ii) a non-exclusive easement and right of way on, over and across the Property for conducting surveys and monitoring which may be reasonably necessary or convenient to Grantee in conducting operations related to the Sequestration Operations including without limitation, seismic or other geological surveys and monitoring fresh water wells and surface water (the **"Access Easement"** and together with the Pore Space Easement, the **"Easements"**).

Under the terms of the Easement Agreement, Grantee shall have no right to construct, maintain or operate permanent facilities or structures upon the surface of the Property without the prior written consent of Grantor; provided, that, Grantee shall have the right to enter upon the surface of the Property to conduct inspections, monitoring and testing, including without limitation placing testing or monitoring equipment on the surface of the Property (such as, by way of example, vibrois trucks also known as thumper trucks, transmitters placed on trucks and/or tractors and receivers), baseline and ongoing geophysical, 2-D and 3-D seismic, water monitoring and testing, and for other purposes necessary or convenient to conduct Sequestration Operations.

3. Term. The term of the Easement Agreement is perpetual. The Easement Agreement shall nevertheless terminate if Grantee has not commenced injection and permanent sequestration of Carbon Dioxide in the Pore Space or a Sequestration Unit within seven (7) years after the Effective Date, other than by reason of delays outside the reasonable control of Grantee.

4. Restrictive Covenants. These provisions are restrictive covenants on Grantor's ownership of and constitute covenants running with the land. Notwithstanding any terms or provisions to the contrary, if Carbon Dioxide is injected into the Pore Space, the Property shall be held, used, sold and conveyed subject to the following restrictions, covenants, and conditions (the "**Restrictive Covenants**"), which shall survive the termination of the easements run with the Property, and be binding on Grantor and its heirs, executors, administrators, personal representatives, successors, successors-in-title, assigns, lessees and tenants:

- (a) The Pore Space is subject to the permanent sequestration of Carbon Dioxide;
- (b) Unless otherwise permitted by Applicable Law and consistent with Indiana Code section 14-39-2-11, no Person shall conduct any drilling, oil, gas or other mineral development, fracking, quarrying or mining operations of any kind on the Property that will or could reasonably be expected to penetrate the Pore Space or a Sequestration Unit. Grantee shall cooperate with Grantor, to the greatest extent practicable, to ensure that such operations may be conducted on the Property alongside Grantee's Sequestration Operations.
- (c) Unless otherwise permitted by Applicable Law and consistent with Indiana Code section 14-39-2-11, no wells (including without limitation, oil, gas and water wells), tanks, tunnels or mineral excavations or shafts shall be installed upon the Property that will or could reasonably be expected to penetrate the Pore Space or Sequestration Unit. Installation of water wells less than five hundred (500) feet in depth is permissible. Grantee shall cooperate with Grantor, to the greatest extent practicable, to ensure that such operations may be conducted on the Property alongside Grantee's Sequestration Operations.
- (d) Except for Grantee's Sequestration Operations, or as required by Applicable Law, no Person shall access, interfere with, disturb or hinder the Pore Space or Sequestration Unit for the permanent sequestration of Carbon Dioxide.
- (e) Grantee, the Customer, and Grantee's agents, employees, contractors and subcontractors (a "**Customer**" is defined as POET Bioprocessing) shall have the right, following termination of the Easements, to go upon the surface of the Property to perform all work to monitor the Carbon Dioxide sequestered in the Pore Space and a Sequestration Unit, for so long as required by any governmental authority, agency, industry practice or as required by applicable law or rules of any entity with an interest in or which allows credit for sequestration of Carbon Dioxide (collectively the "**Post Termination Monitoring**"). The corresponding obligation to pay for any damages caused by the Post Termination Monitoring shall survive the termination of the Easements.

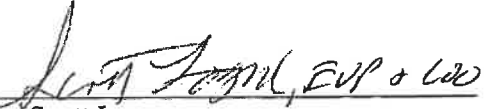
5. Incorporation by Reference. All terms and provisions of the Easement Agreement, and the definitions therein, are incorporated in this Memorandum by reference as if fully set forth herein.

6. Purpose of Memorandum. This Memorandum is prepared for the purpose of recordation only and is intended to give notice of certain terms and conditions of the Easement Agreement and in no way is it intended, nor shall it be deemed, to modify any of the provisions of the Easement Agreement.

EXECUTED on the dates set forth in the notary acknowledgements attached hereto, but effective for all purposes as of the Effective Date here in above specified. This document may be executed in multiple counterparts, any one of which shall be considered an original and binding upon the signatory parties for all purposes herein.

GRANTOR

Keystone Cooperative, Inc. fka Co-Alliance Cooperative, Inc., successor by merger with Ceres Solutions Cooperative, Inc., successor by merger with North Central Cooperative, Inc.

By: 

Name: Scott Logue

Title: Executive Vice President and COO

GRANTEE

Vault GSL CCS LP

By: 

Name: Rob Sadler

Title: Chief Commercial Officer

Corporate/Limited Liability Company Acknowledgement

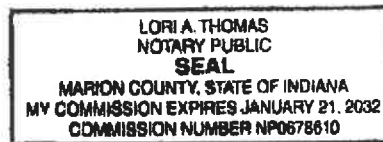
STATE OF INDIANA)
) SS:
COUNTY OF MARION)

I, the undersigned, a notary public in and for said County, in the State aforesaid, do hereby certify that Scott Logue, authorized officer of Keystone Cooperative, Inc. fka Co-Alliance Cooperative, Inc., successor by merger with Ceres Solutions Cooperative, Inc., successor by merger with North Central Cooperative, Inc., personally known to me to be the same person whose name is subscribed to the foregoing instrument, appeared before me this day in person and acknowledged that he signed and delivered the said instrument as the free and voluntary act of said company for the uses and purposes therein set forth.

Given under my hand and official seal this 4th day of April, 2025.

Lori A. Thomas
NOTARY PUBLIC

My Comm. Expires: 1/21/2032



Corporate/Limited Liability Company Acknowledgement

STATE OF CO)
) SS:
COUNTY OF Denver)

I, the undersigned, a notary public in and for said County, in the State aforesaid, do hereby certify that Rob Sadler, authorized officer of Vault GSL CCS LP, personally known to me to be the same person whose name is subscribed to the foregoing instrument, appeared before me this day in person and acknowledged that he signed and delivered the said instrument as the free and voluntary act of said company for the uses and purposes therein set forth.

Given under my hand and official seal this 9 day of April, 2025.

Katharine Hermanspan
NOTARY PUBLIC

My Comm. Expires: 4/24/27

No Sales Disclosure Needed
Aug 04 2026
By: LS
Wabash County Assessor

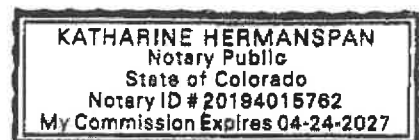


Exhibit A
To that Memorandum of Pore Space Easement

Property

Parcel ID: 85-07-30-100-005.000-001, containing 17.9930 acres, more or less, more particularly described as follows:

Part of the Fractional Northwest Quarter of Section Thirty (30), Township Twenty-nine (29) North, Range Seven (7) East, within Chester Township, being more particularly described as follows:

Beginning at the Northwest Corner of the Fractional Northwest Quarter of Section Thirty (30); thence on an assumed bearing of North Eighty-eight (88) degrees Four (4) minutes Twenty-seven (27) seconds East along the North line of said Northwest Quarter a distance of Six Hundred Twenty-six and Eighty-eight hundredths (626.88) feet to the west right-of-way line of Conrail Railroad; thence South No (0) degrees Twelve (12) minutes Twelve (12) seconds East along said west right-of-way line a distance of One Thousand Three Hundred Nineteen and Thirty-nine hundredths (1319.39) feet to the south line of the North Half of said Northwest Quarter; thence South Eighty-eight (88) degrees Fifty-one (51) minutes Sixteen (16) seconds West along said south line a distance of Six Hundred Twenty-nine and Sixty-six hundredths (629.66) feet to the west line of said Northwest Quarter; thence North No (0) degrees Four (4) minutes Forty-one (41) seconds West along said west line a distance of One Thousand Two Hundred Thirty-one and Fifty hundredths (1231.50) feet to the Northeast Corner of the Northeast Quarter of Section Twenty-five (25), Township Twenty-nine (29) North, Range Six (6) East (standard corner); thence North No (0) degrees No (0) minutes Two (2) seconds East along said West line a distance of Seventy-nine and Forty hundredths (79.40) feet to the POINT OF BEGINNING. Containing Eighteen and Nine Hundred Sixty-four thousandths (18.964) acres, more or less.

Except the following described premises:

Located in Section 24, Township 29 North, Range 6 East, Pleasant Township, Section 25, Township 29 North, Range 6 East, Paw Paw Township and Sections 19 & 30 - Township 29 North, Range 7 East, Chester Township, Wabash County, Indiana.

Line "A" (CR800N) was established along the South line of the Southwest quarter of Section 19, Town 29 North, Range 7 East. Stationing was assumed. Line "B" (SR13) is the reestablishment of Line "A" from the State of Indiana, State Highway Department Road Plans (Wabash - North Manchester Road) for State Road 13 - S Project No. 2 (11) dated July 29, 1952. Stationing was based upon P.I. Station 425+20.0. A county section corner monument was found at this location and was used as a basis of stationing. Tangents to the south and north of 425+20.0 were established from the physical centerline of the existing roadway (splitting the pavement). This seemed to be in agreement with the locations of right of way monuments and property corners located during the survey.

Also except the following described premises:

A part of the Northwest Quarter of Section 30, Township 29 North, Range 7 East, Wabash County, Indiana, and being that part of the grantor's land lying within the right of way lines described as follows: Commencing at the Northwest corner of said section, said corner being South 87 degrees 38 minutes 23 seconds West 1.39 feet from point "6" on said plat; thence along the north line of said section North 87 degrees 38 minutes 23 seconds East 40.06 feet to the prolonged east boundary line of S.R. 13 and the point of beginning of this description; thence continuing along said north line North 87 degrees 38 minutes 23 seconds East 25.16 feet; thence South 2 degrees 21 minutes 37 seconds East 20.00 feet to the south boundary of C.R. 800 N., designated as point "305" on said plat; thence South 47 degrees 12 minutes 38 seconds West 34.92 feet to the east boundary of S.R. 13, designated as point "300" on said plat; thence along said east boundary North 0 degrees 26 minutes 51 seconds West 42.67 feet to the point of beginning and containing 0.018 acres, more or less, inclusive of the presently existing right-of-way which contains 0.011 acres, more or less, for a net additional taking of 0.007 acres, more or less.



INDIANA ACTION TEAM

Putting Power Back in the Hands of Indiana Landowners

The Indiana Action Team works with Hoosiers to provide legal representation to landowners, deliver expert resources, and support communities facing unwanted carbon capture and storage projects.

We're raising funds to cover legal fees associated with protecting our property rights from carbon capture and storage schemes across the state.

All funds will directly support outreach and legal representation for impacted members of the Indiana Action Team. Donations are tax deductible.

DONATE ONLINE

 IndianaActionTeam.org/donate

DONATE BY CHECK

Bold Education Fund for Indiana Action Team
P.O. Box 254 | Hastings, NE 68902

FAST FACTS:

Carbon Capture & Storage

Carbon capture & storage (CCS) has been touted as a solution to the climate crisis and simultaneously, the savior of the fossil fuel industry. **In reality, the technology is nothing more than false promises with real problems.**

1

The long-term impacts of carbon capture & storage (CCS) are unknown

» Carbon pollution is captured from smokestacks and sent by pipeline to be used for enhanced oil recovery or stored underground. **The long-term impacts of this process have not been studied.**

2

CO2 pipeline projects threaten land & property rights

- » Only 5,000 mi of CO2 pipelines exist in the U.S.—compared to 3 million mi of natural gas pipelines.
 - » The projects seek to store CO2 in coal seams, deep aquifers, depleted oil/gas reservoirs, and basalt formations.
 - » Eminent domain rights for CO2 corporations **are open for challenge in most states.**
-

3

CCS plunders public money

- » Our tax dollars subsidize carbon capture projects. Since the 1980s, **more than \$20 billion of our tax dollars have been invested in failed CCS projects.**
- » Capturing all of the nation's carbon emissions would cost between \$613 billion and \$850 billion per year.

4

CCS projects bring serious health & safety hazard

- » Carbon is an odorless, colorless asphyxiant that can cause **confusion, respiratory distress, and death.**
- » Since 2004, there have been **over 100 leaks or ruptures of existing carbon pipelines.**
- » If it ruptures, an 8" pipeline can be lethal more than 1,855 feet from the rupture site. A 20" pipeline **can be lethal more than 1/2 a mile from the rupture site.**

5

Moving pollution is not a climate solution

- » Carbon capture **can actually emit more greenhouse gases** than it captures.
 - » 95% of the CO₂ captured in the United States is used for enhanced oil recovery.
 - » CO₂ acidifies water, posing **a risk to our water** at a time when communities are already struggling with drought concerns.
-

CHECKLIST FOR SUPERVISORS & COMMISSIONERS

Proactive steps for county preparedness, public awareness, & economic protection for carbon capture & storage proposals.

Serve notice to your County Emergency Management & Emergency Planning boards.

These First Responders are our friends and neighbors. They are here to protect us, but they need to be aware of the potential health risks and safety concerns from the very beginning. Share the information you have about the project, including route maps or potential incident zones.

(Many rural counties rely on volunteer emergency responders, who need time to evaluate response capabilities and equipment needs.)

Work closely with your Economic Development Board to ensure development areas are protected.

If Supervisors/Commissioners are not communicating directly with their Economic Development Director and Board, protecting the county's economic vision is at risk of being lost. This should be a top concern for any county as it could potentially lead to a decline in population or future jobs growth.

(It's a big deal with real consequences!)

Help organize public information meetings for affected landowners.

Property owners affected by these projects are often unaware of their rights. They depend on our leadership to help educate them of their rights and how the process works and doesn't work. Getting more local people involved raises awareness levels and creates more problem-solving conversations at the state level – resulting in more favorable outcomes at the local level.

(This is an opportunity to build trust between the community and elected officials.)

Use Supervisor meetings to update your fellow board members & the public.

Keeping the Board and public updated helps everyone better understand the process, address misinformation or misunderstandings, and get on the same page.

(COMMUNICATION, COMMUNICATION, COMMUNICATION.)

Monitor state & federal legislation.

Stay informed on proposed laws, regulations, or funding programs that could impact your county. Understanding the landscape early allows you to advocate, coordinate, and prepare for changes that could affect land use, taxes, or emergency planning.

(Being proactive keeps your county ahead instead of reacting after decisions are made.)

CHECKLIST FOR SUPERVISORS & COMMISSIONERS

Proactive steps for county preparedness, public awareness, & economic protection for carbon capture & storage proposals.

Revise or implement land use & zoning ordinance to include set-backs.

Indiana Code 36-1-4-11 grants counties the right to adopt, codify, and enforce ordinances. Land use and zoning ordinances protect the county's land use intentions. Protecting the growth of your tax base, spreads the property tax burden out amongst a larger pool of property owners keeping property tax levies lower.

(Consult with an experienced land use and zoning attorney.)

Obtain legal counsel for intervention in your state Utility Commission permit proceedings.

When it comes time for your state to consider issuing a CO2 pipeline or storage permit, legal representation is vital in communicating your position, concerns and local laws.

(If you are not at the table, you are on the menu.)

Organize a coalition building of the counties affected by the project.

Being pro-active in recruiting other affected counties forms a unified coalition working together towards the same goals, sharing information, addressing the same challenges, and creating a stronger voice.

(Legal counsel may be able to represent multiple counties, saving costs & redundancy.)

Revise or implement county road crossing/utility right-of-way/road-use permits.

County Supervisors and Commissioners can implement regulations for county roads. Making sure your permits are up to date is essential. Are your bonding requirements and fees appropriate? Will you allow your roads to be open cut or will boring be required?

(These up-front decisions can save tax payer dollars on the back end.)

Communicate with cities, local utility companies, rural water districts, etc. within the proposed project area.

Many assume their local municipalities, utilities and agencies are served notice of these proposed projects, when in all reality, they are left being re-active, fighting to protect their residents and customers before it is too late.

(Being proactive is key!)

KNOW YOUR RIGHTS

Carbon Dioxide Schemes & Eminent Domain

Q: What is an easement?

A: An easement is a legal right allowing someone other than the landowner to use the land for a specific purpose. This can include the right to build a pipeline and related infrastructure, the use of underground pore space, as well as the right to enter the property for maintenance and repairs. It is highly recommended to have an attorney review an easement agreement before signing anything. Easements can be obtained through voluntary negotiations or through eminent domain.

Q: What is the difference between an easement and a lease?

A: An easement simply gives the company a non-exclusive, long-term or permanent right to use your property for their project while you still remain the owner. Since you still own the land, payments could be smaller than what would come with a lease. Compensation is often a one-time payment. A lease is a temporary agreement that gives exclusive use of the property for a defined period, typically with an option to renew the lease later on. A lease usually requires ongoing payments in the form of annual rent or royalties agreement with a company.

Q: Do I have to sign over my land?

A: No. There is nothing in the law that requires a landowner to voluntarily enter into an agreement with a company.

Q: What is eminent domain?

A: Eminent domain is the government's power to take private property for public use, so long as the owner is justly compensated. This authority is often used for infrastructure projects like roads and utilities. In Indiana, the legislature declared carbon pipelines and geologic storage "to be a public use and service, in the public interest, and a benefit to the welfare and people of Indiana" and granted the ability to utilize eminent domain.

Q: How long does an easement or lease last for?

A: It depends. A company could request an easement or lease for perpetuity in the contract terms. In general, if property is taken via eminent domain, it must be used for the acquired purposed within 6 years or the easement is forfeited.

Q: Does an easement only allow the pipeline and/or carbon dumping?

A: Some landowners may have surface facilities. Temporary staging space is also a possibility. The easement agreement should specify certain conditions such as whether any surface facilities may be built on the easement or if the operator can place more than one pipeline. Easement terms can vary, but they may give the company wide-ranging rights over your property, such as the right to enter without notice at any time or the right to remove structures, so it is highly recommended to consult with an attorney before entering an easement agreement.

Q: What are the type of easements to expect?

A: For a carbon pipeline, the company will request a permanent easement for the pipeline called a right-of-way. They will likely request a temporary construction easement in addition to the permanent easement in order to provide space for maneuvering equipment, storing top soil, etc. For pore space, they may request a permanent easement with a potential to transfer of ownership and responsibility for the storage facility to the State once carbon injection ceases.

Q: What options do I have?

A: You do not have to sign anything you do not want to sign. You can certainly wait to sign an easement. You can require the company go through eminent domain to access your land. We recommend consulting with an attorney to help inform your decision.

Q: Is there a threshold of voluntary easements a company must get before eminent domain can be used?

A: For Wabash Valley Resource's project, they are required to obtain easements for 60% of the pore space area before eminent domain may be exercised. For other storage projects, landowners may be forced to integrate their interests if the owner of the carbon dump site has consent to integrate from property owners that make up at least 70% of the facility's land area.

Q: Are there set levels of compensation?

A: For pore space a company must compensate you by offering an annual payment each year that carbon dioxide is injected. The payment has to be equal to 40% of the average estimated cash rent per acre and the average class of land as described in the most recent Farmland Values & Cash Rents Survey Results published by Purdue University. If your land is taken via eminent domain for a carbon pipeline, you are to be paid 125% of the property's fair market value for farmland, or 150% of the fair market value if the easement involves a parcel where the owner is occupying a residence. The landowner must also be compensated for damages and any business losses related to the project.

Q: Do I have to talk to the company about their compensation offer?

A: No, the law requires the company make a good faith effort to obtain easements voluntarily, but you don't necessarily have to engage. However, if you are going to challenge the company's right to take the property, it is best to consult an attorney immediately if an offer is made as there are crucial legal deadlines that take place.

Q: What if I choose to negotiate?

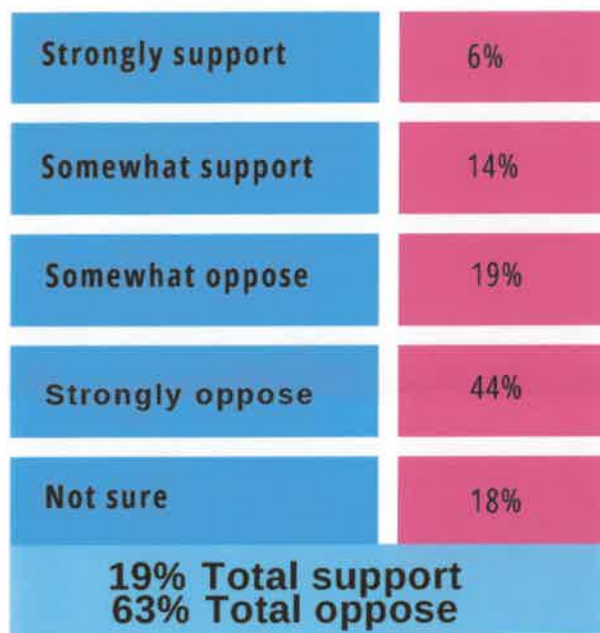
A: We highly suggest you seek legal counsel. An attorney can help secure terms that otherwise might be left out. Many attorneys will accept a percentage of the easement payment as compensation.



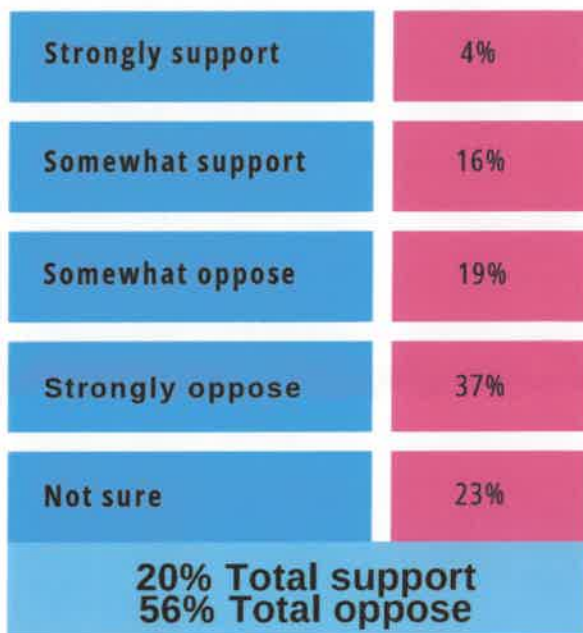
Polling

In July 2024, Bold Alliance commissioned polling from Change Research to find out what Hoosiers think about carbon capture and storage.

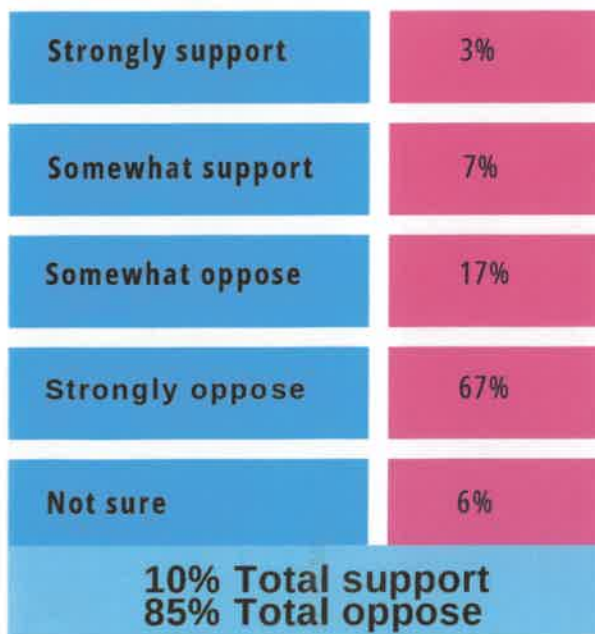
Do you support or oppose the use of eminent domain to store CO2 under privately owned property?



Do you support or oppose the use of eminent domain to build pipelines across Indiana to transport CO2 for storage?



Do you support or oppose eminent domain for private use?



3. The Chair reserves the right to terminate any repetitive, redundant, or irrelevant testimony to ensure everyone has a fair chance to be heard.
4. To ensure all voices are heard tonight, I am imposing a reasonable time limit of 3 minutes per speaker. Please keep your comments focused directly on the ordinance text."

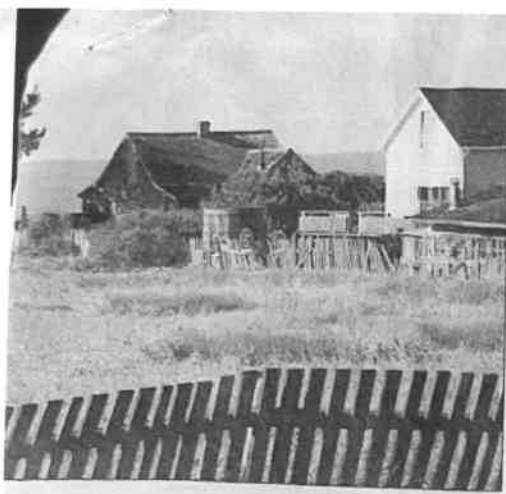
[ORDER OF EVENTS]

"To keep our process transparent, here is the exact order of events for tonight's hearing:

- First, members of the public will be called up individually to voice their support, concerns, or remonstrances.
- Members of the Plan Commission may direct questions to the staff or speakers at any time during the proceedings.
- Following the conclusion of public testimony, the Commission will take all public comments into consideration and officially close the public hearing. **No vote or final recommendation will be made tonight.** The Commission will review the testimony and officially vote on a recommendation at our next regularly scheduled meeting on July 2nd, 2026."

[START PUBLIC TESTIMONY]

"Thank you all for your cooperation and your commitment to our community. We will now begin public testimony. I will have Brian call on the first person from our sign-in sheet to step up to the microphone."



CHAPTER TWO

2

REAL PROPERTY AND THE LAW

■ **LEARNING OBJECTIVES** *When you've finished reading this Chapter, you should be able to:*

- **identify** the rights that convey with ownership of real property and the characteristics of real estate.
- **describe** the difference between real and personal property, and the various types of personality.
- **explain** the types of laws that affect real estate.
- **distinguish** among the concepts of land, real estate, and real property.
- **define** the following *key terms*:

accession	fixture	severance
air rights	heterogeneity	situs
annexation	improvement	subsurface rights
area preference	land	surface right
appurtenance	nonhomogeneity	trade fixture
bundle of legal rights	personal property	water rights
chattel	real estate	
emblems	real property	

■ WHY LEARN ABOUT... REAL PROPERTY AND THE LAW?

Real estate is a market like any other one. Real property is a product, and the licensee is the salesperson. As any successful salesperson will tell you, product knowledge is the key to success. You need to know enough about your product to be able to educate and guide your clients and customers, whether they are buyers, sellers, renters, or investors. Also, you are dealing with a product that has very specific and often very complicated legal issues involved. This Chapter will help you understand the most basic, fundamental principles of the product you will be handling for the rest of your career. ■

■ LAND, REAL ESTATE, AND REAL PROPERTY

The words *land*, *real estate*, and *real property* are often used interchangeably. To most people, they mean the same thing. Strictly speaking, however, the terms refer to different aspects of the same idea. To fully understand the nature of real estate and the laws that affect it, licensees must be aware of the subtle yet important differences in meaning of these words.

Land

*Land is defined as the earth's surface extending downward to the center of the earth and upward to infinity, including permanent natural objects such as trees and water. (See Figure 2.1.)

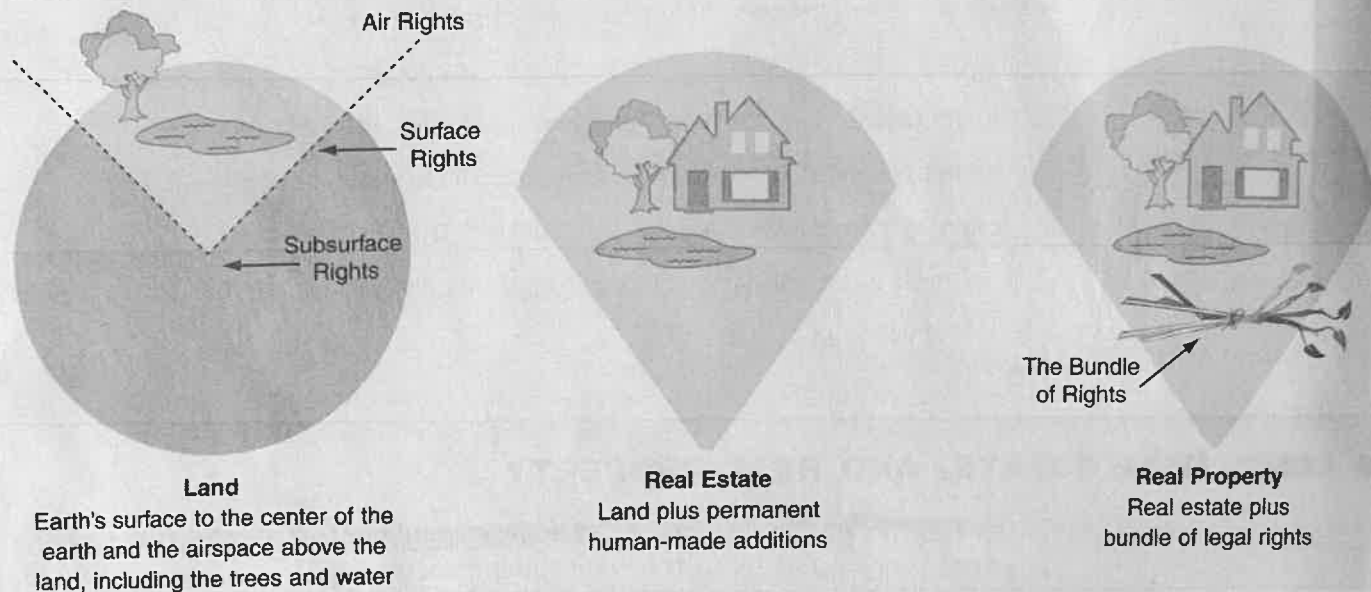
Land, then, means not only the surface of the earth but also the underlying soil. It refers to things that are *naturally* attached to the land, such as boulders and plants. It includes the minerals and substances that lie far below the earth's surface. Land even includes the air above the earth, all the way up into space. These are known respectively as the *subsurface* and the *airspace*. Most of the surface of the earth, of course, is not land at all, but water. Special state and local laws govern the ownership of the wetter part of the earth, including lakes and rivers, as discussed in Chapter 7.

Real Estate

Real estate is defined as land at, above, and below the earth's surface, plus all things permanently attached to it, whether natural or artificial. (See Figure 2.1.)

The term *real estate* is similar to the term *land*, but it means much more. *Real estate* includes not only the natural components of the land but also all man-made improvements. An **improvement** is any artificial thing attached to the land, such as a building or a fence. The term *improvement*, as used in the real estate industry, refers to any addition to the land. The word is neutral. It doesn't matter whether the artificial attachment makes the property better looking or more useful; the land is still said to be *improved*. Land also may be improved by streets, utilities, sewers, and other additions that make it suitable for building.

FIGURE 2.1
Land, Real Estate, and Real Property



Real Property

The term *real property* is the broadest of all. It includes both land and real estate.

✱ **Real property** is defined as *the interests, benefits, and rights that are automatically included in the ownership of land and real estate.* (See Figure 2.1.)

Real property includes the surface, subsurface, and airspace, any improvements, and the legal rights of ownership that attach to ownership of a parcel of real estate.

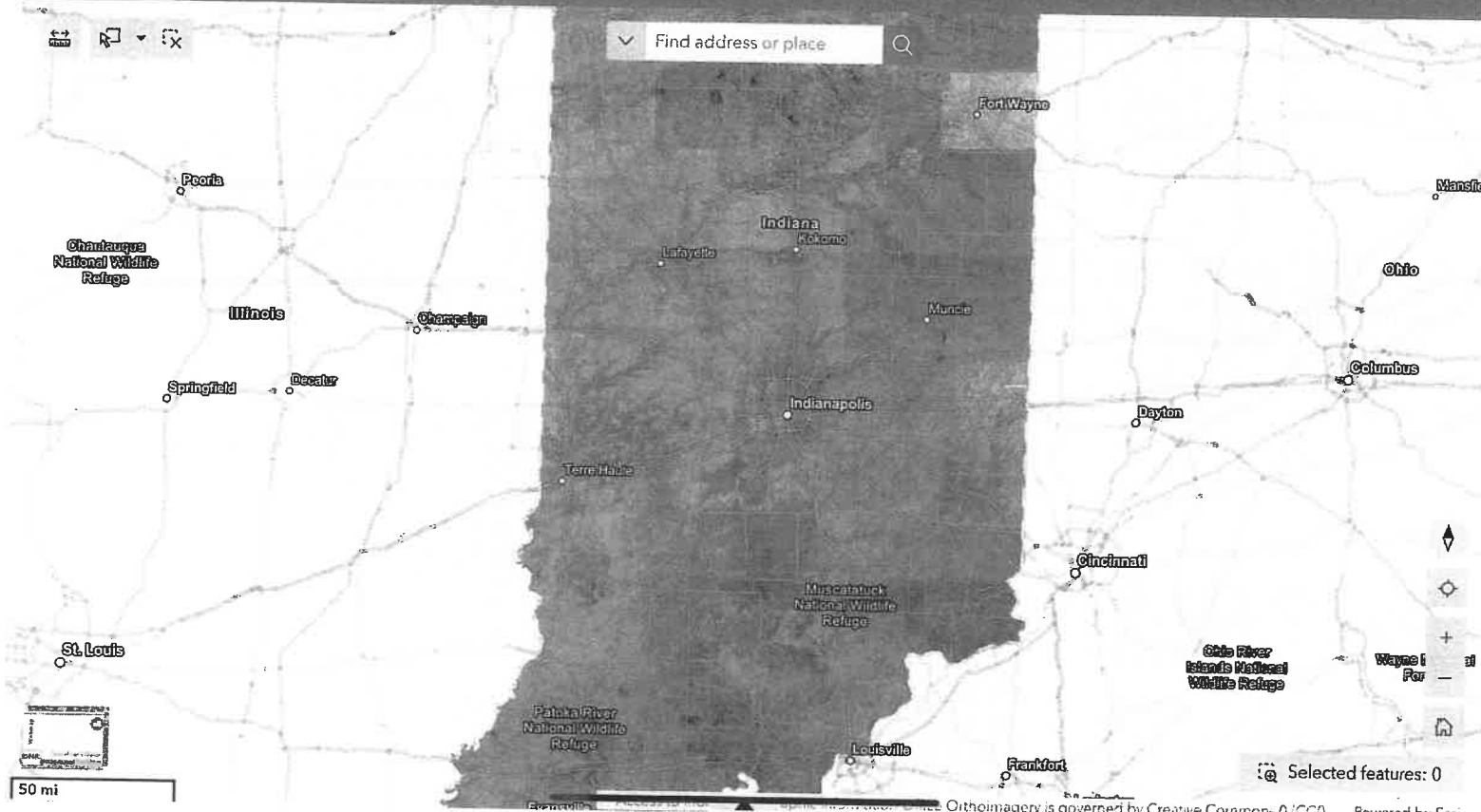
Traditionally, ownership of real property is described as a **bundle of legal rights**. In other words, a purchaser of real estate actually buys the rights of ownership held by the seller. These rights include the

- right of *possession*;
- right to *control* the property within the framework of the law;
- right of *enjoyment* (that is, to use the property in any legal manner);
- right of *exclusion* (to keep others from entering or using the property); and
- right of *disposition* (to sell, will, transfer, or otherwise dispose of or encumber the property).

The concept of a bundle of rights comes from old English law. In the Middle ages, a seller transferred property by giving the purchaser a handful of earth or a bundle of bound sticks from a tree on the property. The purchaser, who accepted the bundle, then owned the tree from which the sticks came and the land to which the tree was attached. Because the rights of ownership (like the sticks) can be separated and individually transferred, the sticks became symbolic of those rights. (See Figure 2.2.)

The word *title* to real property has two meanings: (1) the right to or ownership of the land as represented by the owner's bundle of rights and (2) evidence of

Not proof



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**Map of Indiana Showing Known Faults and Historic Earthquake
Epicenters having Magnitude 3.0 and Larger**
By
Walter F. Gray and John C. Steinmetz
2011

#	Date	Weighted
1	January 10, 1917	3.1
2	January 17, 1917	3.3
3	July 3, 1927	4.1
4	August 7, 1927	7.6
5	June 1, 1949	1.0
6	September 25, 1979	0.2
7	August 17, 1989	0.1
8	February 29, 1999	0.3
9	February 29, 1999	1.5
10	February 29, 1999	0.9
11	February 29, 1999	1.4
12	January 29, 1999	1.1
13	December 30, 1993	1.1
14	April 30, 1999	4.4
15	March 30, 1999	1.5
16	February 15, 1999	4.1
17	September 7, 1989	1.0
18	May 15, 1999	3.2
19	May 1, 1999	3.2
20	May 1, 1999	3.2
21	September 22, 1999	3.2
22	September 27, 1999	6.7
23	January 1, 2019	9.3
24	May 29, 1999	3.8
25	January 15, 1923	3.7
26	September 2, 1939	6.6
27	April 27, 1929	6.9
28	February 14, 1929	3.1
29	January 6, 1921	3.1
30	February 14, 1929	1.9
31	February 14, 1929	3.3
32	August 19, 1999	2.6
33	June 29, 1999	3.7
34	January 29, 1999	5.0
35	January 29, 1999	5.0
36	December 29, 1999	2.5
37	December 17, 1999	1.2
38	December 7, 2000	3.7
39	April 14, 1999	1.2
40	April 14, 1999	4.4
41	December 12, 2004	3.2
42	December 29, 2010	5.8
43	May 18, 2012	1.1

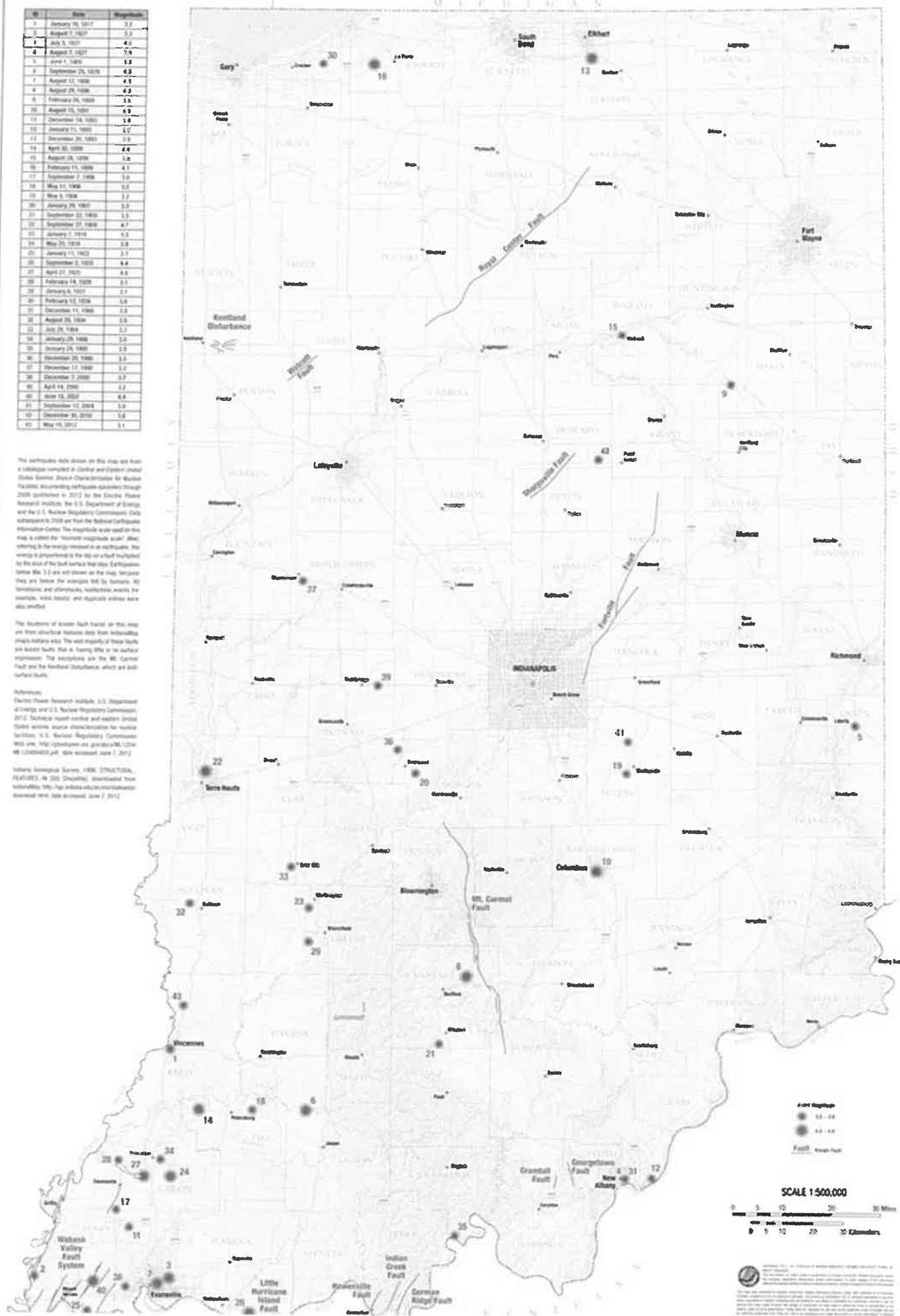
The aerodynamic data shown on this map are from a Cambridge Corvettes C-Series and E-Series underlaid United States Standard Coast Characteristics for Weather Facilities. All aerodynamic properties are through 2019 specifications as of 2017 by the Electric Power Research Institute. The U.S. Department of Energy and the U.S. Nuclear Regulatory Commission. Data subsequent to 2018 are from the National Carbonate Information Center. This magnitude was used as the map is subject to the "current magnitude scale" (also referred to as the energy-magnitude scale) as aerodynamic flow velocity is proportional to the size of the fluid body. By the use of the fluid surface velocity, it is possible to compare the size of the fluid surface velocity. It is known that the size of the fluid surface velocity is not related to the size of the fluid surface velocity. It is known that the size of the fluid surface velocity is not related to the size of the fluid surface velocity.

The locations of known fault traces on this map are from structural features that have subsiding (might define why). The vast majority of these faults are buried faults, that is, having little or no surface expression. The exceptions are the Mt. Carmel Fault and the Portland Disturbance, which are both surface faults.

Differences

Electric Power Research Institute, U.S. Department of Energy, and U.S. Nuclear Regulatory Commission, 2012. Technical report control and eastern United States seismic source characteristics for nuclear facilities. U.S. Nuclear Regulatory Commission, 2012. <http://www.nrc.gov/reactors/100plus/100plus.htm>. 12/14/12. 12/14/2012. pdf. doi:10.1016/j.egres.2012.05.001

Indiana Geological Survey, 608 STRICKLAND PLAZA, # 300 (Daphne) downloaded from ipedsdatahub.org on 06/10/2016
Downloaded from ipedsdatahub.org on 06/10/2016



Basin-scale hydrogeologic impacts of CO₂ storage: Capacity and regulatory implications

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ABSTRACT

Industrial-scale injection of CO₂ into saline formations in sedimentary basins will cause large-scale fluid pressurization and migration of native brines, which may affect valuable groundwater resources overlying the deep sequestration aquifers. In this paper, we discuss how such basin-scale hydrogeologic impacts (1) may reduce current storage capacity estimates, and (2) can affect regulation of CO₂ storage projects. Our assessment arises from a hypothetical future carbon sequestration scenario in the Illinois Basin, which involves twenty individual CO₂ storage projects (sites) in a core injection area most suitable for long-term storage. Each project is assumed to inject five million tonnes of CO₂ per year for 50 years. A regional-scale three-dimensional simulation model was developed for the Illinois Basin that captures both the local-scale CO₂–brine flow processes and the large-scale groundwater flow patterns in response to CO₂ storage. The far-field pressure buildup predicted for this selected sequestration scenario support recent studies in that environmental concerns related to near- and far-field pressure buildup may be a limiting factor on CO₂ storage capacity. In other words, estimates of storage capacity, if solely based on the effective pore volume available for safe trapping of CO₂, may have to be revised based on assessments of pressure perturbations and their potential impacts on caprock integrity and groundwater resources. Our results suggest that (1) the area that needs to be characterized in a permitting process may comprise a very large region within the basin if reservoir pressurization is considered, and (2) permits cannot be granted on a single-site basis alone because the near- and far-field hydrogeologic response may be affected by interference between individual storage sites. We also discuss some of the challenges in making reliable predictions of large-scale hydrogeologic impacts related to CO₂ sequestration projects.

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1. Introduction

Geologic carbon sequestration (GCS) in deep formations (e.g., saline aquifers, oil and gas reservoirs, and coalbeds) has drawn increasing consideration as a promising method to mitigate CO₂ emissions and associated climate change (IPCC, 2005). The amounts of CO₂ that would need to be injected and stored underground to make a noticeable impact on atmospheric emissions are very large. Releases of anthropogenic CO₂ into the atmosphere is currently almost 30 Gt (billion metric tonnes) per year. At typical *in situ* densities of stored CO₂, the corresponding fluid volume would be about eight times larger than the current annual world oil production. This means that geologic storage of 15% of the anthropogenic CO₂ emissions would require a fluid-handling system larger than that in place for world oil production.

By far the greatest storage capacity is in saline aquifers (Dooley et al., 2004; IPCC, 2005), and our discussion will focus primarily on CO₂ storage in saline formations. Injection of CO₂ into deep saline aquifers will impact subsurface volumes much larger than the CO₂ plumes themselves. An industrial-scale CO₂ storage project for a large coal-fired power plant of 1000 MW generation capacity will generate, over a typical lifetime, a subsurface plume with linear dimensions of 10 km or more, while pressurization of more than 0.1 MPa would likely occur over basin-scale regions with dimensions of 100 km and more (Pruess et al., 2003). Such large-scale pressure changes may have environmental impacts on shallow groundwater resources, i.e., causing water table rise, increasing rates of discharge into lakes or streams, and/or mixing of displaced native brine into drinking water aquifers (Bergman and Winter, 1995). The level of impact depends mainly on the magnitude and extent of pressure buildup in a deep storage formation and the hydraulic communication with overlying freshwater aquifers (Birkholzer et al., 2009).

One scenario where freshwater aquifers could be impacted is CO₂ injection into the deep (downip) saline part of an extensive

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E-mail address: jtbirkholzer@lbl.gov (J.T. Birkholzer).

formation that holds potable groundwater in its shallow updip part (Nicot, 2008). Freshwater resources may also be affected if high-permeability conduits such as conductive faults and abandoned boreholes provide local conduits for pressure perturbation and brine migration. In addition, the sealing layers that separate deep storage formations from overlying freshwater aquifers may pinch out at some distance from injection sites, have higher local breaches due to erosional channels, and/or may be degraded geomechanically because of overpressure in the storage formations. All these would allow for increased interlayer communication. Finally, land-surface deformation or uplift is expected in response to large-scale pressure increases, which may change surface and subsurface flow patterns, even without a direct hydraulic impact of brine displacement. The reverse effect, land subsidence in response to groundwater withdrawal (e.g., for water supply and agriculture) or oil production, is a common problem throughout the United States (USGS, 1999).

Concerns about large-scale pressure buildup and brine migration caused by industrial-scale CO₂ sequestration, and their possible environmental impacts, have been raised as early as in the 1990s (van der Meer, 1992; Bergman and Winter, 1995; Gunter et al., 1996). Since then, less emphasis has been placed on evaluating large-scale pressure changes and understanding the fate of native brines displaced by injected CO₂. Most research on geologic storage of CO₂ has instead focused on evaluating the hydrogeologic conditions under which the injected volumes of CO₂ can be safely stored, addressing issues such as the long-term efficiency of structural trapping of CO₂ under sealing units and the possibility of CO₂ leakage through faults and boreholes. The same focus has been seen in risk assessment efforts (e.g., Stenhouse et al., 2006; Pawar et al., 2006; Oldenburg et al., 2008, 2009; Viswanathan et al., 2008; Stauffer et al., 2009), as well as in discussions on and recommendations for regulatory and permitting frameworks. Meanwhile, estimates of regional storage capacity for CO₂ sequestration have been based on simple calculations of the fraction of total reservoir pore space available for safe trapping of CO₂ (Bradshaw et al., 2007; Bachu et al., 2007; USDOE, 2008), making the underlying assumption of “open” formations from which native brine can easily escape laterally and make room for injected CO₂. Moreover, the field experiments of CO₂ storage to date have primarily been quite small and were conducted to improve our understanding of CO₂ injectivity and migration patterns, and to test methods of monitoring and modeling of CO₂ migration (e.g., the Frio experiment as described in Hovorka et al., 2006). Because the injected fluid volumes have been so small, on the order of several thousand to several ten-thousand tonnes of CO₂, pressure buildup was not significant.

Only recently have researchers paid more attention to evaluating the large-scale pressure responses expected for future industrial-scale carbon sequestration, in part on the basis of modeling studies for hypothetical sequestration scenarios. A simulation study of CO₂ injection into compartmentalized saline formations (Zhou et al., 2008) suggests small storage capacity because strong pressurization occurs and geomechanical damage must be avoided. van der Meer and Egberts (2008) and van der Meer and Yavuz (2008) introduced the concept of “total affected space” defined as the region affected by CO₂ plume migration and brine pressurization. Both studies point out that the storage capacity in bounded reservoirs is limited by a yet-to-be-defined maximum allowable pressure increase and the compressibility of the fluids and pore space in the affected area. Birkholzer et al. (2009) modeled CO₂ migration and pressure response in an idealized, laterally open groundwater system, comprising a sequence of laterally extensive aquifers and aquitards (sealing units) that extend from the deep saline storage formation to the uppermost freshwater aquifers. Based on the results from a variety

of sensitivity cases, the authors concluded that the hydraulic characteristics of sealing units strongly affect the lateral and vertical volumes affected by pressure buildup.

Nicot (2008) employed a single-phase flow model to simulate the regional-scale brine flow processes in response to hypothetical future CO₂ sequestration in the Texas Gulf Coast Basin, approximating the injection of CO₂ by adding equivalent volumes of saline water. Built on a calibrated regional-scale groundwater flow model, the single-phase flow model reasonably represents the far-field processes and basin-scale impacts, without accounting for local two-phase CO₂–brine flow, variable density effects, and CO₂ compressibility effects (Nicot et al., 2008a). Yamamoto et al. (2009) reported on a high-performance multi-million gridblock model capable of evaluating local CO₂–brine flow processes together with large-scale groundwater patterns, applied to a possible future CO₂ storage scenario in the Tokyo Bay, Japan. The above model results suggest that the basin-scale hydrogeologic impacts related to pressure buildup and brine migration may affect the way CO₂ storage projects will be regulated. These impacts may in fact be the limiting factor determining the CO₂ sequestration capacity in large sedimentary basins.

In this paper, we elaborate on the issue of large-scale pressure buildup limitations on storage capacity and ensuing regulatory aspects, using the Illinois Basin in the midwest United States as an illustrative example. The Illinois Basin, a deep saline sedimentary basin of roughly 155,000 km² encompassing most of Illinois, southwestern Indiana, and western Kentucky in the United States (Fig. 1), hosts a significant number of large stationary CO₂ emitters (MGSC, 2005; NETL, 2009). If mitigation of climate change via carbon capture and storage is seriously attempted in the United States, the Illinois Basin will be one of the most important target regions for geologic storage of carbon dioxide in the United States. Extensive site characterization has been completed and a large-scale field project is ongoing to demonstrate the suitability of the regionally extensive Mount Simon Sandstone as a storage formation. We developed a regional-scale three-dimensional (3-D) model for the Illinois Basin that captures both the local-scale CO₂–brine flow processes and the large-scale groundwater flow patterns in response to a hypothetical future carbon sequestration scenario, which involves twenty individual CO₂ storage sites in a core injection area most suitable for long-term storage.

Section 2 introduces briefly the geologic and numerical models and describes selected prediction results. A comprehensive paper with focus on the model development and detailed results is being published concurrently (Zhou et al., submitted for publication). In Section 3, the model results are used to demonstrate that CO₂ storage capacity of a given basin, estimated using the effective pore volume available for safe trapping of CO₂, might have to be revised down based on assessment of pressure buildup and its potential hydrogeologic impacts on freshwater aquifers. Section 4 discusses some of the challenges in making reliable predictions of large-scale hydrogeologic impacts of CO₂ sequestration projects and makes tentative suggestions for better understanding and constraining the processes and parameters driving brine pressurization. Section 5 finally demonstrates the importance of understanding large-scale pressure and brine migration patterns for regulating CO₂ storage projects.

While the model development is based on the best information currently available, we caution that the Illinois Basin study discussed here is preliminary, that some simplifications had to be made in the model design, and that considerable uncertainty regarding the large-scale geological model needs to be acknowledged. Further site characterization efforts are underway, and model predictions of hydrogeologic impacts may change as more details for future storage scenarios are being developed. Readers

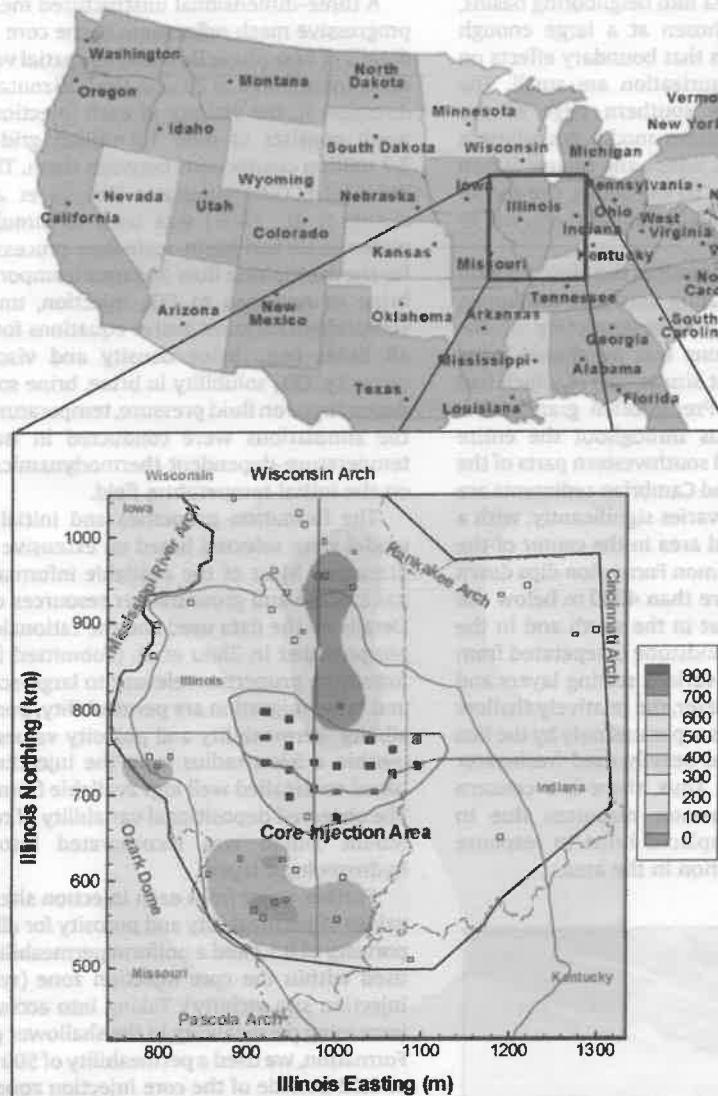


Fig. 1. Thickness of the Mount Simon Sandstone (shaded contours in m). Also shown are the boundary of the model domain as a black line, the Illinois Basin boundary as a gray line, deep boreholes used for developing the geological model as hollow squares, the core injection area as a blue line, 20 hypothetical injection sites as solid squares, and south–north and west–east cross sections (see Fig. 2) as red lines. Illinois Easting and Northing coordinates are given in km.

should view this paper as an attempt to illustrate the important implications of basin-scale impacts of CO_2 sequestration, using a realistic but not necessarily accurate example that may be representative of many other sedimentary basins worldwide.

2. Illinois Basin modeling example

The Illinois Basin region has annual CO_2 emissions of slightly over 300 Mt (million metric tonnes) from stationary sources, primarily from large coal-fired power plants (USDOE, 2008). The primary target for CO_2 storage in the region is the Mount Simon Sandstone, a deep saline aquifer of high permeability, porosity, and sufficient thickness, with proven regional seals (MGSC, 2005). With a large estimated storage capacity (USDOE, 2008), the Mount Simon Formation is expected to host multiple sequestration sites, based on the current portfolio of industrial point sources and the projected future developments.

A regional-scale simulation model was developed for the Illinois Basin region to predict the hydrogeological changes in response to a hypothetical future carbon sequestration scenario, which involves twenty individual CO_2 storage sites spaced 30 km

apart in a core injection area in the center of the basin. The core injection area was selected based on favorable geological settings, sufficient thickness and depth, minimum distance to gas storage fields, and proximity to large stationary CO_2 sources. At each site, an annual injection rate of 5 Mt CO_2 was used for an injection period of 50 years. The total injected mass of 100 Mt per year represents one third of the current annual CO_2 emissions from large stationary sources in the Illinois Basin region. Over the 50 years, the cumulative CO_2 mass adds up to 5000 Mt of CO_2 , which corresponds to an additional fluid volume of about 5.5 km^3 (assuming a CO_2 density of 0.9 metric tonnes/ m^3) that needs to be stored in the Mount Simon Formation.

2.1. Geologic and numerical model

The model domain covers an area of roughly 570 km by 550 km (Fig. 1), a total area of $241,000 \text{ km}^2$ extending beyond the actual basin boundary. The domain includes the core injection area and a far-field area away from the injection sites where regional pressure changes and brine migration processes need to be assessed. With the Mount Simon Formation an open hydrogeologic system that

extends far beyond the Illinois Basin area into neighboring basins, the lateral model boundaries were chosen at a large enough distance from the injection centers such that boundary effects on CO₂ plume migration and brine pressurization are small. The model domain extends north to the southern edge of the Wisconsin Arch (Fig. 1). The southwestern model boundary is formed by the Ozark Uplift in Missouri, where the Mount Simon Formation becomes thin or disappears. To the south, the model domain ends at the extensive and dense faults zones there, and to the east, it ends at the Cincinnati Arch.

In the vertical direction, the model comprises the Mount Simon Sandstone, the overlying Eau Claire sealing unit, and the upper, weathered portion of the underlying granite baserock (Fig. 2). The stratigraphic model for these formations was developed using boreholes that penetrate into the Mount Simon, half of which had been drilled down to the underlying Precambrian granite. The Mount Simon Sandstone is continuous throughout the entire Illinois Basin, except in the southern and southwestern parts of the Basin, where Precambrian highs exist and Cambrian sediments are absent. The thickness of the formation varies significantly, with a maximum of 700 m in the bowl-shaped area in the center of the basin. The top elevation of the Mount Simon Formation dips down from shallow parts in the north to more than 4000 m below the mean sea level in the south. Notice that in the south and in the center of the basin, the Mount Simon Sandstone is separated from freshwater resources by a sequence of various sealing layers and saline aquifers. In northern Illinois, however, the relatively shallow portion of the Mount Simon Formation is separated only by the Eau Claire regional seal from a valuable and heavily used freshwater aquifer, the Ironton–Galesville aquifer. Thus, there is a concern about potential degradation of freshwater resources due to pressure buildup and migration of displaced brine in response to future deployment of CO₂ sequestration in the area.

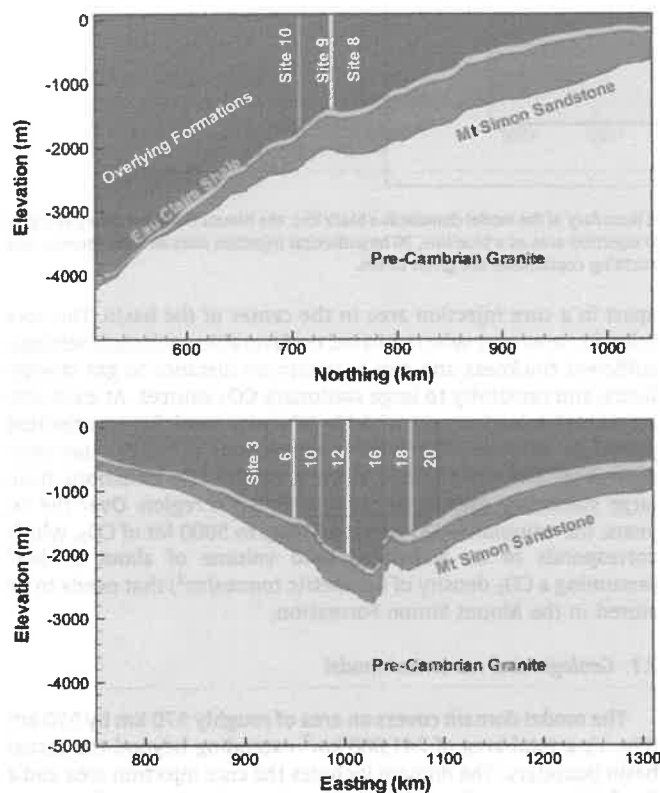


Fig. 2. North-south and east-west cross sections showing simplified stratigraphy and location of CO₂ storage sites.

A three-dimensional unstructured mesh was constructed with progressive mesh refinement in the core injection area to capture details of two-phase flow and its spatial variability, using local grid refinement down to 20 m in the horizontal and 10 m in the vertical direction in the vicinity of each injection center. The entire 3-D mesh consists of over 1.2 million grid-blocks and more than 3.7 million connections between them. The parallel version of the TOUGH2/ECO2N simulator (Pruess et al., 1999; Pruess, 2005; Zhang et al., 2008) was used to simulate simultaneously the plume-scale and basin-scale flow processes. The simulator solves for the multiphase flow and multicomponent transport of CO₂ and brine in response to CO₂ injection, under full account of the comprehensive constitutive equations for the thermodynamics of all fluids (e.g., brine density and viscosity, CO₂ density and viscosity, CO₂ solubility in brine, brine solubility in CO₂, and their dependence on fluid pressure, temperature, and salinity). Note that the simulations were conducted in isothermal mode, though temperature-dependent thermodynamics were considered based on the initial temperature field.

The formation properties and initial conditions used in the model were selected based on extensive investigation of existing literature. Most of the available information stems from natural gas storage and groundwater resources development in the area. Details on the data used and the rationale for parameter selection are provided in Zhou et al. (submitted for publication). The key formation properties relevant to large-scale pressure propagation and brine migration are permeability, porosity, and pore compressibility. Permeability and porosity values near each injection site (within a 5 km radius from the injection center) were assigned based on detailed well logs available from a small number of wells. The observed depositional variability of rock properties within the Mount Simon was incorporated into the model using 24 hydrogeologic layers.

Further away from each injection site, the model uses average values of permeability and porosity for all model layers. A uniform porosity of 0.12 and a uniform permeability of 100 millidarcy were used within the core injection zone (with the exception of the injection site vicinity). Taking into account the regional trend of increasing permeability in the shallower parts of the Mount Simon Formation, we used a permeability of 500 millidarcy and a porosity of 0.12 outside of the core injection zone (Birkholzer et al., 2008; Zhou et al., submitted for publication). The overlying Eau Claire seal has a permeability of 1 microdarcy and a porosity of 0.15. This value represents the effective regional-scale vertical permeability of a low-permeability caprock with some local imperfections (Zhou et al., submitted for publication). To evaluate sensitivity to seal permeability, we ran an alternative simulation case with a vertical permeability value of 0.01 microdarcy, based on measurements conducted on undisturbed core. The upper, weathered portion of the granite baserock, about 40 m thick, has a permeability of 0.1 microdarcy and a porosity of 0.05. This unit was included in the model because some downward migration of brine occurs in response to pressure buildup in the storage formation. In contrast, the underlying intact granite can be considered impermeable for all practical purposes.

No direct measurements of pore compressibility were available for the Mount Simon Sandstone in the region. Therefore, we back-calculated a pore compressibility value of $3.71 \times 10^{-10} \text{ Pa}^{-1}$ based on a pumping test conducted in the Hudson natural gas storage field in 1969 (ISWS and Hittman Associates, 1973; Visocky et al., 1985). This value, quite reasonable for consolidated sandstones, was used throughout the model domain. The parameters needed to describe the CO₂–brine two-phase flow system were based on Doughty et al. (2008).

Vertical profiles of *in situ* temperature and salinity were available from several temperature and salinity logs available in

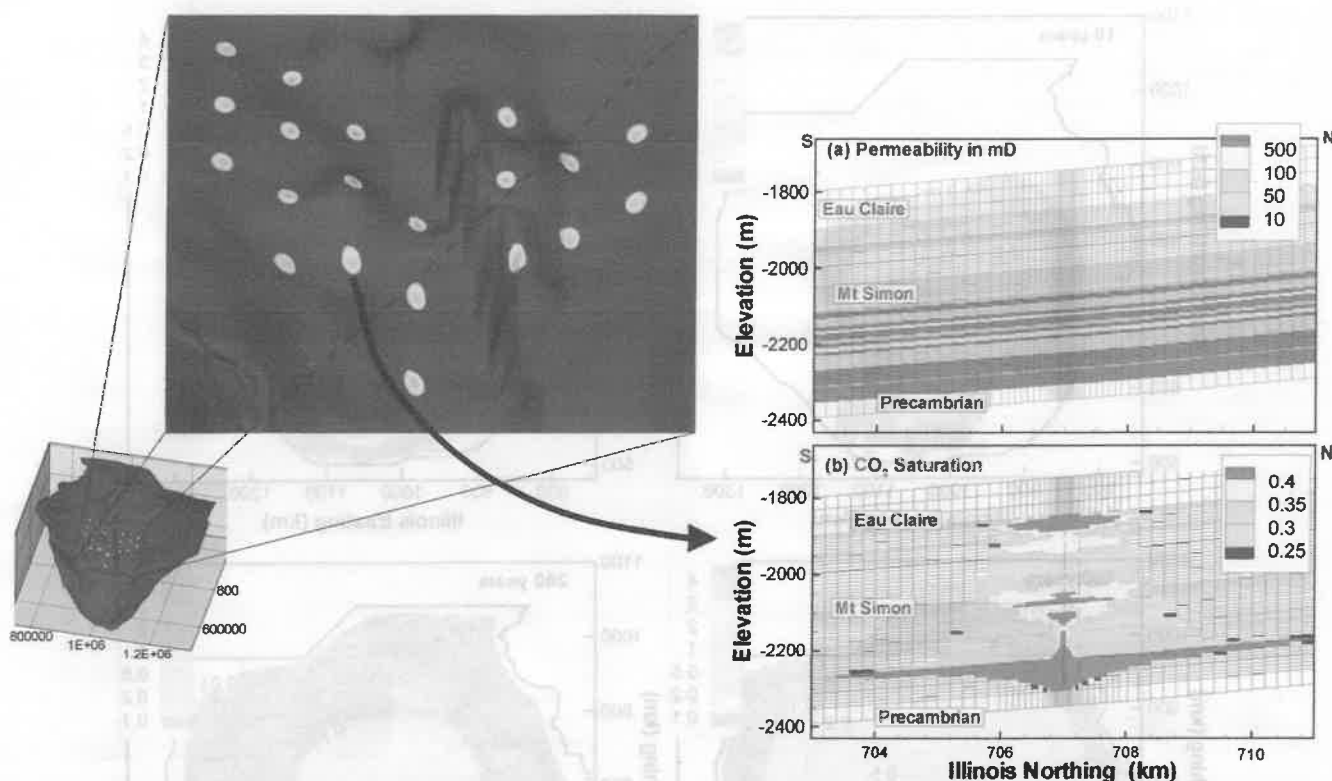


Fig. 3. Graph on left shows contours of CO₂ saturation at 50 years of injection at elevation of maximum plume extent. Graphs on right show (a) vertical permeability field within the Mount Simon Formation (in millidarcy), and (b) CO₂ saturation in a south–north cross section for a selected injection site. The permeabilities assigned to the overlying seal and underlying baserock are 1 and 0.1 microdarcy, respectively.

the area. On the basis of these profiles, an equilibrium (or hydrostatic) condition was simulated, and the resulting distributions of pressure, salinity, and temperature were used as initial conditions for the prediction of the basin-scale environmental impacts of CO₂ injection and storage.

Fixed pressure, temperature, and salinity conditions were defined at the lateral model boundaries (first-type Dirichlet conditions). As mentioned before, the Mount Simon Formation continues to be present beyond the Illinois Basin, allowing brine to escape laterally into neighboring basins further north, west, and east. Since the expected pressure changes caused by CO₂ injection in the basin center are rather small at the model boundaries, we were able to restrict the model to the domain shown in Fig. 1 and define the first-type boundary conditions at the interface with neighboring basins. The effect of other types of lateral boundary conditions (e.g., closed-boundary conditions, infinite-acting aquifer boundary condition) is evaluated in Section 2.2.

The boundary conditions chosen for the top and the bottom of the model domain also deserve some discussion. To reduce the computational load, the model domain comprises only the Mount Simon Formation, the Eau Claire caprock, and the weathered portion of the granite baserock; the overlying sequence of aquifers and aquitards above the primary seal is not included in the model. Since we were interested in an upper-bound estimate of diffuse brine migration from the storage formation through the seal into overlying units, we handled the top of the Eau Claire caprock with a Dirichlet boundary condition assigning fixed pressure, temperature, and salinity values, thereby allowing displaced brine to flow upward and out of the model domain into the overlying sequence of layers, which provide secondary storage space. As discussed in Section 2.2 below, the simulation case with seal permeability of 1 microdarcy represents conditions where diffuse vertical brine migration can significantly attenuate pressure buildup in the

storage formation, while the alternative simulation case with 0.01 microdarcy is virtually identical to a case with a closed top-boundary behavior. The bottom boundary underlying the weathered portion of the granite is assumed to be impermeable in all simulation cases.

2.2. Model results

Illustrative model results showing the characteristics of individual CO₂ plumes after 50 years of continuous injection are presented in Fig. 3. CO₂ is injected into an arkosic unit of high permeability and porosity present in the deep parts of the Mount Simon. This ensures sufficient injectivity, and takes advantage of the intervening shale–sandstone sequences of the Mount Simon, which help retard upward migration of CO₂. The maximum size of CO₂ plumes, on the order of 6–8 km, is smaller than the lateral separation of about 30 km between different injection sites, suggesting that merging of plumes would only occur after very long times, if at all.

The close-up view in the vertical cross section highlights the variability of CO₂ saturation and how it relates to the internal layering and permeability differences within the Mount Simon. In addition to the local heterogeneity structure, the shape of CO₂ plumes is affected by the thickness of the Mount Simon and the slope of the structural surfaces, while pressure interference from neighboring injection sites has little effect on overall plume shape (evident from evaluation of center plumes versus edge plumes, not shown here). The details of CO₂ saturation in Fig. 3 emphasize the importance of local mesh refinement to resolve smaller-scale processes, such as structural trapping from internal layering. Overall, our modeling results suggest favorable conditions for safe storage and effective trapping of CO₂, including the thick arkosic unit of high porosity and permeability with sufficient injectivity at

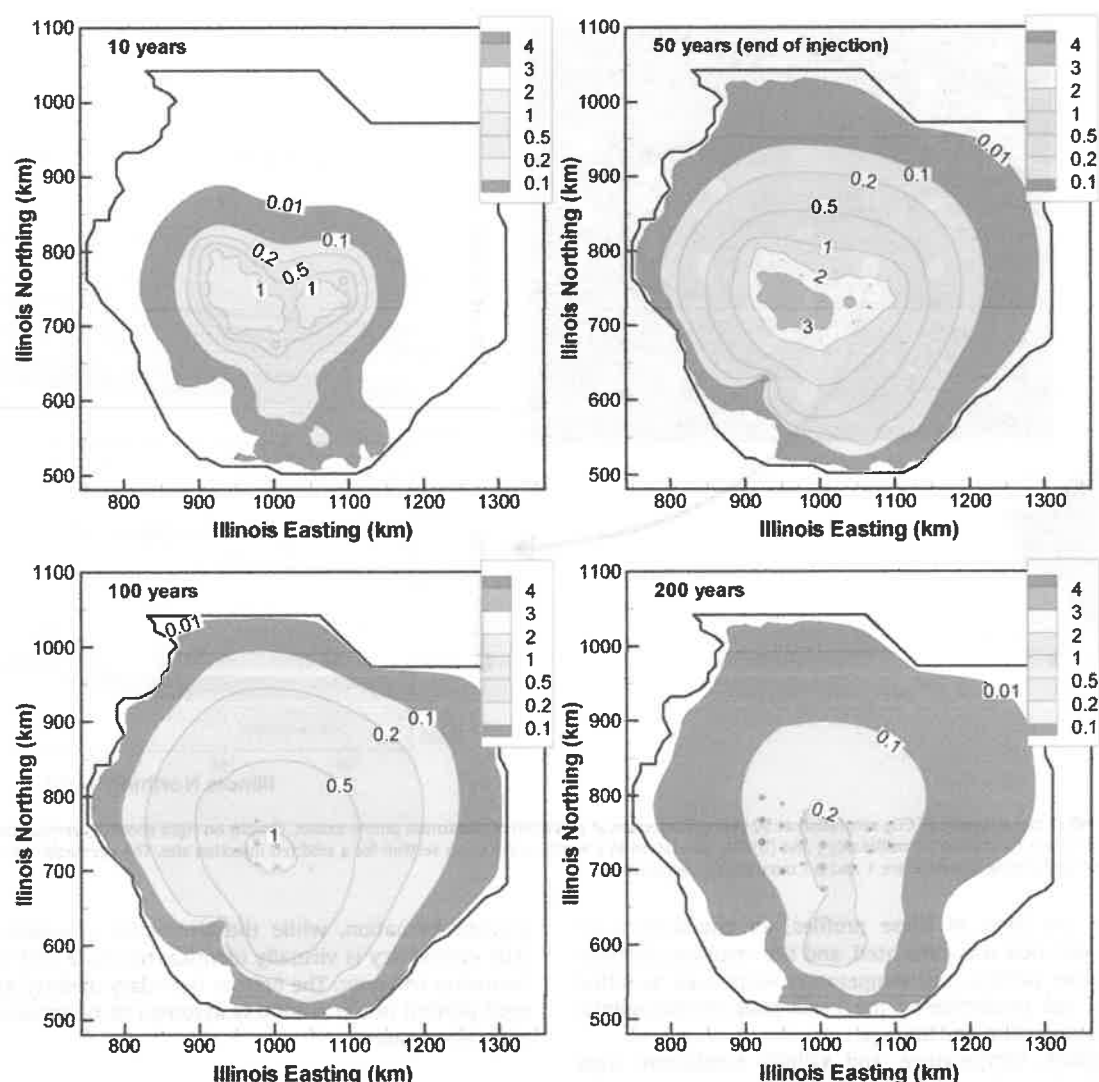


Fig. 4. Contours of pressure increase (in MPa) at the top of the Mount Simon Sandstone at 10 and 50 years (after start of injection) during the 50-year injection period, and 100 and 200 years during the post-injection period. The pressure cut-off value is 0.01 MPa (i.e., pressure buildup below 0.01 MPa is not colored).

the bottom of the Mt. Simon, extensive layering with shaly and sandy deposits in the middle and upper portions of the Mt. Simon, and a thick, low-permeability Eau Claire seal for long-term structural trapping.

Fig. 4 shows the simulated pressure buildup (in MPa) at the top of the Mount Simon at 10, 50 (end of injection period), 100, and 200 years after start of injection. After 10 years, a continuous region with pressure increases of 1 MPa or more has evolved in the core injection area, indicating strong pressure interference between different storage sites located at distances of 30 km or more. After 50 years of injection (i.e., after injection of 5000 Mt of CO_2), the pressure buildup in the core injection area has increased to between 2 and 3 MPa, with peak values above 4 MPa observed near the injection centers. While this is a considerable pressurization over a large region in the center of the basin (of approximately 24,000 km^2), the pressure increase is less than the regulated maximum value above which fracturing of the formation or the caprock may be expected (see further discussion in Section 3). Geomechanical studies may be necessary to evaluate whether the predicted pressure and stress field changes could lead to reactivation of potentially existing faults in the area (e.g., Rutqvist et al., 2007).

With respect to the far-field impacts of CO_2 injection and storage, however, pressure changes propagate extremely far, as much as 150–200 km beyond the core injection area. Eventually the pressure pulse reaches the boundaries of the model domain and thus affects almost the entire basin model, an area of 241,000 km^2 . After 50 years of injection, pressure buildup is on the order of 0.1–0.2 MPa in the northern part of the Illinois Basin where the Iron-ton-Galesville freshwater aquifer overlies the Eau Claire seal. After CO_2 injection ends, the pressure buildup in the core injection area decreases quickly to moderate values around 0.5–1 MPa. As the strong initial pressure perturbation in the core injection area flattens out, the area affected by moderate pressure changes continues to expand laterally.

In a hypothetical storage formation with closed lateral and vertical boundaries, the additional fluid injected into the storage formation would be accommodated only by the compressibility of the rock medium and the fluids, responding to the pressure buildup caused by injection. If fluids can neither exit through the boundaries of the basin nor are allowed to migrate into over- and underlying units, the storage formation will remain at over-pressure indefinitely even after injection ends. In reality, geologic formations are never fully “closed”, meaning that there will always

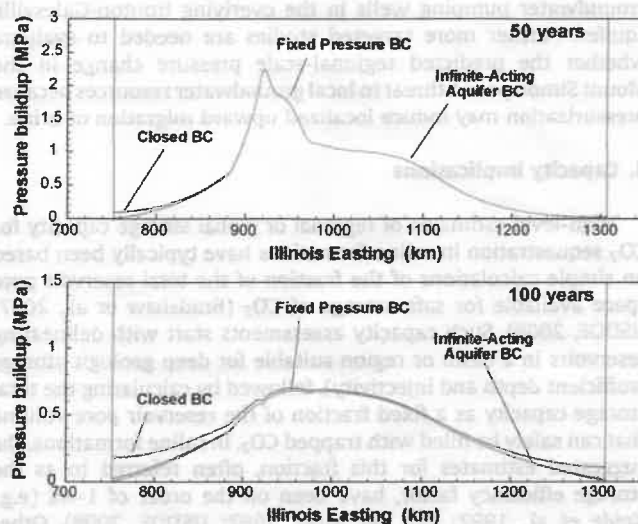


Fig. 5. Profiles of pressure increase (in MPa) along the east–west direction at Illinois Northing of 800 km, for three cases of lateral boundary conditions: a fixed pressure boundary condition (base case, in green), a closed-boundary condition (in blue), and an infinite-acting aquifer boundary condition (in red). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

be some fluid flow across the boundaries. For example, the sealing units in geologic setting suitable for CO_2 storage have typically very small permeability, but are not impermeable. The same would apply to sealing faults that may laterally confine the subsurface space. Or, as is the case with the Illinois Basin, there is no lateral confinement because the storage formation is hydraulically connected to aquifers in neighboring basins. In such “open” systems, pressurization of the storage formation is temporary. With time, as brine is slowly released at the basin boundaries and through the seals, the system progresses towards a new quasi-equilibrated state and pressures eventually return to hydrostatic conditions (Nicot, 2008). The following discussion elucidates these transient processes for the Illinois Basin example and illustrates the importance of choosing appropriate model boundary conditions.

Fig. 5 shows pressure changes along an east–west profile which runs just north of the core injection area at Illinois Northing of 800 km. Three simulation cases with different lateral boundary conditions are depicted. The first case uses a fixed pressure condition which sets pressure buildup to zero along the boundary (i.e., the base case, as shown in Fig. 4). The second case assumes a closed boundary where no fluids can escape into neighboring basins. The third case utilizes a boundary condition with an infinite-acting aquifer attached to the outer boundary, with grid-blocks extending approximately 200 km beyond the original model domain and their properties and thickness set equal to the Mount Simon at the boundary. This boundary condition provides a simplified method for representing the impacts of neighboring basins, allowing brine to move across the domain boundaries but without forcing pressure buildup to be zero as in the base case. All three simulation cases have virtually identical pressure profiles at the end of the injection period (50 years), with the exception of a small pressure increase observed at the eastern model boundary in the closed-boundary case. The effect of a no-flow boundary condition is more visible at 100 years, where pressure buildup is seen along both the eastern and western model boundary. In contrast, the other two cases are very similar, confirming that the fixed pressure boundary condition assumed in the base case allows for a reasonable representation of the brine release into neighboring basins.

The impact of diffuse brine release in vertical direction, through the primary seal overlying the storage formation, is illustrated in

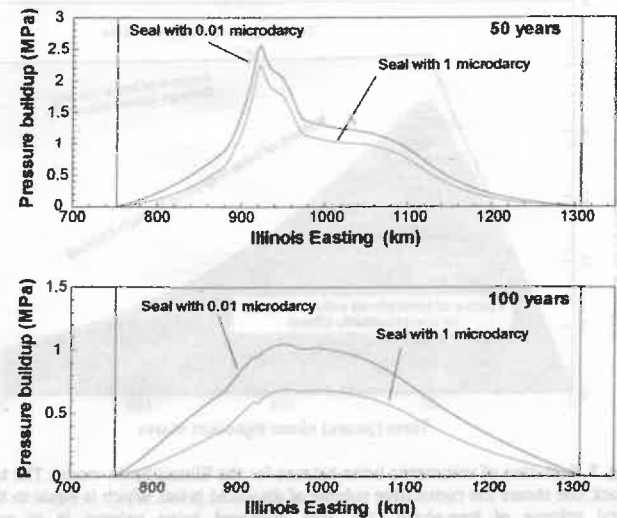


Fig. 6. Profiles of pressure increase (in MPa) along the east–west direction at Illinois Northing of 800 km, for two cases of Eau Claire seal permeability: a permeability value of 1 microdarcy (base case, in green) and a permeability value of 0.01 microdarcy (in red). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

Fig. 6, which shows pressure buildup along the same east–west cross section for two simulation cases: the base case with a seal permeability of 1 microdarcy as well as a sensitivity case with a seal permeability of 0.01 microdarcy. (While results are not shown here, this sensitivity provides pressure results virtually identical to a case with an impermeable seal.) The profiles show clearly the important pressure attenuation caused by vertical brine migration from the storage formation into overlying layers, as pressure values in the lower permeability case are about 10% (50 years) to 50% (100 years) higher than in the base case. These findings are consistent with results from a sensitivity analysis for a multi-layer domain with varying seal permeabilities conducted in Birkholzer et al. (2009). These authors concluded that low-permeability formations suitable for long-term trapping of CO_2 may allow for the egress of large brine volumes out of the storage formation (and correspondingly a considerable pressure mitigation in the storage formation) if the seal permeability is on the order of a microdarcy or higher. It follows that a good understanding of the regional-scale permeability of the confining units is a prerequisite for evaluating the large-scale pressure perturbations generated by CO_2 storage.

Fig. 7 provides a volumetric brine balance for the Illinois Basin model as a function of time, for the base case simulation. The top black line shows the cumulative volume of displaced brine, which is equal to the total volume of injected CO_2 (excluding dissolved CO_2), under storage conditions. This displaced brine volume is in part accommodated by pore and fluid compressibility in response to pressure buildup in the model domain; another part is contributed by brine flow out of the model domain via the lateral and vertical boundaries. The total volume of displaced brine increases almost linearly during the injection period to a maximum value of about 5.2 billion m^3 (5.2 km^3), then reduces slightly as more supercritical CO_2 dissolves. At all times, the total displaced brine volume equals the sum of the (1) compressibility-related pore volume increase and (2) the cumulative brine volume released through the boundaries.

As Fig. 7 suggests, compressibility effects clearly dominate during the injection phase and the early post-injection phase, consistent with the observed pressure trends. Notice that formation compressibility and brine compressibility each contribute about 50% of the total compressibility effect. Brine

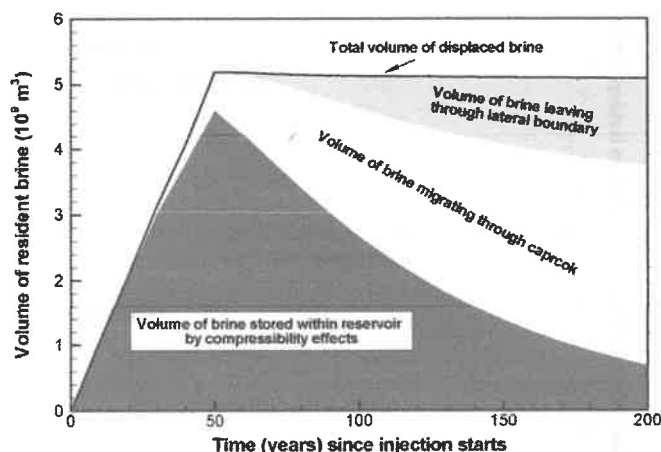


Fig. 7. Evolution of volumetric brine balance for the Illinois Basin model. The top black line shows the cumulative volume of displaced brine, which is equal to the total volume of free-phase CO_2 . This displaced brine volume is in part accommodated by pore and fluid compressibility in response to pressure buildup in the model domain; another part is contributed by brine flow out of the model domain via the lateral and vertical boundaries.

compressibility is $3.38 \times 10^{-10} \text{ Pa}^{-1}$ at average pressure and temperature conditions, while the selected pore compressibility is $3.71 \times 10^{-10} \text{ Pa}^{-1}$. Later, as the system slowly progresses towards quasi-equilibrium, compressibility effects become less relevant, while more and more fluids egress from the model domain. At 50 years (the end of the injection period), the cumulative volume of brine released through the boundaries accounts for 9% of the total displaced brine volume; at 200 years, it accounts for 86%. At early times (up to 50 years), brine flow out of the model domain occurs exclusively into the overlying aquifer, as pressure effects have not yet reached the lateral boundaries. At 200 years, 26% of the total brine release occurs laterally into neighboring basins.

The question arises whether the large volumes of brines slowly released from the storage formation have an impact on the hydrogeologic conditions outside of the domain, i.e., in neighboring basins or in the overlying sequence of layers. Notice that these releases across the boundaries have very small vertical and lateral flow rates, typical of natural groundwater flows in deep basins (Birkholzer et al., 2009). These small velocities translate into large fluid volumes of displaced brine only because they occur over very large areas. For example, the Darcy flow velocity across the top model boundary, averaged over the model domain, is only about 0.47 mm/year at 50 years of injection. At the same time, the average Darcy velocity across the lateral boundaries is on the order of 0.2 m/year, with a maximum velocity of 1.2 m/year. The small migration distances of saline water associated with these boundary flows do not constitute a concern for the groundwater resources in overlying aquifers or neighboring basins.

Similarly, the simulated changes in salinity experienced in the model domain as a result of lateral migration and vertical migration of brine are very small, posing no direct threat to groundwater quality (for brevity, salinity changes are not shown in this paper). Salinity issues could become a concern, however, if deep saline water from the Mount Simon was pushed upward into overlying freshwater aquifers via localized pathways, such as conductive faults or open boreholes, which are currently not included in the model. Also not accounted for in the model is the variable sand content in the Eau Claire seal. It was suggested that the Eau Claire seal might have higher sand content (and thus locally higher permeability) in the northern part of the Illinois Basin, which could allow brine to be pushed towards the

groundwater pumping wells in the overlying Ironton-Galesville aquifer. Further more targeted studies are needed to evaluate whether the predicted regional-scale pressure change in the Mount Simon pose a threat to local groundwater resources because pressurization may induce localized upward migration of brine.

3. Capacity implications

High-level estimates of regional or global storage capacity for CO_2 sequestration in saline formations have typically been based on simple calculations of the fraction of the total reservoir pore space available for safe storage of CO_2 (Bradshaw et al., 2007; USDOE, 2008). Such capacity assessments start with delineating reservoirs in a basin or region suitable for deep geologic storage (sufficient depth and injectivity), followed by calculating the total storage capacity as a fixed fraction of the reservoir pore volume that can safely be filled with trapped CO_2 . In saline formations, the suggested estimates for this fraction, often referred to as the storage efficiency factor, have been on the order of 1–4% (e.g., Koide et al., 1992; van der Meer, 1992; USDOE, 2008). Other researchers have calculated storage potential based on the solubility potential of CO_2 (e.g., Bachu and Adams, 2003). In either way, issues related to pressure buildup or brine migration have not been considered in most regional or global storage estimates, i.e., there is an implicit assumption that the storage capacity is not constrained by pressure buildup and brine migration, and associated impacts on the environment.

As pointed out by Bradshaw et al. (2007), simplistic capacity estimates at the regional or global level can be highly variable and in some instances contradictory, due to the different trapping mechanisms that can occur, and the highly variable nature of geologic settings. These authors suggest that a consistent set of guidelines needs to be developed with clear definitions, rules, and best practices. We strongly agree with Bradshaw et al. (2007), but emphasize the need to base capacity estimates not just on formation suitability with respect to injectivity and trapping of CO_2 , but also on the possible basin-scale hydrogeologic impacts caused by adding large volumes of fluids. Our work presented here, as well as recent studies reported in van der Meer and van Wees (2006), van der Meer and Egberts (2008), van der Meer and Yavuz (2008), Zhou et al. (2008), Nicot (2008), and Birkholzer et al. (2009), suggest that environmental concerns related to large-scale pressure buildup may be the limiting factor in carbon dioxide sequestration capacity.

To illustrate the potential impacts of pressure-related capacity constraints, let us compare our hypothetical future injection scenario studied in Section 2 with the current high-level capacity estimates for the Mount Simon, which were based on pore volume considerations. The annual rate of CO_2 injection in our simulation scenario is 100 Mt, about one third of the total CO_2 emissions from current large point sources in the Illinois Basin, and the total injected fluid mass after 50 years is 5000 Mt CO_2 . In contrast, the total estimated CO_2 storage capacity for the Mount Simon Sandstone, calculated as a fraction of the total reservoir pore space in suitable parts of the Mount Simon, ranges from 27,000 to 109,000 Mt CO_2 (USDOE, 2008). Thus, the stored CO_2 volume in our simulation scenario corresponds to 18.5% of the lower bound and 4.6% of the upper bound of this range. If CO_2 injection were to continue at the assumed injection rate for a much longer period (or if CO_2 was injected at a higher annual rate), such that the estimated storage capacity was fully utilized, the pressure buildup would be much stronger and extend over a much larger area than seen in Fig. 4. While we have not simulated the expected subsurface conditions for such a full-capacity storage scenario, we believe that storage of 27,000–109,000 Mt of CO_2 in the Illinois Basin would be difficult because of (1) the stronger pressure buildup within the

core injection area, which would jeopardize caprock geomechanical integrity, and (2) the stronger pressure buildup and brine migration on the basin scale, which might have environmental impacts on freshwater aquifers in northern Illinois or on neighboring basins.

With respect to caprock integrity, the maximum pressure increase in the current simulation scenario is about 3–4 MPa near the center of individual storage sites, which corresponds to an average fractional pressure buildup, defined as the ratio of pressure increase to pre-injection pressure, of 0.25. (Introduction of additional injection wells at each site may have some local effects, but would not significantly reduce the overall pressure buildup in the core injection area because of the strong interference between individual storage projects.) This value of 0.25 is less than the regulated fractional pressure increase of 0.65 used in the region. If a value of 0.65 (or a maximum pressure buildup of up to 9 MPa) is used and a quasi-linear relationship between injection rate and pressure buildup (Zhou et al., 2009) is considered, the total injection volume assumed in our simulation scenario could be increased from 5000 to 13,000 Mt. However, regulators might be reluctant to allow fluid pressurization of such magnitude over such a large area, or, as mentioned before, smaller threshold pressures may be required if geomechanical studies indicate the potential for reactivation of potentially existing faults.

We may thus conclude that current high-level estimates of regional or global storage capacity in deep saline formations need to be revisited based on the evaluation of pressure buildup and environmental impacts, and we may expect that these estimates would have to be corrected downward in many cases. Because of the complex nature of large-scale hydrogeologic processes, such capacity re-evaluation needs to be site- or basin-specific; it is not conducive to generalization or quick assessment with limited data. It should be noted that pressure-related capacity constraints might be relaxed by creating additional store space in the deep storage reservoirs via brine extraction. The extracted brine could be stored in appropriate overlying/underlying formations, or could be pumped to the surface and desalinated for water supply. While such pressure management schemes can provide a way around capacity limitations, their technical and economic feasibility needs to be evaluated in further studies.

4. Prediction uncertainties

From the standpoint of fluid dynamics, brine pressurization and migration is a much simpler process than two-phase flow of CO₂–brine mixtures. The challenge for predictive modeling is not in fundamental process issues, but rather in obtaining a sufficiently detailed and realistic characterization of large subsurface volumes, in order to be able to place meaningful and reliable limits on quantities and pathways for pressure buildup and brine migration. The propagation of pressure changes in a porous medium is a function of the hydraulic diffusivity D of the formation. Hydraulic diffusivity is defined as the ratio of transmissivity to storativity, given as $D = k/(\beta\phi\mu)$, where k is formation permeability, β is compressibility of both the brine and the pore structure, ϕ is porosity, and μ is dynamic viscosity of the brine. For a given D , the propagation radius R of a pressure wave in a two-dimensional radial system with constant thickness and homogeneous properties can be approximated as $R \approx \sqrt{2Dt}$, where t is the time since injection starts (Nordbotten et al., 2004). We apply this approximate equation below to demonstrate that uncertainties in the key parameters for pressure propagation can strongly affect the extent of the pressure-affected region.

Using the formation properties chosen for the Mount Simon simulation model outside of the core injection zone (see Section 2.1), i.e., $k = 500$ millidarcy ($=5 \times 10^{-13}$ m²), $\beta = 7.09 \times 10^{-10}$ Pa⁻¹

(which comprises contributions from brine compressibility, 3.38×10^{-10} Pa⁻¹, and pore compressibility, 3.71×10^{-10} Pa⁻¹), $\phi = 0.12$, and $\mu \approx 0.0005$ Pa s, D becomes approximately 11.7 m²/s. This translates into a pressure propagation radius from the core injection zone of $R \approx 86$ km after 10 years and $R \approx 190$ km after 50 years, which is in reasonable agreement with the model predictions in Fig. 4. A change in hydraulic diffusivity by one order of magnitude, arguably a reasonable uncertainty range for large-scale hydraulic properties, would translate into a change in pressure propagation radius by roughly a factor of three. In other words, if hydraulic diffusivity is smaller by a factor of 10, which could be caused by a smaller permeability, larger compressibility or porosity, or a combination thereof, the extent of the pressure-affected region outside of the core injection area would reduce from 190 km to only 60 km. This makes a considerable difference with respect to the size of the Area of Review that would have to be characterized in the case of multiple-site sequestration in the region.

Additional factors that are not well understood or hard to characterize can further increase uncertainty about large-scale hydrogeologic impacts, for example the possible dampening of pressure propagation across faults, the far-field effect of small-scale and intermediate-scale heterogeneity (e.g., sand-shale interbedding), or the possibility of pressure relaxation by brine flow into overlying and underlying units. Notice also that the approximate propagation distance calculated above is not a measure of the possible magnitude of the pressure perturbation. While a decrease in permeability and an increase in compressibility have the same effect on propagation distance, the magnitude and spatial distribution of pressure changes would be very different. A smaller permeability value causes less far-field pressurization, but higher pressure buildup in the core injection area, possibly up to the point that injectivity or geomechanical damage may become a concern. While a higher compressibility value also causes less far-field pressurization, the pressure buildup in the core injection area would be reduced as well, as more storage volume per unit volume of rock is created from the same overpressure.

It is clear that a comprehensive site characterization and data review of deep saline formations on the basin scale are needed to allow for reliable prediction of regional brine pressurization and migration; the extent, geology, hydrology, and hydraulic connectivity of deep hydrogeologic systems need to be well understood. It is also obvious that large CO₂ storage field experiments, such as the deployment phase tests soon to start in the United States (NETL, 2009), can be very useful for better understanding and constraining the processes and parameters driving brine pressurization. We strongly recommend making measurements of far-field brine pressurization a significant component of the monitoring strategy in these tests. However, the storage volumes achievable in such experiments, likely close to one million metric tonnes, may still be too small to allow extrapolation to the basin or regional scale. Possibly the best analog for an industrial-scale carbon storage project is the industrial-scale carbon storage project itself. In other words, the pressure monitoring conducted in the early phase of a industrial-scale project can provide valuable data for further pressure impacts during later project stages; these data would feed into periodic re-evaluation with improved prediction models. Similarly, in a basin with multiple storage sites, data from early projects can help to reliably estimate the expected pressure impact from later projects.

5. Implications for the evolving regulatory framework in the United States

While the regulatory environment for geologic carbon sequestration projects is still evolving, it is clear that one aspect of permitting is the protection of valuable groundwater resources.

Since groundwater quality can be affected by intrusion of CO₂ as well as by brine intrusion, the permitting requirements will need to include some assessment of CO₂ leakage risk as well as some assessment of large-scale pressure buildup and associated potential for brine migration. The United States Environmental Protection Agency (USEPA) has recently developed a draft regulation for geologic carbon sequestration under the Safe Drinking Water Act (SDWA), with its main focus being the protection of underground sources of drinking water from injection-related activities (USEPA, 2008). Most elements of the proposed rule are based on the existing framework of the Underground Injection Control (UIC) program, which regulates injection of hazardous and non-hazardous fluids, injection related to oil and gas production, injection related to solution mining operations, and some other types of injection operations.

USEPA requires in its proposed rule that an Area of Review is defined in which all penetrations intersecting the injection formation and confining units must be identified. The purpose is to determine the presence of features such as faults, fractures, and artificial penetrations, through which significant amounts of injected fluid could move into freshwater aquifers or displace native fluids into freshwater aquifers. It is acknowledged in the draft rule that “the CO₂ plume and pressure front associated with a full-scale geologic sequestration project will be much larger than for other types of UIC operations, potentially encompassing many square miles ... It is also possible that multiple owners or operators will be injecting CO₂ into formations that are hydraulically connected, and thus the elevated pressure may intersect or interfere with each other”. USEPA thus realizes that an Area of Review (1) can be extremely large and (2) is likely to be affected by intersecting pressure perturbations in a multiple-site scenario.

The example predictions of basin-wide pressure buildup illustrated in Fig. 4 clearly demonstrate the two points made above. Assuming that a threshold value of pressure increase can be defined to delineate the Area of Review and using reasonable thresholds of about 0.5 and 0.05 MPa (the basis of which will be discussed later in this paper), the Area of Review in our Illinois Basin sequestration scenario would encompass the entire center region of the basin, roughly 300 km by 300 km (for 0.5 MPa at 50 years) and 500 km by 500 km (0.05 MPa at 50 years), respectively. In other words, areas exceeding 100,000 km² would have to be characterized for conductive features and artificial penetrations would have to be tested for proper completion and plugging. This task would likely exceed the capacity and willingness of any single operator in the basin. Additional complexity arises as the large Area of Review would be the composite result of many storage sites operating simultaneously. Owners or operators would likely point out that their individual contribution to the Area of Review extent is only a fraction of the composite Area of Review.

The question arises as to how these regional impacts of geologic sequestration with multiple storage sites in a given basin can be effectively regulated. One possibility could be to regulate under a “first come, first serve” principle, where early applicants in a basin would have the advantage of delineating their Area of Review without consideration of other possible storage operations. Later applicants would have to develop their permitting case under consideration of the pressure impacts of all ongoing or approved operations in the region. The Area of Review for these applicants would be defined by the additional pressure increase expected from the new storage project, determination of which is not an easy task for an applicant because current and future impacts from all other operation need to be known. Also, later applicants might have higher operational costs because they may need to inject into a pressurized formation. The “first come, first serve” principle would favor early projects, a possible incentive for accelerated implementation of carbon capture and storage.

An alternative, more coordinated approach to regulating basin-scale multiple-site CO₂ sequestration is the hierarchical permitting model recently proposed by Nicot and Duncan (2008). These authors suggest two permitting levels: The first level (referred to as general permit) would involve an overarching federal or state agency to develop regional assessments of large brine reservoirs with the goal of characterizing them to the point that they are “sequestration ready”. The second level would involve permit applications for individual sites, with the expectation that (1) the burden faced by an applicant would be less because regional assessments have already been conducted, and (2) the permitting process for each site would be reviewed under the umbrella of a coordinated regional permit.

Expanding on Nicot and Duncan (2008), we suggest a general permit should handle all Area of Review tasks related to far-field pressure change and brine migration, while a single-site permit would focus on the local area near the projected site, including the area of the CO₂ plume and some yet-to-be-defined area beyond the plume extent where pressure impacts are highest. In our Illinois Basin example, individual applicants might be focusing on the core injection area shown in Fig. 1, while the responsible agency for a regional permit would conduct the necessary characterization and corrective action (e.g., plugging of improperly completed wells) activities outside of this core area. The responsible agency would also (1) oversee efforts to build reliable basin-scale simulation models for the region, (2) predict the large-scale hydrogeologic impacts for possible future sequestration scenarios in the region, (3) define the size of the Area of Review, and (4) estimate the maximum storage capacity in the basin based on the projected environmental impacts. The simulation model would be periodically re-evaluated as more storage projects go online and more monitoring data become available. Based on model predictions, new site applications would be evaluated and coordinated in the context of other existing and planned operations.

Of crucial importance for permitting of large storage projects is the question as to how the size of an Area of Review should be determined, in particular with respect to the hydrogeologic consequences of large-scale pressure buildup and possible brine migration into groundwater resources. While there is a general consensus that the region of maximum future CO₂ plume extent needs to be well characterized, it is not clear at present how to handle the much larger region of pressure impact in a site evaluation process. Can the size of an Area of Review be determined based on a threshold value of pressure buildup and, if so, how can this value be determined? While the draft regulation introduced by USEPA currently provides no guidance on this matter, one possible approach could be based on the existing framework of the Underground Injection Control (UIC) program. There, the Area of Review is computed as the region where the pressure increase experienced at any time would be able to lift saline formation water through a potentially existing open borehole to the bottom of an overlying freshwater aquifer. Because the brine being pushed upward has a higher density than the borehole fluid it displaces, upward migration of brine can only be sustained when the pressure increase in the formation exceeds a minimum value, which is mostly determined by the vertical distance and the initial density profile in the borehole. Nicot et al. (2008b) presented a method for calculating this minimum value and applied it to case studies from a site in the Central Valley in California and two sites in the Texas Gulf Coast region. Pressure threshold values ranged from 0.058 MPa for the Central Valley case up to 0.56 MPa for the Texas Gulf Coast cases, the difference mostly caused by the much higher salinity of the deep brines in the latter examples. The calculations assume that the pressure profiles are initially hydrostatic, a condition that may or may not be appropriate.

One may express concern that Area of Review estimates based on the potential existence of completely unplugged boreholes may be too conservative, particularly in regions not or not strongly affected by a long history of oil and gas exploration. Such estimates can be extremely large, as would be the case in our Illinois Basin example. Depending on the site conditions, other conduits for brine migration into freshwater aquifers may be more relevant, such as conductive faults or other caprock imperfections. In the Illinois Basin, the relatively few deep boreholes penetrating down to the Mount Simon Formation may not pose a threat at all as they are likely to be properly plugged, whereas a possibly higher permeability of the Eau Claire seal in the northern part of the basin could allow brine to be pushed towards the groundwater pumping wells in the overlying Ironton-Galesville aquifer. We believe that the size of an Area of Review cannot be determined from a generic one-size-fits-all approach. Rather, the detailed basin- and site-specific conditions, and the vulnerabilities of potential environmental receptors to brine migration, need to be accounted for in any Area of Review definition. We also believe that the site characterization requirements for the region of maximum future CO₂ plume extent would be different from (and likely more stringent than) the requirements imposed on characterizing the much larger region of pressure impact, as the driving forces for CO₂ leakage versus brine migration are different, and so may be the possible environmental impacts.

6. Summary and conclusions

We evaluated regional-scale brine pressurization and migration related to a hypothetical future carbon sequestration scenario in the Illinois Basin in the midwest United States. The area hosts a significant number of large stationary CO₂ emitters and will be one of the most important regions for geologic storage of carbon dioxide in the United States. A regional-scale 3-D simulation model was developed for the Illinois Basin to capture both the local-scale CO₂–brine flow processes and the large-scale groundwater flow patterns in response to CO₂ storage. We assumed in our simulations that each of the twenty individual storage projects spread out in the center of the basin will inject 5 Mt of CO₂ annually over a time period of 50 years. The total annual injection mass of 100 Mt corresponds to roughly one third of the current annual CO₂ emissions from stationary sources in the area. The target reservoir for storage is the Mount Simon Sandstone, a very extended saline formation of good permeability and porosity, and sufficient thickness, with proven seals.

Our predictions demonstrate that multiple-site storage in the Mount Simon will result in a large continuous region with overpressure, in which the pressure perturbations from one storage site strongly interfere with other storage sites. With respect to far-field impacts, pressure changes may propagate as far as 200 km from the core injection area hosting the 20 storage sites. While this pressure buildup and associated brine migration is not likely to impact neighboring basins, the potential of hydrogeologic and geochemical changes in the overlying groundwater regimes requires further evaluation. For example, salinity issues could become a concern if brackish water from the Mount Simon is pushed upward into overlying freshwater aquifers via possibly existing localized pathways, such as conductive faults or open boreholes.

While recognizing considerable uncertainty in our predictive model, we used the Illinois Basin study as an illustrative example to discuss some of the implications related to multiple-site CO₂ sequestration in deep saline formations. Our main conclusions and recommendations are listed below:

- In deep saline formations, geomechanical and environmental concerns related to large-scale pressure buildup may be the

limiting factor for sequestration capacity. We believe that current estimates of storage capacity, which are typically based on the effective pore volume available for safe trapping of CO₂, need to be revisited on the basis of site- or basin-specific assessments of pressure buildup and their potential impacts on freshwater aquifers. Creative pressure management schemes via brine extraction (and subsequent re-injection into other formations, or desalinization and use for water supply) could provide an engineering solution in cases where storage capacity is limited by pressure buildup, but further studies on feasibility and economics are necessary.

- Considering the importance of large-scale predictions of hydrogeologic impacts in response to CO₂ storage, we recognize the usefulness of upcoming large field tests for better understanding the relevant processes and parameters and reducing prediction uncertainty. Far-field measurements of brine pressurization should be included, as an important monitoring component, in these tests.
- Understanding the large-scale pressure buildup and brine migration patterns is extremely important for regulating CO₂ storage projects, in particular when multiple storage sites are hosted in a sedimentary basin with interconnected reservoirs. In such cases, pressure interference between individual sites will require appropriate and effective permitting approaches. Two suggestions are made in this paper, one using a “first come, first serve” principle, the other following Nicot and Duncan’s (2008) proposed hierarchical approach with a general permit for a region and site-specific permits for individual projects.
- Considering the extent of pressure propagation observed in our study, the area that needs to be characterized in a permitting process (referred to as the Area of Review in the new United States draft regulation proposed by USEPA) could comprise an extremely large region. The question as to how to define the size of the Area of Review with respect to large-scale hydrogeologic consequences will thus be of critical importance. We believe that a one-size-fits-all approach, e.g., defining a general fixed-value pressure threshold, will not work; rather we suggest basing the Area of Review size on the detailed basin-scale conditions and the vulnerabilities of potential environmental receptors. Within the Area of Review, the site characterization requirements for the region of maximum CO₂ plume extent should be higher than those for characterizing the much larger region of pressure impact.
- Further research is needed to evaluate the possible consequences of far-field pressurization on groundwater resources, i.e., evaluating the potential for and magnitude of upward brine migration via possibly existing localized pathways, such as conductive faults or open boreholes, or analyzing the water quality changes in response to brine intrusion into freshwater aquifers.

It is important to assess (and regulate) the potential environmental impacts of GCS in the context of other anthropogenic influences affecting our groundwater resources. For example, excessive pumping of groundwater resources for municipal water supply and agricultural uses has caused widespread aquifer drawdown and salinity increases in many areas in the United States. In the Chicago metropolitan area, heavy groundwater pumping in northern Illinois induced drawdown of up to 250 m during the second half of the last century, eventually pulling deeper saline waters towards some withdrawal wells. These impacts dwarf the predicted environmental consequences of the hypothetical CO₂ storage scenario studied in this paper. One also needs to weigh the environmental impacts of GCS against the regional and global benefits of mitigating climate change. In other words, one needs to consider the potential environmental,

socioeconomic, political, and also hydrogeological consequences of continued CO₂ emissions in a business-as-usual climate scenario.

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Should Ohio take a closer look at what fracking does to drinking water?



ROB MOORE

June 18, 2026 3:30 am



File photo of fracking pumpjacks. (Getty Images.)

Carbon emissions in Ohio have fallen by about a third over the past twenty years according to data from the Energy Information Administration.

Americans don't necessarily think about Ohio as a leading state in the move toward decarbonization of our energy system, but Ohio emitted 86 million fewer metric tons of carbon in 2023 than in 2003.

How did the state's energy system do this?

The answer is largely a story about a see-saw in energy consumption in Ohio from coal to natural gas.

Coal consumption in Ohio fell by 71% from 2003 to 2023 while natural gas consumption increased by 65%.

While natural gas is not carbon-free, its 30 million additional metric tons of carbon emissions over the past two decades was far outbalanced by the 100 million fewer metric tons emitted by Ohio's abandoning of coal as an energy source over that time period.

The balance of the carbon emission reductions came from reductions in use of petroleum for energy generation.

Ohio's natural gas boom has also come with concerns about local extraction of natural gas.

The reason Ohio has adopted natural gas so rapidly is because of a well-documented boom in natural gas drilling driven by "fracking" technology deployed in Ohio's eastern Appalachian region.

This has led to frequent clashes between environmental advocates who worry about the broader environmental and health impacts of natural gas drilling and companies looking to tap into this natural resource.

According to the United States Environmental Protection Agency, nearly 1,200 different chemicals have been used for hydraulic fracking.

The United States Department of Energy maintains a database of wells across the United States and disclosed chemicals used within these wells.

A 2016 United States Environmental Protection Agency report found that issues such as water withdrawals, spills, poor well integrity, direct injection into groundwater, inadequate wastewater treatment, and unlined pits can lead to drinking water impacts, potentially causing public health hazards for residents local to drilling projects.

Earlier this month, Northeast Ohio state Reps. Derrick Hall and Sean Brennan introduced legislation to beef up oversight of the chemicals used in oil and gas wells.

Ohio House Bill 958 would require more detailed chemical reporting by well owners, add disclosure for chemicals used to stimulate wells, create a state-level chemical disclosure database, and ensure the accuracy of chemical disclosures with random wastewater testing across the state.

This new oversight regime would move past the current level of reporting in the Department of Energy database by providing information about chemical use throughout the drilling process.

It would also create a testing regime and impose penalties for inaccurate disclosure, ensuring the fidelity of chemical use disclosure.

It would also allow medical professionals access to exact chemical compositions when exposures occur, allowing for better treatment and potentially better health outcomes for people exposed to chemicals.

Functioning energy markets, like any other market, are based on proper disclosure and flow of information.

This matters for consumers of energy, but also to third parties such as people whose drinking water may be contaminated by oil and gas extraction.

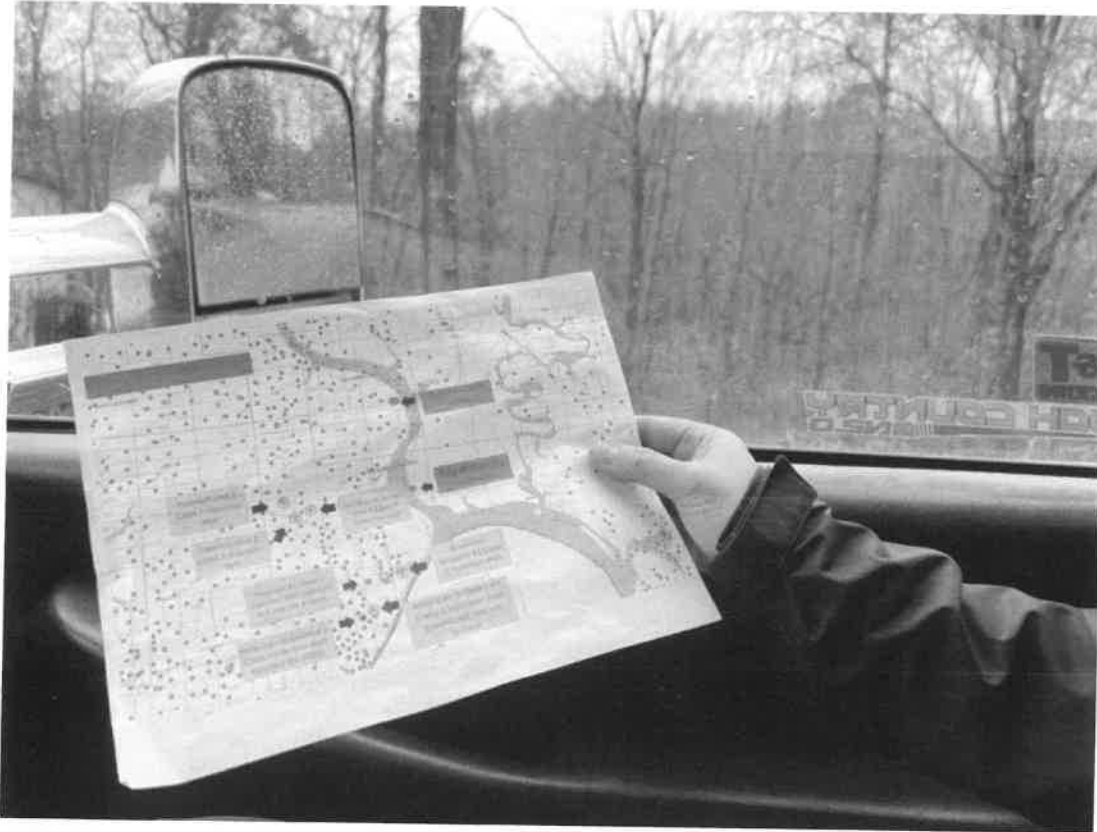
As long as disclosure requirements are not designed to be so onerous that they impede development of safe wells, requirements like this can be an effective tool for making energy markets more efficient and safeguarding environmental and public health.

Fracking produces a lot of wastewater. Millions of gallons of it are stored under eastern Ohio

The Ohio Newsroom | By Erin Gottsacker

Published January 20, 2026 at 3:53 AM EST

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Erin Gottsacker

The Ohio Newsroom

Bev Reed, with the Buckeye Environmental Network, holds a map showing injection well sites near Marietta in southeast Ohio.

Hydraulic fracturing, particularly on public lands, has spurred protests across Ohio. But a lesser known part of the process — where companies discard the wastewater from drilling — is causing an uproar in a small town in southeast Ohio.

Some residents in Marietta are concerned that the wastewater could contaminate the city's drinking water supply.

To understand how that could happen, we're breaking down the science.

How does fracking work?

Americans have been drilling for oil and gas for over a century, but about 15 years ago, a different kind of energy mining took off: hydraulic fracturing, often nicknamed fracking.

This is the first of a three-part series about concerns over injection wells in Washington County. Read the second and third parts here.

Here's how that process works:

"Imagine a hole that goes down about 4,000 feet and then turns 90-degrees and then goes horizontally," said David Jeffery. He teaches courses on petroleum geology at Marietta College and has worked with companies like Mobile and BP.

Jeffery says drilling horizontally allows companies to reach oil and natural gas reserves that were previously difficult to access with conventional vertical drilling.

In order to get those fuels out, operators inject the holes with millions of gallons of fluid at pressures so high it cracks surrounding rock and allows oil and gas to escape.

That fluid is usually composed of water, sand and chemicals like disinfectants. Ohio law requires companies to disclose information about the volume and types of products used in drilling, but there are exemptions for chemicals considered trade secrets.

After the fluid has done its job, it comes back up to the surface. But after sloshing around underground, it picks up a lot of salt and, potentially, some radioactive material.



Julie Grant
/
The Allegheny Front

Protesters gathered to oppose fracking on public lands at the meeting of the Oil and Gas Land Management Commission in Columbus on November 15, 2023.

Between the unknowns about the chemicals in the fluid and the substances it picks up underground, Jeffery says the wastewater isn't safe for humans above ground.

"So they have to dispose of them somehow," Jeffery said.

That's where injection wells come in.

What are injection wells?

Injection wells are drilled deep underground in porous geologic formations to store fluids like the wastewater from hydraulic fracturing.

"That would normally be a very good solution if you find a place in which you can find space underground for this yucky stuff to be in perpetuity," Jeffery said.

There are several types of injection wells. Some are used to store industrial waste, while others are used to mine minerals like uranium and copper. Class II injection wells are the ones used to inject waste from oil and natural gas production.

How many injection wells are in Ohio?

According to a database from the EPA, Ohio had over 250 Class II disposal wells for oil and gas waste in 2023.

A map from the Ohio Department of Natural Resources shows 234 of those wells were active that year. Seventeen were in southeast Ohio's Washington County.

In comparison, the entire state of Pennsylvania had 16 active Class II disposal wells in 2023. The state says it sends most of its "produced fluids" to neighboring states like Ohio.

In Washington County, four injection wells are within two miles of the City of Marietta's aquifers. Last year, the Ohio Department of Natural Resources approved two more to be drilled within that radius.

Jeffery, and many others who live in Marietta, like Dee Wells Arnold, worry that's too many wells in close proximity to the city's drinking water supply. A leak, they say, could be devastating.

"If you don't have fresh water, if you don't have clean water, if you don't have safe water, you can't have a community," Wells Arnold said. "I don't think it's worth the risk."

Are injection wells safe?

In a Q&A style document addressing concerns over a proposed injection well near Marietta, the ODNR said geologists evaluate each injection site and make sure the wells are constructed in a way that protects the environment.

DeepRock Disposal Solutions, which owns the injection wells near Marietta, did not respond to a request for comment. But they passed my number on to Matt Dole, a consultant for the Accountability Project Institute. The 501c4 is a politically active nonprofit that isn't required to report its donors. Over the past decade it has run ads portraying Democratic school board candidates in the Columbus area as 'COVID extremists' and questioning a Democratic gubernatorial candidate's defense of sex offenders in court.

Dole says the risk of injection wells leaking is negligible.

"If you consider that that injection well is two miles from the water's supply, behind reinforced concrete, behind reinforced steel, encased in concrete and 4,000 feet in the ground below solid rock, it might as well be a million miles," he said.

But leaks have happened in Washington County before. Just a few years ago, fracking fluid infiltrated dozens of vertical oil and gas wells there.

Regardless, Dole says any attempt to shut down injection wells could cripple an industry that's become essential to southeast Ohio economies.

"Some opponents of injection wells will say I'm for oil and gas. I don't want to lose the jobs and the economic benefit and the energy developed by the oil and gasoline industry. I'm just against injection wells," he said. "Well, that is an irreconcilable position because the water used in the fracking process needs to be disposed of properly and injection wells are the proper way to dispose of that material."

Tomorrow, we'll hear more from a geologist about the risk of leaks and from locals on why they're not convinced the benefits outweigh the costs.

