Revealing the Fracklands: a framework for addressing the wicked problems of America's hydraulic fracturing landscape

by

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A REPORT

submitted in partial fulfillment of the requirements for the degree

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Department of Landscape Architecture and Regional & Community Planning
College of Architecture, Planning, and Design

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Manhattan, Kansas

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Approved by:

Major Professor
Blake Belanger

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Abstract

In recent decades, traditional methods of oil and gas extraction in the United States have been fortified by hydraulic fracturing, or fracking. The process of fracking involves injecting water, aggregates, and chemicals into the earth to rupture rock that is trapping oil and gas. This process has unlocked access to once unobtainable reserves, and as a result, U.S. oil and gas production has continued to increase despite recurring forecasts that supplies would peak. While increased production has strengthened some sectors in the U.S. economy, it has also renewed a reliance on non-renewable energy, compromised the wellbeing of communities, and poses serious environmental threat.

While research into the process of hydraulic fracturing and its effects are common, little discussion has been generated regarding the broader impacts of the systems required to construct, supply, and maintain fracking operations. The processes of hydraulic fracturing contain a dense array of components that effect both the present and future state of communities, environments, and economies. As energy demands grow and resources deplete, these millions of facilities will demarcate the wicked problems of a post-oil and gas future and reveal a dense system of derelict infrastructure and underutilized lands.

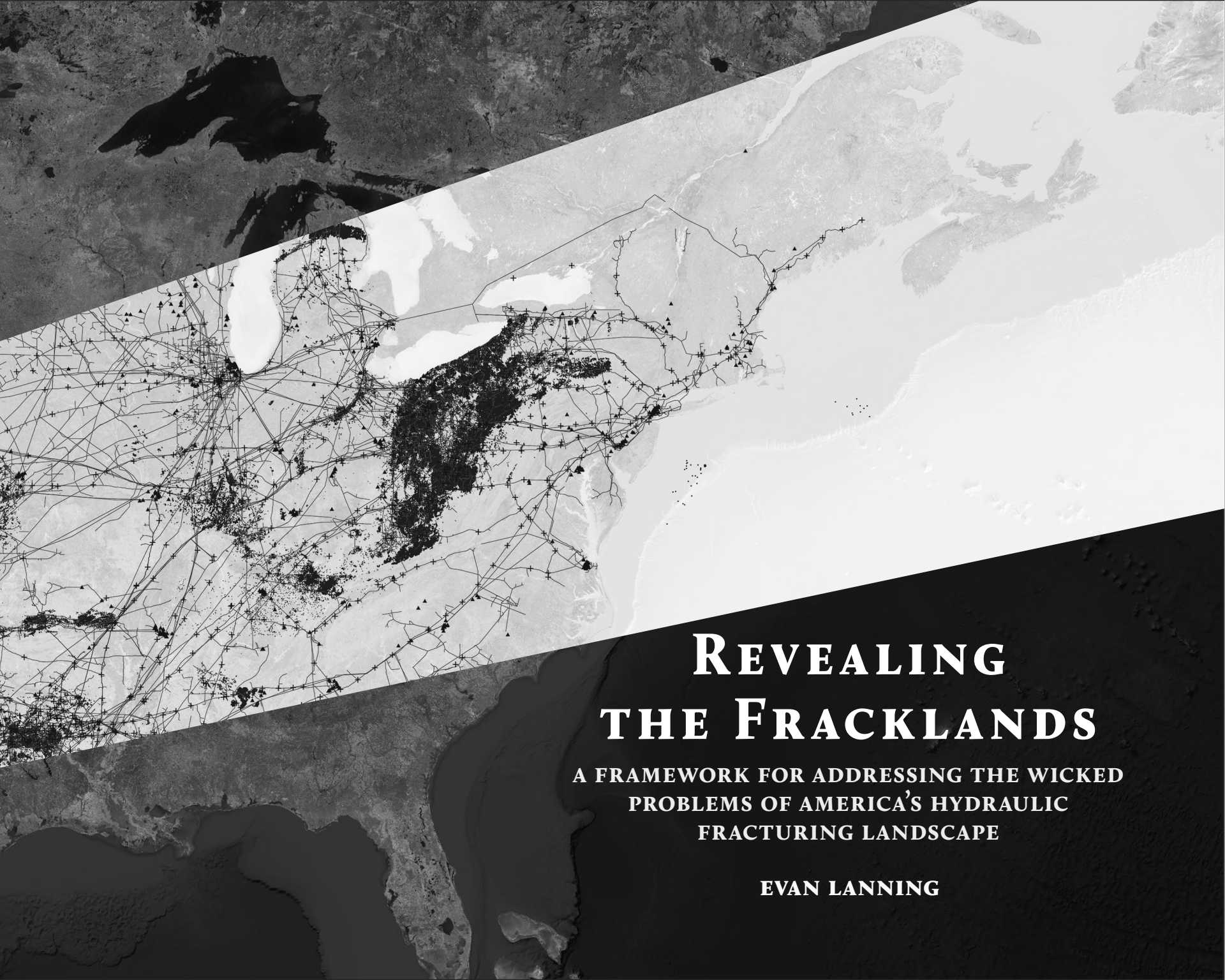
This report presents the Fracklands. Fracklands are a comprehensive telling of the landscapes of hydraulic fracturing. They offer insight into what a dynamic and complex system of modern oil and gas extraction infrastructure looks like. After first defining fracking and discussing current practices and policies as grounds, I present a classification framework for defining the Fracklands. Organized by four approaches – Systems, Typologies, Trends and Futures – this Framework utilizes a set of descriptive methods conducted in three U.S. regions to present and discuss the Fracklands.

Results reveal a more complete picture of fracking's effects on the American landscape today, while giving hints of what the Fracklands will present in the future. The Fracklands are a little understood system of components and processes that profoundly affect land, people, place, and society. By presenting the Fracklands framework in this report, I aspire that planners, designers, and decision-makers will have a clear outline for better understanding the nature of this wicked problem. As a point of departure, I propose three unique design-based alternatives to address the future of the Fracklands and dilemmas yet materialized. With the Fracklands revealed, footholds are set for a methodology to be adapted and used in future study for understanding the ever-changing landscape of hydraulic fracturing.

Revealing the Fracklands

Lanning





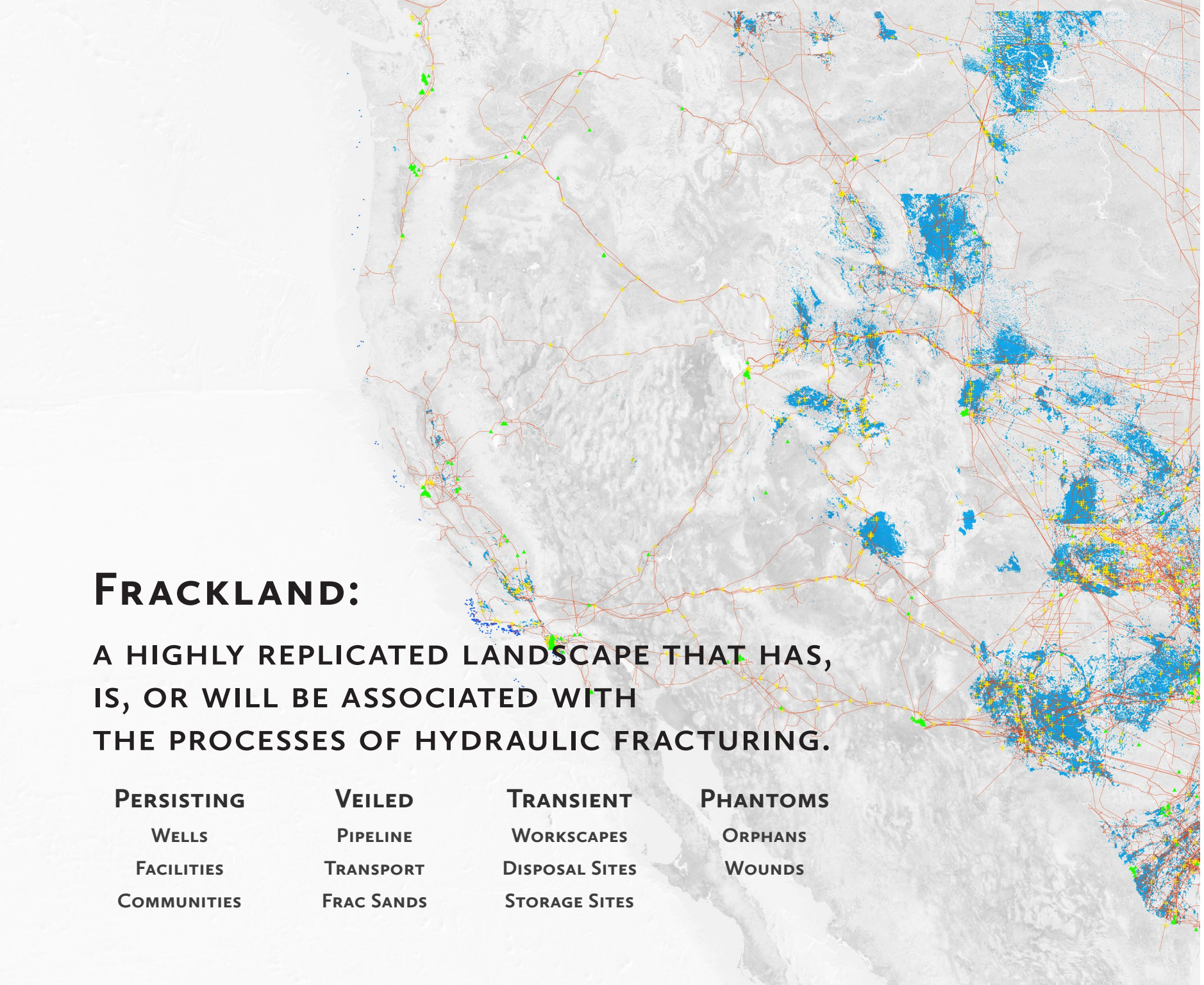
Revealing the Fracklands

A Framework for Addressing the Wicked Problems of America's Hydraulic Fracturing Landscape

Evan Lanning



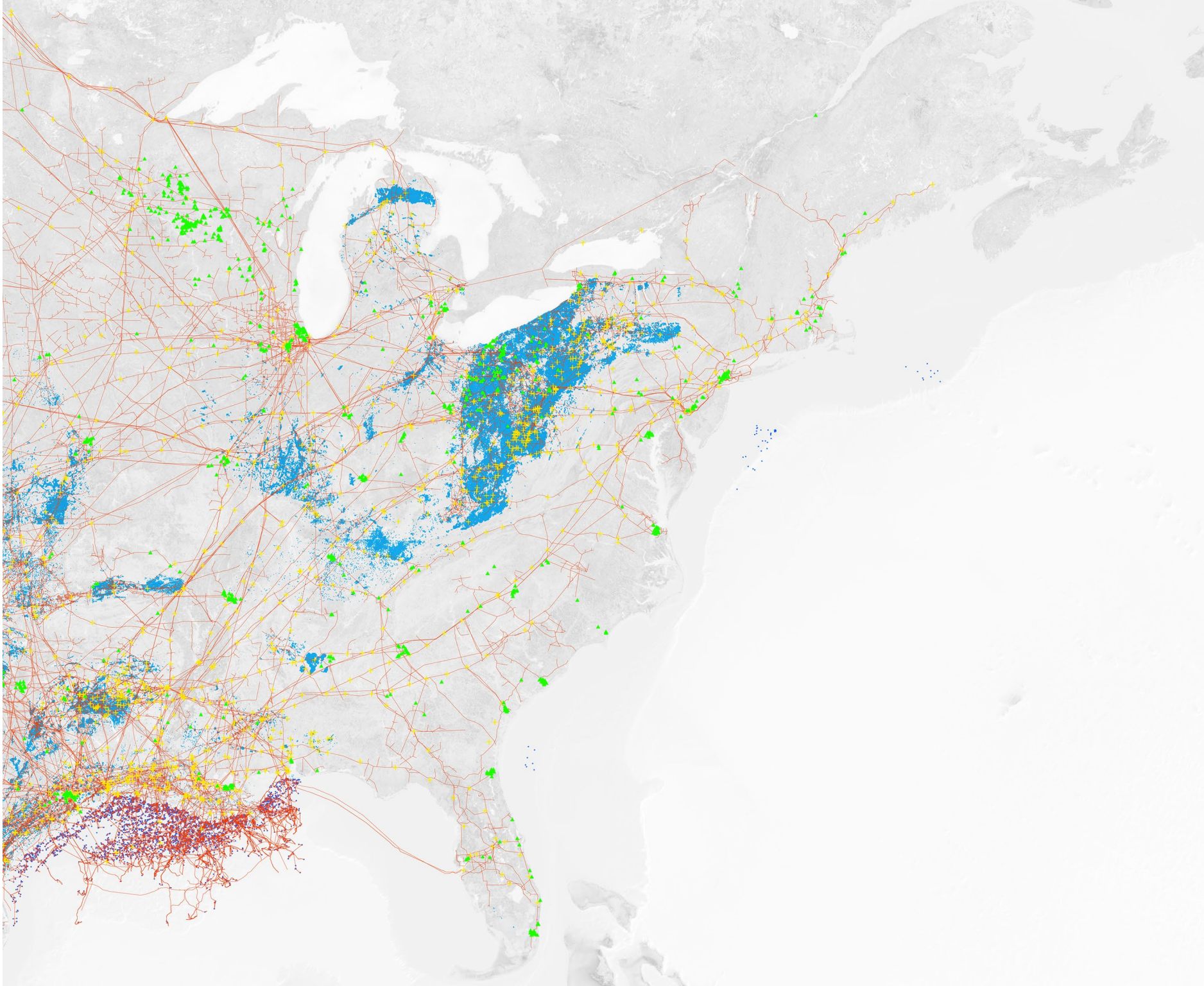




Frackland:

A highly replicated landscape that has, is, or will be associated with the processes of hydraulic fracturing.

Persisting	Veiled	Transient	Phantoms
Wells	Pipeline	Workscapes	Orphans
Facilities	Transport	Disposal Sites	Wounds
Communities	Frac Sands	Storage Sites	





2005



2011



2016



2012

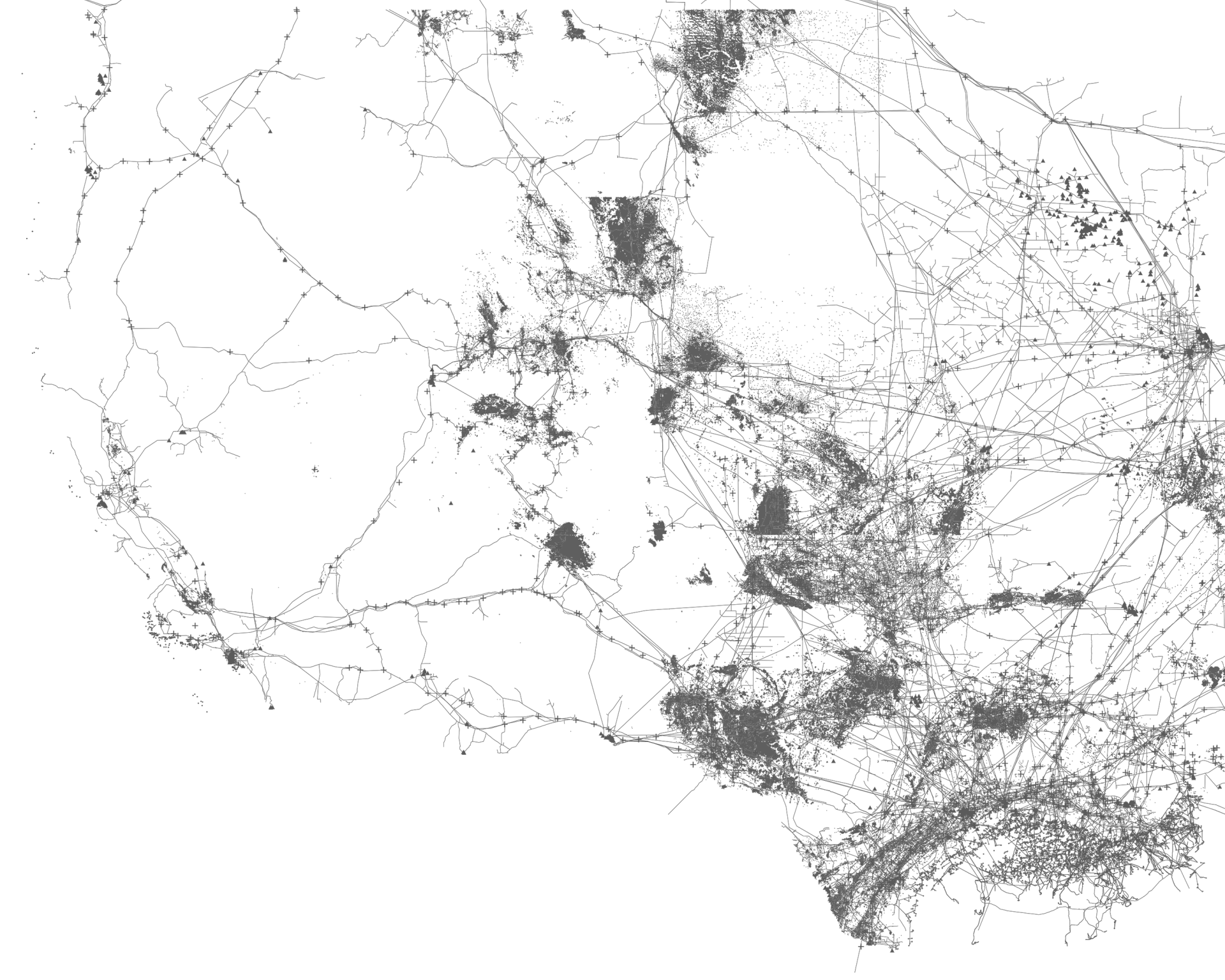
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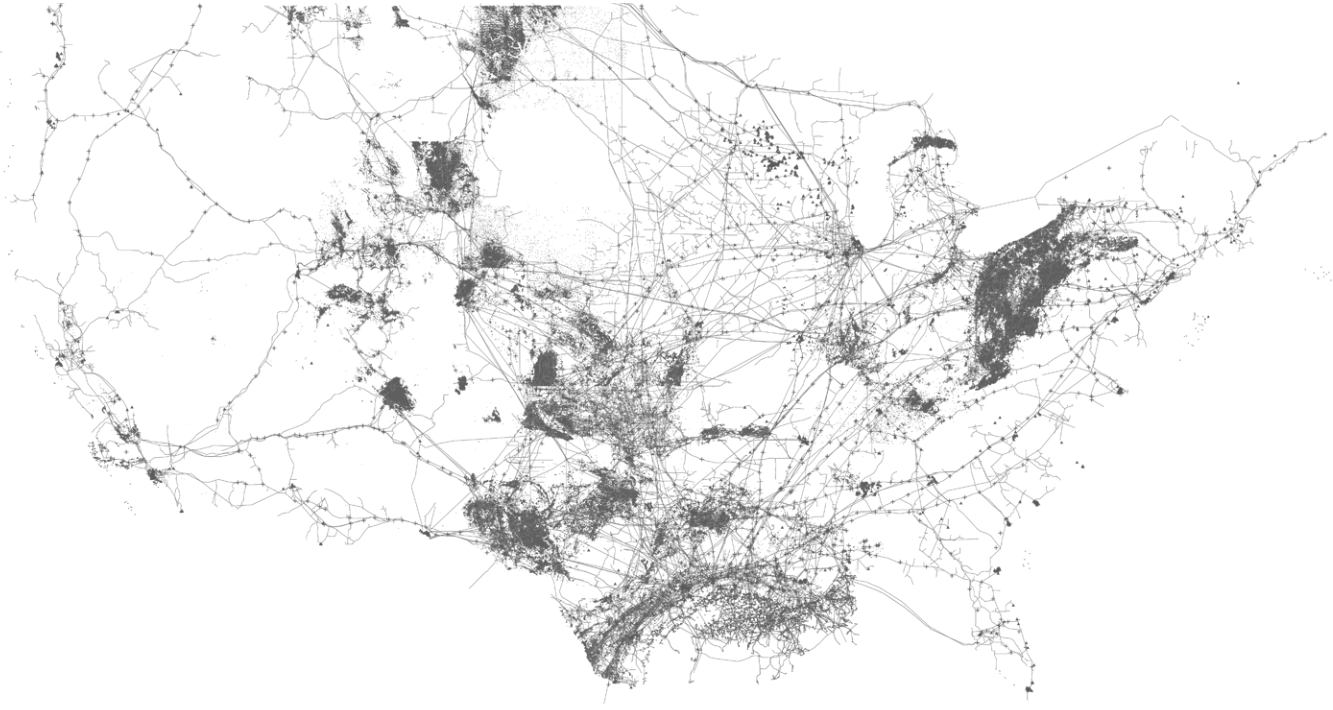
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Revealing the Fracklands

A framework for addressing the wicked problems of America's hydraulic fracturing landscape



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Revealing the Fracklands:
A Framework for Addressing the wicked problems of
America's Hydraulic fracturing landscape

A report submitted in partial fulfillment of the requirements for the degree:
Master of Landscape Architecture

Department of Landscape Architecture and Regional & Community Planning
College of Architecture, Planning and Design
Kansas State University
Manhattan, Kansas

Committee:
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Dr. Audrey Joslin, Associate Professor – Department of Geography

Opening Images:
The Fracklands, (Lanning, 2018)
Dimock, PA (Google Earth, 2005; 2011; 2012; 2016)

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DEDICATION

Dedicated to my family. I could not have done this without your love and support through college and through life.

Dad – For making me tour the architecture school five long years ago. If not for this, I wouldn't have found Landscape Architecture, and my passion in life.

Mom – For home and so much more. Had you not moved to Northern Colorado this project would have never happend.



Figure ii. Beyond the Oilfields. (Lanning, 2017)

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Thank you to Associate Professor Jessica Canfield (LARCP) and Associate Professor Dr. Audrey Joslin (Geography), my other committee members. Jessica, for your experience and knowledge with this type of project. Your many critical questions during reviews greatly shaped the final product. Audrey, for your "outsider knowledge" and support in what is the first but hopefully not the last collaboration with Landscape Architecture. I hope this has not scared you away.

A big thank you to Johnathan Knight (MLA 2017) and your guidance when I was deciding whether to commit to this topic. Your research with the Oil Sands in Canada has been inspirational in reaching the results I have here. I'm sure our experiences, whether good or bad have many parallels.

Thank you to my friends in studio and throughout the college. Thank you for not only keeping spirits up throughout these five years, but also for all the shenanigans we still managed to have. Thank you to my friends outside of the college. For keeping me sane and getting me outside the college to experience what normal college life is like. Thank you for the many memories.

To all of the LARCP faculty and all that you do for your students. You've provided me with a fantastic education that I will cherish for the rest of my life.



Figure iv. Close to home. A drilling rig rises behind a recently built community in Windsor, Colorado. (Lanning, 2018)

PREFACE

As a child, oil derricks were always a fascination during long road trips through Northwest Texas. Facsimiles of industry that brought attention towards a landscape a six year old child could only see as monotonous. Each pump had its own story, unique from others. Some sat announced in wide-open fields; others silent, veiled in foliage. Many relentlessly bobbed up and down, day and night. Many others sat lifeless with little apparent purpose. Some were painted brightly in opposition of the green or brown fields they laid upon. Others blended right in, painted in years of decay and rust. These unique subjects were all a child could understand as oil and gas extraction. Intriguing indications of human presence in an otherwise expansive nothingness.

This project began unintentionally several years ago over being first exposed to fracking. In several visits to northern Colorado I was exposed to towering drilling rigs, large tank batteries, oversized pumps and more. My fascination with the oil and gas landscape had become unhinged. This was the full mechanization of unconventional oil and gas. Small pumps that dotted vista were now 6-acre clearings of large complex equipment difficult to wrap ones head around. As my exposure to the changes in Northern Colorado grew, so too were studies far from this place. I was learning how landscape architecture can be used for communicating complexities in our world and addressing significant change.

I did not connect the two together until years later. There was no “aha!” moment in grafting this project. It was not met with jubilation, it was met with hesitation. As I would later learn, this was the same hesitation that many of my landscape architecture contemporaries had experienced before: How could landscape architecture possibly intervene with the oil and gas industry, one the most influential economic forces in human history? How could we address the extraction industry while it is still active? –Subjects that appear as though they would be the last thing on the mind of a landscape architect.

The odd combo of hesitation met with a yearning to approach an innately wicked and challenging project allowed me to persevere and approach this topic differently. I am not a scientist, an expert in ethnography, a cartographer, or a photographer. I am a design student. Yet it was these realms outside of design that became key to grafting this project. I was forced into finding new ways of looking at the subject of hydraulic fracturing while retaining a focus on the landscape.

While the Fracklands are a collection of viewpoints from myself, from others, and various media, in totality they are one man’s quest for understanding what the hydraulic fracturing landscape really is. They are a journey in understanding that the candid curiosities of a child have transformed into the wicked realities of a 21st century society.



Figure v. A sign near oildfields in Grover, Colorado (Lanning, 2017)



INTRODUCTION

Welcome to the Anthropocene, an era where the grip of human influence and exploitation encompasses the entire planet. Best characterized by climate change, this era has given way to major change that yields complex and opaque dilemmas no longer able to be met by straight answers and known solutions. From social injustices, mass migrations, food insecurity, climate change and sea-level rise, land degradation and resource depletion, deforestation, and more, the Anthropocene is an era of dilemmas that humanity has never had to face until now (Dalbotten 2014).

Such impasse will require a level of attention unlike any other. It will be necessary to acknowledge that these dilemmas are inherently wicked, where no true cessation or resolution exists (Rittel and Webber 1973). Their complex nature will require inter-disciplinary collaboration and novel thinking; warrant for the creation of new methods for finding solutions. These are callous and continually evolving issues. They are dynamic systems of complex inputs and outputs. These are the wicked problems of the Anthropocene.



Figure vi. A gas flare in Weld County, Colorado. Excess gas coming to the surface must be burned off to prevent pressure buildup. (Lanning, 2017)

Energy: An Increasingly Wicked Problem

Human progress and history has been vastly shaped by consumption and production of energy. It is the fuel of the human machine. For the past 150 years that chief fuel has been fossil fuels – oil and natural gas. They have formed the root of global economy, conflict, and change. As humanity progresses further into the Anthropocene, the wickedness of global energy demand and the resources that fuel that demand will grow with it. This rapid unrenewable energy production and consumption has led to global conflict, human induced climate change, mass land exploitation, and reckless growth created by and for the sake of combustible resources. Researchers fear that to meet this growing demand, irreparable damages to the environment will need to take place (Bradshaw 2010). Global energy use has exceeded predictions, near doubling in the past two decades (EIA 2017d). As this demand grows, the resources that have been relied upon to fuel that demand – coal, oil, and natural gas, are dissipating (EIA 2017b, 2017d). Today, easy access resource reserves have grown thin.

The depletion of easy access energy and the continued reliance on oil and gas has created a "desperate search for 'extreme energy'" – sources requiring extreme methods to be reached (Butler and Wuerthner 2012). These extreme, or unconventional sources will require extreme and unconventional methods to reach them. Unconventional methods consist of offshore oil and gas drilling, tar sand and oil shale strip mining, and shale oil and gas hydraulic fracturing (Ma and Holditch 2015). Modern energy has always been exploitative. Land and community has routinely been sacrificed for energy and economy. Extreme energy and unconventional extraction methods have amplified this doctrine of sacrifice, paving way for a vast network of unique and pervasive energy infrastructure that threatens both communities and the natural environment. For the United States, its own extreme energy policies have flourished due to hydraulic fracturing.



Figure vii. Kuwaiti Oil Fires, April, 1991. Image taken by space shuttle astronauts of over 700 oil wells that were set on fire by retreating armies of Iraqi dictator Saddam Hussein. (NASA, 1991)

Hydraulic Fracturing: The Despot of America's Extreme Energy

Hydraulic fracturing or 'fracking' for oil and gas has quickly become a dominant form of energy production in the United States. It is a resource intensive process that uses a sand, water, and chemical mix to be injected into the earth, freeing up trapped pockets of oil and gas. While this injection process is synonymous with fracking, the process represents the entire story of oil and gas; extraction, production, and depletion. Altogether it is a complex network of facilities, large amounts of extracted resources, and vast fields of diffuse land that represents what the process of fracking really is.

By the end of the 20th century, hydraulic fracturing technology would be ready for mass implementation across the country. Fracking has allowed the country to continually meet and increase its demand for unwearable energy and its reliance on oil and gas. Entire regions of the U.S. have been greatly shaped by the process, transforming the fabric of social, ecological, and economic system. Hydraulic fracturing's influence is creating unique fracking related facilities which are playing host to their own unique dilemmas as well.

Hydraulic fracturing in the United States has become, and will continue to grow as a wicked problem, nested within greater dilemmas of energy supply and demand. The depletion of oil and gas reserves will lead to growing energy desperation. This desperation in-turn will lead to the marginalization of boundaries set between the facilities and landscapes of fracking and their surroundings. As fracking's influence grows, its facilities are encroaching upon more places unaccustomed to its trials and tribulations. In addition to these blurred lines, the future of what becomes of these places remains uncertain.

The dilemmas of extraction and environmental sacrifice are no longer an issue left to rural communities. The complexity of these processes and the future of fracking infrastructure will leave effects being felt far beyond immediate extents. Problems that arise will become problems of the masses.

These trends trace the current path U.S. energy production is on. While many may be well aware of fracking, literature shows few see the systematic effects of fracking and even fewer its implications for the future. This is the most wicked problem of hydraulic fracturing; the lack in seeing and understanding the extents, phenomena, trends, and future of fracking and its many landscapes.



Figure viii. Fracking well pads in Central Texas. The first was completed in 2007. Today there are 22,000 of these landscapes. (Google Earth, 2016)

Investigating Hydraulic Fracturing: Focusing on Landscape

While complex, much of the dilemmas surrounding hydraulic fracturing can be traced back to the landscape. Yet there is a common disconnect in looking at the entire story of fracking and relating that to the spaces it inhabits. In addition to the oil and gas wells where the fracking or injection occurs, the complete process of fracking discussed on the previsous page requires an array of components to function. Together these pieces, not just the wells, play a significant role in shaping the landscapes and populations that interact with them. While they may share commonalities, each landscape and its components associated with the process of hydraulic fracturing has its own unique story. Each influences their surroundings in different ways.

As for the future of these landscapes, each share a common path. As unconventional oil and gas reserves shrink in size, the desperation to meet energy demands will increase fracking's presence within landscapes. While more than a million fracking landscapes exist in the U.S. today, millions will be created tomorrow. Likewise, as reserves empty, these landscapes will be left in limbo; to decay or returned to a state that is neither nominal nor productive.

Being a problem transposed in landscape, landscape architects are in a unique position to address these dilemmas. Research and design discourse has laid out a critical path. However, while landscape architects have the tools and abilities to address the landscapes of hydraulic fracturing they lack an understanding of them. These landscapes must be delineated into a more workable system. Strong understanding and knowledge leads towards better telling of what these landscapes *are* today, what they *will be* tomorrow, and what they *can be* tomorrow. Once understanding is grafted, then landscape architects can lead discussion over how we address these landscapes today and how we address the evolution of these places tomorrow – from landscapes of industry and waste, to landscapes of social, economic, and ecological armature.

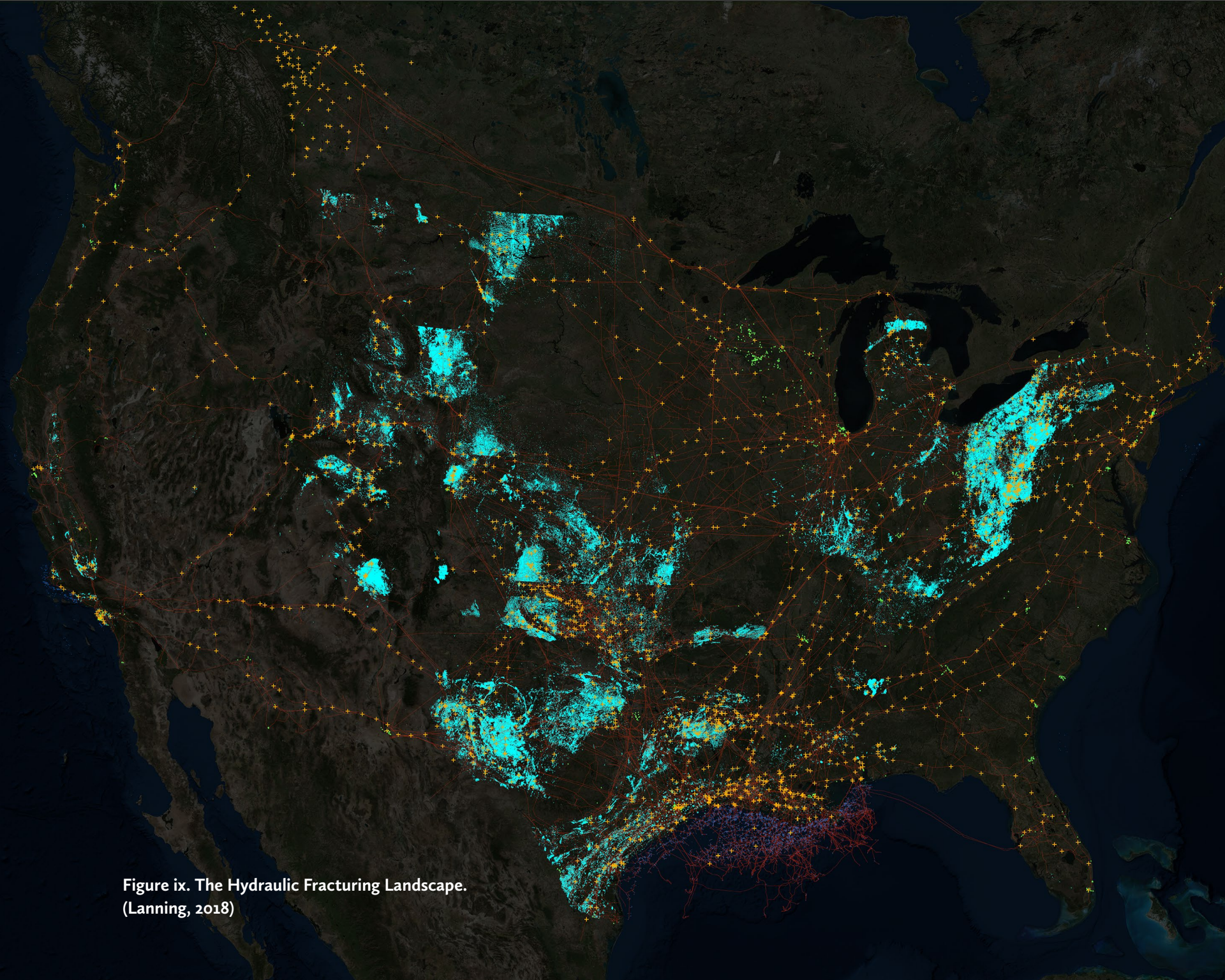


Figure ix. The Hydraulic Fracturing Landscape.
(Lanning, 2018)

Summary of Research

Across this text is a vast amount of research that seeks to uncover the totality of fracking, what is being done about it, and what can be done about it. The most influential of findings are highlighted below. These sources shaped the direction and goals of this research:

- Oil and gas fracking is a highly complex process that significantly impacts the social, ecological, and economic systems within its context. (Kaden and Rose, 2015)
- U.S. and Global oil and gas reserves are not infinite, and will likely be depleted before 2100. (EIA 2017b, 2017d; Hughes 2014; Korpela 2007)
- The point of peak production is unknown, however production declines will require fracking operations to increase by up to 4 times to meet consumer demands. (Hughes 2014)
- Current discussions with community members and leaders, design and planning professionals, and scholars and researchers are remiss in addressing the landscapes of a post-oil and gas future.
- Be it resource depletion, alternatives, or bans, the landscapes of oil and gas will cease use as landscapes of production providing opportunity to be re-adapted for forward thinking outcomes. Time to prepare for these dilemmas before they become a reality is shrinking.
- Oil and gas companies are not planning for such a future and are not being held accountable to do so. (Jenkins and Sutton 2017; McGranahan, Fernando, and Kirkwood 2017; Picard 2015)
- Planning and design professionals are ill-equipped to handle the landscapes of unconventional oil and gas today let alone tomorrow, and have expressed the need to develop new means of doing so. (Green 2014; Murtha and Orland 2014; Sorvig 2014b)

Guiding Inquiry and Project Goals

From these findings the primary question of this research is: **What are the landscapes of hydraulic fracturing and what needs to be done to better understand these landscapes in order to properly address the wicked problems that they have and will initiate?**

Three goals to answer this question were constructed:

1. **Understand the Landscapes of Hydraulic Fracturing:**
   Understand these landscapes from a systems-based perspective. Classify these landscapes into the "Fracklands", arranged in a series of typologies. Delineate common and regional trends of the Fracklands. Explore the future of the Fracklands and develop preliminary design discussion on alternatives to these futures.



Literature expressed the need for new methods of understanding hydraulic fracturing if landscape architects and planners are to try and work out its problems. As an answer to this call, I created a classification system for delineating and understanding these landscapes; forming the Fracklands.

2. **Understand Hydraulic Fracturing:**
   What is it? Why has it become a mainstay for U.S. energy production? Where is it predominately located? What are its benefits and its costs? What is its future?



In order to understand the landscapes of hydraulic fracturing one needs to first understand the processes of hydraulic fracturing, its history, and its future. This research forms the foundation of this project.

3. **Understand Actions for Addressing Hydraulic Fracturing:**
   What is being done today by citizens, government, planners and designers? What related discussions in the design field can be drawn upon? What discussion regarding complex landscape systems can be utilized?



In addition to understanding an overview of hydraulic fracturing, it's necessary to understand what actions are being taken today to address fracking. The findings here were key in developing the methodology and methods for this project.

Overview of Methods

Step 1: Understand Hydraulic Fracturing:
Understand Hydraulic fracturing – what it is, how it has come to be, its impact on social, economic and environmental systems.

Universal consensus among planners and design professionals have expressed the need for their colleagues as well as citizens to be clearly informed and educated on the subject of hydraulic fracturing before acting on them. (Green 2014; Murtha and Orland 2014; Sorvig 2014b)

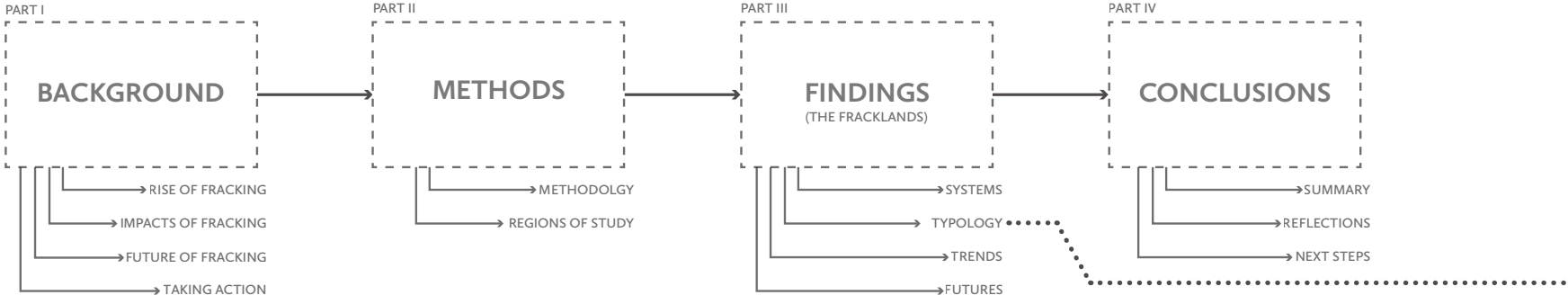
Step 2: Understand Actions to Address Fracking:
Understand what is being done and what can be done to address the dilemmas of hydraulic fracturing.

Design professionals have begun to look at new adaptations of industrial landscapes from prior generations, but few have have related such discussions to oil and gas fracking landscapes. (Kirkwood 2001; Berger 2002; Byrne 2017; Jenkins and Sutton 2017)

Step 3: Utilize Research to Develop New Methods:
Develop a classification system for better understanding these landscapes at a systemic and phenomenological level. – Make it easier and more efficient to understand and approach these landscapes.

Designers have expressed the need for better methods to address the complexities of the landscapes of hydraulic fracturing. (Sorvig 2014a; Murtha and Orland 2014)

A classification system, like that of Alan Berger's "Drossscape" is comparable. (Berger 2007)



Step 4: The Fracklands

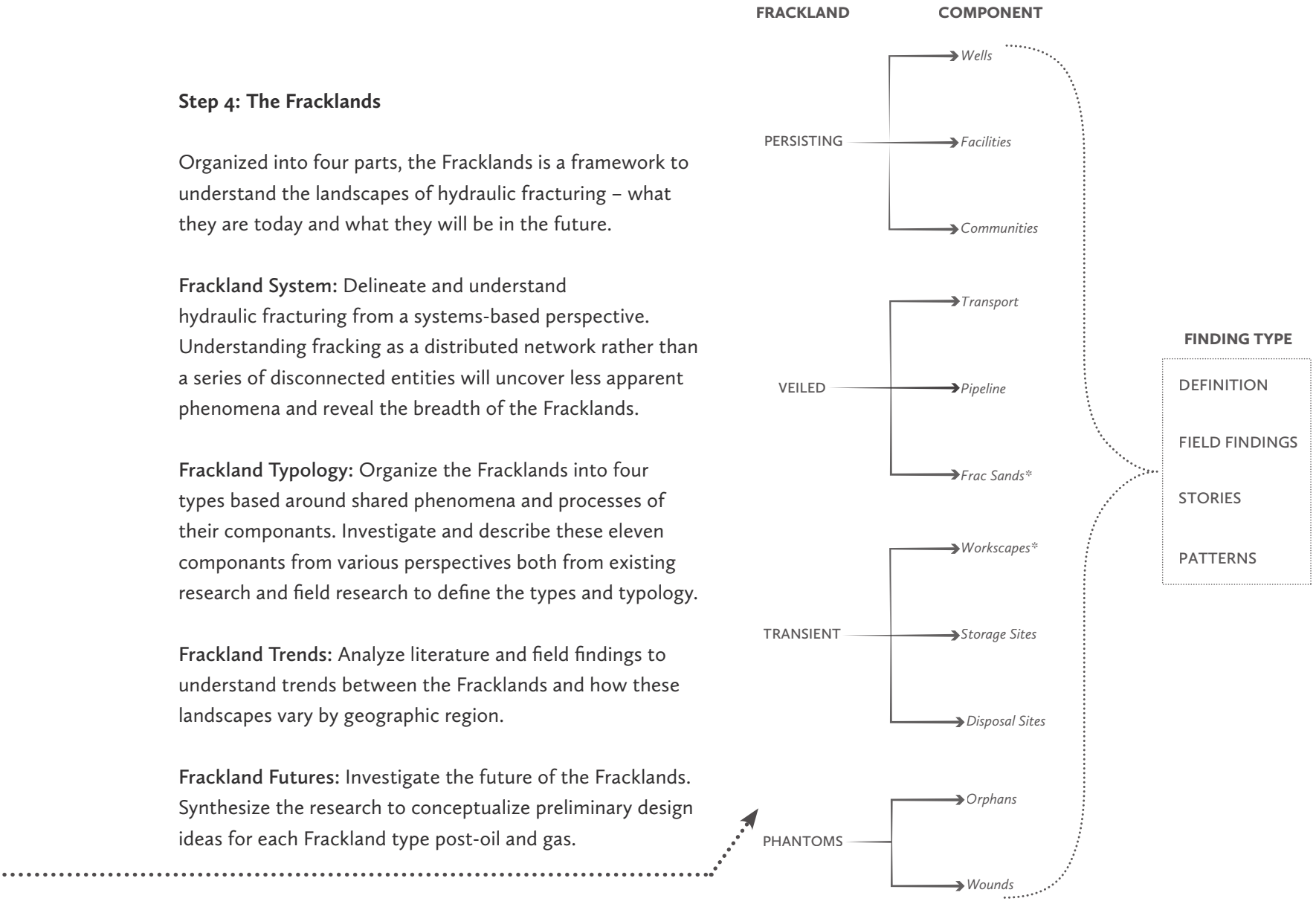
Organized into four parts, the Fracklands is a framework to understand the landscapes of hydraulic fracturing – what they are today and what they will be in the future.

Frackland System: Delineate and understand hydraulic fracturing from a systems-based perspective. Understanding fracking as a distributed network rather than a series of disconnected entities will uncover less apparent phenomena and reveal the breadth of the Fracklands.

Frackland Typology: Organize the Fracklands into four types based around shared phenomena and processes of their componants. Investigate and describe these eleven componants from various perspectives both from existing research and field research to define the types and typology.

Frackland Trends: Analyze literature and field findings to understand trends between the Fracklands and how these landscapes vary by geographic region.

Frackland Futures: Investigate the future of the Fracklands. Synthesize the research to conceptualize preliminary design ideas for each Frackland type post-oil and gas.



Why Landscape Architecture?

- *The New LAF Declaration:*

The role of landscape architecture in this research is rooted in the profession's core ideals. Since the 1960's, The Landscape Architecture Foundation (LAF) has made a call for sustaining and preserving the natural environment. Today, that doctrine has evolved into one that seeks solutions to complex anthropocentric dilemmas such as the ones highlighted here (LAF 2017). Designers have been asking what can be done to address these dilemmas before it is too late, and changes become irreversible. They are seeking ways to rethink and revolutionize landscape infrastructure to address profound change to the planet's communities and ecologies.

- *The Profession:*

Landscape Architects are trained to think holistically, comprehend the temporality and complexity of landscape systems, and are trained to address wicked problems. They have the skills to visualize these complex facets for common people. Landscape architecture is seen as one of many answers in addressing the dilemmas outlined by this project and one skill set that can produce positive social, ecological, and economic outcomes.

Why Act Now?

- *What can be seen and studied today, will become amplified tomorrow:*

As time passes, oil and gas reserves will diminish. If projections stay true, oil and gas will remain the U.S.' chief energy source. Demand will rise, while availability will diminish. To keep up with demand and availability, new regions will be opened up to hydraulic fracturing and existing ones will see more and more layered on. What is being seen today has the potential to be greatly amplified tomorrow. If addressing wicked problems such as this are a priority of 21st century citizens, then discussions over how to address them needs to begin now. It may only get worse.

- *The past may be foreshadowing the future:*

The future of hydraulic fracturing may already be apparent today. Oil and gas extraction has existed for more than 150 years in the United States. Scars from oil and coal extraction already run through much of Appalachia. Hundreds of thousands of conventional oil and gas landscapes have been left to decay for decades here and across the country (Kang et al. 2016). Only now are these landscapes being addressed through EPA superfund sites and taxpayer money. While the future of unconventional oil and gas landscapes are uncertain, it is unwise to sit back and test if history repeats.

Figure x. Defunct conventional oilfield in the Allegheny National Forest of Northern Pennsylvania. Inactivity of the oilfield was identified through Pennsylvania oil and gas data. (Google Earth, 2014)





Figure I. Fracking wells and solar farms near Windsor, Colorado (Lanning, 2017)



I | BACKGROUND

This section focuses on hydraulic fracturing. It distills a large amount of literature to familiarize one with what fracking is, how it works, its history, its impacts, and its future. In addition to outlining these facts it investigates how various groups are responding to the many problems it is creating. This information is the foundation of the project's methodology discussed in Section 2, and is foundational to understanding the findings presented and discussed in Sections 3 and 4. To understand the rest of what this report investigates, is necessary to understand what is at the root of the issue.

01 THE RISE OF FRACKING

Conventional Oil and Gas extraction began in the mid-19th century around easily accessible sources near or at the surface. In some cases it flowed naturally to the surface (Donaldson, Alam, and Begum 2014). The conception of modern drilling methods and tools in 1859 would kick off the conventional oil and gas boom lasting for the next hundred years. The 1960's however, signaled the beginning of the end for conventional oil and gas extraction in the United States, "the first nation to explore, exploit, and begin to deplete its conventional resources" (Butler and Wuerthner, pg. 15, 2012).

The ethos of Fordism and modernization had quickly led to this depletion of conventional oil and gas sources. While resource scarcity was rising, the demand for oil kept rising. American society was increasingly shaping itself around oil and gas (Butler and Wuerthner 2012). Lack in its own oil/gas reserves to fuel a modern America, desperation and numerous other factors would heighten the United States' involvement in foreign oil affairs and conflict throughout the 20th century (Price-Smith 2015).

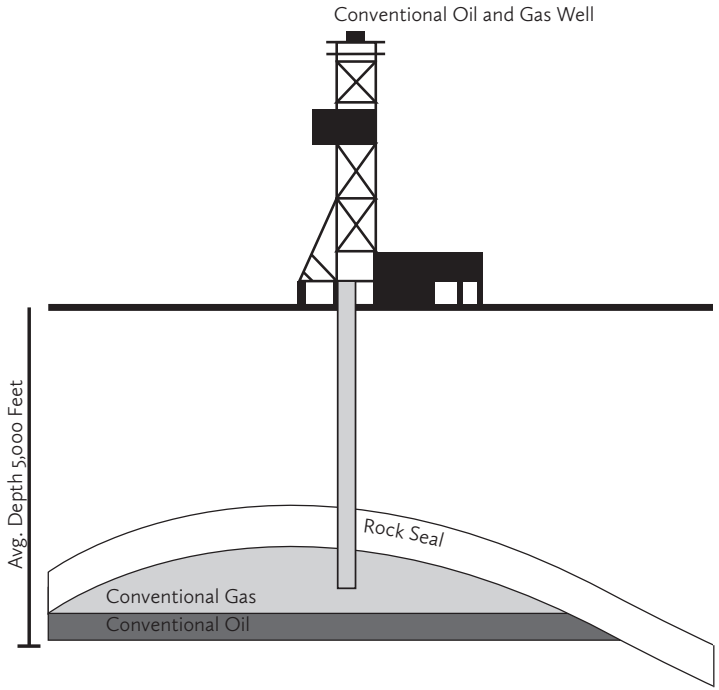


Figure 1.1. Conventional oil and gas extraction. (Lanning, 2018)

The cost of foreign oil and its conflicts in addition to consistently rising demands would eventually lead to a revision of domestic oil strategies in the late 20th century (Price-Smith 2015). Geological surveys revealed that a vast amount of oil and gas in the U.S. remained trapped deep underground behind dense layers of rock. These deposits make up much of the available oil and gas reserves left across the planet (EIA 2015). To reach these sources drillers would need new, unconventional methods to access and maximize yield. Hydraulic fracturing would be their answer.

While developed as early as the 1940's, hydraulic fracturing would not take off until the late 20th century. Referred to as horizontal drilling, fracking, or hydro-fracking, the process has quickly become the primary means of oil and gas extraction in the United States and greatly decreased its reliance on foreign reserves. U.S. Oil production declined from the 1970's through 2008 as conventional oil and gas was exhausted. However, due to hydraulic fracturing, production is now rising for the first time in almost 50 years (EIA 2017a).



Figure 1.2. "Cleveland. The City of Oil Derricks" - Cleveland, Oklahoma.
(Department of the Interior, 1905)

In the late 2000's additional shifts in the politics of the United States would further encourage Hydraulic fracturing's spread. The Great Recession and resulting economic initiatives as well as further distancing from foreign oil reliance would turn more attention towards domestic energy and hydraulic fracturing (Furnman and Sperling 2013; Holloway and Rudd 2013). Natural gas interest would also become more of a focus. Historically, interest in natural gas as an energy source has been comparatively low (Lin 2016). The large quantities of natural gas that fracking has opened up however, has been seen as an opportunity to increase use, creating a shift in attention away from coal while reducing energy costs (Ma and Holditch 2015). While coal has historically dominated energy production in the U.S. since industrialization, it's been unable to compete with natural gas which has been pushed as a cheaper, clean alternative (EIA 2017a). Whether it is truly a clean alternative is still a topic of debate.

As of 2018, more than 50% of the United States' oil and almost 70% of its natural gas comes from hydraulically fractured wells. This share in the market will continue to rise sharply as legacy conventional wells(those drilled before frackings implementation) are converted or phased out for fracked wells. Hydraulically fractured wells accounted for 95% of all new wells drilled in 2017 (EIA 2017c).

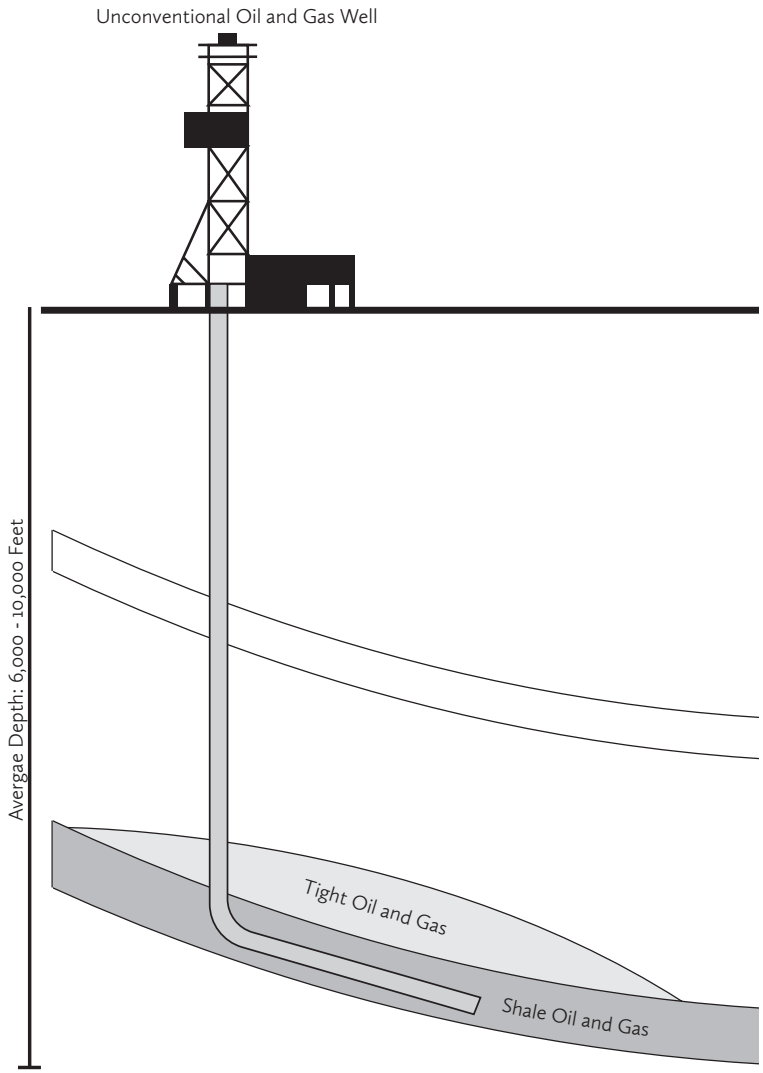


Figure 1.3. Unconventional oil and gas extraction diagram. (Lanning, 2018)

Hydraulic Fracturing's rapid rise to domination over U.S. domestic energy production has extended the nations reliance on fossil fuels. Prolonged reliance on oil, and new reliance on natural gas is warrant for why attention needs to be given to Hydraulic Fracturing. Within a matter of two decades it has led to a new oil and gas boom in the United States. Hundreds of thousands of new facilities have been constructed across the country and communities around this activity have been transformed. Hydraulic fracturing is here and now, and will continue to spread. Understanding what it is, what it entails, and where it is headed next is crucial.



Figure 1.4. A community in Windsor, Colorado takes shape around a fracking well. (Lanning, 2018)

02 FRACKING TODAY

As of 2018, hydraulic fracturing is common practice where oil and gas can no longer be obtainable through conventional means. Today there are 23 states actively fracking. Tens of thousands of new wells are being constructed each month, while many more conventional wells are being converted (EIA 2017e). While implementation of renewable energy infrastructure has slowly been rising in the last decade, natural gas and oil production has near doubled (EIA 2017a). The rise to domination over energy production shows that fracking is no longer in its infancy.

While known for controversy and polarizing debate, study shows that the majority of Americans may not understand what Fracking is (Boudet et al. 2014). Many may not know how it works, how widespread it is and how influential it has been in shaping many aspects of their community, region, and/or country. Unknown or known, it will continue to grow in influence not just within the U.S. but globally, as leaders maintain support for this type of energy. As seen by current trends, fracking will creep towards new resource deposits, unattuned to the controversy that surrounds it.



Figure 2.1. A row of water containers are readied for a fracking operation in the Bakken oilfields of North Dakota. (Doubek, 2011. Attributed under a CC BY-SA 3.0 License)

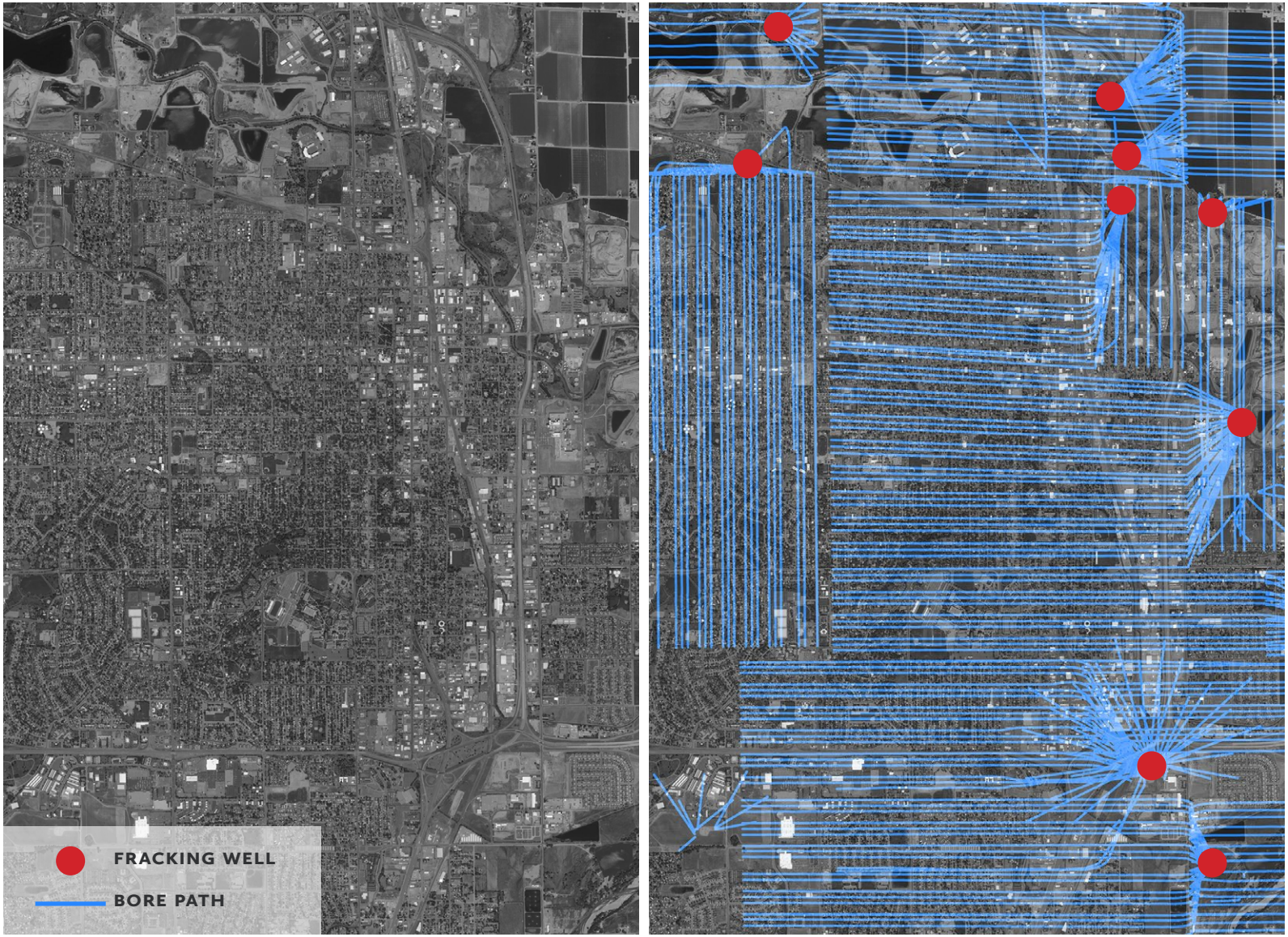


Figure 2.2. Horizontal well bore paths of nine fracking wells under Greeley, Colorado. Some extend as much as three miles from the well pad at the surface. While many may think they are not near fracking activity, it may in fact be right under them. (Lanning, 2018)

Source Data: Directional Lines, Oil and Gas Locations – Colorado Oil and Gas Conservation Commission, 2018. Base Imagery – ESRI, 2018

What is the Process of Hydraulic Fracturing? (Holloway and Rudd, 2013)

1. Survey and Preparation: Unconventionally sourced oil and gas is often referred to as 'tight' or 'shale' oil and gas. If this oil and/or gas is present and demand is high, then preliminary steps can be taken. This process begins with field surveys and land leasing and/or land acquisition. This may take place over long periods of time before enough land and mineral rights are acquired to start fracking. The very first step is to construct a well pad where all of the following steps will take place. After the pad is constructed, materials are staged, and pilot bores are drilled. The next step is to drill the wells and prep for fracking.

2. Horizontal Drilling: Once the site is prepped, a temporary drilling rig is constructed, and the well is drilled. Drilling and Injection can last from one to three months. Well bores are the pipes that are drilled below the surface up to a mile, where fracking occurs, and what oil and gas will flow through to the surface. Fracking or unconventional wells are often referred to as horizontal wells because they turn horizontal once below the earth. Turning horizontal allows drillers to reach underneath trapped deposits. Once the horizontal well bore is drilled the injection or fracking process can begin.

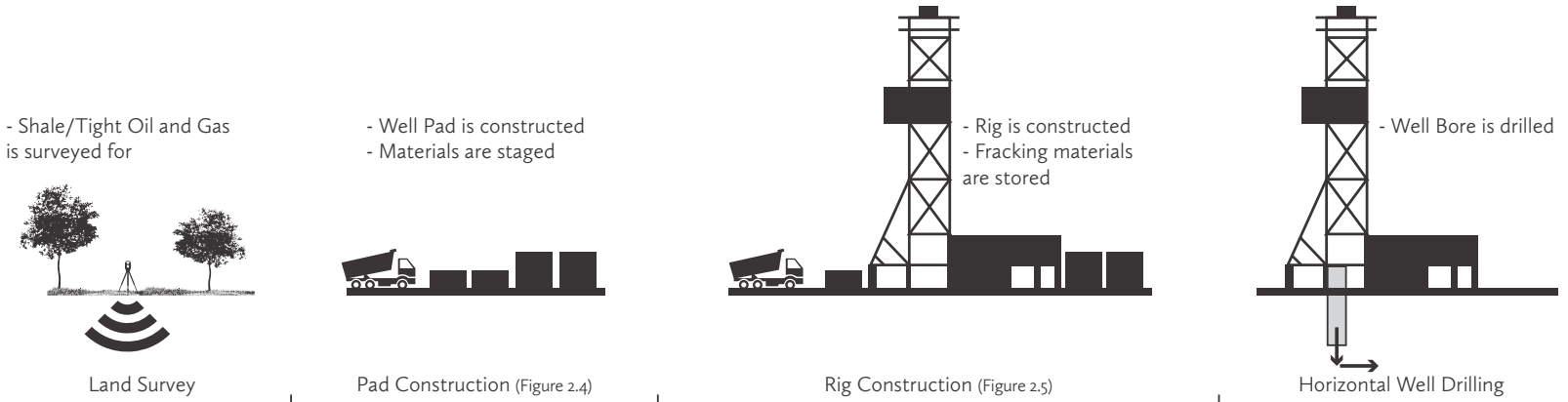
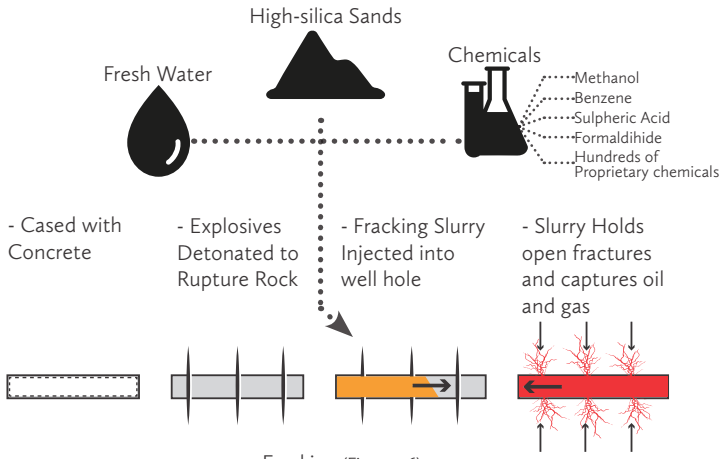


Figure 2.3. The Hydraulic Fracturing Process Simplified. (Lanning, 2018)

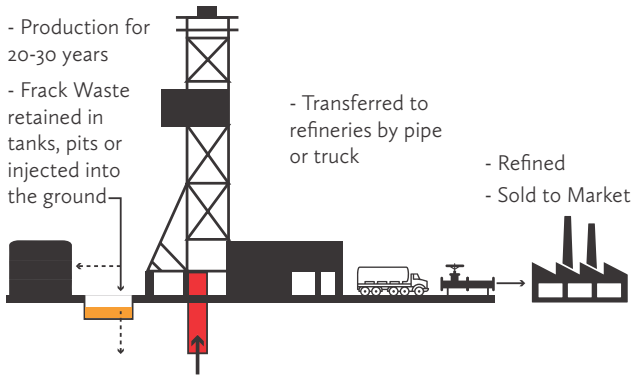
3. Injection: Injection is where fracking gets its name. It is when highly pressurized fluid is injected into the earth to rupture rock and allow for product to flow to the surface. The fluid is a mix of water, high-sillica sand and gravel, and various chemicals. Before injection, charges deep below are detonated to ease the flow of the injection fluid. Once injection begins, the high pressure of the injection ruptures the surrounding rock. The sand and chemicals act as an agent that hold open fissures in the ruptured rock and let oil and gas get by and flow up to the surface.

4. Completion/Production: After the injection or frack, and oil/gas is flowing, the well is cased in concrete and fitted with a well head. Completion is reached. Production has begun and can last for 30-40 years. Product is routinely transported via pipeline or truck off-site to various processing facilities where it is processed and sold.

5. Plugging: When production ends due to various reasons, a few outcomes are possible. Wells may be re-fracked to try and extend its production life. If it can no longer produce it is called a dry well and will be plugged. Ideally the well is sealed with concrete and the site is remediated, however abandonment without observing adequate practices can occur. These abandoned wells are referred to as orphans.



Fracking (Figure 2.6)



Production (Figure 2.7)



Termination (Figure 2.8)



Figure 2.4. Preparation Phase. Shown is a well pad in Pennsylvania being prepared for drilling. Various materials and containers full of sand, water, and chemicals are being staged. (Google Earth, 2011)



Figure 2.5. Drilling. Shown at night is a brightly lit drilling rig near Greeley, Colorado. Once drilled the wells will be fracked. (Lanning, 2018)



Figure 2.6. Fracking. Image of a frack in process.
(Doubek, 2011. Attributed under a CC BY-SA 3.0 License)


HALLIBURTON



Figure 2.7. Production. Shown is a well pad in Weld County, Colorado producing oil or gas. Only production related equipment remains. Vehicles will visit to monitor the site or collect product. (Lanning, 2017)



Figure 2.8. Termination. Shown is a gas wellhead in Greeley, Colorado. Signage states it will be removed and the land remediated. While not a fracking well, the fate of fracking wells are similar. (Lanning, 2017)

Where is Hydraulic Fracturing Most Common and Where Does Product Go? – Regional Trends

Typically major geological formations called Shale Plays delineate major oil and gas regions. These formations of dense shale rock contain the majority of the nation's oil and gas supply. The seven primary oil and gas plays and hydraulic fracturing prone regions in the United States are:

1. Anadarko: **Oklahoma**, *South Kansas*
2. Appalachia: **Ohio, West Virginia, Pennsylvania**
3. Bakken: **North Dakota**, *Northeast Montana*
4. Eagle Ford: **South-Central Texas**
5. Haynesville: **East Texas,** Arkansas, *Louisiana*
6. Niobrara: **Northern Colorado, Wyoming,** Utah
7. Permian: **North Texas,** Southeast New Mexico

High Activity | Moderate Activity | *Low Activity*

These Regions account for 82% of oil and 88% of natural gas obtained from fracking (Hughes 2014)

Statewide, in many of these shale formation regions, reactions have been polarizing. Ohio, Pennsylvania, and West Virginia have widely implemented fracking, while New York and Maryland have banned it statewide. In other places where there are known shale reserves such as Kansas, fracking has yet to take off due to still-remaining conventional reserves. However, the overall direction has been to fully implement the practice if there are enough reserves and it is deemed economically viable to frack.

Both the Trump and Obama administrations have moved to increase domestic energy reliance and production across the country, however the Trump administration has moved to reverse the former Obama administration's plans to protect public lands from fracking (NRDC 2017), opening up large portions of the West and Arctic. State governments have also shown to be pro-fracking, overturning municipal bans or making them hard to establish (Fry, Briggle, and Kincaid 2015). Such pro-fracking moves have opened the door to a huge amount of public and private land – populated and unpopulated – to be exploited for oil and gas production. Today there are 37 states where Fracking has been or will likely be implemented soon.

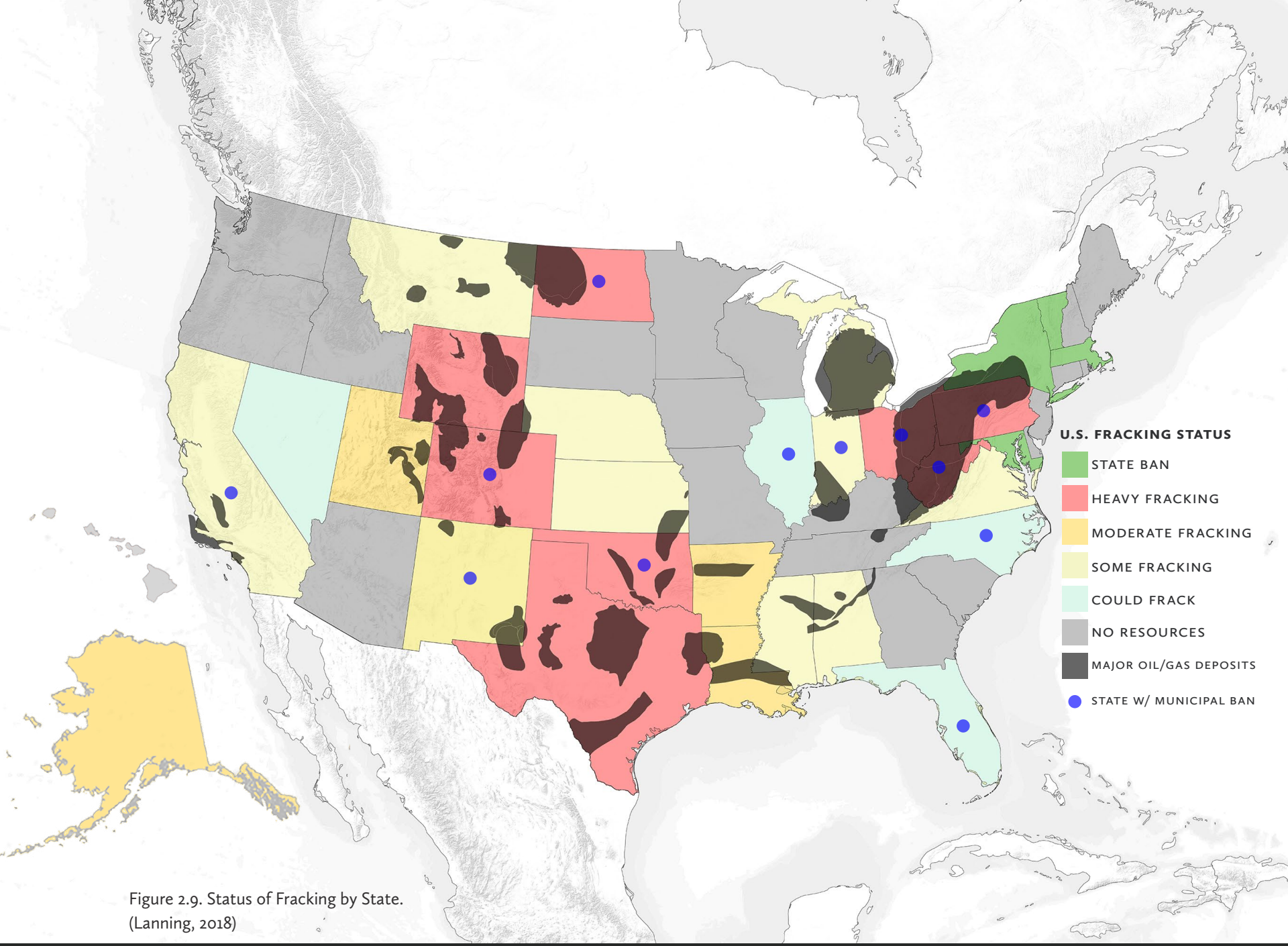


Figure 2.9. Status of Fracking by State.
(Lanning, 2018)

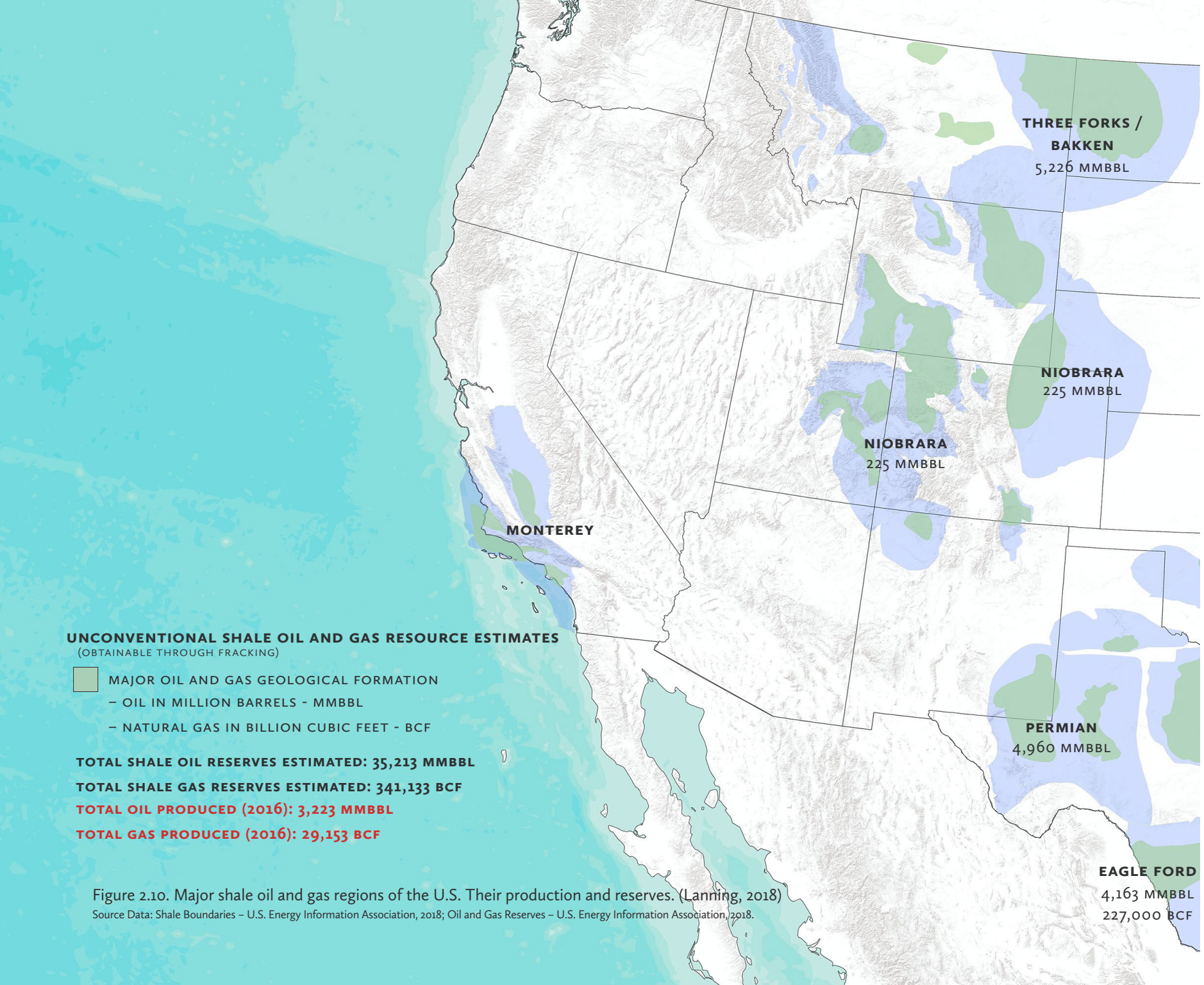
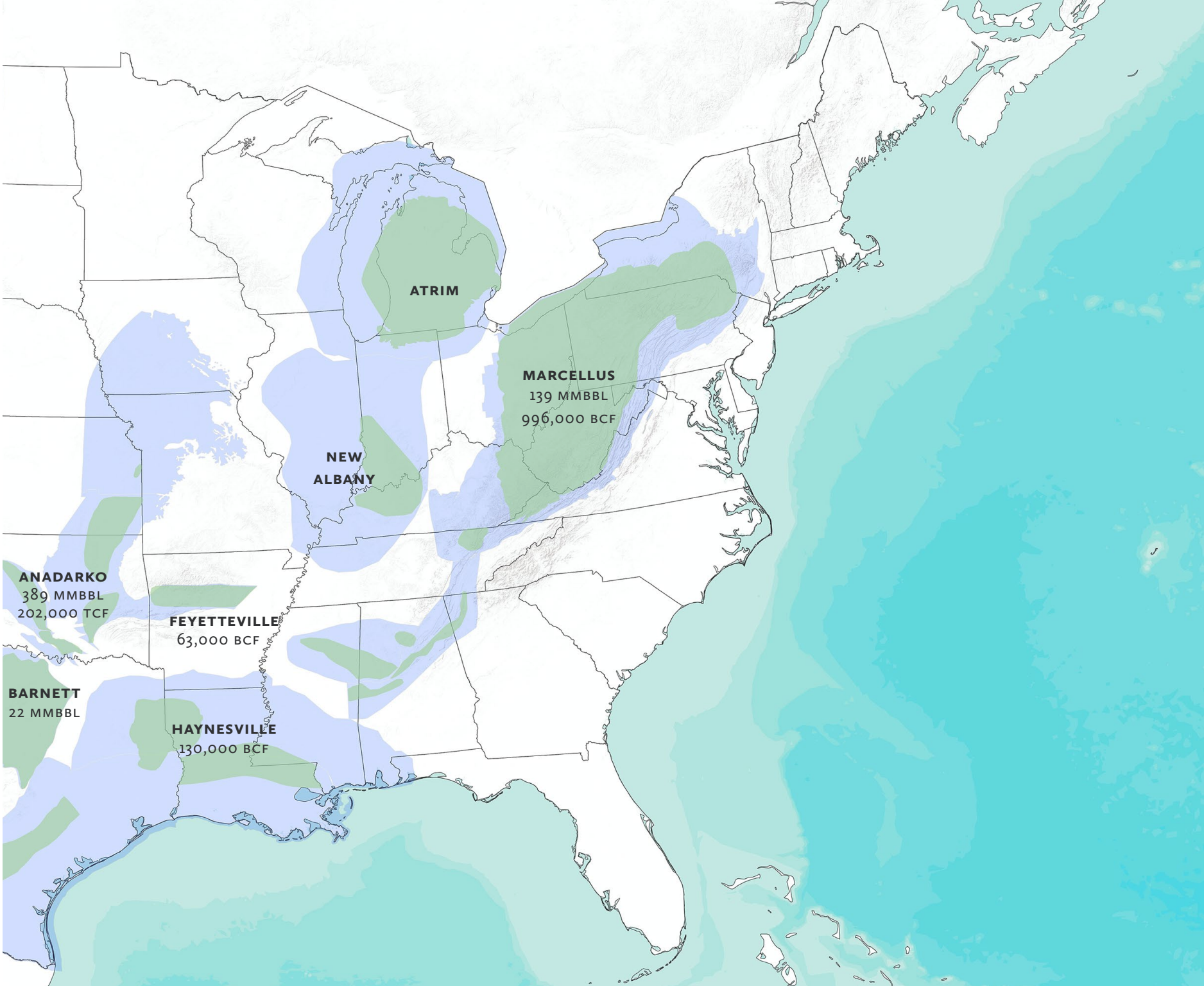


Figure 2.10. Major shale oil and gas regions of the U.S. Their production and reserves. (Lanning, 2018)

Source Data: Shale Boundaries – U.S. Energy Information Association, 2018; Oil and Gas Reserves – U.S. Energy Information Association, 2018.


ATRIM
MARCELLUS
139 MMBBL
996,000 BCF
NEW
ALBANY
ANADARKO
389 MMBBL
202,000 TCF
FEYETTEVILLE
63,000 BCF
BARNETT
22 MMBBL
HAYNESVILLE
130,000 BCF

Where is Hydraulic Fracturing Most Common and Where Does Product Go? – Global Trends

Oil and gas produced by the U.S. primarily ends up being used by the U.S.. However, oil and gas exports are predicted to overtake imports by 2026, a trend that hasn't shifted since 1953 (EIA 2017a). While the price of oil and gas is predicted to rise and renewables to decrease, oil production is still predicted to grow from 48% to 60% by 2026. Natural gas will continue to rapidly grow as it recently has (EIA 2017a). These predictions over the future growth of U.S. oil and gas production are largely dependent on technology and demand both domestic and international (EIA 2017a). Rising competition with renewables will greatly impact oil and gas's future.

The U.S. is one of the first but not last to fully implement hydraulic fracturing. As the United States' domestic energy policy and reliance on hydraulic fracturing is expanding, nations across the globe are doing the same. Hydraulic fracturing has and is becoming more of a polarizing topic of debate across much of the globe. Canada, Eastern European countries like Poland and Ukraine have fracked for decades (Haak 2014). While other developed countries in western Europe such as Germany and France have banned it nationally (Haak 2014).

For other countries, conventional sources have been adequate and/or fracking technology has been a limiting factor. However, conventional sources are rapidly dissipating, demand is growing, and the technology to frack is becoming more accessible (Lin 2016). Vast amounts of resources that can reached though hydraulic fracturing are being uncovered each year, adding life to the global supply of oil and gas reserves (EIA 2015).

Argentina, China, and South Africa sit on impressive shale oil and gas reserves and have recently begun to implement hydraulic fracturing in their oil and gas fields (EIA 2017a). As for countries in Asia – China, India, Southeast Asia – fracking is being viewed with interest as both extensive reserves to fuel modernization, and as a means of shifting energy dependence away from high pollution emitting coal and wood burning (Lin 2016). Other world regions that sit on substantial oil and gas reserves are in Australia, South America, North Africa, and Russia, yet they have yet to show interest in hydraulic fracturing, or have held reservations similar to those in Western Europe (Kaden and Rose 2015). The fracking trends that are being observed in the United States may very well become a global phenomenon in the near future, if not already.

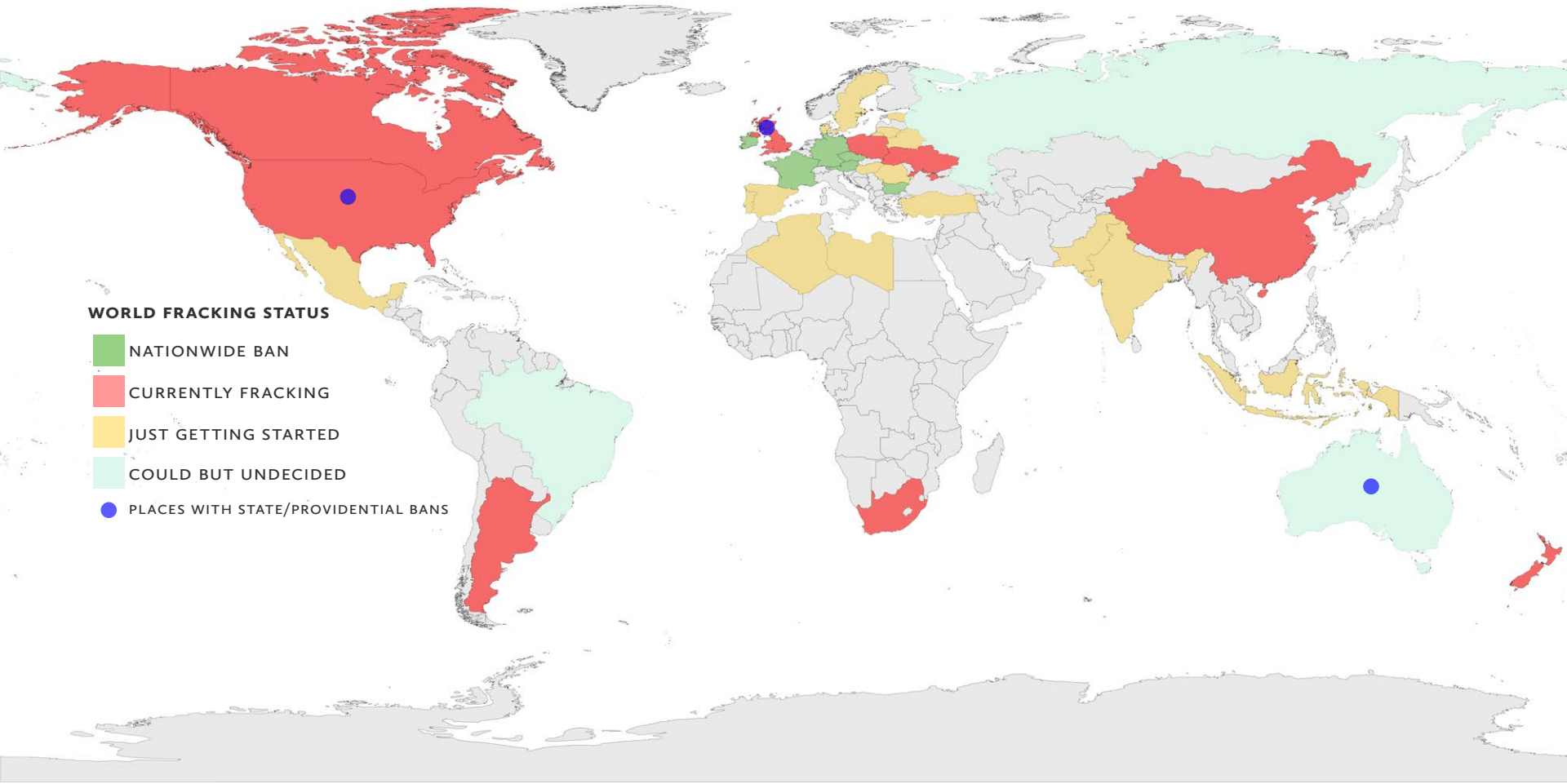


Figure 2.11. Status of fracking across the World (Lanning, 2018)

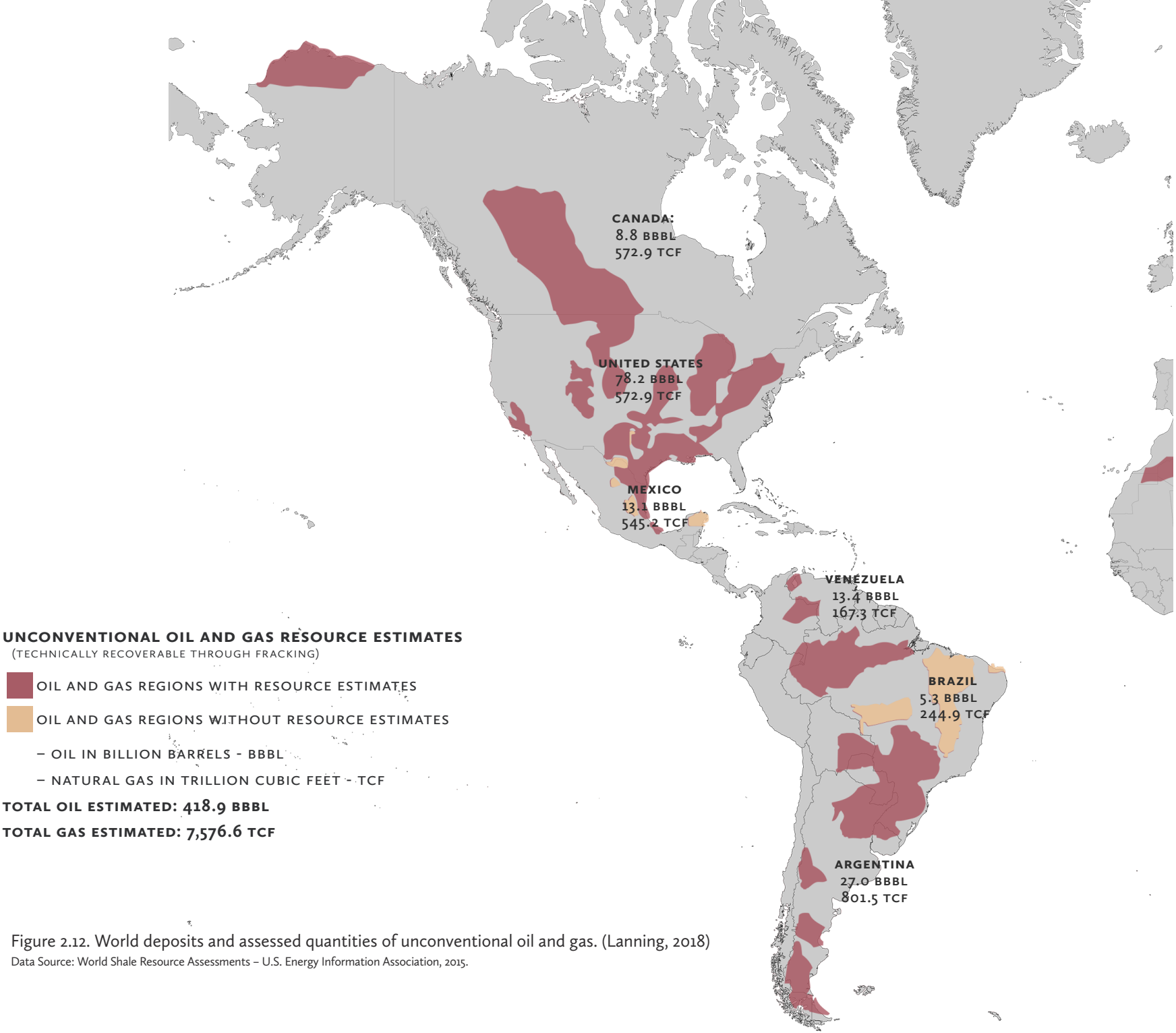
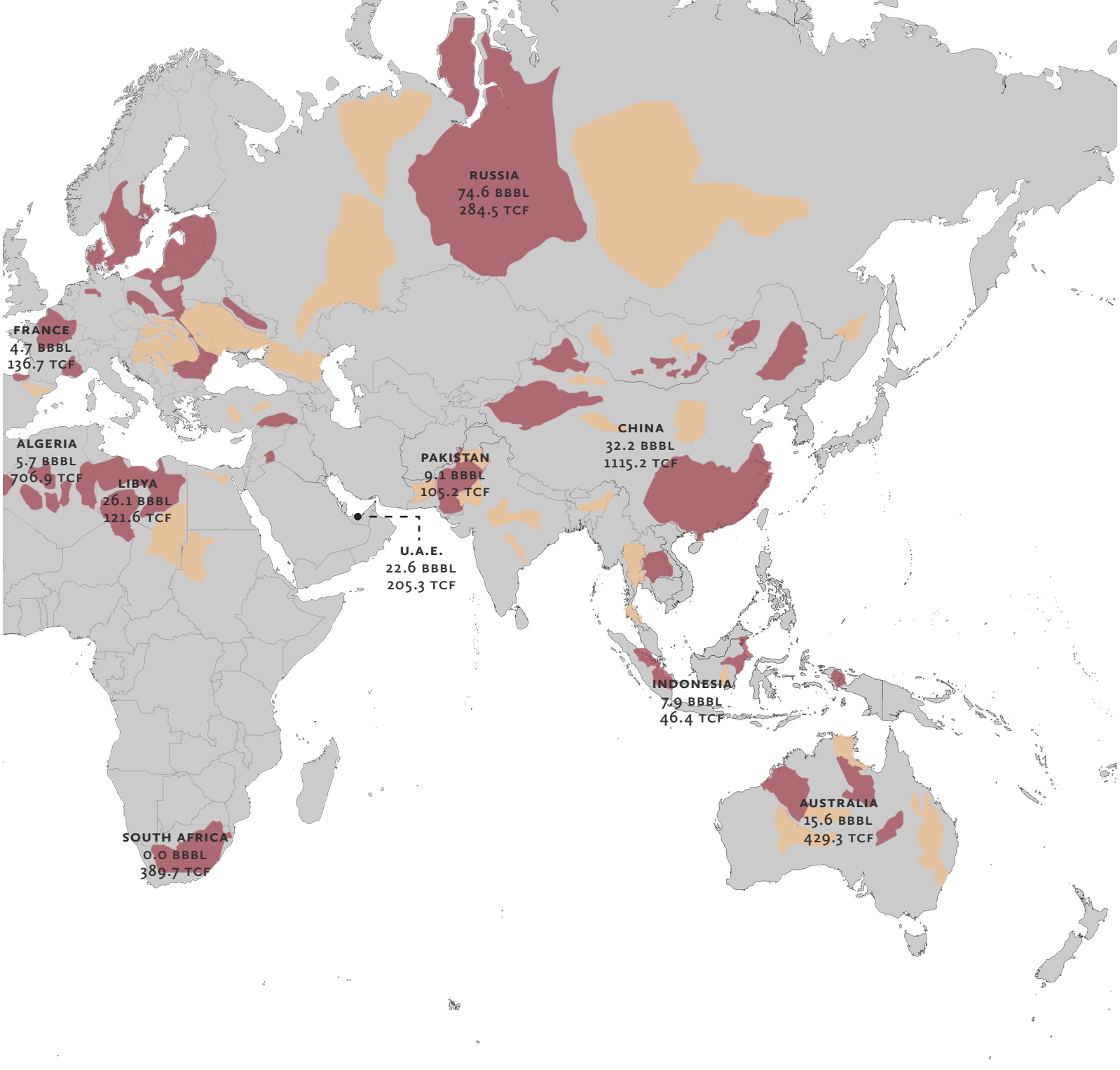


Figure 2.12. World deposits and assessed quantities of unconventional oil and gas. (Lanning, 2018)
Data Source: World Shale Resource Assessments – U.S. Energy Information Association, 2015.


RUSSIA
74.6 BBBL
284.5 TCF
FRANCE
4.7 BBBL
136.7 TCF
ALGERIA
5.7 BBBL
706.9 TCF
LIBYA
26.1 BBBL
121.6 TCF
PAKISTAN
9.1 BBBL
105.2 TCF
U.A.E.
22.6 BBBL
205.3 TCF
CHINA
32.2 BBBL
1115.2 TCF
INDONESIA
7.9 BBBL
46.4 TCF
AUSTRALIA
15.6 BBBL
429.3 TCF
SOUTH AFRICA
0.0 BBBL
389.7 TCF

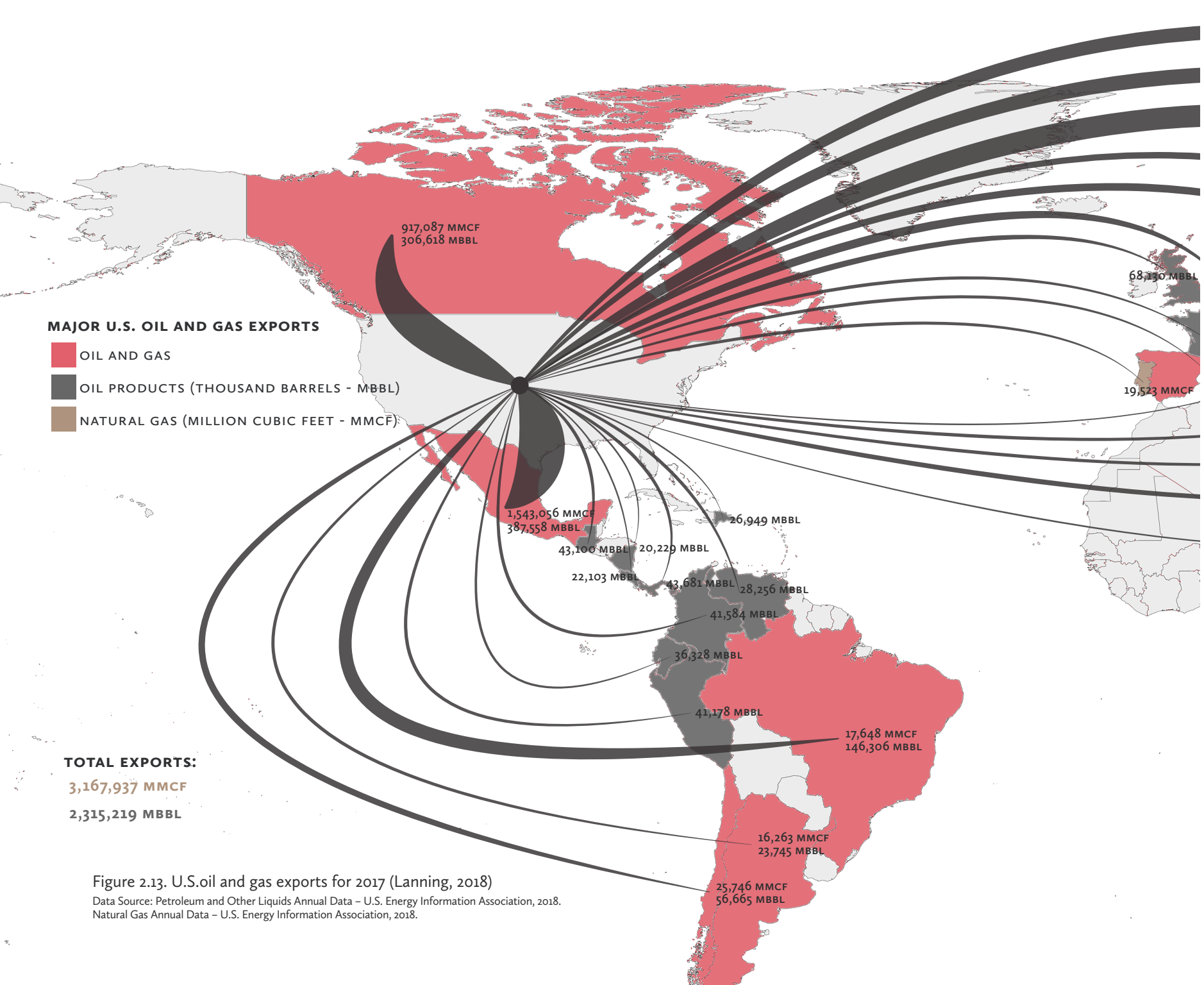
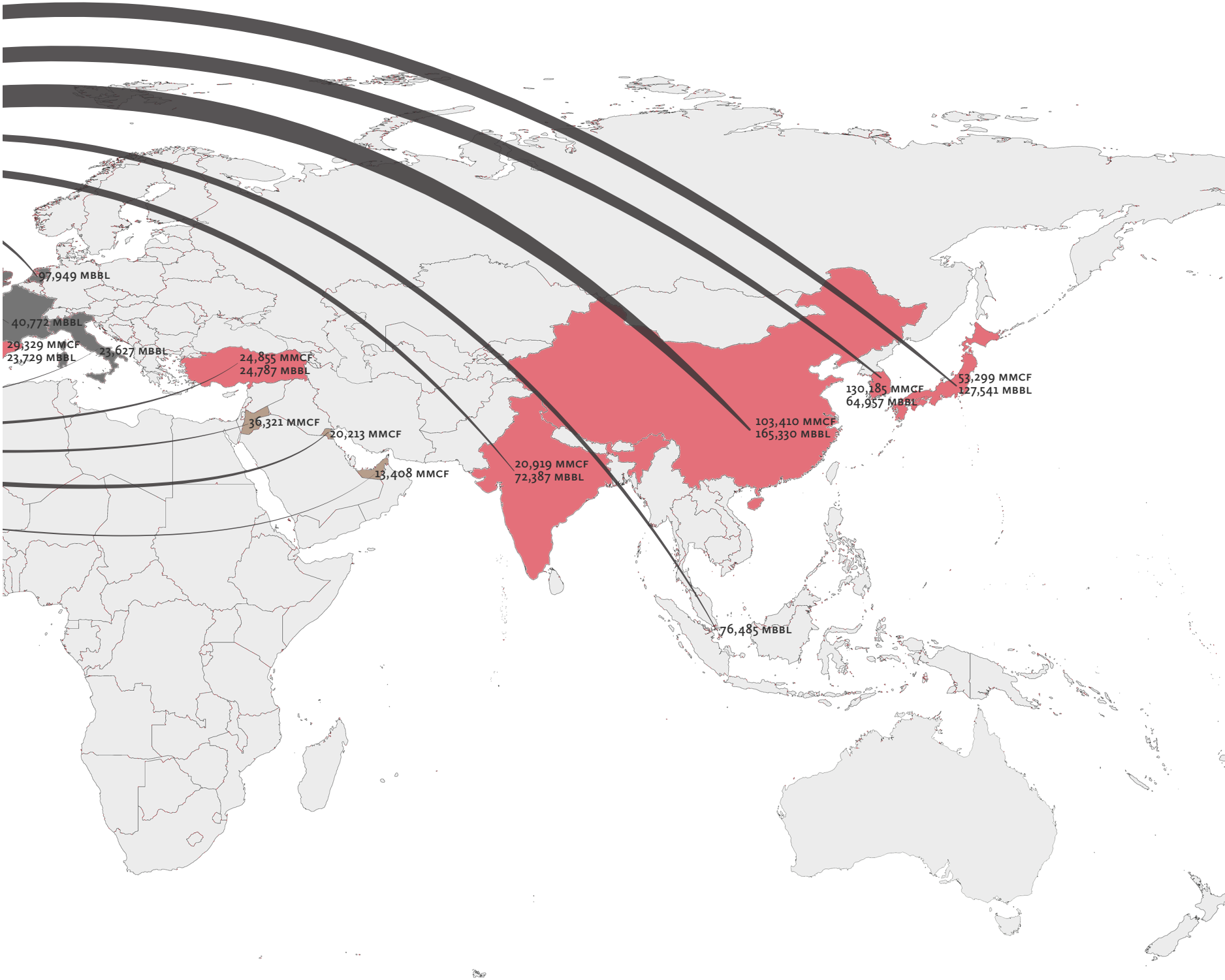


Figure 2.13. U.S.oil and gas exports for 2017 (Lanning, 2018)

Data Source: Petroleum and Other Liquids Annual Data – U.S. Energy Information Association, 2018.
Natural Gas Annual Data – U.S. Energy Information Association, 2018.


97,949 MBBL
40,772 MBBL
29,329 MMCF
23,729 MBBL
23,627 MBBL
24,855 MMCF
24,787 MBBL
36,321 MMCF
20,213 MMCF
13,408 MMCF
20,919 MMCF
72,387 MBBL
103,410 MMCF
165,330 MBBL
130,185 MMCF
64,957 MBBL
53,299 MMCF
127,541 MBBL
76,485 MBBL

What are the Benefits of Hydraulic Fracturing?

Regionally and Locally:

While reports funded by oil and gas companies have been found to overstate regional economic impacts of hydraulic fracturing by as much as 200% (Hoy, Kelsey, and Shields 2017), accurate estimates of financial impacts are still considerable. Figures estimate that the hydraulic fracturing boom has accounted for around 550,000 jobs so far (Maniloff and Mastromonaco 2017). Communities with fracking activity have seen a 14.4% employment gain, while boom towns experienced a 38.4% employment increase. Counties where at least one well was drilled before 2011 saw 10.8% higher average incomes than counties without. Boom counties saw 28.6% higher average incomes than counties without oil and gas development. (Maniloff and Mastromonaco 2017)

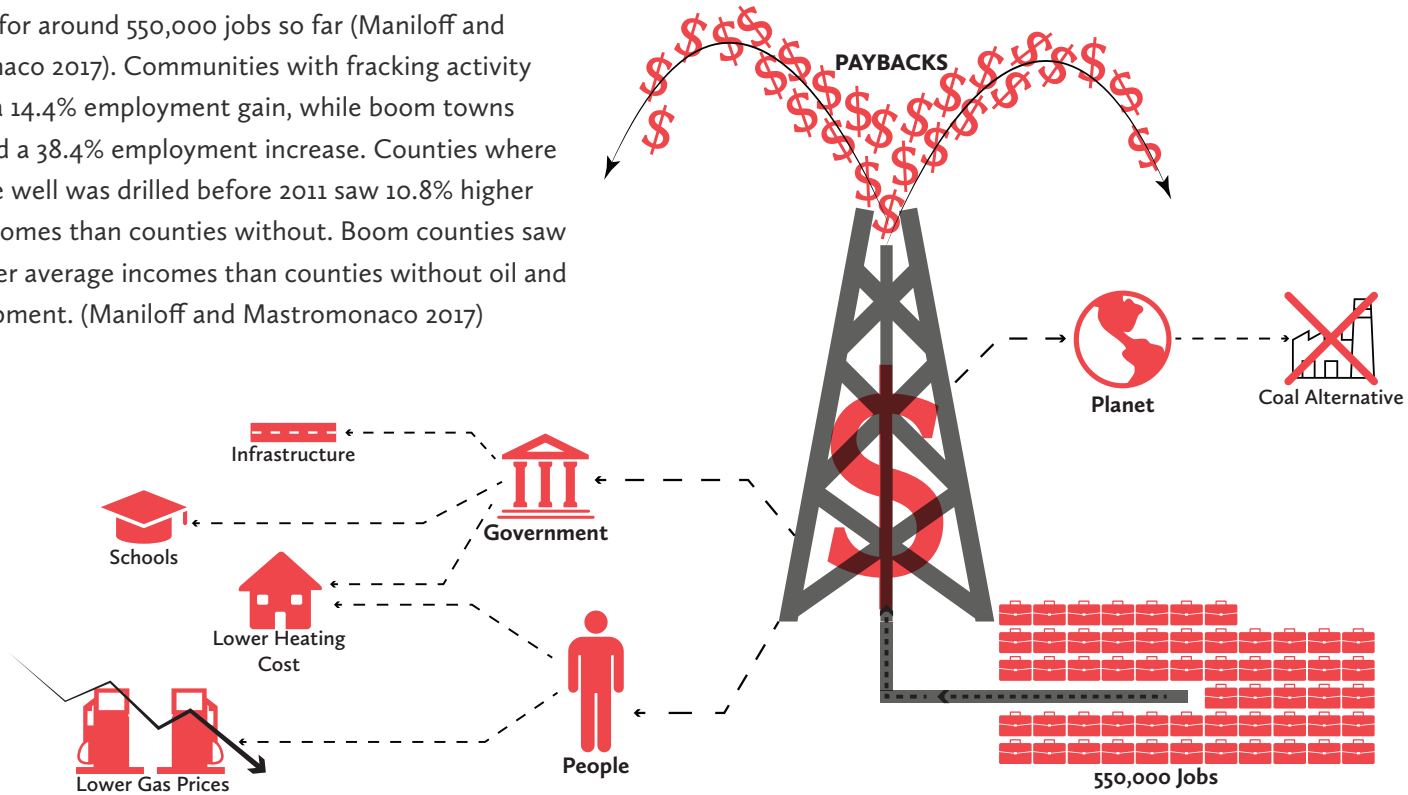


Figure 2.14. Economic gain breakdown of hydraulic fracturing. (Lanning, 2018)

National:

The U.S.'s recent hydraulic fracturing boom has amounted to major change in its national economy and paid off for the public in some cases. It is even credited with pulling the U.S. out of the economic downturn of the late 2000's (Gold 2015). Surge in domestic oil and gas has kept oil and gas prices stable, saturated job markets, and produced large amounts of wealth (EIA 2017a; Fitzgerald 2012). While gasoline prices rose sharply in the mid-2000's they have remained around $2-$3 for the last 5 years, even while consumption has risen by almost 7% in that time (EIA 2018b).

In the case of natural gas, fracking has reduced costs by as much as 400%. This has encouraged greater use of natural gas for residential and commercial heating, and in use as an alternative to coal for regional electricity generation (Dews 2015). Natural gas has been coined as a "bridge-fuel" in transitioning from coal to renewables (EIA 2017b).

Analysis of the wealth pay-out has found that U.S. consumers of natural gas have seen a $75 billion increase in surplus, while producers of natural gas have seen around a $7.2 billion increase in surplus (Loomis and Haefele 2017). However, this same study found that while the rest of the country is benefiting from reduced costs of oil and natural gas, the areas where hydraulic fracturing is widespread are taking a hit. These regions are having to deal with almost all of the costs associated with Fracking which are discussed in the next chapter. It's estimated that these costs total around $37 billion for 14 states (Loomis and Haefele 2017). While there are gains associated with hydraulic fracturing, extensive research shows that they may not be enough to outweigh the vast amount of costs associated with it.

Loomis & Haefele, 2017 – Gains

(Created by 14 major oil and gas producing states)

- $46 – $95 billion consumer surplus
- $7.24 billion producer surplus
- $3.9 – $21.9 billion gains from switching from coal to gas

03 THE RISKS & IMPACTS OF FRACKING

Fracking is one of the United States' most controversial methods of resource extraction. This controversy is rooted in the vast array of social, economic, environmental, and infrastructural damage that fracking can create. Opposition is not unjustified, as incidents of damaging leaks and spills, social injustices, environmental destruction and more have been recorded with frequency. Such incidents have sparked an unprecedented amount of research conducted in various frack-prone regions. These studies are seeking to understand the effects of fracking and its resulting incidents, delineating the extents of damage that has and can be generated.

The following pages highlight some of the many potential impacts poised by fracking; supported by examples of recent scholarly study. These studies referenced are not linked to single incident, they reflect on fracking infrastructure and processes as a whole or within a region. All fracking related infrastructure carries the risk of impacting its surroundings. If that risk is not mitigated through proper policy and best management practices, consider higher likelihood of such incident happening (Kaden and Rose, 2015). However, note that some impacts cannot be mitigated due to the nature of the fracking process.

Despite the large amounts of jobs and wealth Fracking has created, the gains cannot compete with the costs (Loomis and Haefele, 2017). Current fracking policy and practices warrant risk for costly damages (Kaden and Rose, 2015). As fracking continues to exist, we will see potential for these costly effects to remain in play, ready to impact nearby individuals and communities, and the environment.

Loomis & Haefele, 2017 – Costs

(Costs to 14 major oil and gas producing states)

- $12.5 – $41.95 billion in health damages from air pollution
- $3.5 – $4.45 billion in habitat fragmentation
- $1.15 – $5.89 billion in greenhouse emissions
- $0.5 – $1.6 billion in private drinking water well pollution
- $250,000 million water usage and reduced property values
- Unknown cost for surface water contamination



Figure 3.1. Breaking down the impacts of hydraulic fracturing. (Lanning, 2018)



Environmental Impacts:

- High degree of land disturbance is required for hydraulic fracturing and all of its subsequent activities:
- Requirements per fracking operation and its related landscapes were estimated to average around 8.8 acres – millions of acres cleared in total (Walton and Woocay 2013)
- Land use 40% higher on privately owned land vs. publicly owned land due to infrastructure not being strategically located in close proximity (Langlois, Drohan, and Brittingham 2017)
- Soil contamination potential from spills, leaks, and failures both sites and their surroundings (Donaldson, Alam, and Begum 2014)
- Majority of fracking in rural areas, where wildlife habitats exists. High levels of fragmentation: Impacts behavior, endangered and threatened species, unique habitats (Wilbert, Thomson, and Culver 2008)
- Tripled oil and gas well-pad density in Wyoming resulted in a 25% decline in the population of male sage-grouse (Gregory and Beck 2014).

Figure 3.2. Aerial image of a pipeline corridor cutting through core forest near Clarendon, Pennsylvania. Effects of pipelines in the region are highly evident and highly controversial. (Google Earth, 2013)



Impacts on Water Quality:

- Fresh water (primary ingredient in fracking slurry):
  - 2004-2014, 250 billion gallons of water used for hydraulic fracturing. 210 Billion gallons (84%) became waste water (Duke Today 2015).
  - Accounts for around 1% of the national water use for industrial activity, however water usage may pose significant harm to local water resources, especially to those in dry areas (Cook Margaret A. and Webber Michael E. 2014; Magill 2015; Duke Today 2015).
    - Average fracking water use 28 times higher in 2015 than in 2000 (Magill 2015)
    - Texas water demand from growing populations conflicts with the water demand of fracking, affecting local water supply, droughts, and costs. From 1987 to 2008 water cost per 264,000 gallons increased from $30 to $3,100 (Cook Margaret A. and Webber Michael E. 2014).
- Combined with climate change, drought, depletion and contamination from other industry, as fracking grows hydraulic fracturing will increasingly aggravate regional water crises (USGS 2009; Southwest Farm Press 2012).

- Constant potential for water bodies to be contaminated due to the extensive amount of chemicals that have been intentionally or unintentionally mixed in fracking water, which can spill into water bodies (Gagnon et al. 2016).
  - Frack Hits: Operational and abandoned conventional wells can be fracked. Called Frack Hits, the aged infrastructure has high potential to fail and leak, possibly contaminating surrounding bodies of water.

Impacts on Water Use:

- Most chemicals added to the frack water are disclosed by oil and gas companies. Tests have found dozens of harmful compounds ranging from hydrochloric acid to formaldehyde (Environment America 2016).
  - Other contaminates included may be naturally occurring radioactive materials such as radium, or originate from stray gas contamination from well leaks (Walton and Woocay 2013)
  - A majority of the chemicals used in for frack slurry poise short and longterm health risks to communities and ecosystems exposed to them (Walton and Woocay 2013; Gagnon et al. 2016).
- Groundwater contamination occurs largely because of faulty or inadequate infrastructure and implementation. Active well sites and a vast number of orphaned wells (between 150k and 3 million) may experience leaks due to inadequate infrastructure or oversight resulting in both surface and groundwater contamination (Gagnon et al. 2016).
  - Properly, sealed wells left behind have the potential to leach contaminates (Holloway and Rudd 2013).
  - Other contamination and spills can occur from unintentional flowback, where liquid flows back to the surface unintentionally in large volume after injection (Zhang and Yang 2015).

Figure 3.3. A tank leaks an unknown fluid during a flood in Weld County, Colorado. (Used with Permission from Fractracker Alliance, ©Andy Cross, 2013)



Impacts on People and Communities:

- Economic Impact – Long-term economic effects on nearby communities have potential to be detrimental.
  - In North Dakota, hydraulic fracturing has shifted issues centered on urban migration and economic downturn to one of the opposite. Existing social support systems are overwhelmed, and fear over crime and loss of cultural values is growing (Weber, Geigle, and Barkdull 2014).
- Boomtowns and Gilmore's Problem Triangle: The failure of social services can lead to a depravity in quality of life which can then degrade the stability of local jobs. Loss of workforce leads to bust. (Gilmore 1976)
  - Fracking's high economic risk creates these boom to bust cycles where it is a town economy's major focus.
- Wealth: Communities and residents may not see a majority of the wealth produced from nearby oil and gas wells.
  - In Texas, a community received only %1 of the total value produced. While the municipality received a large share it was not levied evenly, especially to those who live in direct proximity to wells and face increased health risk (Fry, Briggle, and Kincaid 2015). Homes within 3,500 feet of a well experienced housing values 1.5-3.5% less than the average market price. Calculated to be a loss of $750 million for the whole county (Balthrop and Hawley 2017).
  - In Appalachia, fracking wells are disproportionately situated in poorer, rural communities, often due to land owners not owning mineral rights. Therefore, wells are being built against their will exposing to health risks and other fracking related issues than others (Ogneva-Himmelberger and Huang 2015)

Figure 3.4. The Lac-Mégantic rail disaster. In 2013 a train carrying oil from North Dakota derailed in downtown Lac-Mégantic, Quebec killing 42 people. (Sûreté du Québec, 2013. Attributed under a CC BY-SA 1.0 license)

- Health and Infrastructure Risks: Hydraulic Fracturing can result in dangerous leaks of volatile gases. These can build up near the surface and pose risk for explosion.
  - Catastrophe: People and Communities can be caught in incidents which have been known to be fatal
- Earthquakes: Known contribution to seismicity of regions previously not prone to earthquakes. The USGS states that in areas such as Oklahoma, Texas, and Colorado where waste water is re-injected into depleted well basins, earthquakes are more prone (Rubinstein and Mahani 2015).
  - Earthquakes in Oklahoma went from dozens over decades, to hundreds in a single year, can be felt in neighboring states, and have caused significant damage in communities in some cases (McGarr et al. 2015).
- Roads: Significant increase in road usage due to the influx of vehicles transporting materials, products, and workers. Increased traffic has resulted in increased traffic deaths, spills, and increased noise levels (Walton and Woocay 2013).
  - One well can have significant impact on local traffic, noise, and air pollution. While highest during drilling and fracking, conglomerate activity on multiple well pads in a region amplifies effects (Goodman et al. 2016).
- Air Pollution: Fracking wells are known to produce volatile organic compounds (VOC's), hazardous air pollutants (HAP's), and high emissions from traffic activity, which results in increased health complications, and long term health risks (Walton and Woocay 2013).
  - Natural Gas wells have contributed to global warming through excess methane emissions. Methane emissions may contribute more to global warming than coal burning (Walton and Woocay 2013).

Case Study: Visualizing the Risks of Fracking in Weld County, Colorado.

While much evidence exists that fracking creates an array of problems, its less clear who and what these problems are affecting. As pointed out by Meng and Ashby, 2014, spatial analysis of the impacts of hydraulic fracturing is necessary to understand risk for harmful water contamination and air pollution created by fracking. Meng and Ashby conducted an environmental risk assessment on wells in Southwest Pennsylvania. They concluded that water contamination risk is most significant within 3250 feet of wells and air contamination risk is most significant within 2600 feet of wells (Meng & Ashby, 2014).

Similar studies to Meng and Ashby's exist however there was no indication that such a study has been conducted in Colorado. In Weld County in Northern Colorado, fracking has rapidly spread and greatly changed the region. In the last decade well counts in Colorado have doubled from 22,000 to more than 54,000, with Weld accounting for almost half with 25,000 wells (COGCC 2013). Therefore, I conducted an inventory of the County's existing assets and their spatial relationships to oil and gas wells. Then, by utilizing the distances provided by Meng and Ashby's findings, I condicted a risk assessment of these oil and gas wells. The result is a visual understanding of fracking's potential effects on a particular place.

For reference: Weld County's population is around 305,000 as of 2017, its total land area is around 4,010 square miles and has 24,960 active wells as of November 2017; around 6.22 wells per square mile. Looking at land use, the majority; around 3,175 square miles – 60% – of Weld County is considered agricultural. (Weld County Government 2017; Weld County 2017)

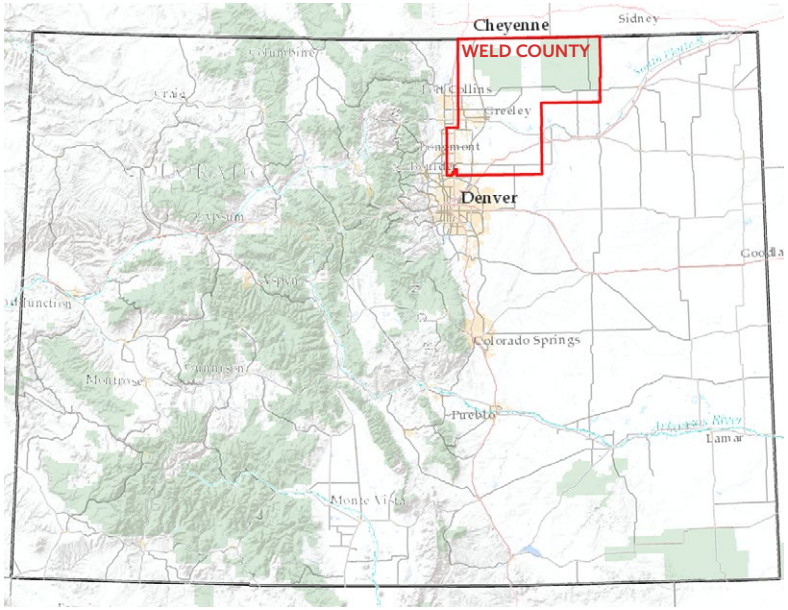


Figure 3.5. Weld County, Colorado Context Map. (Lanning, 2017)

How it was Done:

Inventory and Analysis:

The inventory and analysis delineated variables that were to be examined with the risk assessment. Obtained from local and state agencies, various data was used. Key social, ecological, and economic variables and their spatial context to oil and gas wells was measured. Occurrence of wells was measured in terms of contextual land use and county features such as municipalities, federally managed land, dry/irrigated agriculture, protected wildlife areas, and adjacent to hydrological features (streams, water bodies, aquifers).

Risk Assessment:

The risk assessment looks at understanding risk associated with the emittance of harmful chemicals into the air and water from oil and gas wells. The two distances used were derived from Meng and Ashby, 2014 – 1000m (3250') significant water contamination risk, and 800m (2600') significant air contamination risk (Meng & Ashby, 2014). Analysis of these two distances was conducted by buffering all 25,000 wells 3250 and 2600 feet. Area of influence, occurrence of compromised features (from inventory and analysis), and wells responsible were analyzed and mapped. Buildings were separated into occupied and non-occupied building to understand population impact, weighted by the average home size in Weld County: 2.75 per household.

Results:

This case study revealed that a majority of Weld county is at risk for being compromised by air and water contaminates originating from oil and gas wells. 80% of the county's population faces health risk from hazardous air contaminates released by wells. Community health is further undermined by the fact that almost 90% of its freshwater assets, and 85% of its food assets are within zones where significant water contamination from wells is possible. This study also revealed that nearly all of the county's remaining ecologically sensitive areas are at risk for being exposed to hazardous contaminates.

These effects will be felt beyond conty lines. With Weld leading as Colorado's food producer, much of state gets its produce from the County; exposing a greater population to health risk. Much of Weld's hydrological systems feeds into the Platte river, a major tributary of the Missouri River. Along the way this water is used for communities and agriculture. While the dangers of oil and gas are high in Weld itself, they poise potential to spread far outside the county.

This supplementary study highlights that fracking needs to be considered spatially and contextually. That its impacts and risks extend great distance outward unto communities

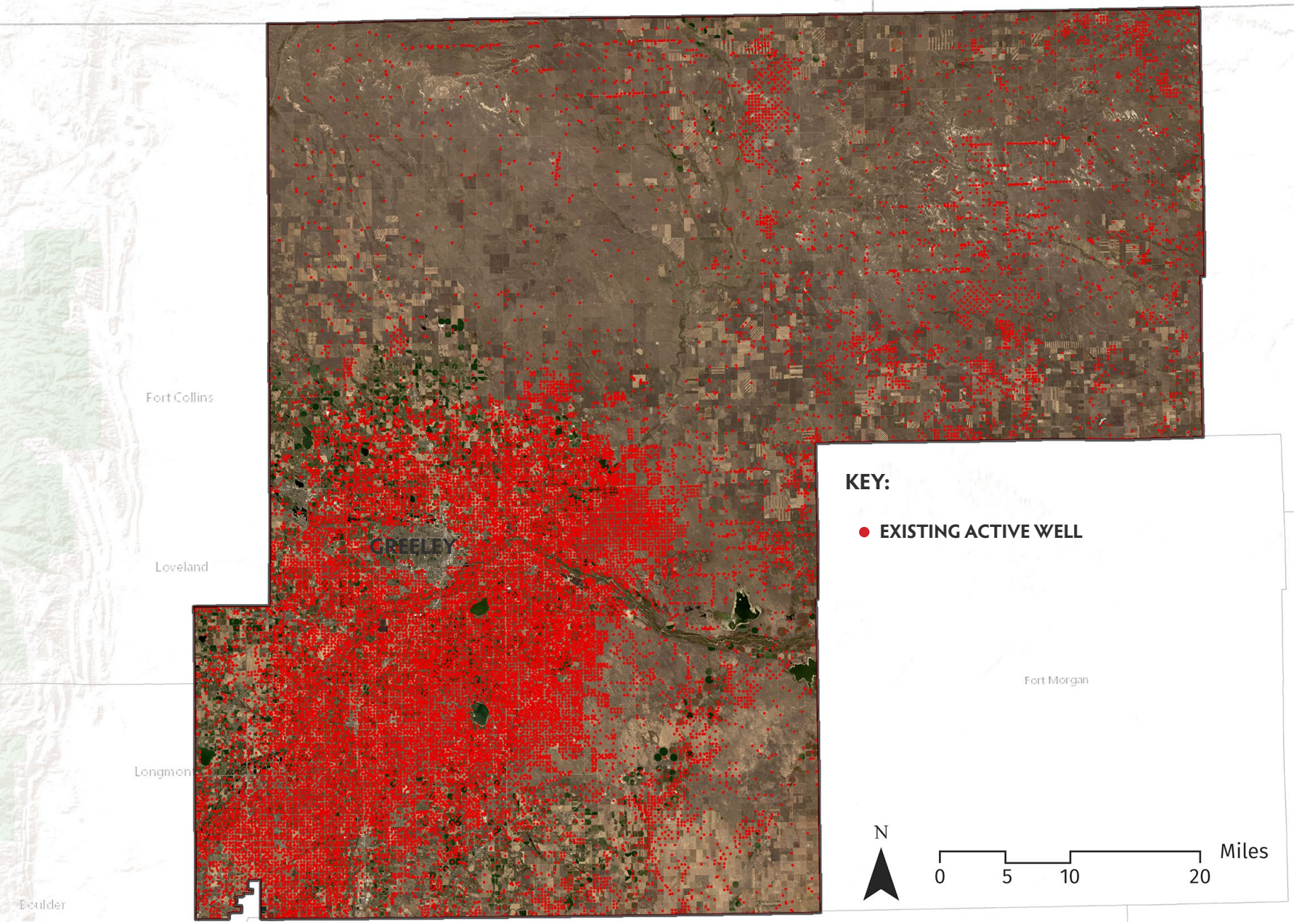


Figure 3.6. Distribution of active wells in Weld County. (Lanning, 2017)
Source Data: COGCC, 2017; Weld County Dept. of GIS, 2017

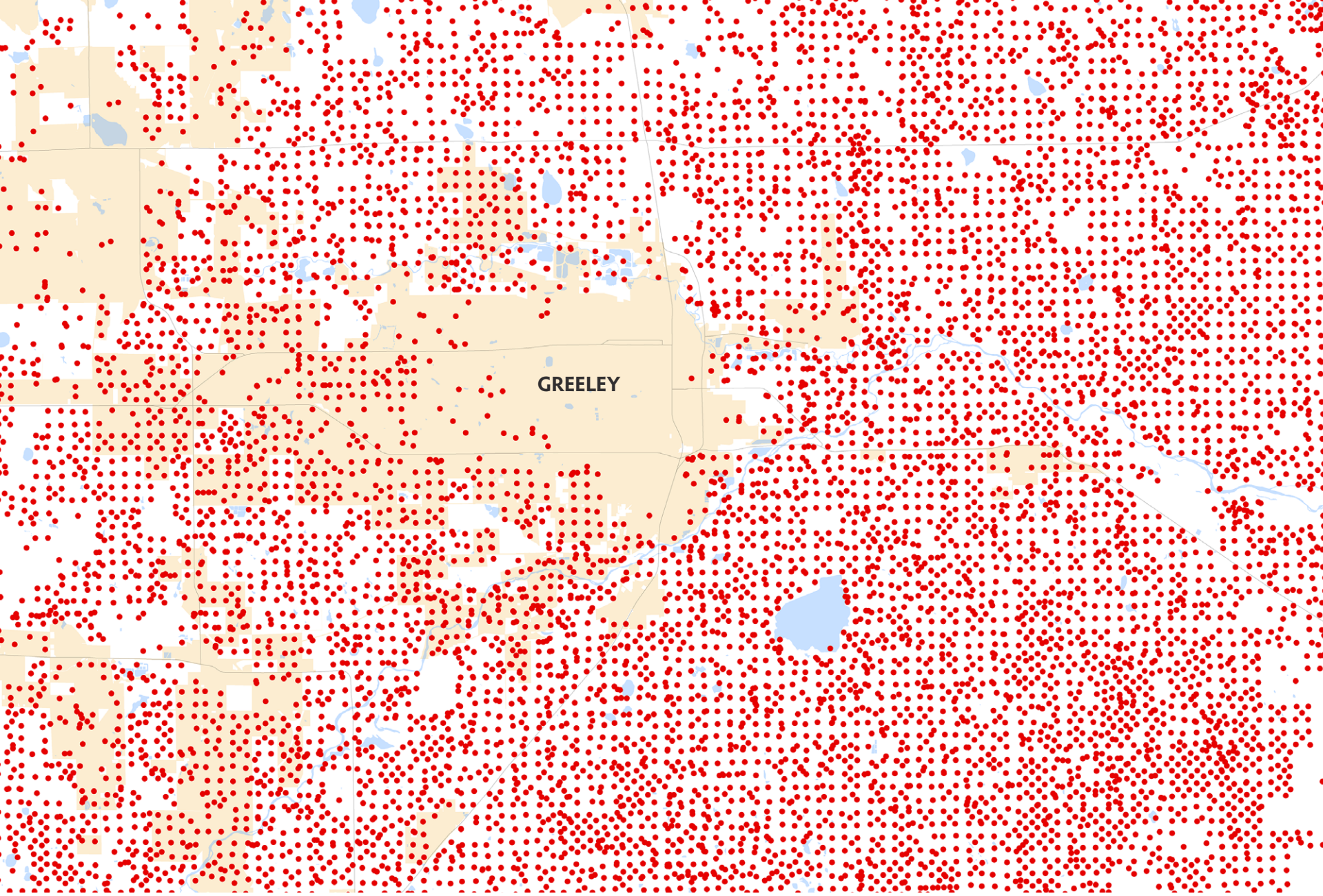


Figure 3.7. Active wells located around Greeley. (Lanning, 2017)
Source Data: COGCC, 2017; Weld County Dept. of GIS, 2017



Figure 3.8. Wells and their relation to surrounding land uses. (Lanning, 2017)
Source Data: COGCC,,2017; Weld County Dept. of GIS, 2017; USGS, 2017.

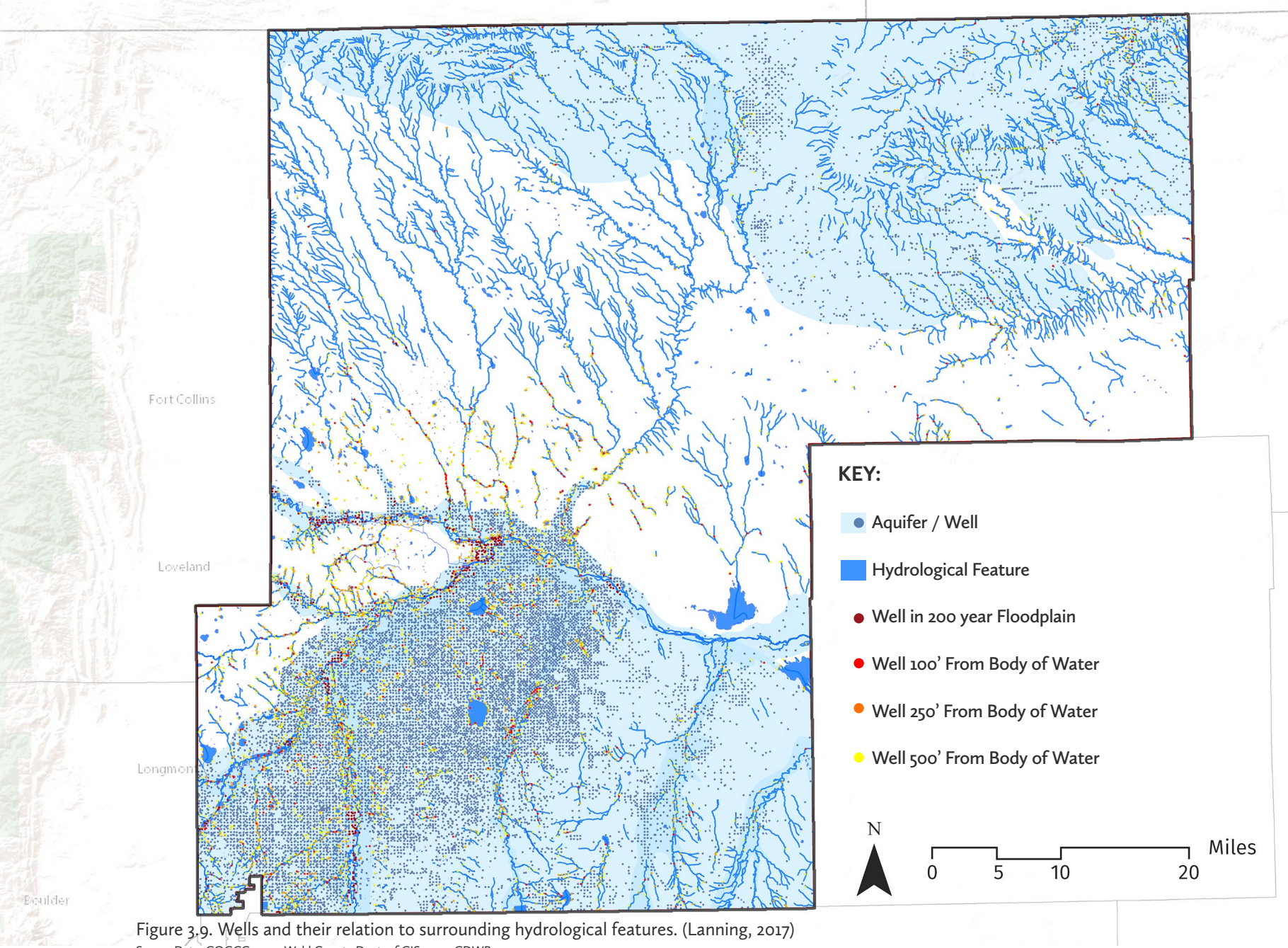


Figure 3.9. Wells and their relation to surrounding hydrological features. (Lanning, 2017)
Source Data: COGCC, 2017; Weld County Dept. of GIS, 2017; CDWR, 2017

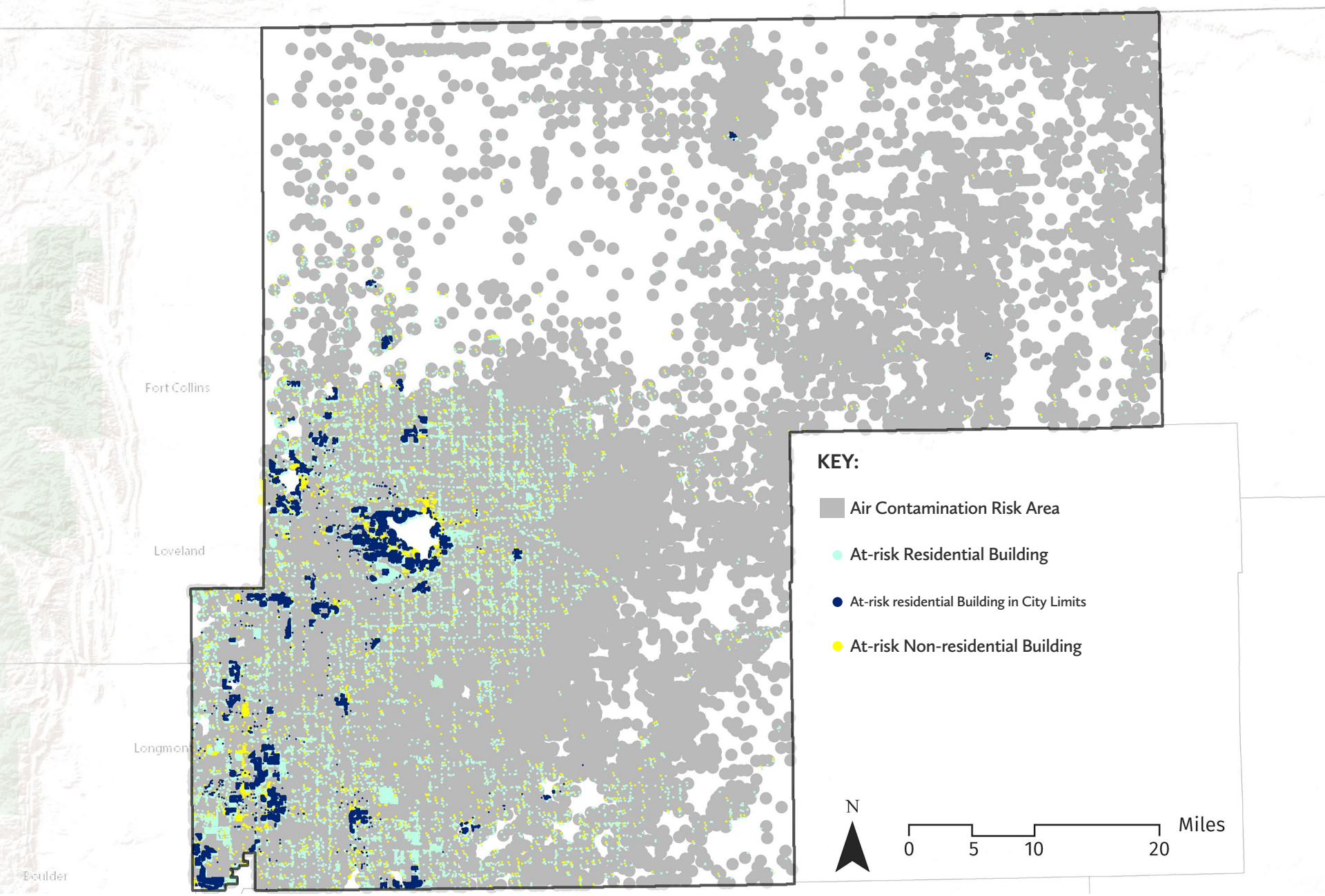


Figure 3.10. Area of air contamination risk and at-risk populations.. (Lanning, 2017)

Source Data: COGCC,,2017; Weld County Dept. of GIS, 2017.

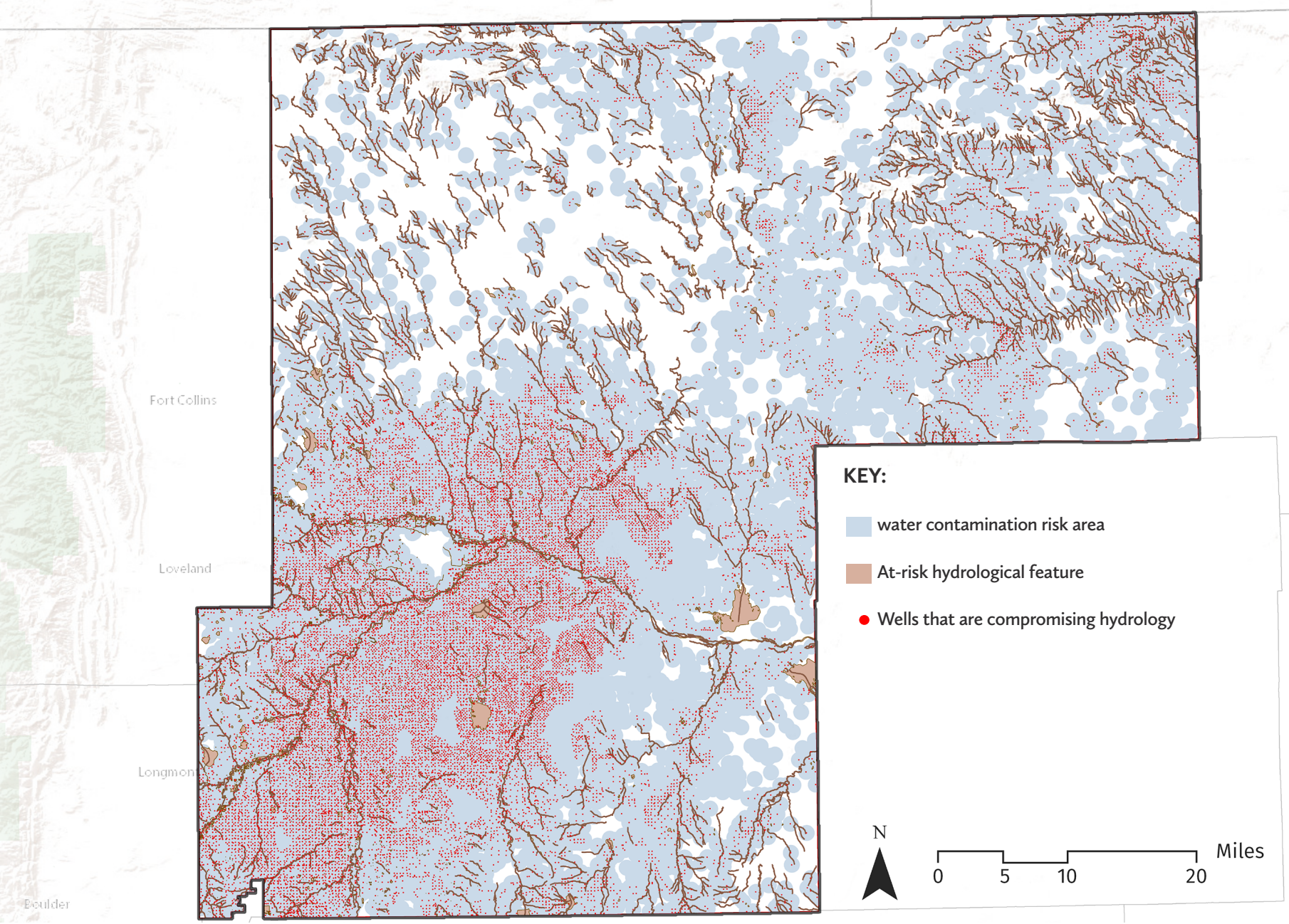


Figure 3.11. Area of watercontamination risk and at-risk hydrological features. (Lanning, 2017)
Source Data: COGCC, 2017; Weld County Dept. of GIS, 2017; CDWR, 2017

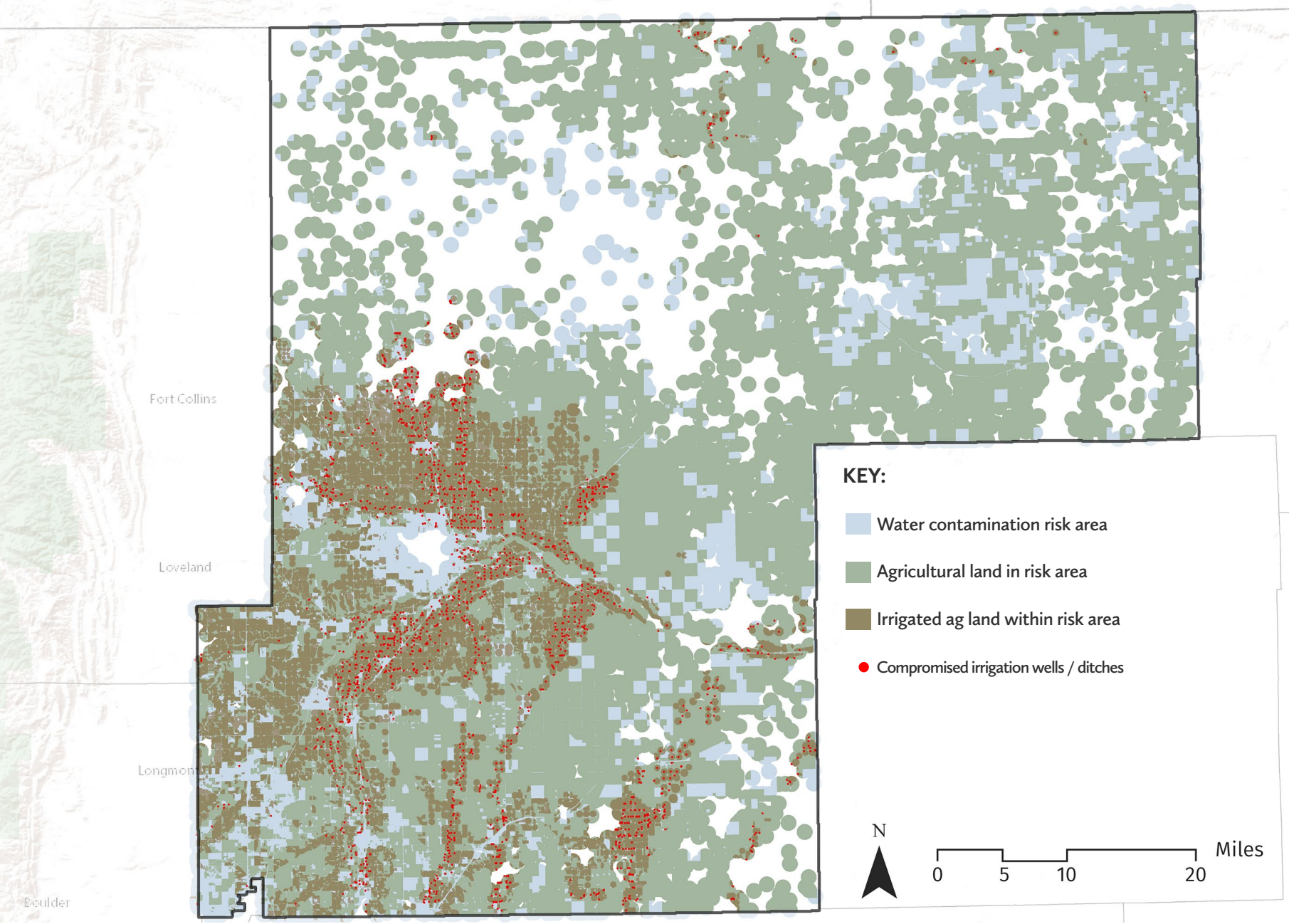


Figure 3.12. Area of watercontamination risk and at-risk agricultural features. (Lanning, 2017)
Source Data: COGCC,,2017; Weld County Dept. of GIS, 2017.

Summary of Findings

Inventory:

- 26% of unincorporated parcels have at least one or more wells within its bounds.
- 20,261 wells (81%) were on agricultural lands.
  - 9,029 (36%) of such wells were in irrigated ag areas.
- 1,951 wells (8%) were on public lands managed by the Bureau of Land Management
- 2,520 wells (10%) were within city limits.
- 17,188 wells (69%) were located over an aquifer.
  - 527 were within 100 feet of a body of water,
  - 2,059 within 250 feet, and
  - 4,146 – 17% – within 500 feet of water bodies.
  - 331 wells were located in a 20-year floodplain.
- Colorado oil and gas setback laws cover 800 square miles (20%) of the county.
  - 4,957 wells (20%) violated these setbacks.

Risk Assessment:

- Water contamination risk is most significant within 1000m (3250') of wells. Air contamination risk is most significant within 800m (2600') of wells (Meng & Ashby, 2014).
  - 3,150 square miles (78.5%) of Weld is within the 1000m water contamination risk zone.
  - 2,780 square miles (69%) of Weld is within the 800m air contamination risk zone.
  - Only 870 square miles of the 4,010 square mile county is completely outside these threat zones.

Air Risk:

- 78,184 residential structures (80%) of 97,793 total occupied buildings were within the zone of risk for significant air contamination.
  - 215,006 people (70% of population) with Weld's average household size of 2.75 people.
  - 63,714 of these structures were within municipalities
  - 89,288 (80%) non-residential structures were within the area of significant air contamination risk
- 365 (86%) designated recreation areas were within the zone of risk for significant exposure to air contaminates.
- 91 out of 105 of the Colorado Parks and Wildlife protected native bird nesting areas were within air risk zones.

Water Risk:

- 10,548 (86%) of Weld's water bodies and streams were within the extent of significant water contamination risk.
  - 19,259 wells (77%) put 4,242 (94%) water bodies and 6,306 (81%) of stream networks at risk of being contaminated.
- 2,508 square miles (70%) of agricultural land is within water contamination risk areas.
  - 570 square miles of irrigated agricultural land, 2,014 (87%) of irrigation wells, and 44 of 49 irrigation ditches were found to be in water contamination risk areas.

04 FRACKING TOMORROW

A large amount of literature discusses fracking as it is today, however discussions over the end of fracking and the stages beyond unconventional oil and gas extraction are largely absent. In accounting for global trends, global oil may be depleted within 50-80 years (EIA 2017d; Korpela 2007). U.S. Natural gas supply will be gone by the end of the century, with reserve estimates predicted to last for the next 84 years (EIA 2017b). Institutional research has criticized the Energy Information Administration's (EIA) oil and gas outlooks as "high to very high optimism bias", full of misleading information, and unrealistic outcomes (Hughes 2014).

While predictions on oil and gas peak are often debated, the industry is not planning for a decline. Recklessness and inability to anticipate the decline of oil and gas production will play host to the strengthening of known dilemmas tomorrow. Supply constraints will become more of a problem over time, which could spell energy crisis. Infrastructure and the resources required to maintain supply will be exhausted at increasing rates – more fracking activity will lead to more land, money, and resources being used. (Korpela 2007; Hughes, 2014)

Coinciding with the decline of reserves and production, movements across the country to ban hydraulic fracturing, development in the renewable energy market, and implementation of alternative unconventional oil and gas methods leave the future of fracking uncertain. Renewable energy production in the U.S. has grown by 30% in the last 10 years and now amounts to around 20% of all energy production (EIA 2018a). Global interests threaten the spread of fracking, as interest in renewables and sustainable energy has been much higher outside the U.S. (REN21 2017). Modernizing countries which have large shale oil and gas deposits like China is turning more attention towards renewables over fracking (Letcher 2013; REN21 2017). Others are seeking ways to optimize fracking and reduce its inherent environmental impacts, through chemical, microwave, or electric fracking (Pijaudier-Cabot 2013).

While threats to future hydraulic fracturing operations exist, the existing infrastructure of fracking will eventually cease operations. At any phase in the process, operations can cease. This may be due to decreased demand, cost factors, and low or no production. If all goes as planned, a well's production lifetime will be around 30 years (Donaldson, Alam, and Begum 2014).

From Hughes, 2014:

- Peak production of both oil and gas will most likely be met before the year 2020.
- Maintaining production or restricting decline will result in increased drilling rates, which demands more resources essential to fracking processes.
- To meet this demand, higher prices are needed to justify further drilling.
- Drilling today is always over the highest quality areas. These high-quality areas will become exhausted first. Lower quality areas will require more resources and infrastructure to produce oil and gas than today.
- Well production is showing to decline much more rapidly than what's been anticipated. In the Bakken oilfield in North Dakota average horizontal well production declined from 550 barrels of oil a day to just 90 within three years.
- 25 – 50% of gas production needs to be replaced each year
- By 2040, production is estimated to be a fraction of what it is today.
- EIA predicts 1.04 million barrels of oil per day in 2040. Hughes, 2014 predicts .073 million barrels of oil per day.
- "Rather than viewing tight oil as an unlimited bounty, it should be viewed for what it is—a short term reprieve from the inexorable decline in U.S. oil production". (149)
- EIA predicts 41.8 Billion cubic feet of gas per day in 2040. Hughes, 2014 predicts 14.8 billion cubic feet of gas per day.
- "The wisdom of liquidating [natural gas] as quickly as possible what will likely turn out to be a short-term bonanza should be questioned". (302)

On leased lands a defunct facility is usually the responsibility of oil and gas companies to clean up and restore the site it to how it was. If land is owned by the facility that operates it however, its future is less certain, and dependent upon local municipal regulations. Additionally, abandoned wells or orphaned wells have no owner and are complicated in addressing who's responsible for removal. They become the responsibility of nearby residents, communities, and future generations (Hand, 2018). Many such sites are EPA Superfund sites which often take decades to be cleaned up.

Claimed or abandoned, when wells are remediated, standard practice is that any equipment is removed, well holes are plugged with concrete and abandoned, and the site is remediated (Holloway and Rudd, 2013). Reclamation companies such as the OERB in Oklahoma claim to remediate additional oil and gas related sites such as roads and pads, eroded land, waste pits, and trash/debris (OERB, 2017). However, the plugging process has been criticized as only a surface level restoration, where risks for contamination below the surface are still present (Davies et al. 2014). Others have criticized remediation as not meeting standards and lacking insight into best practices for land reclamation (McGranahan, Fernando, and Kirkwood 2017).



Figure 4.1. Image of an abandoned gas well head in South Texas. (Hillebrand, 2016)

While methods of oil/gas site remediation are numerous and the science behind it is well developed (Khaitan et al. 2006), there is little study into whether these methods are being utilized by oil and gas companies in their reclamation operations. Due to oil and gas companies not being required to disclose their practices, cases of malpractice, and the currently lax cleanup policies on requirements and level of expertise required, it's hard to gauge the state in which these landscapes will be in once reclaimed. The market volatility that's common with the oil and gas industry, the potential decline of oil and gas, and the exhaustion of reserves, will leave all of the infrastructure of fracking defunct. However, there is still time until much of the infrastructure and landscapes of hydraulic fracturing become unused and left in some condition along the lines of abandoned or reclaimed.

Over time the dilemmas that have been highlighted thus far will become amplified and more challenging to address. The places where we get our oil and gas will be increasingly problematic. Boundaries will shrink between populated areas and impact on surrounding natural systems will grow. Accountability of oil and gas companies has shown to be low, with abandonment and sub-par cleanup commonly reported. The time to address such dilemma is needed now, not. Understanding how people are currently addressing and how they could address them is the next step.

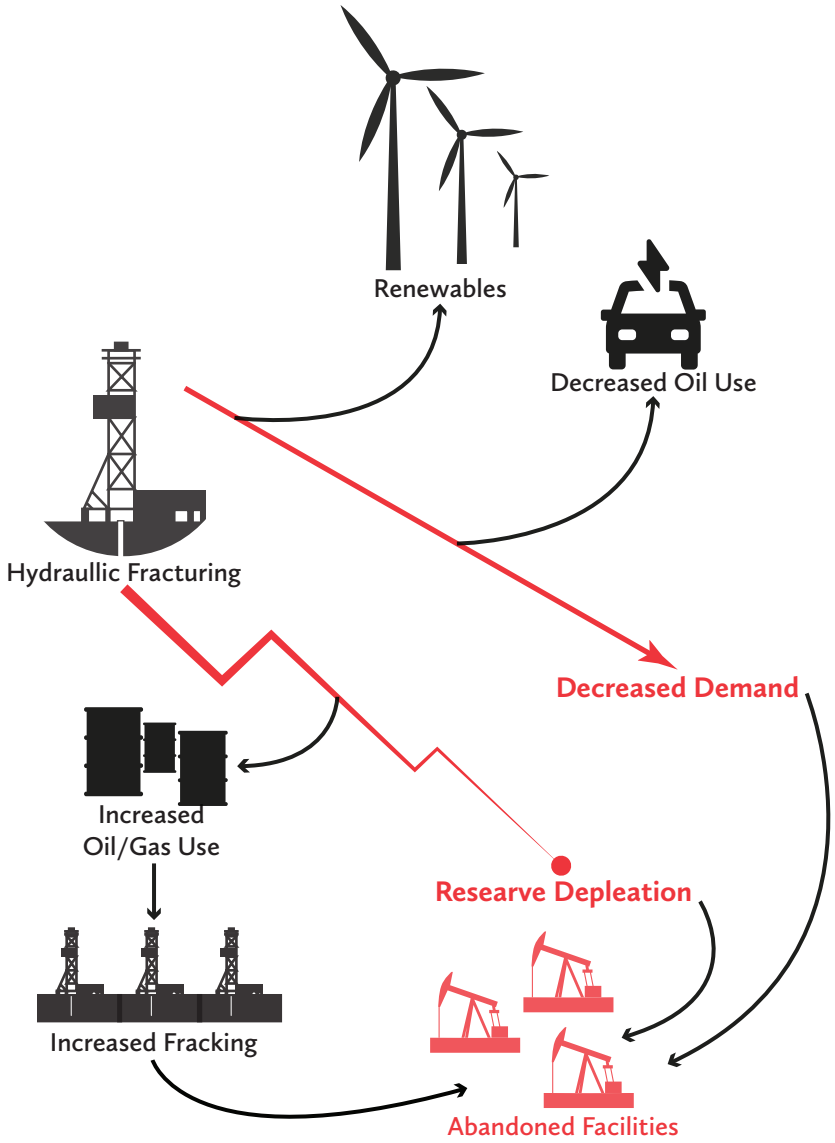


Figure 4.2. The dilemma of the future of fracking and its facilities. (Lanning, 2018)

05 TAKING ACTION

As shown in chapter 3, large amounts of discussion is being generated regarding the effects of hydraulic fracturing, yet an equal amount of discussion has been directed towards taking action against such effects. This chapter takes an in-depth look at current discussions into how researchers, community members, policy makers, planners, and designers are addressing or could address the dilemmas associated with hydraulic fracturing. The primary focus is on the landscapes – infrastructure – of hydraulic fracturing and the associated dilemmas that were identified in the previous chapters.

The first part of this chapter focuses on actions to directly address these dilemmas. Part two part builds off of the literature gaps from part one and investigates related literature on industrial landscapes to fill them in. Part three then looks at trending tools and methods used in related literature and from landscape architecture and planning to gain understanding in how the dilemmas that have been highlighted can be best addressed. The aim is to understand how to approach the landscapes of hydraulic fracturing and their various dilemmas: What is working, what is not working, and what could work.

Figure 5.1. Public activism in New York led to a statewide ban of hydraulic fracturing. (CREDO, 2012. Attributed under a CC BY 2.0 License)


DON'T FRACK NEW YORK
DON'T FRACK NEW YORK
DON'T FRACK NEW YORK
welcome
TEXT "FRACK" TO 69866
Ban Fracking Now

Taking Action: Current Concepts for Addressing Fracking's Impact

The literature that has been detailed in the previous chapters on the impacts of fracking do investigate actions that can be taken. The majority of these sources touch on the existence of management overcite by government and that extraction companies need to be held more accountable. Solutions are prescribed as policy change and stricter regulation. Texts such as (Kaden and Rose 2015) go into great depth over fracking related issues and what policies can be developed to address them. Policy may call for limitations on activity and land leases, or rewriting resource development law (Kaden and Rose 2015). Many sources prescribe increasing setbacks to distance people and infrastructure from the risks of hydraulic fracturing; a topic discussed in detail in (Meng and Ashby 2014). Others call for both government and oil and gas companies to implement improved best practice methods to insure sustainable industry standards (Burton et al. 2014). Sources deeply opposed to hydraulic fracturing call for flat-out bans or severe limitations (Environment America 2016).

Public action:

Across the literature, hydraulic fracturing is discussed as a national, state, and municipal issue. Verschuuren 2015 shows that fracking is politically complex – a grey-area for many legislatures, and a controversial topic for U.S. voters. The interests of people has shown to conflict with those of the state and federal government (Verschuuren 2015). Legislature and regulation has also been lax in keeping up with fracking and remediating its harmful effects. Movements to close "fracking-loopholes" and protect citizens interests are gaining attention (Cartwright 2015).

Citizen involvement and protest has been able to set up limitations and bans on fracking in places such as Texas and Colorado (Fry, Briggle, and Kincaid 2015). However, despite the interest of some citizens, these fracking limitations legislation have been overturned by state governments in the interest of oil and gas companies (Marmaduke 2016). Despite concerns over compromised health of land and people, some residents see the benefit of economy and job growth to outweigh the costs (Gullion 2015; Maniloff and Mastromonaco 2017). While conflicting interests exist, public input and involvement has proven to be a useful tool in making change at the municipal and state level (Christenson, Goldfarb, and Kriner 2017).

Planning and Policy Making:

Numerous local community planners who are experiencing hydraulic fracturing within their own communities are asking how their expertise can address hydraulic fracturing. Articles cite how fracking's rapid development has blindsided communities before they can properly prepare and act (Loh and Osland 2016). Dilemmas over water quality and drinking water contamination are a big concern for planners as well, and are pushing for better impact assessments (Burton et al. 2014). Other planners cite the community health risks and infrastructure damage communities are experiencing from fracking. They express anguish over being financially unable to address these changes due to oil and gas money not being properly distributed (Rawlins 2013).

Overall, trends show that planners are calling for moratoria to allow for time to adapt to the major changes brought on by rapid hydraulic fracturing development. They call for improved risk mitigation regulations, and seek various land-use planning policies for long term results (Loh and Osland 2016; Sorvig 2014a; Rawlins 2013). However, despite uprisings and action in various communities across the nation by both community members and local planners, state and national policy makers are getting the last say in addressing hydraulic fracturing operations.

Current state and national political bodies are moving forward with fracking, reversing municipal moratoria, all while failing to instill best practice management strategies for oil and gas companies to uphold (Rawlins 2013; Verschuuren 2015). Regulations to hold companies accountable for their actions have also been left out, and legalaliaztion of hydraulic fracturing in federal land has been green-lit (Terry-Cobo 2017; Balthrop and Hawley 2017). Such changes have been the result of complete policy reversals as seen from the United States' 2016 election and the new administrations domestic energy policies (NRDC 2017).

Non-Traditional Approaches:

The literature reviewed thus far reflects a majority of the discussions about how to address the predicaments of hydraulic fracturing. Their methods and solutions are generally straightforward, tried and true. The instability associated with addressing hydraulic fracturing at a regulatory and policy level, the need for deeper understanding of phenomena, and the growing complexity of these dilemmas has been cause for investigation into alternative methods and actions. Researchers Weber, Geigle, and Barkdull 2014, looked at concepts in resilience theory and how it can address the dilemmas of the rural fracking boom towns in South Dakota. The authors believed that these concept could address dilemmas over time and involve people directly, rather than be reliant of governing bodies (Weber, Geigle, and Barkdull 2014).

Research methods, and new means of understanding fracking have been a chief focus of many looking into alternative actions. Researcher Qingmin Meng took a new approach to discussing the socio-ecological dynamics of fracking by developing a new research framework on equity and spatial justice. This includes an array of complex variables to address benefit and harm related issues of fracking at a three-dimensional level (Meng 2018).

Discussions from Planning and Design Professionals:

Discussion beyond blanket policy change and the utilization of novel research methods from design and planning professionals is relatively absent. Most discussion is held either between the public or with social and environmental scientists. Landscape Architect Kim Sorvig stresses the importance and need for improved education on the topic within his profession – the necessity to gather and utilize meaningful data to educate and incite change. With such knowledge, tailored planning and design practices can be crafted (Sorvig 2014b).

Despite these calls for action, a common trend (when discussions are documented) among planning and design professionals has been a sense of hesitation. Hesitation being held towards taking action against legislature and big oil/gas companies, debating whether planning and design can do much to address the concerns over hydraulic fracturing. (Green 2014; Sorvig 2014a).

Designing for oil and gas:

Though hesitance to challenge oil and gas companies is a trend throughout the literature, a few designers have been documenting their efforts to find solutions to current fracking dilemmas. Timothy Murtha and Brian Orland look at addressing the dilemmas of fracking through planning, design, and visualization. One study looks at the greater impacts of hydraulic fracturing activity such as pipelines and roads in rural Appalachia. They cite a need for better planning tools that directly address the entire systemic impacts of hydraulic fracturing beyond the health and water risks, such as temporal qualities of landscape and preserving sense of place and culture (Murtha and Orland 2014).

A later study by the same authors take these ideas on improved analysis and applies it to community engagement workshops. They conduct an environmental impact assessment and develop better placement of oil and gas facilities that reflects on the assessment (Orland and Murtha 2015). Results from workshops showed that such processes are needed for not just informing communities on the issues of fracking, but how these communities can begin envisioning actual designed solutions (Orland and Murtha 2015). These studies by Orland and Murtha, are keystones of discussion over how designers can involve themselves in addressing the wicked problems of fracking through understanding spatial relationships.

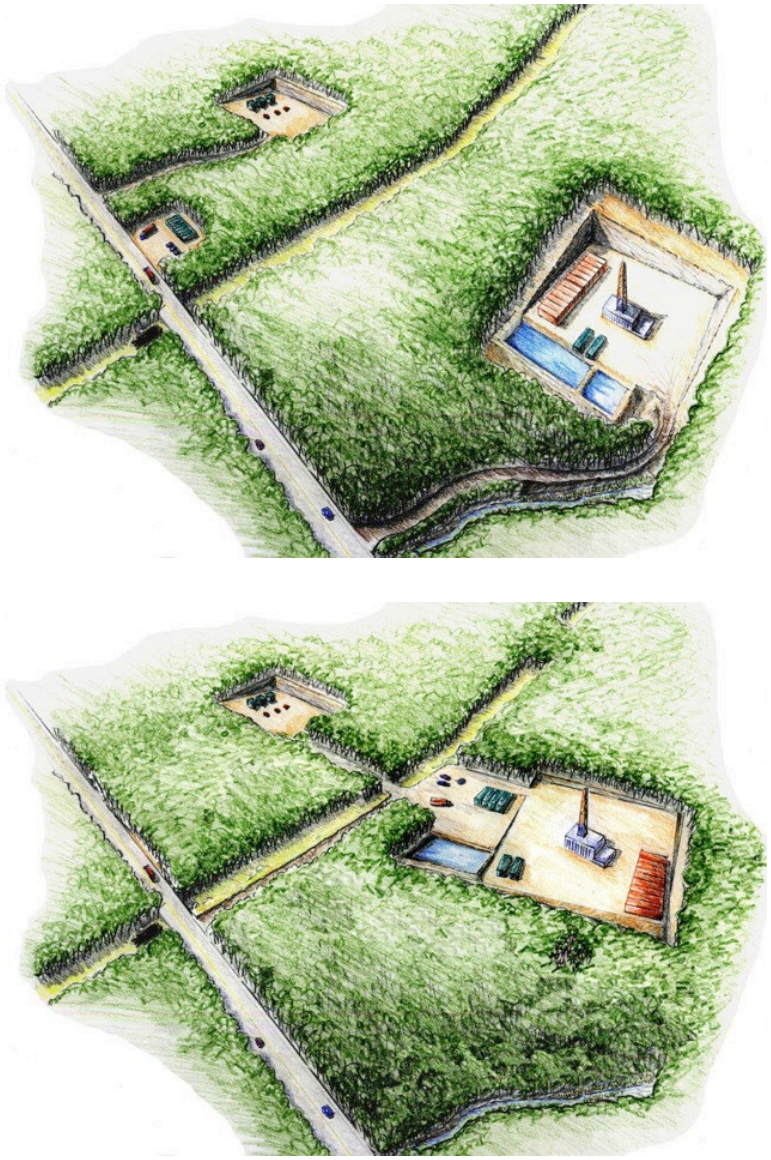


Figure 5.2. Sketches by a student working with Orland and Murtha in discussing reducing Fracking's impact. Top: Existing condition Bottom: Proposed. (Used with permission ©Nicholas Monroe, 2015)

Designing for a post-oil and gas future:

Discussions over how to address the future of landscapes impacted by fracking have also been scarce. Landscape architecture design firm SWA had begun discussion over how to address the landscapes of hydraulic fracturing at all phases of the process, specifically how to generate design solutions that address implementation and remediation (Dalton 2014). SWA made a call for landscape architects to join in interdisciplinary discussion and take on these ideas. Three years later however, evidence of such collaborations are near absent.

One example of such collaboration is from Katherine Jenkins and Parker Sutton at the Ohio State University, who have proposed real design alternatives for the future of the Trans-Alaskan pipeline. Called the TAPS, this is an 800 mile oil pipeline that stretches across Alaska. In their presentation, "A Post Oil Future in America's Arctic", Jenkins and Sutton looked at the decline of the TAPS and how it could be efficiently and economically feasible to be re-purposed into a regional recreation trail: The Trans-Alaska Trail (Jenkins and Sutton 2017). The discussion from Jenkins and Sutton is framed by major declines in oil production in the region. While conceptualized in 2014, this project's ongoing efforts have resulted in an 80-mile test trail implemented along the southern end of the TAPS (Jenkins and Sutton 2017).

Little to no projects related to Jenikins and Sutton's research could be found. This source represents all of the discussion being generated in understanding the value in developing design alternatives for post-oil and gas landscapes in America. While theirs focused on re-envisioning these landscapes, Murtha, Orland, and SWA's proposals are still largely focused on processes not infrastructure, and what is happening today not tomorrow. Discussions like those of Jenkins and Sutton's is greatly needed.

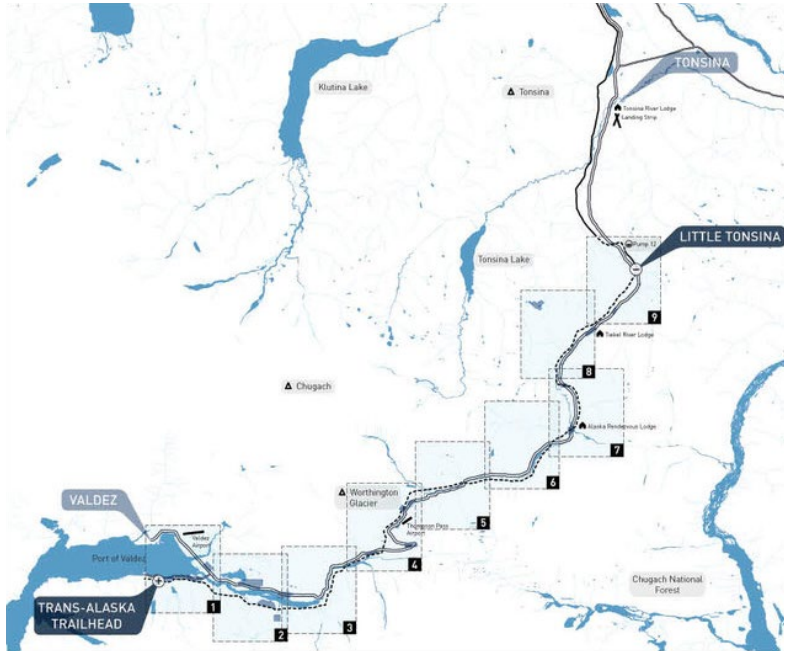


Figure 5.3. Current extent of the Trans-Alaska Trail.
(Used with permission ©Katherine Jenkins and Parker Sutton, 2017)

Absence of Literature:

Landscape architects have made calls for acting on the wicked problems of hydraulic fracturing at varying degrees. Such doctrines have called for action, identifying inherent skill-sets, abilities, and expertise that can serve in forming alternative solutions (Green 2014). However, despite these decrees, published literature and discussions within the profession has fallen off. Little to no discussion from landscape architects on the topic of hydraulic fracturing was found dated after 2014. And since that time, hydraulic fracturing has grown more and more pervasive throughout the country. However, while discussion has declined and the hesitation of landscape architects was unanticipated, the work and studies by Jenkins & Sutton, Orland & Murtha, and Kim Sorvig are foundational to understanding how landscape architecture can address the impact, scope, and dilemmas of fracking in new ways. While landscape architecture may offer more ideal outcomes, new methods to educate on and understand the landscapes of hydraulic fracturing are needed to do so.

Although adequate examples of better methods and evocative design exploration are currently lacking, design is interrelated. Discussion among planning and design professionals towards related topics can be extrapolated and utilized for this project.



Figure 5.4. Photograph of the trans alaska pipeline as it passes over the Denali fault-line. (USGS, 2002)

Finding Action: Post-industrial Landscapes as a Model for Action

In today's landscape architectural design field, designers are increasingly addressing complex landscape dilemmas from regional to site-based levels. Due to the lack in current discussions over hydraulic fracturing, these ideas should be highlighted for understanding various ways in which the dilemmas of hydraulic fracturing can be addressed in novel ways. Post-fracking landscapes of the future fall within a greater category of design: reclamation and post-industrial-landscapes. These landscapes encompass a vast array of landscapes that have been exploited for commodity and economy. Conventional oil and gas, coal mining, and oil sands have all resulted, and/or will result in a vast amount of disturbed land in need of reclamation.



Figure 5.5. Kemess Mine reclamation site in British Columbia Canada. (McKenna, 2014. Attributed under a CC BY-NC-ND 2.0 License)

Alternative Futures for post-mining landscapes:
Mining in the U.S. and beyond has legacy far exceeding that of Oil and Gas. Today there are more than 500,000 mine sites in need of reclamation in the U.S., a major mission of the EPA (Berger 2007b). Mine reclamation projects have been a focus for some time now, however more innovative designs are of relative recent occurrence. Alan Berger has contributed significant discussion towards addressing the futures of mining landscapes in novel ways. His primary concern is similar to this project's, that mine resources in the West will be depleted by 2200, poising a vast amount of landscapes that will need to be re-adapted for post-mining uses (Berger 2002). Common themes across this work call for a need to blend the aesthetics of design with the data collection of science (Berger 2007b). Completed projects show that restoration exhibits novel outcomes rather than outcomes that seek restoring land to what it functioned as or looked like before mining. Arguments state that these landscapes have been altered far from what they once were. Reclaimed sites incorporate local community desires, as well as desired environmental outcomes (Berger 2007b).

Alternative Futures for post-oil sands landscapes:
Discussions similar to Berger's are being applied to the Oil Sands of Canada. Researchers describe wicked problems like what has been defined in this text, however the Oil Sands are immense conglomerated landscapes. Designers have taken approaches similar to what Kim Sorvig has asked for: Research that informs new methods. Those looking at these landscapes have investigated them at considerable depth and looked into the future of these systems. This thinking has lead to preliminary concepts that address their future post-oil (Byrne 2017; Knight 2017).

While the future of the landscapes of unconventional oil and gas – fracking and oil sands – poise significant cause for attention, little-to-no discussion beyond these examples have been discussed. Whether actual or hypothetical, these discussions on alternative reclamation strategies are key to understanding how the landscapes of hydraulic fracturing can be addressed. A concept that bridges all of these projects are discussions focusing on post-industrial landscapes.

Brownfields and Post-Industrial Landscapes:
While the previous examples looks at large-scale environmental landscapes, Brownfields and Post-Industrial landscapes are often concerned with re-adapting smaller contaminated sites and individual industrial landscapes. Often these landscapes are addressed in more populated areas. These landscapes have become a trending focus for designers to explore in practice over the last couple decades. Numerous sites of industrialization have been imagined as places to demonstrate adaptive site design that accomplishes many social design outcomes, such as culture and legacy, education, and integration (Kirkwood 2001).

Two prominent post-industrial landscape sites are Gas Works Park in Seattle, Washington, and Landschaftspark in Duisberg, Germany. Both were once abandoned relics of the coal industry. Today they have been re-adapted and redesigned into public spaces. These landscapes show how oil and gas facilities could be re-adapted in the future once they no-longer serve their intended purpose. Common arguments for such interventions were that removing them would lead to even more disturbances, and that the sites would lose the sense of memory and history associated with them (Kirkwood 2001).

Industrial sites result in a massive amount of site contamination from years of activity. Extensive research into the subject has lead to the designation of contaminated sites as brownfields. Brownfields are often characterized as abandoned or derelict landscapes in urban to sub-urban context that currently provide no benefit to society. They require intervention to be brought back to having value to society, beyond their original intention (Dixon et al. 2007). The topics in this field of design are focused on adaptive reuse principals and utilizing what land has already been severely altered, rather than that which is still natural or nominal. the depth of research reaches into understanding contamination regimes and their remediation, and developing scientifically derived research to integrate with rich design narratives (Dixon et al. 2007; Hollander, Kirkwood, and Gold 2010). The brownfield regeneration movement has spurred a series of subset movements such as phytoremediation which looks at the utilization of plants as a means to remediate soils and remove contaminates from them (Kennen and Kirkwood 2015). The future holds the potential for the landscapes of hydraulic fracturing to look no different than these examples. These concepts presented may offer sound direction in how to address post-oil and gas fracking sites in unique ways.



Figure 5.6. Photograph of Landschlaftpark in Duisberg, Germany. (Carschten, 2012. Attributed under a CC BY-SA 3.0 DE License)

Rural Communities:

Current design trends within landscape architecture are largely focused urban design and addressing populated areas. This is warranted as urbanization is and will continue to increase into the foreseeable future. However, the landscapes of hydraulic fracturing still operate largely within a rural setting at the moment. Rural areas account for almost 97% of U.S.'s land, however only around 19% of the U.S. population resides here (US Census Bureau 2016). (Brown and Schafft 2011) is a useful text for understanding modern rural communities, how they will transform in the 21st century, and how they can become more resilient to adverse effects. Rural communities are argued as important places to consider because they are what hold cities together; providing food, resource, and infrastructure (Brown and Schafft 2011). This text details how rural communities that have been shaped by resource extraction bare many conflict. Often they are viewed as "politically and economically subordinate" to metropolitan areas. Cycles of boom to bust are common, resulting in various social, infrastructural, and economic conflict (Brown and Schafft 2011).

Sense of community is argued as one of the most important elements that keeps rural communities together, more so than urban ones (Brown and Schafft 2011). Addressing the future of Rural communities and this valuable notion of sense of community. One common concept growing in popularity for designers and planners is 'New Ruralism'. Contradicting the New Urbanism movement, New Ruralism is focused on improving and sustaining rural communities "innovative economy"; identifying as places of "community leadership, volunteerism, and creative financing.", not, "food [and resource] sheds for metropolitan areas." (Green 2017). New Ruralism is largely associated with agricultural preservation, food networks, and rural migrations (Newman and Saginor 2016). New Ruralism is also meant as a means of addressing how they can move past the stigma of subordination to urban areas (Green 2017). A vast amount of land has been set aside for hydraulic fracturing in rural communities. These concepts are key to understanding how the communities around hydraulic fracturing may be included in the discussion of the future of the hydraulic fracturing and its array of infrastructure.

Communicating Chaos – Tools for Understanding Complex Systems:

There are numerous tangible design concepts to integrate into this project. Less tangible tools and concepts are needed to make these theories a reality and validate their statements. The goal is to maximize communication of concepts, data, and systems for visions of an improved future. Tools range from physical to digital, and employ many different methods.

Systems Based Thinking:

While approaching landscapes as complex, interrelated systems is common in ecology, the concept is just now becoming more and more common in landscape architectural design monologues (Reed and Lister 2014). Discussion over means and methods for such systems-based thinking include topics on emergence, succession and regime shift, adaptability and resiliency. These are being adapted to fit varying projects and is evolving rapidly, shaping how designers approach projects (Murphy 2016).

A related methodology is Alan Berger's Drosscape. Focusing on landscapes of waste – static, decentralized landscapes of sprawl – Berger's research is largely aimed at delineating these landscapes and addressing them as systems, not singular entities. He argues that current strategies are too focused on these landscapes as self-operating. They should be addressed as an entire landscape collective (Berger 2007a).

Berger's systems based methodology delineates the landscapes of waste and their processes which then informs creating strategies for understanding, defining, and addressing their future post-sprawl (Berger 2007a). Berger's methodology and arguments are synonymous to those centered around the landscapes of hydraulic fracturing. Both these landscape systems are vast networks of decentralized land that form an armature of production. They need to be understood at a systems-based level from multiple points of view for any sort of design to properly address them. Such a methodology should be considered for this project.

Systems Based Post-Industrial Landscapes:
Synthesizing the ideas laid out previously in terms of brownfields, land utilization, and systems-based thinking is Pierre Bélanger's research into "Landscape as Infrastructure". Bélanger's research looks at the patterns, processes, and interactions of industrial landscapes across America as a complete system (Bélanger 2009) – similar to that of Alan Berger's Drosscape. Bélanger's focus on industrial landscapes and their future is that of a paradigm shift. Highlighting a transition from their prior use as landscapes of environmental sacrifice and industrial economy into ones of ecological co-dependence – landscapes of biophilia and biophysical resources that support modern economies and social systems (Bélanger 2009).

The arguments of Bélanger are foundational to understanding how landscapes of industry which number in extremes and will eventually lack use can become an armature of America's future. Incorporating these discussions on systems-based and post-industrial thinking into the discussions over the landscapes of hydraulic fracturing is essential in moving towards novel solutions.



Figure 5.7. Salvage yard in Dallas, Texas. An example of Berger's Drosscapes and an example of a 'waste landscape of obsolescence'. (Google Earth, 2017)

Other Tools for Communicating Complexity:

In looking at previously discussed projects of (Berger 2002, 2007b, 2007a; Byrne 2017; Knight 2017), they employ a number of the following methods and tools, in addition to systems based thinking, and typical visualization techniques such as modeling, geospatial analysis, diagramming, and design projections:

- Mapping and Critical Mapping: Discussed much in landscape architect James Corner's essays, his "Agency of Mapping" explores how maps can used as agents of visualizing reality, systems and operations, time and space, layers, and more (Corner 2014). Critical mapping is a branch of Corner's agency arguments, and focuses on developing inquiry driven visualization.
- Photomontage and eidetic imagery: James Corner and his contemporaries have written much on representation, with a focus on the idea of creating eidetic visualizations. Visualizations that portray many ideas, often intangible (Corner 1999, 2014; Swaffield and Deming 2011).
- Photomontage has been a growing form of these hybrid visualizations in communicating a number of phenomena and ideas through digital media (Belanger and Urton 2014).
- Other Visualization Techniques: Visualization strategies are highly variable and range from designer to designer. Often it depends on subject and what the intention of the communication is needed. Visualizations can be physical, digital, or hybridized. (Amoroso 2012, 2015, 2016)



Figure 5.8. Example of eidetic photomontage in Johnathan Knights 2017 Masters report which focused on the Oil sands of Alberta and their future.
(Used with permission ©Jonathan Knight, 2017)

Discussion:

From the literature reviewed, there are numerous discussions being had that seek to resolve issues of hydraulic fracturing. A vast wealth of research has been published to understand fracking's effect, and an equal amount of discussion over how to address those effects has come out as well. However, much of the focus has been one tracked for a multi-tracked, complex issue. Proposed solutions rely too much on making broad policy based changes. Few are discussing how fracking can be addressed in terms of spatial context. Additionally, little discussion is being generated over the complexity of hydraulic fracturing and how processes interrelate.

However, while discussions directly related to addressing hydraulic fracturing have generally been unimaginative, there is plenty to pull from in related realms of reclamation and post-industrial landscape architectural design. There are valuable sources of information that can be bridged to begin looking at hydraulic fracturing more in terms of its spatial context and as a complex entity with interrelated pieces. Within the design field the trend has been a call for insight and more knowledge; new methods for understanding and addressing hydraulic fracturing. A methodology that takes a systems-based approach is shown to be an effective means of filling this need.

06 SECTION SUMMARY

The aim of this section was to complete goal 1 and 2 of this report: 1. To understand hydraulic fracturing and 2. To understand methods for addressing hydraulic fracturing. In summarizing these findings we know that:

- Fracking is a highly technical process requiring substantial amounts of land, resources, and expertise.
- Fracking has rapidly taken hold of the United States energy policy. It is an answer to reducing reliance on imports, and a means of supporting domestic economy.
- Fracking is highly controversial and often a polarizing topic. Despite this, governing bodies are generally open to Fracking. However, this openness has created lax regulations and policy for mitigating risk. In its current state fracking has high potential for costly damages to the health of the environment, communities, and infrastructure.
- The future of fracking is uncertain. It may continue to rise or dissipate quickly. However, the infrastructure that has already been constructed for hydraulic fracturing will not disappear.
- Cleanup of fracking related infrastructure is not well documented. When documented it has been shown to be minimal. In the end these landscapes are largely seen as sacrificial.

Based on findings from the literature detailed across this section, fracking and what is being done about it is clearly definable. A massive amount of knowledge exists that can detail its ins and outs. Despite this, there are still several gaps and discrepancies that need to be addressed:

- Researchers need to look at these landscapes more systematically in terms of how they operate together and how they impact their inputs and outputs. While the phenomena of fracking has been described well, there has been a lack in drawing connections between them.
- A deeper understanding of hydraulic fracturing's landscapes and its spatial interface is needed. While the obvious landscapes such as wells are highly detailed, there are many other landscapes associated with Fracking that are overlooked. Many more may be hiding in plain site.
- Acknowledging that these landscapes need to be investigated with greater depth researchers have made calls to create better methods for understanding these landscapes. However, as of yet there is little action being taken to do so.
- Desired infomation on these landscapes does exist in cases, however it is often stand alone and unconnected with other sources. There lacks one source that catalogues and details these landscapes as a whole.

In addition to these gaps, one literature trend is cause for concern for design professionals and planners:

- **Landscape architects and planners who are in a position to address the dilemmas of hydraulic fracturing, are no longer contributing discussion towards this topic. If they are they are not doing so in ways that can address the gaps highlighted above.**

With this information collected, the next step is goal 3, the chief goal of this research: To better understand the landscapes of hydraulic fracturing. Only once are these landscapes understood more completely as a system; a system of individual pieces with their own stories, can discussions of how to address them then be done. To do so, a unique methodology is to be constructed.



Figure 6.1. Oil and Gas fields of the Texas Panhandle. (Google Earth, 2017)



Figure II. Drilling rig near Severance, Colorado. (Lanning, 2017)



II | METHODS

This section focuses on developing new methods of understanding the landscapes of hydraulic fracturing. Utilizing the findings from the previous section, a novel methodology is constructed in hopes of generating new information. Regions of focus to implement this methodology are delineated as well. While this methodology does not solve many of the problems highlighted in this report, it creates a set of methods that can be used to do so.

07 METHODOLOGY

This report's methodology seeks to clearly define fracking from a spatial perspective. Its primary goal is to delineate the landscapes of hydraulic fracturing into the Fracklands. Frackland is a constructed term that represents the complex physical, spatial, and temporal phenomena of hydraulic fracturing's infrastructure and operations. Fracking is a highly complex process; therefore, its landscapes need to be viewed much in the same way. This strategy is a classification scheme for organizing a vast amount of information. In doing so, additional information can be generated from reorganization . This methodology is the first attempt at such a process for understanding hydraulic fracturing and its interface with surrounding landscapes.

Utilizing both research that has been detailed thus far and methods detailed in this section, the goal of this classification system is to collect and generate information on the landscapes of hydraulic fracturing and define them as the Fracklands. Doing so reveals a more true image of hydraulic fracturing's phenomena. Whereas a *Landscape of Hydraulic Fracturing* is a place for unconventional oil and gas extraction, a *Frackland* is a unique and complex entity – functioning as part of a system, exhibiting unique interactions with people and community, and displaying unique spatial phenomena from place to place over time.

To properly execute this classification strategy and understand the Fracklands from various perspectives, a framework was constructed. Organized by four approaches – System, Typology, Trends, Futures – this framework is meant to not only define the Fracklands, but discuss them from various perspectives both as what they are today and what they will be in the future. This framework relies on the exploration of the components of the Fracklands. These components are the physical pieces; evidence of a Frackland. Understanding these components and centering the four approaches of the framework on them is key to understanding all of the characteristics of the Fracklands. A series of descriptive methods are therefore utilized to explore each component.

In total the methodology of classifying the landscapes of hydraulic fracturing into the Fracklands is a strategy for parsing through a large amount of information and to understand these places both from place-based and people-based perspectives. The methods highlighted in the following pages are essential in meeting this end.

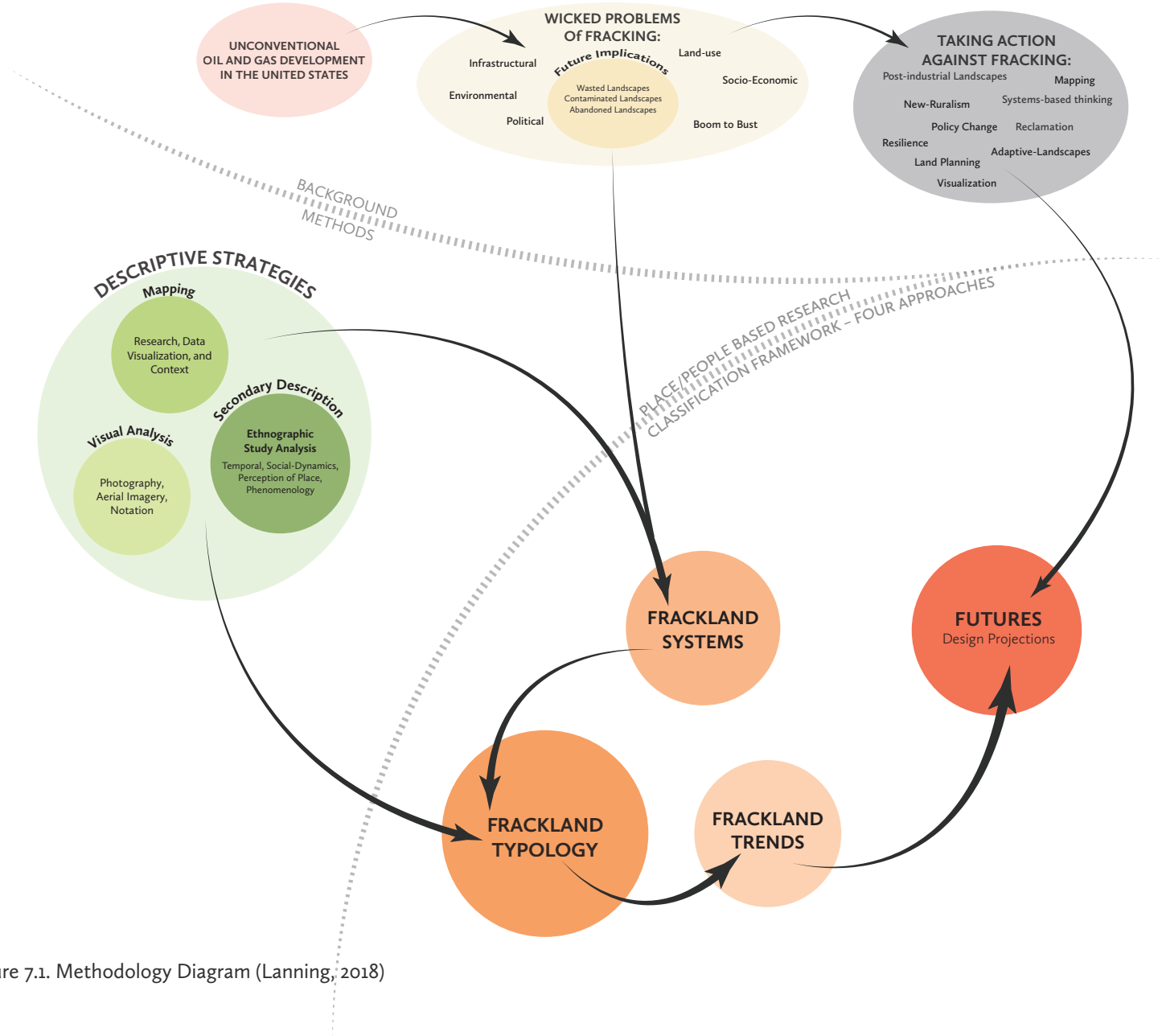


Figure 7.1. Methodology Diagram (Lanning, 2018)

Classification Framework – Four Approaches

The four approaches that form the classification scheme seek to classify the Fracklands from different perspectives. Each is focused on different factors relating to space, place, subject, and various points in the fracking timeline. Together these four parts come together to form a complete picture of what the Fracklands and their components are, what they have been and/or what they will be, what they look like and how they function, how they vary by place and/or region, and how they will transition into a post-oil and gas future. Each approach is covered in more detail on pages 91-94.

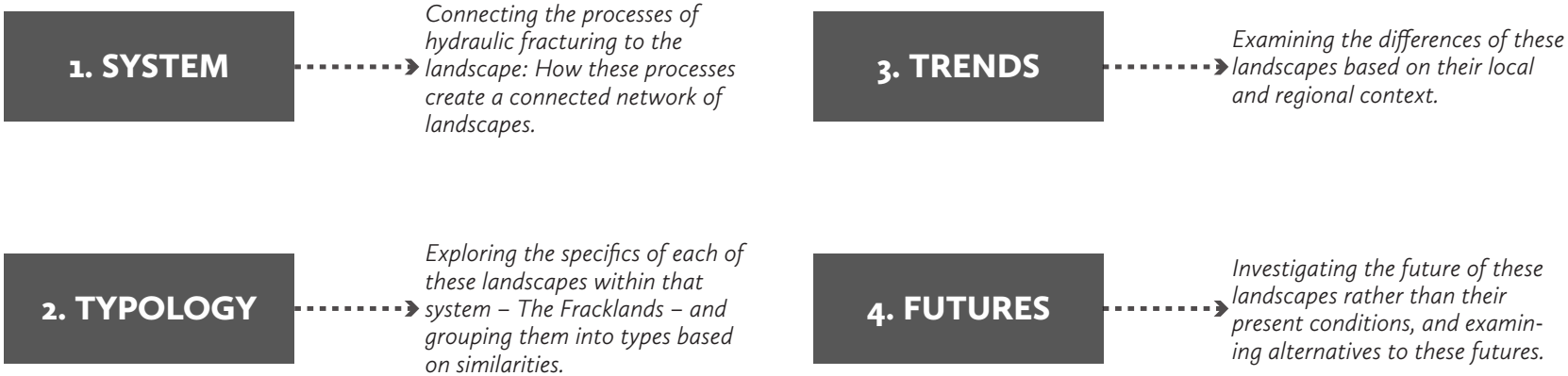


Figure 7.2. The Four parts of the classification scheme. (Lanning, 2018)

Investigating Frackland Components:

As noted on the previous spread, research into Frackland components is vital for the classification. Eleven components were identified from literature to be investigated across this report. Aside from the research detailed in Section 1 and where existing information could not be found or utilized, the classification scheme utilizes descriptive strategies to detail these Frackland components.

The classification framework and its four approaches are the means in which findings on the Frackland components can be presented. Each approach relies on information collected from researching these components. Therefore components had to first be understood and researched. Each componant was investigated by utilizing a set of unique descriptive strategies. These four strategies – Definition, Field Reflections, Stories, and Patterns – develop an understanding of the Frackland components from various perspectives. Each strategy is aimed at describing a specific set of criteria and relies upon its own set of methods. These criteria and methods are detailed on the following spread.

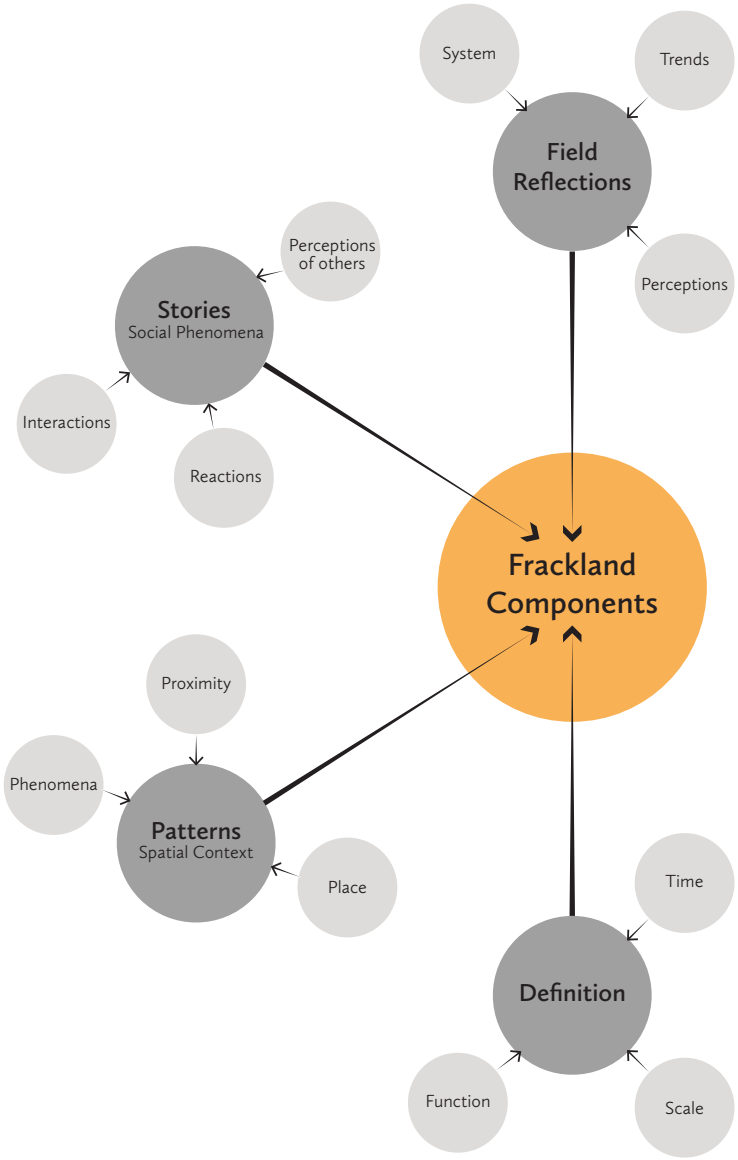


Figure 7.3. Descriptive strategies to describe Frackland components. (Lanning, 2018)

Four Descriptive Strategies for Understanding Fracklands and their Components:

Definition – Time, Function, Scale:

What is it? How does the Frackland Operate?

Description defines the component and sets the groundwork for understanding a Frackland and its components intended functions. It describes and uncovers how the land has and will operate over time, and at what scale that operation pertains to. Information needed for Definition is common information, therefore existing literature generated by experts on the subject is the best method for this strategy.

- Function: *How does the component Operate?*
  - Intended functions and operation
- Scale: *At what scale are its operations?*
  - Extent of the site
  - Extent of its operation
- Time: *What is the timeline of this place?*
  - Lifespan
  - Reasons for end

Field Reflections – System, Trends, Perceptions:

How does the author react to how it is situated in a space/place?

Reflections from the field describe the thoughts of the author as they experience a Frackland in person. These thoughts, feelings, and observations uncover reactions towards these places from the view of an individual, a landscape architect, and an outsider. This information was generated from field visits and descriptive methods such as journaling, photography, and remote imagery analysis.

- Perceptions: *How were they perceived in person?*
  - Effect on perception of place and the area around
  - Visual evidence of activity and impact
  - Expectations – following its intended use or not
- Trends: *What were common trends seen in the visits?*
  - Regionally based
  - Local land use based
- System: How do these places relate to one another? What forces do they exhibit on external factors?
  - Evidence it is part of a greater system.
  - Defines if it is an input and/or output of the local and regional system it is within
  - Forces exhibited on non fracking surroundings.

Figure 2.x. Frackland Descreptive Strategies

Stories – Interactions, Reactions, Perceptions:
How are other people experiencing the Fracklands?
Stories tell of how other people perceive and react to Fracklands. Similar in nature to the field reactions, these are meant to gauge how other people experience a Frackland and its components. Stories outline many of the sociological phenomena associated with these places from regions across the country, and from various perspectives. This information was collected from review of existing sociological studies.

- Interaction: *How do people interact with these landscapes?*
  - Social dynamics and interactions – Direct or Indirect
  - Land leasers and those caught in the middle
  - With Oil/Gas companies and workers
- Perception: *How do people perceive these landscapes and their surroundings?*
  - How individuals feel emotionally
  - How Communities feel
  - Place Based Perceptions
- Reactions: *How are people reacting to these landscapes?*
  - Reactions by communities and individuals
  - Actions taken for or against
  - Actions taken to adapt to changes

Patterns – Proximity, Place, Spatial Phenomena
What are the spatial phenomena of the Fracklands?
Patterns describe a Frackland from a spatial perspective. They reveal ways in which Fracklands and their components interface with their surroundings at various scales. Patterns distill much of the often complex information that has been delineated from the other three strategies and showing them visually as maps and diagrams in a more condensed easy to understand diagrammatic and visual nature.

- Place: *How is it situated in the greater landscape fabric?*
  - Local, Regional, National
  - Integration with its surroundings
- Proximity: *What surrounding activity does it interface with?*
  - Social, ecological, and economic land use and activity nearby
  - Potential Impact on surroundings
  - Future development on surroundings
- Phenomena: *How does it interact with its surroundings?*
  - Positive and Negative effects
  - Mutually beneficial or mutually exclusive

1. Frackland System:

The Fracklands and their components are a dense web of interconnected landscapes. This approach investigates these various components from a systems-based perspective. As noted in Section 1, a systems-based approach can reveal new information that may not be inherently evident. To define and visualize the fracklands system, information from literature was synthesized with information generated descriptive methods (see page91). The process of fracking and everything that it interacts with, produces, requires, and affects was noted. Once noted, it was visualized into a set of digestible diagrams.

By visualizing this system, one can clearly see the complexity of fracking and see much deeper than what a traditional non-systems approaches would. Each component and their relations to each other and various internal/external phenomena can be seen. The systems diagrams resulted in the generation of new information regarding the Fracklands and their components, showing common themes and patterns between them.

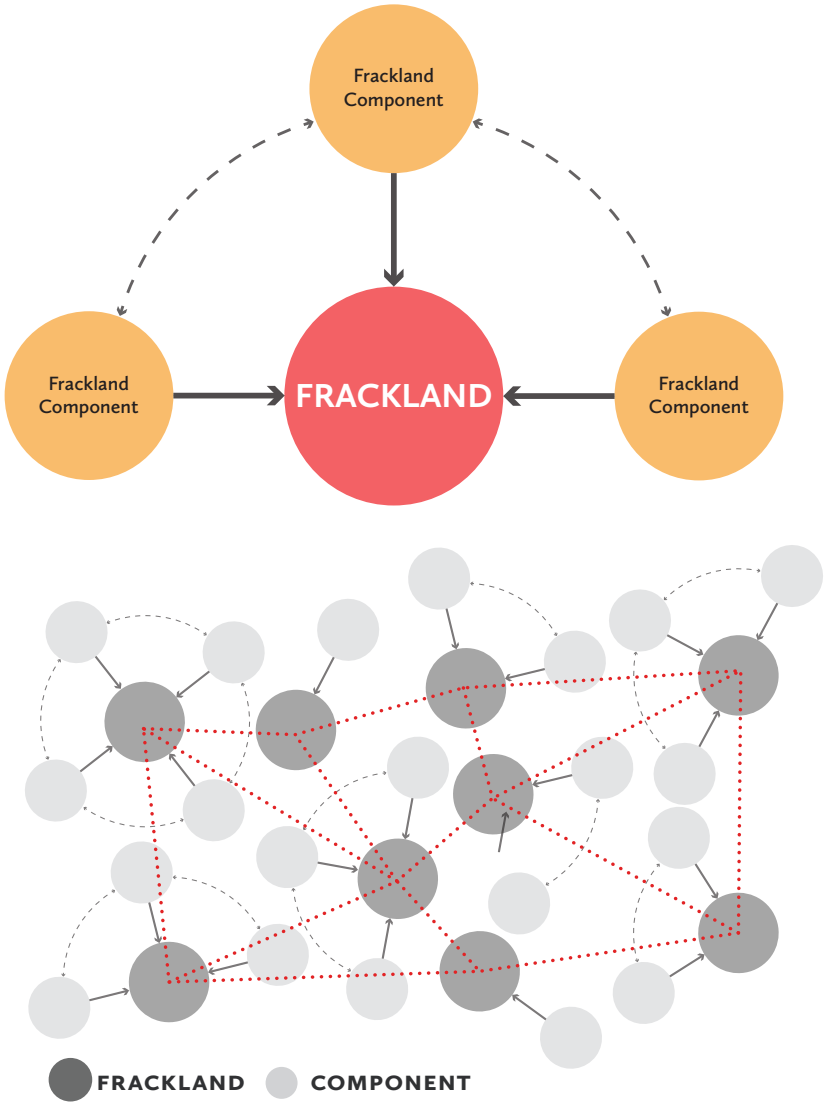


Figure 7.4. Fracklands System. (Lanning, 2018)

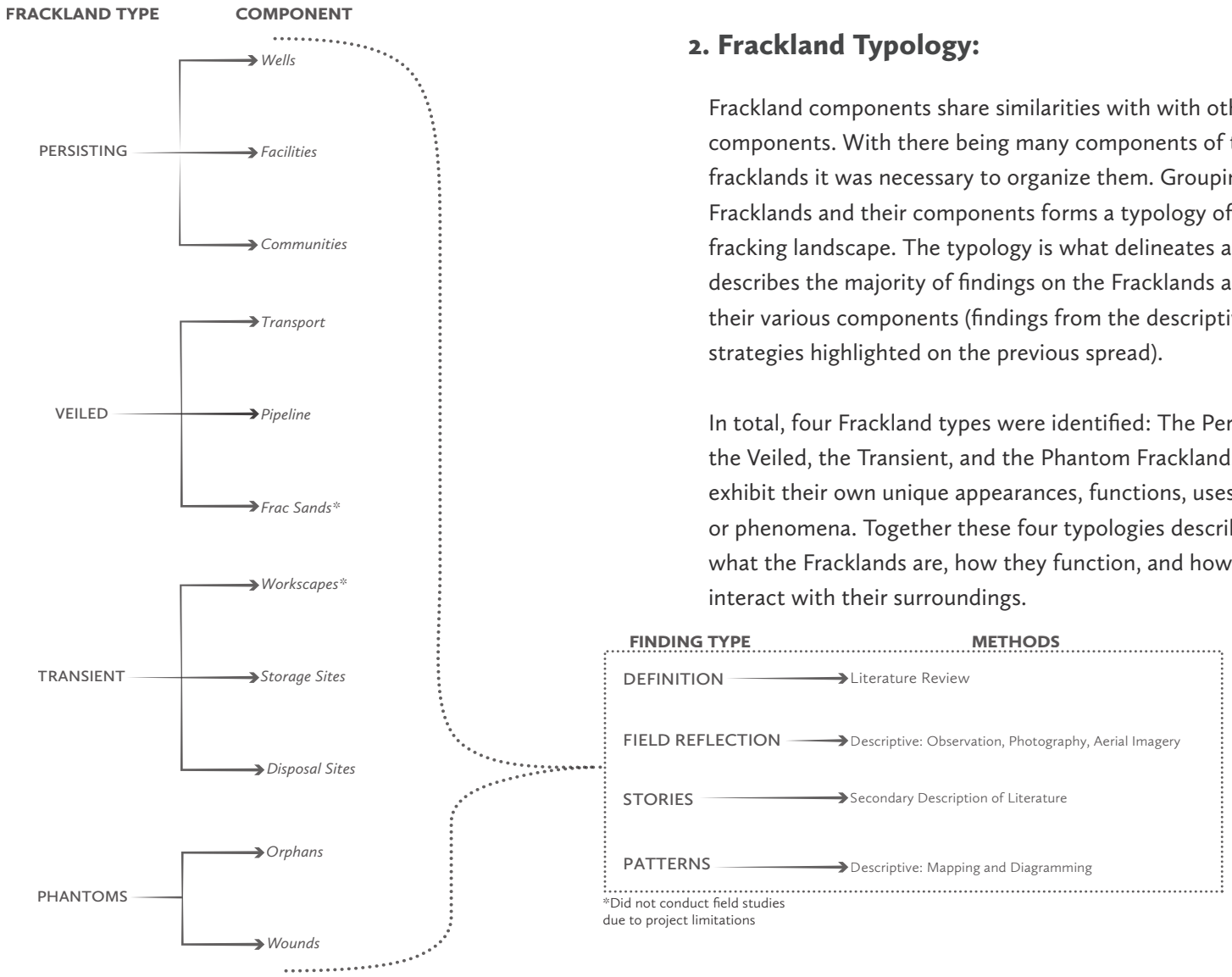


Figure 7.4. Fracklands, Frackland components, and Methods. (Lanning, 2018)

2. Frackland Typology:

Frackland components share similarities with with other components. With there being many components of the fracklands it was necessary to organize them. Grouping Fracklands and their components forms a typology of the fracking landscape. The typology is what delineates and describes the majority of findings on the Fracklands and their various components (findings from the descriptive strategies highlighted on the previous spread).

In total, four Frackland types were identified: The Persisting, the Veiled, the Transient, and the Phantom Fracklands. Each exhibit their own unique appearances, functions, uses, and/or phenomena. Together these four typologies describe what the Fracklands are, how they function, and how interact with their surroundings.

3. Frackland Trends:

Fracking is not the same throughout the country. It varies depending on several factors both regional and local. Information generated from the descriptive strategies was utilized for describing common trends of the Fracklands by region and place. Regions being the study regions examined in this report (see chapter 8), and places such as rural or urban communities. Trends primarily defined differences in appearances and practices. Trends also aided in describing the complexity of a Fracklands surroundings and how their appearances and/or operations varied by complexity.

The trends examined in this report were:

- Trends by Region – Which looks at differences between the regions of study.
- Follow the Well – Which looks at how other facilities relate to nearby wells in various contextual settings.
- Trends by land use – which compares differences between the Fracklands based on surrounding land use.
- Trends by population – which compares differences between the fracklands based on nearby population sizes.

4. Frackland Futures:

The System, Types, and Trends are a parsing of information that define the Fracklands. In response to the literature, the classification was expanded to include the future of the Fracklands and their components. While touching on the future of where the Fracklands will be and how they will end, the primary aim is a critical application of design to address these places once their purpose for use as a Frackland is no more.

This critical application of design towards the future of the Fracklands was created through the synthesis of information generated throughout the report. With reclamation being the primary future of Fracklands, outcomes of the practice was investigated. Such outcomes would inform what's desired: unique social, ecological, and economic outcomes. To reach these desired outcomes three strategies – Reform, for social outcomes, Rewild, for ecological, and Recycle, for economic – were developed from information presented throughout the report:. Each strategy had a number of unique ideas developed around it. Each strategy responded to prior findings from the classification, on the reflections, stories, and patterns of the Frackland components. The result was a range of adaptable ideas that can begin discussions over the future of the Fracklands.

With the uncertainties of the future in terms of where the Fracklands will be and when they will end, there is not enough information or context to come to true design solutions yet. Therefore designs were made to be generative and schematic, focused on generating discussion. Designs were not targeted at individual components of the Fracklands, rather a generalization of the Fracklands themselves. Ideas were made to be broad, prescribing the ideas that can address problems laid throughout the report and other anthropocentric dilemmas.

To visualize these ideas various visualization tools were used. To summarize each of these ideas and the overall outcomes they are trying to accomplish, a composite photo-montage was created. This composite image features notions of the ideas described in the diagrammatic renderings. Each idea was then represented through schematic diagrams.

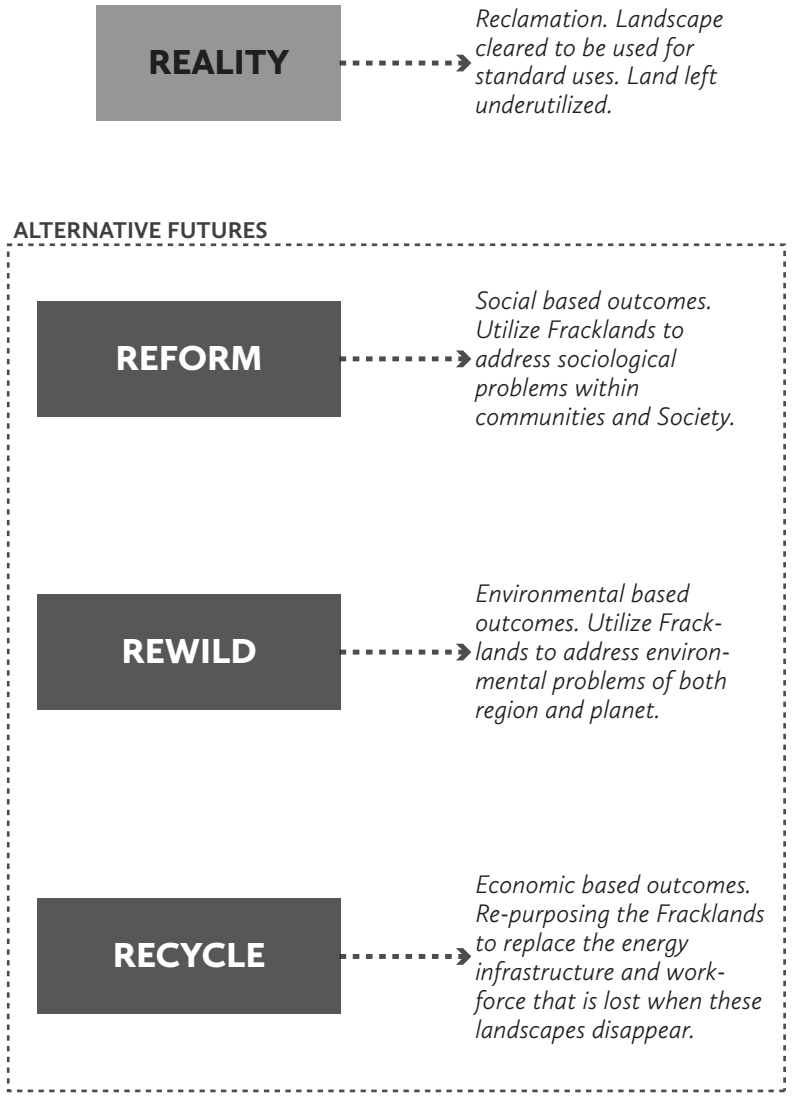


Figure 7.6. Frackland Futures. (Lanning, 2018)

Classification Process and Methods

1. Delineate the system of hydraulic fracturing (preliminay):

- By utilizing literature, description, and imagery of the fracking process, visualize this process diagrammatically.

- Separated functions and operations during each stage.
- Linked these processes with social, ecological, and economic effects.
- Associated these operations and/or their effects with the landscape. Separated based on their differences.
  - Many were obvious e.g. wells vs. processing
  - Other less obvious e.g. storage and disposal
- Visualized in an easily digestible diagram. Showed the linkages that form between these landscapes and how they are all connected as one due to the associated processes and phenomena.
- The landscapes defined in this system were the landscapes to explore and understand in greater detail in the field.

2. Explore each landscape defined in the system in greater detail – Field Study:

- Selected regions of study (See Chapter 8)

- Delineated areas of interest in each region to conduct field studies by utilizing, literature, geospatial data, and aerial imagery. (See Chapter 8)

- Obtained Oil and Gas facilities data for selected regions and used the data to locate facilities in the region.
- Utilized aerial imagery with the data to define areas of interest, and used imagery to find locations of landscapes that data did not reveal.
  - Used to parse through and select specific areas to examine in person. Made inferences as to whether a field visit in this area would yield new findings beyond what is known. (With regions containing thousands of these landscapes utilizing aerial imagery to define specific areas of interest was key to maximizing field visits)
    - Areas where unique patterns and phenomena may be most prevalent, became the areas visited in the field.
- Utilized the literature to demarcate areas of interest that both data and aerial imagery could not clearly define.
  - Many of these studies highlight phenomenological instances that geospatial data and static aerial imagery could not define

- Conducted field study in selected areas of interest, utilizing various descriptive tools:
  - Journaling: Hand written notes of field observations
  - Photography: The primary means of field observation was through a camera lens
  - Aerial Photography: A drone was flown on multiple occasions to capture phenomena from a different perspective. Also gave perspective where ground level observation was not useful.
  - Aerial imagery: Used when neither of the above methods were able to be utilized.

- Return to Aerial Imagery

  In cases where certain phenomena or information was unable to be captured in person, aerial imagery was utilized to capture these instances. Since the Appalachian region was unable to be visited. Aerial imagery analysis was used entirely to generate findings.

- Repeat Process and Iteration

  Field visits also uncovered new landscapes or differentiated information, requiring repeat process. This was not one and done, it was iterative and required multiple field visits.

- Finalization of Systems and Typology

  Once field study was completed, the findings could be organized and meshed with those from literature to finalize the Frackland System and Typology.

3. After Field Visits: Diagramming and Data Visualization

- Visually described and documented numerous phenomena that imagery cannot.
  - Visualize data hidden from the eyes view.

- Summarized findings from the fields and document contextual and systematic relationships. (Trends)

4. Utilized Collected Information to Investigate the Future of these Landscapes (Futures)

Visualization Tools:

- Critical Mapping – Visualizing Complex Interactions
  - Uncovering relationships not inherently seen
  - Visualizing important systematical relationships
  - Creating a meaningful and evocative map that geospatial maps often fail to do
- Diagramming, Eidetic Photomontage, Design Visualization:
  - Summarizing vast amounts of information visually
  - Utilizing diagrams for organization
  - Producing evocative imagery
  - Visualize complex interactions
  - Universal communicating to readers
  - Generating eidetic design ideas for alternative futures concepts

08 REGIONS OF STUDY

Hydraulic fracturing is widespread across the country, with its activity highly dispersed across various regions. Some processes may be the same, however there's often variations in appearances and phenomena based on contextual surroundings and local and state government policies. While it would be ideal to look at the entire United States and understand all of the occurrences of hydraulic fracturing landscapes, that is beyond the scope of the project. Therefore, this project looks at three distinct regions that have been impacted by high amounts of oil and gas fracking. These three regions are believed to provide a good in-depth understanding of the variability of fracking landscapes and their associated phenomena found across the country.

These three study regions are Weld County, Colorado, Tarrant County, Texas, and Select Areas of West Virginia and Pennsylvania (Appalachia). Each Region was selected for various criteria, in hopes that each would tell a different story of the Fracklands. Selection of these overall regions was done so through a selection process based on a number of criteria. More specific areas of interest were chosen from findings in literature or during field visits and analysis of aerial imagery. In addition to these primary areas, additional areas of focus were selected in order to fill in any gaps where vital information was needed.

Visitation:

For this study, visits to Tarrant County and Weld County were conducted. Due to project limitations, West Virginia and Pennsylvania could not be visited and could only be visited through non-site specific methods. Each visit or remote study looked at specific areas of interest. Literature review, data analysis and analysis of satellite imagery aided in selecting these areas of interest. Once in these areas of interest qualitative data and the methods detailed in the previous chapter were utilized to collect information on the Fracklands and their components.

Region Selection Criteria											
	Prevalence of Fracking	Fracking and Geography	Land types in area	Oil and gas History	Prevelence in research	Data Avalibility	Personal Connection	Easy to visit	Totals (+ / --)	Primary focus area	What used for
Select Areas in PA and WV	Vergy high in certainf areas: NE PA, S PA, N WV. E OH	Primarily located in rural areas. Farms, hilltops, forest	Federal land, private - agrarian / some urban	The birthplace of the oil and gas industry	Very high - environmental / ethnographic studies	Moderate: Wells, facilities	*Low: no prior visit or prior knowledge*	*No*	4 | 2	YES	*aerial imagery analysis, data collection and visualization, research*
Tarrant County Texas	Very high throughout the region	Located anywhere	State Parks, Private - predominately urban	Deep roots in Texas, but recent for Tarrant	Moderate - urban interface. High when looking at Texas as a whole	*Low: Wells with minimal information*	Moderate: Personally familiar with region	Yes	4 | 1	YES	*Field visits, aerial imagery analysis, data collection and visualization, research*
Weld County Colorado	Very high in Weld but not many other places	Located anywhere but the most densely populated areas	Federally managed land/grassland, private - urban / agrarian	Since the 70's but not on a scale that it is today	*Little to none*	High: Wells, facilities, and more	Very High: Home	Yes	6 | 1	YES	*Field visits, aerial imagery analysis, data collection and visualization, research*
Bakken: Western North Dakota	Very High	*Agrarian*	Private - agrarian	Unsignificant until last decade	Much focuing on the effects of the boom	High: Wells, facilities, and more	*Low: no prior visit or prior knowledge*	*No*	4 | 3	Yes (Backup)	*aerial imagery analysis, research*
Oklahoma	High - Statewide	*Agrarian*	Private - agrarian	Somewhat	*Little to none*	Moderate: Wells, facilities	Moderate: Personally familiar with region	Yes	2 | 2	No	*Nothing*
Wyoming	Moderate - Certain areas of state	Farms and open rangeland	Federal land, private - agrarian	Moderate	Low - Fracking and earthquakes	High: Wells, facilities, and more	*Low: only minimal prior knowledge*	Yes but not in areas where fracking is highest	1 | 1	No	*Nothing*
Eagle Ford: South/Central Texas	Very High	Farms, open rangeland, sparseley populated communities	Private - agrarian / some urban	In some parts yes, others no	Moderate - environmental injustices, infrastructural effects of fracking	*Low: Wells with minimal information*	*Low: no prior visit or prior knowledge*	*No*	1 | 3	No	*Nothing*
Louisiana and Arkansas	Moderate - Certain areas of region	Farms, forest, coast, wetlands	Private - agrarian / some urban	Moderate	*Little to none*	*Low*	*Low: no prior visit or prior knowledge*	*No*	1 | 4	No	*Nothing*
Wisonson/Illinois (Frac Sands)	Lots of frac sands facilities	Primarily located in rural areas. Farms, forest	Private - agrarian	Fracking is what created the Frac Sands	Very high - environmental / ethnographic studies	*Low: Just Locations*	*Low: no prior visit or prior knowledge*	*No*	2 | 3	Yes (Frac sands)	*aerial imagery analysis, data collection and visualization, research*

Table 8.1. Region Selection Criteria. (Lanning, 2018)

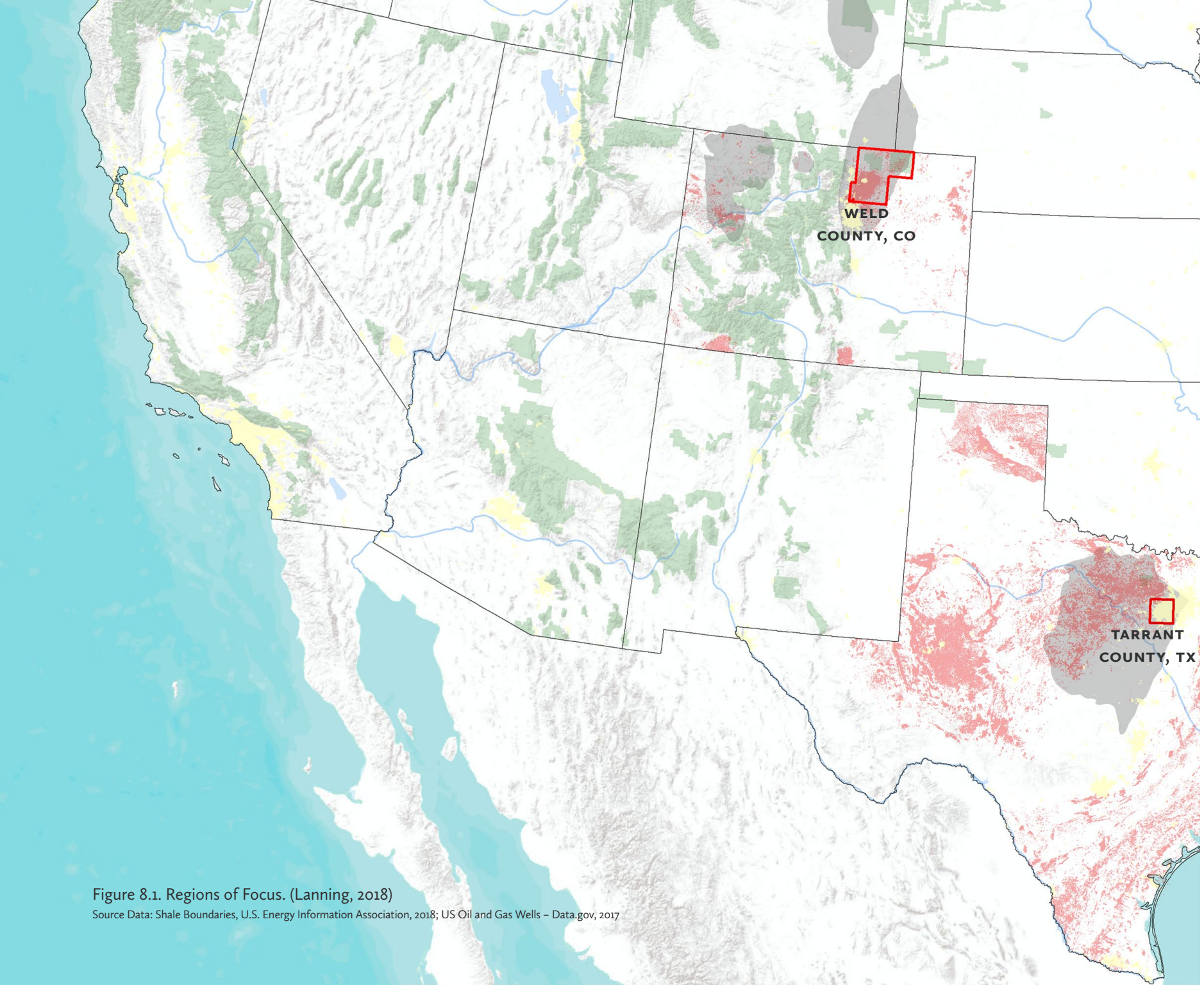


Figure 8.1. Regions of Focus. (Lanning, 2018)

Source Data: Shale Boundaries, U.S. Energy Information Association, 2018; US Oil and Gas Wells – Data.gov, 2017


PENNSYLVANIA
WEST
VIRGINIA

WELD COUNTY, COLORADO

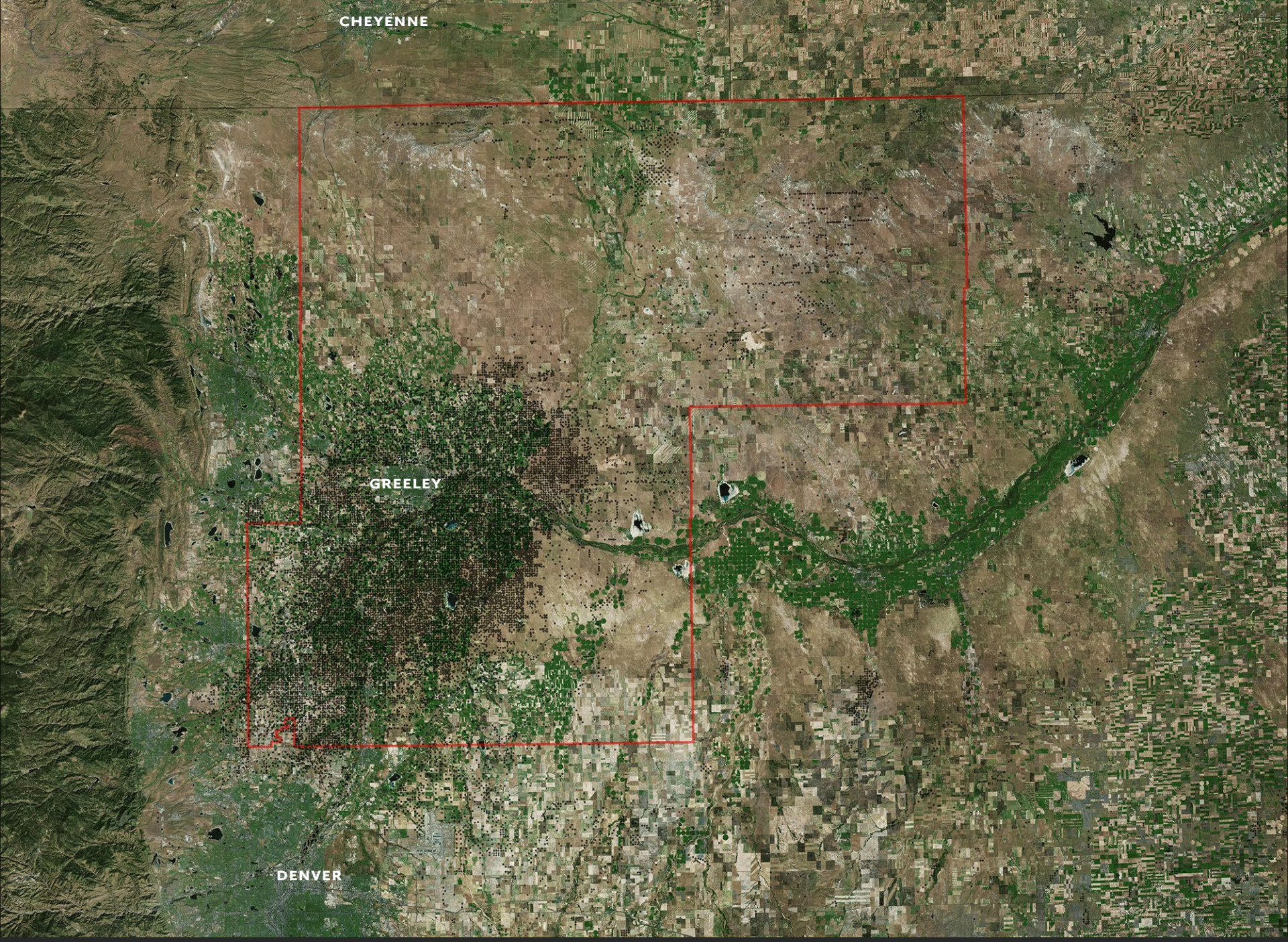
Weld County was selected primarily over familiarity, its use in the case study, and its ease of access. As a resident of Weld County, I was already quite familiar with the region despite a lack of discussion within literature. Compared to the other two regions of study Weld is quite different contextually.

Weld County sits along the northernmost edge of the State. It is part of the Niobrara Shale Play which spans across parts of northern Colorado and Wyoming. It is the State's leader in oil and gas production accounting for more than 50% of State's wells and 90% of the State's oil and gas production (Weld County 2017). Weld presents a number of unique features, a range of land types, and activity unique to the region. Today the Weld is largely defined by farms and oil/gas, however populated areas are growing and encroaching upon fracking more and more.

Weld is unique in that it is a dichotomy with its surroundings. Fracking is near absent in areas surrounding Weld. Unlike other regions where fracking is common throughout the greater region, it is largely concentrated in Weld; absent once one crosses county boundaries.

- **Size: 4,017 square miles**
- **Population: 300,000 residents**
- **Well Count: 25,000 wells**

Figure 8.2. Weld County Context Map. (Lanning, 2018)
Source Data: Oil/gas wells – Colorado Oil & Gas Conservation Commission, 2017


CHEYENNE
GREELEY
DENVER

Areas of Interest

Many areas of interest for the other regions were selected from literature. However, literature focusing on the region was largely absent. Selection of areas of interest had to be done remotely based on my familiarity with the region. Areas selected were meant to represent a range of conditions found throughout the county regarding percieved level of fracking activity, the prescense of residents, and land uses such as the Pawnee grasslands to the north, and agrarian lands spread throughout the county.

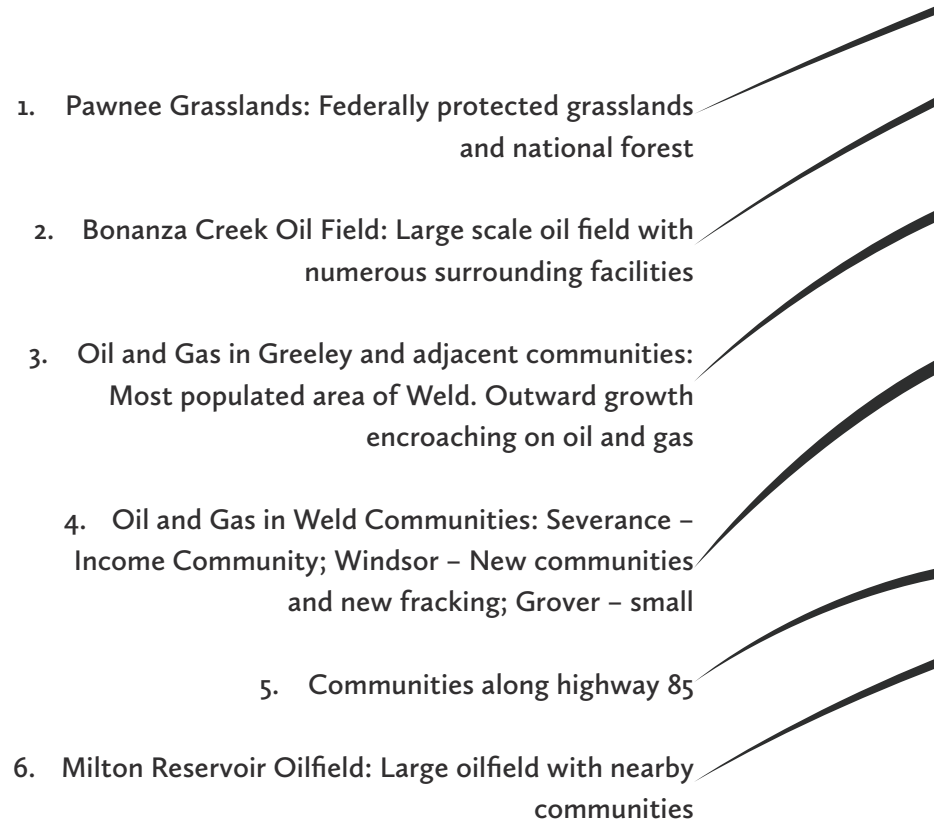


Figure 8.3. Map: Areas of Focus in Weld County. (Lanning, 2018)
Source Image: Google Earth, 2017



TARRANT COUNTY, TEXAS

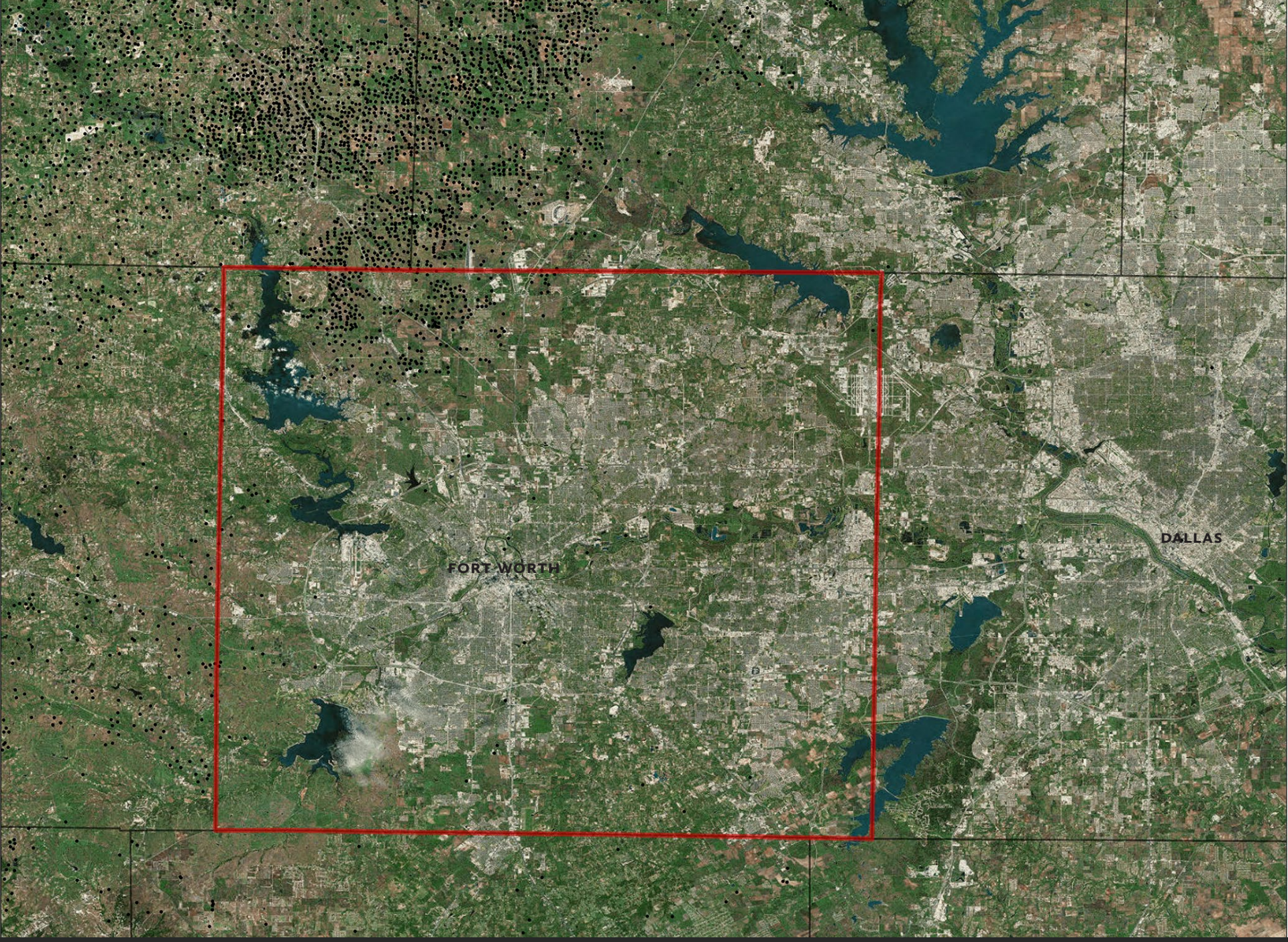
The entire state of Texas plays host to a large amount of oil and gas fracking activity. Tarrant county is a small window into the state, chosen primarily because of its context and the unique phenomena of the area which was seen throughout literature. It was also chosen due to prior familiarity of the region and its relative proximity.

Tarrant is where the city of Fort Worth is located. It is a highly populated area, with a high degree of fracking activity. This phenomena of fracking in highly populated areas is uncommon and of significant interest. In the future what is een here may be more and more common in the other regions examined.

In Texas as a whole, fracking is in more rural areas, similar to what is seen in Colorado and Appalachia. To reduce redundancy Tarrant County was selected as a region that demonstrates variability in where Fracklands exist. Discussions of social interaction and socio-economical phenomena in Tarrant county was a common topic in literature, pushing interactions to extremes.

- **Size: 902 square miles**
- **Population: 1,982,000 residents**
- **Well Count: ~1,000 wells**

Figure 8.4. Tarrant County Context Map. (Lanning, 2018)
Source Data: US Oil and Gas Wells – Data.gov, 2017


FORT WORTH
DALLAS

Areas of Interest

Literature highly informed the selection of focus areas in the region. Many studies on its integration with suburbs to the northwest of Fort Worth were of interest to go and document for this study. Other areas of study were selected from satellite imagery. The relatively low number of fracking activity in the area made the selection of interest areas easier to parse through. From these selected areas, like that of Weld County, they were selected to represent an array of land uses and perceived contextual factors in the area.

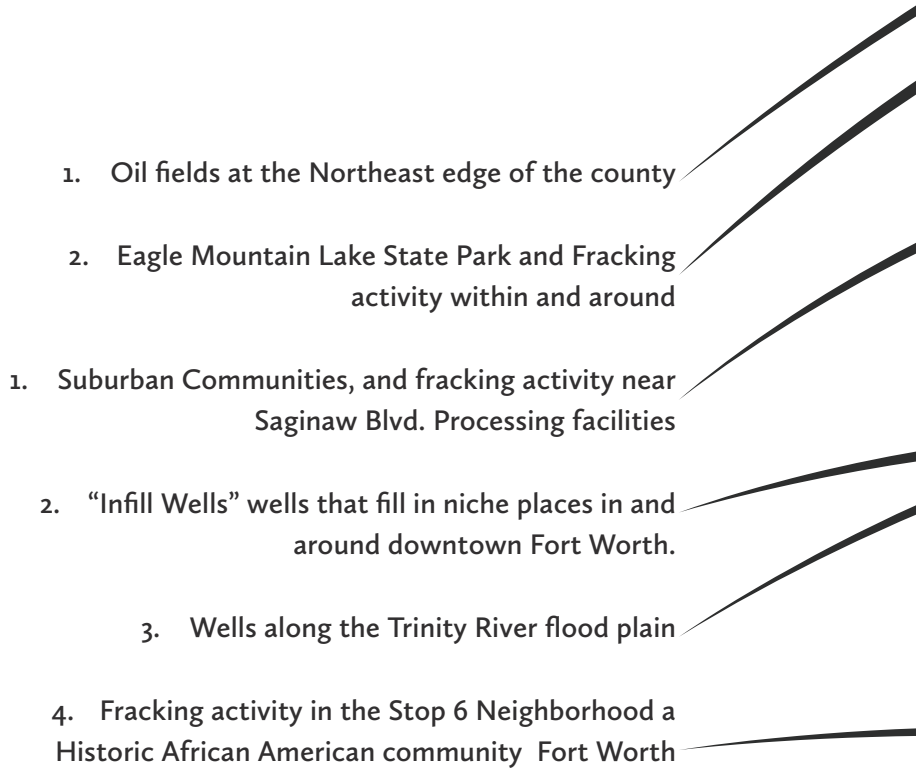


Figure 8.5. Areas of Focus in Tarrant County. (Lanning, 2018)
Source Image: Google Earth, 2017



APPALACHIA - SELECT REGIONS

Unlike Weld and Tarrant which were selected primarily over familiarity and ease of access, this region was selected largely because of literature and its unique contextual factors. West Virginia and Pennsylvania were selected to represent the Appalachian region, Ohio was left out. The largest of all the study areas, Appalachia accounts for more than 60% of the U.S.' natural gas production (EIA 2017). This region is the birthplace of oil and gas development, and its people have deep ties to the extraction industry. Much of the literature that focuses on this region focus on the people and the interactions fracking has had with them.

This area was also selected because of its range of contextual factors where fracking is located: in national forest, agrarian lands, highly populated areas, and more. While the other two regions represent areas where fracking has rapidly come to dominate the region in places oil an dgas has not, this is one where such effects resemble those of the past booms.

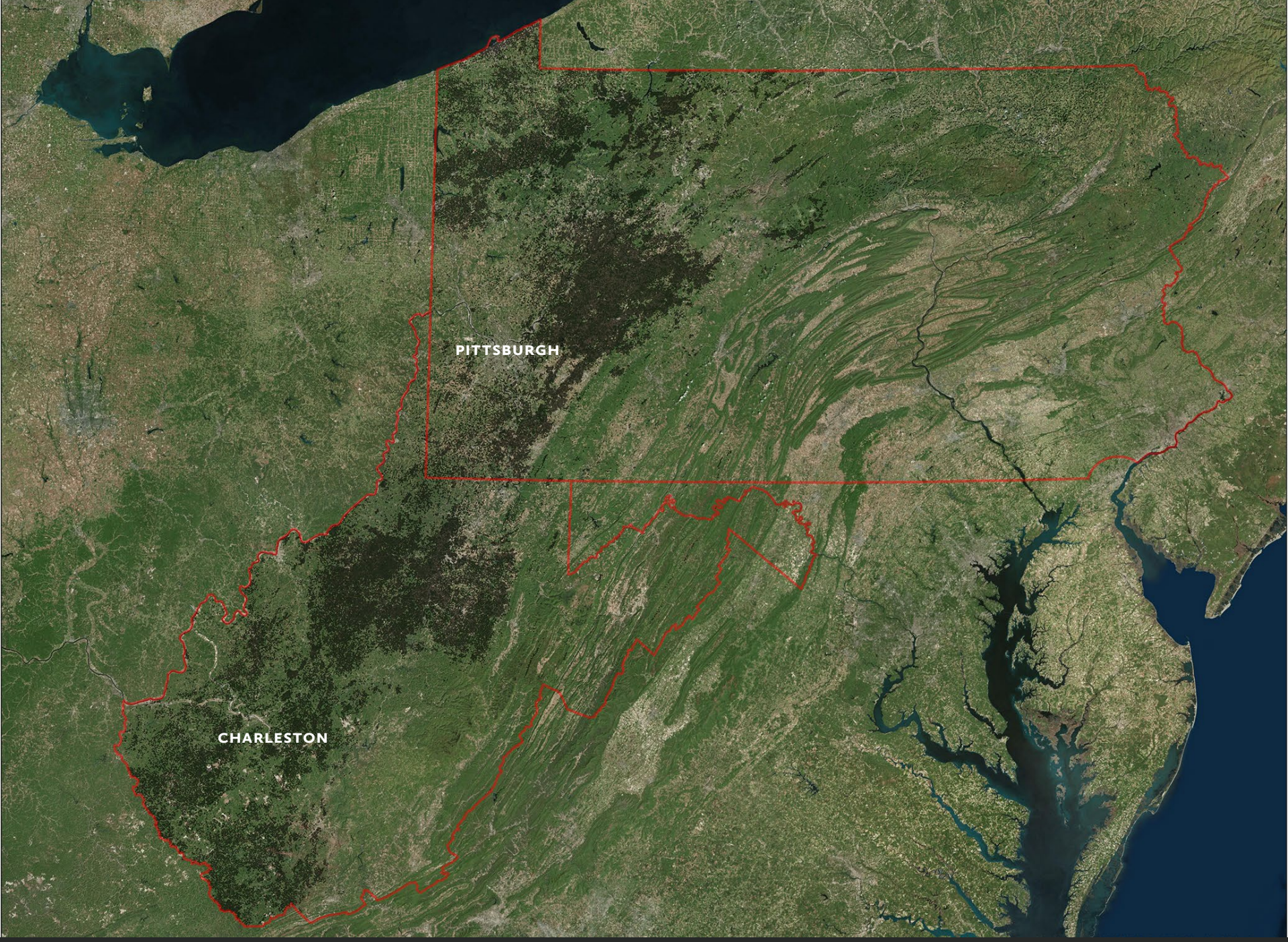
Pennsylvania

- Size: 46,055 square miles
- Population: 12,806,000 residents
- Well Count: 108,500 wells

West Virginia

- Size: 24,230 square miles
- Population: 1,831,000 residents
- Well Count: 79,400 wells

Figure 8.6. Appalachia Area Context Map (Lanning, 2018)
Source Data: Oil/gas wells – Pennsylvania Department of Environmental Protection, 2017;
Oil/gas wells – West Virginia Department of Environmental Protection, 2017


PITTSBURGH
CHARLESTON

Areas of Interest

Selection of areas of interest was largely informed by the literature and from data/aerial imagery. Areas where fracking activity was the highest such as the North East of Pennsylvania was informed by the data and literature. Many areas became chosen based on if they could be compared with similar types of areas in Weld and Tarrant. An example of this is the area around Pittsburgh which was chosen to compare with other population centers in Tarrant and Weld. Due to the size of this study area and the inability to visit in the field, these areas of interest remained broadly defined.

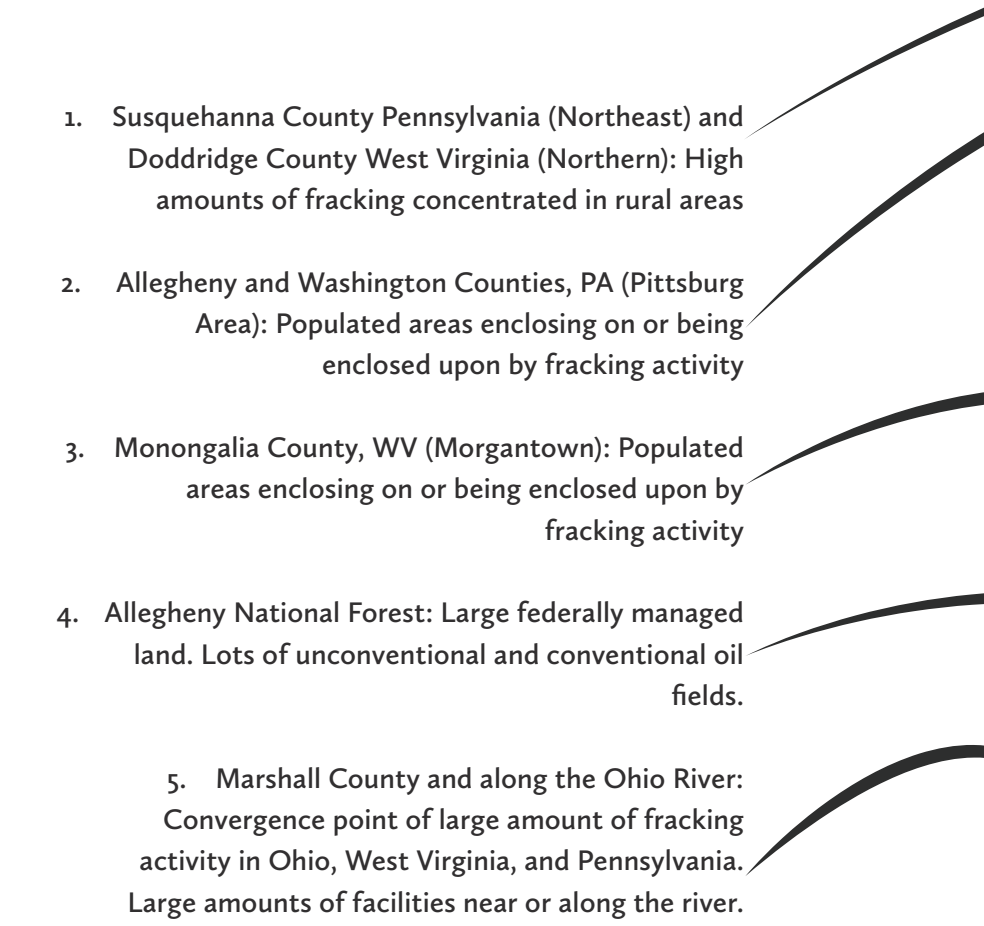


Figure 8.7. Areas of Focus in West Virginia and Pennsylvania (Lanning, 2018)
Source Image: Google Earth, 2017



AREAS BEYOND

While the three selected regions are the primary regions of study, there are several other regions that were considered as well. There were also other specific areas of interest both inside of outside regions of hydraulic fracturing. Not all Fracklands are locked to major oil and gas producing regions. Additionally other regions with fracking may have unique phenomena that should be touched on. These select areas of interest were chosen based on findings within literature, available data, or prior knowledge.

Subsidiary Regions of Focus:

North Dakota – The Bakken: The Bakken oilfield has experienced many similar effects as the other regions. However, unlike others it has experienced a boom greater than most. Rapid influx of oil field workers and money has quickly changed the region. While not a primary focus area, the Bakken was selected as an area of interest for select cases. Data for the region is also more avalible than others so it can be used in cases where information from the three primary regions is unavailable.

South/Central Texas – Eagle Ford: Much like the Bakken, the Eagle Ford region of texas has been rapidly transformed and experienced booms more than others. Phenomena related to his boom are touched on where applicable.

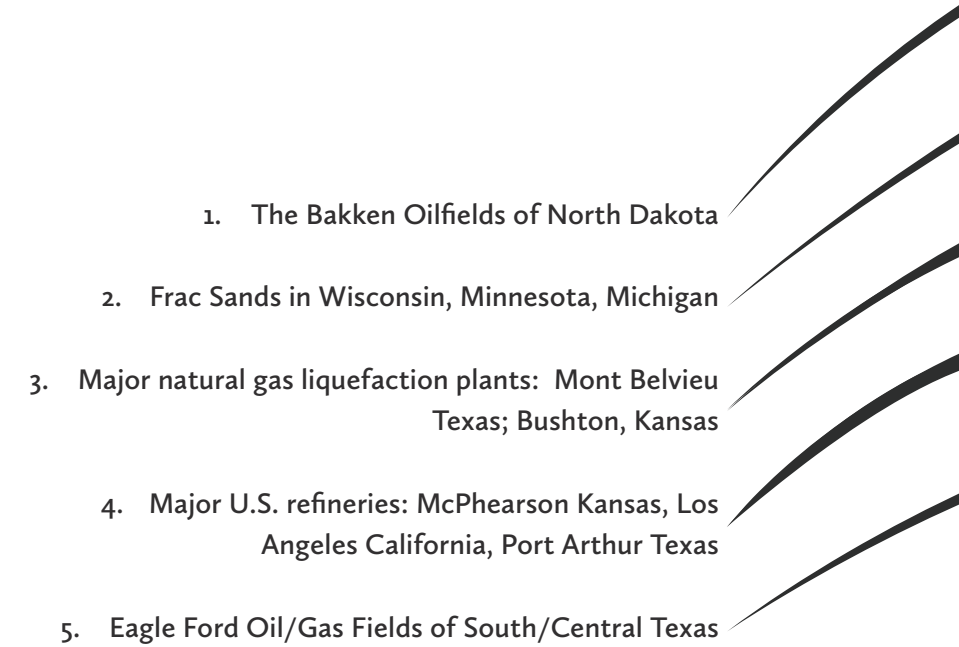
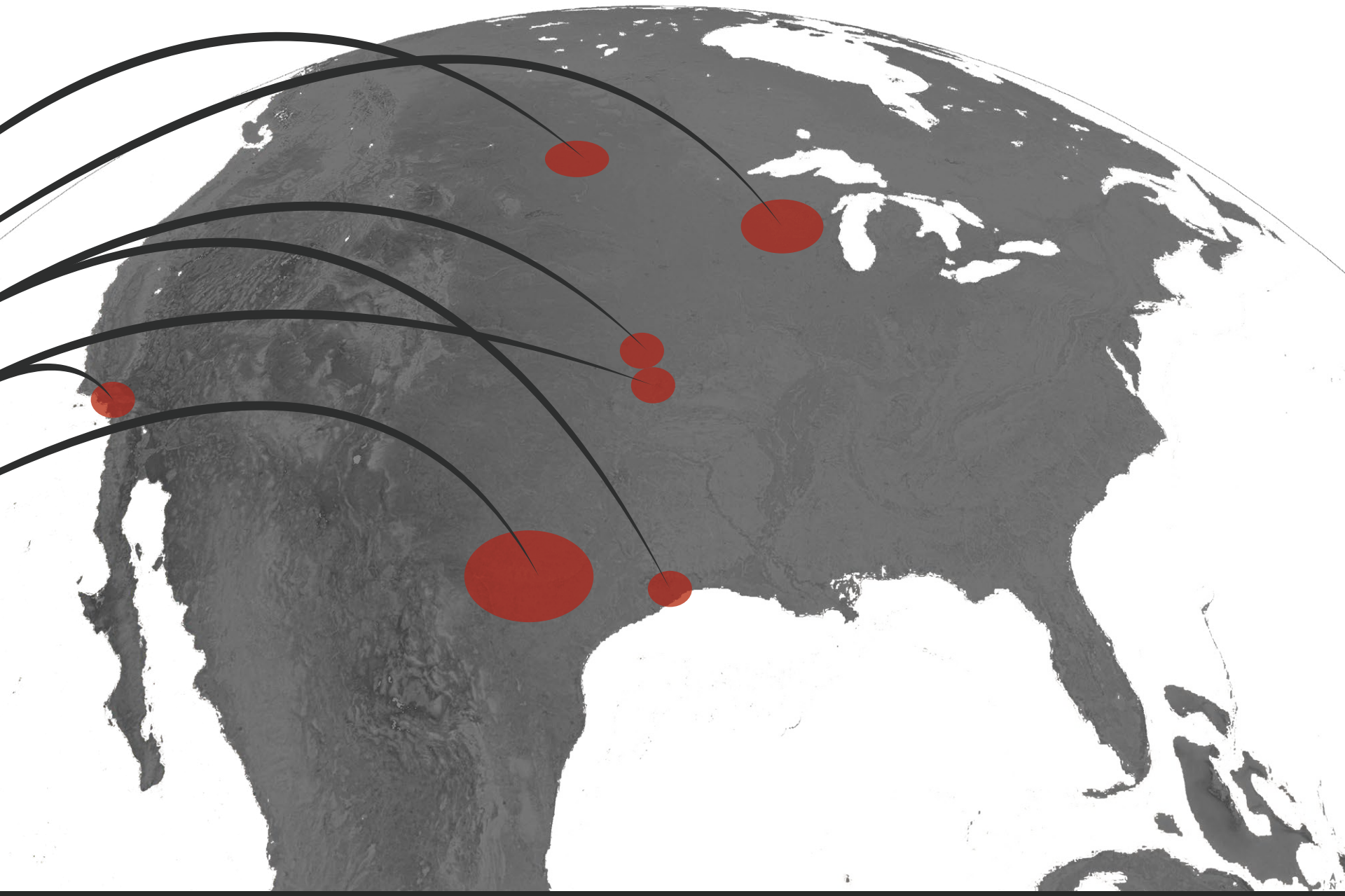


Figure 8.8. Areas of Focus across the United States outside primary study areas. (Lanning, 2018)



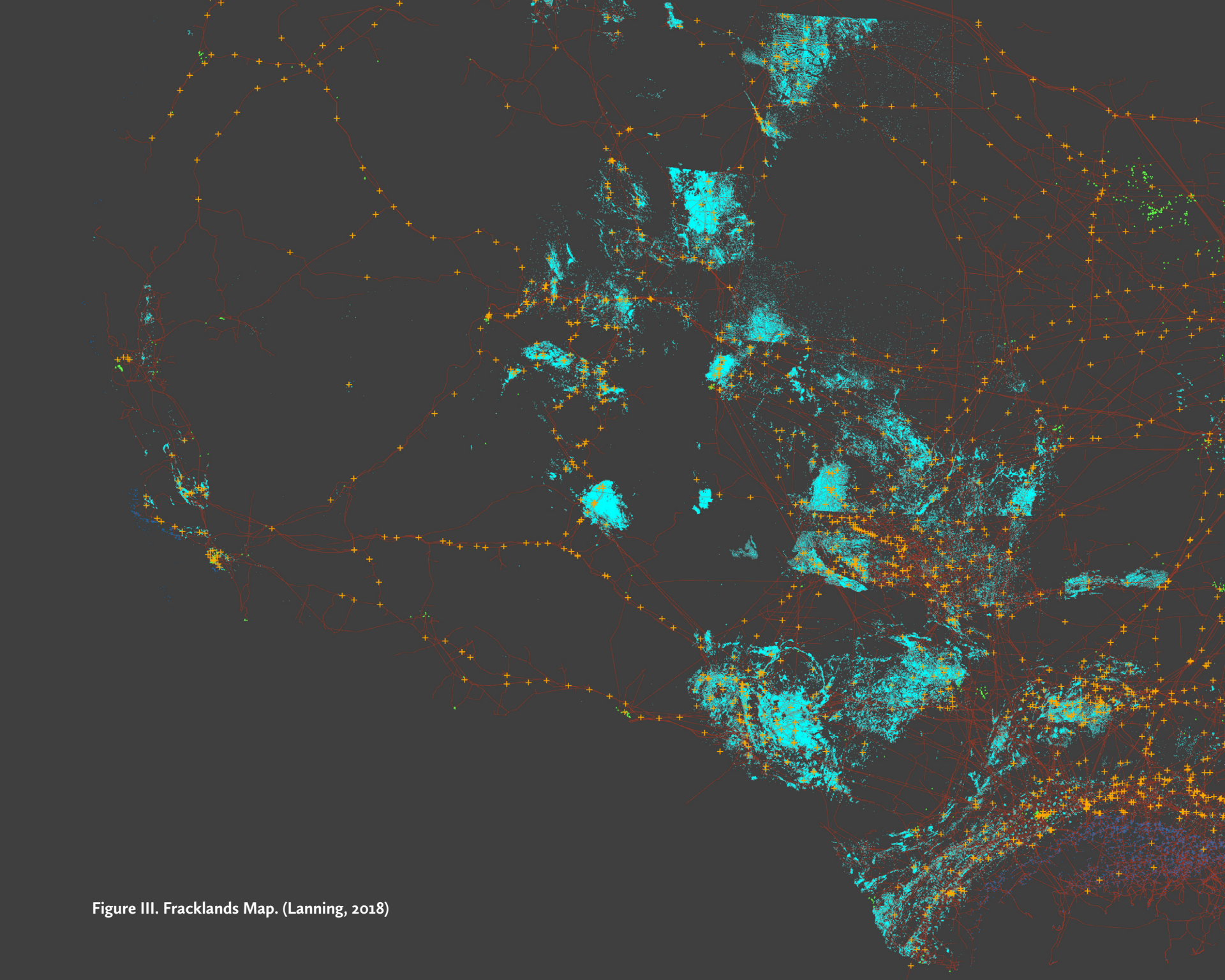
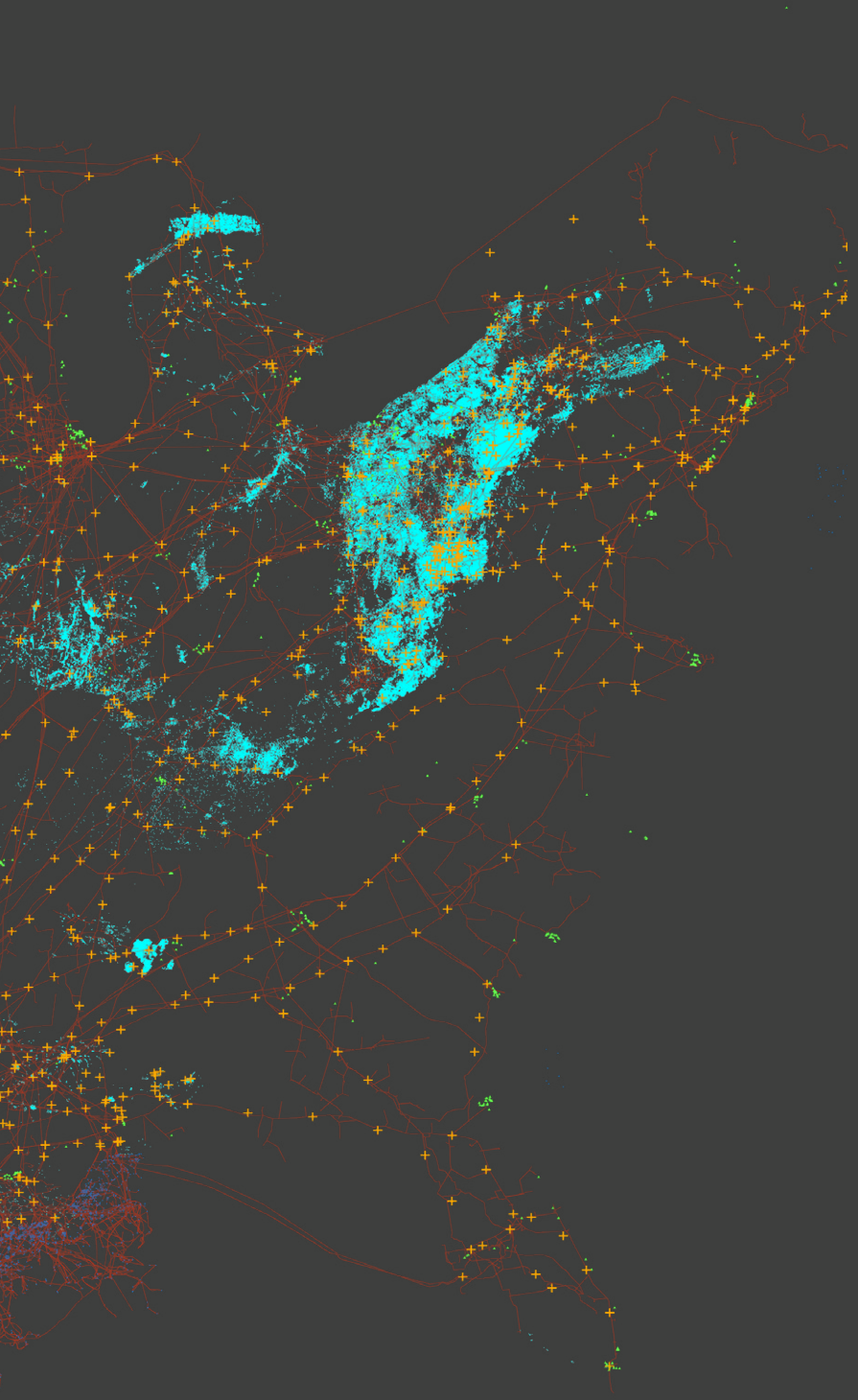


Figure III. Fracklands Map. (Lanning, 2018)



III | FINDINGS

This section defines and classifies the Fracklands. Through the synthesis of in-depth research and field study new findings on the Fracklands is generated. Findings that detail the system in which the fracklands and their components operate within. Findings that delineate the components of the Fracklands and how they inform four unique Frackland types. Findings presenting the contextual differences of the Fracklands place by place. And findings on the future of the Fracklands and what they could become.

The Fracklands and their components represent millions of facilities, spaces, and places, each with their own unique phenomena. They form a fragmented and tessellated landscape that is in essence a landscape being sacrificed for the extraction, transportation, and production of unconventional oil and gas. Enter the Fracklands.



Section Outline:

This Section compiles all of the findings from research and execution of the methodology. It occupies a large number of pages to completely tell the story of the Fracklands. The Fracklands are told through four approaches in order of: 1. Systems 2. Typology 3. Trends 4. Futures. The typology occupies the majority of the pages within this section as it presents findings on the components of the fracklands. Each of four Frackland types are further broken down into their own sub-chapter. Utilize the table to the right to navigate across the Fracklands.

This section utilizes photography, satellite imagery, maps, and diagrams to primarily tell this story, however much information can be found in the text that accompanies these visuals. Photographs and aerial imagery are the most common visualizations of the Fracklands throughout. Note that these compositions are static views into something that is dynamic and active at all times day and night. Each images tell of elements and phenomena that are common both in time and place. Each image was selected to represent common sights of the Fracklands and not abnormalities.

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09 THE FRACKLAND SYSTEM

The Fracklands and their many components are always a part of a larger system whether evident or not. This system and the processes that revolve around it involves a massive amount of land spread across the entire U.S. While many of the components of the Fracklands are wells, many more components exist as lands for by-products and waste, processing, transportation, materials, and more. Together they form a network of components that amounts to millions of facilities spread across the Unites States.

The approach in understanding the Fracklands is to understand the system in which their components revolve around. Each component spawns from an action or practice relating to hydraulic fracturing. Many revolve around extraction itself, while others may be more far removed. Understanding each node within this system, the linkages they form with others, and where they fit within the system is necessary for understanding how these landscapes should be approached and understood. The following diagrams are meant to illustrate this system in various ways in which it can be viewed. They highlight the hierarchy within, the inputs and outputs of created, and the ways connections are formed between them.

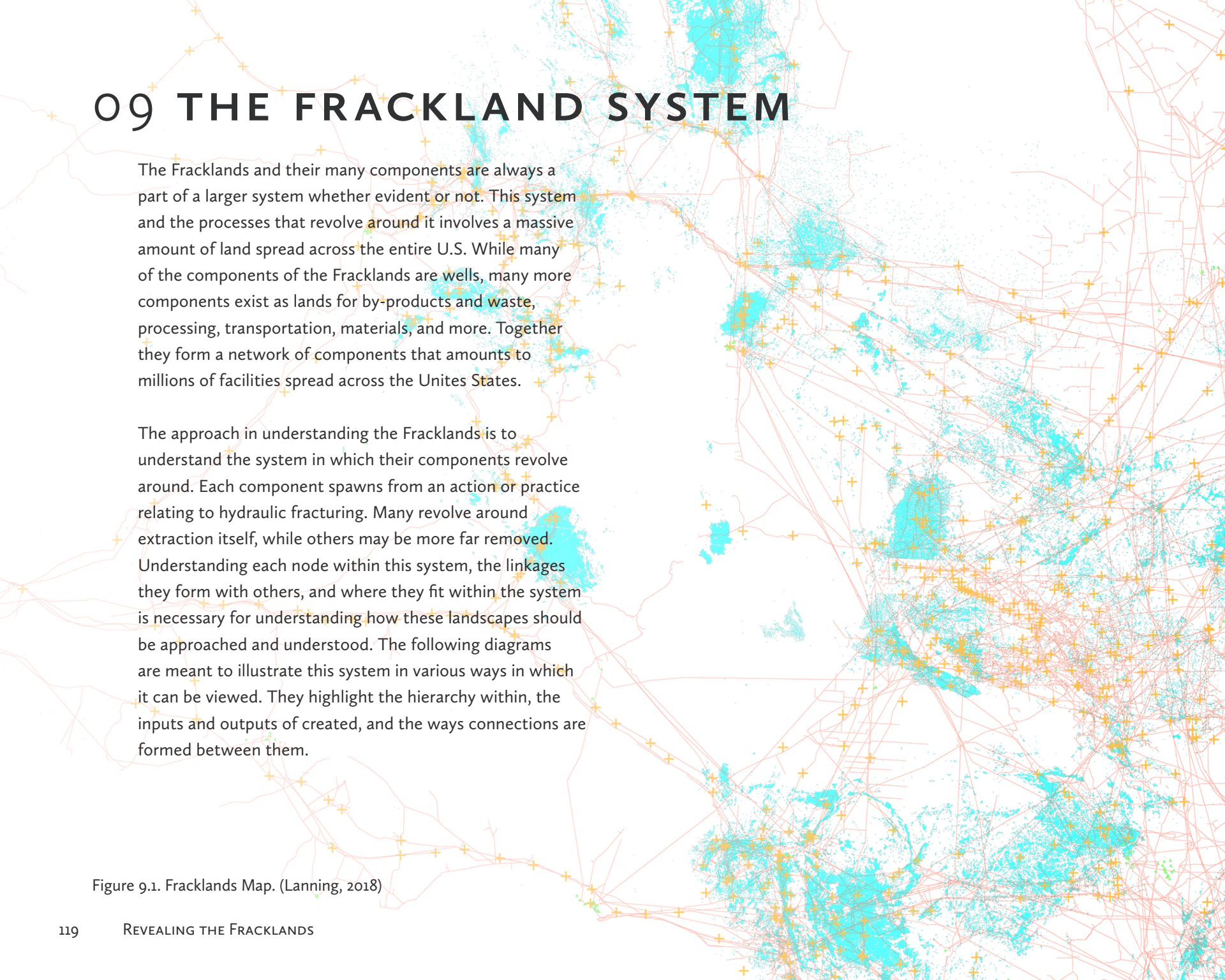
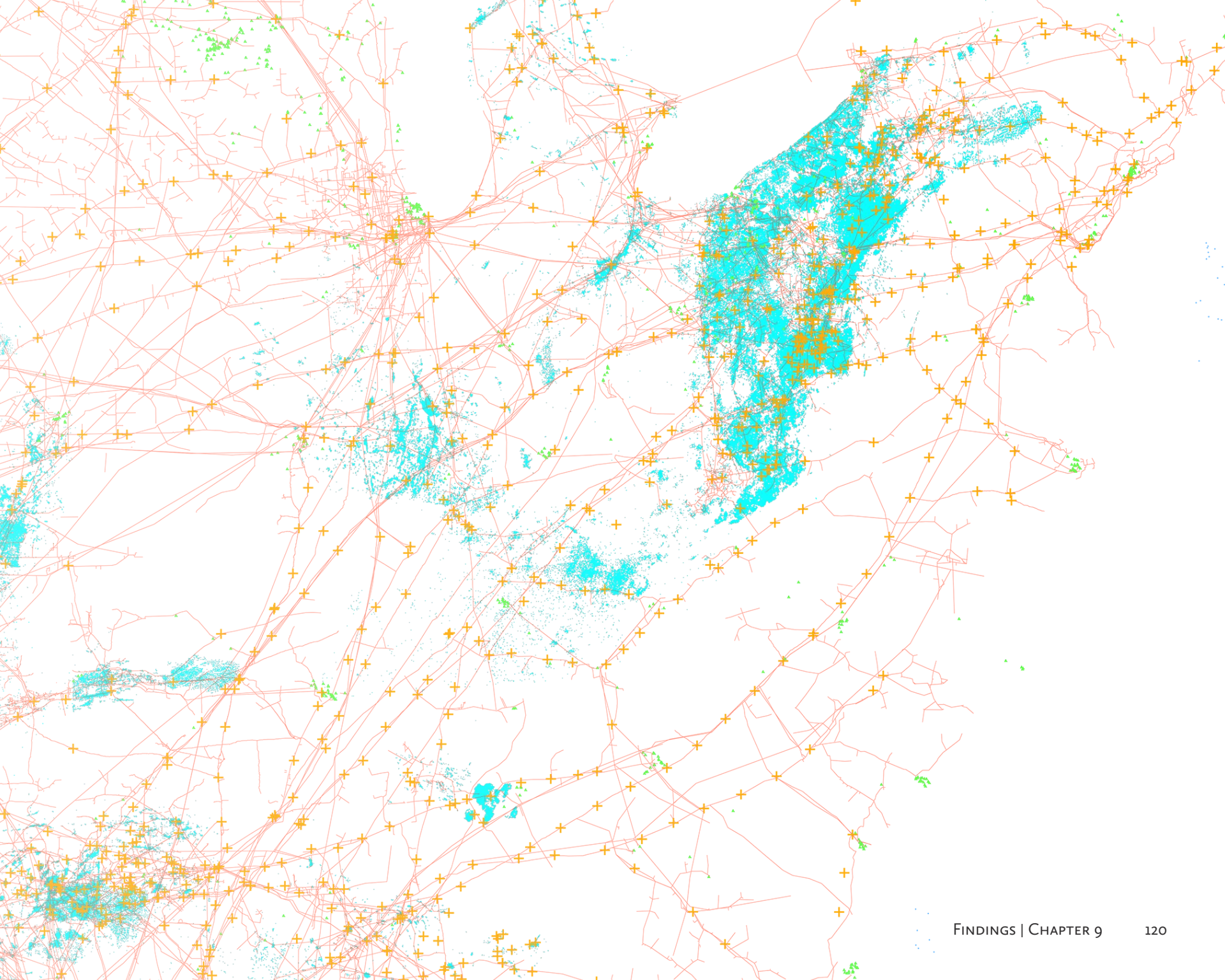


Figure 9.1. Fracklands Map. (Lanning, 2018)



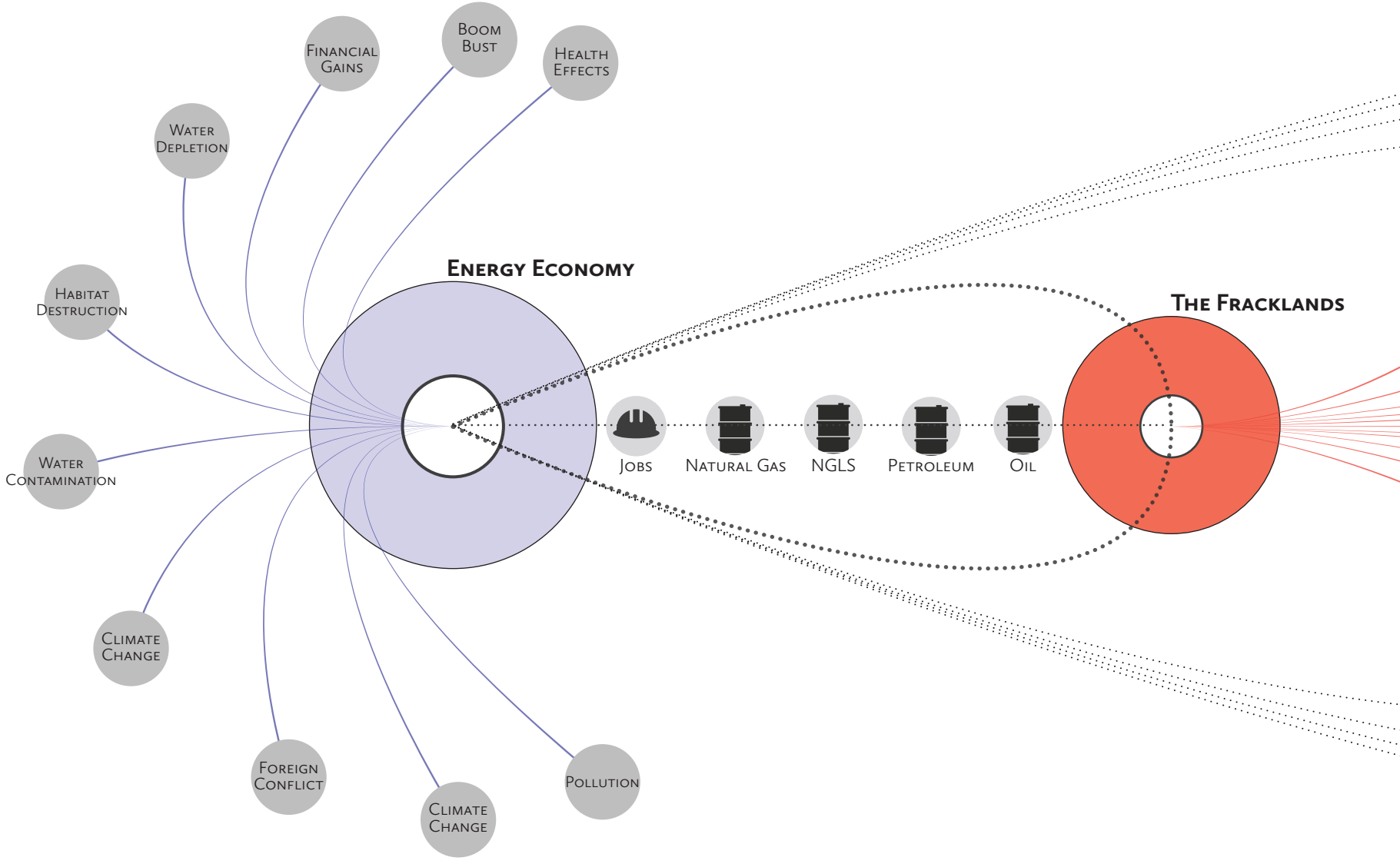
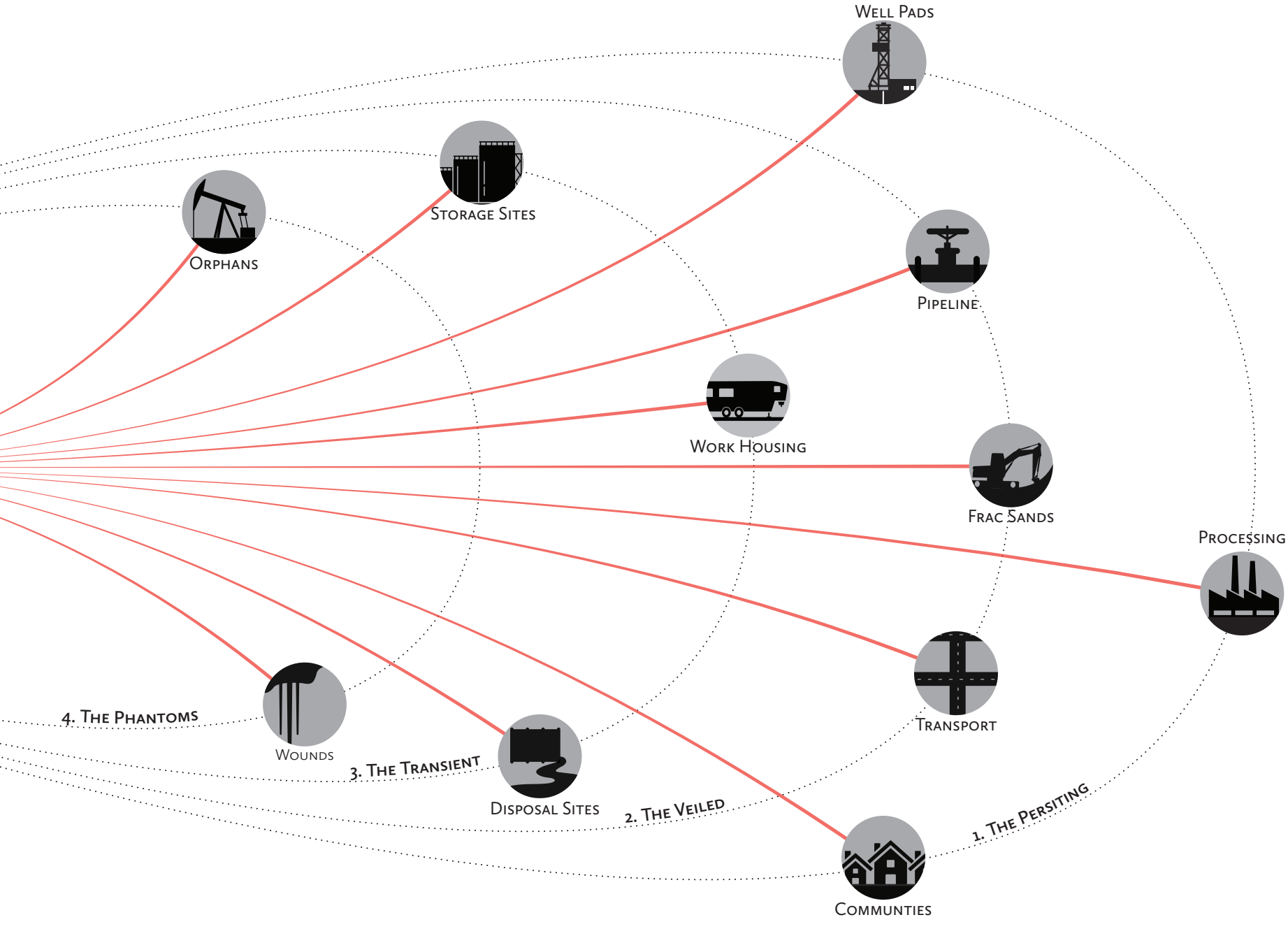
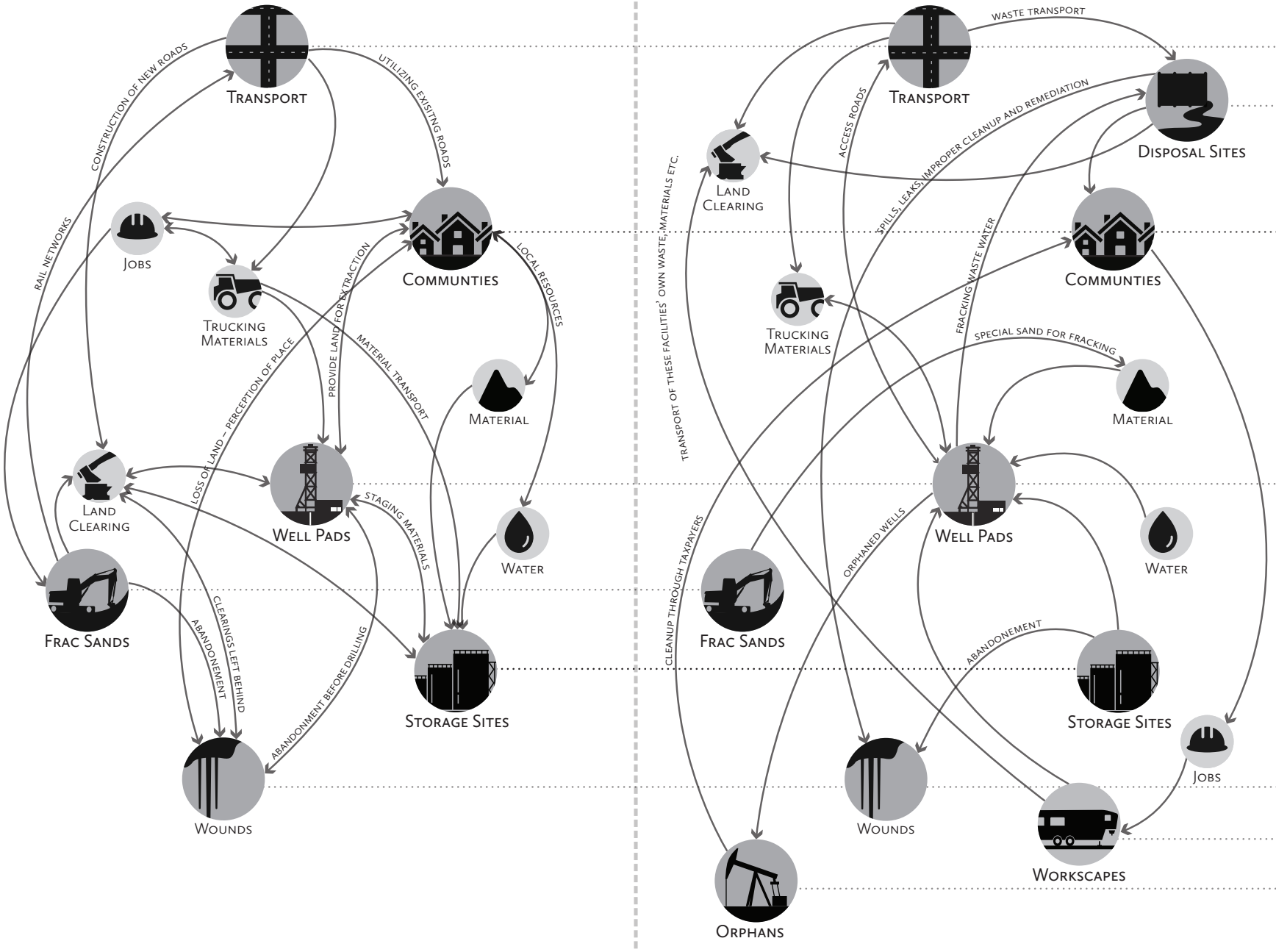


Figure 9.2. The systems of hydraulic fracturing. (Lanning, 2018)

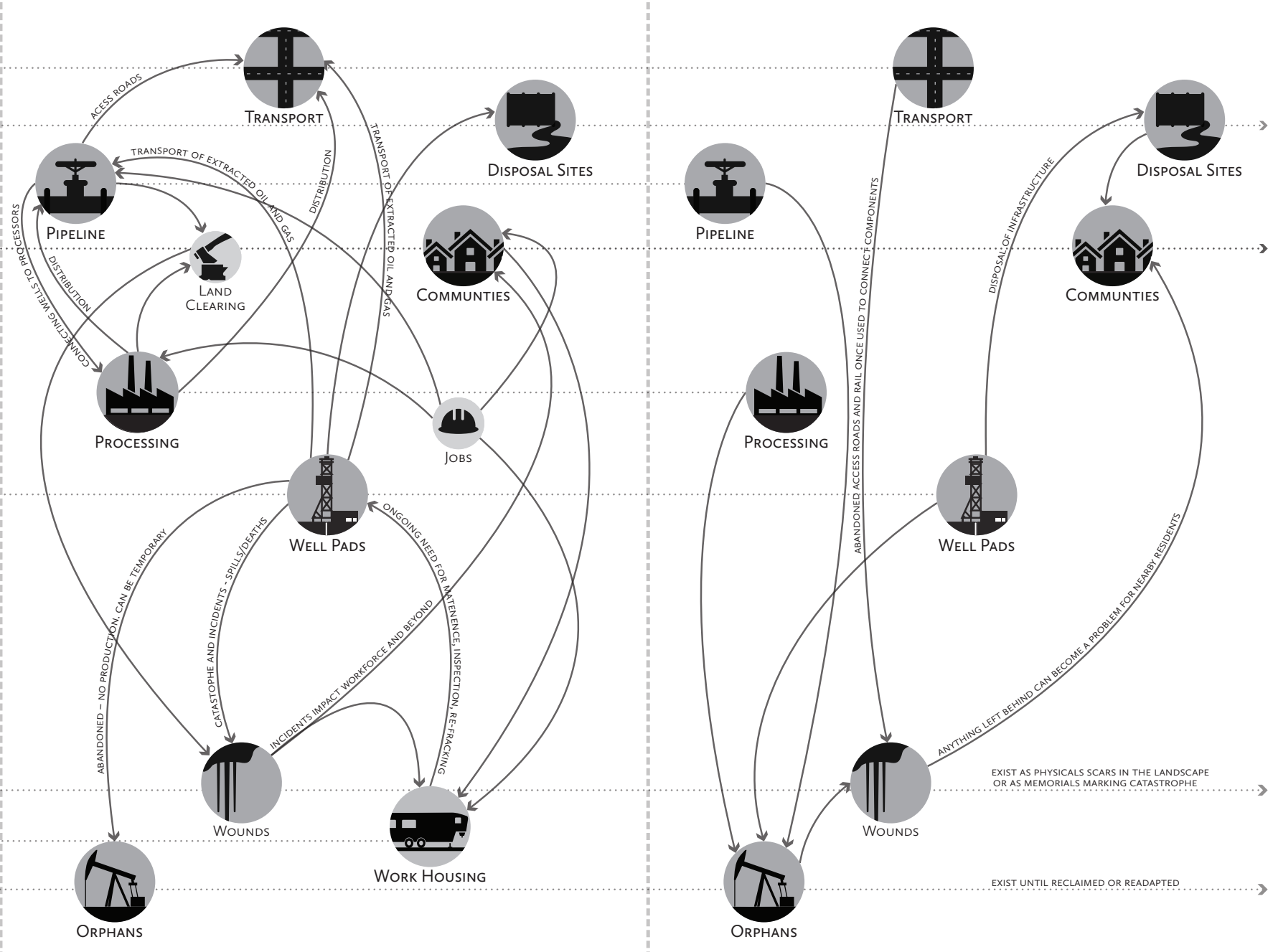

Well Pads
Storage Sites
Orphans
Pipeline
Work Housing
Frac Sands
Processing
Transport
Wounds
Disposal Sites
Communties
4. The Phantoms
3. The Transient
2. The Veiled
1. The Persiting



I. Site Preparation

II. Drilling/Fracking

Figure 9.3. The systems of hydraulic fracturing by phase. (Lanning, 2018)


ACESS ROADS
TRANSPORT
DISPOSAL SITES
TRANSPORT OF EXTRACTED OIL AND GAS
DISTRIBUTION
TRANSPORT OF EXTRACTED OIL AND GAS
PIPELINE
CONNECTING WELLS TO PROCESSORS
DISTRIBUTION
LAND CLEARING
COMMUNTIES
PROCESSING
JOBS
WELL PADS
ABANDONED – NO PRODUCTION, CAN BE TEMPORARY
CATASTOPHE AND INCIDENTS - SPILLS/DEATHS
INCIDENTS IMPACT WORKFORCE AND BEYOND
ONGOING NEED FOR MAITENENCE, INSPECTION, RE-FRACKING
WOUNDS
WORK HOUSING
ORPHANS
III. PRODUCTION
TRANSPORT
DISPOSAL SITES
PIPELINE
ABANDONED ACCESS ROADS AND RAIL ONCE USED TO CONNECT COMPONENTS
DISPOSAL OF INFRASTRUCTURE
COMMUNTIES
PROCESSING
WELL PADS
ANYTHING LEFT BEHIND CAN BECOME A PROBLEM FOR NEARBY RESIDENTS
WOUNDS
EXIST AS PHYSICALS SCARS IN THE LANDSCAPE
OR AS MEMORIALS MARKING CATASTROPHE
EXIST UNTIL RECLAIMED OR READAPTED
ORPHANS
IV. TERMINATION

Seeing the System in Reality

The following are examples of the Fracklands system in reality. Both are presented at a site-scaled level from an aerial or satellite perspective. These examples are also meant as a guide for how to interpret imagery throughout the rest of the section. To see how the underlying system is present at all times and the potential linkages that are present. Not one Frackland component is an individual piece. While some images presented in later pages may focus on just one component, refer back to these examples to understand the system they inhabit.

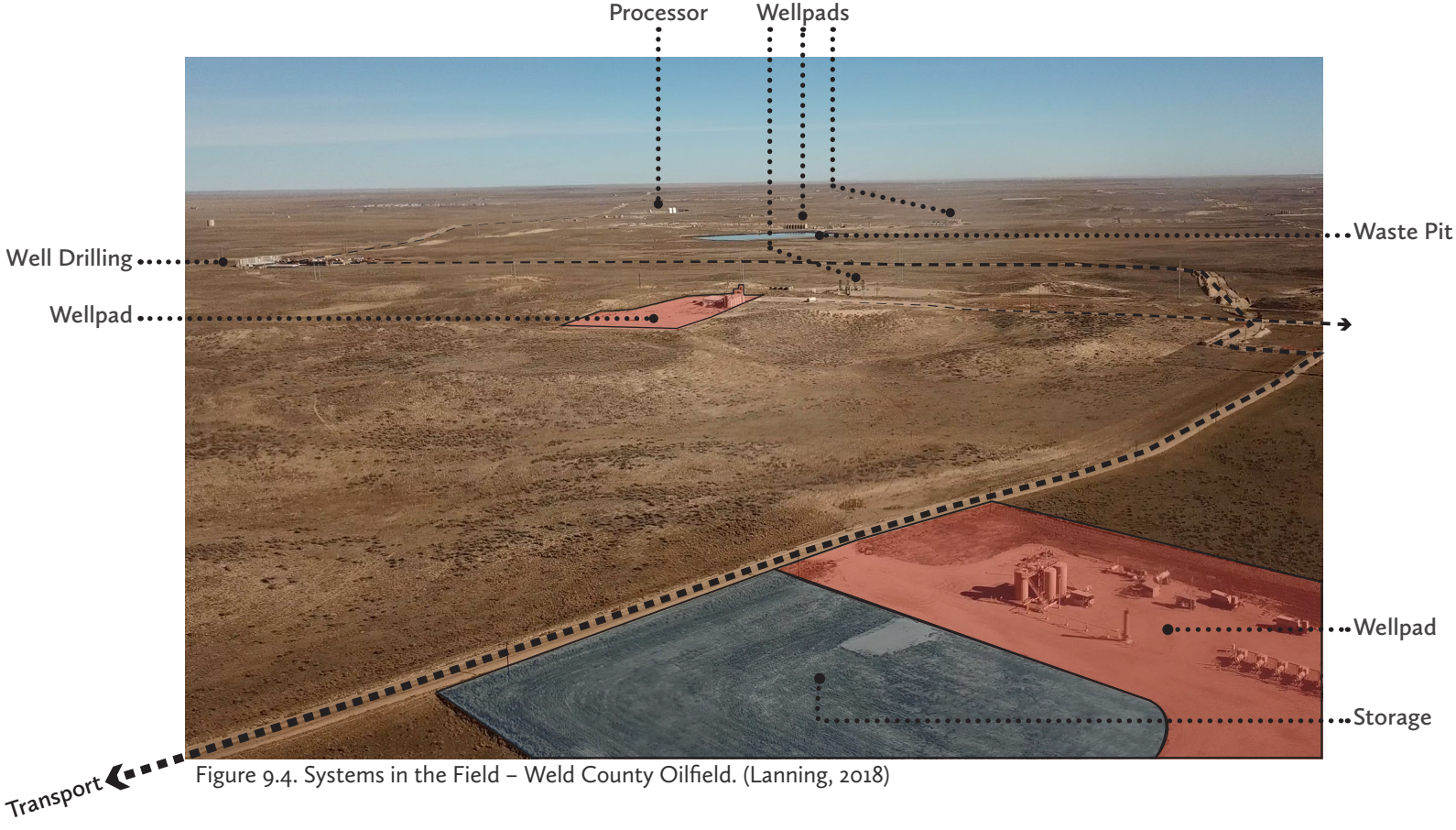


Figure 9.4. Systems in the Field – Weld County Oilfield. (Lanning, 2018)

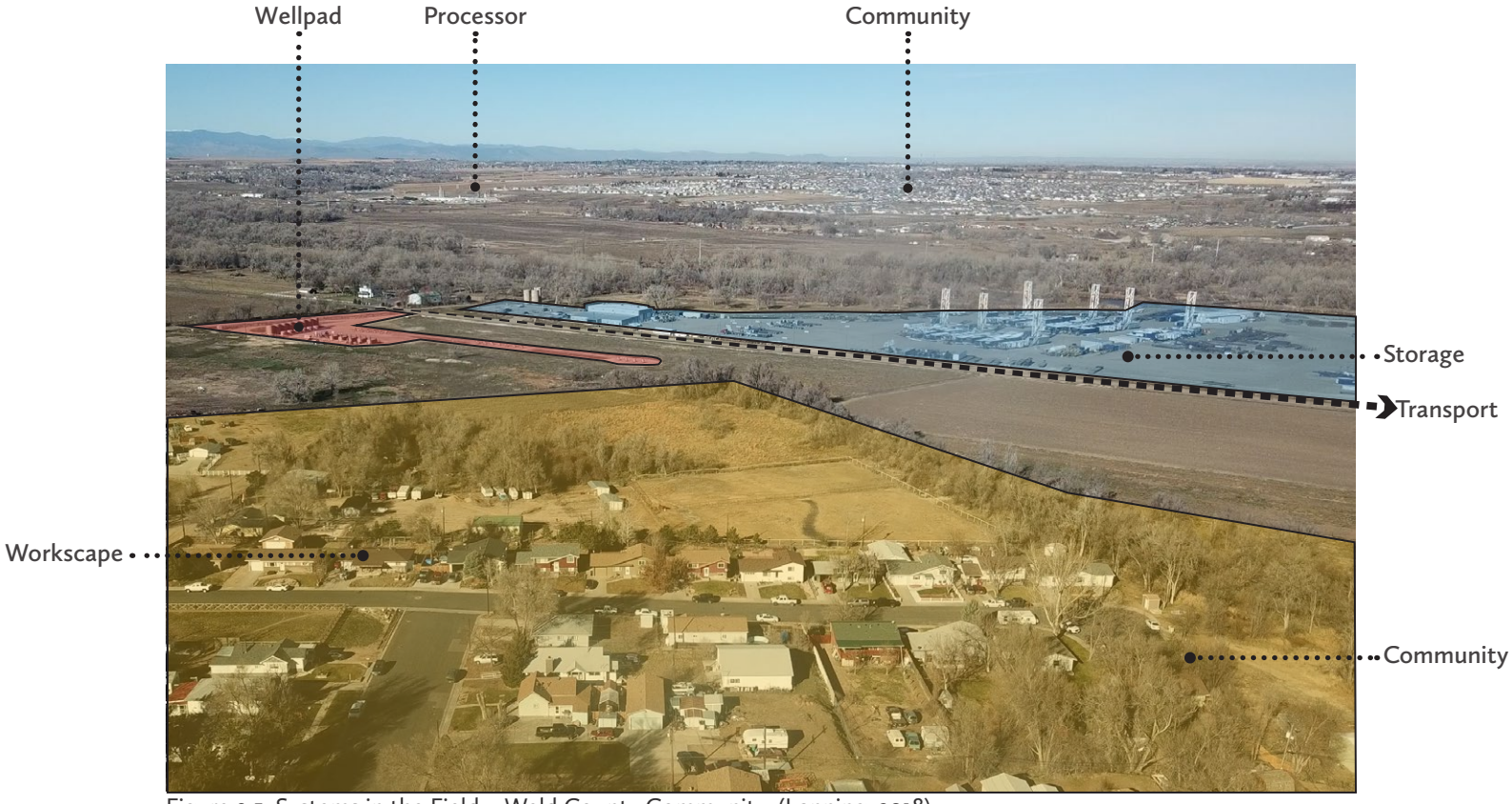


Figure 9.5. Systems in the Field – Weld County Community. (Lanning, 2018)

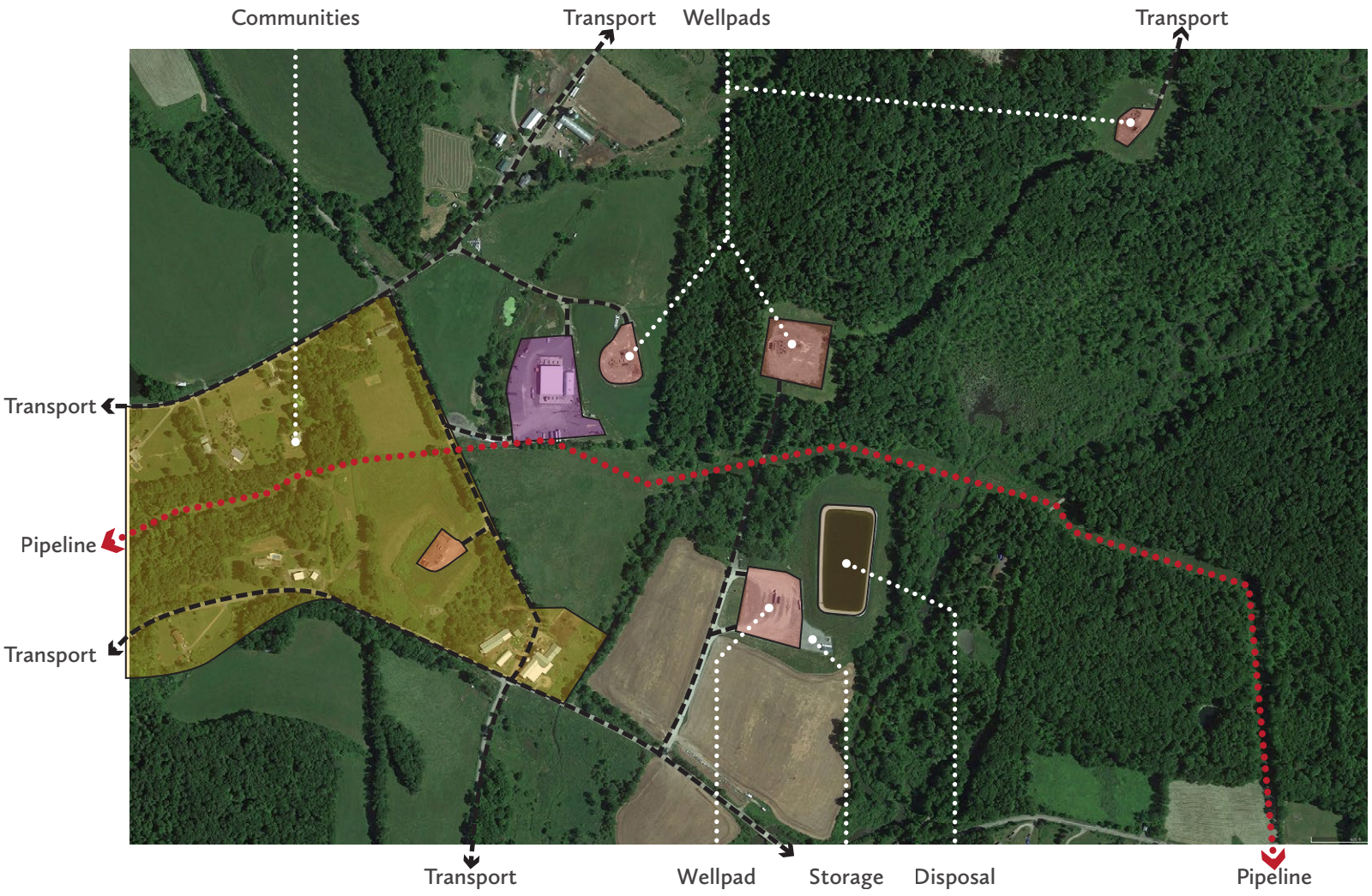


Figure 9.6. Systems in the Field – Pennsylvania. (Lanning, 2018)

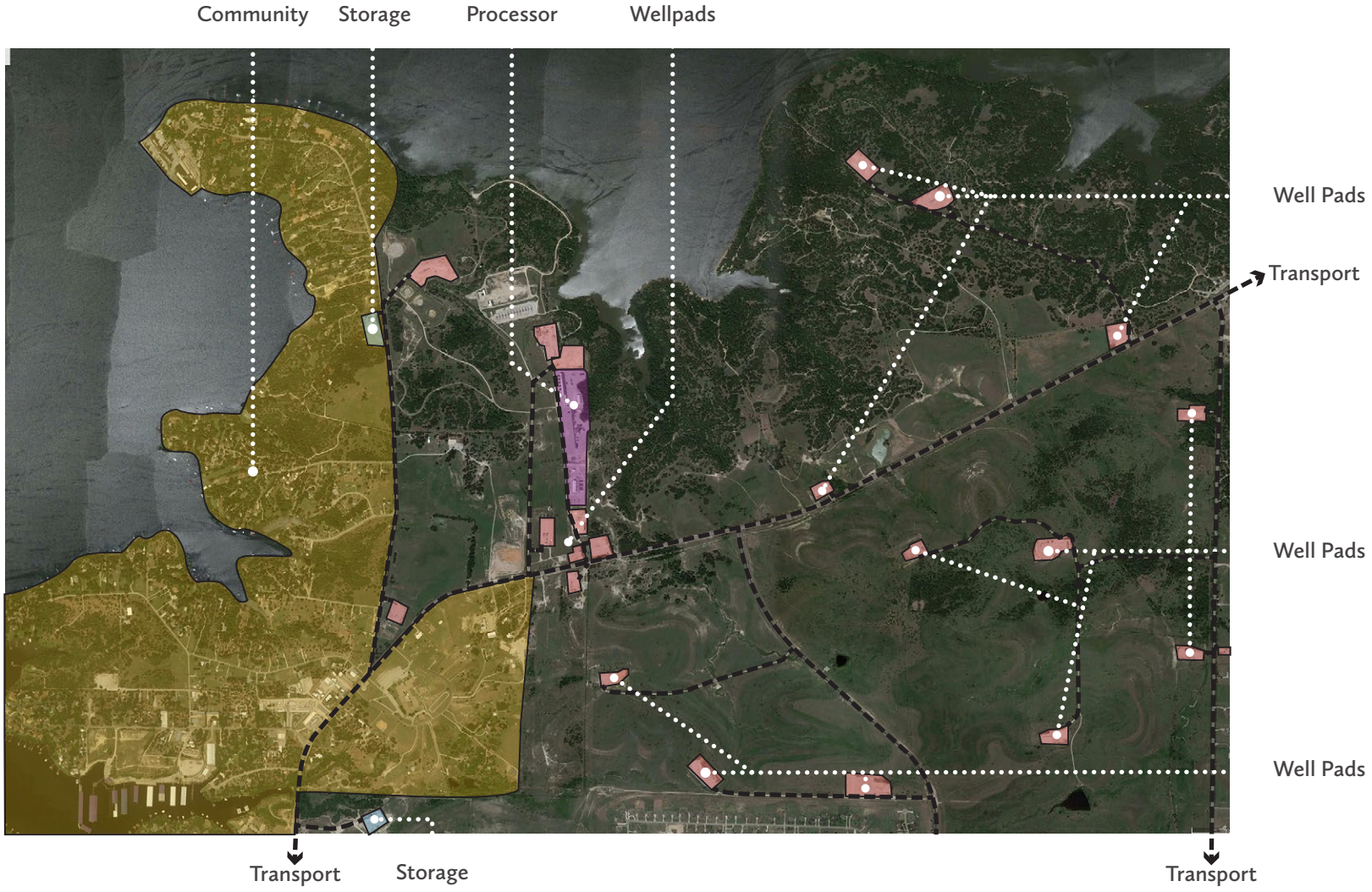


Figure 9.7. Systems in the Field – Tarrant County. (Lanning, 2018)

10 FRACKLANDS TYPOLOGY

As shown from the previous chapter, the Fracklands and their components are linked together pri-marily by the processes of fracking. While the system delineated the linkages and connections made within a Frackland – a component's place within the fracking process – it cannot completely reveal what a Frackland and its components look like. Frackland components share many characteristic simi-larities whether they are directly linked together within this system. When grouping components based on these commonalities, they begin to form characteristics of a unique landscape type.

This Chapter presents the Fracklands Typology, the four Frackland types that were identified, and the 11 components that define them. Each Frackland type represents an amalgamation of extensive field-based research on the Fracklands components. These types are a generalization of what was exam-ined and a representation of a Frackland in its truest idea and form. The typology is a way organizing the extensive amount of information collected, while revealing connections that may not be inherent. Each Frackland type – The Persisting, Veiled, Transient, and Phantom Fracklands – are detailed below:

I. The Persisting:

These Fracklands are finite; Concrete. Their components are fixed as apparent and known entities, and are easily understood. They will last far into the future, serving as a clear landmark as to what hydraulic fracturing is or what it has created.

II. The Veiled:

These Fracklands are hidden from view either physically or in a way that their relation to hydraulic fracturing is not inherently apparent. What describes each of their components may be dissimilar, but what each share is that their connection to hydraulic fracturing is and will be hidden unless one looks deeper.

III. The Transient:

These Fracklands are those that are ephemeral. Their components may occupy a time or space for a moment, only to fade away. Their existence may be entirely missed unless one is looking at a specific point in the process of hydraulic fracturing. They may be persisting or veiled, full of activity at one moment, and silent another; rising and falling like the demand for oil and gas.

IV. Phantoms:

These Fracklands are remnants left behind by the industry. Their components are products of past development and tell of what may be left after oil and gas. They may be any components that's been touched on in prior sections, or their use may be unknown. What is known is they are components that have and will haunt their surroundings for as long as they remain in the state they are.

This chapter breaks down 11 common components of the Fracklands and reveals their stories from four separate perspectives. Perspectives from different places, different people, and different forms of communication. Each component is unique in many different ways. Within each sub-chapter these components are presented through text, imagery, maps, and diagrams. Components tell of what the Fracklands are and phenomena that can be seen within them. While eleven Frackland components are detailed in this chapter, more exist. These elevem were identified as the most common or essential components of the Fracklands.

Each Frackland component is presented as follows:

- Definition: Introduction and Overview.
- Reflections from the Field: Personal reflections from field visits to each region regarding the component.
- Stories from the Fracklands: Various examples of how people are interacting with these components.
- Patterns of the Fracklands: Visual analysis of the components' patterns and phenomena

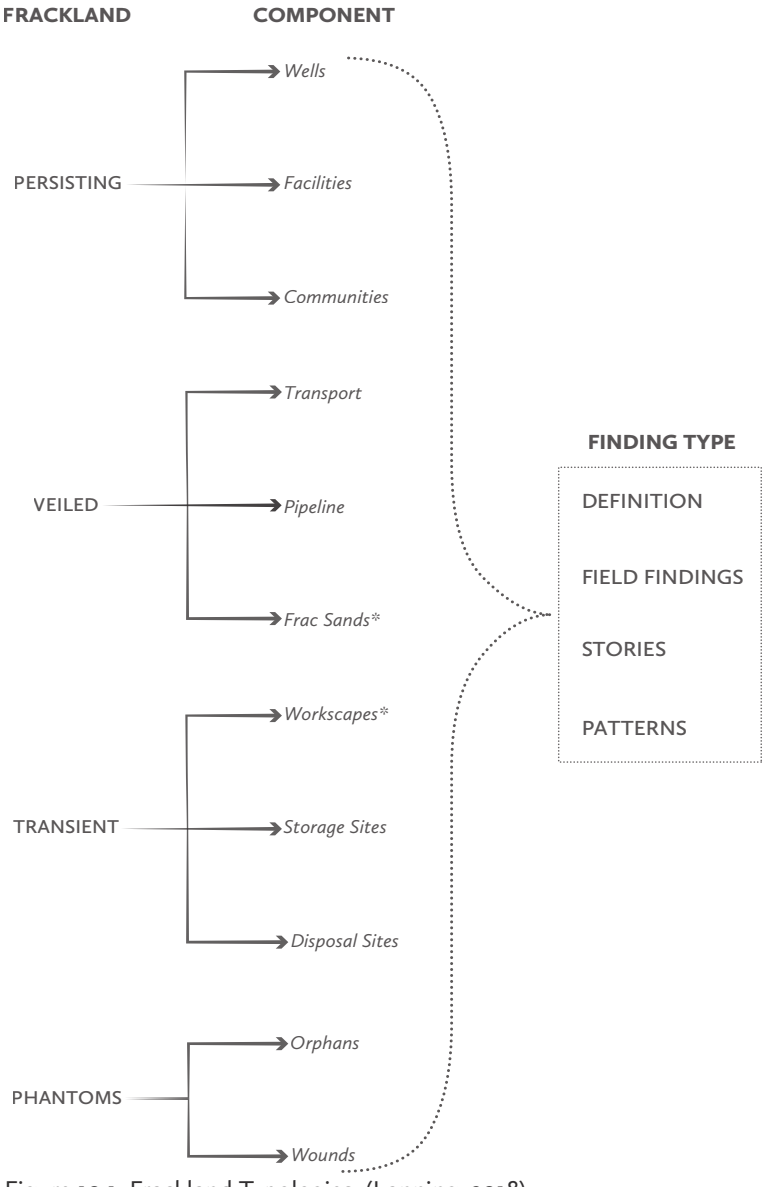


Figure 10.1. Frackland Typologies. (Lanning, 2018)

Persisting



Figure 10.2.. Tank batteries impose themselves on the landscape. An example of a components of persisting Frackland. (Lanning, 2017)

Transient



Figure 10.3. An empty staging area for oil and gas equipment, indicating a Frackland component in transience. (Lanning, 2017)

Veiled



Figure 10.4. Sign indicating the presence of a buried gas pipeline. An example of a component of a Veiled Frackland. (Lanning, 2017)

Phantoms



Figure 10.5. A fracking well indicated as out of service. A component of Phantom Fracklands. (Lanning, 2017)

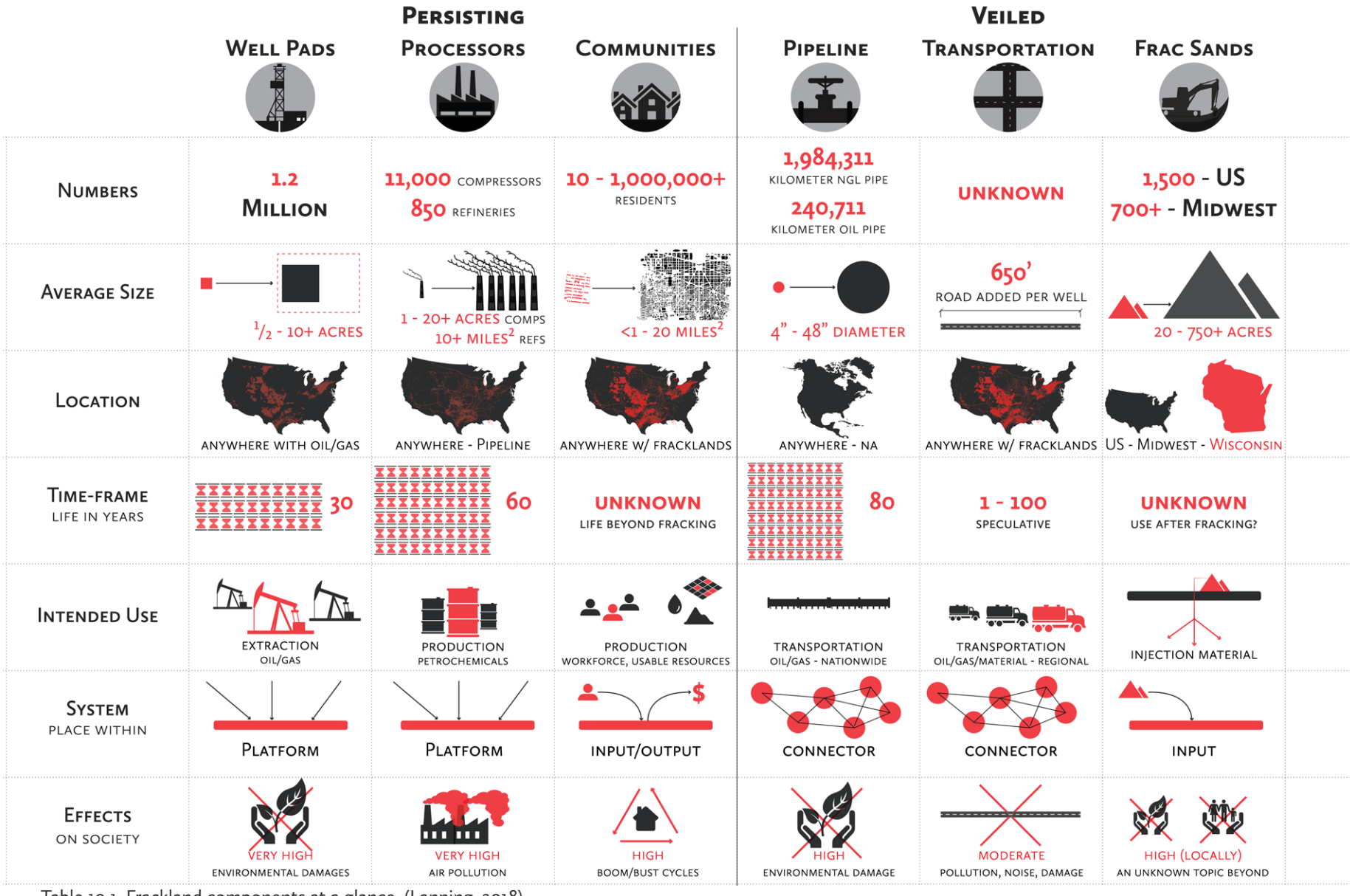
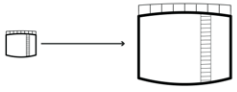
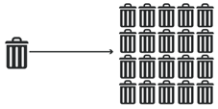
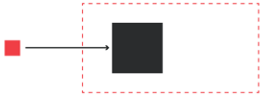
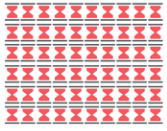


Table 10.1. Frackland components at a glance. (Lanning, 2018)

	Transient			Phantoms		
	Workscapes	Storage Sites	Disposal Sites	Orphans	Wounds	
						
	UNKNOWN	**UNKNOWN**	**UNKNOWN** WASTE PITS **38,169** INJECTION WELLS	**MILLIONS** CONVENTIONAL **THOUSANDS** UNCONV.	**1,189** WORK DEATHS IN 10 YEARS **10,000** SPILLS IN 10 YEARS	Numbers
	 <10 - >500 WORKERS	 1 - 50 ACRES	 1 - 20 ACRES	 1 - 20+ ACRES	 ANY	Average Size
	 VARIES BY REGION	 NEAR WELLS	 NEAR WELLS	 ANYWHERE WITH OIL/GAS	 ANYWHERE FRACKING INFLUENCES	Location
	 <1 - 5	 <10	 60	 UNTIL REMEDIATED	 UNTIL REMEDIATED	Time-frame LIFE IN YEARS
	 WORKFORCE HOUSING	 STORAGE FRACK MATERIAL/VEHICLES/EQUIPMENT	 WASTE DISPOSAL SOLID/LIQUID/HAZARDOUS	 NONE	 NONE	Intended Use
	 DEPENDENT ON WELLS	 PART OF WELLS/FACILITIES	 OUTPUT	 POTENTIAL FUTURE	 OUTPUT CONSEQUENCE	System PLACE WITHIN
	 LOW IMPACTS LOCAL SOCIAL SERVICES	 LOW UNDERUTILIZED LAND	 VERY HIGH WATER CONTAMINATION	 HIGH TAXES PAY THE COST TO CLEAN UP	 VERY HIGH DAMAGE TO PEOPLE AND ENVIRONMENT	Effects ON SOCIETY

10.1 THE PERSISTING

Persisting Fracklands are the most common Frackland type. These are the Fracklands that persevere before our eyes. Their components are the easiest to associate with the processes of hydraulic fracturing and the extraction and production of oil and gas. These Fracklands are made of the wells, facilities, and the communities that surround them. They are the primary means of function of hydraulic fracturing and the backbone to all operations. The pertinence of these Fracklands in the greater fabric of the landscape is clear and evident, and their intended use is most likely to persist for decades after their completion.



Figure 10.1.1. The Wattenberg gas field. Since the 1980's, this 2,000 square mile area which encompasses much of Weld County has been a site of widespread hydraulic fracturing operations. (Google Earth, 2016)





Figure 10.1.2. Vegetation creeps up on a Fort Worth well pad. (Lanning, 2017)



WELL PADS

COUNT

1.2
MILLION

SIZE



1/2 - 10+ ACRES

PLACE



ANYWHERE WITH OIL/GAS

LIFE



30

USE



EXTRACTION
OIL/GAS

SYSTEM



PLATFORM

IMPACT



VERY HIGH
ENVIRONMENTAL DAMAGES

Well pads are the principal components of Persisting Fracklands. With hundreds of thousands of active fracking wells spread across the country, they are the most commonly distributed and most numerous of all Frackland components. They are the platforms for almost every fracking operation and the systemic epicenter of the Fracklands. The highest amount of attention should be given to these facilities as all activity can be traced back to them. This is the point where oil and gas first reaches the surface, and where the last remaining bit will flow. Because of their nature, well pads are highly variable in form and their relationships with their surroundings is unique from place to place.

While wells have been principal to both conventional and unconventional extraction, large well pads were not common until fracking became the norm. Pads have reduced the sprawl of oil fields, concentrating facilities on larger parcels of land rather than individual micro-sites. Studies have found current pads to average around 5.7 acres (Walton and Woocay, 2013), however they can be more than three times that size during construction (Vandecasteele et al. 2015). In 2017 there were estimated to be more than 20,000 fracking wells completed during the year (EIA 2017b; US Department of Energy 2017; World Oil 2017).

Common well pad equipment:

- Control Station: Structure for monitoring the well, data collection, etc.
- Well head ("Christmas Tree"): Set of valves, fittings etc. that caps the top of a well and controls fluid flow.
- Scrubber: Air pollution control device to remove unwanted pollutants. Pollutants will need disposal.
- Well pump: Pump oil/gas to the surface if needed. Various types. The larger the pump the greater the production. Oil derricks are a common pump.
- Flare stack: Burns off excess gas if there is too much.
- Separator: Separates oil, gas, and/or water from the fluid coming to the surface.
- Vapor Recovery Unit – VRU: System to extract vapors that form in tanks. Get sent to a scrubber.
- Tank Battery: Large tanks that are used to store oil, gas, and sometimes water. Oil will be indicated in barrels BBL (42 gallons); gas as cubic feet.
- Spill Protection: Landforms or structure to contain spills.
- Well Compressor: Small engine to compress oil and gas to be sent off-site.



Figure 10.1.3. A small gas well near Greeley, Colorado with typical equipment. (Lanning, 2017)



Figure 10.1.4. Equipment on a well pad in Tarrant County (Lanning, 2017)

Reflections from the Field:

While they are the easiest of all components to distinguish, wells became the most unique and complex of Frackland components. No matter what was being examined in the field, wells were always in focus. They never left one's view or attention. All activity could be traced back to or from them. They were the center of all activity. If there were wells, there were near every other type of fracking related component somewhere in the vicinity. Every wellpad had its own unique story. Appearance were different from place to place. Each was fixed with its surroundings in ways both tame and profound. And each operated and connected to the greater system in its own manner.

Each and every well in operation is worked 24 hours a day, 365 days a year. From drilling of the well to plugging, wellpads are hubs of activity at all times. Activity does not stop, it never appeared to stop. During drilling and fracking hundreds of trucks were seen moving to and from a site day-in day-out. Delivering materials, carrying workers, taking material off site etc. It is an impressively dirty, dusty, and loud sight. Once this heavy activity subsides all becomes quiet. What's left has become a largely empty, flat piece of land, home to various scattered equipment. It will sit like this for the next few decades receiving the occasional truck or maintenance crew. Then it will be cleared and forgotten.



Figure 10.1.4. While small conventional wells such as this one dot hillsides in West Virginia, larger fracking wells flatten them. (Used with permission ©Blake Belanger, 2017)

In Weld nearly every farm had one or more well pads. In Tarrant well pads were becoming infill projects,. And in Appalachia well pads lay more hidden, scattered across hilltops and and nested within dense forest. In these regions well pads and their equipment, especially tank batteries, became the defining landmarks. Shaping these these places more and more. It was not possible to go anywhere without seeing these imposing objects and the land cleared for them and the wells they serve.

While conventional oil and gas development was largely left to rural landscapes, what was seen in the field is that fracking is encroaching upon people more and more. In Colorado, growth in communities such as Greeley had left wells adjacent to neighborhoods, even million-dollar homes. In Fort Worth in Tarrant County such a site was even more apparent. It was McMansion hell and fracking wells

Beyond places heavily occupied by people or owned privately were public lands. It was here that wells, and fracking become super sized. The Pawnee Grasslands of Weld County, Eagle Mountain Lake Reserve in Tarrant, and the State Forests in Pennsylvania were some of the public lands where wellpads have been springing up in number. And in turn their accessibility was seen as all but depreciating.

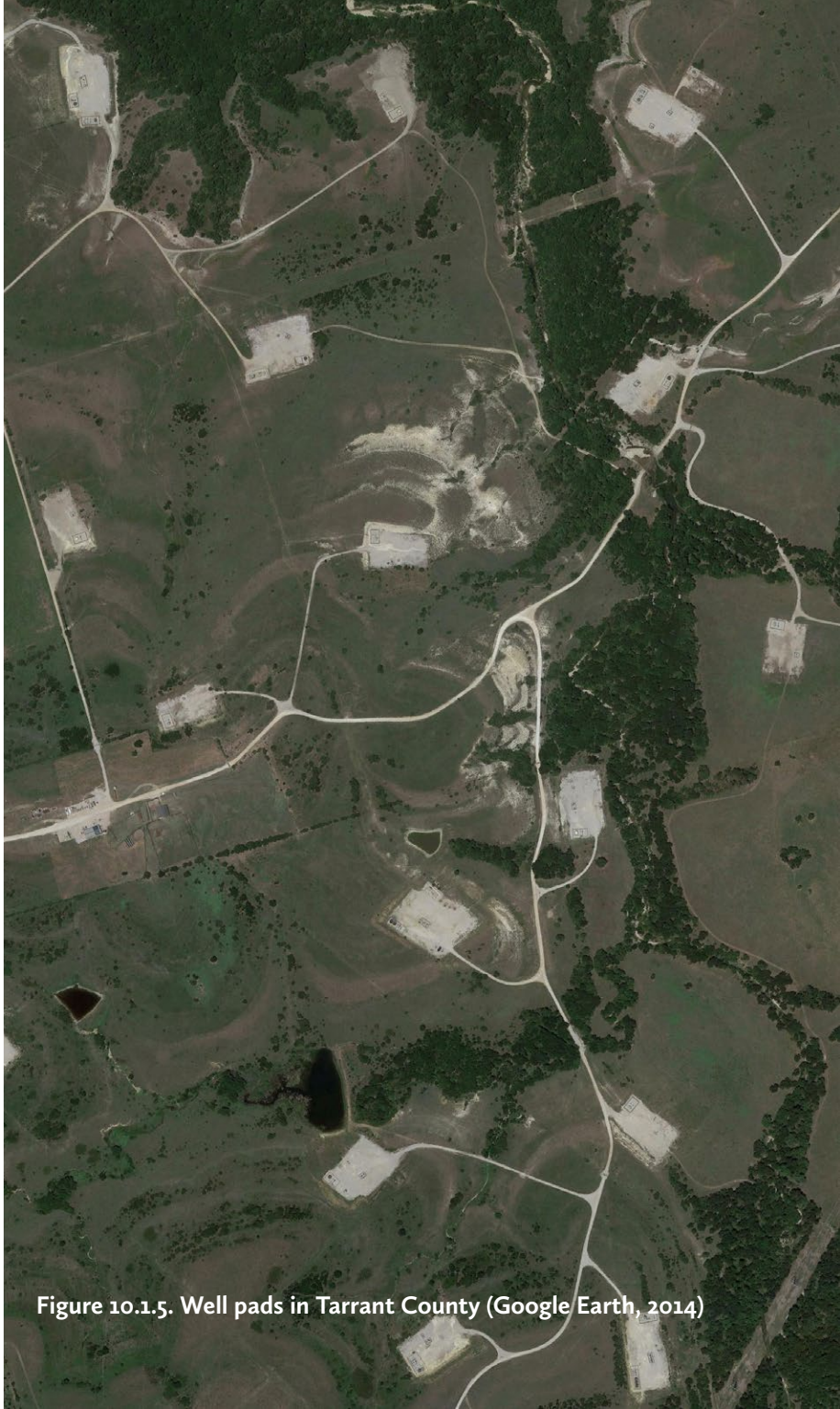


Figure 10.1.5. Well pads in Tarrant County (Google Earth, 2014)



Figure 10.1.6. A large oil pump near the Pawnee Buttes in Colorado. While wind turbine lined the tops of the bluffs, the oil and gas facilities lined the base. (Lanning, 2017)



Figure 10.1.7. A well pad flanks the view of a Junior Highschool. Sights like this showed the extent of fracking's interface with Tarrant Communites. (Lanning, 2017)



Figure 10.1.8. A drilling operation about to begin in a crop field in Weld County. In a few months this will be the place of a new well pad. Seeing small or large drilling operations is an everyday site in all three regions. (Lanning, 2017)

Story: Hydraulic Fracturing's Impact on Perception of Place (Sangaramoorthy et al. 2016):

While a large amount of research has been conducted into understanding fracking's impact on the physical health of people, infrastructure and the environment, there lacks insight into how it impacts peoples perceptions of their surroundings. Sangaramoorthy et al., 2016 held focus groups in rural West Virginia to understand such impacts.

Participants both newcomers and long-term residents of the area equally expressed a distress over the landscape transformation that fracking has created. Long term residents described how fracking has changed compared to conventional oil and gas development, how social tensions between them and drilling companies has risen, and how they feel trapped financially.



Figure 10.1.9. Land being cleared for a future well site in Morgantown, West Virginia. (Used with permission ©Blake Belanger 2017)

“”I just love the area and I’m distressed. I’m grieving, grieving the loss of [my] environment… pipe yard within 100 yards of my home that has since been converted to have a heavy equipment yard.’” (31)

“’It was a little pad. I’ve got two of them on my property… it, doesn’t bother a thing… Now these leases are being used to devastate and destroy our property while the gas companies get all the benefits.’” (32)

“’It takes a quarter million to drill a well [today]; your little mom-and-pop drilling companies can’t afford it. They had a vested interest in the community… They couldn’t compete with the Exon’s, the AEP’s…’” (32)

“’They need to compensate people for the value of the property… I invested everything we had… now I’m just trying to get my money out of it… No one will touch it!’” (32)



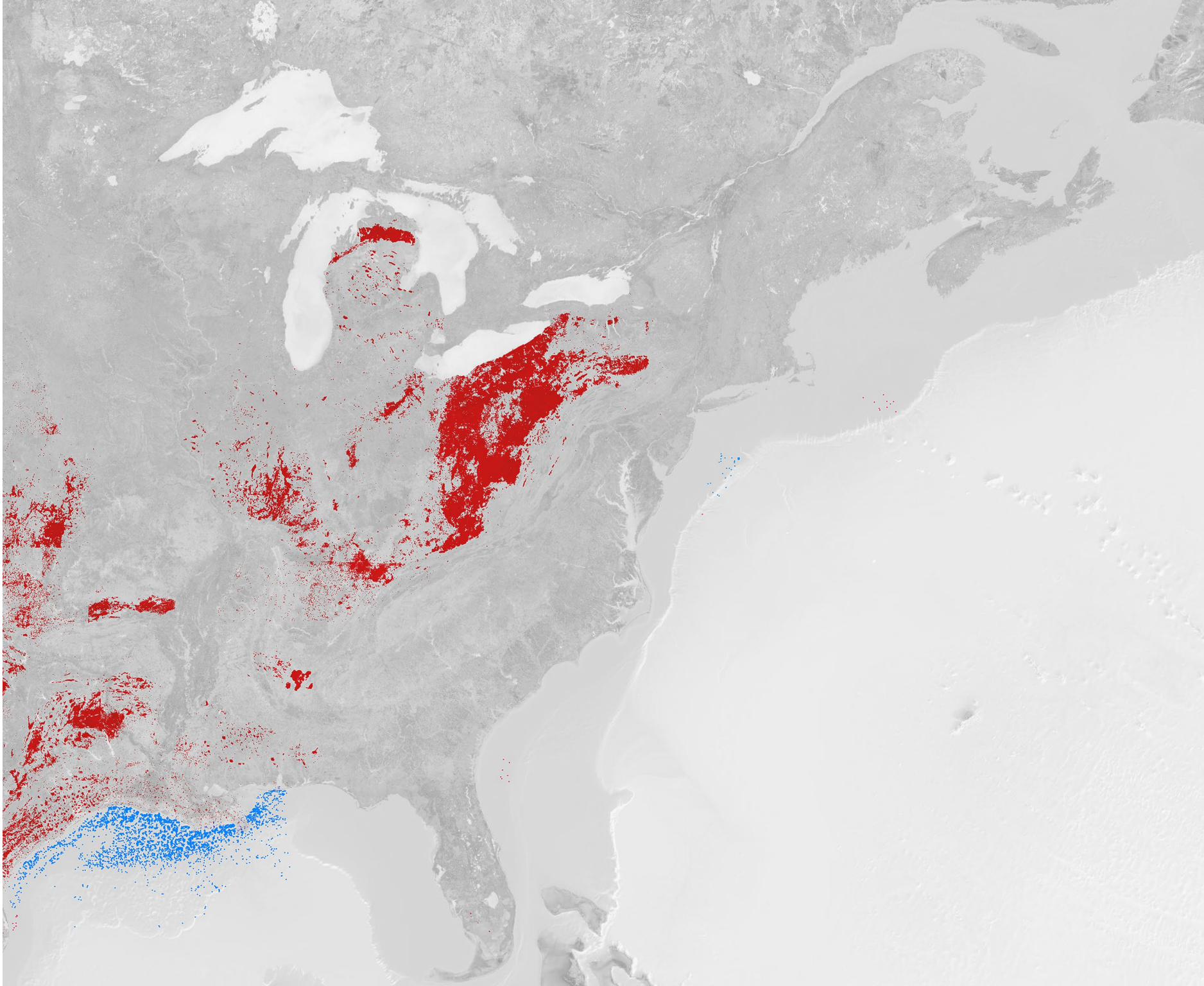
Figure 10.1.10. Signs like this in Weld County are common; put up by residents in frack-prone areas to keep well traffic off their property. (Lanning, 2017)

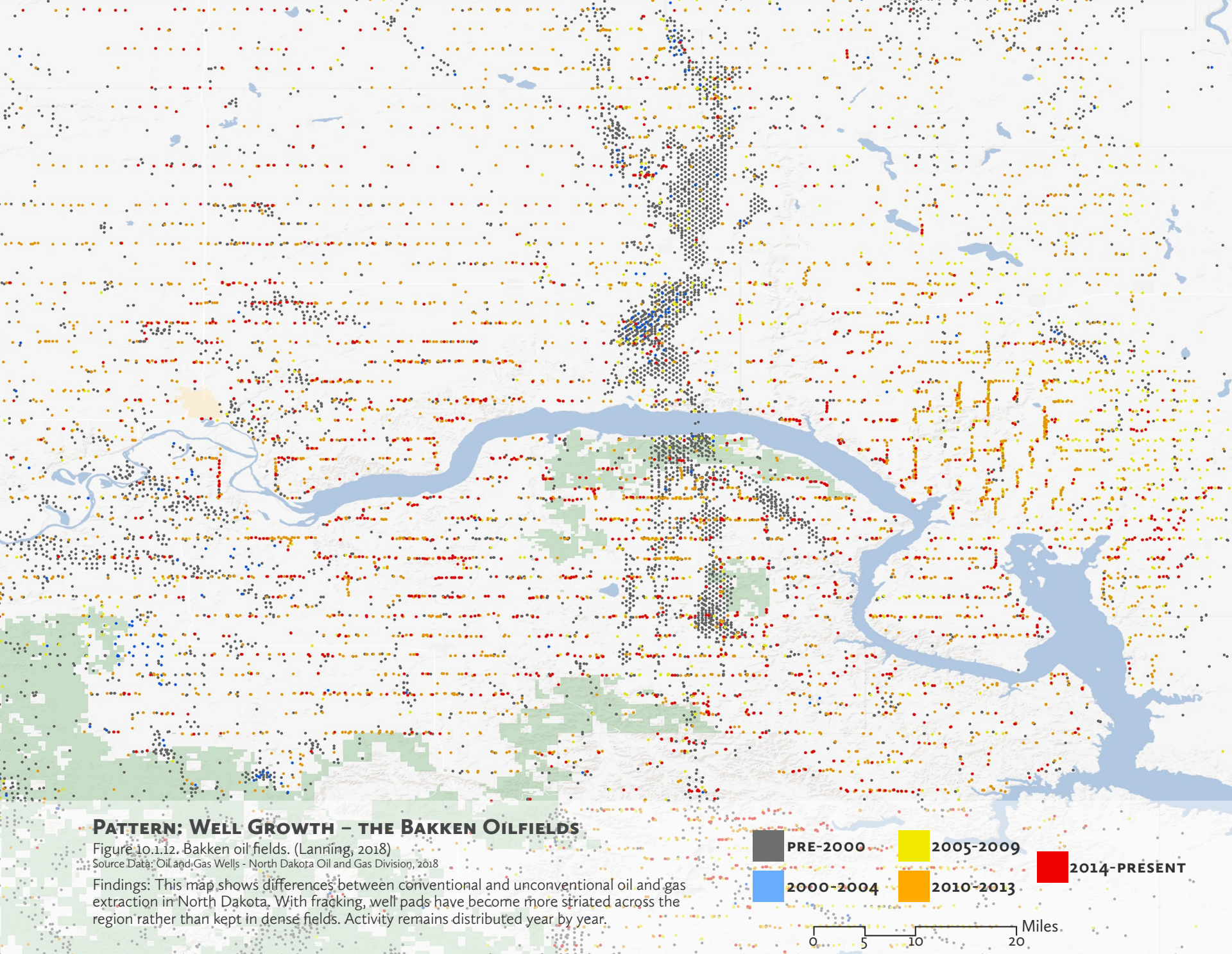


Pattern: Active U.S. Wells – 1.2 Million Total

Figure 10.1.11. U.S. Active Wells (Lanning, 2018)
Source Data: Oil and Gas Wells - Data.gov, 2017; Offshore Wells - Bureau of Ocean Energy Management, 2018

Findings: This map shows active conventional and unconventional wells in the U.S. Due to lack in information, differentiating between wells that are and arent fracked could not be made, however estimates predict ~70% or 700,000 may have been fracked (EIA, 2017).

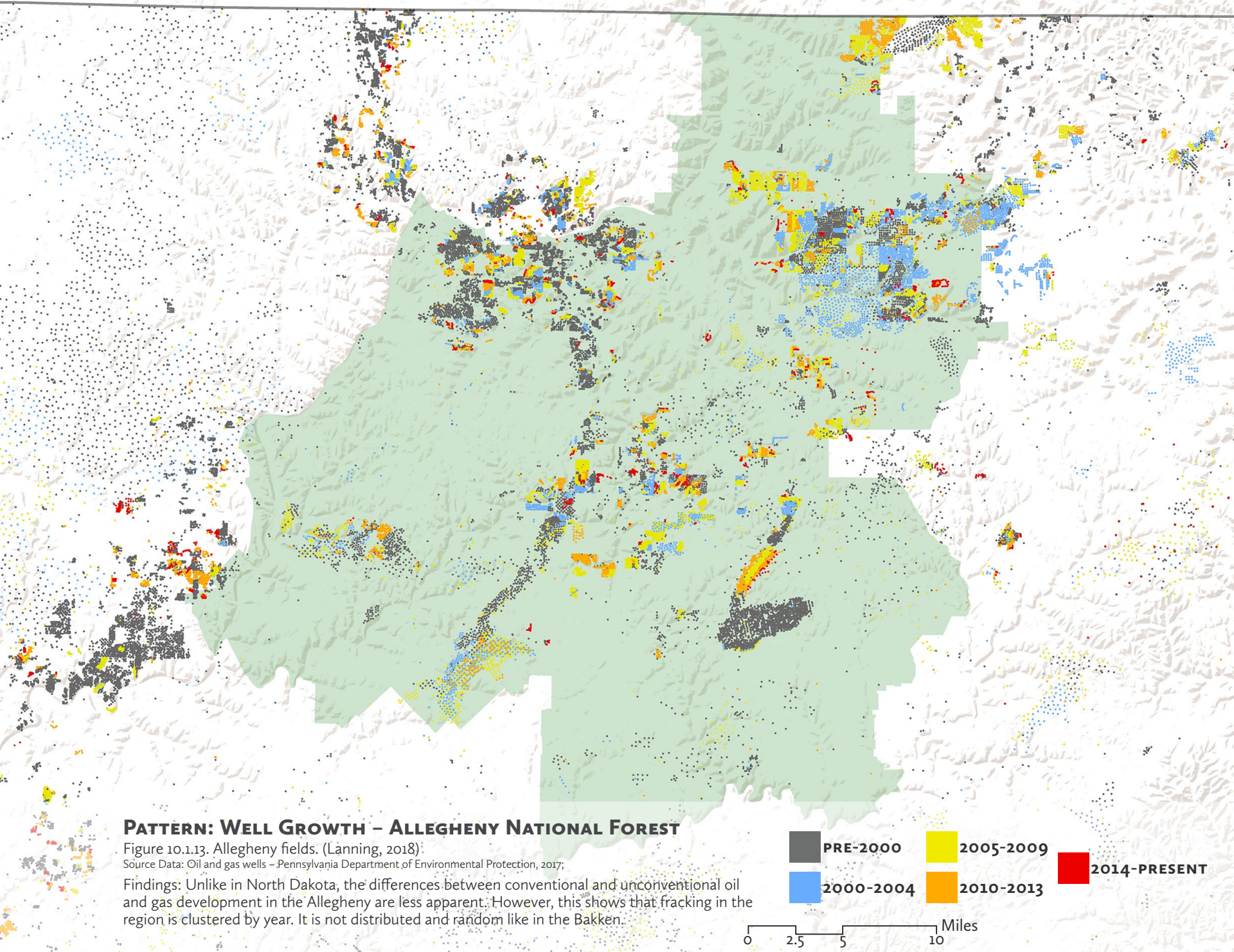




Pattern: Well Growth – the Bakken Oilfields

Figure 10.1.12. Bakken oil fields. (Lanning, 2018)
Source Data: Oil and Gas Wells - North Dakota Oil and Gas Division, 2018

Findings: This map shows differences between conventional and unconventional oil and gas extraction in North Dakota. With fracking, well pads have become more striated across the region rather than kept in dense fields. Activity remains distributed year by year.

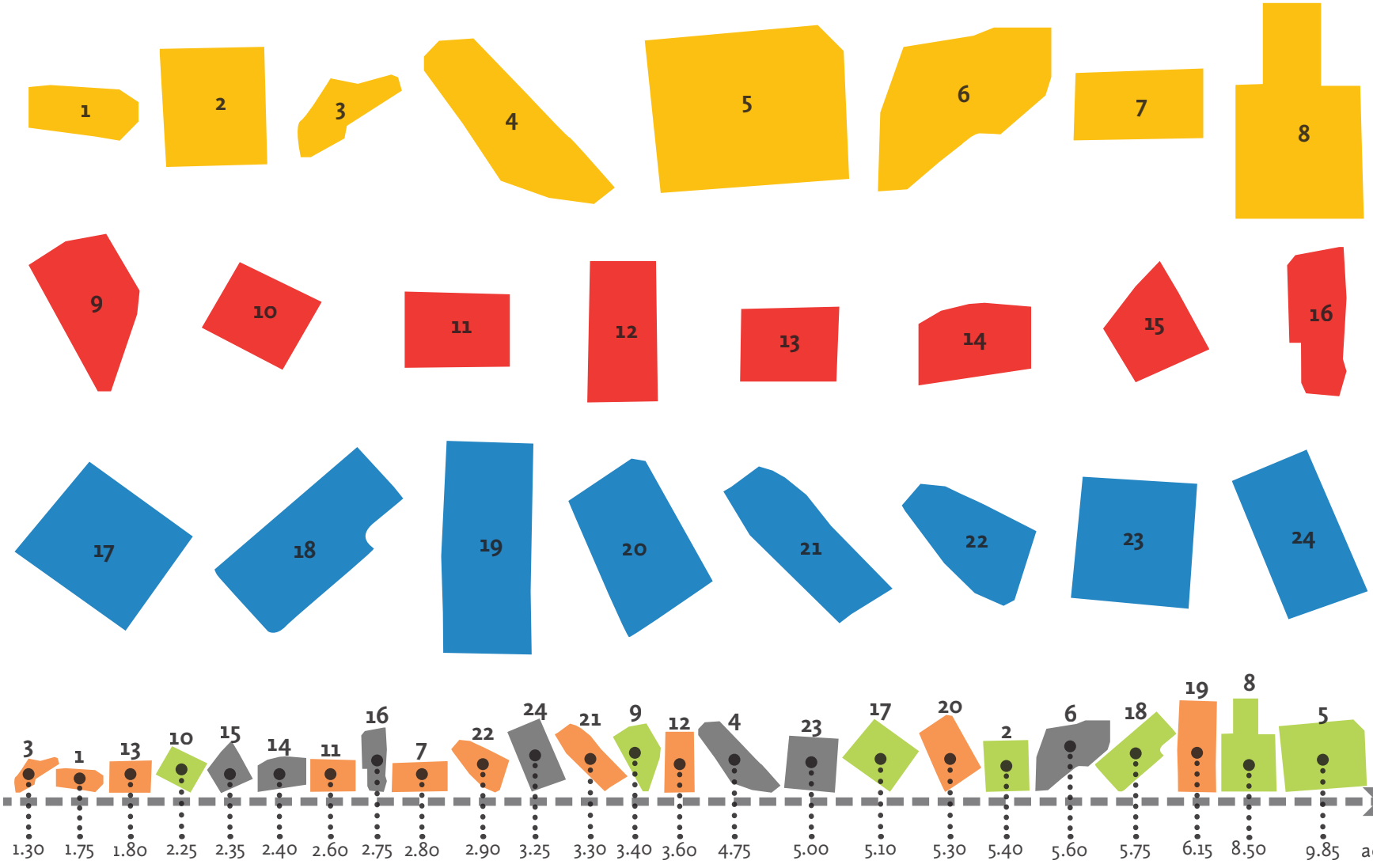


Pattern: Well Growth – Allegheny National Forest

Figure 10.1.13. Allegheny fields. (Lanning, 2018)

Source Data: Oil and gas wells – Pennsylvania Department of Environmental Protection, 2017;

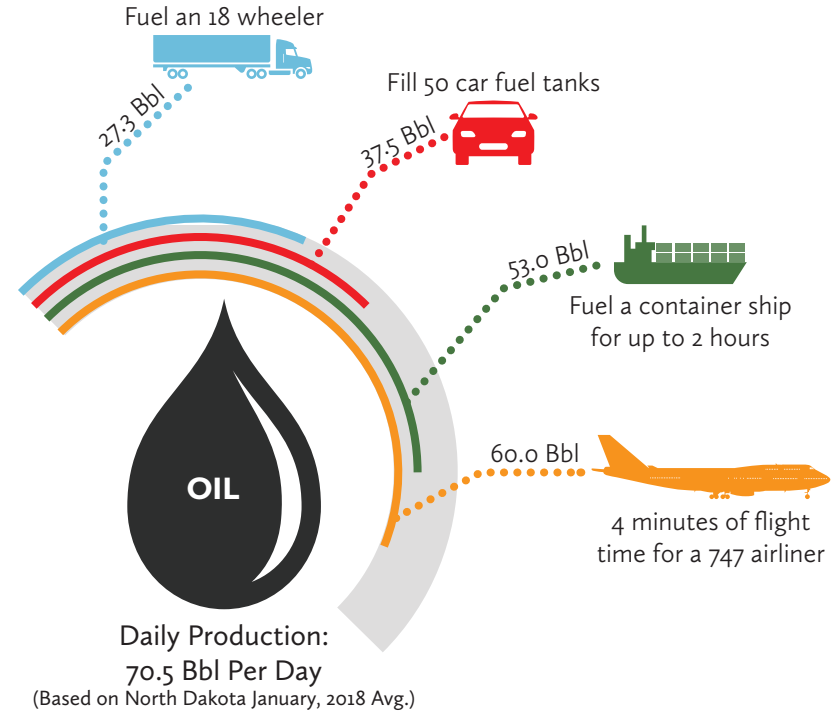
Findings: Unlike in North Dakota, the differences between conventional and unconventional oil and gas development in the Allegheny are less apparent. However, this shows that fracking in the region is clustered by year. It is not distributed and random like in the Bakken.

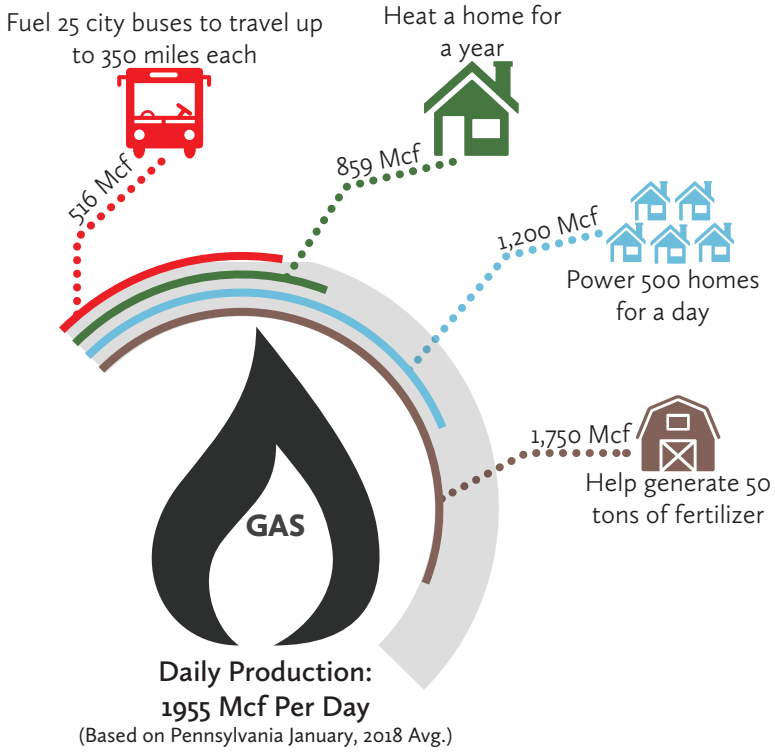


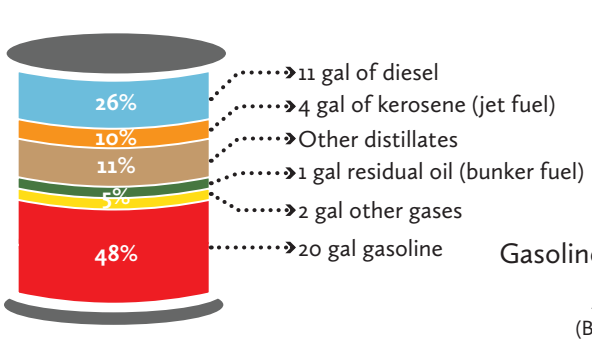
Pattern: Comparing Well Pad Sizes (in acres) and Context

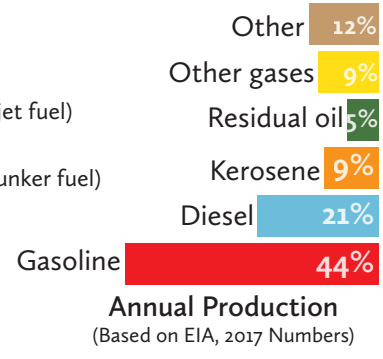
Figure 10.1.14. Well sizes. (Lanning, 2018)

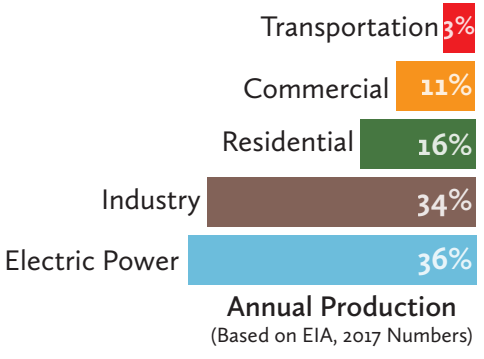
Findings: While 24 individual well pads cannot summarize hundreds of thousands, this exploration shows how variable well pads can be by region and context. These findings are similar to what was seen in the field, e.g. public lands had the largest well pads, farmlands the smallest.











Pattern: Production and Consumption. What Does the Typical Well Give You?

Figure 10.1.15. Well production. (Lanning, 2018)

Source Data: Oil and Gas Use, Energy Explained – EIA, 2018; Well Production Data – ND Department of Natural Resources; Well Production Data – PA Department of Environmental Protection

Findings: Just one oil or gas producing well can create considerable amounts of fuel needed to fuel modern society. If just one well can do all the above, think of what hundreds of thousands can do.



Highest Producing Well:

- Location: Mountrail County, ND
- Size: 378,780 SF – 8.70 Acres
- Date Completed: 2017
- Oil/Gas Produced January, 2018:
  46,587 Barrels – 1,503 Barrels a day
  26,153 Mcf – 844 Mcf a day
  46,921 Runs (Trips to Collect Product)

Figure 12.1.16. Image of the highlighted well being drilled. Notice the flaring at the NW corner. Production is so high 647Mcf of gas had to be burned off in January, 2018. (Google Earth, 2017)



Lowest Producing Well:

- Location: McKenzie County, ND
- Size: 263,100 SF – 6.00 Acres
- Date Completed: 2015
- Oil Produced January, 2018:
  1 Barrel of Oil, No Gas
  38 Runs

- 2,300 wells (15%) produced no oil in January out of the 15,290 total wells recorded in the dataset.

Figure 12.1.17. Image of the highlighted well in its completed state. (Google Earth, 2017)

Pattern: Comparing Production Sites - Oil in North Dakota

Source Data: Well Production Data – North Dakota Department of Natural Resources;

Findings: Both wells have little differences. Appearances may not be a telling sign of how much a well is producing and how active the site is. Surprising is the number not producing at all.



Highest Producing Well:

- Location: Washington County, PA
- Size: 141,750 SF – 3.25 Acres
- Date Completed: 2017
- Gas Produced January, 2018: 1,409,844 Mcf – 12,218 Mcf a day

Figure 12.1.18. Image of the highlighted well almost completed. (Google Earth, 2016)



Lowest Producing Well:

- Location: Washington County, PA
- Size: 200,500 SF – 4.60 Acres
- Date Completed: 2012
- Gas Produced January, 2018: 10 Mcf – <1 Mcf a day
- 2,140 wells (21%) produced no gas in January out of the 10,270 total wells recorded in the data.

Figure 12.1.19. Image of the highlighted well in its completed state. (Google Earth, 2016)

Pattern: Comparing Production - Natural Gas in Pennsylvania

Source Data: Well Production Data – PA Department of Environmental Protection

Findings: Like in North Dakota, appearances do little in indicating whether a well is producing or not. Only review of data (if it is publicly available) or extensive field observation can come to such conclusions.



Figure 10.1.20. Compressor stations in Pennsylvania. (Google Earth, 2017)



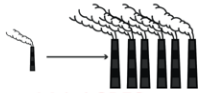
PROCESSING FACILITIES

COUNT

11,000 COMPRESSORS

850 REFINERIES

SIZE



1 - 20+ ACRES COMPS

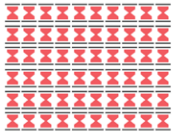
10+ MILES^2 REFS

PLACE



ANYWHERE - PIPELINE

LIFE



60

USE



PRODUCTION

PETROCHEMICALS

SYSTEM



PLATFORM

IMPACT



VERY HIGH

AIR POLLUTION

Processing facilities are the next step for oil and gas once extracted. The most common facilities are compressor stations and processors; estimated to number around 12,000 total across the country (Rubright 2017). Compressor stations are where natural gas is pressurized to be transported through pipeline. While smaller compressors can be found on well pads, these larger facilities utilize large turbine engines to route natural gas across the country. Compressors can be found anywhere along a gas pipeline as it needs to be routinely compressed in its travels.

Processing facilities are the facilities that process or refine oil and gas to be marketed or used in various applications. Oil is predominately refined into petroleum products and gas liquefied. Oil is processed at refineries into gasoline, diesel, kerosene etc. Gas is processed at fractionators into ethane, propane, butane, etc. There may be a series of these facilities that oil and gas goes through, often far from where it originated before then being sent off for use. Road, rail, and pipeline corridor connections are vital to these facilities during and after processing. (EIA 2017a).

Aside from these primary facilities are less common facilities that process waste from fracking. Wastewater processing facilities try to recover water from fracking wastewater to be reused and are not to be confused with disposal facilities (page 223). They are similar in size in to compressor stations and feature large numbers of waste holding tanks. At first glance some may look like a well pad with large tank batteries. However, these facilities will also have buildings, and equipment for handling the waste.

Processors: Nodes and Ends

However oil and gas may travel once leaving a well pad – pipeline, road, rail – a processing facility will be its destination. These facilities act as both nodes and the terminus of this journey. As nodes, a compressor station or stage 1 processing facility; rerouting or redistributing to the next location. As end points, a refinery or fractionator; where oil and gas becomes usable to society. And as the distance within this network of nodes and ends grows, these facilities become larger and larger.

An example of this phenomenon was seen when tracing the flow of natural gas in Weld County. Here, gas will be deposited via truck at an approximately 30 acre compressor station. That gas will join with other gas coming in via pipeline from Wyoming and North Dakota to the North. Together it will routed to a 750-acre fractionator in Bushton, Kansas. Here, some of this gas will be processed and distributed across the Midwest to be used. The remainder will flow onward, joining gas extracted from across the county at Mont Belvieu near Houston, Texas, a 7,500 acre fractionator. From here it will be distributed globally.



Figure 10.1.21. Natural gas compressor station in Tarrant County. (Lanning, 2017)



Figure 10.1.22. Mont Belvieu NGL plant near Houston, TX. America's largest natural gas liquefaction plant. Near double the size of downtown Houston, this facility has devoured what was once the town of Mont Belvieu. (Google Earth, 2017)

Reflections from the Field:

Processors are the most striking of all the components of the Fracklands. Not only was it for their shear size, but the mass amounts of activity that was seen happening in and around them. While compressors played host to high activity, it was processing facilities that overshadowed the compressors. Their presence boldly claims them as the flagships of the oil and gas industry. The massive tanks and machinery of these sites could be seen far off on the horizon. While at night the lights of refineries looked like the lights of a small town. Countless trucks swarmed the roads nearby these sites, like a central hive. A city of oil and gas.

Where compressors stand out among others is their appearance. Often looking like a warehouse with stalls for tanker trucks, it was their large roaring turbine engines that made them apparent. And in Fort Worth some compressors were even found directly adjacent to populated areas. Both in Texas and Colorado compressor stations and processing facilities seemed to follow no real patterns. They were found in both rural and populated areas, spread out over large plots of land, or condensed in small areas.



Figure 10.1.23. Oil and Gas processing facility in Weld County. Shown are massive storage tanks for holding either oil or liquefied natural gas. (Lanning, 2017)



Story: Local Attitudes towards the Oil and Gas Industry in North Dakota (McGranahan et al. 2017)

Oil and Gas companies that oversee Hydraulic Fracturing interact with communities and community members regularly. A majority of oil and gas development happens on leased land. Land owners, will lease their land and mineral rights out to oil and gas companies. Understanding the dialogue that happens with these interactions between land owners and oil and gas companies is little documented. When it is documented, feelings range from trust to scorn.

McGranahan et al. 2017 conducted both focus groups and surveys in the Bakken oil field region of North Dakota to understand concerns of residents. While most respondents were found to be open to energy development and the economic yields it carries, many shared common concerns. Respondents were primarily upset over the changes to the community and effects heavy fracking activity had on their land and day to day lives (McGranahan et al. 2017).



Figure 10.1.24. Wastewater processing facility in Weld County. (Lanning, 2017)

"respondents agreed to some extent that money alone does not mitigate the additional time and effort required to address these disruptions [created by fracking]." (2002)

"respondents generally agreed that the energy industry approached locals aggressively, with little apparent respect for local traditions and ways of business, and with standard, off-the-shelf contracts landowners were expected to agree to.." (2003)

"responses were dominated by concerns over the safety of roads given high traffic volume and perceived recklessness of drivers in the energy industry." (2004)

"respondents repeatedly described a lack of respect for the integrity of land resources and a lack of awareness for how locals rely on these resources for their livelihoods." (2006)

"respondents cited an increase in criminal activity... on account of increased population and a greater degree of transience related to the demographics of the energy industry." (2006)

"respondents expressed general concern that oil workers expected support from social services... without "paying in" to these institutions through regular attendance, donation, or volunteering." (2006)

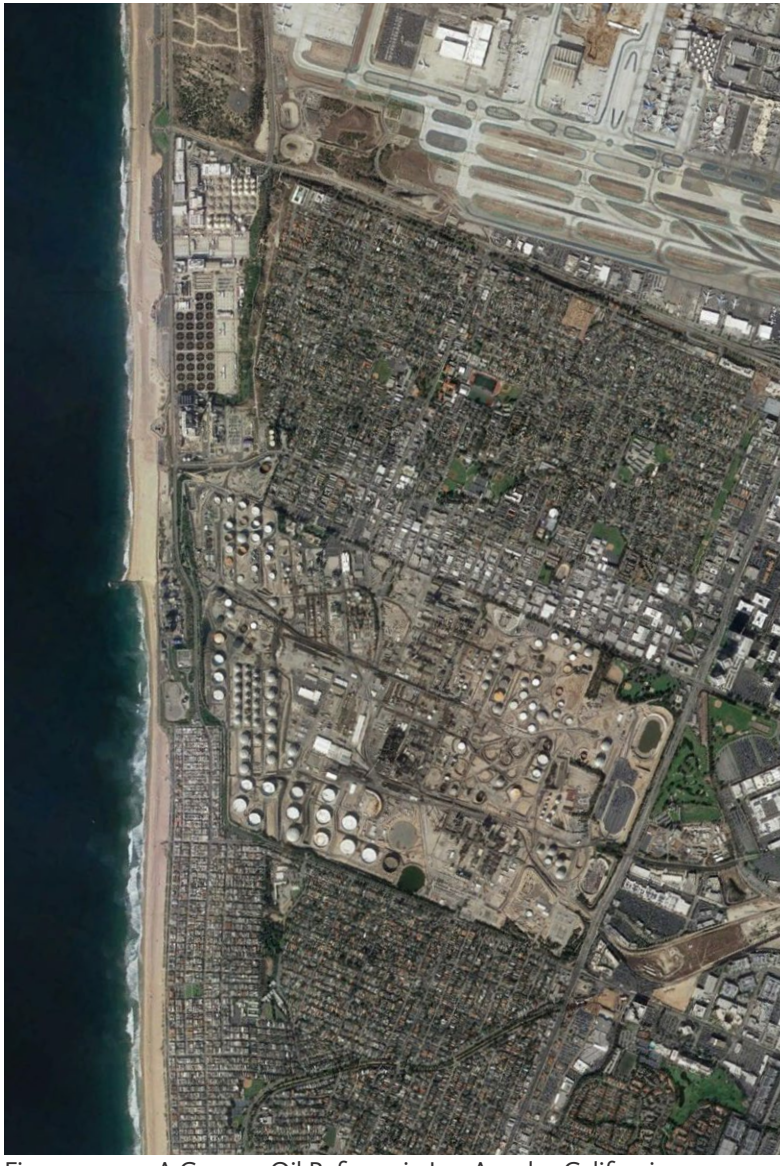
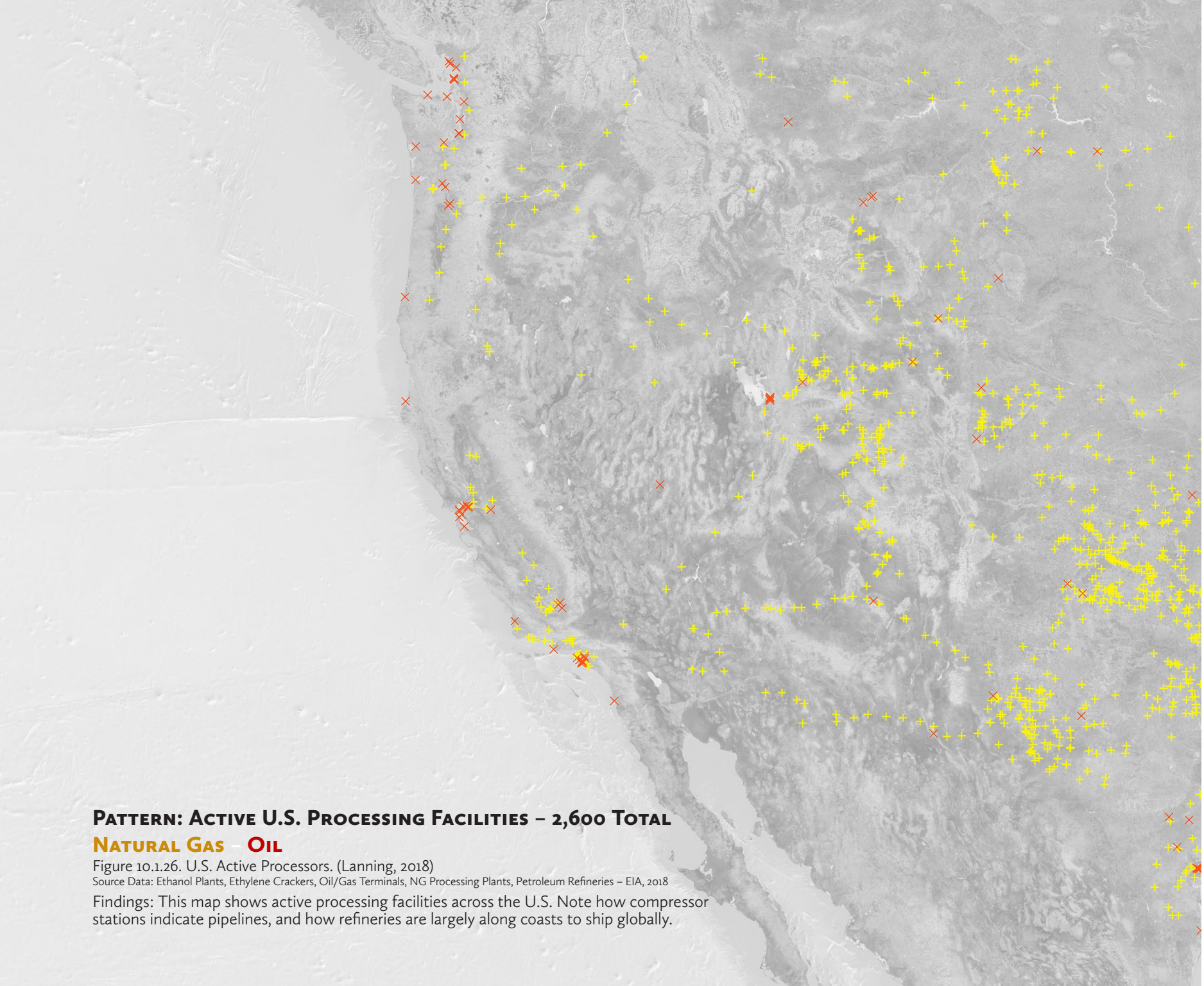


Figure 10.1.25. A Conoco Oil Refinery in Los Angeles California. (Google Earth, 2017)

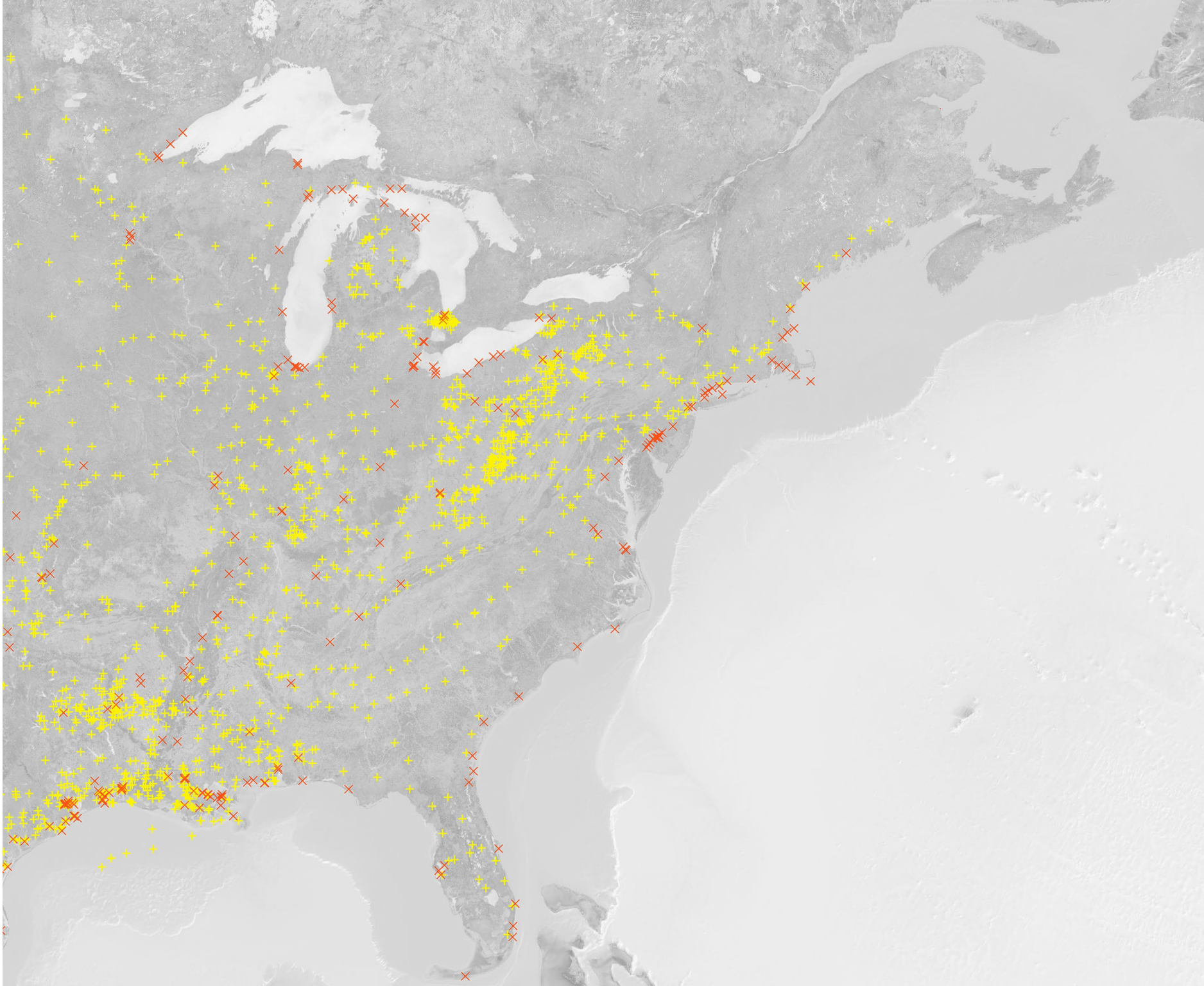


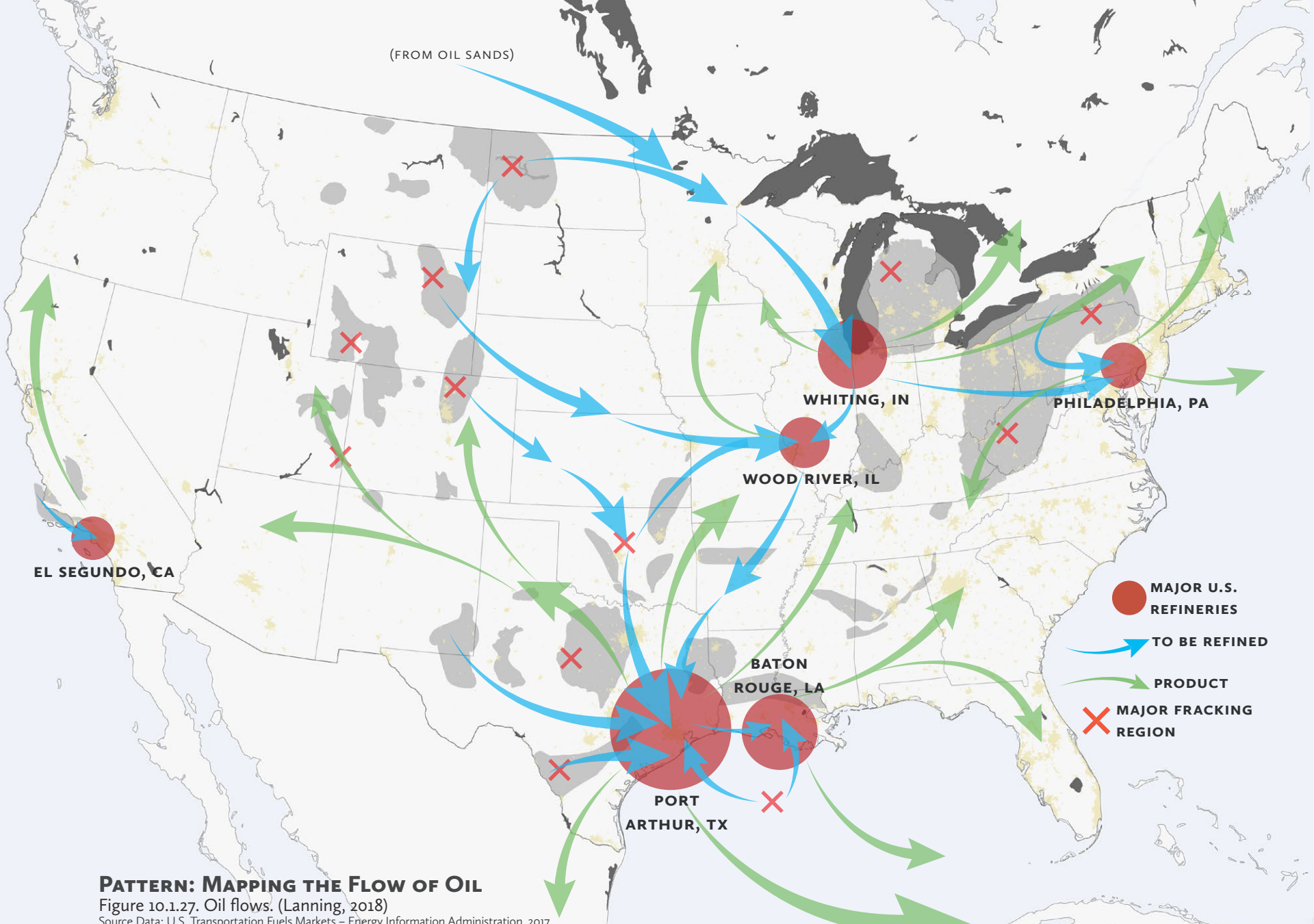
Pattern: Active U.S. Processing Facilities – 2,600 Total

Natural Gas – Oil

Figure 10.1.26. U.S. Active Processors. (Lanning, 2018)
Source Data: Ethanol Plants, Ethylene Crackers, Oil/Gas Terminals, NG Processing Plants, Petroleum Refineries – EIA, 2018

Findings: This map shows active processing facilities across the U.S. Note how compressor stations indicate pipelines, and how refineries are largely along coasts to ship globally.



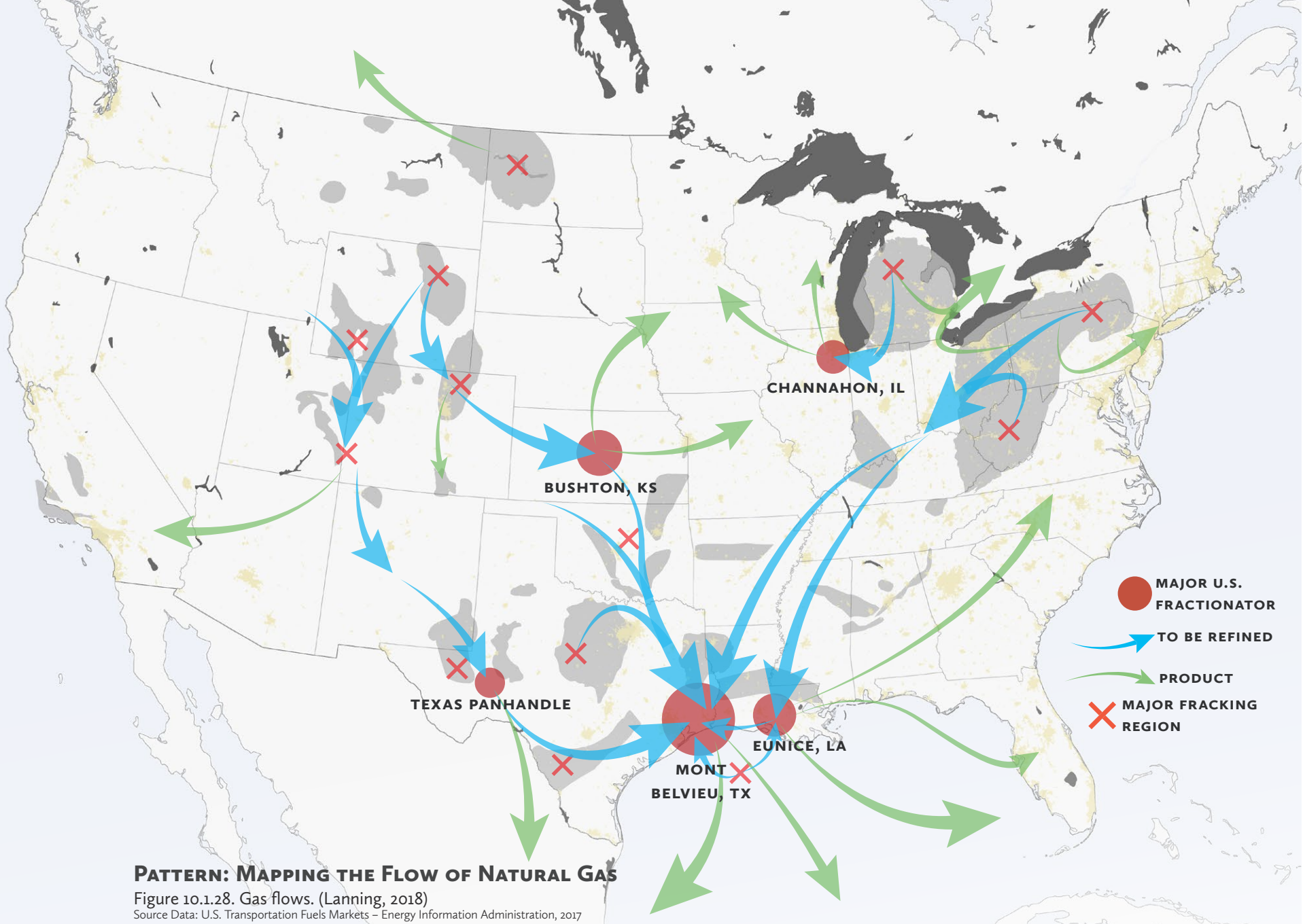


Pattern: Mapping the Flow of Oil

Figure 10.1.27. Oil flows. (Lanning, 2018)

Source Data: U.S. Transportation Fuels Markets – Energy Information Administration, 2017

Findings: While smaller refineries exist in most major U.S. cities this map shows how significant coastal and border refineries are and how they control the flow of oil across the country. Foreign oil which is not shown is another contributing factor to the location of these facilities.



Pattern: Mapping the Flow of Natural Gas

Figure 10.1.28. Gas flows. (Lanning, 2018)
Source Data: U.S. Transportation Fuels Markets – Energy Information Administration, 2017

Findings: Unlike refineries, fractionators are less common in U.S. cities and are more located in areas where gas distribution across the U.S. can be more strategic. However, as with oil the Gulf still remains the primary hub for gas to flow to.



Figure 10.1.29. Well pad within a Tarrant County suburban neighborhood. (Lanning, 2017)

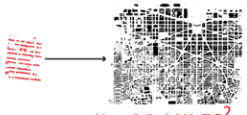


COMMUNITIES

COUNT

10 - 1,000,000+
RESIDENTS

SIZE



<1 - 20 MILES^2

PLACE

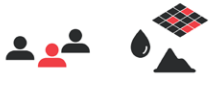


ANYWHERE W/ FRACKLANDS

LIFE

UNKNOWN
LIFE BEYOND FRACKING

USE



PRODUCTION
WORKFORCE, USABLE RESOURCES

SYSTEM



INPUT/OUTPUT

IMPACT



HIGH
BOOM/BUST CYCLES

Rural or urban, hydraulic fracturing weaves within the fabric of communities. Communities may exist before fracking began or develop along with it. These may places beyond wellpads, facilities, and all other oil and gas infrastructure but still feel their effects. Most often they are the proprietors, instigators, and/or the victims of hydraulic fracturing. These communities can be symbiotic with oil and gas development, supporting the processes of fracking while receiving something in return. Jobs, resources, land, and infrastructure are provided by communities, which in turn secure economic stimulus. This symbiosis is greatest in communities that derive their economies entirely on fracking. However this subjects them to the boom-bust cycles. If fracking falls these communities will fall with it (Brown and Schafft 2011).

While symbioses is an identifier for some of these communities, parasitism may define others. Fracking follows oil and gas, not people. Yet, oil and gas often exists within established communities. Thus the interface between populated areas and fracking – places where fracking more often than not is not instigated by its residents – is becoming commonplace. Here, land is treated as sacrificial. Sacrifice for the generation of energy. Residents and their concerns often appear unnoticed. Common occurrences have been depreciation of infrastructure and amenities, loss of communal identity, and the deterioration of relationships between residents. All of these effects have been documented to varying degrees across the nation (Gullion 2015; Jerolmack and Berman 2016; McGranahan et al. 2017).

Reflections from the Field:

Each community that was studied varies greatly from the other, as each community regardless of fracking development exhibited individualism. While understanding of hydraulic fracturing's impact on many rural agrarian communities in Weld county or Appalachia was easier to grasp, gaging impact in complex urban areas such as Greeley in Weld County, or Fort Worth in Tarrant county was difficult.

In rural communities impacts of fracking was clearer. Residents appeared to want a slice of money from oil and gas companies based on their willingness to lease lands for facilities or wells. In populated communities however, (while the interface of hydraulic fracturing may be visually evident) it was hard to grasp how the community has let this happen. Unlike the rural agrarian communities, many of these households were built prior, or alongside with hydraulic fracturing. Fracking was not at their discretion, they did not lease the land for the activity, yet they must live with all the affects that come with fracking.

Questions over how the residents in these communities feel about being a part of the Fracklands still linger. Especially for those in Colorado and Texas.



Figure 10.1.30. Newly constructed neighborhood in Windsor Colorado with nearby fracking wells. (Lanning, 2018)



Story: Spillover effects - Fracking's impact on communal structure (Jerolmack and Berman 2016)

Fracking has swept up many communities and has rapidly changed the life of residents. It may very well be breaking down the bonds that communities rely on, more so in rural communities. This is shown through interviews and photographic investigation in Northeast Pennsylvania by researchers Jerolmack and Berman. Their study reveals that the deeper cause of this social schism may in fact be from residents themselves, who see fracking leases as a means to a better life. Their study is a window into understanding why fracking has become so rampant in rural communities.

Their investigation showed that unlike past history with coal mining, fracking allows for individual dependence and personal approval. It does not require the input of the larger community, and is at the discretion of individual landowners And beyond these individuals are individuals within non-fracking communities. While fracking may not be a part of these individuals' lives, it may become so at a point in time, in the places they visit – publicly accessible lands. (Jerolmack and Berman 2016)



Figure 10.1.31. These Gas well heads occupy the greenspaces of this newly constructed 'ranch' community in rural Weld County. The tank batteries and other equipment they feed into sit nearby out of frame. (Lanning, 2017)

"fracking has initiated a "tragedy of the commons" in historically communal locales: lessors keep all the money earned for themselves, while any negative impacts (e.g., traffic or water contamination) are shared, which incentivizes everyone to lease" (195)

"the traffic, the smells, noise, and light pollution from fracking do not stop at the property lines of those who hold or profit from gas leases. Everyone experiences a diminished capacity to access peace and quiet, unbroken vistas, dark skies, unhurried country roads, and the sounds of nature." (203)

"There were no public town hall debates or referenda about whether "the community" should allow drilling… it is in the aggregate that personal land-use decisions can produce consequences that have an impact on almost everyone — even if they do not host natural gas infrastructure on their property or receive lease bonuses or royalties." (195)

"[What] lessors seemingly failed to realize was the extent to which the "guests" they invited onto their premises have the run of the place… in effect, lessors became tenants on their own property" (207)

"one's right to do what one will with one's property increasingly infringes on others' ability to enjoy their own property or common pool resources, and norms of neighborliness give way to legal doctrine." (205)

"the spillover effects brought about such global changes to their experience of place and community that it introduced a different way of life — one that they wanted no part of." (204)

"Because state and federal governments have leased public land for drilling, fracking entails our collective alienation from large portions of the literal commons as well." (195)

"[fracking on public lands] if replicated nationally, it could result in significant environmental degradation and enclosure of portions of America's most ecologically significant commons… even those of us not residing amid fracking operations may absorb the spillover effects from the government's decision to lease and develop (ostensibly) public land." (211)

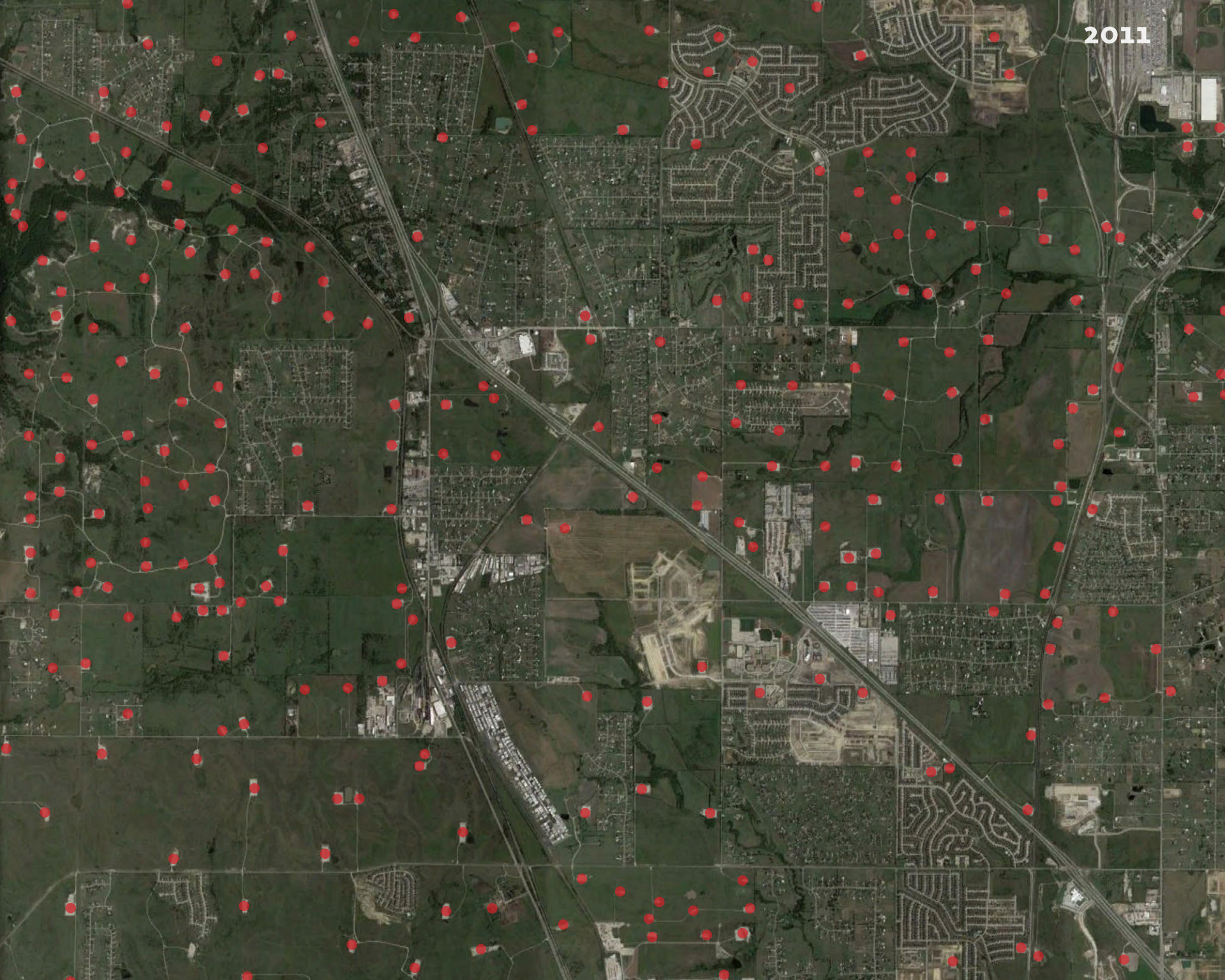


Pattern: Growth of Fort Worth suburbs and oil/gas fields

Figure 10.1.32. Changes in Tarrant County (Lanning, 2018)

Source Data: Base Imagery – Google Earth, 2001, 2017

Findings: These images show the changes that the northwestern part of Tarrant county has undergone in the last two decades. What was once rural farmland with a dozen or so wells is now sprawling suburbs and oilfields. Shown in this image are 286 wellpads. The same effects can be seen in the southern portion of the county.


2011



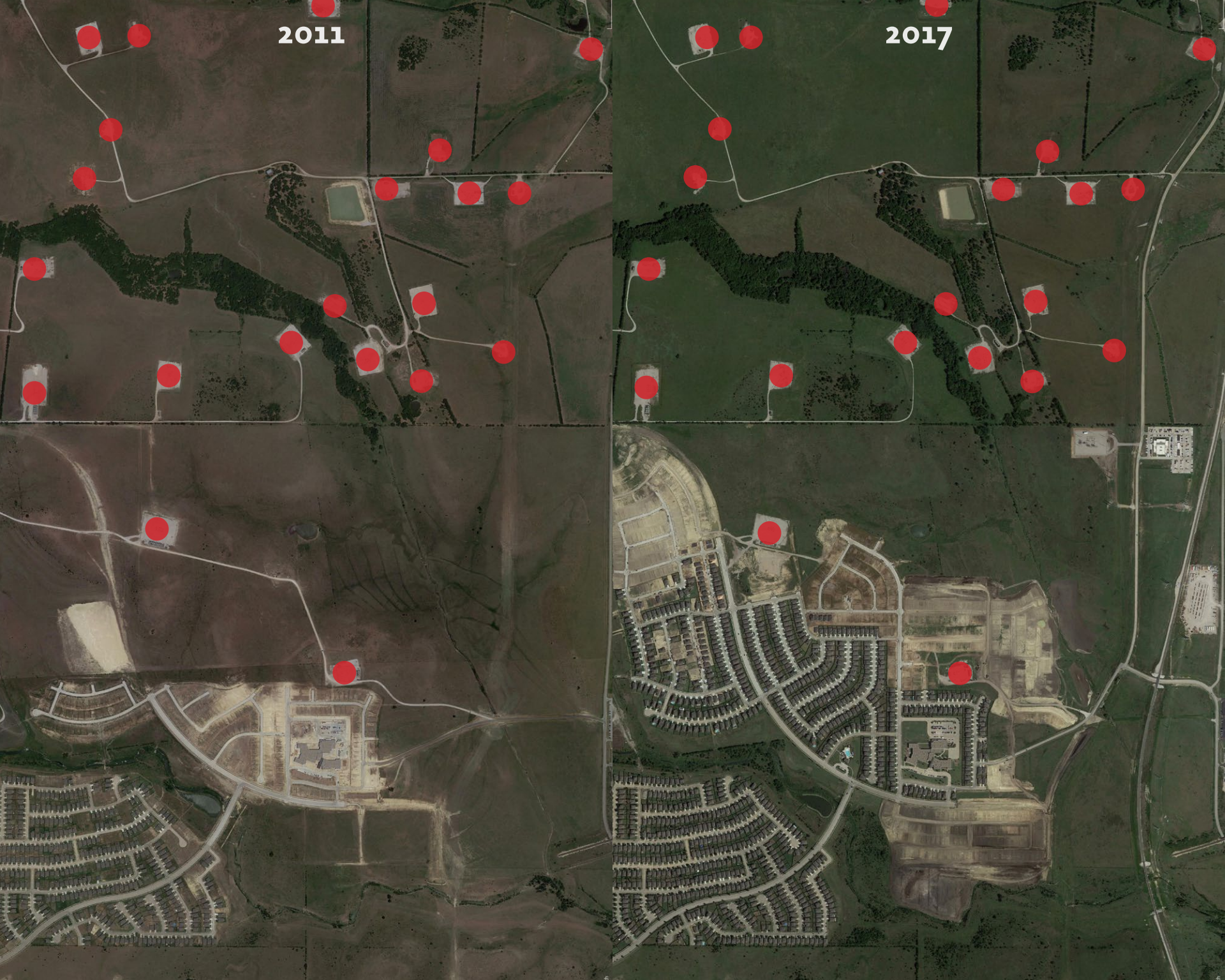


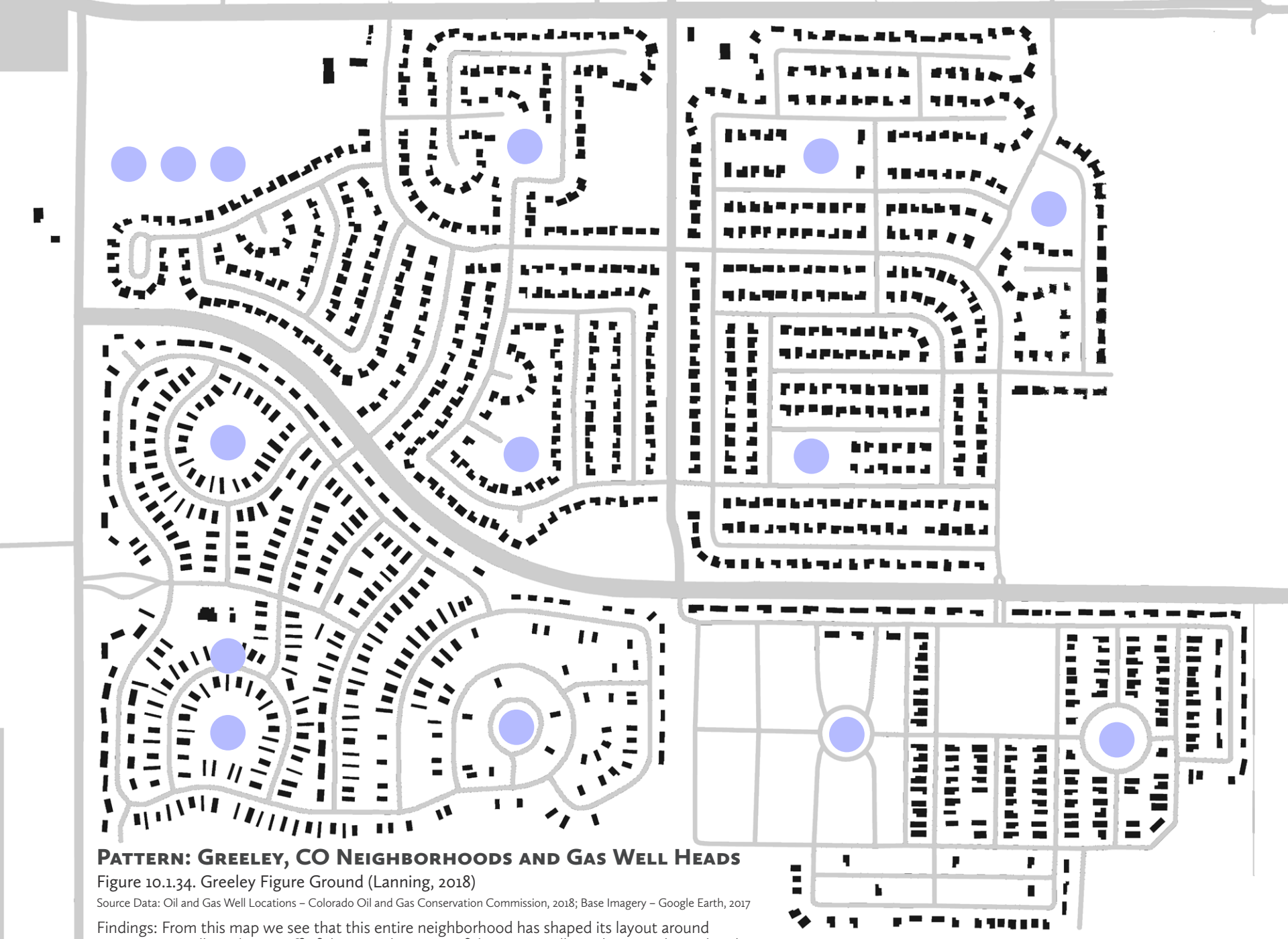
Pattern: Growth of suburbs and oil/gas fields

Figure 10.1.33. Changes in Tarrant County (Lanning, 2018)

Source Data: Base Imagery – Google Earth, 1995; 2001, 2011; 2017

Findings: Like the images on the previous spread, these show the changes to a particular area of Tarrant county over the past two decades and its transition from an agrarian to suburban area.


2011
2017

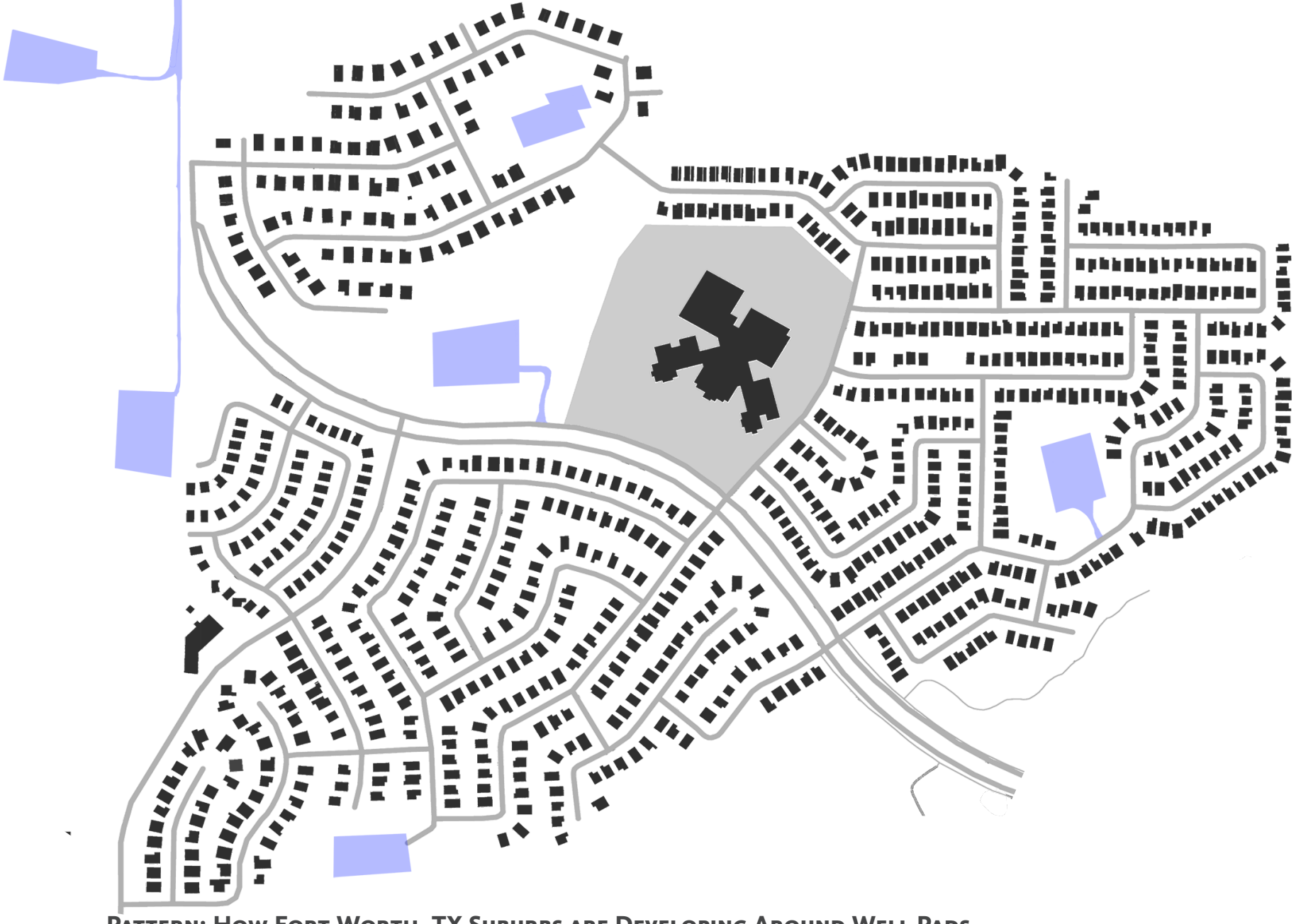


Pattern: Greeley, CO Neighborhoods and Gas Well Heads

Figure 10.1.34. Greeley Figure Ground (Lanning, 2018)

Source Data: Oil and Gas Well Locations – Colorado Oil and Gas Conservation Commission, 2018; Base Imagery – Google Earth, 2017

Findings: From this map we see that this entire neighborhood has shaped its layout around existing gas wells, radiating off of them. Today many of these gas wells are being reclaimed and left as now unusable pieces of land between roads or the backs of houses.



Pattern: How Fort Worth, TX Suburbs are Developing Around Well Pads

Figure 10.1.35. Fort Worth Figure Ground (Lanning, 2018)

Source Data: Base Imagery – Google Earth, 2017

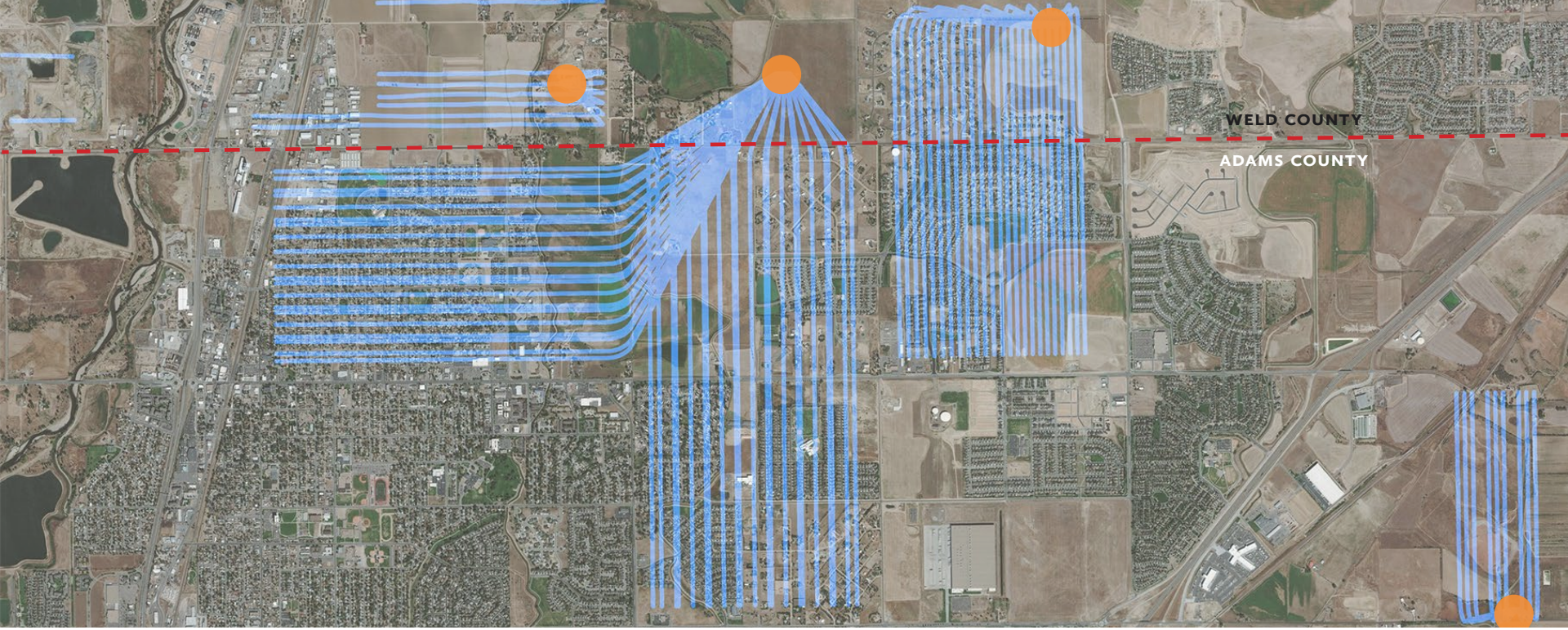
Findings: In Fort Worth the developments of communities around well pads is much the same as in Greeley. Whole blocks encircle a well pad and roads just simply terminate when they hit the boundary between community and oilfield.

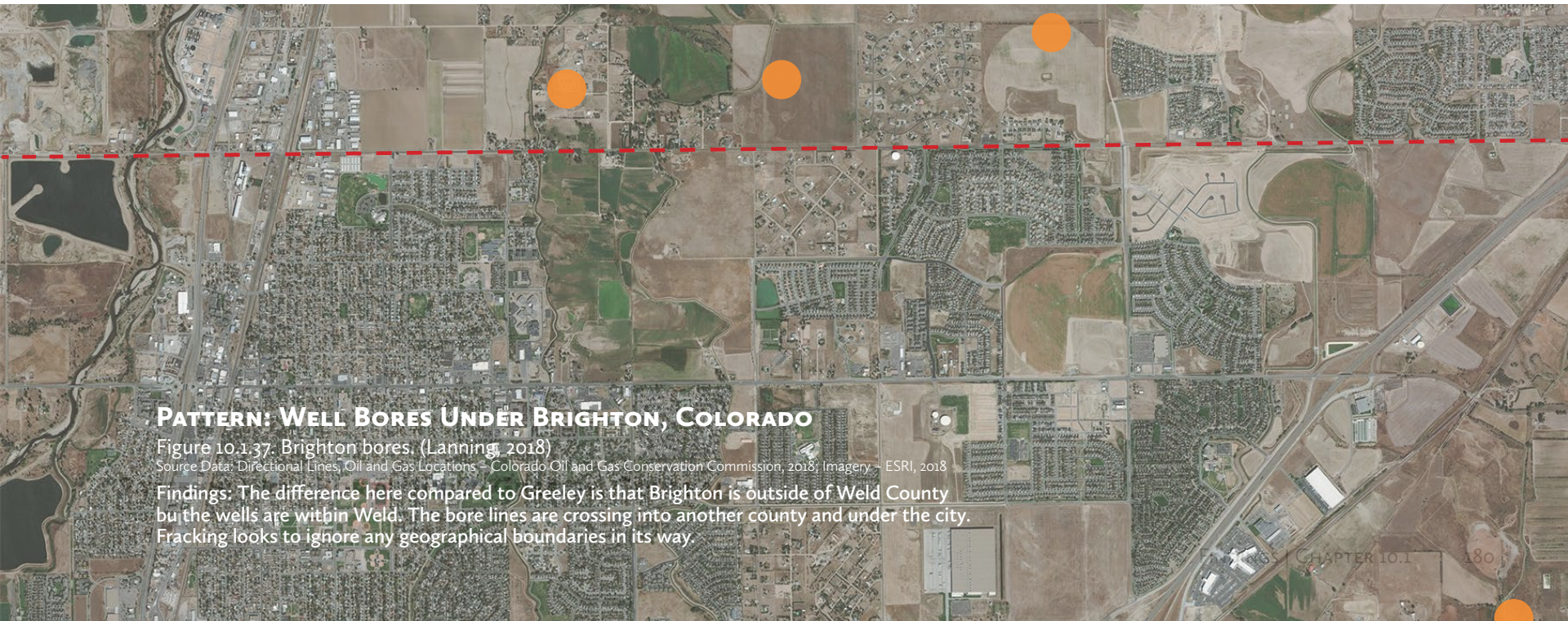


Pattern: Well Bores Under Greeley, Colorado

Figure 10.1 36. Greeley bores. (Lanning, 2018)
Source Data: Directional Lines, Oil and Gas Locations – Colorado Oil and Gas Conservation Commission, 2018; Imagery – ESRI, 2018

Findings: These bore lines are the paths that fracking lines take deep underground. While these may be up to a mile underground, it shows that even if a fracking wellpad is far away from a community, its infrastructure may in fact be right below.





Pattern: Well Bores Under Brighton, Colorado

Figure 10.1.37. Brighton bores. (Lanning, 2018)
Source Data: Directional Lines, Oil and Gas Locations – Colorado Oil and Gas Conservation Commission, 2018; Imagery – ESRI, 2018

Findings: The difference here compared to Greeley is that Brighton is outside of Weld County bu the wells are within Weld. The bore lines are crossing into another county and under the city. Fracking looks to ignore any geographical boundaries in its way.

10.2 THE VEILED

These are the Fracklands that lay hidden from view. They may be physically hidden from view, or they may be hidden in their association; unknown at initial glance that they are a part of hydraulic fracturing. Their use may be fully or only partially committed to the processes of hydraulic fracturing. The components of the Veiled Fracklands create the support network of the oil and gas industry. They are the pipelines and roads that connect and spread oil and gas across the planet. They are the little known sand pits which allow for fracking to be so successful. These Fracklands when unveiled are what reveal greater extents of hydraulic fracturing.



Figure 10.2.1. Road into Grover Colorado. Adjacent to oil and gas fields in the Pawnee grasslands, Grover, a town of 100 is one of many communities which have experience the side-effects of fracking. (Lanning, 2017)





Figure 10.2.2. Sign indicating presence of a gas pipeline in Weld County. Towards the right of the image one can see see its faint path from surface disturbances. (Lanning, 2017)



PIPELINE

COUNT

1,984,311
KILOMETER NGL PIPE

240,711
KILOMETER OIL PIPE

SIZE



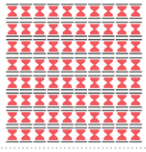
4" - 48" DIAMETER

PLACE



ANYWHERE - NA

LIFE



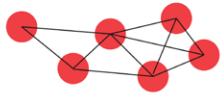
80

USE



TRANSPORTATION
OIL/GAS - NATIONWIDE

SYSTEM



CONNECTOR

IMPACT



HIGH
ENVIRONMENTAL DAMAGE

Pipelines are the most widespread of any other Frackland component. They represent a component of the Veiled Fracklands that are easily associated with the processes of hydraulic fracturing, but remain visually veiled. Pipelines connect much of North America via a dense interconnected web of underground infrastructure. Pipelines are the most efficient method of transporting large quantities of oil and natural gas over extensive distances as opposed to road and rail. The extensive networks of pipeline allows for product to virtually flow from a well on one side of the country to a facility on the other, all while being masked below the surface.

While pipelines are primarily underground systems, major lines require a surface right-of-way for access (Walton and Woocay 2013), leading to an array of ecological concerns and habitat loss (Moran et al. 2015). These effects make these components one of the more debated, having fueled major protest against their implementation in recent decades. Despite this attention, pipeline remains hidden from view and their network is growing rapidly. Their existence is only evident by utility flags and signs, the occasional surface valve, or compressor stations. Only in cases such as the Trans-Alaska Pipeline will it be found above ground, where the surrounding permafrost requires it be elevated.

Reflections from the Field:

Spotting pipelines was difficult. They were often only indicated with a splint of metal fixed with a small round sign indicating their presence below. That or a chance occurrence when one was being laid in the ground. While valves may come up to surface, occupying a few square feet of land, they remain primary hidden below ground. And due to lack in disclosure, only the most major of pipelines are available as data. Who knows how much pipeline was traveled over during visits in the field.

These components were best observed from above, where one can see their disturbance, the long linear paths they lay across extensive lengths of land. These paths were most visually evident in the forests of Pennsylvania and West Virginia where pipeline and their rights of way cut through core forest. In Colorado and Texas, where prairies dominate the regional geography, these corridors become even less apparent even when looked on from above. Only faint linear scars and an educated guess could identify their presence. Only could acquired data of their locations truly reveal the extent of these landscapes across the country.

Because of their nature, these landscapes remain and will remain as hidden entities within the Fracklands.



Figure 10.2.3. A pipeline in the process of being buried. (Lanning, 2017)



Figure 10.2.4. Images from Dimock, Pennsylvania showing how hidden pipeline can be. (Google Earth, 2011; 2017)

Story: Fighting Oil and Gas – Hesitation and Hopelessness in Fort Worth, Texas (Gullion 2015)

When it comes to acting against oil and gas development, pipelines tend to gain the majority of national outcry and attention. Outcry towards the sources of the pipeline, wells however are only being raised at a local level. That is, if they are at all. Hesitation towards activisms looks to be a common trend in fracking-prone regions where activity is undesirable. Such phenomena is apparent in Fort Worth Texas as detailed by Guillion, 2015:



Figure 10.2.5. Pipeline surface valve for a large capacity gas pipeline in Weld County. Often the only indicator of pipeline infrastructure aside from signage. (Lanning, 2017)

"I found myself conducting interviews in $250,000 - $500,000 homes… The people in my study were primarily white, middle-class to upper-middle class, and highly educated… before the arrival of natural gas drilling in their communities, social activism was not part of their identity."

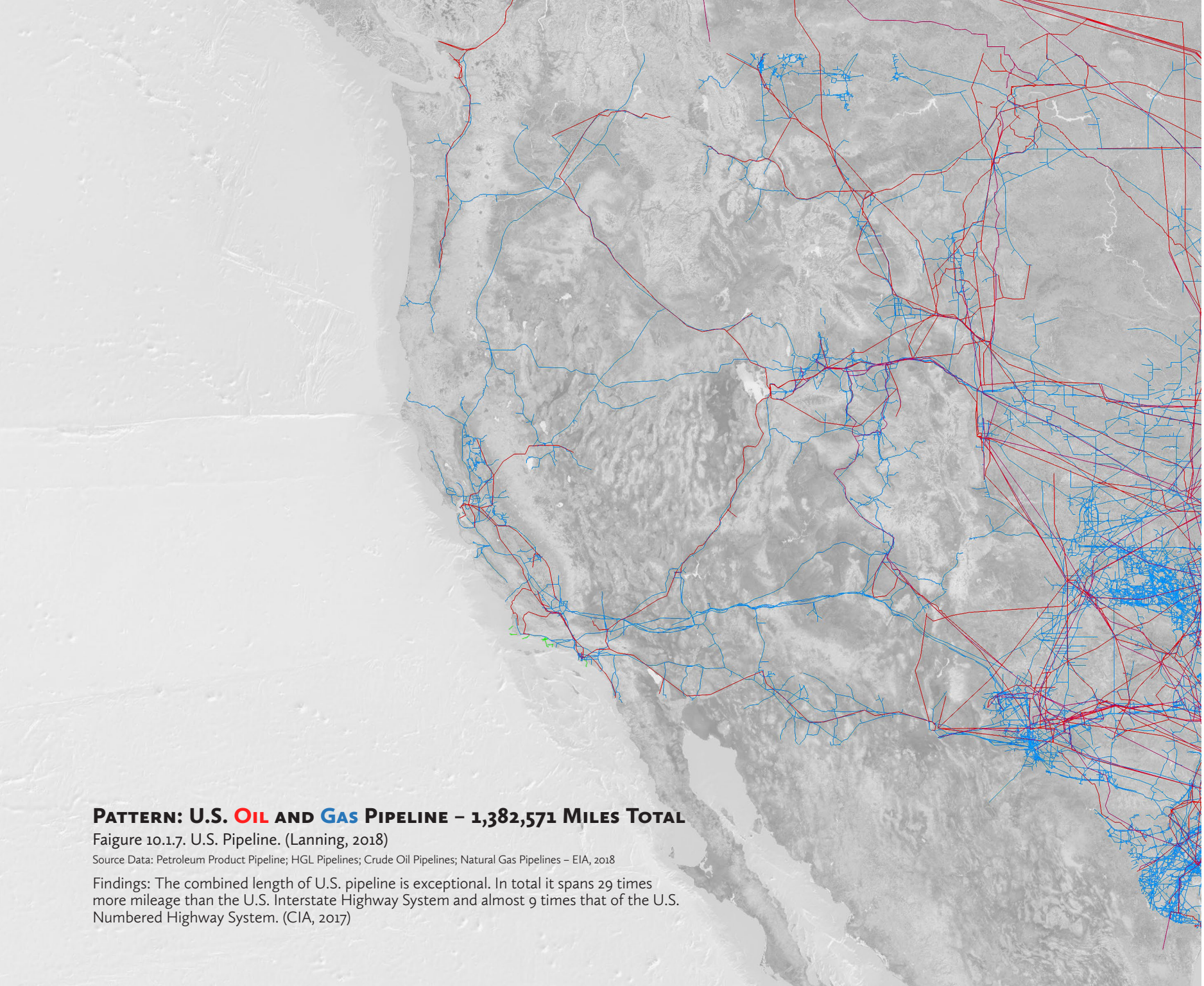
"Environmental problems can be a shock to these people, because they are typically sheltered from industrial activities. Used to buying their way to safety… they are often not aware of the difficulties of living in proximity to polluting industries… although they have resources, theirs are nothing in comparison with those of the oil and gas industry… many give up in frustration."

"[an interview] 'I feel like were being taken advantage of… you can't get away from pollution. So you stay where you are and fight where you live. But you don't know what youre up against.'"

"[These] communities are nonetheless disproportionally burdened by the negative effects of natural gas development. They are living in a sacrifice zone… albeit one that is relatively posh."



Figure 10.2.6. Image of a pipeline valve and a school behind. This part of Tarrant county is the same area that Guillion, 2015 conducted their study. (Lanning, 2017)

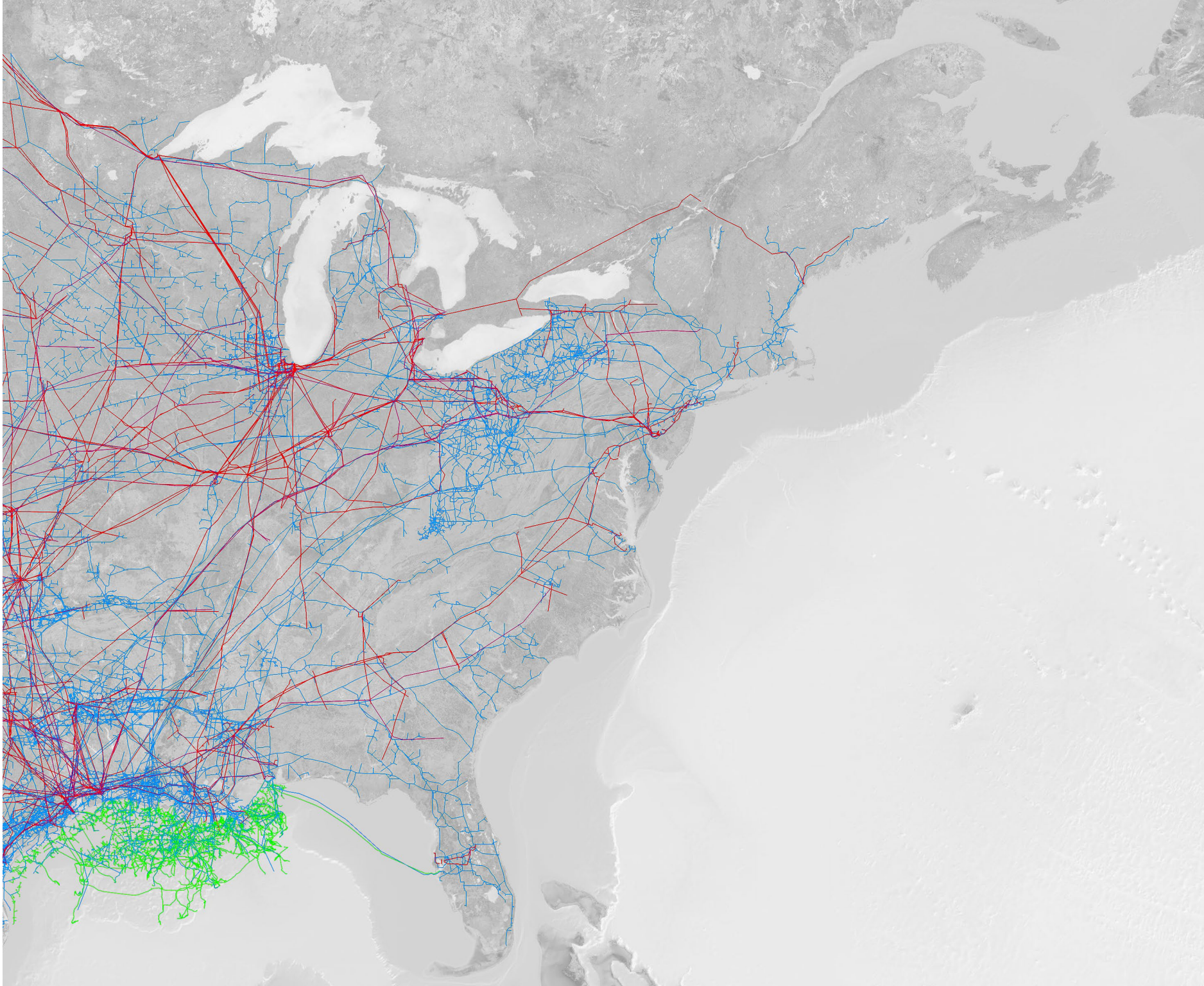


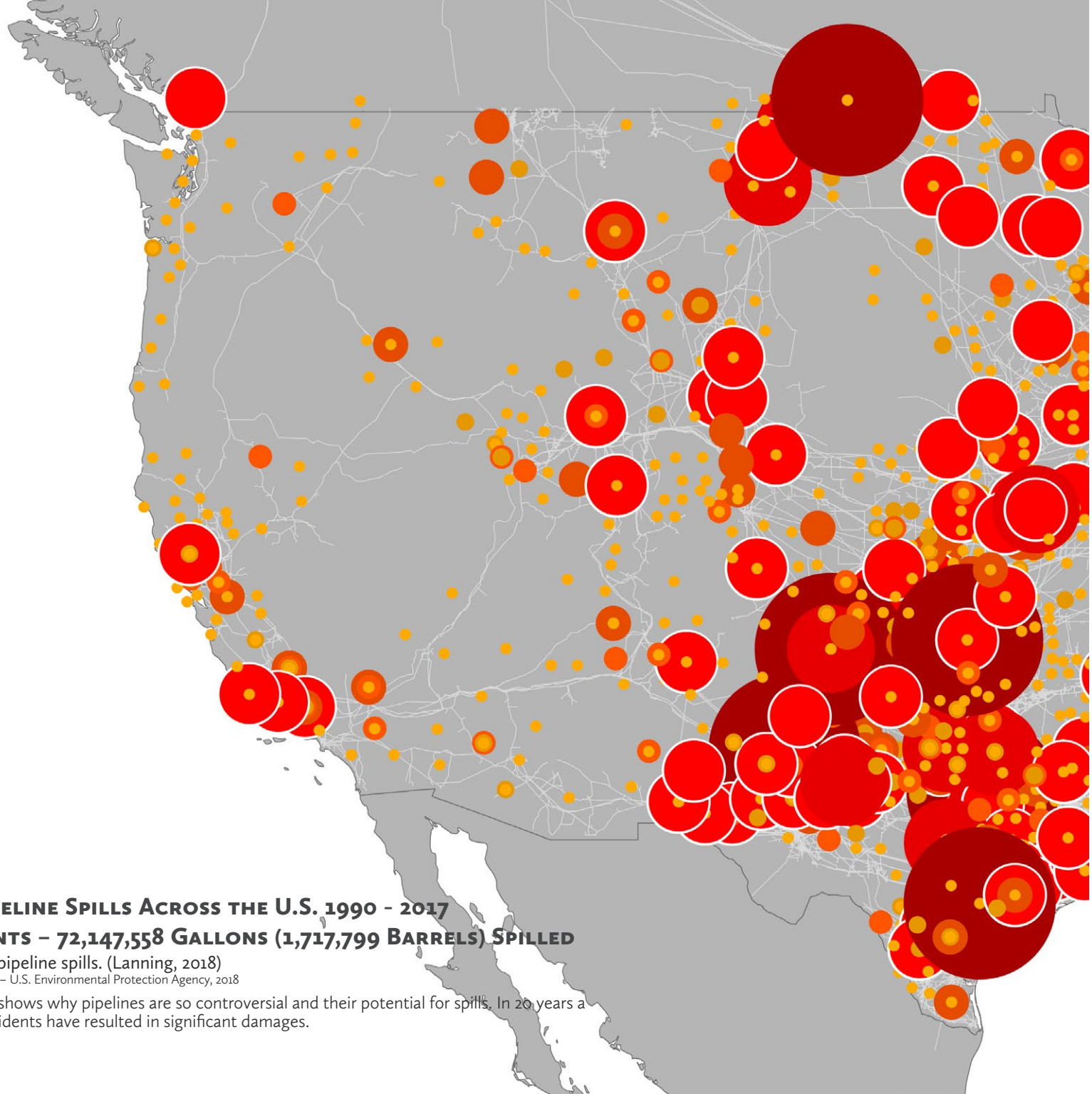
Pattern: U.S. Oil and Gas Pipeline – 1,382,571 Miles Total

Faigure 10.1.7. U.S. Pipeline. (Lanning, 2018)

Source Data: Petroleum Product Pipeline; HGL Pipelines; Crude Oil Pipelines; Natural Gas Pipelines – EIA, 2018

Findings: The combined length of U.S. pipeline is exceptional. In total it spans 29 times more mileage than the U.S. Interstate Highway System and almost 9 times that of the U.S. Numbered Highway System. (CIA, 2017)





Pattern: Pipeline Spills Across the U.S. 1990 - 2017
4,615 Incidents – 72,147,558 Gallons (1,717,799 Barrels) Spilled

Figure 10.1.8. U.S. pipeline spills. (Lanning, 2018)
Source Data:Pipeline Spills – U.S. Environmental Protection Agency, 2018

Findings: This map shows why pipelines are so controversial and their potential for spills. In 20 years a large amount of incidents have resulted in significant damages.

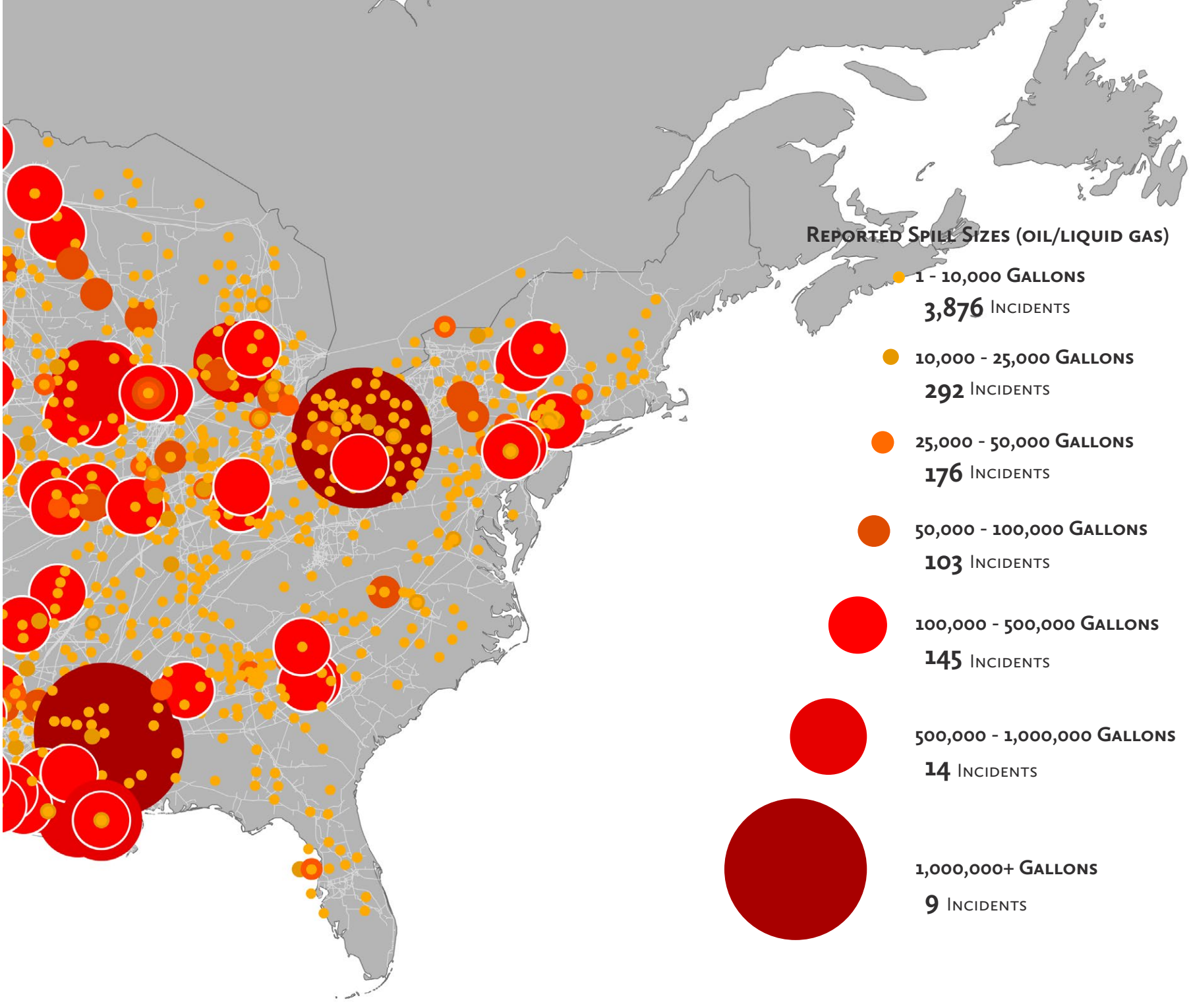

Reported Spill Sizes (oil/liquid gas)
1 - 10,000 Gallons
3,876 Incidents
10,000 - 25,000 Gallons
292 Incidents
25,000 - 50,000 Gallons
176 Incidents
50,000 - 100,000 Gallons
103 Incidents
100,000 - 500,000 Gallons
145 Incidents
500,000 - 1,000,000 Gallons
14 Incidents
1,000,000+ Gallons
9 Incidents



Figure 10.2.9. Trucks in the Pawnee Grasslands.
Free range grassland has become dominated by well traffic. (Lanning, 2017)

TRANSPORTATION INFRASTRUCTURE



COUNT

UNKNOWN

SIZE

650'

ROAD ADDED PER WELL



PLACE

ANYWHERE W/ FRACKLANDS

LIFE

1 - 100

SPECULATIVE



USE

TRANSPORTATION

OIL/GAS/MATERIAL - REGIONAL



SYSTEM

CONNECTOR



IMPACT

MODERATE

POLLUTION, NOISE, DAMAGE

Roadways and railways are key to the transportation of material across the Fracklands. They are necessary for both the transportation of inputs and outputs. Like pipelines, these transportation networks are a substantial means of transporting oil and gas. Unlike pipelines however, road and rail is also what is used to bring in the large amounts of material required to initiate hydraulic fracturing and construct related facilities.

Road:

Roads are very much the primary transit system by which the Fracklands are organized around. Although a large amount of roadway will be constructed for fracking (Hill 2015), many of these road networks have existed before fracking. Both result in straining local resources and vital infrastructure needed for communities to function. A study in Texas found that improvements and maintenance to roads to allow for both industry and regular use to cost around $133,000 per well (Naismith Engineering, Inc 2015). A separate study in North Texas found that Approximately 1,272 truck trips were required to drill and frack a gas well in the area. After this, an additional 88 trips are required per year for the life of the well for maintenance. If the wells is to be fracked again, an additional 1,000 truck trips are needed (Quiroga, Fernando, and Oh 2012). These truck trips lead to compromised air quality, increased noise levels, and increased risk for traffic incidents and vehicle collisions (Goodman et al. 2016; Muehlenbachs and Krupnick 2013).

Rail:

Rail is responsible for bulk distribution of material. It is vital to the transportation of Frac sand out of the Midwest, and industrial equipment from manufacturing plants. Once transported to fracking heavy regions roads are used to take whats being transported to individual sites. Almost all the railways utilized are existing rail corridors. However large distribution centers are built to stage equipment such as oil cars and sand cars both in fracking regions and regions where the material originates. Often cars will sit idled until they make their journey across the Nation.

Rail is also vital for bulk distribution of oil and gas across the U.S. While pipeline is the preferred means of distribution due to cost, rail is more flexible and can be used when pipeline infrastructure is not in place. Such was the case before the Dakota Access Pipeline – which was at the center of protest and controversy – was completed connecting oil from the Bakken to refineries in the Midwest and along the coast. Rail was heavily used instead, which resulted in a number of major significant catastrophe and spills.



Figure 10.2.10. Oil cars site idled at a rail-yard in Fort Worth, Texas. (Lanning, 2017)



Figure 10.2.11. Rail Facility in North Dakota. Frac Sand comes in from the Midwest, while Oil is sent out to be refined. (Google Earth, 2016)

Reflections from the Field:

In many places at first glance it was hard to associate many roadways and railways as a components of the Fracklands. Often this infrastructure had existed for decades prior to fracking. However, observation over time revealed relentless fracking related vehicle activity. During drilling and injection, activity was highest, where dozens of trucks passed to and from drilling sites transporting material. Near active wells, tankers were seen visiting more infrequently to collect product. However, smaller vehicles – most always white pickup trucks – were seen constantly around active wells and facilities, inspecting, maintaining, and so on . Near processing facilities, a steady flow of semis transporting product was evident at all hours.

In Weld County road activity was most evident. It was shocking to see the level of truck traffic on unpaved local roads outside of populated areas. Semis transporting oil and gas, water, and materials dominated these roads, while white pickup trucks with workers, and inspection crews were just if not more common. In areas with large-scale operations such as the Pawnee grasslands, large trucks and crew vehicles were often the only observed vehicles.

In Appalachia, fracking roads are just as common, however they are more hidden from view. Views from above show roads in West Virginia and Pennsylvania winding from valley highways up to wells and facilities that occupy hilltops. These roads often end up being more than a mile long.

In Tarrant County, the presence of large vehicles was less apparent around oil/gas facilities. While small trucks were common, semis were only seen in large number near facilities. Such phenomena may be largely owed to pipelines rather than roads being used to connect wells to processing facilities. Despite the lower road activity, rail was seen as a major component. Multiple large rail yards holding hundreds of idle oil cars were observed.



Figure 10.2.12. What may look like a small road winding up one hillside like in figure 10.2.x, may actually be a long network of roads connecting numerous facilities together. (Google Earth, 2017)

Story: Oil-field Traffic and Community Responses in South Texas (Rahm et al. 2015)

Through survey of county residents, Rahm et al., 2015 looks at understanding the impact that fracking has on transportation networks and community assets. Every respondent agreed that well traffic was creating issues in their communities. This amounted to respondents wanting to expand both roadway infrastructure and roadway services: The survey was taken during a time in which the region was experiencing a boom in fracking However:



Figure 10.2.13. Evidence of the Impacts of well traffic on county roads in Weld County. Trucks are dumping water (possibly waste water) on recently placed dirt to harden the road, easing accessibility for large trucks. (Lanning, 2017)

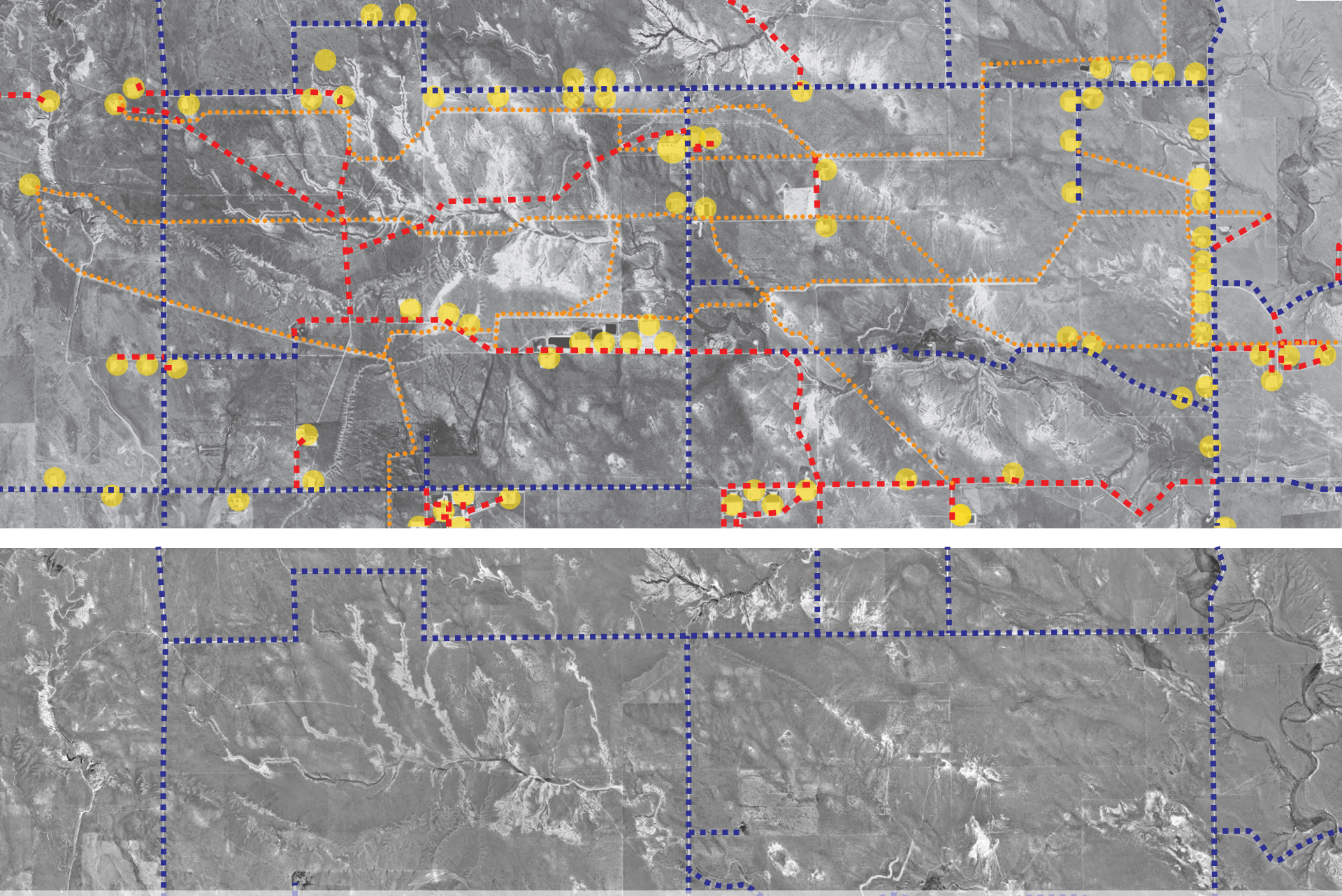
"68% of respondents argued that there was a moderate or great amount of need to widen roadways and/or add shoulders… there had been moderate or great amount of increased costs for EMS in their counties… 87% of respondents also reported that there was a moderate or great amount of increase needed in police services." (93)

"Most respondents felt that there were insufficient resources available to meet their increased transportation needs… respondents reported that the amount received from the program [for road infrastructure] was substantially less than what was needed to cover expected costs." (94)

"Perceptions on the overall impact of fracking [as good] in the region may change if the boom cycle dissipates and local communities are left with a network of poorly maintained roads and significantly diminished economic resources to address the transportation problems" (95)



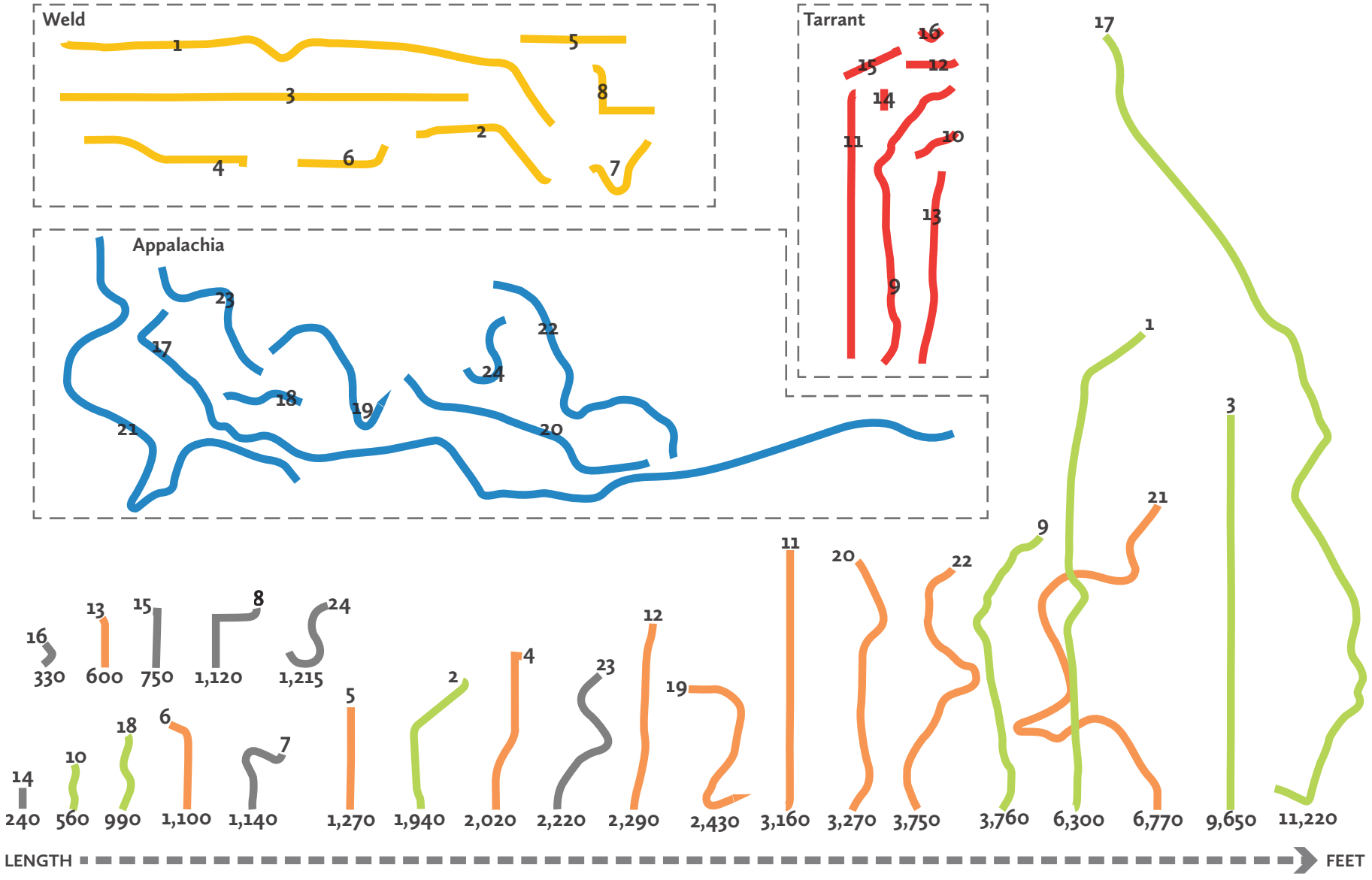
Figure 10.2.14. Well traffic, signage, and roads winding up wooded hillsides are a common view like this from West Virginia. (Used with permission ©Blake Belanger, 2017)



Pattern: Cutting through the Pawnee Grasslands

Figure 10.1.15. Roads in the Pawnee. (Lanning, 2018)
Base Imagery: Bottom – USGS, 1998; Top – USGS, 2017

Findings: These images show how one area can be transformed by fracking related roads. What was once open range has been largely dissected many times over.



Pattern: Comparing Wellpad Access Roads

Figure 10.1.16. Road Comparison. (Lanning, 2018)

Findings: The roads examined here were access roads that originate from the same wells examined on page 152. Like the wells these roads are highly variable by region and context. However geography looks to impact the length of roads the most.



Figure 10.2.17. Frac sand operation in Wisconsin.
(Used with permission ©Ted Auch – FracTracker Alliance, 2013)



FRAC SANDS

COUNT

1,500 - US
700+ - MIDWEST

SIZE



20 - 750+ ACRES

PLACE



US - MIDWEST - WISCONSIN

LIFE

UNKNOWN
USE AFTER FRACKING?

USE



INJECTION MATERIAL

SYSTEM



INPUT

IMPACT



HIGH (LOCALLY)
AN UNKNOWN TOPIC BEYOND

The hydraulic fracturing process is resource intensive, demanding large amounts of water, sand and chemicals. As fracking has grown, the demand for these resources has grown too. Sand used in fracking is used to hold open fissures, allowing oil and gas to flow easily to the surface (Bensen and Wilson 2015). While sand used in fracking can come from all over the country, unique high-silica sands or 'frac sands' located predominately in the Midwest have been found to maximize oil and gas uptake (Rubright 2017). As a result, a frac sand mining boom has taken off across the Midwest in places like Illinois, Minnesota, and Wisconsin. Sand that has sat under the soil for millennia will be dug up, processed and shipped across the country, then re-injected back into the earth.

This frac sand boom has created its own host of phenomena, but is seldom discussed outside the region. It is also seldom discussed when discussing fracking. While positive economic impacts like job growth have been seen near frac sand operations, it comes at the expense of infrastructure, social structures, and the environment (Deller and Schreiber 2012; Pearson 2013). Frac sand, like the fracklands themselves have their own unique network of components to take sand from the earth, process it, and send it off to fracking regions across the country. For this report these components – mines, processors, logistics – are grouped together to represent the entirety of the Frac Sands.

Reflections from the Field:

In investigating the Frac Sands of the Midwest, review of literature and visual analysis of known frac sand facilities was utilized in place of field visits. Visual analysis shows that the extraction of high-silica sand for use in fracking has rapidly transformed regions of the Midwest despite being hundreds of miles away from significant fracking activity. The existence of these landscapes is evidence that the Fracklands extend far beyond the extent of wells, facilities, and their infrastructure.

Frac Sands operate much like wells in that they are the epicenter of activity and platforms of many other landscapes. They require land for processing, production and waste, have influenced and shaped communities, and they are connected by extensive transportation networks – both rail and road. Activity off of these sites can be just as high as on the site themselves, where thousands of trucks will go to and from sites transporting sand to be processed and shipped via rail to fracking regions.



Figure 10.2.18. Frac Sands of Troy Field, Illinois. Like others, this town has been rapidly transformed in just a few years. (Google Earth, 2017)



Figure 10.2.19. Frac sand site in Sparta, WI.
(Google Earth, 2010; 2013)

Story: Communities and Sand Mining in rural Wisconsin (Pearson 2016)

Frac Sand mining is a new phenomenon in the United States. As such, so is understanding the social dynamics behind it. Pearson, 2016 documents how people in rural Wisconsin, the epicenter of Frac Sand mining have been affected by its recent boom. Results reveal similar sociological phenomena to that of fracking, though happening far from the fracking. Residents near Frac Sand operations were noted as experiencing some or all of the following:



Figure 10.2.20. Frac sand operation in Wisconsin.
(Used with permission ©Ted Auch – FracTracker Alliance, 2016)

Loss in sense of place, community and regional identity; feelings of alienation:

"The new frac sand mine represents a disquieting transformation of a familiar landscape once defined by fire truck-red barns… the remnants of previous ways of life are destroyed to make way for a new extractive industry…"

"'I could live anywhere, and I chose to move here because I like the community… the farm, the farmers...and now the farmers are leaving and all we have are giant pits of sand.'"

"'the sand company just north over here has the farm that my grandfather grew up on…' For Marlene, mining not only flattens a pretty hill; it transforms a landscape saturated with meaning."

Marginalization; feeling of helplessness to stop the changes occurring:

"'I'm frustrated. I'm angry. I'm embarrassed to live here. I want out horribly, cuz I know they don't want me here. The community doesn't want me here anymore because I'm not pro sand.'"

Good, bad, or no change:

"Some will reap the financial benefits, others will shoulder the social and environmental costs, and still others will remain unaffected and indifferent."

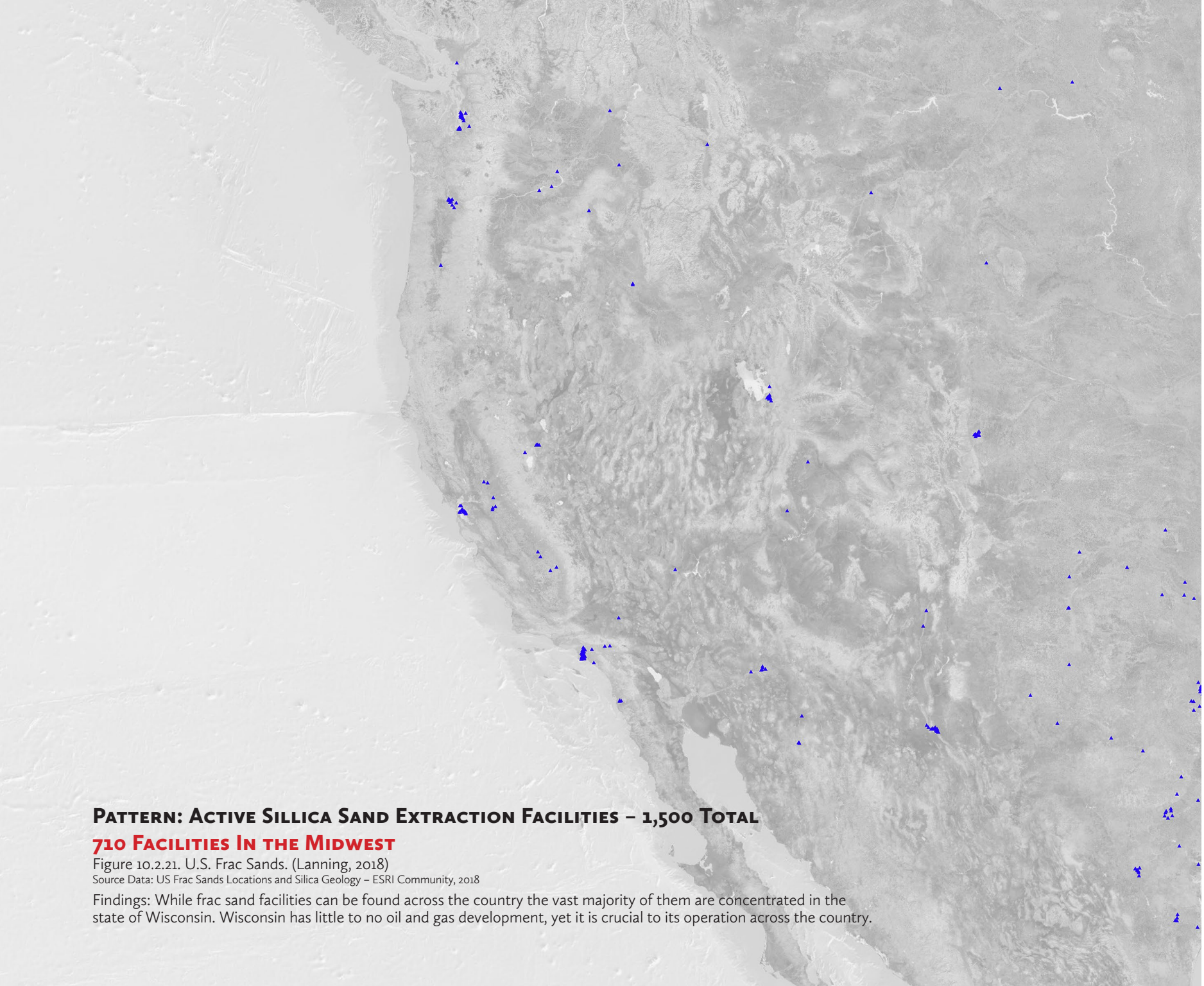
Community upheaval:

Both frac sand mining and fracking are also characterized by "human causality" but also "involuntariness," setting the stage for intense distrust and anger targeted at neighbors, community institutions, and corporations

"Confusion and betrayal are common sentiments when people realize that their neighbors had been discreetly negotiating leases or sales… in some cases, the uncertainty and sense of secrecy divide once close-knit communities."

"People begin to doubt basic social structures such as the organization of their community and the function of local government… 'They lied to us over and over and over again. We don't trust anybody anymore.'"

"'it's also the landowners versus the people who don't have sand on their property.'"

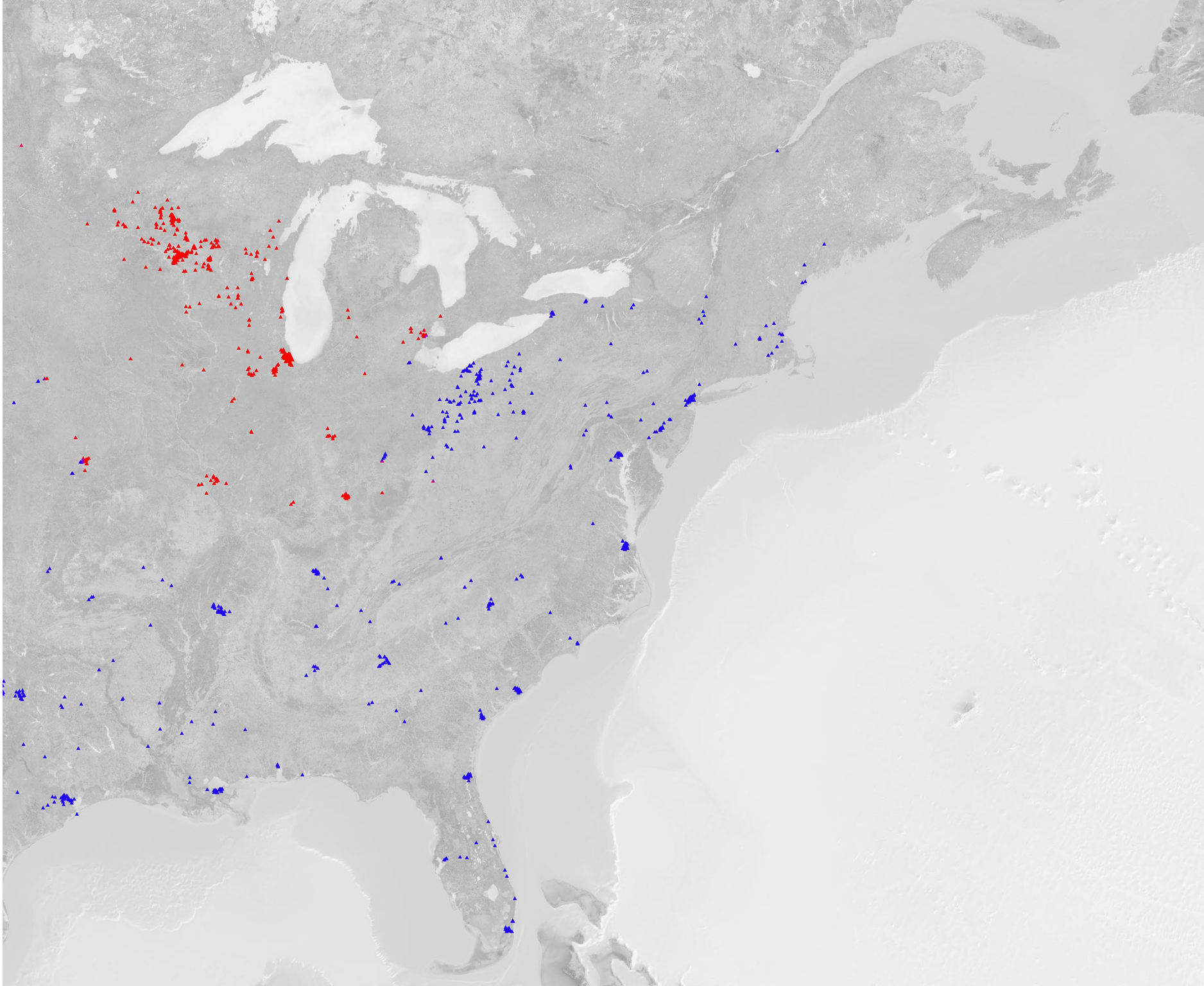


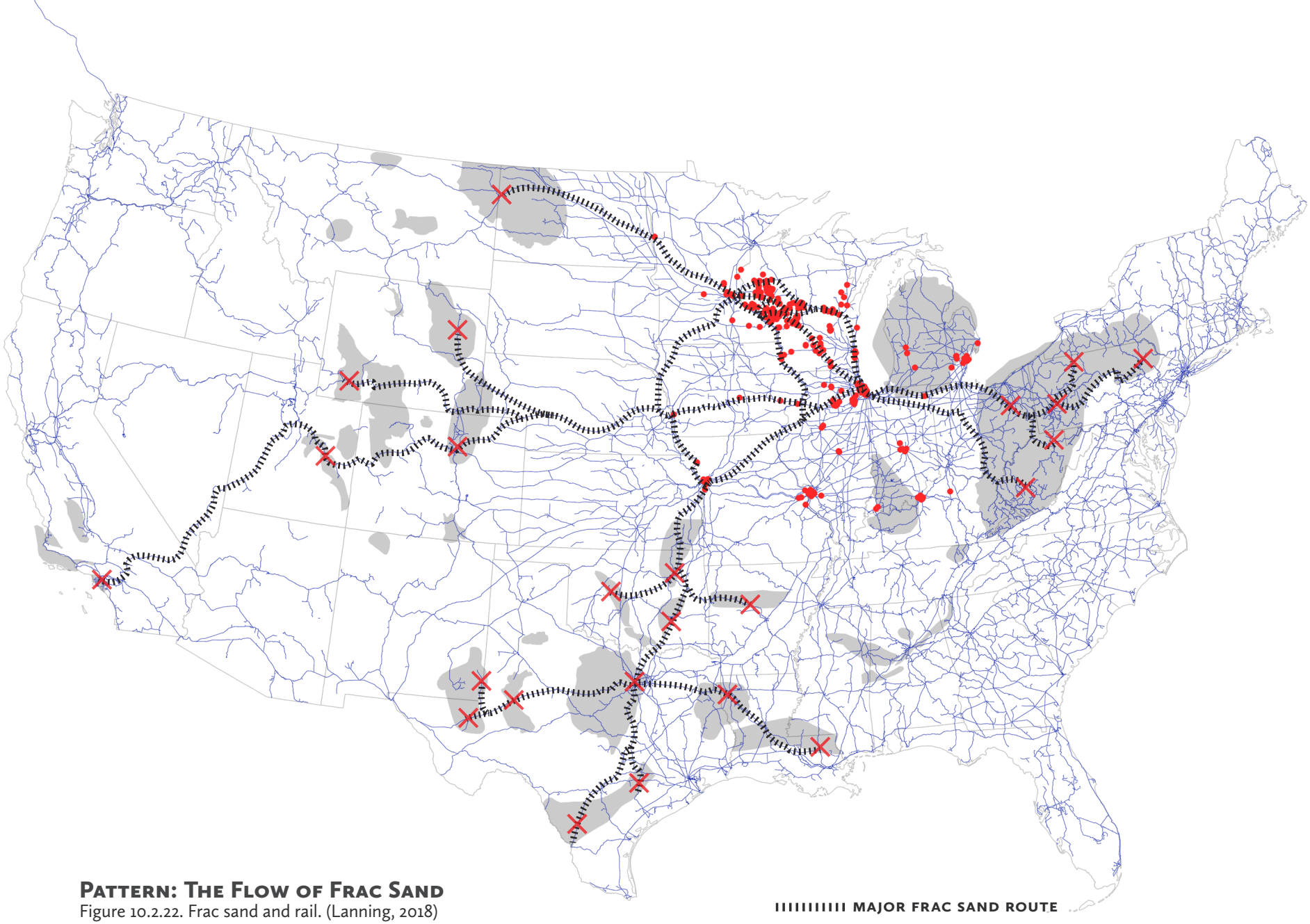
Pattern: Active Sillica Sand Extraction Facilities – 1,500 Total

710 Facilities In the Midwest

Figure 10.2.21. U.S. Frac Sands. (Lanning, 2018)
Source Data: US Frac Sands Locations and Silica Geology – ESRI Community, 2018

Findings: While frac sand facilities can be found across the country the vast majority of them are concentrated in the state of Wisconsin. Wisconsin has little to no oil and gas development, yet it is crucial to its operation across the country.



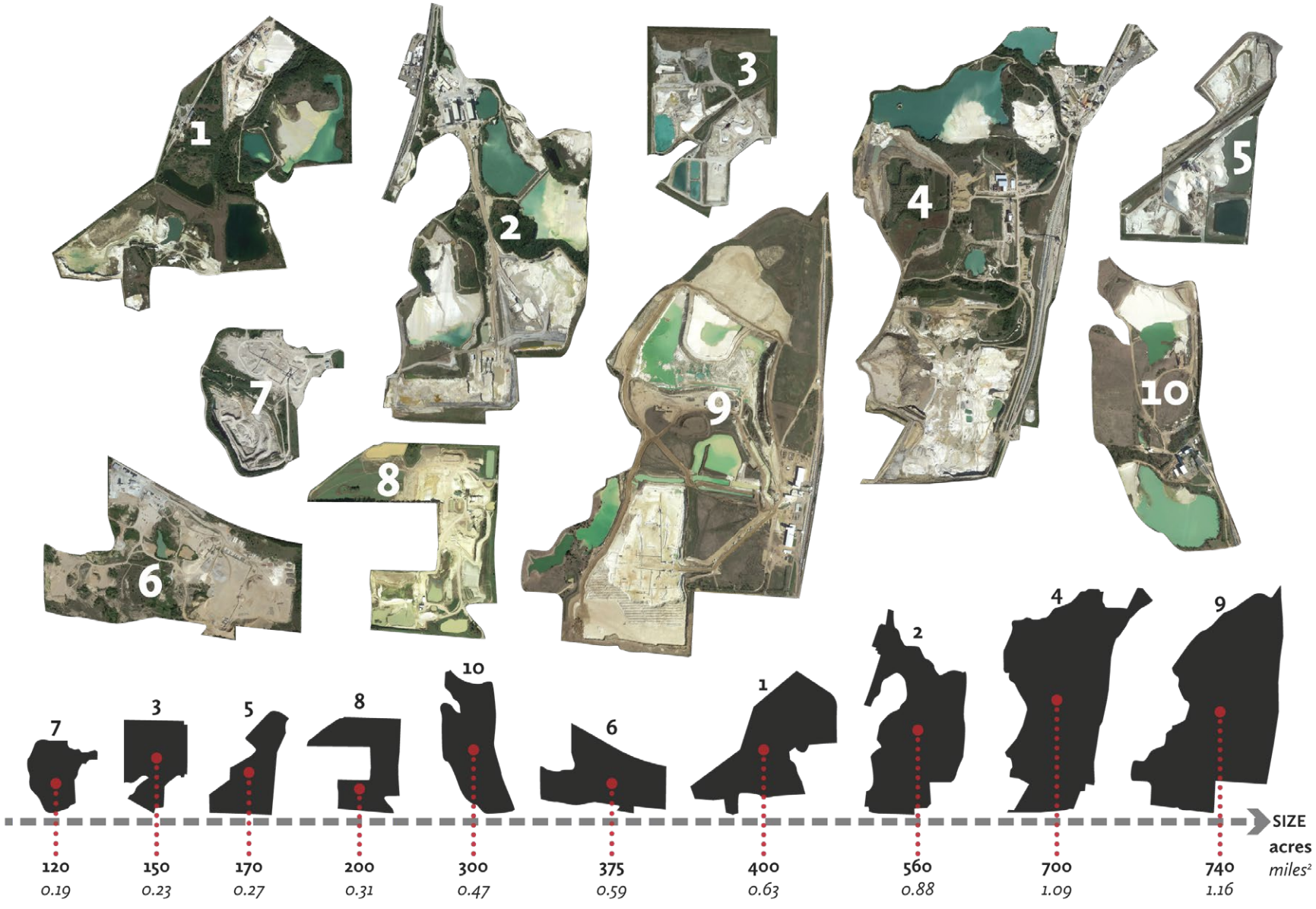


Pattern: The Flow of Frac Sand

Figure 10.2.22. Frac sand and rail. (Lanning, 2018)

Source Data: US Frac Sands Locations and Silica Geology – ESRI Community, 2018; U.S. Rails National – U.S. Census Bureau

Findings: This map shows how critical rail networks are for the transportation of frac sands from the Midwest to regions of heavy hydraulic fracturing. Almost every large frack sand facility was connected to a rail-yard.



Pattern: Comparing Frack Sand Facilities of the Midwest

Figure 10.2.23. Frac sand comparison. (Lanning, 2018)

Base Imagery – Google Earth, 2018

Findings: Looking at these 10 different frack sand facilities found across Illinois, Minnesota, and Wisconsin, there are a number of features to see beyond the size of these facilities. Every facility not only has sand but large pools of water for separation. Some mines are deep excavations others shallow. And the largest of facilities commonly have a rail yards adjacent to them.

10.3 THE TRANSIENT

Transient Fracklands are those that flicker and burn out quickly. They are ephemeral places that may briefly serve a purpose and then disappear. Their function may be more long term, periodically in use and periodically abandoned. They exist in dependence of hydraulic fracturing growing or fading in number with production. Many of their components have already come and gone, missed unless examined at a certain point in time. Uncovering them as products of fracking can be impossible or clear. They may act as veils, appearing as an empty piece of land, or they may persist as built infrastructure.

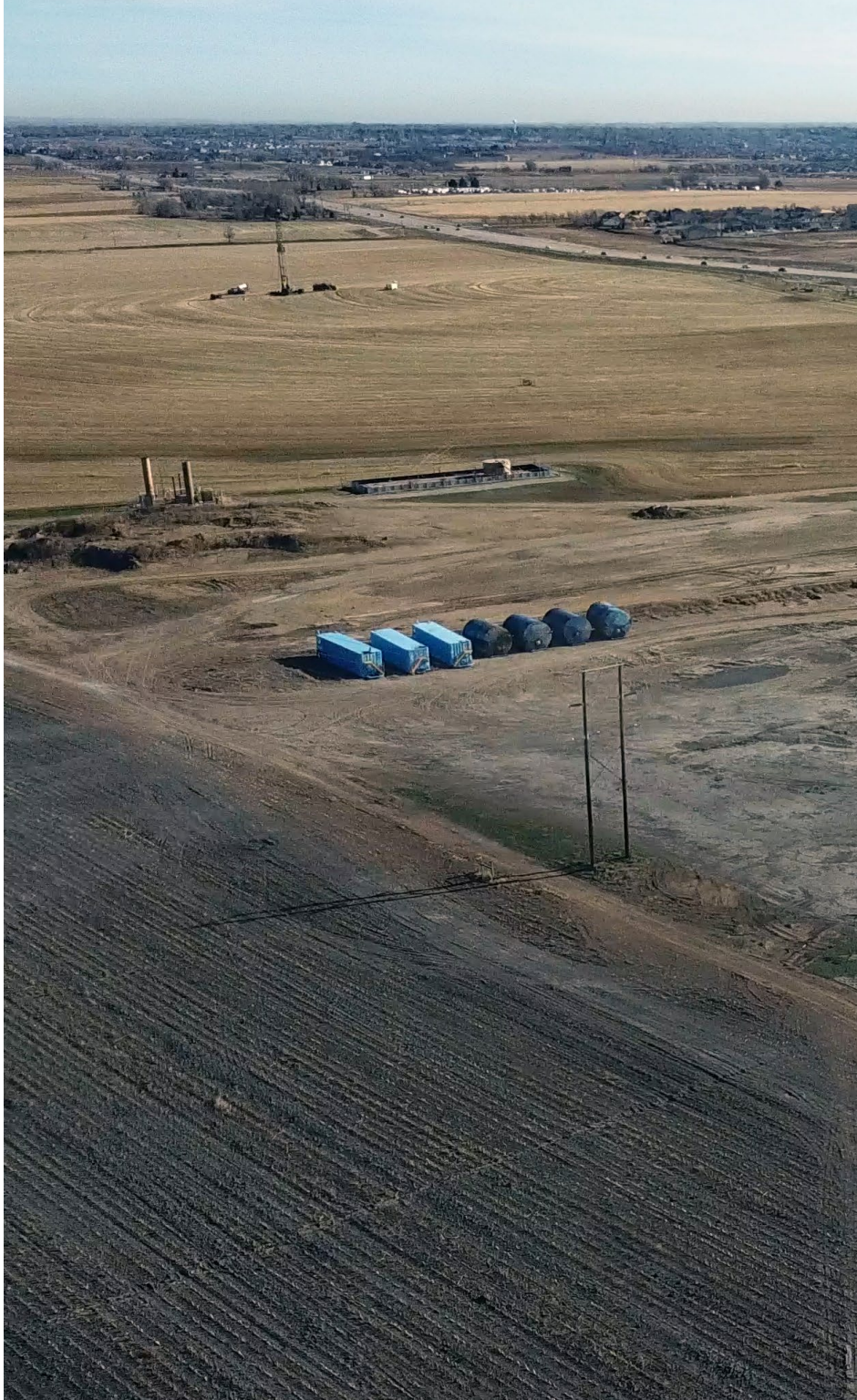


Figure 10.3.1. A storage site for various fracking related materials near Greeley Colorado. Its usage is dependent upon surrounding fracking activity. Shown are water containers and tank batteries.(Lanning, 2017)





Figure 10.3.2. A man camp in the Bakken oilfields of North Dakota.
(Donn Barrett, 2013. Atrributed under a CC BY-NC-ND 2.0 License)

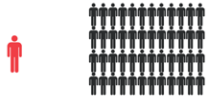


WORKSCAPES

COUNT

UNKNOWN

SIZE



<10 - >500 WORKERS

PLACE



VARIES BY REGION

LIFE



<1 - 5

USE



WORKFORCE HOUSING

SYSTEM



DEPENDENT ON WELLS

IMPACT



LOW

IMPACTS LOCAL SOCIAL SERVICES

The facilities, infrastructure, and processes of hydraulic fracturing are held afloat by the hundreds of thousands of oil and gas workers. A large portion of these employees are not specialists. They are temporary laborers whose numbers rise and fall with demand and drilling activity. While pay is high, the work they do is not easy. Hours are long; at all times and conditions. Work is physically demanding, and dangerous. Turnover rate is often high, and workers will only stay on for up to 12 weeks at a time. Together these factors play to high volatility within the workforce, and their own unique dilemmas, some extending into the physical landscape. (Zawojski 2015).

In regions of heavy hydraulic fracturing activity, influx of the temporary workforce is substantial. When there is little to no existing infrastructure to support this workforce, infrastructure dedicated to housing and accommodating oil and gas workers is hastily constructed. In existing communities apartments and homes will be quickly built. In rural areas, entirely self-sufficient communities,"Man Camps" will be constructed.

These places are built with temporality in mind. They provide bare minimums and have extremely inflated prices and/or have workers pay daily rates. As for the workers themselves many may be living a "work hard, play hard" lifestyle where high alcohol consumption, drug abuse, and sex solicitation are common occurrence (Zawojski 2015). Workforce landscapes follow the demand of oil. Boom to bust means construction then desertion and even dis-assembly. (Hampton 2017; Vorys 2013; Zawojski 2015).

Description Continued:

Housing: Many workforce landscapes may be subjects within a greater community (like those highlighted previously). Being that they are within a greater community, their presence or use as workforce housing and their vacancy status may not be evident. It was not evident in the field. Field visits were unable to delineate the patterns of these landscapes beyond their notion of being low-grade homes. Seeing the changes they undergo and the effects they create requires more extensive analysis, which is provided in literature. Housing creates many of the effects outlined previously, where worker influx and housing booms result in straining community resources, services and infrastructure needed to function (Jerolmack and Berman 2016).

Man-Camps: Man camps are dynamic workforce landscapes existing outside of communities in places where there's little to no existing housing infrastructure. They are made to be self-sufficient, and self-operating. Their existence is ephemeral and intentionally temporary. Built bare-bones, they are erected as quickly as they can be torn down. Man-camps vary be region and are shaped by their surroundings. They may be trailer parks, barracks-like houses, massive lodges, or may be outlawed entirely like in Weld County. The further removed from urbanized areas, the more common (and larger) they become. South Texas and North Dakota are places where existing settlement is sparse and where man-camps are a defining component of the Fracklands.



Figure 10.3.3. Man camp in North Dakota.
(Donn Barrett, 2013. Attributed under a CC BY-NC-ND 2.0 License)



Figure 10.3.4. Double C Resort Work housing in Chrystal City, Texas. Paved roads here indicate more permanence in settlement than camps in the Bakken. (Google Earth, 2016)

Story: *The North Dakota Man Camp Project: The Archaeology of Home in the Bakken Oil Fields* (Caraher et al. 2017)

This research documents more than 50 temporary housing developments in the Bakken oilfields. It examines these settlements from perspectives of architecture and social sciences. Being outside the jurisdiction of municipalities, these settlements have been allowed to be shaped by those who live within them, rather than shaped by codes and standards, architects and so on. this report details how those living in these settlements are taking attempts at making temporary housing more like permanent housing.

Caraaher et al. focuses on five aspects of the informal housing – insulation, enclosures, platforms, property demarcations, and ritual objects – in which, "to establish the fixity of the RV and make it more suitable as a year-round residence..." to, "make them more 'like home.'" and to make them more like home elsewhere, in the suburbs. (Caraher et al., pg. 285, 2017)



Figure 10.3.5 Example of the more impromptu housing found in the Bakken. An entryway added on to an RV, and attempts at exterior decorations. (Used with permission ©William R. Caraher, 2014.)

"the residents of mass-produced mobile homes and RVs modified and improved their homes to meet the practical realities of challenging climates." (276)

"Polystyrene blue is ubiquitous throughout the man camps, creating a surreal relationship between the verticality of the weatherizing plastic and the horizontally expansive blue sky above." (277)

"The addition of enclosed space not only increases the fixity of the RV, but also creates the kind of meaningful spatial individuation associated with traditional domestic space." (279)

"The architectural elaboration of RVs and mobile homes represents a key strategy in consolidating informal settlements and can mark a step toward permanent and more formal settlement." (280)

"one of the most remarkable aspects of man-camp life is this interplay between the temporary character of most settlements and the willingness – even the insistence – of residents to negotiate domestic space and reinforce some sense of fixed domesticity." (283) -In regards to creating enclosures.

"The weight bench, camping furniture, and the barbecue become icons of the male who is absent at work and reinforce the space of workforce housing as the space of work in the domestic realm." (283) -In regards to objects of ritual.



Figure 10.3.6. Farmland being cleared and converted for temporary housing in McKenzie County, North Dakota.
(Evanson, 2013. Attributed under a CC BY-SA 2.0 license)



Figure 10.3.7. RV Man camp near Tioga. (Google Earth, 2014)



Figure 10.3.8. RV Man camp near Tioga. (Google Earth, 2016)



Figure 10.3.9. RV Man camp near Williston. (Google Earth, 2014)



Figure 10.3.10. RV Man camp near Williston. (Google Earth, 2017)

Pattern: Housing and Boom to Bust Cycles in North Dakota – RV Camps

Findings: North Dakota experienced a major boom in the Bakken oilfields in the early 2010's. However, by 2016 the boom had already declined, catching many off-guard. The boom to bust is most evident in the RV camps of the region. In Tioga all that's left are piles of debris. In Williston, only a few trailers remain.



Figure 10.3.11. Man camp near Wattford (Google Earth, 2014)



Figure 10.3.12. Man camp near Wattford. (Google Earth, 2017)



Figure 10.3.13. Man camp near Wattford. (Google Earth, 2014)



Figure 10.3.14. Man camp near Wattford. (Google Earth, 2017)

Pattern: Housing and Boom to Bust Cycles in North Dakota – Housing

Findings: Shown in these four images are changes to 2 different man camps. In the top two images changes are most apparent with entire structures being removed or moved. In the bottom development, changes are less apparent. Lack in vehicles looks ghostly in appearance.



Figure 10.3.15. 'Rain Containers' sit idle on an otherwise empty area of land in Weld County. (Lanning, 2017)

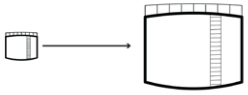


STORAGE SITES

COUNT

UNKNOWN

SIZE



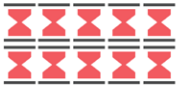
1 - 50 ACRES

PLACE



NEAR WELLS

LIFE



<10

USE



STORAGE
FRACK MATERIAL/VEHICLES/EQUIPMENT

SYSTEM



PART OF WELLS/FACILITIES

IMPACT



Low
UNDERUTILIZED LAND

All aspects of hydraulic fracturing require large amounts of material to function. While substantial resources are needed to construct a well site or facility and frack, additional materials are needed to operate it. These material in-turn require large amounts of land to be available as a staging ground for such operations. Often storage sites are temporary. Many exist or have existed on lands functioning as well pads and facilities.

Well pads are made much larger when being drilled, as additional land is needed for staging materials and vehicles. Once a well is producing, these temporary land clearings are either remediated, or left to nature. Temporary clearing may also exist near a well site rather than on. Storage sites can also be more permanent, serving many facilities instead of one. These are often run by independent companies, providing equipment such as tank batteries, pipe, metal, vehicles, etc. However, these places are highly subject demand. Shrinking or growing in size; being used or unused.

Individual materials have common storage sites associated with them:

- Impoundments: Freshwater is often stored in large constructed holding ponds. These can then be reused for waste-water disposal or be in-filled.
- Container sites: Chemicals, sand, and water are stored in large transport containers on or near well pads. These are only needed for drilling and injection phases.
- Equipment sites: Places for storing fracking equipment, infrastructure, and vehicles. Often maintained by local business who sell / rent equipment out to oil and gas drillers.

Reflections from the Field:

Field visits revealed the variability of storage sites. Many places where large amounts of materials were being stored was simply on well pads during drilling or fracking. However, large cleared areas of land with fracking related materials or equipment were also seen, often in arbitrary locations. In Weld County numerous examples of this was seen, where often less than 10% of a cleared area of land was being utilized for storage while the rest was left empty.

In all three regions large scale staging areas for equipment were common. Often these were being run by local businesses. Some were extensions of gas stations, others were staging grounds for trucks, rigs, and cranes. In all three regions water impoundments existed, however they appear most common in Appalachia. In Colorado and Texas, trucks transporting containers holding water were more common.

Overall the usage of such landscapes was hard to grasp from field visits. Long term examination in weeks not hours was needed in understanding the temporal phenomena associated with these sites, e.g. Will these landscapes sit stocked full of tank batteries indefinitely or will they fill demand then fade into the surrounding landscape? However, it became clear that if any sort of fracking facility exists their will most likely be one or many landscapes for storage in close proximity.



Figure 10.3.16. A large rig, truck, and equipment storage facility near La Salle, Colorado. (Lanning, 2018)



Story: Perspectives from Oilfield Workers (Filteau 2015)

Sociological perspectives and opinions from that of community members, land owners, lessees and so on have been well documented thus far. However, the perspective of oil field workers has not. Filteau, 2015 demonstrates examples of how oil and gas workers in Appalachia see themselves, how they perceive fracking, and how they perceive the perceptions of the communities they have come to work within. It shows that workers are stigmatized by locals, yet have their own stigma of the locals. As a result, while they may reap benefits of high income, they are left alienated and unwanted by the rest of the community contributing to a lower quality of life.



Figure 10.3.17. A well in Dimock, PA just after being drilled in 2011. (Google Earth, 2011)



Figure 10.3 .18. Same well in Dimock, PA six years later in 2017. (Google Earth, 2017)

"'Let's just say if somebody asks me what I do, I don't tell 'em... a lot of people talk trash about us—they all thought of us as [oil-field] trash for years... alls we're known for is getting drunk or partying or getting DWIs or getting thrown in jail.'" (1157)

"'If it wasn't for guys like us up here drilling these wells for oil and gas, they don't realize how much petroleum is used in everyday stuff. Anything you touch in one single day has got something to do with the oil and gas industry... And I just think that what we do is really under appreciated by a lot of people... it's not the most glamorous job in the world but somebody's got to do it.'" (1159)

"'There's a sign going out to one of our rigs underneath an overpass and it says: "Go back to Texas, gas bastards." I think that person needs to either stop hatin' us, hate us all the way, or don't hate us at all, because I'm sure you drove your vehicle to get to that overpass. I'm sure that paint can you used was made from petroleum products.'" (1161)

"'Our biggest thing out here is safety and the environment... A lot of people judge us because they look at us like we hurt the environment and we really, really don't. I mean, [safety and the environment] that's top priority out here... The local mom and pops love us. They see that their revenue is jumping 200–300% a month. So knowing that in the back of your mind... we're evil?'" (1160)

"'It's a really well-paying job and it's fun... The schedule is 14 days on and 14 days off, so you work two weeks in a row and you're on call for those two weeks and then you're off.'" (1161)

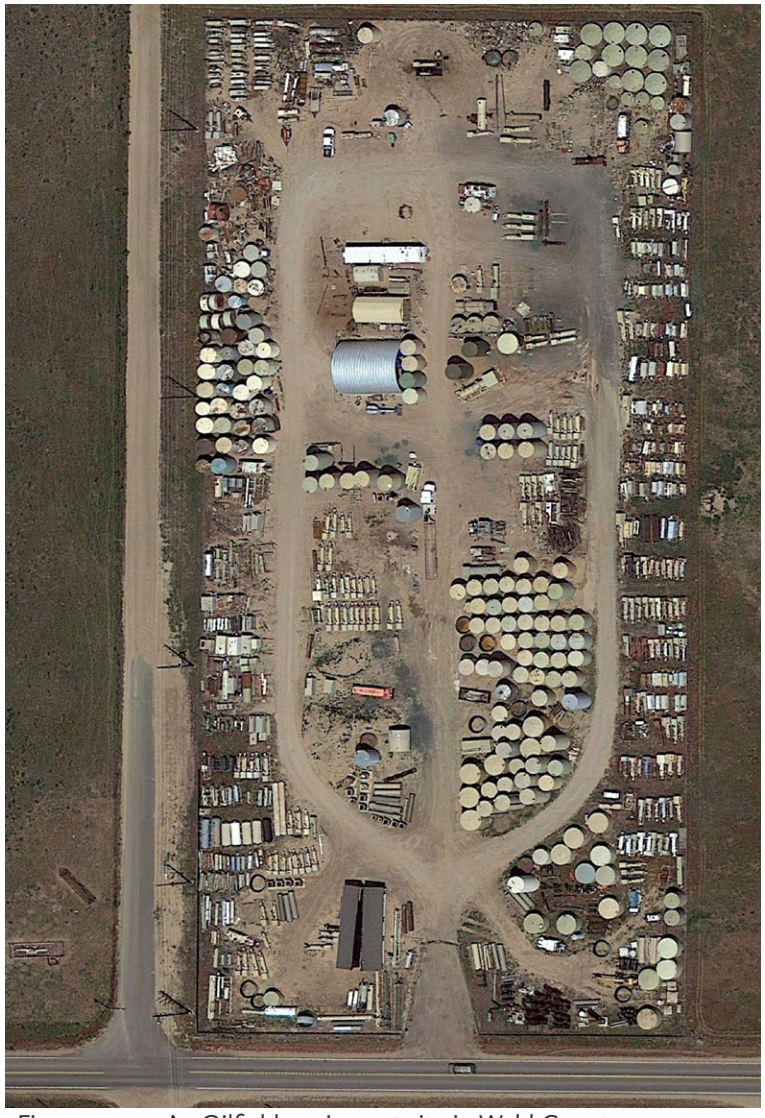
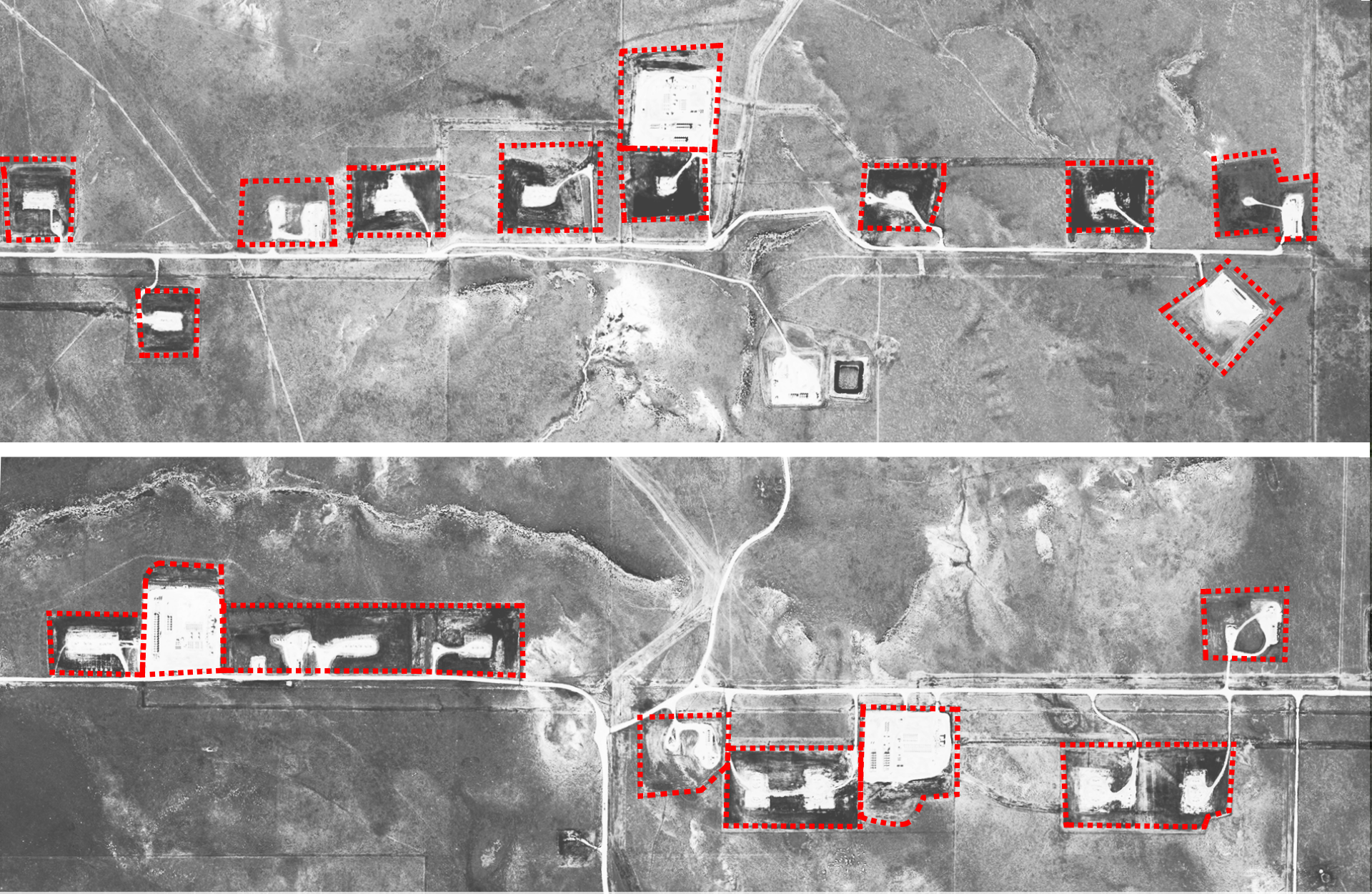


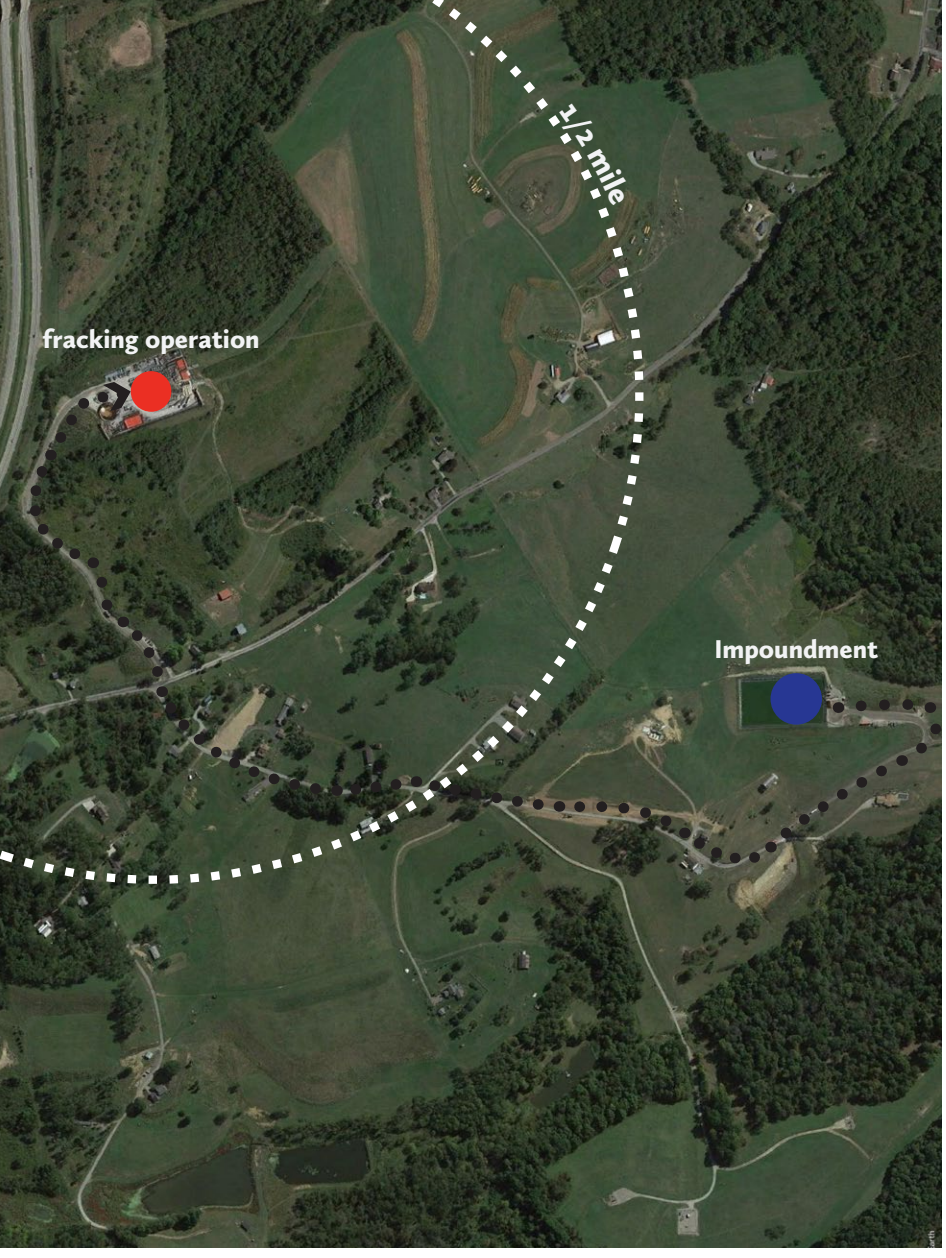
Figure10.3.19. An Oilfield equipment site in Weld County. (Google Earth, 2016)

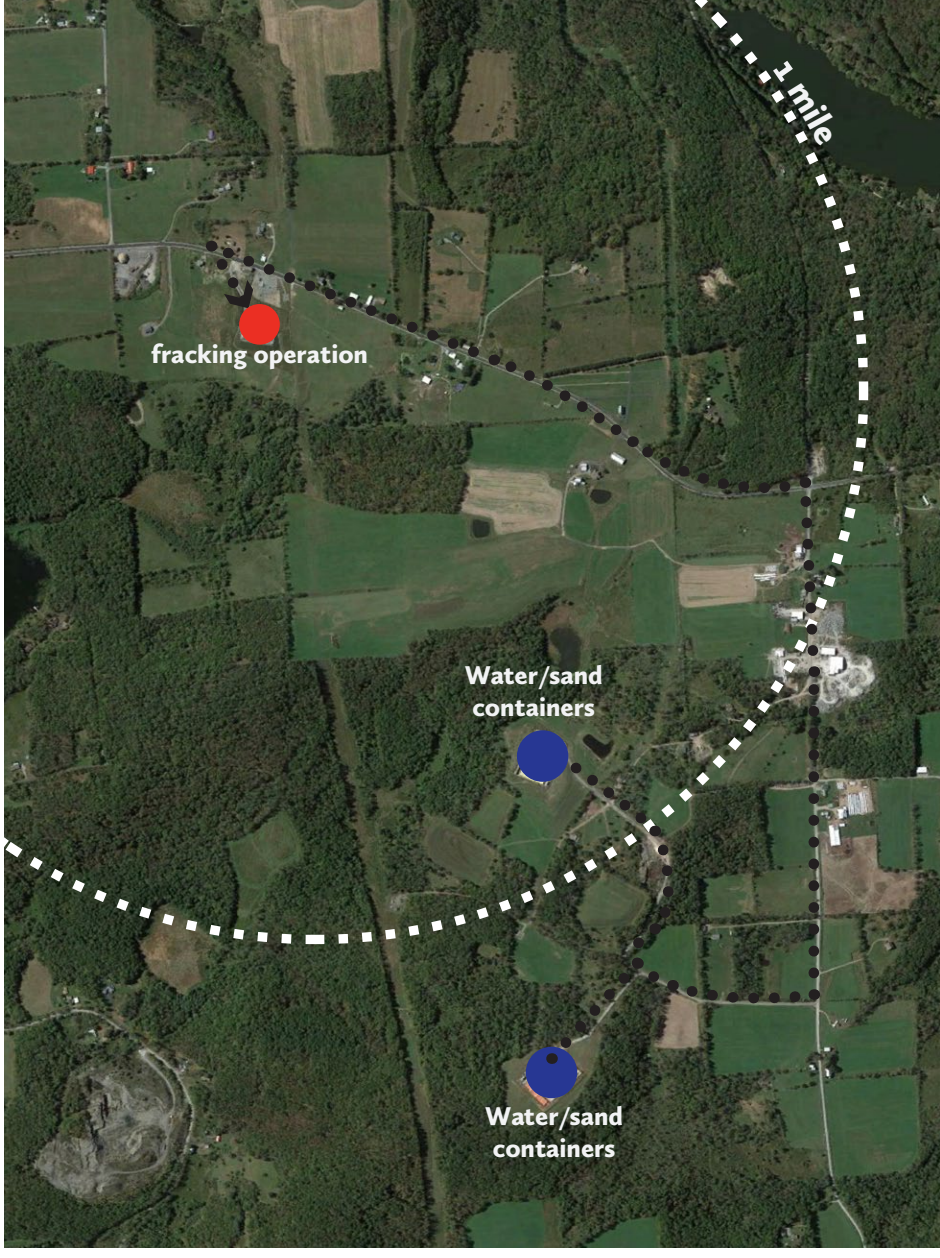


Pattern: The Retreat of Well Pads After Drilling

Figure 10.3.20. Well Retreat. (Lanning, 2018)
Base Imagery: (U.S. Geological Survey, 2017)

Findings: These example from the Pawnee Grasslands of Weld County shows how much a wellpad will shrink after Fracking. While land is reclaimed the issue is that the land had to be heavily disturbed in the first place.





Pattern: Finding Storage Landscapes – Material Storage Sites in Pennsylvania

Figure 10.3.21. Finding Storage. (Lanning, 2018)
Base Imagery: Google Earth, 2017

Findings: As shown from findings in the field, locating storage landscapes that were not a part of a well was not easy. However taking a view from above, in these examples from Pennsylvania, connections can be traced . The issue is that by locating these sites far from wells, road infrastructure is heavily strained by the increased transportation demands.



Figure 10.3.22. Waste water disposal site near Pennfield PA with both a pit and tanks. (Google Earth, 2017)



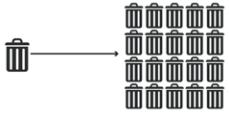
DISPOSAL SITES

COUNT

UNKNOWN WASTE PITS

38,169 INJECTION WELLS

SIZE



1 - 20 ACRES

PLACE



NEAR WELLS

LIFE



60

USE



WASTE DISPOSAL
SOLID/LIQUID/HAZARDOUS

SYSTEM



OUTPUT

IMPACT



VERY HIGH
WATER CONTAMINATION

While Hydraulic fracturing requires substantial input, it also creates a substantial amount of waste. Disposal sites are in a sense storage landscapes. Storage of waste. They are landscapes intentionally or unintentionally created for the disposal various materials and equipment, chemicals, liquids and gases. These landscapes may have more permanent facilities for disposal, be temporary fittings, or be entirely meshed within the greater landscape. They may be documented, or more often than not, undocumented. Their use may be entirely for fracking related waste, or as part of a larger landscape of waste disposal. These sites can range in size from that of a minuscule waste pit to that of a large-scale landfill. Thus, disposal sites are highly variable and may number in extremes.

Disposal sites may also be one of the most controversial and damaging of the Frackland components. They can substantially effect the health of communities and the environment, compromising both groundwater and air quality. While a disposal site may be transient in nature, fading in and out of existence with haste, the damage it may leave behind may persist for generations.

Waste Water Disposal:

Chief among disposed fracking material is waste-water, the primary bi-product of fracking. Waste water is the leftover liquid from the fracking process that comes up with oil and gas. Millions of gallons of wastewater can be produced with each frack (Duke Today 2015). Its disposal is handled differently by region. Disposal methods include:

Class II injection: Waste water is re-injected into the earth in wells that have been depleted. These are common nationwide, but most common in Kansas, Oklahoma, and Texas. In addition to water contamination concerns, injection wells are to blame for recent increase in seismic activity plaguing areas in and around Oklahoma (McGarr et al. 2015).

Surface Pits: Water storage sites are often re-adapted to be used for storing waste water. Over time the water will slowly evaporate. These are the most common throughout.

Surface tanks: Waste water can be transported to tanks where it will sit in permanent containment.

Facilities: As touched on with processors, there are also facilities where waste-water is cleaned. However, waste still exists and will need to be disposed of, most likely in a landfill.

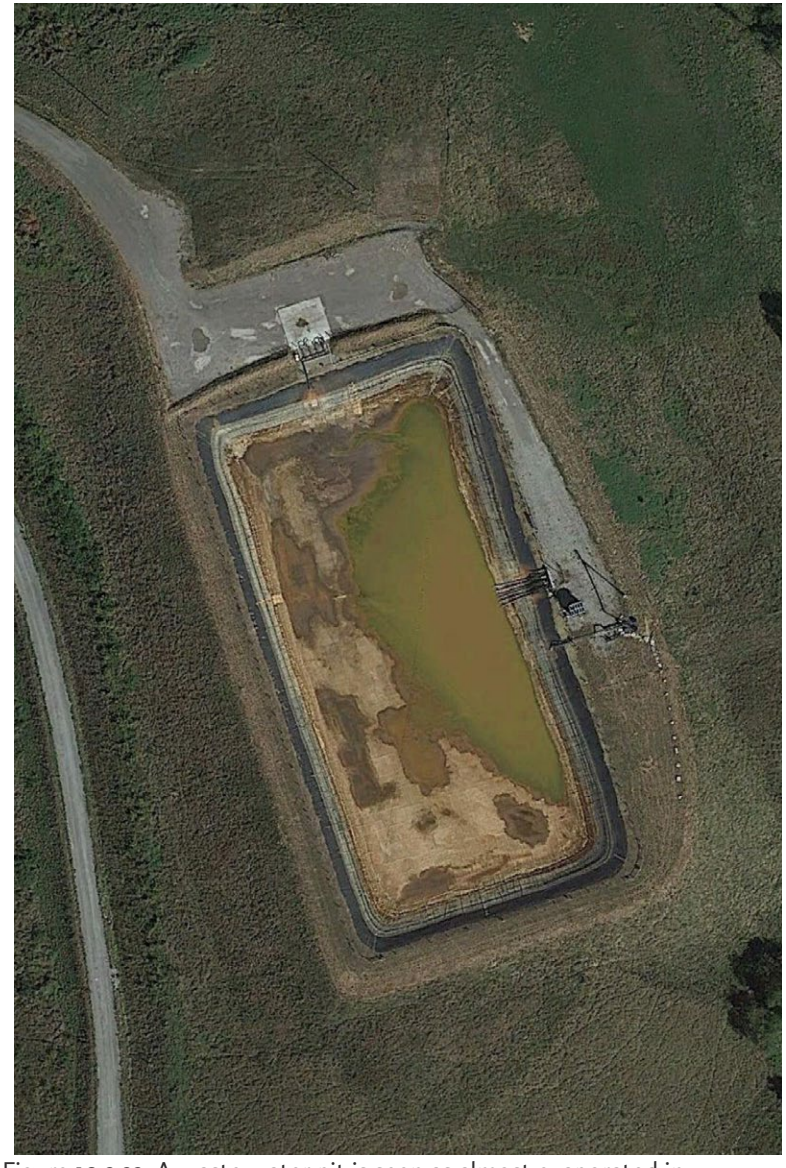


Figure 10.3.23. A waste water pit is seen as almost evaporated in Washington County, Pennsylvania. (Google Earth, 2017)

Reflections from the Field on Waste Water:

Wastewater disposal was the most visually evident disposal site in the field. In all three regions waste water pits were seen. In the field however they were well hidden from view, often hiding behind large hills or buried deep within inaccessible areas. Only could aerial imagery truly reveal their location and their story. In Texas these pits were uncommon but still meshed within communities like all the other facilities. Two sat within the historic African American Stop-Six neighborhood of Fort Worth. What appeared to be a large hill with recently planted trees was a strategically raised earthwork to hide the existence of a waste water pit. In Weld County waste pits were located deep within public land accessible only to oilfield workers. In Pennsylvania and West Virginia well pads (which are commonly hidden within forest or on hilltops) typically had waste pits or tanks nearby.

It became clear that surface pits, while the most provocative, do not account for all the waste water generated. Injection wells were unobserved, perhaps appearing as any other well. Storage tanks were less common in Weld and Tarrant. Historic imagery from each region revealed that many pits existed at a point, but have since faded – evaporate, filled, or paved over. Ultimately the non-existence of either surface pits or tanks predominately in Texas and Colorado can only point to the surface below. Waste must end up somewhere.



Figure 10.3.24. Waste water pits in the Pawnee Grasslands. (USGS, 2017)

Reflections Beyond Waste Water:

Disposal sites unrelated to waste water were harder to find. Short observation periods made it difficult to see where much of the industrial waste of fracking ends up. Much may end up recycled, scrapped, in a landfill, or simply discarded nearby. Often differentiating between what was being stored for reuse (a storage site) or stored indefinitely as waste was hard to come by. However, scrap sites were seen in each region, where piles of metal, tank batteries and more sat rusting. It can only be assumed these are being treated as waste and will not be reused.

While varying by state regulations, oilfield waste that does not end up in surface pits will end up being disposed of in commercial hazardous disposal landfills. In Colorado, multiple landfills were seen near the densest oilfields. Lack of data and government transparency makes it was hard to say how much the two interface, however this did reveal an association between fracking and another landscape system: the landscapes of waste.



Figure 10.3.25. Tank Battery disposal located behind a gas station in Weld County. (Lanning, 2017)



Figure 10.3.26. Fracking waste disposal landfill in Weld County. (Google Earth, 2016)

Story: Fracking and Social Injustices in Rural Pennsylvania (Malin and DeMaster 2016)

The Appalachian region produces the majority of the nation's natural gas. Existing primarily in rural, often impoverished agrarian areas, fracking development has greatly impacted the lives of farmers with small to mid-sized operations. Malin and DeMaster 2016 interviewed 36 Pennsylvanian farmers to investigate the injustices being seen in this region.

"When farmers face both procedural inequities and the inability to avoid dependencies on volatile industries, this represents a unique form of environmental injustice. Farmers therefore take on leases they feel unable to reject and then contend with multiple environmental risks and uncertainties as a result." (287)

33 of the 36 interviewed had natural gas activity on their land and had accepted the risks because they needed the income:

"[the 33 respondents'] reported in clear, simple terms that their farming livelihoods now depended on natural gas-related income, due to the instability associated with farming, their lack of safety nets, and the volatility of global commodities markets" (285)

"'we are really, really hurting. So a lot of us are looking for any way out. We're doing what we love, and it costs us money to farm. So we finally break down and say 'I'll sign the damn lease. It's a way to save my cows.'" (283)

Once respondents had signed-on, nearly all experienced trouble:

"they put in the pipeline…it's our hayfield. You should see the disgrace. They put in a temporary waterline down here… And it broke. We had frack water all over the friggin' place. They completely destroyed our land."

"'A lot of people have given up farming because they [the gas companies] weren't careful…For us, they put in water lines and didn't re-seed the hay field properly. That might affect us next year, on the amount of cattle we're able to keep. They don't care. If I lose a year, that means I lose the calves that I can't send to market.'"

"'There was one time, two years ago now, something leaked from a gas truck going down the road… they had to dig out the whole road and replace it.'"

Farmers are caught focusing solely on immediate financial safety and not long term, leaving many in hopes of striking big; those that have often leave.

"'This year we lost 90–95% of our crop… So, in our case, financially I don't know where we'd be without gas money.'"

"'Before the gas boom, there were so many dairy farmers. Yeah, they were struggling, they had a hard time making ends meet… But there are so many dairy farmers that as soon as they started getting royalties…they're gone, they're not ever coming back.'"



Figure 10.3.27. Wastewater pit in Weld County. One of the only pits that was not hidden behind earthwork and could be seen in the field from groud level. (Lanning, 2018)

Story: Fracking and Social Injustices in urban Texas (Johnston et al. 2016)

While in rural Appalachia it was found that impoverished residents were more likely to be adjacent to fracking activity, there has not been any connections to race. Most of the regions looked at in this study are predominately white, however Southeastern Texas – The Eagle Ford Shale – has a large number of non-white residents. Johnston et al. set out to see if there were any injustices associated with the high number of minority populations in this region. This study may also clear up uncertainties regarding the phenomena of injection wells. From their findings, they found that:

"An estimated 385 000 people (13.7% of study area) lived within 5 kilometers of a waste disposal well, whereas 790 000 lived near a unconventional oil and gas extraction well." (552)

"The proportion of people of color living near an injection well was 1.30 times higher than was the proportion of non-Hispanic Whites living near an injection well." (552)

"Our findings mirror a national trend that was notably identified more than 2 decades ago in studies confirming that toxic waste sites were sited disproportionately near people of color." (553)

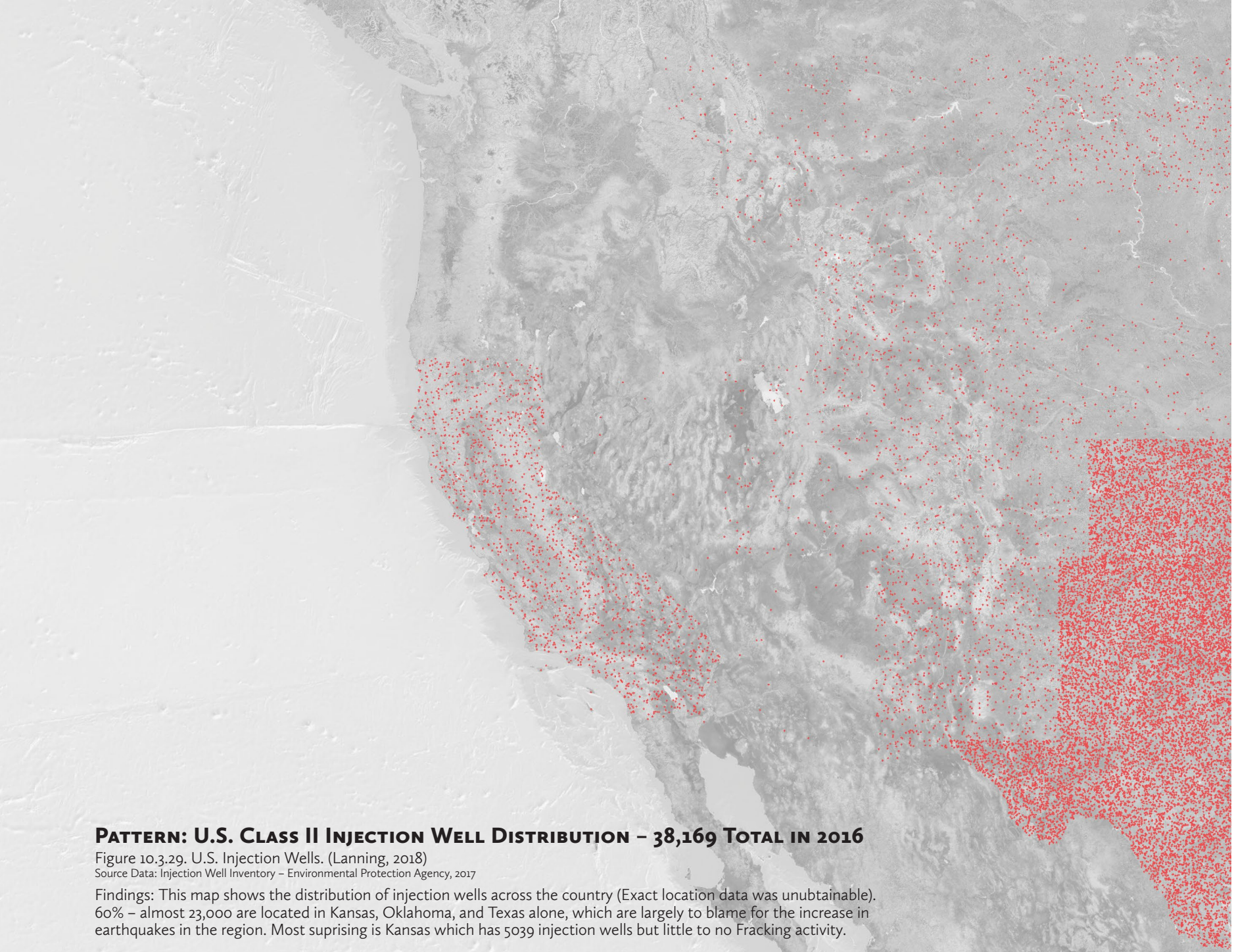
"disposal wells are more likely to be permitted in communities with higher levels of poverty, although patterns of racial disparities persist after accounting for poverty." (553)

"Whites own the vast majority of land above the shale formation. These landowners may receive economic benefits from UOG drilling operations, and they potentially avoid environmental ills when wastewater is transported to other communities for disposal." (554)

"Marginalized communities are often targeted because of the perceived lack of political power and limited resources with which to challenge a permit. In this case, owning land is one indicator of power—and people of color own only a fraction of land compared with White residents. (554)



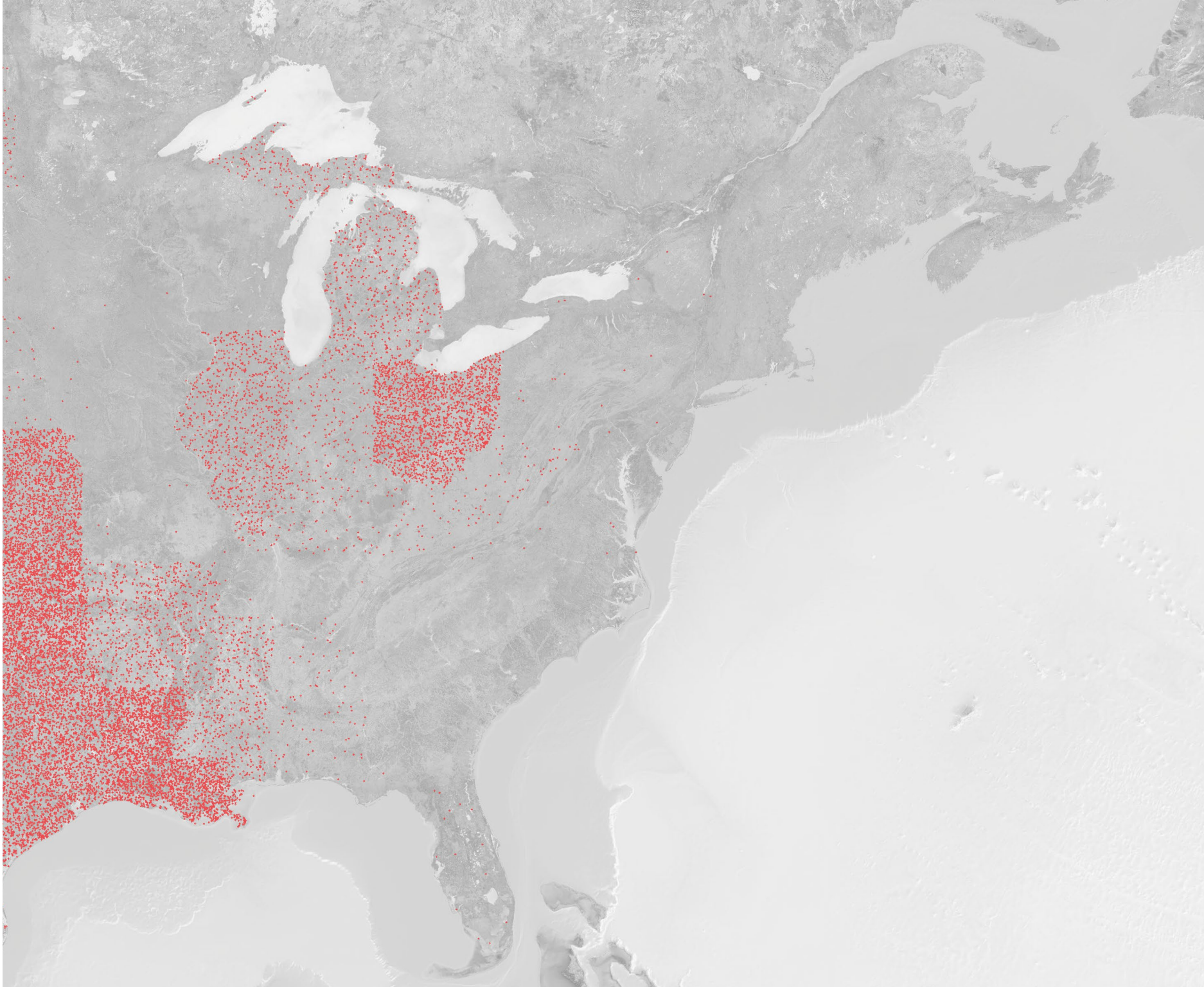
Figure 10.3.28. Waste water pit in the Stop 6 neighborhood of Fort Worth. (U.S. Geological Survey, 2015)



Pattern: U.S. Class II Injection Well Distribution – 38,169 Total in 2016

Figure 10.3.29. U.S. Injection Wells. (Lanning, 2018)
Source Data: Injection Well Inventory – Environmental Protection Agency, 2017

Findings: This map shows the distribution of injection wells across the country (Exact location data was unubtainable). 60% – almost 23,000 are located in Kansas, Oklahoma, and Texas alone, which are largely to blame for the increase in earthquakes in the region. Most suprising is Kansas which has 5039 injection wells but little to no Fracking activity.



10.4 THE PHANTOMS

Phantom Fracklands have components of every Frackland discussed thus far. They are the echoes of past oil and gas extraction, and omens of what may be to come. Their components may be, persisting: existing until directly addressed. They may be veiled: hidden below or behind. And they may be transient: scars left behind from unknown sources. Whatever the story is that they tell, Phantom Fracklands and their components exist as lingering reminders of what desperation for energy carries with it. And they will do so until they are acknowledged and addressed.



Figure 10.4.1. A phantom. In May, 2017 in Firestone, Colorado a gas buildup from a nearby abandoned gas well exploded underneath a home, killing two who were inside. One year later a ghostly footprint remains.





Figure 10.4.2. An abandoned pump in Oklahoma. (USGS, 2011)



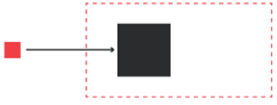
ORPHANS

COUNT

MILLIONS CONVENTIONAL

THOUSANDS UNCONV.

SIZE



1 - 20+ ACRES

PLACE



ANYWHERE WITH OIL/GAS

LIFE



UNTIL REMEDIATED

USE



NONE

SYSTEM



POTENTIAL FUTURE

IMPACT



HIGH

TAXES PAY THE COST TO CLEAN UP

Orphans are facilities that have been left behind. They no longer serve a purpose other than to be rusting reminders of forlorn oil and gas boom. Orphans are an industry term referring to wells, facilities, or pipelines identified as having no legal or financial affiliation with its current or future state (OWA 2003). However, this notion of lost affiliation can be attributed to any of the landscapes highlighted previously. At some point in the process they have been left behind irresponsibly due to lax regulations, low or no production, or rapid swings in market demand. Often this puts oil companies into bankruptcy which relinquishes ownership. Since ownership no longer exists, deciding whose responsibility to remove that land and pay for it is complicated. Often it ends up as the responsibility of the taxpayer to pay for addressing these sites (Hand, 2018).

These landscapes may be relics of conventional oil and gas development or of more recent hydraulic fracturing activity. Their numbers are generally unknown, with most orphans being undocumented (Zbrorowski 2014). What's good is that total abandonment has become less common with fracking. However, a common trend is for facilities to sit in production limbo, temporarily shutting down until demand is high enough for someone to buy in and restart production. Unless they are restarted, the responsibility of addressing these facilities becomes an issue for society whether aware or not.

Reflections from the Field:

Abandoned oil and gas facilities dot the landscape anywhere that has experienced an oil boom. The reality of a boom is that some win and some lose. The losers are the rusting oil derricks that litter agricultural fields, and the abandoned processors in the Gulf -amongst others. For those of the regions that experienced these booms, (Appalachia, Texas, Kansas, Oklahoma) smaller well equipment is a familiar element of rural landscape. Their presence is veiled or subtle when present. It is the larger facilities that sit unused for years or decades that beg the question: why? What lead to the numerous fracking well pads along a stretch of road in Weld county to be branded “out of service”? What lead to the abandonment of a refinery in Ventura County California? What left an entire oilfield in Pennsylvania labeled as abandoned? But ultimately: Why do they persist?

Fracking related orphan facilities are an uncommon site. However, the presence of these facilities grafted among those that are currently active conjures up visions of the future: A future that mirrors that of the past with conventional facilities. Only the larger more mechanized abandoned facilities of today will leave a much greater impression upon the landscape than those of yesterday .



Figure 10.4.3. Tank Batteries marked as out of service in Weld County. (Lanning, 2017)



Figure 10.4.4. Abandoned refinery near Los Angeles, California. (Gustafsson, 2011. Attributed under a CC BY-SA 2.0 license)

Story: Learning from Canada's Orphan well dilemma (Jeneroux 2017; Power 2016; Sandals 2017)

While orphan wells are a known widespread dilemma in the United States, they may be an even larger issue in Canada. The providence of Alberta has been known for major oil booms in the past yet has been irresponsible in cleaning up its now defunct facilities, which includes 77,658 well bores (Jeneroux 2017). Understanding the orphan well problem in Canada may be an insightful window into what may come about in the United States if it does not address its own orphan well problem today and in the future as current booms dissolve and regulation is unable to keep up with reclamation.

Power, 2016 highlights Alberta's orphan well problem:

"thousands of inactive wells dot the provincial landscape on at times valuable farmland, like environmental potholes left for future generations… there are orphaned wells dating back to the 50s and 60s that still have not been dealt with. The longer a well sits abandoned, the higher the risk of accidental release or groundwater contamination." (1)

"Since its inception just over two decades ago the Orphan Well Association has reclaimed over 650 wells. Over 540 wells have been abandoned in Alberta in the last 12 months, up four times from previous years as especially junior and intermediate companies have struggled with record-low oil prices. An estimated 700 orphaned wells are the result of bankruptcy." (1)

Jeneroux 2017 proposes to convert these wells into geothermal facilities:

"the decommissioning of the inactive wells would cost anywhere from $7.8 billion to $23.3 billion. Alternatively, the environmental cost of inaction is immeasurable… the struggling oil and gas industry has meant thousands of oil and gas workers have been laid off." (71)

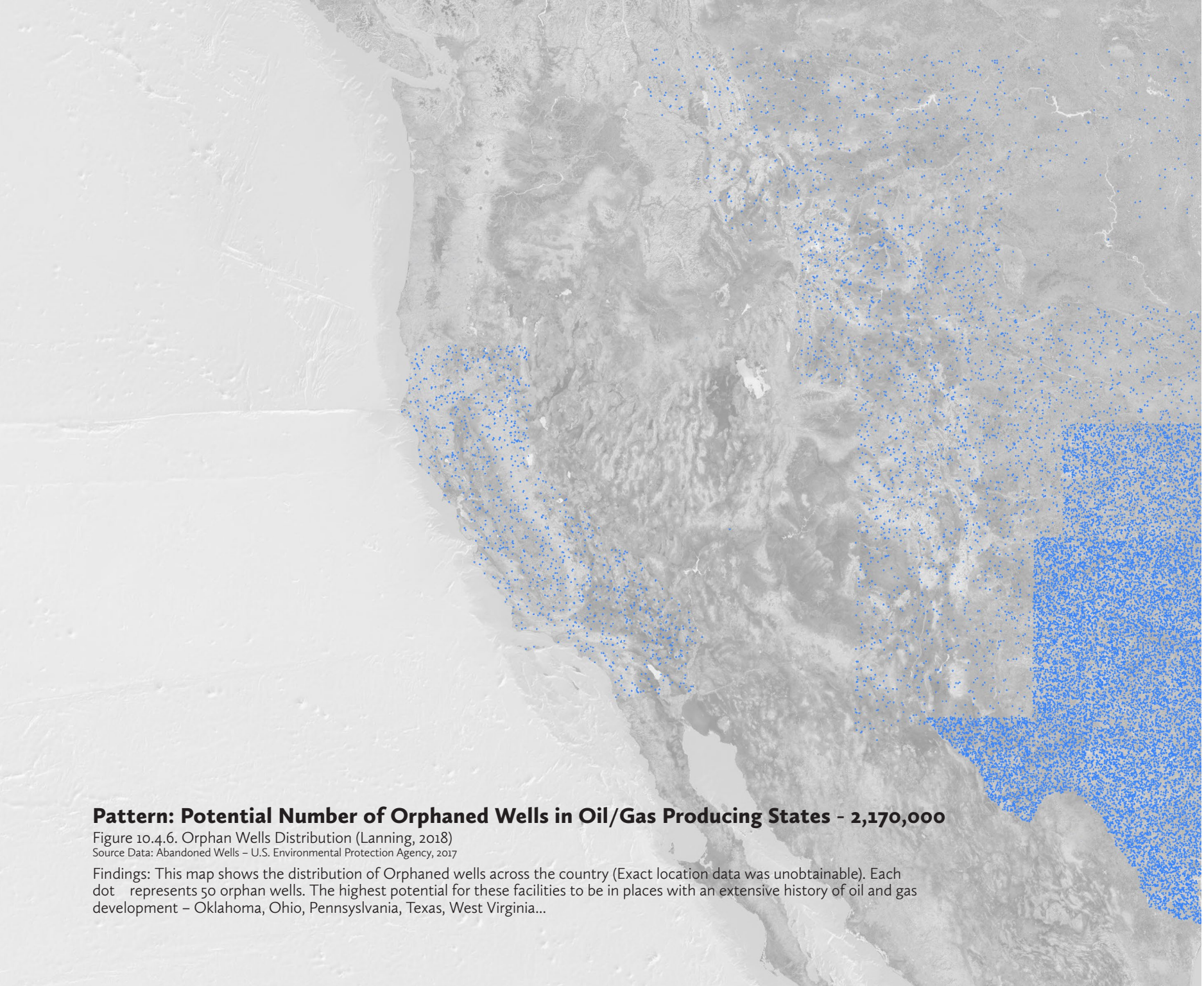
The conversion of these wells into geothermal-producing assets was repeatedly raised as a cost-effective, environmentally sustainable and job-creating solution to the problem.

Sandals 2017 presents an artist that is getting people to "adopt these wells"

"'the adoption process allows people to think about the issue in another way. Some people aren't even aware of orphan wells, so I hope this at least builds awareness'" (1)



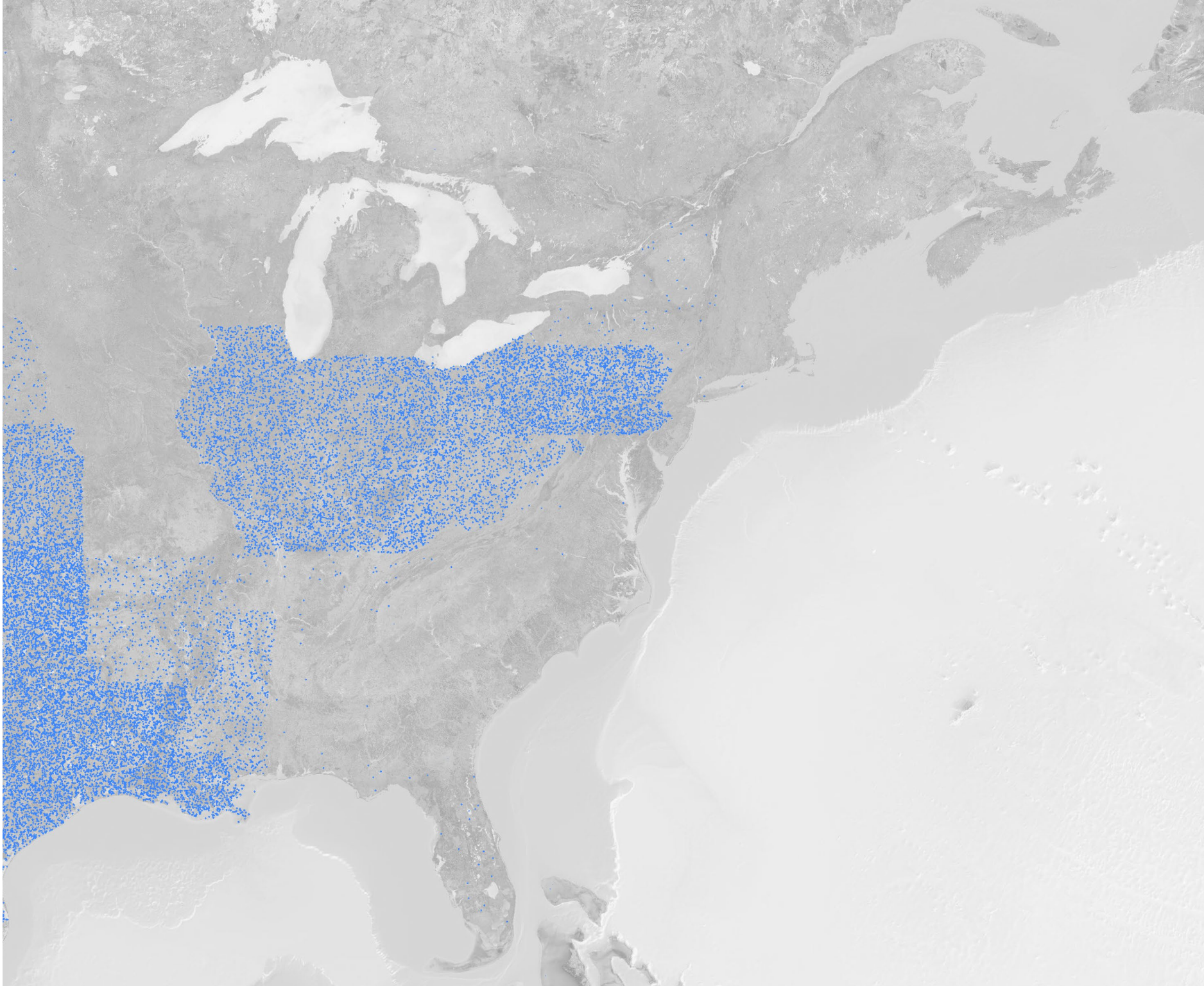
Figure 10.4.5. Defunct oilfield as indicated by WV state data near Folsom, West Virginia. (Google Earth, 2017)



Pattern: Potential Number of Orphaned Wells in Oil/Gas Producing States - 2,170,000

Figure 10.4.6. Orphan Wells Distribution (Lanning, 2018)
Source Data: Abandoned Wells – U.S. Environmental Protection Agency, 2017

Findings: This map shows the distribution of Orphaned wells across the country (Exact location data was unobtainable). Each dot represents 50 orphan wells. The highest potential for these facilities to be in places with an extensive history of oil and gas development – Oklahoma, Ohio, Pennsyslvania, Texas, West Virginia...



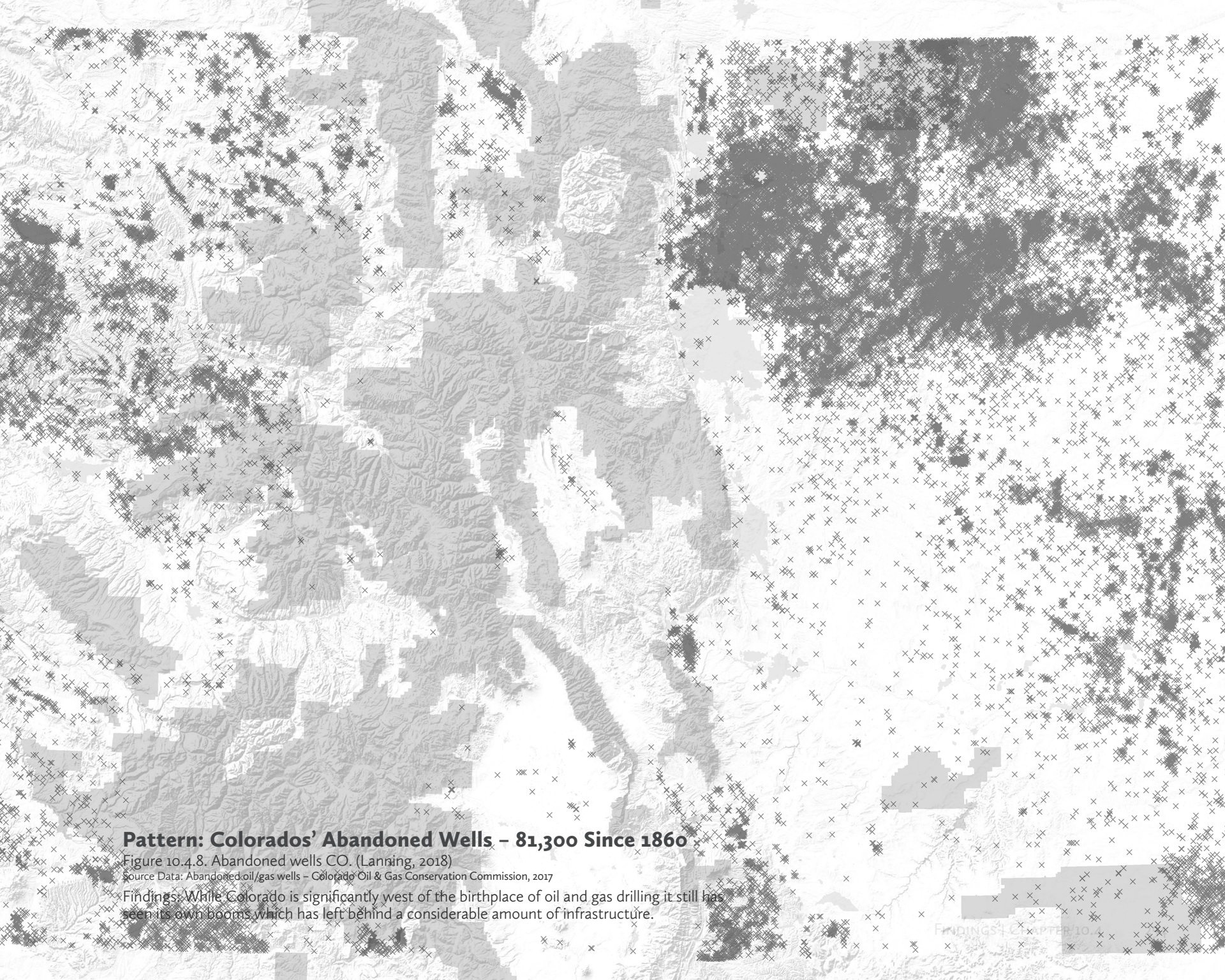


Pattern: West Virginia's Abandoned Wells – 57,491 Since 1859

Figure 10.4.7. Abandoned wells WV. (Lanning, 2018)

Source Data: Abandoned oil/gas wells – West Virginia Department of Environmental Protection, 2017

Findings: West Virginia is one of the birthplaces of drilling for oil and gas. This extractive industry is a significant part of its history and which has left considerable marks across the state.



Pattern: Colorados' Abandoned Wells – 81,300 Since 1860

Figure 10.4.8. Abandoned wells CO. (Lanning, 2018)
Source Data: Abandoned oil/gas wells – Colorado Oil & Gas Conservation Commission, 2017

Findings: While Colorado is significantly west of the birthplace of oil and gas drilling it still has seen its own booms which has left behind a considerable amount of infrastructure.



Figure 10.4.9. A Fort Worth well pad is left to nature. A wound for the landscape.
(Google Earth, 2007; 2016; 2017)



WOUNDS

COUNT

1,189 WORK DEATHS IN 10 YEARS

10,000 SPILLS IN 10 YEARS

SIZE

ANY

PLACE



ANYWHERE FRACKING INFLUENCES

LIFE

∞

UNTIL REMEDIATED

USE



NONE

SYSTEM



OUTPUT

CONSEQUENCE

IMPACT



VERY HIGH

DAMAGE TO PEOPLE AND ENVIRONMENT

Unlike orphans which are physical facilities left behind, wounds are the remnants of damage left by the Fracklands and their components themselves. They are the marks, blemishes, and imprints that fracking has left on a landscape, an individual, a community, and/or a society. They may have once been purposely made such as a well pad that has been stripped of equipment and left as a physical wound on the land. Or they may be unintentional, unplanned or unaccounted for. Happenings that have resulted in physical change to the landscape, to communities, and to the lives of those who inhabit them.

Intentional (planned) Wounds:

Most regulation today does not strictly enforce adequate remediation techniques. As discussed, many oil and gas lessees have felt that their remediated land that's been disturbed by the oil and gas industry has not been brought back to levels it was once at (McGranahan et al. 2017). Sites are left in a place of limbo, unproductive and not yet functioning as reclaimed to having a function . A defunct facility may be cleaned up, but the footprint, slab, or compacted soil will be left behind for weeds and scrub grass to slowly swallow up. Over time these landscapes will slowly fade, forming a faint outline that they were once used for extraction.

Unintentional Wounds:

With all the processes of Hydraulic fracturing, its infrastructure, activity and movement, and large amount of waste, there's always the probability that a spill, leak, or other catastrophe such as a facility explosion will occur. Documented spills and leaks of petrochemicals and fracking waste number in the tens of thousands across the nation. While less common, catastrophic events such as fires and facility explosions will result in wounding beyond just the landscape. These incidents have the potential to wound nearby communities and sow deep scars into the lives of individuals both physical and emotional.

Unintentional events require extensive clean up measures. As these incidents grow in volume, so too does the amount of land disturbance and modification required to contain it. Cleanup of spills may take extensive amounts of time and resources or be put on a 'to-do' list for future cleanup. Many of these landscapes are and will be hidden from view unless documented. Even when documented, much of a wound may be visually indistinguishable at the surface. The true disturbance may rest beneath with the soil. Regarding catastrophe and death, wounds may never be healed, remaining in memory in people and in the landscape.



Figure 10.4.10. The Lac-Mégantic rail disaster. A train carrying oil from North Dakota derailed and exploded in downtown Lac-Mégantic, Quebec. It killed 42 people and demolished half of the downtown. (Elias Schewel, 2013. Attributed under a CC BY-NC-ND 2.0 license)



Reflections from the Field:

Finding wounds in the field is often impossible without prior knowledge. Signs of whether a place contains a scar from fracking activity, the site of a spill, or even an explosion were not immediately evident. With intentional wounds, aerial imagery transposed at different points in time can reveal the telling of how a wound came to be. In Texas these were well pads that had their wells sealed and tank batteries stripped, leaving vegetation to slowly creep over the site until its existence faded. In Weld county, wounds were locations of waste pits now filled in with soil. The visual indication only being soil color, differentiating what has been contaminated and disturbed with what has remained undisturbed.

With unintentional wounds, only by happenstance can one come across visual evidence of one. Often spills and leaks are only evident in data, as a dot of on a map which indicates what happened x amount of time ago. Like spills, catastrophe such as facility explosions are random unintended events that effect far beyond their extent. Yet often only when they are truly catastrophic like the Lac-Mégantic disaster will memory of those wounds be transcribed in place. Sadly, the memory of many wounds will go unannounced and forgotten. While in the field in Weld, one such incident occurred where a well pad went up in flames seriously wounding one worker. Whether that site retains recollection of this event is unlikely.



Figure 10.4.11. Well fire in West Virginia which burned for 9 days.
(Used with permission ©Ed Wade Jr. 2015 – Fractracker Alliance)



Figure 10.4.12. Another rail incident involving Bakken oil. The train derailed near Aliceville Alabama, spilling more than a million gallons of oil into surrounding wetlands. (Wanthen, 2013. Attributed under a CC BY-NC-ND 2.0 License)

Story: From Boom and Bust to in the Eagle Ford, Texas (Murphy et al. 2018)

One region that has seen substantial change from hydraulic fracturing is the Eagle Ford Shale region of South Texas. In a little more than a decade this region has gone from no unconventional wells to tens of thousands. The booms in this region has rapidly transformed surrounding communities. However, the boom has already lead to busts or severe decline prompting dilemmas for those who are permanent residents of the region. Murphy et al. 2018 conducted interviews both during the boom in this region in 2014-2015 and then returned after the boom in 2016.

During the Boom in 2014-2015:

"'It's not over. This isn't like the first boom... This one here is going to go on for I'd say twenty years.'.. 'I see this town as being an oil town, every bit of twenty years!'" (30)

Regarding roads: "'That's the one thing that the oil industry has brought here is getting our roads slapped up, and we only have 'x' number of dollars to put into our roads" (31)

Regarding housing: "'The reason why these people aren't bringing their families here is because there is nowhere to house the family here... '[we have] the lowest unemployment rate and no housing to go with that'" (34)

"officials have attempted to entice permanent housing developers to the region, often unsuccessfully, because the "initial costs of land are high so it drives the square-footage costs to build'... 'When you go to buy housing here... it's so high because [they think] we have a potential oil well under here!'" (35)

On retaining labor: "'we lost three or four deputies [in the county police force] to the oil industry because it paid so much better. And so, when you only have twelve deputies, that's 25 percent of your law enforcement workforce'... stakeholders lacked the financial means to attract labor away from the oil and gas industry, resulting in shortages of police, road workers, border guards, teachers, and coaches." (15)

During the Bust in 2016:

"Some stakeholders used the bust to diversify their economies: 'We'll keep reaching out to other industries, and when oil comes back, it will come back, and we'll still be here. [The shale] ain't going nowhere'" (38)

"[We've] been able to catch up on some of our infrastructure needs'"

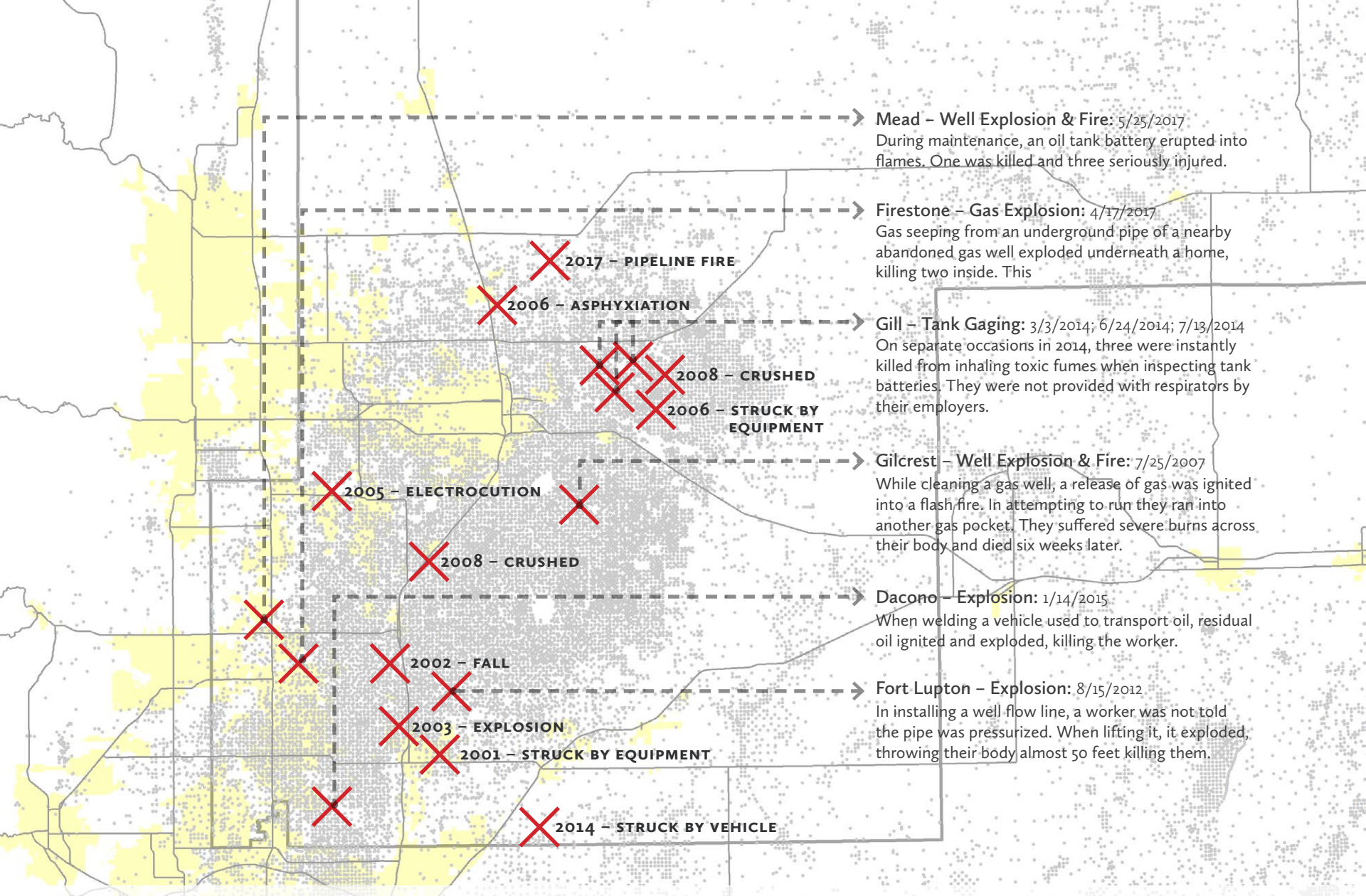
[Housing] "'The [hotels and motels] that came in late, I bet they're struggling,'... 'A lot of the apartment complexes too are struggling'... 'We've had one hotel that closed its doors... one of the last hotels that came in. It didn't do well.'" (38)

[Wages] "'We're no longer competing with McDonald's for employees. At one point, McDonald's paid entry level employees more than we did,' explained a city manager." (39)

"...petroleum workers were 'back in town, flipping burgers, back to the minimum-wage ranks,' while waiting for the boom to return." (39)



Figure 10.4.13. Remnants of a waste pit in the Pawnee Grasslands. Verified in by GIS data. (Google Earth, 2016)

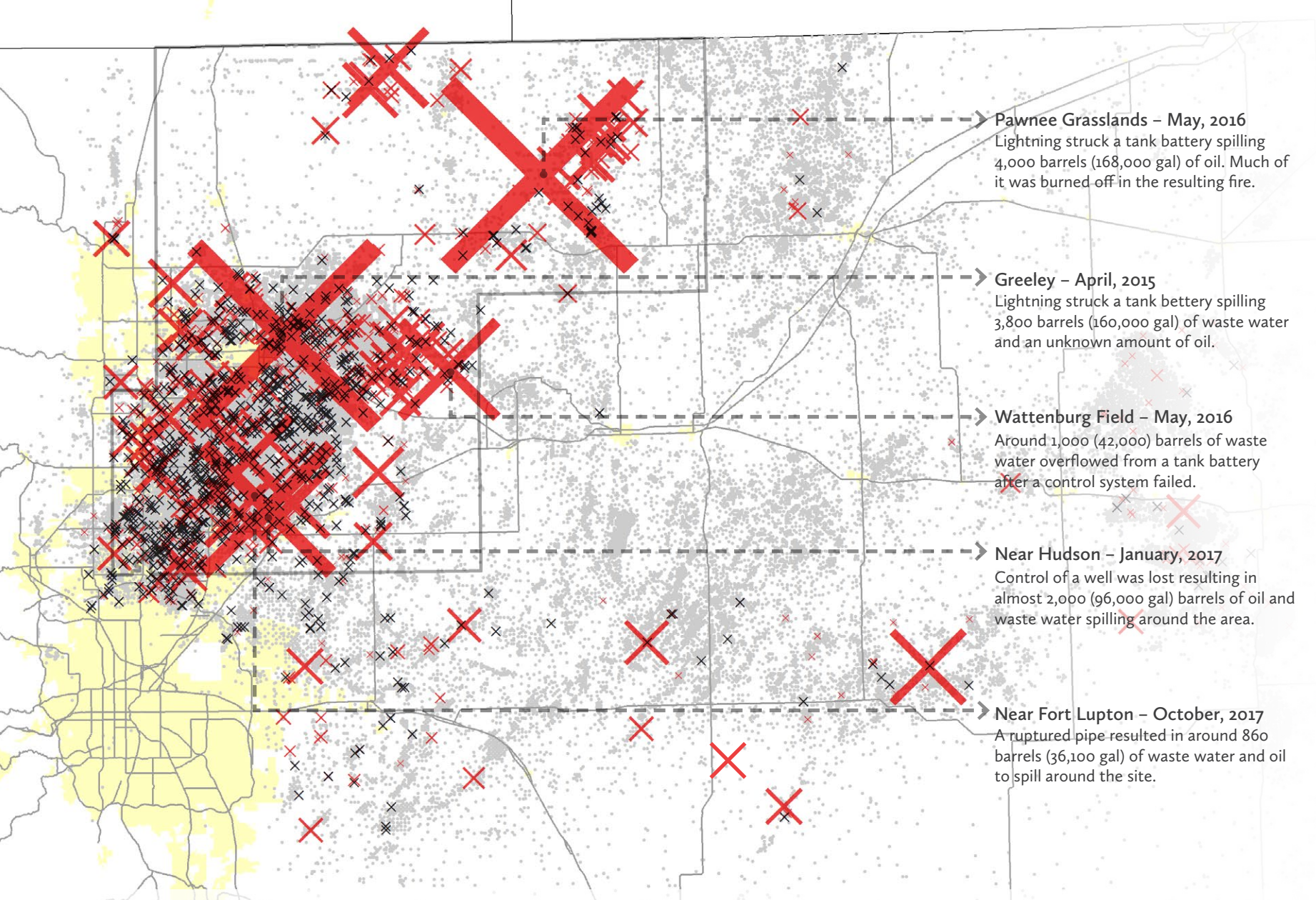


Pattern: Oil and Gas Related Deaths in Northern Colorado 18 since 2001

Figure 10.4.14. Colorado oil and gas deaths. (Lanning, 2018)

Source Data: Work Fatalities by Industry, Oil and Gas Extraction – OSHA, 2018

Findings: More than 60 fatal incidents have been recorded across the state in this time-frame in addition to those shown here. What is not shown are the dozens of incidents where workers were seriously injured from similar incidents above, explosions and fires, vehicle incidents, equipment strikes and so on.



Pattern: Oil and Gas Spills in Northern Colorado – 5,736 since 2009

Figure 10.4.15. Colorado fracking spills. (Lanning, 2018)

Source Data: Spills – Colorado Oil & Gas Conservation Commission, 2017

Findings: This map shows how common spills can around fracking prone areas. Many of the spills involved waste water or a mix of waste water and oil. Gas however does not spill and leaks. Information on how much gas has leaked into the air across this region is not documented and unknown.

11 FRACKLAND TRENDS

Trends are a summation of themes and patterns that were commonly seen when conducting research both in the field and remotely. These themes largely focus on adjacencies and context and how such influences the Fracklands. Field visits showed that there were a number of differences between the components of fracklands in one region of the country when compared to another. While hydraulic fracturing follows geology and what's below the surface, these findings show that hydraulic fracturing still responds heavily to its geographical surroundings at the surface.

Differences in these trends* shown in this chapter are contextual and based on physical surroundings such as adjacent land use. While differences may exist in these regions be due to differing laws and regulations, it is thought that these landscapes respond primarily to surroundings and appear/function as they do based on what is around them. Laws and regulations primarily determine where these landscapes can and cannot be, not how they look or interface with their surroundings.

*Note: In this chapter wells are a major focus. Being the most common component of the Fracklands they were the most telling of the trends.

Trends may range from the largest of detail to the smallest. From the differences between areas of high population and areas of low population, how wastewater is handled, or even differences between signage and how objects communicate to people what is happening. While many trends could be discussed on these finer details, this chapter explores the broader trends that define the Fracklands. They are:

- **Trends by Regions of Study, Weld County, Tarrant County, and West Virginia/Pennsylvania**
- **Trends by component, and their correlation with well pads.**
- **Trends by Population density: Rural to urban**
- **Trends by land type and ownership: Public, private.**



Figure 11.1. A distant oil well. Depending on one's focus, trends may look at even the miniscule. The individual equipment of wells such as the one pictured, the practices in implementing them such as using water containers not impoundments, or the signage that sits around them and what they are communicating to onlookers. (Lanning, 2017)

Trends by Region

Tarrant County: Tarrant could be defined as the extreme in regard to fracking integrating with highly populated areas. Within and around Fort Worth, wells acted as interstitial entities. If there was a left-over parcel it was common that it would be filled in with a oil or gas well. Even near the densest downtown areas one could find at least one instance of a Frackland component. Another shocking trend were waste water pits in Fort Worth's poorest communities. Rather than being far removed from civilization like in Weld County or Appalachia they ran right up against it.

Despite the clear signs of environmental injustices, fracking was equally as common in suburban neighborhoods of the middle to upper class. Well pads ran right up against large suburban homes, schools, and parks. Regarding other trends, roads seemed less a part of fracking infrastructure, possibly due to the already high amount of traffic. Processing facilities were grouped closer together and pipeline appeared to much more common. The lack of waste water pits overall and indication of the patterns points that most is likely injected through wells.

Weld County: Weld was a good example of seeing many of the various trends of the Fracklands regarding both appearances and contextual trends. Components could be found anywhere in the area and were not locked to any particular place. They were in many rural and urban settings; public and private. Unlike other regions which had more consistency with facility sizes, Weld facilities' size varied depending on their context. Well pads for example were smallest on leased lands, but were the largest seen within publicly owned land. Other activity in publicly owned lands were just as extreme. A large amount of semi-trucks were seen, often dominating the roads, and disposal pits were more common in these areas than anywhere else examined. While considered public, much of it was closed off. It looked as though it was being set aside as a sacrifice for the sake of energy production.

While disposal pits were prevalent in public lands and rangelands, they were not seen anywhere else in the county. Waste water processing facilities appeared to be common in Weld unlike the other study areas. A notion that the County is attempting to handle its waste beyond injecting or dumping it back into the ground.

Appalachia: Fracklands across West Virginia and Pennsylvania were on the opposite spectra of the more extreme trends seen in Tarrant county. Components were all generally found in an agrarian setting. While some activity was seen enclosing on parts of greater Pittsburgh, or Morgantown in West Virginia, most were almost entirely left to dot hilltops and farmland. Unlike the other two regions where their geography was more open and expansive, the forests and hillsides made Frackland components often invisible when at the ground level. Unless viewed from above, trucks and signage were often the only objects that could reveal one was in the presence of a Frackland.

Unlike the others, Stories from this region were the most prevalent. They revealed a number of unique sociological trends telling of exploitation of locals and their land. These phenomena resemble a lot of what the region's past history has been with other industries of extraction such as coal. However unlike coal, fracking has become non-communal and is left in the hands of individual land owners. However the common trend was that these land owners were still generally poor and struggling to get by, relying on oil and gas income to subsist. Indication of such phenomena in Colorado and Texas did not appear to be evident based on the quality of living seen in these areas.



Figure 11.2. A small well pad in Weld County. (Lanning, 2017)



Figure 11.3. A small well pad in Tarrant County. (Lanning, 2017)

Wells – the Indicator Component

In every region a common trend was that wells were the sure sign that almost all other components of Fracklands could be found nearby. If you see a well, expect many other components to be close nearby, whether there use is completely evident or not in the field. And where there are wells, there will be roads on the surface and pipeline below being utilized to connect the system together.

See a fracking well? Drive down the road and you'll likely see another well, a processing facility, a disposal or storage site, warning signs for well traffic or pipeline, and more. This was true in expansive and rural areas in Weld County and Appalachia, and was true even in the most urban of places where there was fracking activity such as Fort Worth.

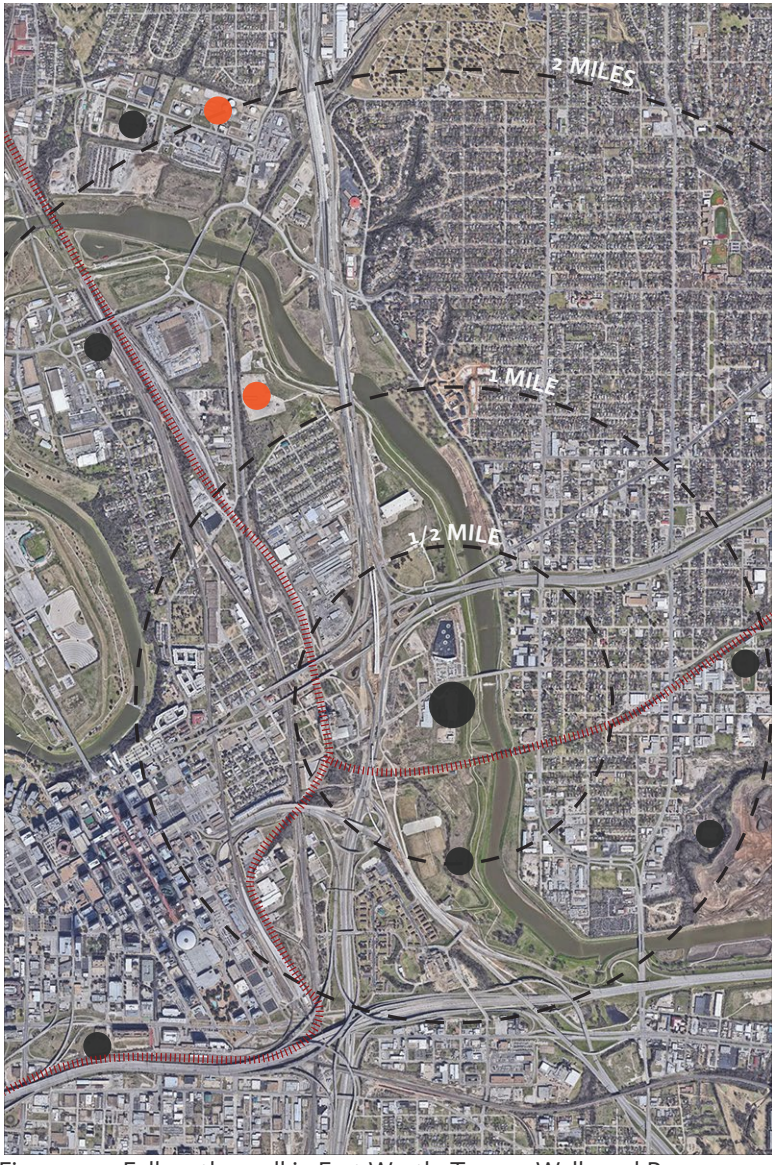


Figure 11.4. Follow the well in Fort Worth, Texas – Wells and Processors. (Lanning, 2018) Base image: Google Earth, 2016

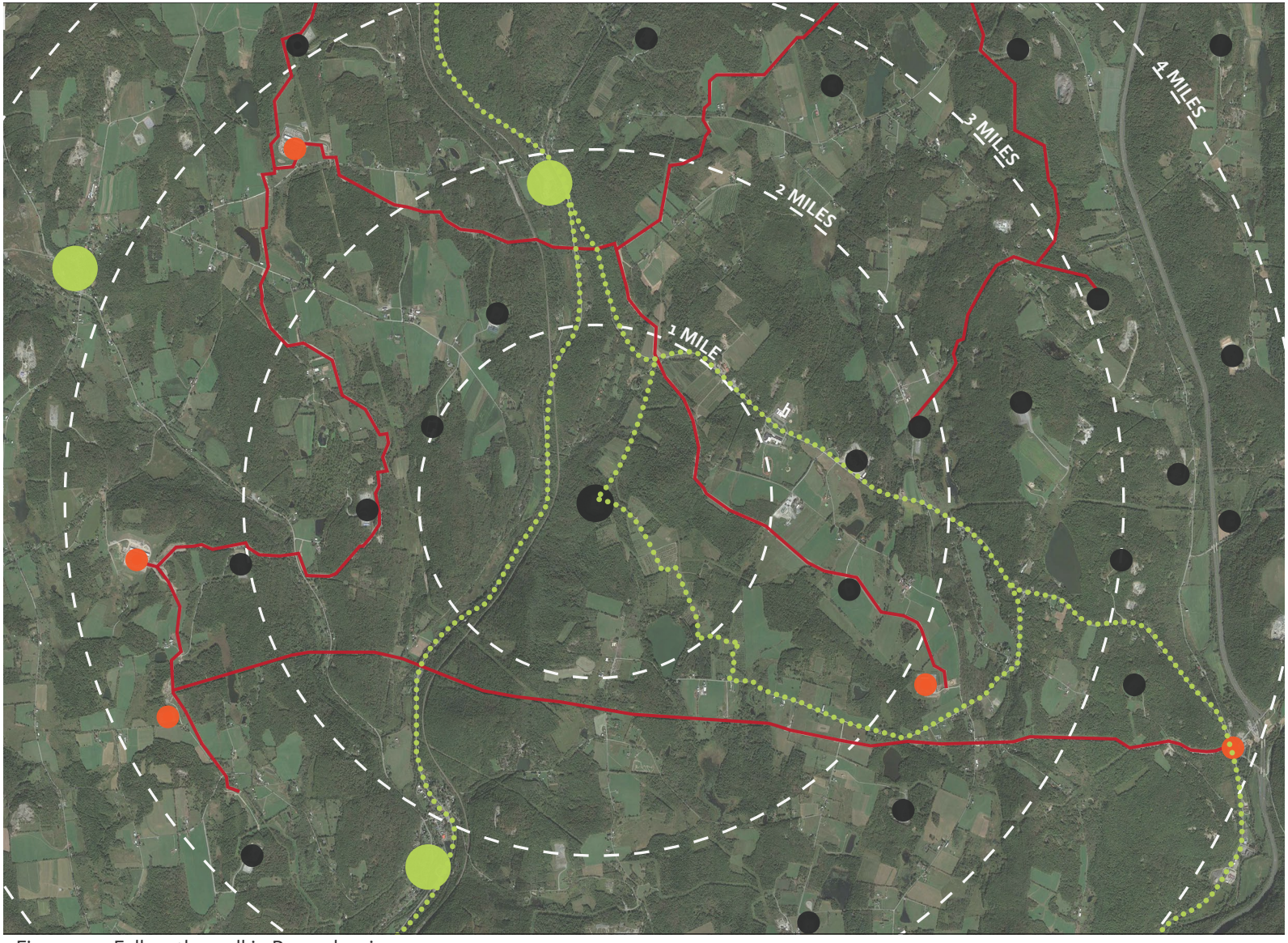


Figure 11.5. Follow the well in Pennsylvania (Lanning, 2018) Base Image: Google Earth, 2016

Trend: Variations by Population Density

Field visits quickly revealed that the Fracklands are a part of both populated and sparsely populated regions. The communities investigated: Fort Worth, TX - Tarrant County, Greeley, CO - Weld County, and Pittsburg, PA - Allegheny/ Washington County, all were found to interface with hydraulic fracturing activity in various ways. While hydraulic fracturing activity is far more common outside of these populated areas, interactions between populated places and fracking is becoming more and more common and will continue to grow as these communities expand into oil/gas fields and vice versa. Many striking differences were seen when investigating the differences between populated and unpopulated areas. What was witnessed was that various components, interactions, and phenomena associated with fracking were different as one moved towards or away from populated areas.



Figure 11.6. A well being drilled in open rangeland of Weld County. (Lanning, 2018)



Figure 11.7. A well being drilled in a more populated area of Weld. Large walls are required in populated areas to reduce dust and sound leaving the site. (Lanning, 2017)

Rural Fracklands:

Rural areas are currently where the majority of hydraulic fracturing activity is located. In the examined areas of study, all the components of the Fracklands thrived in areas of sparse population. As population thinned activity appeared to grow larger. In the most remote areas, the highest of amount of fracking was seen. Well pads were among these components as the definitive part of these rural areas. Wells riddled crop fields and pastures. Roads and pipeline further dived up this land, connecting it all together.

While fracking has largely been something land owners lease their land out for, recent pro-fracking legislation has opened the door for fracking on public lands. Analysis of satellite imagery shows wells have moved quickly into these place over the past 2 years, tearing up forest and grassland. Being in such expansive areas, it often goes unnoticed. For many of these components, they will remain fixed in rurality as entities in a rural landscape that will remain far removed from society for the entirety of their lives.



Figure 11.8. A small drilling operation near the banks of Eagle Mountain Lake in Tarrant County. (Lanning, 2017)



Figure 11.9. A large oil and gas well pad in Rural Weld County. (Lanning, 2017)



Figure 11.10. Wattenburg gas field in Weld County. Located primarily across very rural rangeland. Once a place for smaller conventional gas wells, large scale fracking operations and their subsequent components have moved in. (Lanning, 2017)



Urban and Suburban Fracklands:

As communities near oil and gas grow outward they are beginning to clash with oil and gas development. Today communities in Weld and Tarrant counties are seeing wells become objects of neighborhoods and towns. They fill underutilized spaces, sit within community greenspaces, or parks and trail systems. What was once a familiar site in the countryside is now becoming a common element for large populations, and something people are having to confront.

While in many cases these facilities have existed before the community was built, wells are still being put up in large number near existing communities. In Weld and Tarrant counties large drilling rigs were witnessed immediately adjacent to newly constructed suburban communities. Massive walls for noise proofing are put up, creating a site one can see thousands of feet away. As these communities continue to grow along with oil and gas development, their interface with one another will grow. Other components beyond just wells will also become more common.



Figure 11.11. Well Pad nested within a suburban neighborhood of Fort Worth in Tarrant County. (Lanning, 2017)



Figure 11.12. Gas wellhead in a Greeley, CO neighborhood.
(Lanning, 2017)



Figure 11.13. Looking west towards downtown Fort Worth, Texas. Well pads fill underutilized spaces of the city. In this case, the floodplain of the Trinity River. (Lanning, 2017)



Trend: Variations by Land Ownership

Leased Lands:
The majority of the Fracklands operate on leased lands, leased by private landowners. While some components may be privately owned by the oil and gas company, most will be leased. Within these privately owned lands, Frackland components varied greatly by size and operation. Most remained relatively small so as not to interfere with activity such as farming happening around them.

However, while these facilities were smaller they were unconsolidated and scattered, resulting in more of them. Processing facilities and other various supportive components were located further away from the wells they support, requiring larger and longer transportation networks to connect them. This was different from larger leased lands often owned by the government where facilities could be larger and more concentrated.



Figure 11.14. Well pads, farms, and forest in rural Pennsylvania near New Milford.
(Google Earth, 2017)

Government Leased Lands (Public Lands):
Within public lands – National forest, nature reserves etc. – the numbers of Frackland components are growing rapidly. Facilities themselves are growing larger in size than anywhere else. In the Pawnee Grasslands of Weld County, oilfield activity, well and facility sizes, road lengths were the greatest witnessed out of any location visited. In Texas at Eagle Mountain Park, a 400 acre recreation park, multiple well pads were put in within the past year hidden among the hilltops and thickets away from public eyes. The same was seen at the Pawnee Buttes in Northern Colorado, where huge areas of the publicly accessible land were closed off for oil field activity. In Appalachia these places have been leased out for oil and gas activity for decades. While in the Allegheny National Forest in Pennsylvania is still dominated by conventional oil and gas fields, many of the State forests of the region are seeing a large amount of fracking activity move in and close off access (Jerolmack and Burman, 2016).

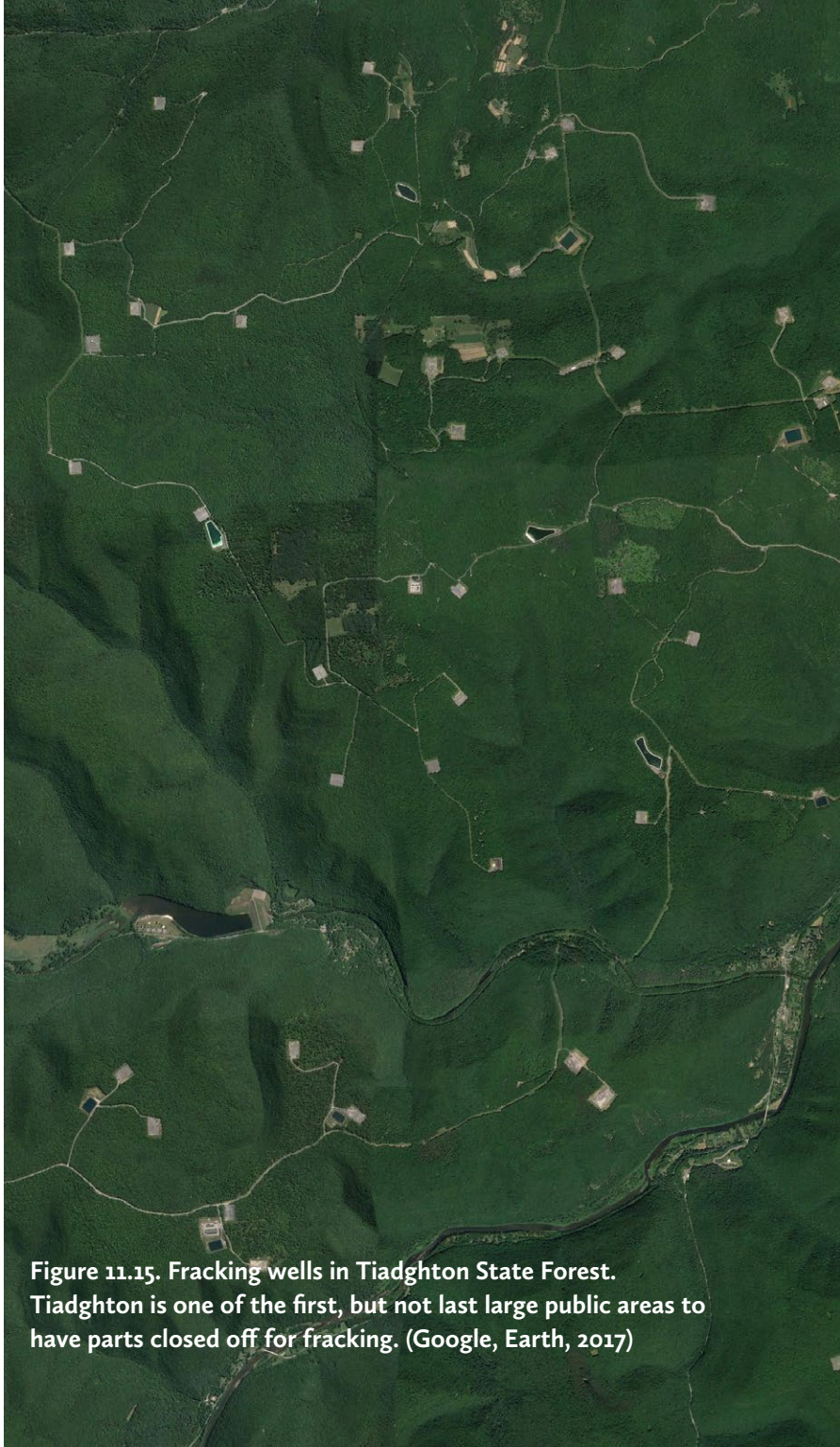


Figure 11.15. Fracking wells in Tiadghton State Forest. Tiadghton is one of the first, but not last large public areas to have parts closed off for fracking. (Google, Earth, 2017)



Figure 11.16. A Small well pad occupies a crop field of a Weld County homestead. This wellpad is likely on privately owned land being leased out to oil and gas companies. (Lanning, 2017)



Figure 11.17. A large gas well sits nested within Eagle Mountain Lake State Park near Fort Worth, Texas. This and other wells have been recently constructed within this state owned land which features hiking trails and wildlife habitat. (Lanning, 2017)



Figure 11.18. The Pawnee Buttes are a popular area to hike in Weld County. However some of largest fracking sites like the one to the right have been closing in on this place. (Lanning, 2017)



Trends in the Future

Fracklands follow oil and gas: They do not follow geographical boundaries, they follow geological ones. Fracking will become more ingrained within every place that has been examined so far.

All of the trends discussed validated this point that Fracklands are not limited to a specific place. They can be found everywhere. Yet, in field visits it was common to see areas that didn't have Fracklands. Was it because people didn't want to lease their land? Was there no oil or gas below? And, will these places eventually be a part of the Fracklands?

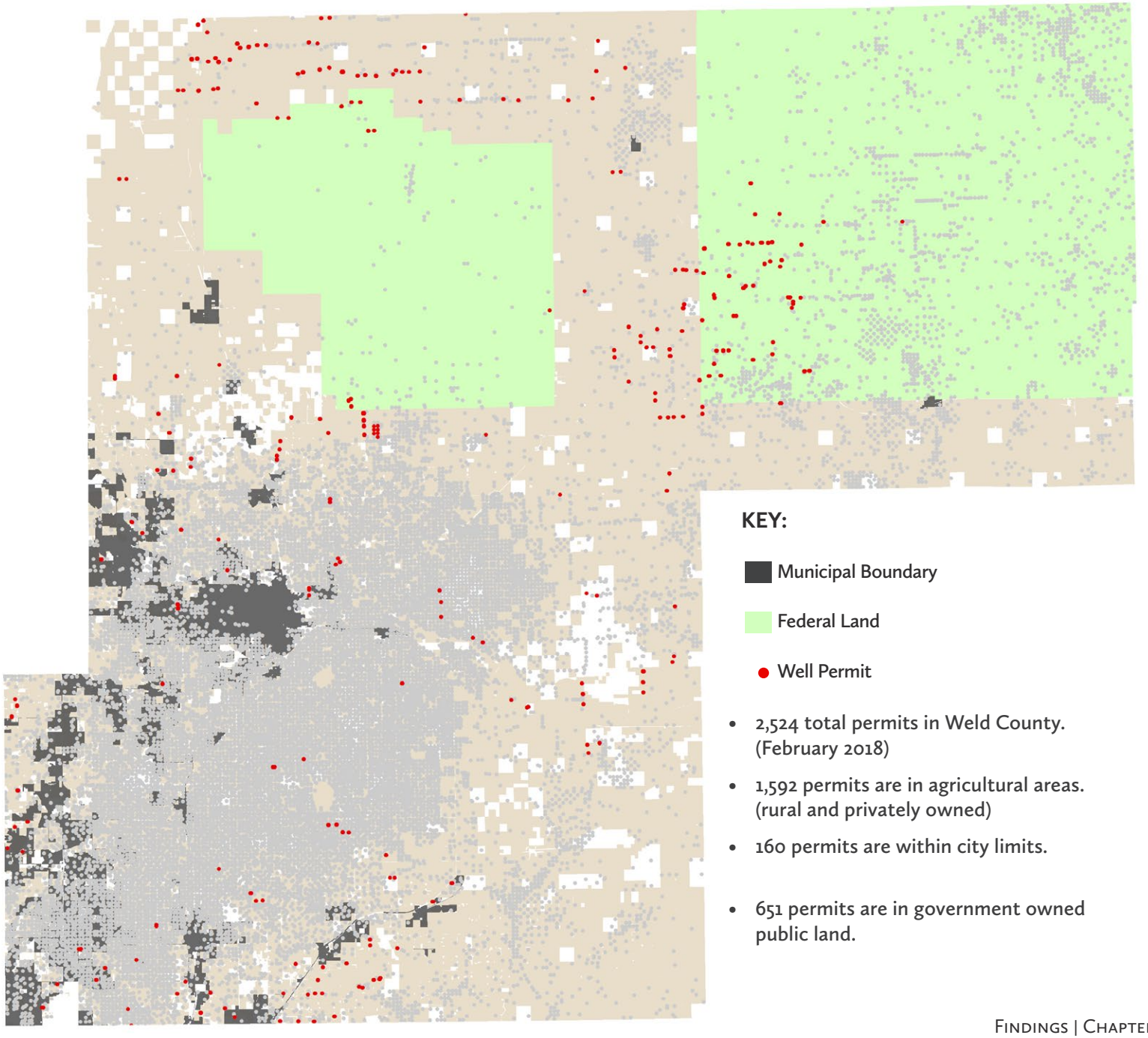
Based on what is known from research, the Fracklands that are seen today will continue to grow in number. Their phenomena, the stories they tell, and their patterns will grow in prevalence. Their spread will densify their presence in places where already common, and blemish where currently free. Estimating places of future Fracklands is difficult because its existence is almost entirely derived from the price of oil and demand. While the long-term outlook is speculative, more immediate hints as to where fracking is headed next do exist in the form of permits.

Public and Protected Lands: As current legislation loosens limitations on fracking, it will become more and more common in public and protected lands. We are already seeing this happen in the Pawnee grasslands of Weld County and the State Forests of Pennsylvania. However, untouched portions of these places still exist.
How long can these environments near fracking persist until the first well is drilled?

Agrarian Lands: In all three of the frack-prone regions examined, fracking has completely taken over the agrarian landscape. Over time more landowners will sign leases, wanting cash in on the boom like their neighbors. Many will be forced financially as a way to make ends meet.
When will fracking take over agrarian communities not yet familiar with fracking but with oil and gas beneath their feet?

Populated Areas: Weld and Tarrant county are prime notions that fracking ignores geographical boundaries. Communities in these regions are being built as drilling rigs complete frack below them. Communities both old and new will be experiencing life next to fracking more and more.
At what point does fracking become an element to coexist with within neighborhoods and communities?

Figure 11.19. Pending permits for oil and wells in Weld County. These permits indicate a potential well being drilled sometime in the near Future. (Lanning, 2018)



- 2,524 total permits in Weld County. (February 2018)
- 1,592 permits are in agricultural areas. (rural and privately owned)
- 160 permits are within city limits.
- 651 permits are in government owned public land.

12 FRACKLAND FUTURES

This chapter looks at the future of the Fracklands and how the information acquired in previous chapters can be used to address that future and create positive outcomes. How the future of the Fracklands will play out is relatively uncertain. While it is known that oil and gas will run out at a point in time, the cessation of Fracklands is unknown, and the demise of their components is unique on its own.

The reserves of individual oil and gas wells, the volatility of the market and price changes, and the change in politics are just some of the reasons for the Fracklands to decline. While these are reasons for their end, many components will operate accordingly long after oil and gas is gone, or will be used partially for other purposes. Whatever their end will be; as a whole their end will be gradual. Times passing will reveal these landscapes as losing their purpose as landscapes of extraction and industry. Each Frackland, one of millions will at some point cease existing as they do today. How we address this outcome is still undecided.

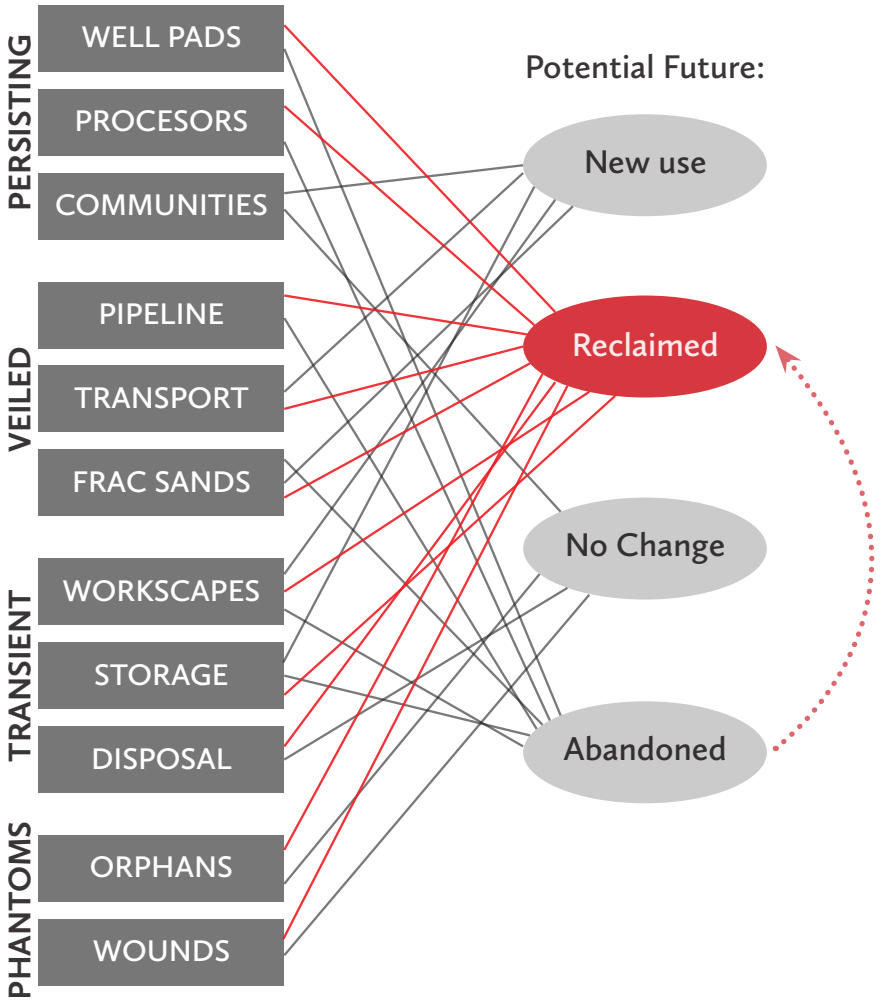


Figure 12.1. Potential futures of the Fracklands (Lanning, 2018)



Figure 12.2. Abandoned tank batteries in Louisiana in need of removal and a new future.
Their removal will be paid for through tax payer money.
(Louisiana Department of Natural Resources, 2018)

Investigating Reclamation

While uncommon, termination of the Fracklands and their components is happening today, just not on a scale that will be seen tomorrow. From what is known today, they will either be abandoned or remediated. Parties that operate these landscapes are not being held to higher standards to make these landscapes any better once they expire. Evidence shows that remediation practices, while effective, are unimaginative and often achieve the minimum required. Current remediation also removes all traces of fracking or the land's relation to fracking at the surface.

The chief goal of remediation today is to return these landscapes back to what they were before. Reason could be attributed to the nature of the operation. Fracking is thought of as a temporary thing. For many who lease their land its a way to bring in money temporarily. Then once that lease ends, that land can be remediated and returned to functioning as it did before. From there it may persist as so or be built over for something entirely new. However in looking at this practice of returning to a prior use, its often decades later. While the Frackland may not have changed, its surroundings could be vastly different. Returning to prior use may end up being wasteful or full of missed opportunities.



Figure 12.3.Changes in Tarrant County from 2003 to 2017. While the well pads have stayed the same, urbanization has enclosed around them in what was once rural farmland. (Google Earth, 2013; 2017)

Three primary outcomes come out of reclaiming and oil and gas landscapes today:

1. Re-purposed: A majority of these landscapes were once a piece farmland or land used for agriculture. Once they are no longer needed for oil and gas they are remediated and reclaimed for a different type of industry and economy; one that is agrarian. Industry has been the legacy of many Fracklands and will be re-purposed for new industry post-oil and gas.

2. Overwritten: Many landscapes will be reclaimed to be built over, becoming something entirely new for surrounding populations. These landscapes could become the next place for a household, an entire community, a shopping center, and more. Evidence of the Fracklands will be overwritten as communities and the desires of its residents grow.

3. Stagnation: When there is no desire to re-purpose these lands, many are reclaimed to nature; to a "natural" state. Sites are remediated, naturalized, or nature is simply allowed to swallow them up. However, unless stringent cleanup occurs, these sites will bear the marks of industry becoming brownfields. Whether remediated or a brownfield, many Fracklands will sit in stagnation; indefinitely unless redeveloped for a new use in the future.

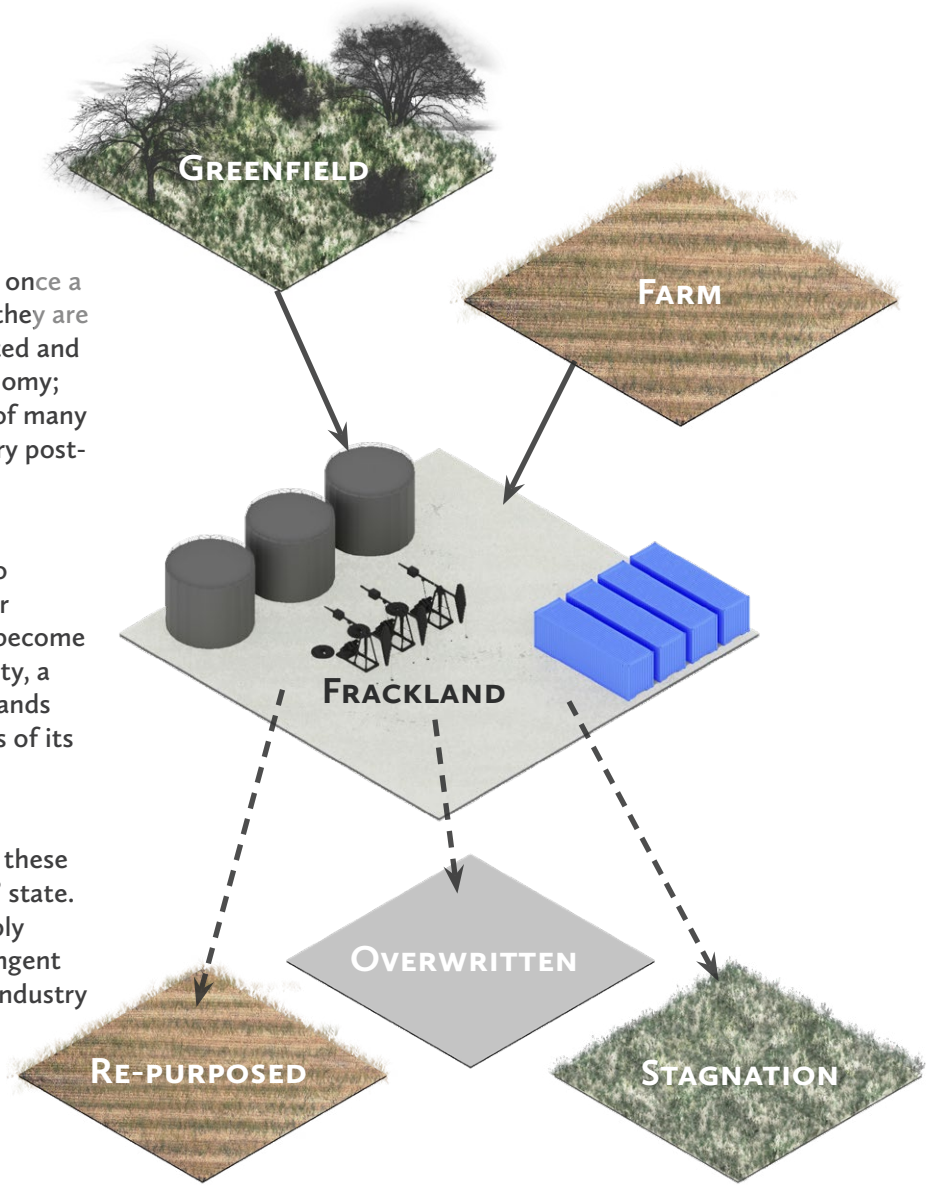
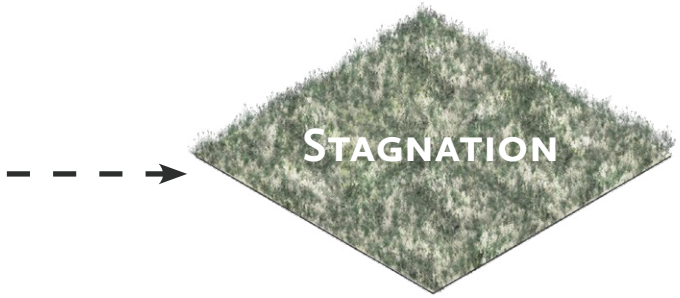


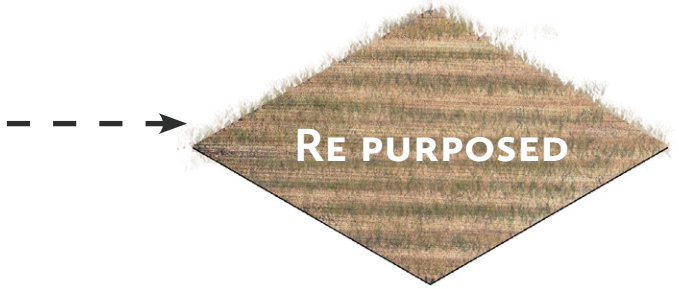
Figure 12.4. Transitions of Fracklands. (Lanning, 2018)

Each of these outcomes can and should be questioned:

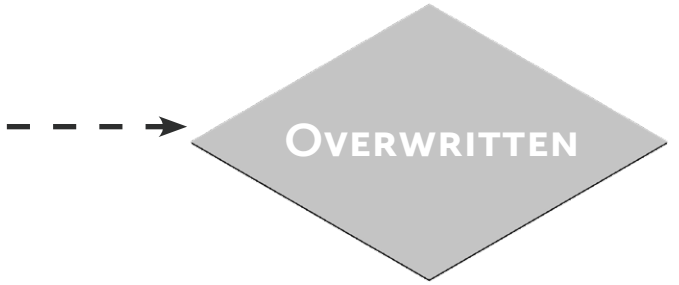
- *Regarding naturalization and reclamation to nature, why should we take a landscape that has been so severely altered, and exhaust resources to try to bring it back to that state, a state of little to no use?*



- *The same could be asked about returning these landscapes to farmland, except, why spend all of this effort to return land and soil to a state that's re-purposed to support standard crop fields or a few more acres of grazing land that or no different than the lands where fracking activity didn't happen?*



- *In overwriting these landscapes, is it fair to build over these landscapes and disregard the large amount of incident that may have occurred on the land? Or the existing infrastructure below that may endanger lives?*



- *Based on these outcomes that have been laid out, is it best to continue producing these outcomes, knowing that we are exhausting a large amount of resources to bring these lands back to what they were or for new standard uses?*



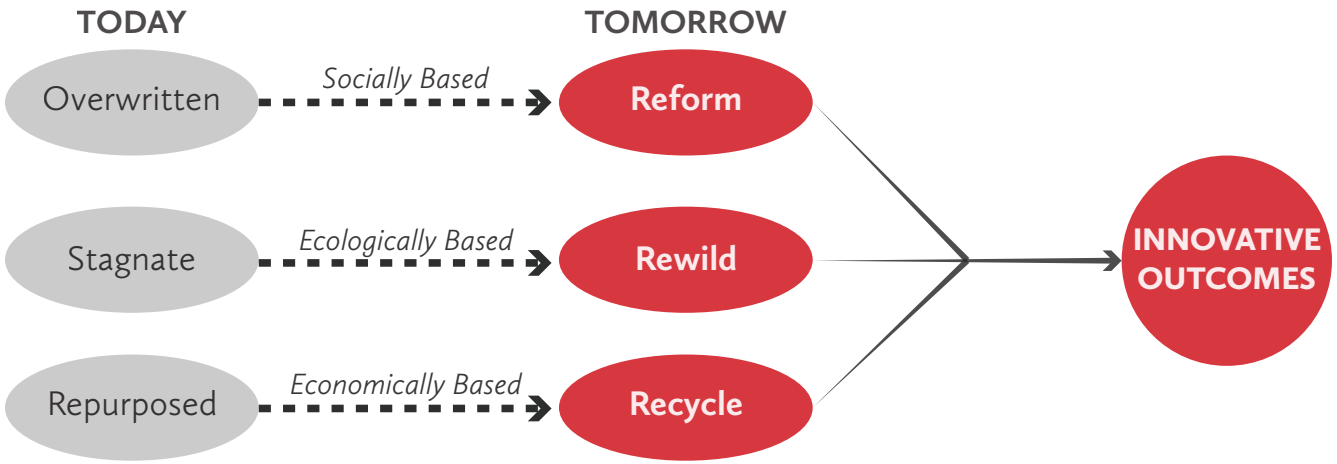
Figure 12.5. Dante Park in Greeley, Colorado. Once a gas well this reclaimed facility has been overwritten and now functions as a community greenspace. All that indicates its former existence are lines in the turf outlining where the pad and road once were. (Lanning, 2017)

Design Strategies

While the three outcomes of reclamation are notably underwhelming, the intention of reclamation has hints of creating social, ecological, or economically based outcomes. The futures of the Fracklands should have these same outcomes, but made into a point of greater focus and made for addressing a larger audience and not individuals. Three strategies based on concepts from Chapter 5 and findings from the Fracklands can be used. These three distinct strategies are to: Reform, Rewild, and Recycle the Fracklands. Each of these strategies carries with a range of ideas to respond to the various phenomena of the Fracklands.

These strategies and the ideas derived from them can be tools to argue against these landscapes being left behind, converted, or paved over for sub-standard uses. Ideas laid out in this chapter can show how these landscapes can evolve into assets of 21st century America, and how they can be used to addressed various dilemmas of the era.

Ideas explore adaptively reusing existing infrastructure as well as creating new infrastructure. And rather than pave over and forget about these landscapes and their phenomena, they build off of them to create innovative and adaptable alternatives. The findings from the fracklands are core to the ideas that are laid out here.



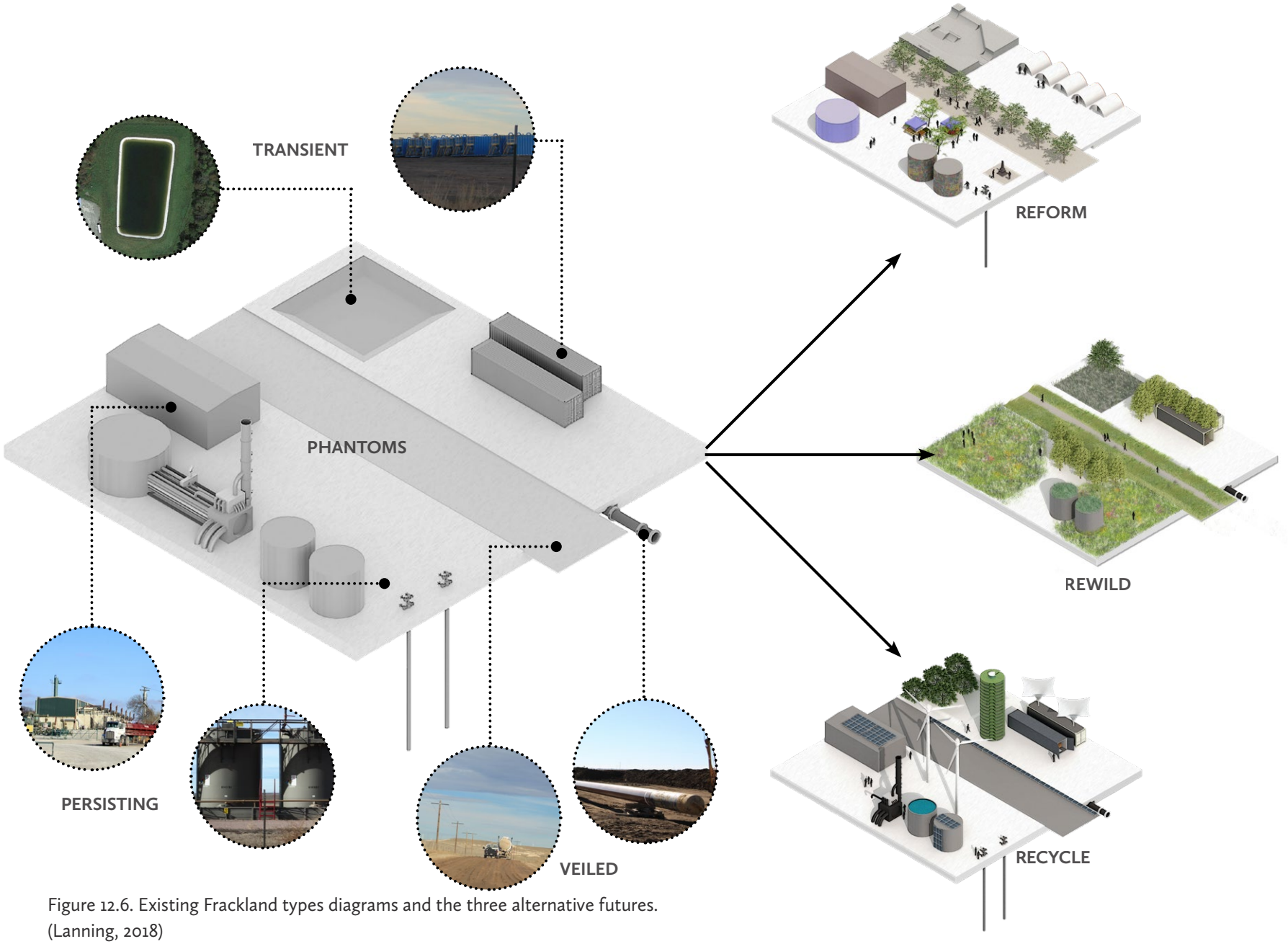


Figure 12.6. Existing Frackland types diagrams and the three alternative futures. (Lanning, 2018)

Why Design

From the information that has been laid out throughout this report on the effects of fracking, the social, environmental, and economic damages, the stories from individuals that show major changes to the lives of individuals and communities, and the patterns that show changes effecting far beyond the site itself, the Fracklands should become something above standard. They should be platforms for innovative uses, designed with intention for positive social, ecological and economically forthright outcomes. They should be reconfigured or built upon, not overwritten and forgotten. Simply following the three sub-standard steps laid before will only waste away the potential for a better tomorrow and fade away the Fracklands and all they reveal about energy and extraction.

Considerations:

Types:

When considering these design strategies, each Frackland type and its characteristics should be considered. Each type was shown to be unique. How these strategies respond to those differences is key to developing how ideas can be applied to these individual types.

- *Persisting: Persisting facilities are the most built out of the four types. How can design address the large amount of existing infrastructure that is present in these landscapes?*

- *Veiled: Veiled facilities are often used for dual purposes or hidden from view. How can design address dual uses and design for sub-surface landscapes?*

- *Transient: Transient landscapes in the future will be cleared. With no more use they will be emptied and left as blank sites. While this may look like a blank slate, their past history says otherwise. How can design address the history of transience of these landscapes and design dynamic uses on a "blank-slate" site?*

- *Phantoms: Phantoms could be any of the above, except they differ in that these have experienced discord. They've been damaged physically or have negative emotions associated with them. How can design address the phantoms and the social and ecological damages of the past.*

Systems Morphology:

In addition to addressing the dilemmas of each Frackland type, the futures of the Fracklands should be considered as a system. Just like how the Fracklands themselves are a system, what they become in the future still should be made as so. By making these landscapes a par of a system, it allows them to be decentralized and spread throughout. This decentralization also makes them resilient. If one were to fail, the others would not fall with it. And furthermore, by staying as a system they can adapt to local change, while responding to greater regional effects.

Together these adapted Fracklands can act as armature of social, ecologic, and economic outcomes. They communicate and work together to form a mesh that holds society together and accomplishes its goals and desires. Components of the Fracklands will be unable to solve any of the problems laid out previously. However, if they work together they may just be able to do so.

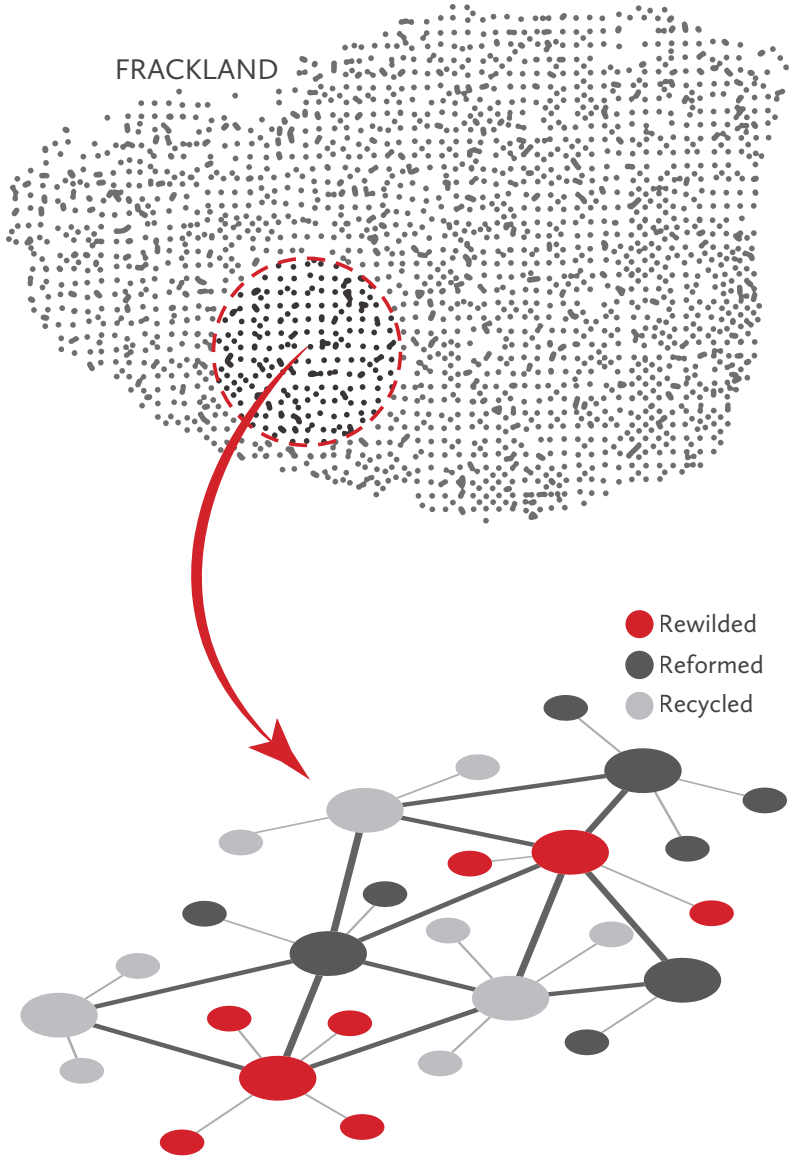


Figure 12.7. Future Systems. (Lanning, 2018)

REFORM

Reforming looks at modifying these lands to reach social, or people based outcomes. It looks at how these landscapes can be utilized for the benefit of communities and society, rather than individuals. In addition to focusing on community and creating spaces for people to come together, it looks at promoting sense of place, identity, and culture. Lastly it looks to the history of these lands and the stories they tell. How they can become landmarks and to signal the past, or be spaces to reflect on and heal from the wickedness of industry.

Hydraulic fracturing has changed lives of individuals and entire communities and change the identities of place and region. Extractive industry has exploited people and taken advantage of communities. If we are to remove all traces of the landscapes that have caused this how will we reflect on the transgressions of the past?

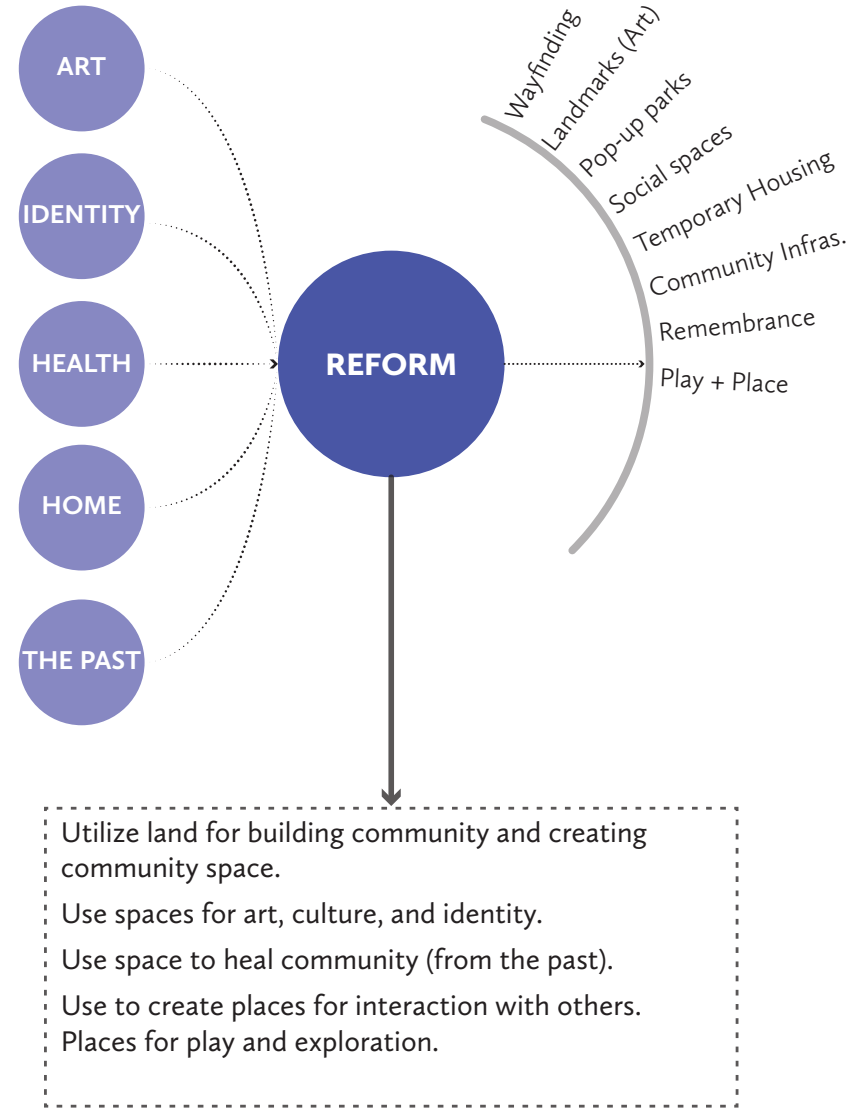


Figure 12.9. Reform concept diagram. (Lanning, 2018)

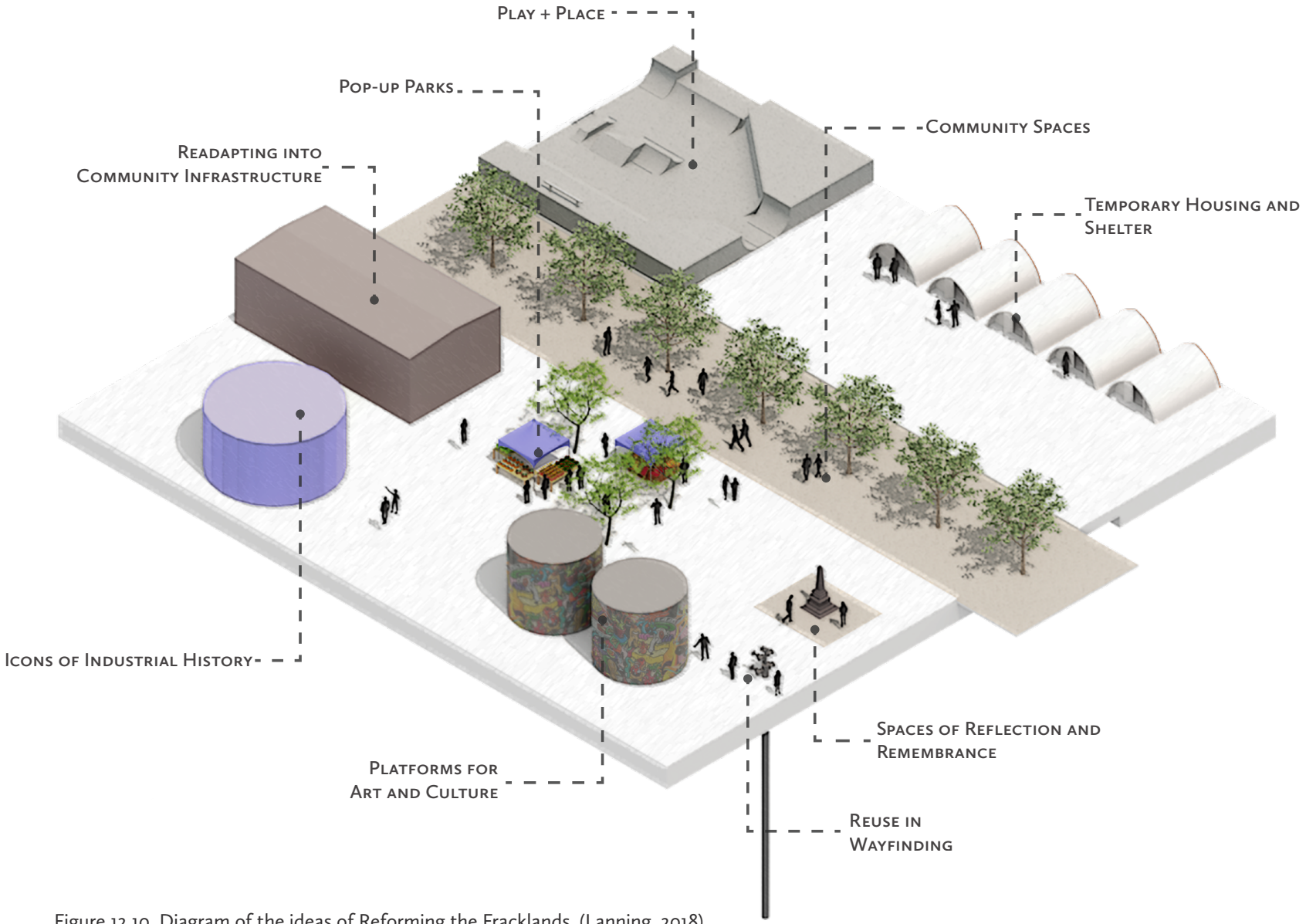


Figure 12.10. Diagram of the ideas of Reforming the Fracklands. (Lanning, 2018)

REWILD

This design strategy embraces the idea of biophilia. It looks at bringing the Fracklands back to nature, to reach an outcomes that are ecologically based. Rather than take on a traditional ecological restoration approach which looks at restoring landscapes to true native baselines, this concept looks at creating more novel ecology. It takes nature and condenses ideas to accomplish dilemmas both on site and off site related to ecological dilemmas. In addition to remediating the site with nature, creating habitats, and condensing ecology, this idea also looks at creating ways for people to experience it all. To visit, experience, and learn.

Hydraulic fracturing has greatly changed ecological systems and greatly damaged the American landscape. If we are to mend these wounds we need to break away from traditional restoration which is resource intensive and time consuming. These landscapes will never be able to return to what they were, so why should we try?

Rewilded Fracklands also look at addressing greater anthropocentric environmental dilemmas:

The 21st century will be categorized by major environmental change. How can we offset these changes by utilizing nature?

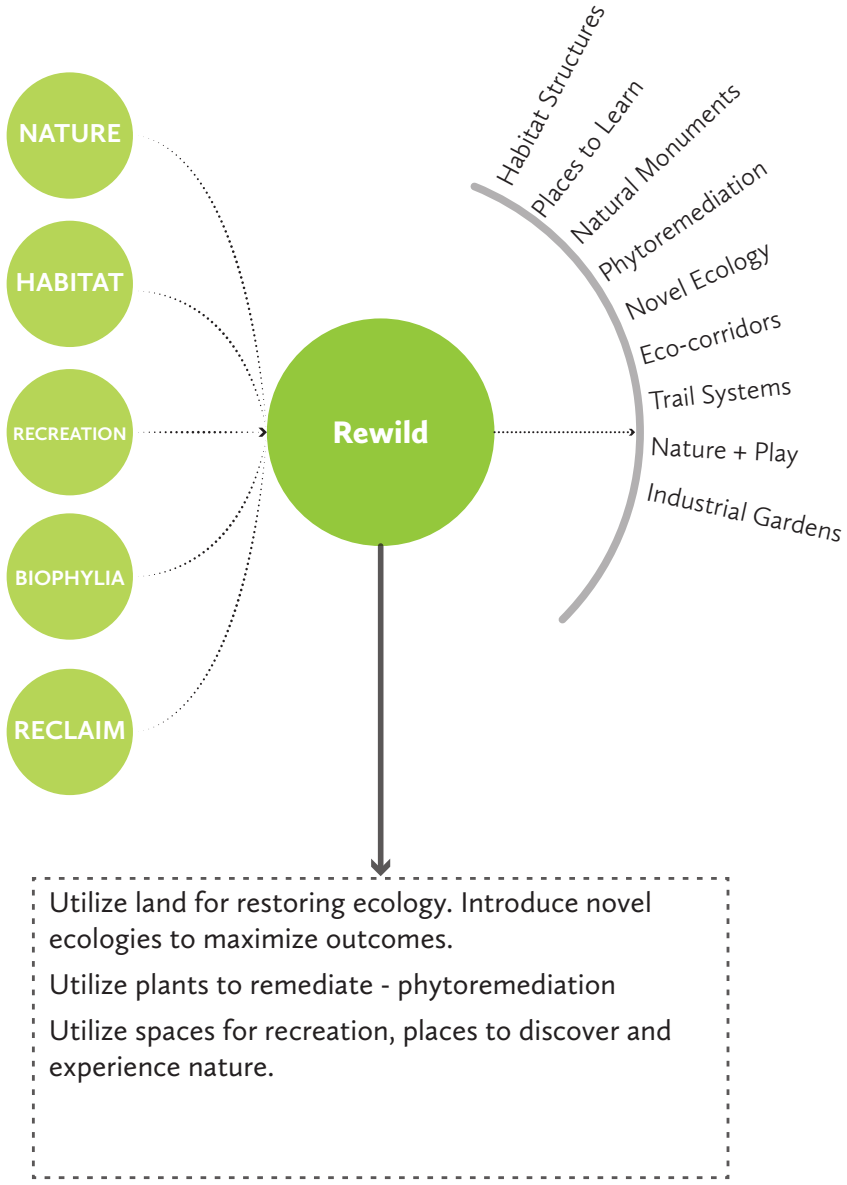


Figure 12.11. Rewild concept diagram. (Lanning, 2018)

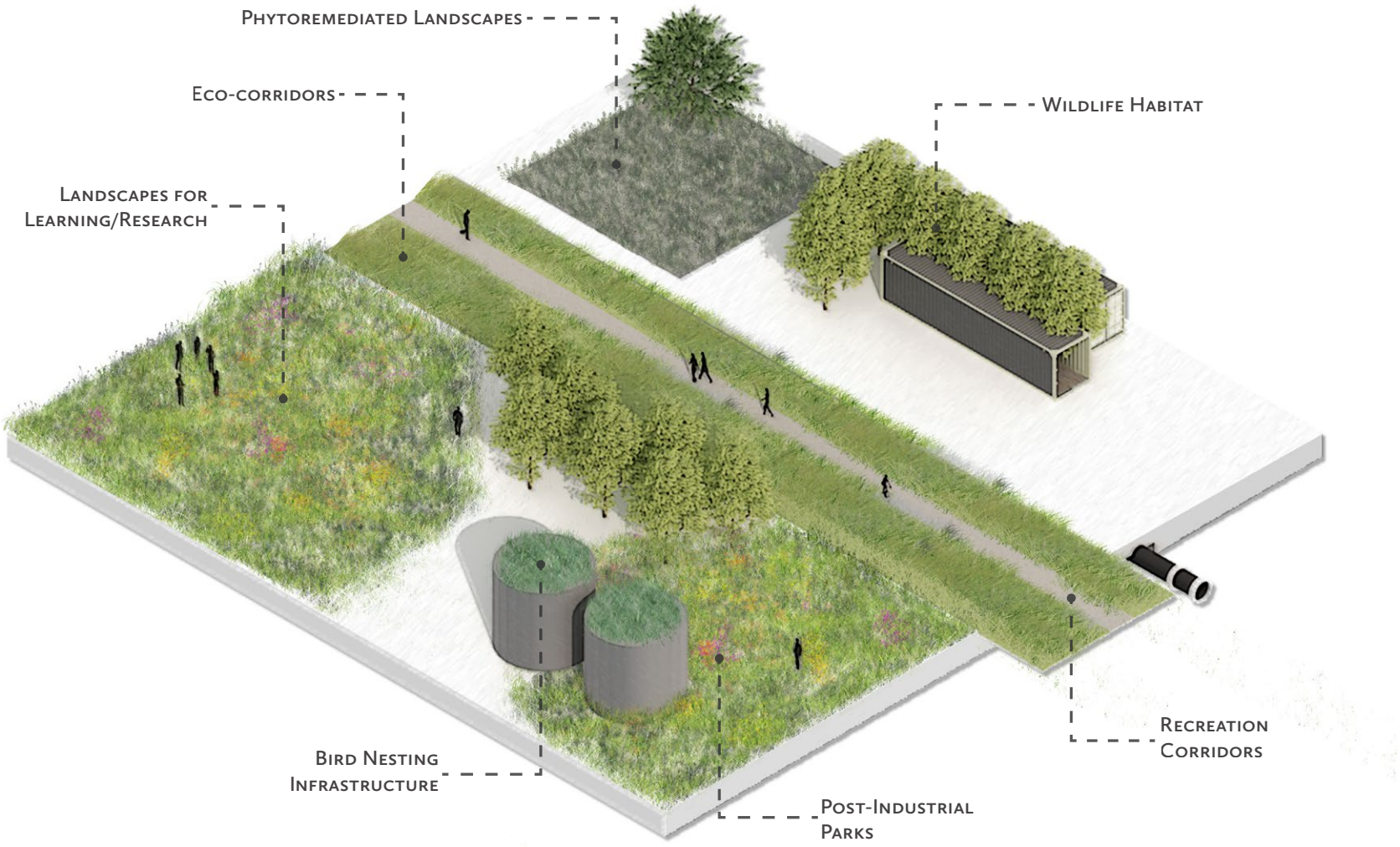


Figure 12.12. Diagram of the ideas of Rewilding the Fracklands. (Lanning, 2018)

RECYCLE:

This strategy looks at reusing Fracklands for economic outcomes – modern industry. It looks at how these landscapes which are currently landscapes of industry be re-purposed for new industrial uses. Although unlike the former industry, the new is meant to be clean and promote sustainable/resilient practices. It looks at generating food, jobs, energy, and commerce for communities and greater society. Like the previous ideas it looks at concentrating these concepts on site. Industry has historically not been conscious of its footprint, the industry of Recycled Fracklands will.

Hydraulic fracturing employs a very large number of individuals, produces a majority of the U.S. energy, and contributes greatly to the nations economy. If we were to lose these landscapes and not have a replacement, how would we adequately support the needs of the nation? How can we do so while also being conscious of people and the environment, something Fracking failed to do?

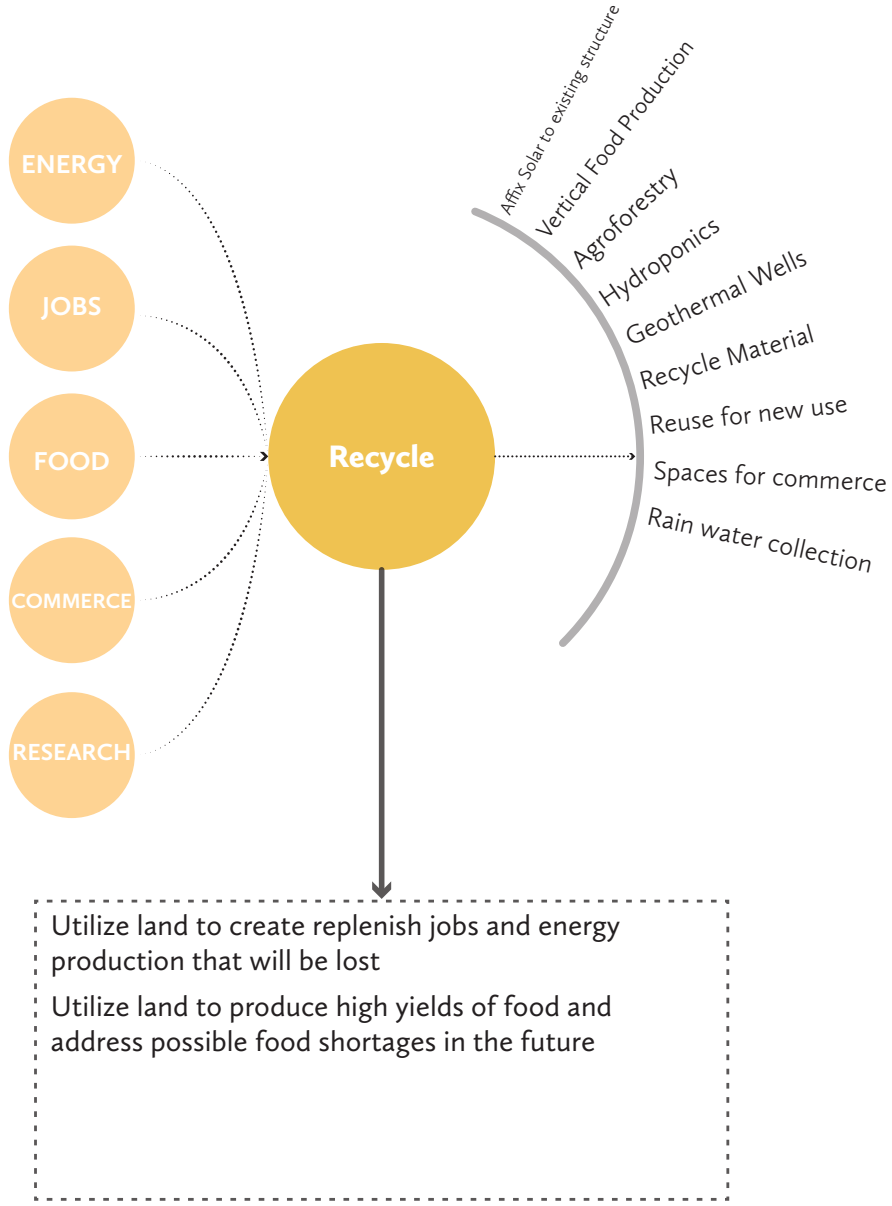


Figure 12.13. Recycle concept diagram. (Lanning, 2018)

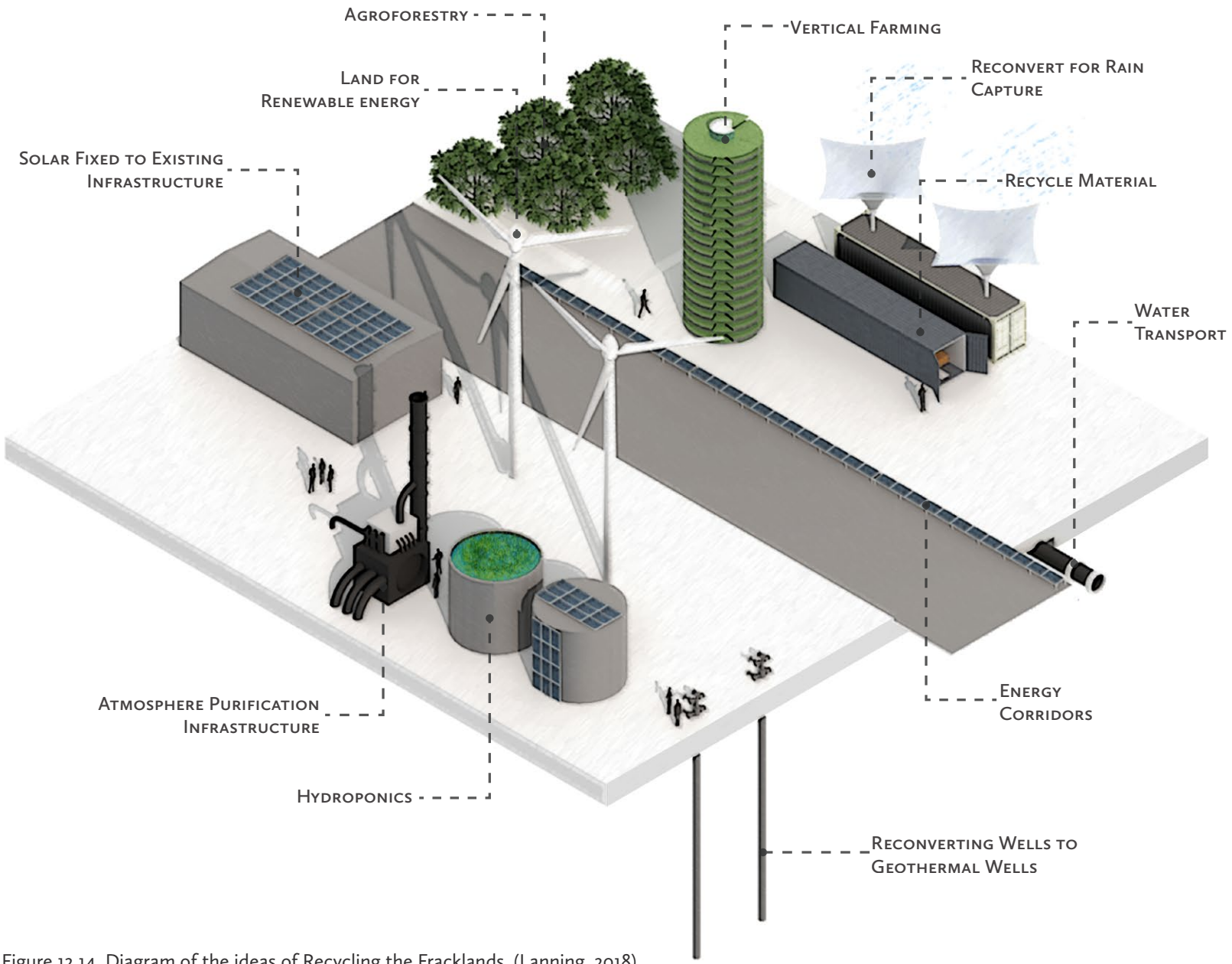


Figure 12.14. Diagram of the ideas of Recycling the Fracklands. (Lanning, 2018)



Figure 12.1. Drilling rigs sit in storage in LaSalle, Colorado. (Lanning, 2017)

IV | CONCLUSIONS

With the Fracklands revealed, this final section summarizes, discusses, and concludes on the numerous findings that were generated across the previous section. A large amount of information has been presented. Understanding what all of this means and what can be done with it is needed. Furthermore, next steps beyond this report need to be brainstormed. This report is just the footholds of addressing an increasingly complicated topic.



13 PROJECT SUMMARY

Section 1: background – chapters 1-6 (15-82):

From background research and literature review presented in Section 1. we know that the presence and processes of hydraulic fracturing are widely discussed. However this section had also shown how little hydraulic fracturing was being discussed in terms of complexity and how fracking acts as a force on and in the landscape. Little to no sources have adequately grasped and/or shown the vastness and complexity of the fracking landscape, and the uniqueness of each of its components from place to place. Research also pointed that expansion of this landscape and its components is unprecedented. Fracking now defines entire regions and is changing the lives of individuals and communities. Yet few have seen the connections between fracking, people, and place.

The information collected from section 1 would determine the primary question and overarching goals that would guide the rest of the research:

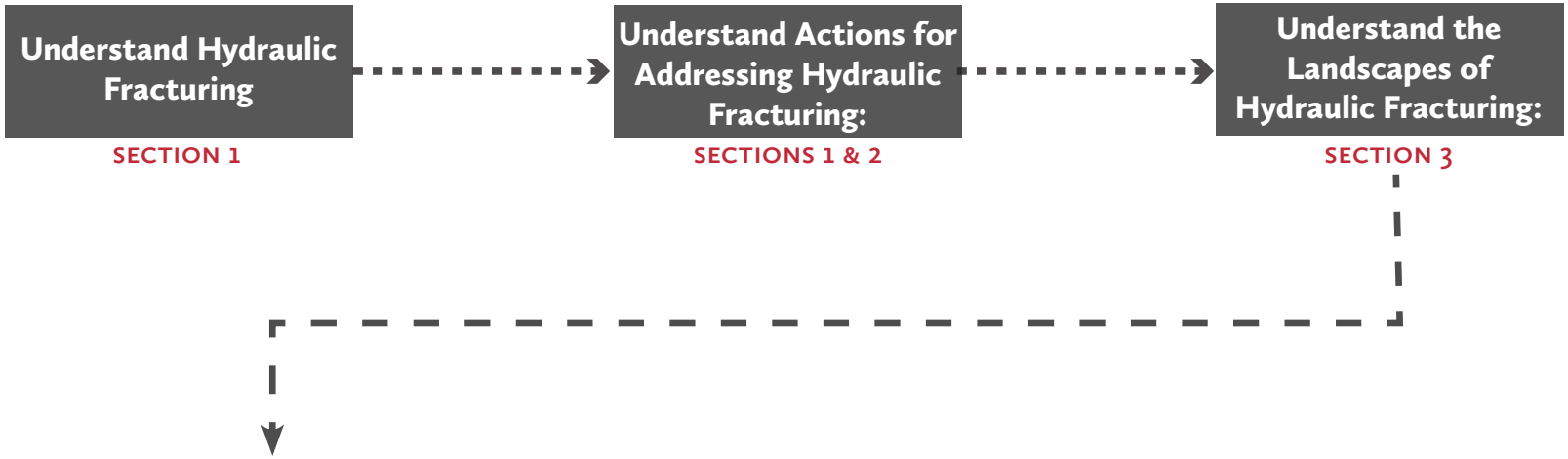
What are the landscapes of hydraulic fracturing and what methods can be developed to better understand these landscapes and their components to properly address the wicked problems that they have and will initiate?

Section 2: methods – chapters 7-8 (83-114):

Section 2 focused on creating a methodology for answering the primary research question and establishing regions of study. The means to explore the landscapes of hydraulic fracturing beyond precedent would be the Fracklands, which are a reorganization of and analysis of the landscapes of hydraulic fracturing and their components. To do so, the Fracklands were revealed through a constructed classification scheme. The classification of this landscape system into the Fracklands was fit for both parsing through dense amounts of existing information while enabling new findings to be made. This methodology was predicted to be a better telling of what these landscapes are today, what they will be tomorrow, and what they can be tomorrow.

Developed and implemented in this research was a framework for the classification of the Fracklands. The first attempt at arriving at a methodology best fit to tackle the dilemmas presented throughout. The framework was organized into four unique approaches: *System, Typology, Trends, and Futures*. Each approach sought to understand, organize, and discuss findings on the Fracklands and their components via different modes of research, thought, visualization, and subject matter.

Three Goals for Reaching the Project's Outcome:



Developing a Classification Framework: Four Approaches

1. SYSTEM

Investigated the Fracklands and their components from a systems-based perspective. It connected the processes of fracking to other phenomena within the landscape and investigated how these processes create a connected network.

2. TYPOLOGY

Organized the Fracklands and their components, differentiating them into four distinct types: Persisting, Veiled, Transient, and Phantom type Fracklands.

3. TRENDS

Examined the differences of the Fracklands from place to place. It investigated how local and regional context effects the structure and operation of the Fracklands across the country.

4. FUTURES

Investigated the future of the Fracklands rather than their present conditions. It bridged background research and field findings with concepts from contemporary landscape architecture theory to develop a set of typological design alternatives for the future of the Fracklands.

Section 2, chapter 7 (methods):

The primary focus of the classification scheme would be on the components that define and compose the Fracklands. Section 2 described methods for researching these components, determined to be the vital pieces of landscape infrastructure required for fracking related processes. Eleven components identified from background research – *Wells, Processors, Communities, Pipeline, Transport-Infrastructure, Frac Sands, Workscapes, Storage Sites, Disposal Sites, Orphans, and Wounds* – were explored in depth through four constructed descriptive strategies. Results were shown throughout Section 3.

- Definition: Defines the component; its operations, extents, scale, and timeline. Generally common information, background research and literature review was utilized.
- Field Reflections: Reactions and perceptions of the author towards the Fracklands and their components. Documentation of evidence of Fracklands and their components. Reflections were documented through field study, and remote geospatial analysis.
- Stories: How various people are experiencing, interacting with, perceiving, and reacting to the Fracklands and their components. Told through secondary sources – interviews, surveys and questionnaires, and ethnographic studies.
- Patterns: Examine the spatial phenomena of the Fracklands and their components. They are critical thought-based maps and diagrams which reveal unique spatial relationships through quantitative and qualitative data.

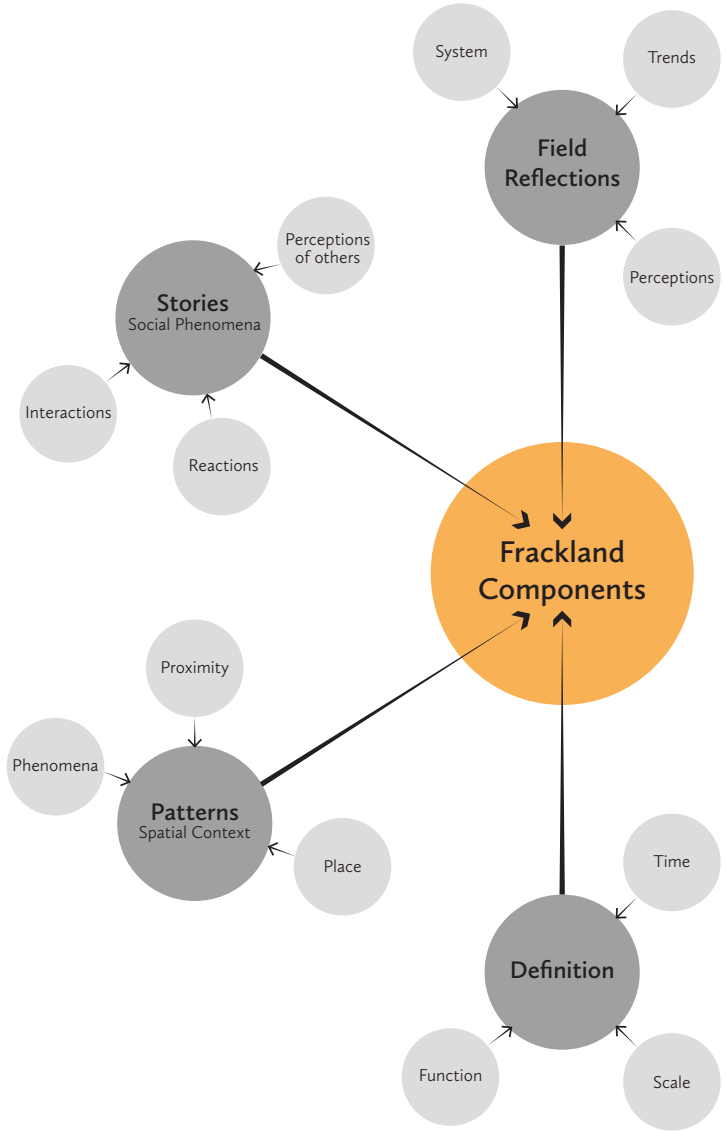


Figure 13.1. Descriptive strategies for defining Frackland components. (Lanning, 2018)

Section 2, chapter 8 – regions of study (97-114):

In addition to delineating the methodology, Section 2 of this report defines the regions of study. The descriptive strategies described in the methodology were to be conducted both in the field and remotely. Eight regions were identified and three selected for study, weighted by various selection criteria. Chosen were Weld County in Northern Colorado, Tarrant County, the seat of the city of Fort Worth, Texas, and frack-prone areas of Pennsylvania and West Virginia. Each region selected exhibited unique contextual and phenomenological qualities to be investigated.

Specific areas of interest in these three regions were then selected for visit or remote study. Multiple field visits to Weld and Tarrant counties were conducted. Areas of Pennsylvania and West Virginia could only be researched remotely due to limitations discussed in the next chapter. Other study areas such as the Bakken oilfields of South Dakota and Frac Sands of the Midwest were remotely researched in order to study specific phenomena unique to that region, or used as a substitute if information/data for the primary study areas were absent.

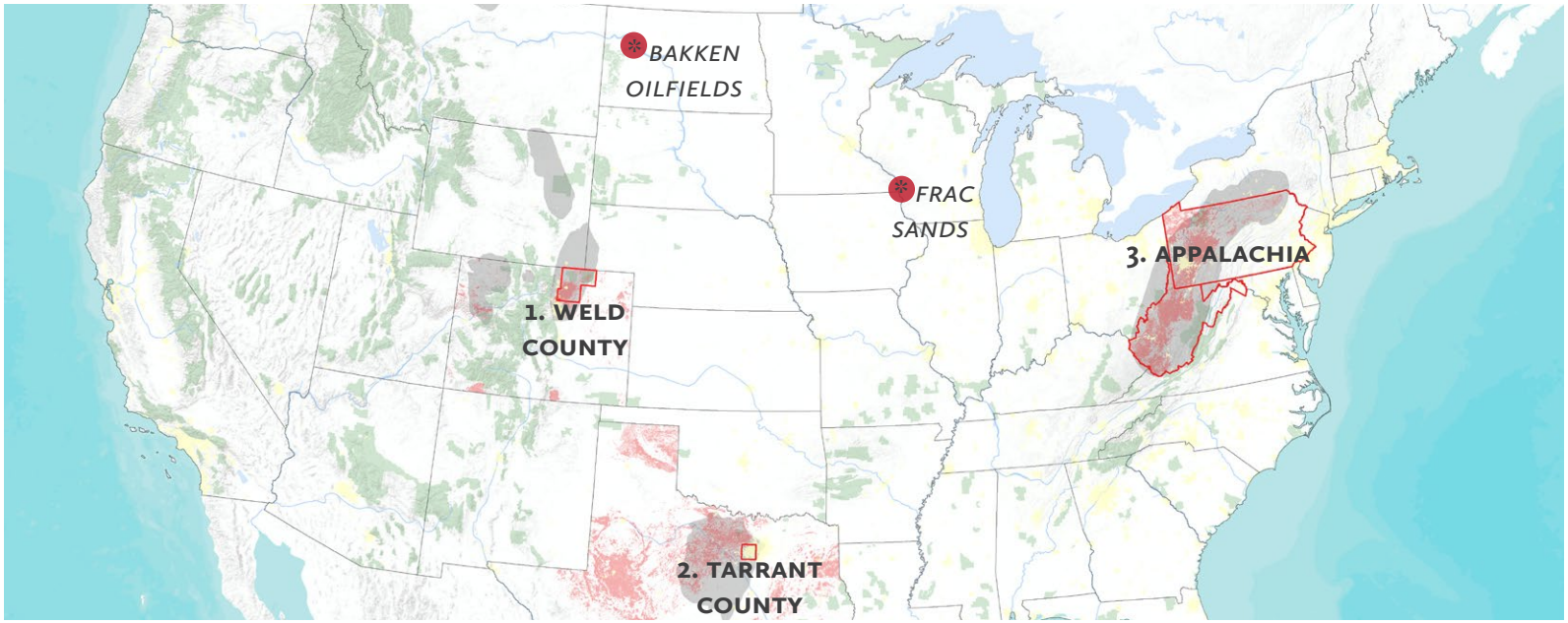


Figure 13.2. Regions of Focus map from Section 2. (Lanning, 2018)

Section 3: findings – chapters 9-12 (115-304)

Section 3 of this report presents the results of the research methods utilized. This section was presented through the four approaches of the classification framework. Results reveal that fracking is deeply ingrained not just in the regions researched, but across the American landscape. Over 200 pages discuss the Fracklands through these four unique lenses and through various facets of description, visualization and reflection.

Section 3, chapter 9 – systems (119-128):

This chapter revealed how the Fracklands operate and weave their components together. It showed that while components may appear as self-sustaining or independent from fracking, they can be linked by various means. Diagrams in this chapter focused on these component connections from a conceptual level, how they connect via the functional processes of fracking, and how they connect spatially in the actual landscape. The concept of these components and the Fracklands themselves of an interconnected and complex system would be echoed throughout the rest of the section.

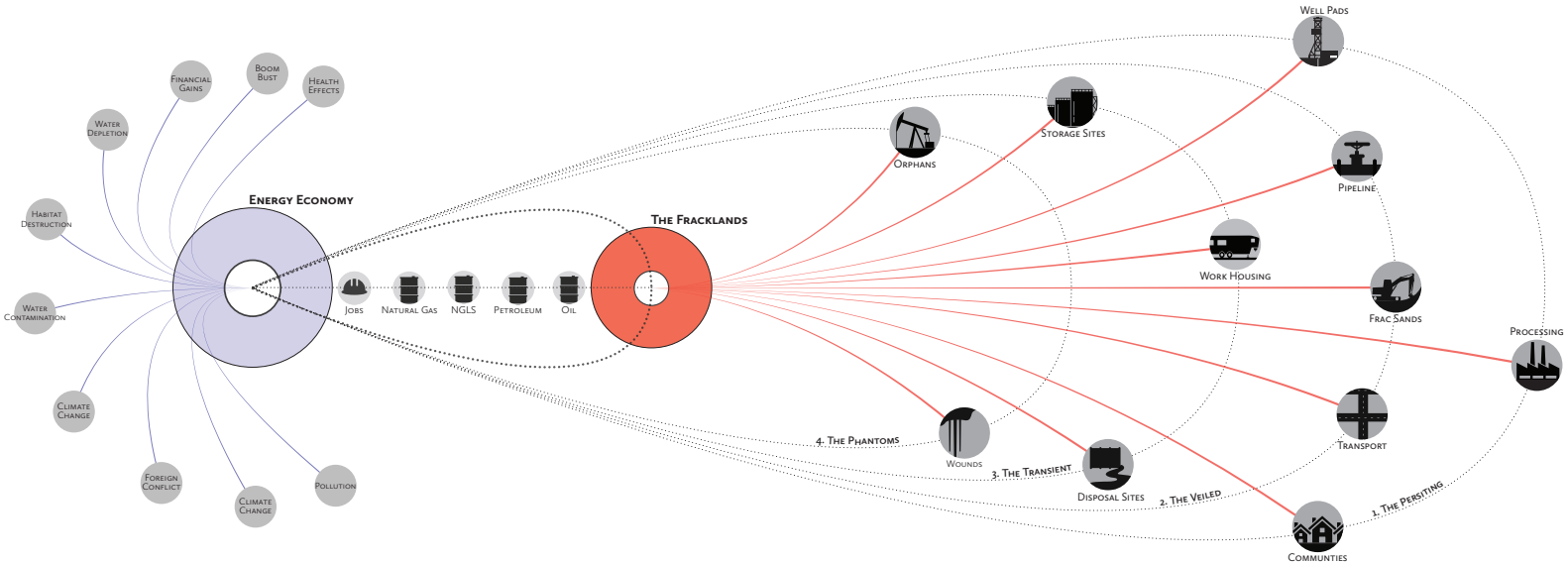


Figure 13.3. Conceptually based systems diagram. (Lanning, 2018)

Section 3, chapter 10 – typology (129-264):

This extensive chapter presented the majority of the findings on the Fracklands by heavily investigating their components. The typology itself was made up of four types:

- **Persisting Fracklands:** Those which are fixed, known, and/or finite entities in the landscape.
- **Veiled Fracklands:** Those which are hidden physically and/or by association to fracking processes.
- **Transient Fracklands:** Those which are ephemeral and subject to change rapidly. Activity is infrequent.
- **Phantom Fracklands:** Fragments, physical or metaphysical left behind by fracking processes.

Each Frackland type plays host to its own set of components which evoke the nature of that type. It is these thirteen components that this chapter most heavily explored. Each components is presented the same; with the four descriptive strategies highlighted above in the order of *Definition, Field Reflections, Stories, and Patterns.* As a whole this chapter presents the Fracklands through various modes of evidence. 80+ photographs accompanied with written descriptions and field reflections document how the Fracklands have come to define entire regional landscape systems.

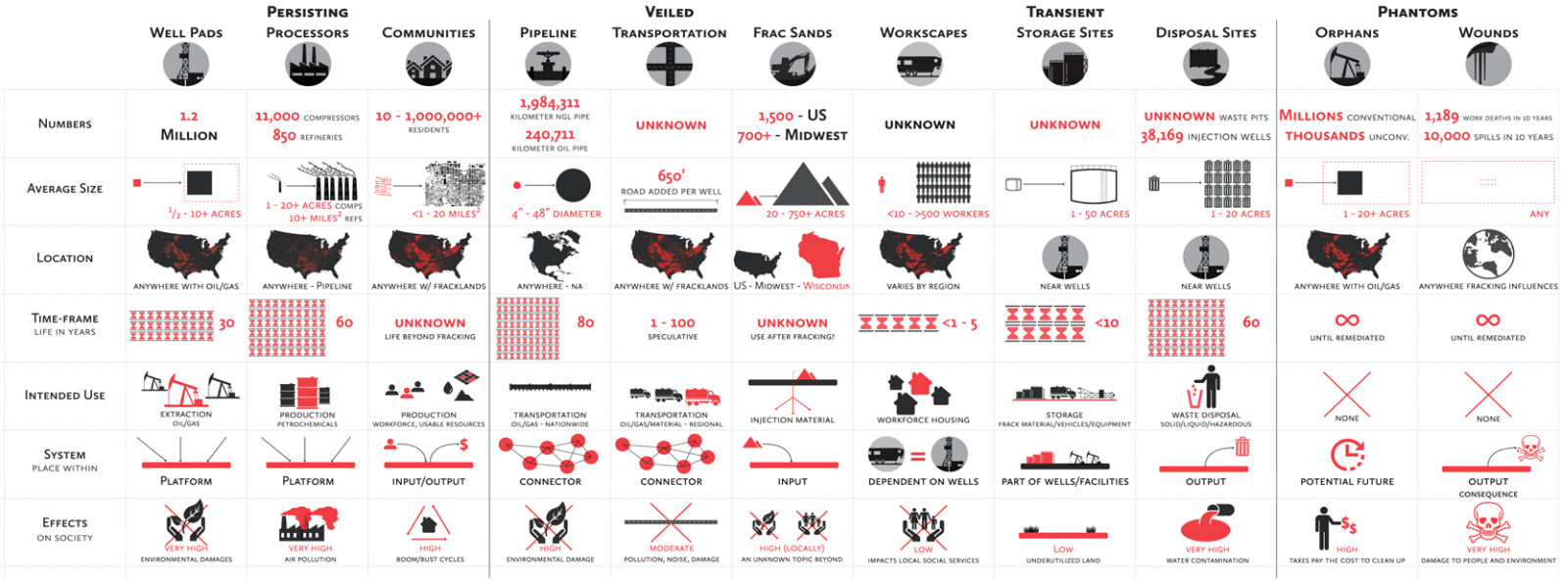


Table 13.1. Breakdown of the Fracklands and their components. This table can be found on page 133. (Lanning, 2018)

Chapter 10: typology – stories:

Throughout the typology, each component was represented through a thematically similar "story", a review and discussion of already documented sociological phenomenon. These 12 stories document how fracking has unhinged lives of both rural and urban dwellers, how the structures of entire communities have diminished, and how it has pitted people against one another and against their changing landscape.

1. **Wells – Hydraulic Fracturing's Impact on Perception of Place (Sangaramoorthy et al. 2016):** Fracking's effect on West Virginians' feelings about their surroundings.

2. **Processors – Local Attitudes Towards the Oil and Gas Industry in North Dakota (McGranahan et al. 2017):** Social phenomena between oil and gas companies and those who lease land for exploration.

3. **Communities – Spillover Effects: Fracking's Impact on Communities (Jerolmack and Berman 2016):** How fracking has compromised the social fabric of communities across Northwest Pennsylvania.

4. **Pipeline – Fighting Oil and Gas – Hesitation and Hopelessness in Fort Worth, Texas (Gullion 2015):** The phenomena of fracking in urban middle class communities of Fort Worth, TX and these residents' reactions towards it.

5. **Transport Infras. – Oil-field Traffic and Community Responses in South Texas (Rahm et al. 2015):** Fracking's impact on communities' transportation infrastructure.

6. **Frac Sands – Communities and Sand Mining in Rural Wisconsin (Pearson 2016):** Various sociological phenomena associated with frac sand mining in Wisconsin.

7. **Workscapes – *The North Dakota Man Camp Project: The Archaeology of Home in the Bakken Oil Fields* (Caraher et al. 2017):** Phenomena associated with temporary housing found in North Dakota's oilfields.

8. **Storage Sites – Perspectives from Oilfield Workers (Filteau 2015):** Thoughts and feeling of oil/gas workers in Pennsylvania, and their perceptions of community/place.

9. **Disposal Sites – Fracking and Social Injustices in Rural Pennsylvania (Malin and DeMaster 2016):** Socio-economical phenomena between oil and gas extraction and farmers of rural Pennsylvania.

10. **Disposal Sites – Fracking and Social Injustices in Urban Texas (Johnston et al. 2016):** Investigation into the disposal of fracking waste and occurrences of injustices.

11. **Orphans – Learning from Canada's Orphan well dilemma (Jeneroux 2017; Power 2016; Sandals 2017):** Looking into how canada is addressing its own orphan well dilemmas.

12. **Wounds – From Boom and Bust to in the Eagle Ford, Texas (Murphy et al. 2018):** Examining the fracking boom to bust cycle in a rural texas community and the changes to social fabric and community infrastructure.

Chapter 10: typology – patterns:

Within the Typology 33 different "pattern" maps and diagrams document how the Fracklands' components are fixed in the landscape. This imagery ranges in scale from the site scale to the entire nation, and portrays information both qualitatively as well as quantitatively.

Told throughout the course of the chapter, these maps were created to show not only the system of the Fracklands spatially, but show the Fracklands from a granular perspective, and the variation of components from region, community and place.

- 10 maps represented information across the entire country highlighting how components are spread across the nation and how their processes are connected to and/or effect the Nation as a whole.
- 6 regional maps highlighted unique phenomena in specific areas despite relative homogeneity between the distribution of Frackland components as shown in the national maps.
- 13 site/community scaled maps displayed unique spatial interfaces within a specific place. Most of these maps focused on communities and neighborhoods and their interface with hydraulic fracturing activity.
- 4 diagrammatic maps investigated specific Frackland components, revealing them as more than just symbols on a map, showing their physical footprint and more.

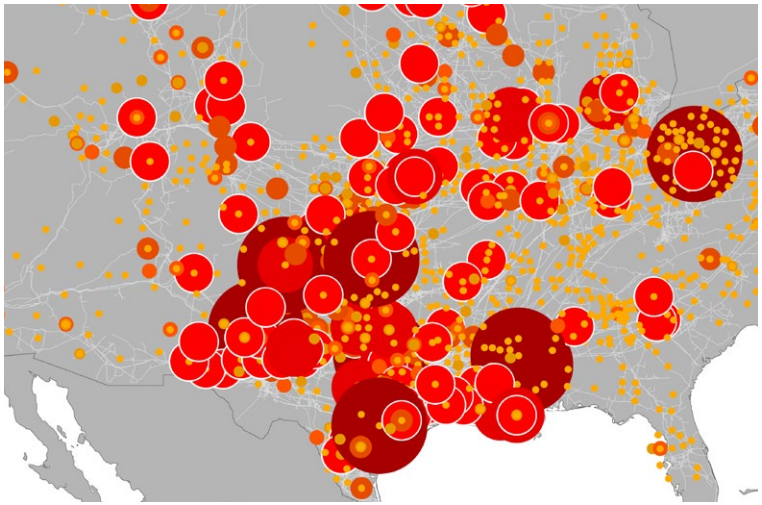


Figure 13.4. Close up of a Nationwide map showing pipeline spills and spill size amounts found on page 191. (Lanning, 2018)

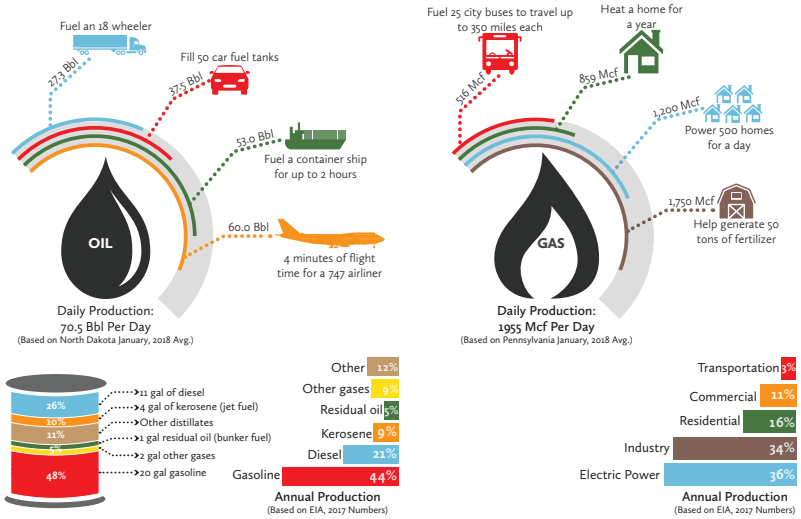


Figure 13.5. Example of a more diagrammatic pattern found on page 152 showing what the average oil and gas well produces. (Lanning, 2018)

Section 3, chapter 11 – trends (265-288):

Trends: This chapter summarizes many of the findings from remote and field based study. It focuses on shared and unshared themes seen across the regions of study. Its primary focus was how social, ecological, and geographical context affected the Fracklands and their components from place to place. Trends documented were finely and broadly detailed.

Numerous trends within the research could be uncovered, those highlighted in this chapter were examples of the many trend types that were evident. Trends discussed in this chapter not only revealed extensive obtrusion in the American landscape today, but gave hints of a future where the Fracklands become abandoned, stagnate, or cleared for standard uses.

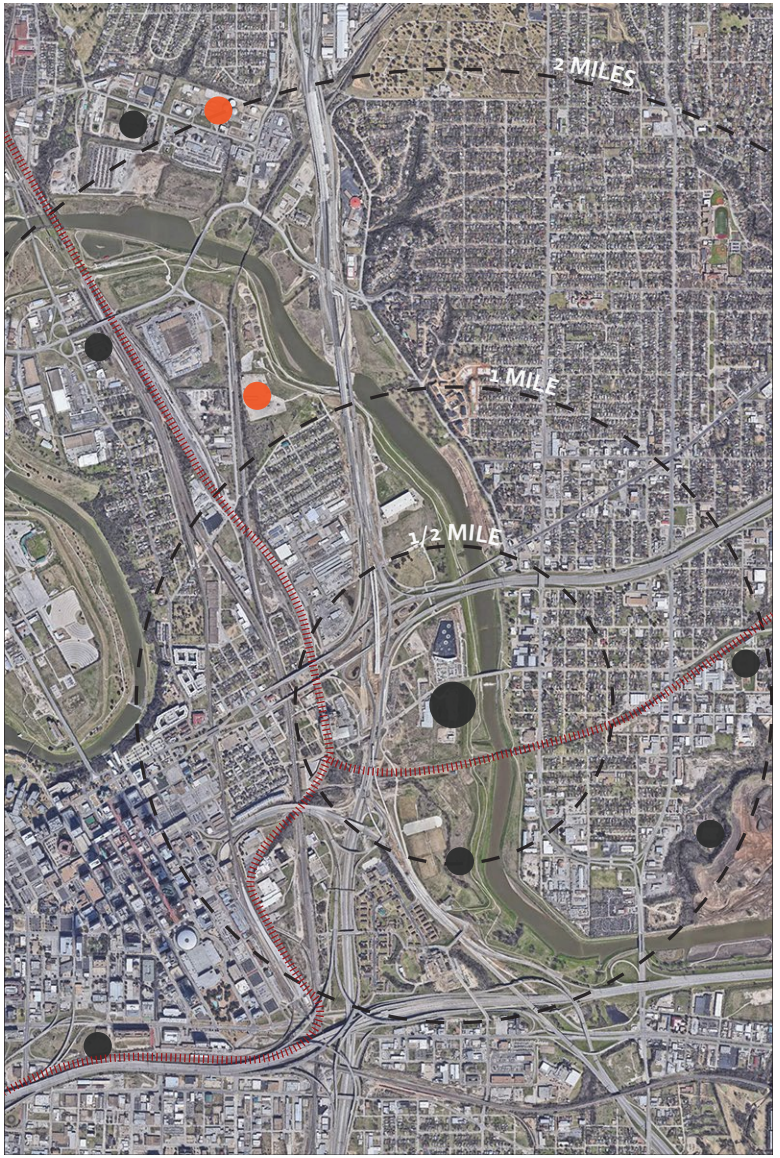


Figure 13.6. Diagram on page 269 showing the trend of wellpads as indicators of other Frackland components. The digram shows this phenomena occuring in downtown Fort Worth. (Lanning, 2018)

Section 3, chapter 10: futures (289-306)

Futures: The final chapter of Section 3 discussed the potential future of the Fracklands and their components post-oil and gas (positive or negative). The outcome of Reclamation was the primary focus of this chapter as it presented the most potential for design and innovation to be made. Discussed was why design should be considered, and considerations for designing around the Fracklands from findings made in the research.

This chapter concluded that there are three primary outcomes that occur from today's reclamation practices but that they lack social, ecological, and economical welfare needed in the 21st century. Three alternative, reclamation practices were proposed:

1. **Reform the Fracklands:** Supporting social based outcomes. People, place, community.
2. **Rewild the Fracklands:** Ecologically based outcomes.
3. **Recycle the Fracklands:** Replacing the industry and energy lost with the loss of fossil fuels.

These three concepts were proposed to be adapted to address not only the social, ecological, and economic, dilemmas created by fracking itself, but those created by the overarching economy of energy.

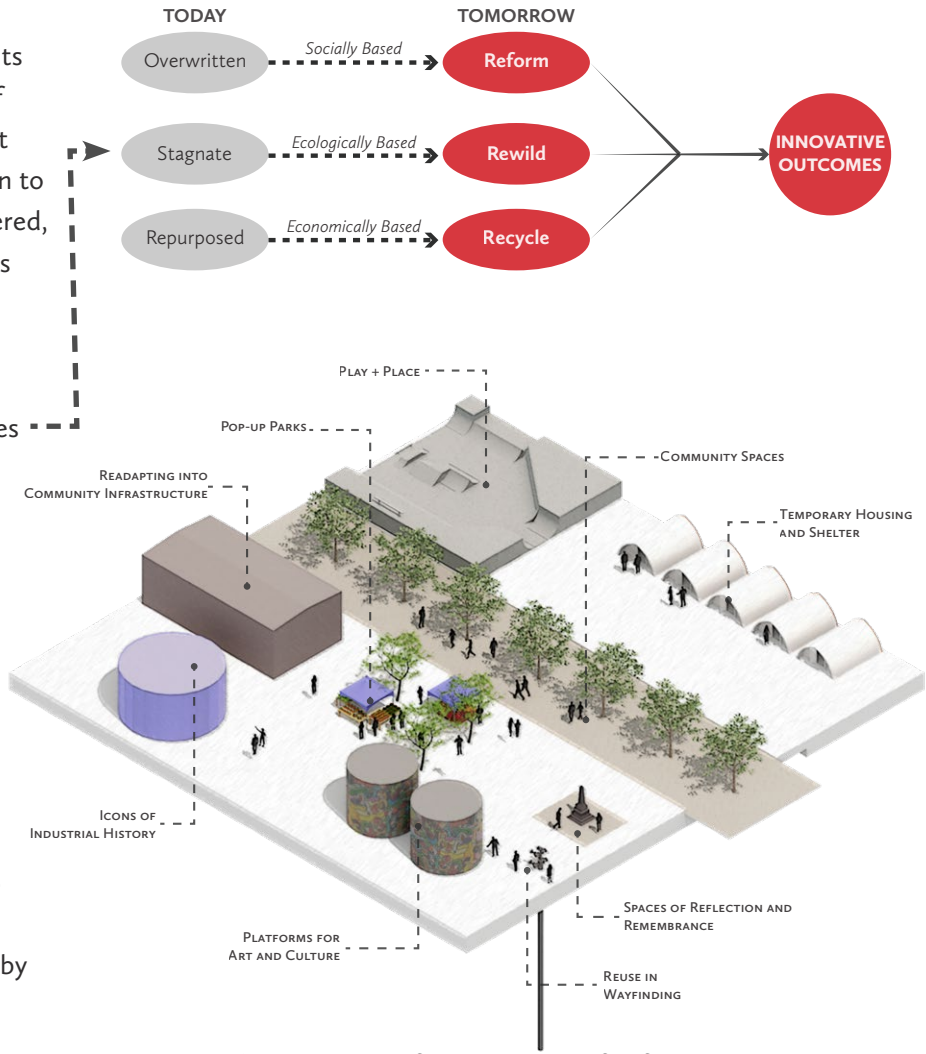


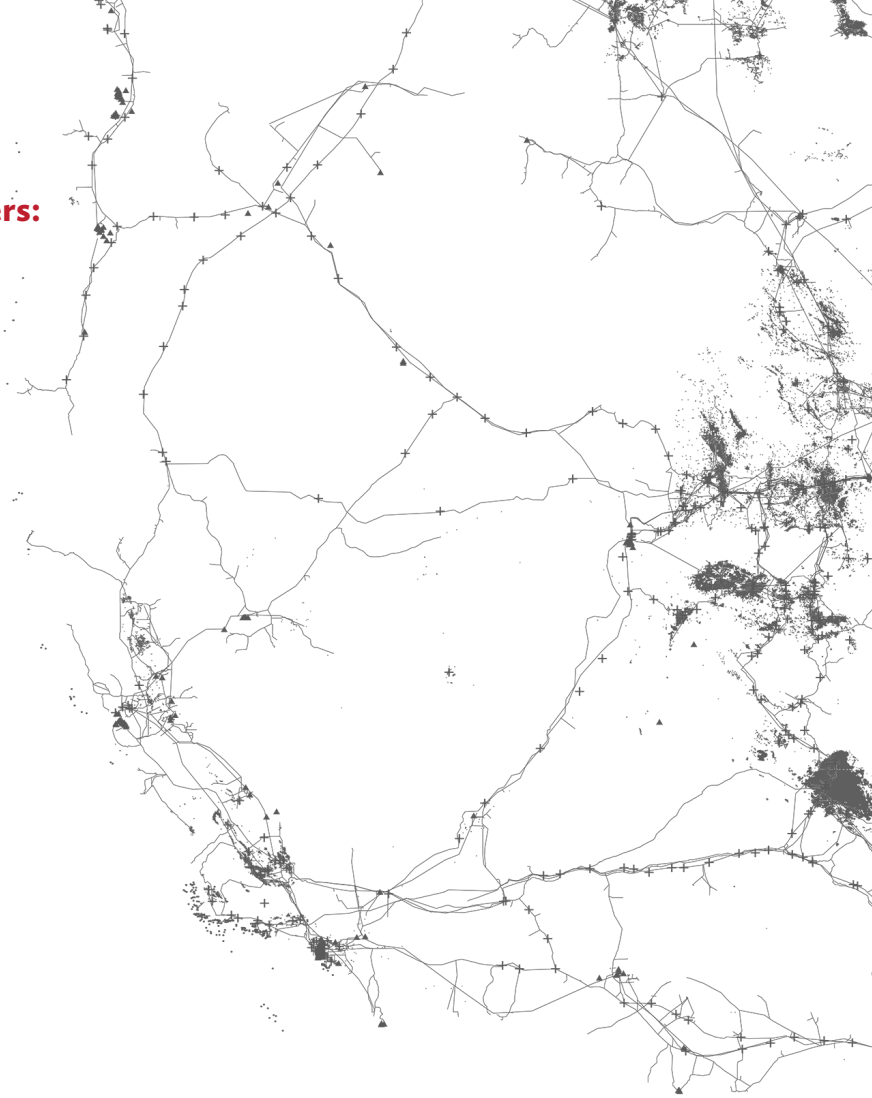
Figure 13.7. Example on page 302 of a visualization of Reforming the Fracklands, one of the three alternative futures discussed. (Lanning, 2018)

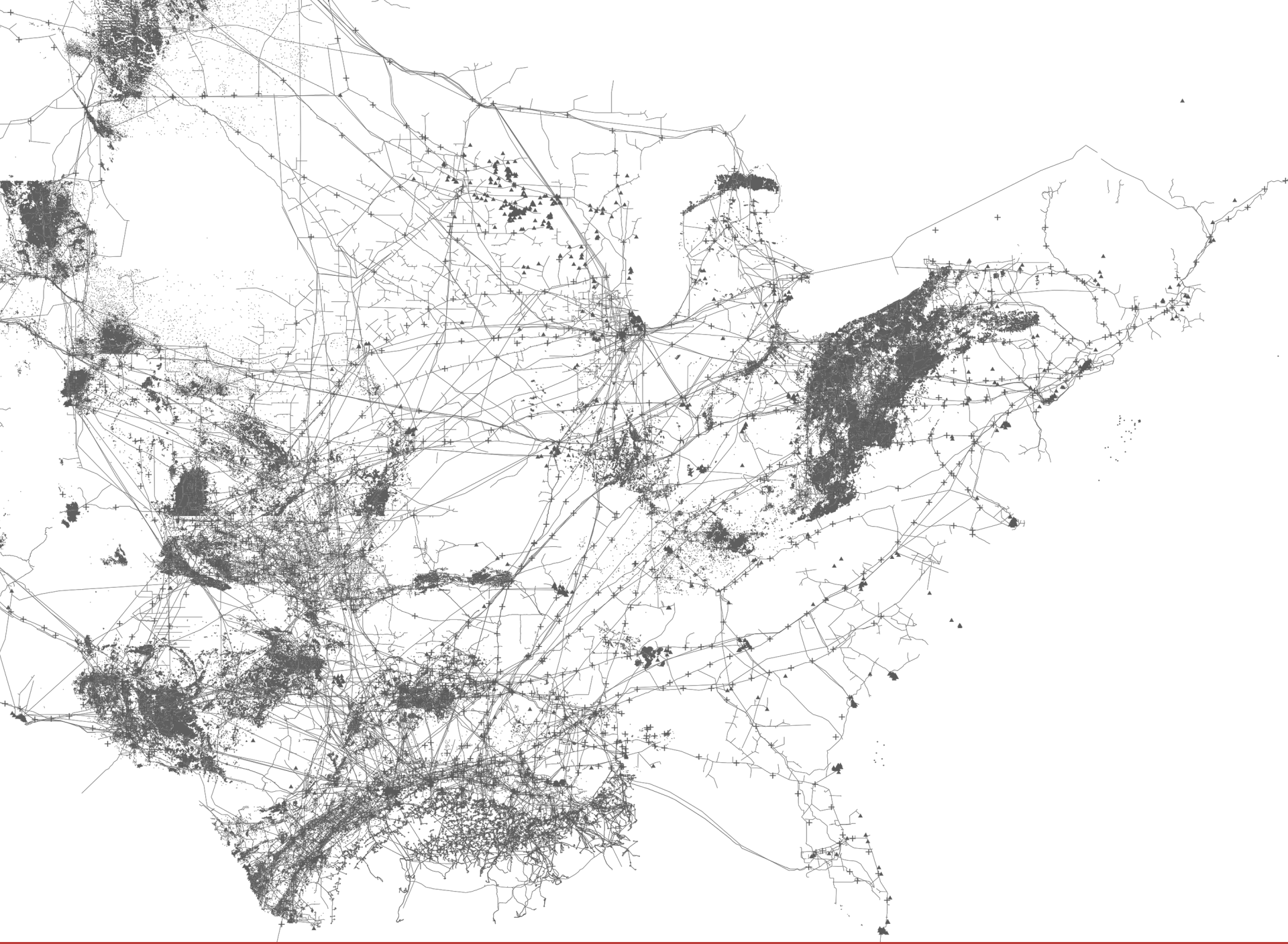
Summarizing the Research:
A Message for Landscape Architects and Decision Makers:

Findings from this research suggest fracking will become more ingrained within society as oil and gas demands grow, further complicating matters. Now is the time for landscape architects and decision makers to address the dilemmas highlighted across this research. To begin understanding the Fracklands.

Findings made clear that fracking follows geology not geography; the lines between extraction landscapes and all others will increasingly become blurred. As stewards to the land, landscape architects cannot sit idle and watch these landscapes fester. This report presented and tested a framework for understanding the various phenomena of the Fracklands. It has also presented means of moving decision makers forward towards a future where these landscapes can become armatures of community and society, ecology and nature, economy and low-impact energy.

The methods of this research are significant in that they set up a framework for further study. What's been established is a methodology that can be readily adapted and applied to any region or place. Many regions of study were left out of this report, but can be filled in by future study. Future study can reveal more components and more about the Fracklands. This is just the beginning for understanding a complex and wicked problem that is the Fracklands.





14 REFLECTIONS

Reflecting on the Methods:
The methods used across this report are an answer to the call for better understanding hydraulic fracturing and its interactions with landscape, people, and place. The methodology and the classification scheme used to reveal the Fracklands was created to be used by anyone seeking to understand the landscapes of hydraulic fracturing beyond known literature. Each of the four approaches of this framework reveal unique findings from differing means of researching, categorizing, and presenting data. This process is the first attempt in understanding the complex entities that are the Fracklands – the first attempt at summarizing various phenomena for the millions of pieces of infrastructure that make up these landscapes.

Systems: While systems-based thinking is growing more popular in many fields, the literature showed a lack in such thinking in regards to fracking. Uncovering the Fracklands system had to be done without precedent and throughout the project time frame. While initially defined through literature, observations in the field revealed the systems much more clearly. It could be seen in action. While represented through only a few diagrams amongst a mass of dozens, the systems-based approach was foundational to the project, droving much of the thought and findings.

Typology: In the early stages of crafting the methodology addressing how one might develop findings on millions of pieces of infrastructure was daunting. The typology became the ideal solution, a means of grouping the Fracklands and their components by shared characteristics. Seeing as these components define the Fracklands, the majority of the findings in this report became focused on components themselves. In the field, each of the four descriptive strategies were crucial in further organizing and separating the large amount of information collected. Field photography proved valuable for documenting the Fracklands and aerial drone photography was essential in looking at these landscapes from further out and taking in a new perspective.

While various forms of imagery played an important in this research, my reactions to experiencing these landscapes (much for the first time) was equally as important. Field reflections showed the thoughts of an individual experiencing these landscapes. The goal was that with both my own evidence and evidence from the literature, one could take away a clear understanding of the workings of the Fracklands. The value in the field notes was also that little to no literature has made personal connections such as these – an individual's quest to wrangle the complexities and often absurdities of these landscapes, many of which were close to home.

Stories were essential in understanding more than just my own thoughts on the Fracklands. It was about understanding how other people were responding to them. Imagery fell short in being unable to show an individual's relationship with the Fracklands, only their own words could. These 12 stories were selected so that one could see a range of sociological happenings from across the country. The struggles to triumphs of those who live amongst the Fracklands and who see and experience these places on a day to day basis.. However, many more such stories need to be told to fully understand the sociological phenomena of the Fracklands.

Frackland Patterns were essential for visualizing how Fracklands are distributed across the country, a region, or a place. While notes and images from the field develop a clear understanding of what a single component of the Fracklands could look and function as, Patterns showed them together and in a greater context, revealing common spatial traits or themes of what each component means in time and space. These exercises revealed more extensive networks of what these landscapes really mean for a region and the country. It became clear that each region where Fracklands are common sees its own unique patterns eliciting many more maps than originally intended.

Trends: Consideration of trends began when researching regions of Fracking and seeing how big and how little differences between the two can be. Trends became essential for summarizing the information collected from the field visits and showing the importance context plays in defining the Fracklands. While many trends were ruled by land-use and surrounding population density, findings suggested that Frackland trends are highly variable and difficult to predict region to region. Tarrant County was a good example of this, displaying unique trends not found elsewhere. Generally no two regions were or will be the same.

Futures: While the primary goal was to understand the Fracklands and understand them as they are today, it was a strong desire to investigate their future. Looking into this future showed what many of these landscapes will regrettably become – abandoned, or paved over with sub-standard uses. However, investigating alternatives gave hope to the future in developing ideas of what this infrastructure could become. These conceptual visualizations proved to be an effective means of detailing ideas and connecting them to both literature and findings from the field.

Limitations:

- Limitations of methodology:

  A major limitation were the regions of study. While three were selected only two were actually visited. And with each region where fracking is significant (a total of 7), this is not enough to understand these landscapes as they are across the country. Other issues with the selected regions were inconsistencies between them. The three selected regions were inconsistent in scale. Tarrant was a fraction of the size of the Appalachian region. Many patterns within the greater area outside of Tarrant may have been completely missed because this study area was so small. Each region also had varying degrees of data availability. Texas had zero data transparency. Often one region had certain data no others did , so it had to be specifically focused on. While it would've been ideal to have patterns for each region, many could not be created because of this lack in data. In some cases data was so poor an entirely separate region which was not the primary region of focus has to used.

  Perhaps the biggest limitation to this report has been time. There has not been enough time to adequately collect all the desired information. With more time, the project could be refined, more field visits could be completed, additional maps and diagrams could be created and so on. Also regarding time, I have only had a short time to become familiar with this topic. I am no industry expert and have lacked total knowledge on the subject until it began 8 months ago.

- The Future and Reality:

  The last major set of limitations for this project is realty itself. All we can rely on is information that has been collected thus far, and what we are seeing in the field today. This is much of the reasoning for why the future is not touched on in more depth. The only thing that is certain is that at some point in the next 80 years, the Fracklands will cease and become something new. The reality is that most of these landscapes will become reclaimed and forgotten. Complications with land ownership, money, and regulations were ignored when developing the alternative futures for the Fracklands. The hypothetical nature was meant to get ideas out, but in reality those who own these lands have the final say in what becomes of their future – a majority of which are privately owned. Only a fraction is owned by governments.

- Wicked Problems:

  The complexity of this project and the dilemma it has focused on addressing is a limitation within itself. This is a topic that is rapidly shifting and changing every day. It is impossible to properly predict the direction it is headed. Additionally while the methods sought to completely uncover these landscapes, there is just too much happening to understand all of the happenings with these landscapes. So much more information is needed that couldn't be collected. There were many such limitations along the way that hampered findings.

Finding Value in this Report:

The information laid out across this report is vital for many reasons, both to the profession of Landscape Architecture and to the greater realm of Academia in understanding hydraulic fracturing. This research has offered the following:

1. **A summary of literature and research into understanding hydraulic fracturing in general, and what various groups are doing about it.**
    - One does not have to dig through numerous journal articles or papers, one can turn to Section 1 of this report.
2. **An attempt to address what many have called for: Developing a novel methodology for better understanding hydraulic fracturing processes, and a methodology that can be adapted and built upon by researchers and decision makers.**
3. **A revealing of the true landscapes of hydraulic fracturing – The Fracklands. A telling of this landscape from multiple perspectives on numerous subjects in various regions of the country.**
4. **A discussion of the future of the Fracklands, and the future of hydraulic fracturing. What that future is on track to become and how we might intervene and create more improved alternatives.**
    - A telling of the dire future of fracking, warrant for why attention needs to be given now, not later.
5. **A catalogue of information on many of the components that make up the Fracklands, organized for easy understanding four typologies for grouping that information into shared common associations.**
    - Extensive written findings on these components that portray them factually as they are, as they are viewed from that of the author, as they are viewed or experienced from groups of people across the country.
    - Extensive photographic evidence of these landscapes and various phenomena associated with them.
    - Various visualizations of these components at a regional and national scale. A portrayal of them as dense system and not as standalone entities.
6. **Field study and visitation to three unique regions where Fracking has greatly impacted the landscape and its people.**
    - Summary of the Trends and differences within and between these regions. Discussion of the important role that context and adjacency plays.

15 NEXT STEPS & NEW DIRECTIONS

Hydraulic fracturing quite possibly represents man's last desperate attempt to extract oil and gas. It is a fascinating, highly technical process that allows us to access even the hardest to reach reserves. The fracking process represents the extreme actions that are being taken to extraction fossil fuels before they become depleted. Despite fracking's rapid ascension to dominance over American energy, hydraulic fracturing will likely not last through the century.

Many challenges lay ahead in the coming decades in addressing hydraulic fracturing and the Fracklands. While this project is concluding there is much more work that can and needs to be done. New branches in research on this topic or open. The implementation fracking will continue and its infrastructure will increasingly grow in size. Therefore maximizing understanding before the weight of the issues are too much to handle adequately is essential.

Figure 15.1. Safety First. A sign at the entrance to an oilfield in Weld County. (Lanning, 2017)


Whiting
Oil & Gas Corp.
EMERGENCY PHONE: 800-723-4608
SAFETY FIRST!
DANGER
NO SMOKING
OPEN FLAMES
NO SPARKS
NOTICE
AUTHORIZED
PERSONNEL
ONLY
CAUTION
SAFETY GLASSES,
HARD HAT, STEEL
TOED BOOTS ARE
REQUIRED BEYOND
THIS POINT
NOTICE

Adaptation of Methods & Applicability to Professional Practice

The classification scheme of the Fracklands is the first attempt at developing a methodology to clearly define the landscapes of hydraulic fracturing. It is meant to be adapted, used and improved so that these landscapes can be completely understood, more-so than they are here in this text. Additionally the Fracklands are ever changing and growing. Many more Fracklands will be created and need to be understood beyond the ability of this text. The hope is that Landscape architects, planners, and all other decision makers who are concerned about both the future and our lack in understanding of these landscapes can use this methodology to find new answers.

Since it is the intention for one to adapt the methodology and methods in this report, there are a number of things that should be noted to be done differently.

1. Keep it specific and define scope of project early on. It was the desire to present as many findings as possible on this topic, however conflict arose when under time constraints. Additionally not honing in on more specific areas of focus lead to an almost 400 page report.
2. Narrow down the region of study as early as possible, and make sure the areas within this region to be researched are carefully selected to maximize findings. Try to avoid happening upon areas of interest in the field.
3. Talk to people, to industry experts, those who live around and are familiar with these landscapes. Obtaining this kind of information may reveal many findings that this report could not.
4. Spend more time in the field, and spend more time in one given area. During the field visits, many areas of interest were visited, but time spent within them was low.
5. Spend more time with data and developing quantitative findings as well as qualitative ones. Having more time to work on this project would've allowed more quantitative analysis of the Fracklands.
6. Ground yourself more in reality. The proposals of the final chapter ignored many considerable limiting factors.

Future Research

Decision makers should see this report as a first step amongst many more. An establishment of approaches to thinking about the complex landscape system of hydraulic fracturing. With addressing wicked problems becoming a zeitgeist amongst many professions, the methods laid out can be taken and developed further to adapt to the changes that will take place.

Regarding the methodology, the four approaches offer starting points for various individuals whether they have a background in design, physical sciences, social-sciences, and more. One doesn't have to replicate the entirety of what this project has done. One can choose a specific approach such as Trends and look into uncovering new findings on a specific subject.

This would be the ideal next step, to take the classification framework and the methods utilized in this report and uncover more granular findings on the Fracklands. Understanding the Fracklands leads to better understanding of how to address the dilemmas of fracking.

While much research needs to be done into understanding the Fracklands as the are now, discussion also needs to be moved forward on the future of these landscapes. This is where Landscape Architecture can really step in. The broad and bold proposals laid out in this book can be taken and moved more towards becoming a reality.

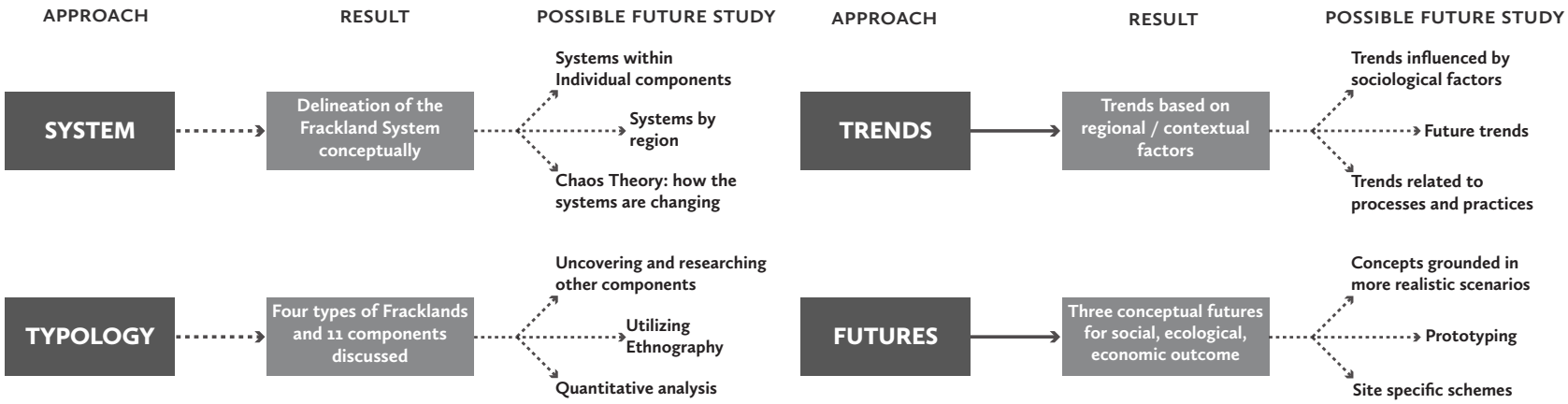


Figure 15.2. Results generated form this report and potential branches of future study. (Lanning, 2018)

APPENDICES



Figure V. Tank Batteries in Weld County. (Lanning, 2017)


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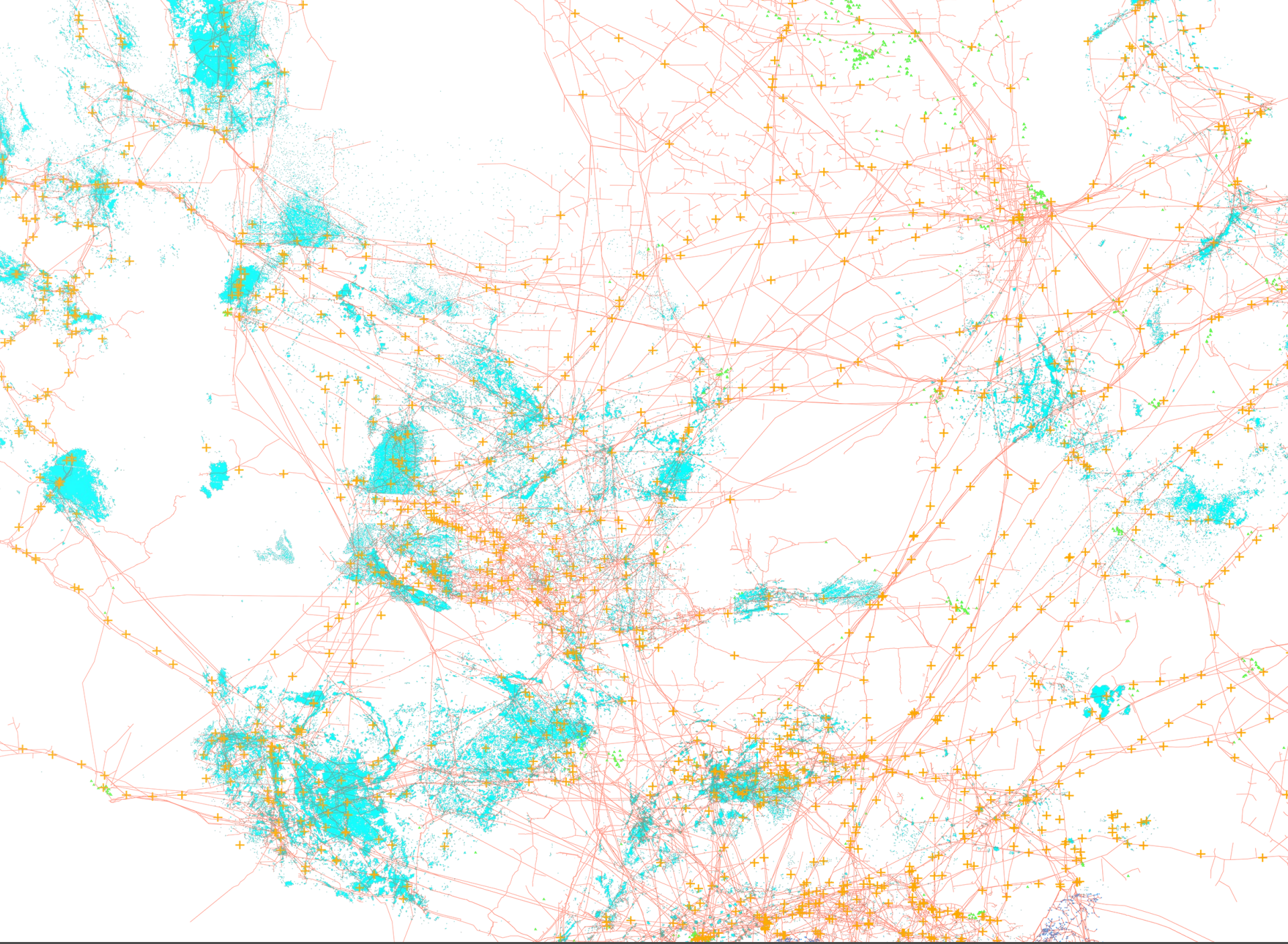
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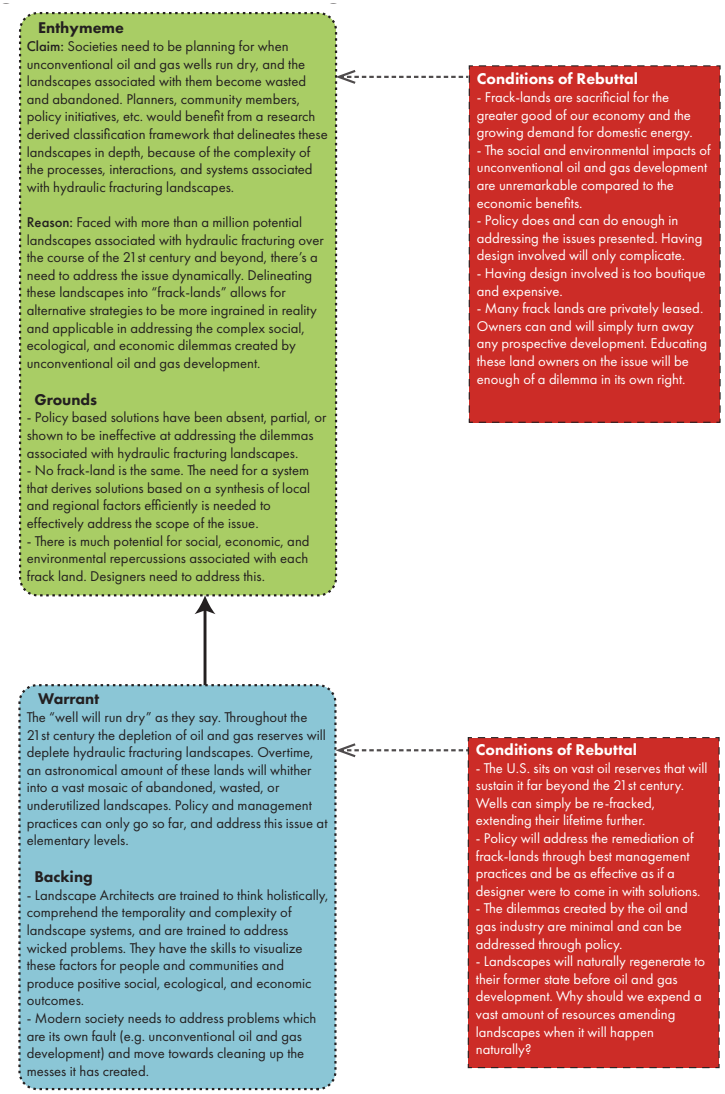


B: GLOSSARY

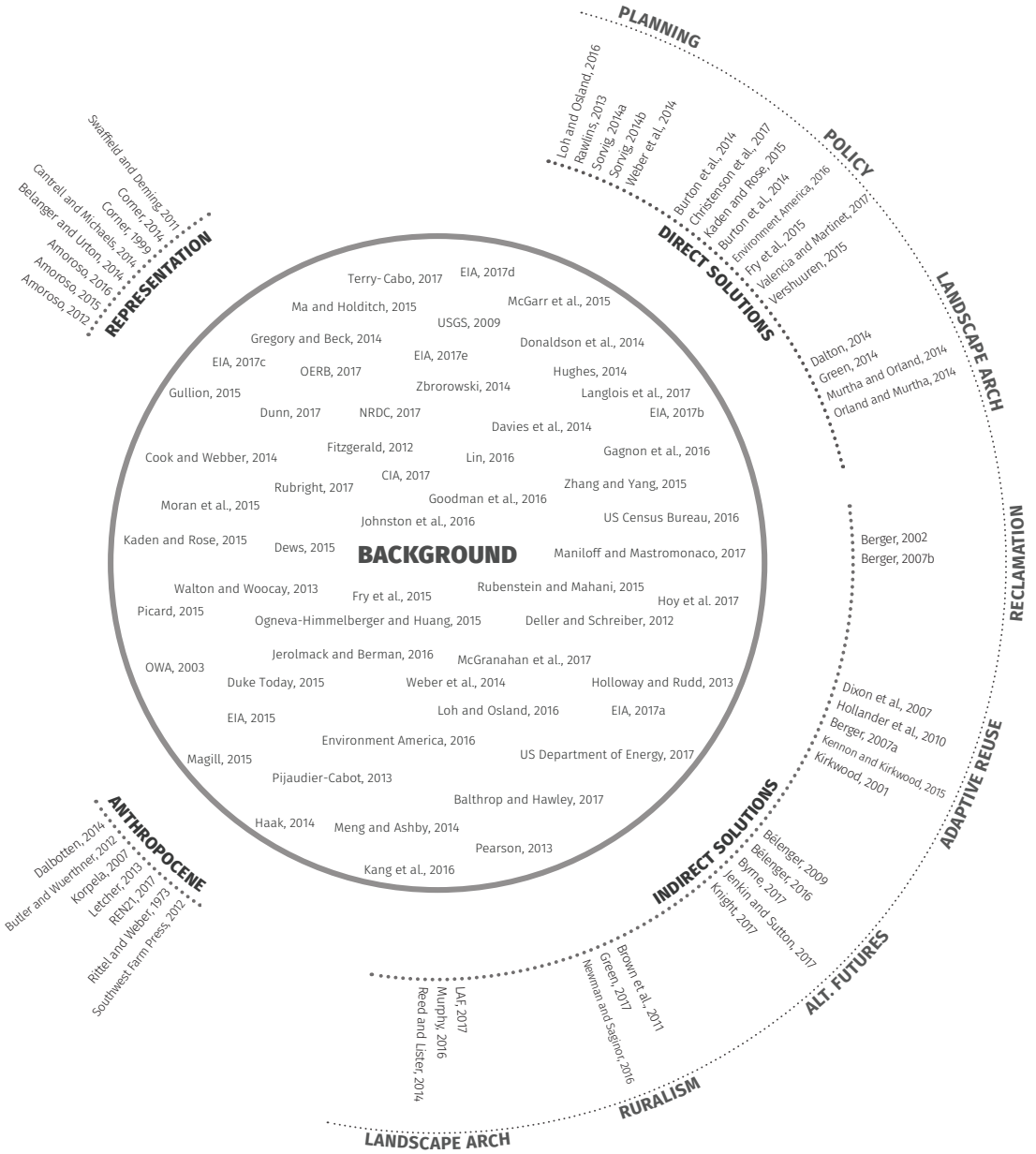
- Anthropocene: The current geological time period where human activity is the primary influence on climate and the environment.
- Blowout: Unintentional release of pressurized gas and or fluid below or at the surface. Can lead to contamination and hazardous waste spills.
- Compressor Station: Facility that compresses gas allowing it to flow along pipeline. If gas is not compressed it will liquify.
- Conventional oil/gas: oil/gas that is extracted through conventional means. Crude oil is an example. Conventional sources are largely depleted today.
- Drilled but Incomplete Wells (DUC): wells that are drilled but are left behind due to shift in the energy markets or other reasons.
- Environmental Injustice: The wrongful treatment people of a particular race, origin, or income with respect to environmental laws, regulations, and policies.
- Environmental racism: A form of environmental injustice where a racial minority is exposed to harmful chemicals and or not given access to clean air and water.
- Flowback: The flow of fracking slurry, oil, and gas back to the surface
- Frac Sands: Unique high-sillica sands found primarily in the Midwest whose properties are beneficial to the fracking process.
- Frack Slurry: Name for the pressurized mix of water, sand, and chemicals that is injected into the earth to fracture rock.
- Fracking: Common term for Hydraulic Fracturing
- Frack-hit: When an existing conventional oil/gas well is fracked. Has a high potential to fail and leak.
- Frackland: a landscape of hydraulic fracturing .
- Fragmentation (ecology): Effect where ecosystems (core) are broken apart due to various reasons.
- Fractionator: A natural gas processing facility that refines natural gas into products such as natural gas liquids (NGLs).
- Gas flare: Burn off of access gases when drilling. If not done gasses will build up and potentially explode.
- Horizontal Wells: Wells drilled that turn 90 degrees underground. Fracking wells are horizontal wells
- Human Induced Seismicity: Seismic events such as earthquakes, created due to human, and not normal tectonic activity. Fracking is attributed as a cause of increased seismicity in places like Oklahoma that were previously not subject to earthquakes.
- Hydraulic Fracturing: Unconventional oil and gas extraction method in which rock is fractured by pressurized fluid allowing trapped reserves to be recovered.
- Impoundment: Areas where fracking materials such as sand, chemicals, and freshwater are held temporarily before being used for injection.
- Injection: Refers to the injection of fracking slurry into the earth. The primary process of hydraulic fracturing.
- Man Camp: An informal housing community built for and/or by a workforce. Common in rural oilfields. Named for the large amount of men that live in them.

- Oil Sands: also called tar sands. A from of unconventional oil. These are oil soaked sands that are strip mined. Found predominately in Canada and parts of the Northern US
- Oil Shales: Not to be confused with shale oil. A form of unconventional oil. Oil shales are rocks soaked in oil and strip mined. Sound predominately in the American west.
- Orphan: A piece of oil and gas infrastructure, often wells that have been abandoned and have no ownership.
- Plugging: When oil/gas well is terminated it is plugged with concrete and abandoned
- Reclamation: Recovering a landscape from one that is unused and/or abandoned to one that is usable.
- Remediation: Removal of pollutants from something in that landscape to restore and protect the environment
- Shale Gas Development (SGD): Another term for fracking. Fracking is done over shale gas and shale oil formations.
- Shale oil and Gas: Oil and Gas that forms in shale rock formations. The predominate source of oil and gas reserves across the planet.
- Shale play: A major geological formation of shale rock. Are indicators of regional oil/gas pockets.
- Tank Battery: A large metal tank used for holding oil or gas. An essential component of well pads.
- Tight oil and gas: Another term for Shale oil and gas. Tight refers to the nature of the oil and gas, which is held tight between rock.
- Unconventional Gas Development (UGD): Another term for fracking, as fracking is the primary form of unconventional gas extraction.
- Unconventional Oil and Gas: Oil and Gas that cannot be extracted easily or through simple means.
- Waste Water: A byproduct of fracking that flows back to the surface after injection. Contains a large amount of toxic chemicals and compounds. Is not easily recoverable and is often disposed of in surface tanks and pits, or injected back into the earth.
- Well bore: A hole drilled into the surface of the earth where a well pipe will be inserted. Are cased in concrete once the pipe is laid.
- Wicked Problem: A complex problem that is difficult to resolve, does not have a true solution, and requires novel methods of thinking to address.

C: SUPPLEMENTAL IMAGES



Argumentation Diagram (Lanning, 2017)



Literature Map (Lanning, 2017)

A Final Note to Readers:

This report takes an extensive look at hydraulic fracking. If you have read through every page then congratulations! If you have only glanced through the text and/or read the summary, I encourage one more glance, specifically at the imagery and the stories they reveal. Provided is an example below:

To the right is an example of many images shown throughout this report. They hide a deeper narrative on the subject of fracking. This example from Fort Worth, Texas of a wellpad looks straightforward, however it is an image into the past and the legacy of the region – cattle, oil, and gas. This is not what the future of Fracking will look like. This image is taken from the fringe of Suburban Fort Worth. As the city grows and expands into this country, clashes between the desperation for energy and the desires of modern society to grow will likely grow exponentially. While such incidents were documented within this report, it is still limited to specific communities and regions. The image shown to the right is one that can be found many places elsewhere. Time still remains to address the creep of fracking and its many dilemmas, and to address it in new ways for positive social, ecological, and economical outcomes.



Figure VI. At the edge of Fort Worth, (Lanning, 2017)




SHUT-IN
OFFSET
FRAC





