Assessment of the regulatory response to complaints related to unconventional oil and gas operations

by

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ABSTRACT

Unconventional oil and gas development in Alberta has been rapidly expanding over the past couple of decades and has raised public concerns regarding the potential public health impacts and environmental contamination. The objectives of this thesis were to identify the types of unconventional oil and gas issues that government agencies, like health and environment departments, respond to, and to determine the complaint investigation approaches that have worked best for experienced jurisdictions to respond appropriately to the identified concerns.

To fulfill the objectives, seven agencies from four US States were selected to be surveyed based on the presence of unconventional oil and gas plays in their State, the extent of resource development and their role in investigating complaints. These States were Colorado, North Dakota, Pennsylvania, and Texas. The types of agencies that responded to the survey were state health departments, state environment departments, and state oil and gas regulators.

The survey results suggest that there is variation with the types and nature of public concerns investigated by each State agency. However, air quality complaints were likely to be one of the most abundant concerns and also the most challenging to mitigate due to intermittent emissions and non-specific exposures. Survey participants also cited water concerns and general health complaints as being issues that their state agencies respond to on a frequent basis.

The approach taken by the agencies to act upon the concerns mentioned above was similar; all agencies investigated all complaints, including non-specific issues, with priority given to health and odour concerns. Interagency collaboration was critical to ensure a multiple lines of evidence approach and was best achieved by clarifying roles and responsibilities of all stakeholders in the context of the different types of anticipated complaints.

Other complaint investigation strategies included centralized intake and coordination of complaints, the ability of agencies to respond quickly to concerns with suitable equipment and tools, appropriate training and expertise of regulatory and advisory agency personnel, health-based regulations, and a comprehensive reporting system.

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Thank you to all of the survey participants who generously offered their time and expertise to speak about their organization. I hope we learned from each other, and I look forward to future collaborations.

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LIST OF ABBREVIATIONS

AEP	Alberta Environment and Parks
AER	Alberta Energy Regulator
AESRD	Alberta Environment and Sustainable Resource Development
AH	Alberta Health
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
CAPP	Canadian Association of Petroleum Producers
CDPHE	Colorado Department of Public Health and Environment
CO_2	Carbon dioxide
COGCC	Colorado Oil and Gas Conservation Commission
CSUG	Canadian Society for Unconventional Gas
CSUR	Canadian Society for Unconventional Resources
DBP	Disinfection Byproduct
DPM	Diesel Particulate Matter
EDC	Endocrine Disrupting Compound
EH	Environmental Health
EHO	Environmental Health Officer
EIA	Environmental Impact Assessment
EIS	Environmental Impact Statement
ELCR	Excess Lifetime Cancer Risks
EPH	Environmental Public Health
EQB	Environmental Quality Board
ERCB	Energy Resources Conservation Board
ERP	Emergency Response Plan
EUB	Energy Utilities Board
FLIR	Forward Looking Infrared
GOA	Government of Alberta
HBACV	Health-Based Air Comparison Values
HHRA	Human Health Risk Assessment
HIA	Health Impact Assessment
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MCL	Maximum Contaminant Limit
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
N_2	Nitrogen
NAAQS	National Ambient Air Quality Standards
NDDOH	North Dakota Department of Health

NIOSH	National Institute for Occupational Safety and Health
NOAA	National Oceanic and Atmospheric Administration
NORM	Naturally Occurring Radioactive Material
NOx	Nitrogen oxides
NRC	Natural Resources Canada
OGCB	Oil and Gas Conservation Board
OSHA	Occupational Safety and Health Administration
PADEP	Pennsylvania Department of Environmental Protection
PADOH	Pennsylvania Department of Health
PAH	Polyaromatic Hydrocarbons
PEL	Permissible Exposure Level
PM	Particulate Matter
PNGCB	Petroleum and Natural Gas Conservation Board
PPE	Personal Protective Equipment
PSAC	Petroleum Services Association of Canada
RRC	Railroad Commission of Texas
SDWA	Safe Drinking Water Act
TACPHOGI	Technical Advisory Committee on Public Health and the Oil and Gas Industry
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
TVGCB	Turner Valley Gas Conservation Board
TXDSHS	Texas Department of State Health Services
UIC	Underground Injection Control
UOG	Unconventional Oil and Gas
UOGD	Unconventional Oil and Gas Development
US	United States of America
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOC	Volatile Organic Compound
WWTP	Wastewater Treatment Plant

CHAPTER 1 – INTRODUCTION

1.1 A Brief History of the Oil and Gas Industry in Alberta

The history of the oil and gas industry in Alberta dates back to 1883 when natural gas was accidently discovered near Medicine Hat when a Canadian Pacific Railway crew was drilling for water (GOA, 2015). Over thirty years later, light oil was found near Turner Valley in 1914 (AER, 2014a). Development of these hydrocarbon resources began as urban populations saw the potential to use them for home heating, cooking, and lighting (AER, 2014a). In 1950, pipelines were built, which allowed for the transportation of natural gas from Alberta to the main cities across Canada that did not have direct access to these energy resources (GOA, 2015). Alberta saw its first oil rush in 1947 when an oil well coined "Leduc Number One" was discovered. In 1967, work on the first oil sands mine, called The Great Canadian Oil Sands, started. A few decades later, at the start of the millennium, the first commercial production of coalbed methane began.

Since the development and use of hydrocarbon resources in Alberta in the 1930s, there have been many regulatory bodies responsible for overseeing the oil and gas industry. The Alberta Department of Lands and Mines was formed in 1930 and soon after, in 1932, the Turner Valley Gas Conservation Board (TVGCB) was established (AER, 2014a). The function of the latter was to enforce a reduction in flaring and venting of natural gas, as an estimated 260 million cubic feet of natural gas was flared every day. In 1938, the Petroleum and Natural Gas Conservation Board (PNGCB) was formed, replacing the TVGCB. The first enforcement action taken by the PNGCB was in 1946 when it shut down leaking gas wells near Medicine Hat. In 1953, further enforcement actions shut down hundreds of gas wells because operators refused to conserve gas solution. In 1957, the PNGCB was renamed the Oil and Gas Conservation Board (OGCB), which was again renamed the Energy Resources Conservation Board (ERCB) in 1971. The ERCB remained in place until 1995, at which time it was amalgamated with the Public Utilities Board to become the Energy Utilities Board (EUB). In 1996, the EUB established a facilities application process, which emphasized streamlined review and corporate compliance, along with an audit and enforcement component. In 2003, the EUB split back into the ERCB and the Alberta Utilities Commission, and by 2013, the Alberta Energy Regulator (AER) took over as the current governing body. As of the date of the publication of this thesis, the AER is currently Alberta's single regulator of energy who "*ensures the safe, efficient, orderly, and environmentally responsible development of hydrocarbon resources over their entire life cycle"* (AER, 2015a).

With the discovery of the different types of petroleum resources, technologies have evolved to accommodate the changing extraction challenges and to meet the energy needs for the Province. As these technologies advanced and regulatory bodies transformed, legislation governing the oil and gas industry also evolved to keep up with the changing oil and gas landscape. Responsible energy development was first made law through the passing of *the Oil and Gas Conservation Act* in 1938 (AER, 2014a). In 1949, the *Gas Resources Preservation Act* was established, which gave the PNGCB authority to regulate the removal of gas from Alberta. In the 1980s, following a 67 day Lodgepole sour gas blowout, the ERCB held an inquiry which resulted in significant changes in regulations about sour gas drilling, emergency preparedness, and worker training. This incident also led to long-term scientific research into hydrogen sulphide exposure limits. Under the current AER, legislation takes the form of *Acts*, *Regulations,* and *Directives,* all of which are specific to the different types of resources found in Alberta.

1.2 Conventional Versus Unconventional Oil and Gas Development

The composition of unconventional and conventional resources is essentially the same; natural gas that comes from an unconventional formation is similar to the natural gas produced from a conventional one. Where they differ is the types of rock they originate from and the methods used to develop them (AER, 2014b). Conventional oil and gas development refers to the development of hydrocarbon resources that are present in formations characterized by being highly permeable and porous, such as sandstone, limestone or dolostone. These types of resources are difficult to find but are typically quite economical and easy to develop. The hydrocarbons can be recovered using simple methods like a pumpjack or wellhead compressor (PSAC, 2013).

Figure 1 provides a schematic to help illustrate the difference between conventional and unconventional hydrocarbon resources. Conventional resources are either associated with the underlying shale, like the oil and gas on the right, or not associated with the shale, like the gas shown on the far left (NRC, 2015a). The conventional resources are depicted as having definable boundaries, as denoted by the straight horizontal lines.

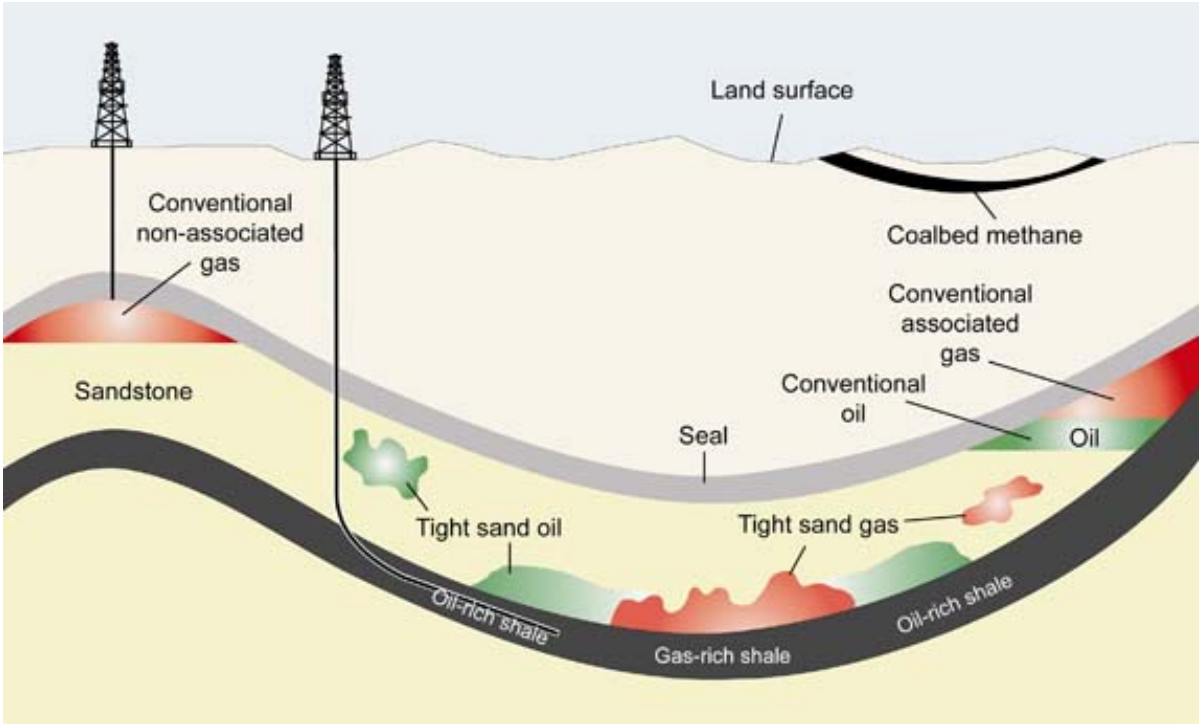
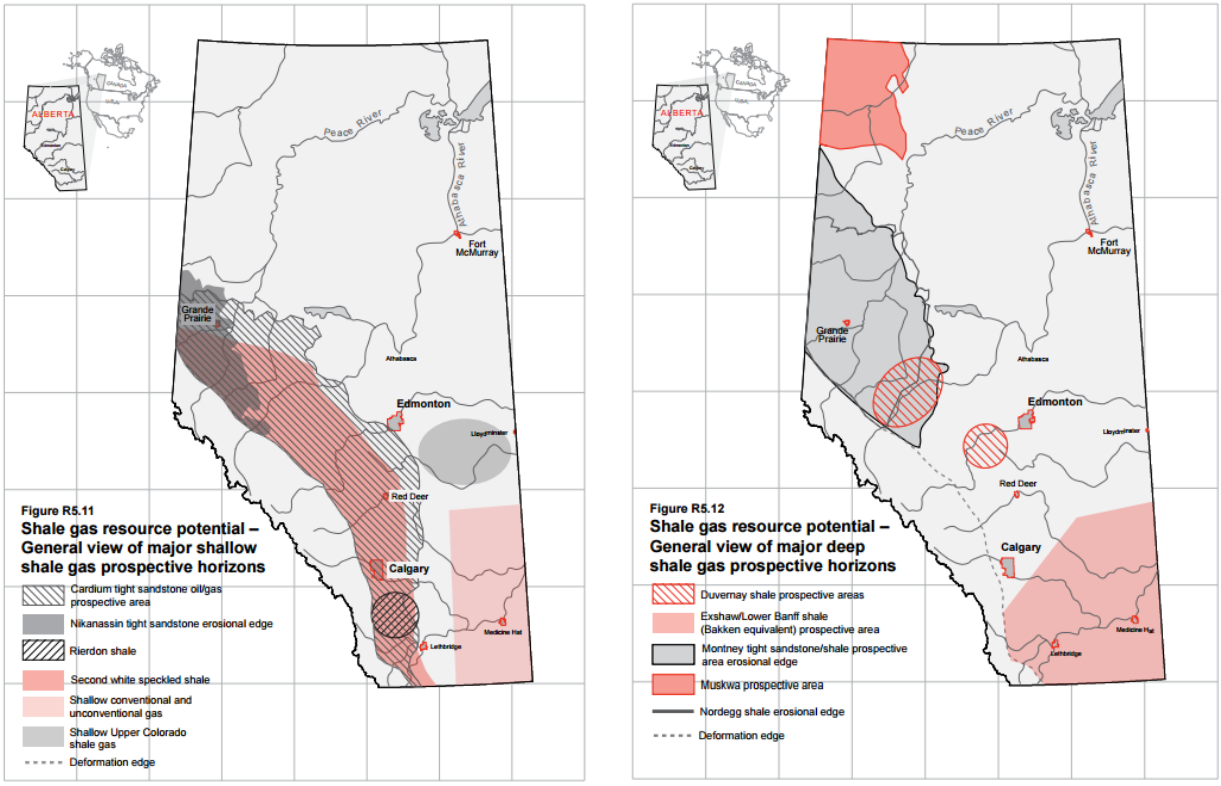


Figure 1: Schematic Representation of Conventional and Unconventional Hydrocarbon Resources (NRC, 2015a)

In contrast, unconventional oil and gas development, herein referred to as UOGD, includes development of hydrocarbons that are present in formations that have poor or very low permeability, such as shale or tight sand, as shown in Figure 1 (NRC, 2015a)[1]. As such, other stimulation techniques are required to release the hydrocarbons from the source rock and bring them to the surface for utilization (PSAC, 2013). Although these resources are more difficult to develop than their conventional counterparts, they are much more abundant in volume. For example, in Alberta, the National Energy Board estimates that Canada has between 885 and 1,566 trillion cubic feet of remaining marketable gas resources, of which between 60% to 70% is unconventional (coal-bed methane, shale gas, and tight gas) (NRC, 2015b). Figure 2 shows the location of the shale gas resources throughout Alberta.

[1] Unconventional oil and gas development can also refer to bitumen/tar sands extraction and processing, and other types of fossil fuel development that employ novel engineering and production techniques to obtain fuels from unconventional resources (e.g., coalbed methane) (Shonkoff et al., 2014). However, these novel techniques and processes will not be discussed further as the focus of the research is on the development of shale and tight oil and gas resources.



(a) **(b)**

Figure 2: Shale Gas Resource Potential in Alberta. Figure 2(a) depicts the location of shallow shale gas and figure 2(b) depicts the location of deep shale gas (AER, 2014c)

Based on the large area that the resources cover, it is evident that the shale gas resource potential is tremendous. As mentioned above, one challenge with the development of unconventional resources is that their extraction requires technology beyond conventional means.

UOGD combines two long-established but rapidly advancing technologies. The first is hydraulic fracturing or fracking, which is regularly used as an umbrella term in the popular media to describe all processes used for UOGD, from land clearing and well drilling, to transmission of products to market (Shonkoff et al., 2014). However, taken literally, hydraulic fracturing refers only to a well-stimulation process in which water treated with chemical additives and sand gets injected into formations at high pressure to crack or fracture the rock so that trapped oil and gas can flow to the surface. This process has been used on over 180,000 oil and gas wells in Alberta since around 1950 (NRC, 2015b). The second technology is horizontal drilling, in which the wellbore is pivoted horizontally to follow the contours of

oil and gas producing layers of rock. Together, these two technologies allow energy companies to produce oil and gas from formations that were previously uneconomical to tap (Gordalla et al., 2013).

1.3 Unconventional Oil and Gas Development in the Media

Widespread UOGD over the past decade has stimulated heated controversy and intense public debate. Regulatory catch-up, poor communication, lack of data, and disagreements in literature have all contributed to the controversy (Howarth & Ingraffea, 2011). Proponents argue that the techniques used during UOGD are efficient methods for extracting a previously untapped source of plentiful fuel that can help address the ever growing demand for cheap energy, while detractors maintain that these methods are an environmental disaster in the making; not only costly in the use of resources, but also able to release potential carcinogens into the air and pollute groundwater sources (Mackie et al., 2013). Others, taking a more cautious position, say that the potential risk to the environment and human health need assessment before more wells are drilled (Finkel & Hays, 2013). Some of the main issues identified by both sides of the debate include waste disposal, groundwater contamination, soil contamination, air quality concerns, traffic, seismic activity, noise, and light pollution.

In the US, UOGD is openly sanctioned by some states such as Texas, Colorado, North Dakota, and Pennsylvania. Other states, such as New York and Maryland have postponed development of their shale gas resources through moratoria until they have more data on the safety of further development. Even more extreme are states, such as Vermont, that have chosen to ban the process outright, even though the State does not have significant shale gas deposits (de Melo-Martín et al., 2014).

In an article in *Nature*, Howarth et al. (2011) stated that 60% of media headlines shed a negative light on the UOG industry but only 20% of the reports speak about the science. Some of the headlines include:

Earthquakes shake Alberta town's faith in fracking (Giovanetti, 2015);
Wisconsin locals fear dust from mines for fracking sand even as boom wanes (Schuessler, 2015);
Fracking contamination 'will get worse': Alberta expert (Nikiforuk, 2011); and
Fracking tied to premature births (Bakalar, 2015).

Documentaries have portrayed UOGD in the same unfavorable manner. One such film is *Gasland*, which sets out to see how communities and individuals are being affected in areas of the US where UOGD is taking place (Fox, 2010). The director speaks with residents who have claimed to experience a multitude of chronic health problems from the contaminated air and water wells. In one scene, a resident ignites his domestic water supply on fire and claims that nearby fracking contaminated his

water with natural gas. In another documentary called *FrackNation*, the filmmakers examine and argue against several of the claims made in *Gasland* (McAleer & McElhinney, 2013).

1.4 Environmental Health Investigations

As a result of the conflicting messages in the literature and of the debate in the media on the safety of UOGD, there has been an increase in research of the potential environmental health effects. During a workshop held in Washington, DC, in 2012, which focused on the health impact assessment of shale gas extraction, a panel of scientists was convened to discuss research opportunities and needs for understanding health impacts of UOGD. Specifically, they were asked what the next steps were to minimize health effects and where there was uncertainty in the available evidence (IOM, 2013). One of the scientists suggested that public concerns are usually followed by calls for investigation of a potential causal relationship between UOGD and adverse health consequences. However, these investigations are usually hampered by inadequate exposure and toxicity information to perform a proper analysis (IOM, 2013).

Other similar workshops have occurred across North America. From November 2-3, 2012, a conference titled, "Responsibility for the land: Conversations on fracking in Alberta," was held at the University of Alberta's Augustana Campus. Here, the organizers assembled panels of experts, landowners, and industry representatives, with the aim to foster constructive dialogue around wise resource management. At the conference, some of the presentations included accounts from the public of their experiences with health and environmental concerns around UOGD activities that occurred near their homes (Campbell & Campbell, 2012; Lauridsen, 2012). In one of the accounts, the citizens were advised to contact the oil and gas company directly to investigate the complaint related to water contamination (Lauridsen, 2012), while in another the landowner with a similar concern was advised to contact Alberta Environment and Sustainable Resource Development (AESRD) (Campbell & Campbell, 2012), which is now Alberta Environment and Parks (AEP), leading to some confusion over what the proper complaint process is or should be. Despite similar concerns being raised by the two families, different investigative approaches (stakeholders, methods, communication, etc.) were used.

At the time of these complaints, the ERCB was the main oil and gas regulator, with AESRD having some direct regulatory duties (AER, 2015a). Since this time, the AER has become the single regulator of all oil and gas operations. Although the AER regulates the development of UOG, when potential environmental and public health impacts are identified or come into question, such as noise, odour or

water quality, other regulatory agencies, like government ministries (e.g., AEP, Alberta Health (AH), Alberta Energy, Alberta Agriculture and Rural Development) and AHS Environmental Public Health (EPH) can be asked to participate in investigations. These types of field investigations are necessary, as they can help to illuminate the potential environmental health issues associated with UOGD and findings can add to the current body of knowledge around UOGD (Shonkoff et al., 2014).

The purpose of conducting this research stemmed from AHS and AH anticipated assuming greater responsibility to address EPH concerns received from the public in the wake of increased UOGD activities. Also, the Provincial energy regulator (ERCB at the start of this research, but now the AER) also asked these health agencies to participate in some complex investigations in recent years. As this is a new focus area for EPH and not specifically addressed by the *Public Health Act* (Province of Alberta, 2000) and associated regulations, research into complaint investigations is necessary to equip the AHS-EPH program with the tools and knowledge of experienced jurisdictions to be able to respond to concerns adequately.

1.5 Research Objectives

The objectives of this thesis were to identify, through a literature search and survey:

- The types of issues that health and environment regulators respond to concerning unconventional oil and gas developments.
- The complaint investigation approaches, including needs and challenges, which are required to respond appropriately to these issues.

The results may assist government regulators, industry practitioners, and other stakeholders to understand what issues they need to prepare themselves for and what approaches are used to respond to these issues to protect public health. The information gathered will be applied by stakeholders to aid in the development of a comprehensive investigation processes not just in jurisdictions where oil and gas exploration is in its infancy but also for regions in Canada that are familiar with this industry.

CHAPTER 2 – BACKGROUND

This chapter contains two reviews. The first provides further technical insight into UOGD processes (Section 2.1) and the second reviews potential human health risks associated with this development (Section 2.2).

2.1 Technical Review of Unconventional Oil and Gas Development

For agencies to effectively investigate oil and gas complaints, there needs to be a level of knowledge around oil and gas development. For example, this is akin to conducting complaint inspections of swimming pool facilities. To investigate a complaint, an Environmental Health Officer (EHO) needs to comprehend the general principles behind swimming pool design, equipment functions, and water quality. Without this knowledge, it is very difficult to understand the potential exposures and manage associated risks as part of a successful investigation.

This section will review the general processes involved in the modern development of unconventional oil and gas resources.

2.1.1 Scope of Review

The scope of this technical review includes activities in the upstream industry, which includes drilling, fracturing, and extraction, but not exploration or site assessment. It also does not include any activities associated with the midstream or downstream industry like transporting, refining or selling the oil and gas. It is important to note that the components of each development will differ slightly, and therefore, the following is only a general review of the main processes involved in UOGD.

2.1.2 Well Pad and Infrastructure Preparation

Once a site has been selected and approved for development through licensing and permitting rules and regulations, an access road is created, if required, and then the land is cleared. An area of roughly 5,000 to 10,000 square metres for a single-well pad and up to 20,000 square metres for a multi-well pad is cleared (Statoil, 2013). Multi-well pads are necessary for the development of unconventional resources since many wells need to intersect the oil and gas bearing formation(s) for the extraction to be economical (CSUR, n.d.). Although a multi-well pad will have a larger surface area impact compared to a single-well pad, the total surface area for the same number of wells is reduced (CSUR, n.d.). Part of the clearing process involves leveling the ground with careful consideration given to existing pipelines and utilities and proximity to surface water. The cleared land needs to be capable of supporting many temporary and semi-permanent structures and tanks, all brought in by truck. Reserve pits can also be

excavated to prepare for produced and flowback water during drilling. At this stage, pipeline gathering systems designed to transport oil, gas, and water can also be constructed to attempt to reduce traffic and impact on roads and local infrastructure (Statoil, 2013).

2.1.3 Well Drilling and Construction

Once the well pad is complete, a drilling rig is usually assembled with the use of a crane, rig up trucks or a forklift, depending on the size. Drilling activities are regulated and require multiple permits. These permits can cover aspects such as well depth, completion process, potential impacts of well site construction and measures to protect surface and groundwater (Statoil, 2013). On-site diesel-powered generators are used to power most drilling rigs (CSUR, n.d.). On a multi-well pad, moving the rig about the pad to drill new wells requires very little disassembly and reassembly.

Once assembly and inspection of the rig are complete, the drilling can begin. The first step is to drill a conductor hole (a.k.a. starter hole). This large diameter hole is lined with pipes that vary in depth and contain the blowout preventer. The blowout preventer, in combination with the accumulator and choke manifold, is used to prevent a blowout from the well in the case where a pressure event could occur. Next, a surface hole is drilled to the base of groundwater protection and cased and cemented to isolate potential shallow groundwater aquifers from the wellbore (CSUR, n.d.). The integrity of the cement surrounding the casing is tested to ensure it is set and can withstand further drilling.

For modern UOGD, horizontal drilling is employed to increase the amount of oil and gas reservoir formation that intersects the wellbore. The well is first drilled vertically until the wellbore reaches the kickoff point above the targeted formation (ALL Consulting, 2012). The depths of the natural gas and oil production zones vary but are commonly about 1500 metres to 3700 metres, which is far beneath groundwater aquifers (CSUG, 2011; Rahm, 2011). Once at the kickoff point, the well is then drilled at an increasing angle until it horizontally intersects the reservoir formation. Horizontal drilling continues until the desired length is reached, which is typically between 400 metres and 2,000 metres but can be as long as 3500 metres (CSUR, n.d.).

Although the horizontal portion of the wellbore is usually depicted as being straight, it can curve to follow the formation, intersect different pockets of the resource, or even follow a lease line (ALL Consulting, 2012). Production casing is placed into the wellbore and cemented in a similar fashion to the surface casing process with the intent to protect groundwater aquifers from communication with the wellbore during drilling, completion, and final production. The number of steel casings installed

depends on the expected reservoir conditions and the well stimulation techniques (CSUR, n.d.). The total time required to drill and complete a well depends on the target depth, the length of the lateral and the geological conditions encountered (Statoil, 2013). To maximize recovery of UOG, as mentioned before, it is common for each pad to have multiple horizontal wells drilled.

Throughout the life cycle of a well, several steps are implemented to maintain groundwater protection. Groundwater protection is a regulated process to ensure that the well integrity does not degrade. Possible well integrity concerns include poor cement bond, casing shift, and casing corrosion (CSUR, n.d.). Although these well integrity issues can occur, there are diagnostic tools present that can promote wellbore integrity and there are many tools that can help identify issues after they have occurred (CSUR, n.d.).

The wastes produced from the drilling process include drilling muds and cuttings (Rahm & Riha, 2014). These wastes typically are stored with wastewater produced from stimulation processes discussed in Section 2.2.1.c.

2.1.4 Stimulation (Hydraulic Fracturing)

After a well has been drilled, cased, cemented, and the cement has cured, well stimulation takes place. There are a variety of stimulation processes, but the most common is hydraulic fracturing (CSUR, n.d.). Hydraulic fracturing involves injecting large volumes of water, sand, and chemicals into a drilled well at high pressure to produce an array of fractures at specific points to allow recovery of oil and gas. The sand or "proppant" is driven into these fractures to brace them open. The natural gas (and/or oil) can then flow into the well at an enhanced rate (CSUG, 2011). The fracturing operation for a single lateral run of a horizontal well typically takes 2–5 days, but may take more time for longer lateral wellbores. Sequential stimulation of upward of eight wells from the same drill pad can continue for months (Goldstein et al. 2014).

The following section describes the a) treatment design, b) equipment, c) fluids, d) fracturing, e) monitoring, and f) water considerations.

a) Hydraulic Fracture Treatment Design

The process of developing a design for a hydraulic fracture treatment begins well before the fracture treatment, typically during reservoir evaluation (ALL Consulting, 2012). Engineers often use the details of microseismic data obtained during drilling and from nearby wells drilled in the

same or similar formations. They use the characteristics of the reservoir and other dynamics of the formation to predict probable fracture propagation. This site-specific attention to detail improves the fracture treatment and reduces the time between design and execution of the treatment. As more fracture treatments are performed in a specific play and data is collected, the designs of future treatments are able to be refined (ALL Consulting, 2012).

b) Equipment

The process of drilling and hydraulic stimulation of the well is very equipment intensive, but usually only for a short period (CSUR, n.d.). Fracture treatments can usually be completed in a day for a single fracture up to a couple of months depending on location and number of fracture treatments (CSUG, 2011). The type, size, and number of pieces of equipment needed are dependent on the size of the fracture treatment, type of treatment, as well as the additives, proppants, and fluids used. Figure 3 shows an aerial view of a very large-scale hydraulic fracturing job.

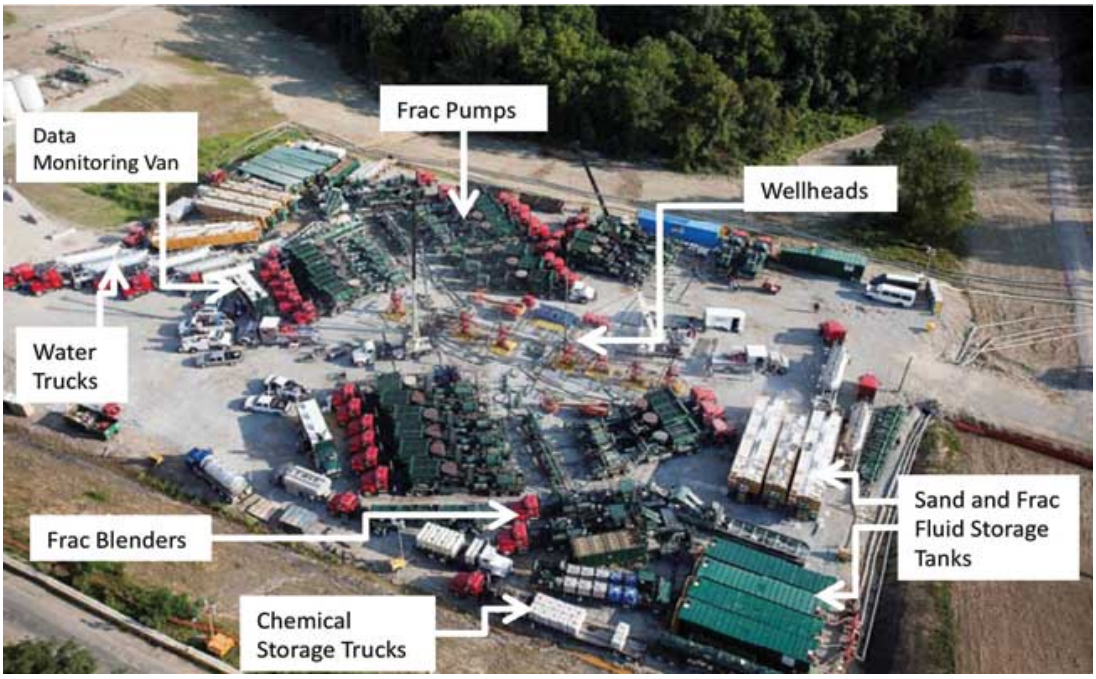


Figure 3: Large-Scale Hydraulic Fracturing Job Performed on a Marcellus Shale Multi-well Pad in Pennsylvania (Suchy & Newell, 2012)

From Figure 3, it is evident that the process to hydraulically fracture a well requires a large concentration of equipment. Table 1 lists the typical equipment used during a fracturing job and the purpose of the identified equipment.

Once the equipment is on-site, it gets "rigged up," which is a process of making all connections between the fracturing head, the manifold trailer, the fracturing pumps, and the additive equipment which feed fluids and additives into the pumps (ALL Consulting, 2012). These connections undergo a series of assessments and pre-tests to ensure that the connections have been properly made and sealed and that they are capable of handling the pressure of the fracturing job.

Table 1: Typical Equipment Used for Hydraulic Fracturing and its Purpose (adapted from ALL Consulting, 2012)

Equipment	Purpose
Fracturing Head	A well head connection that allows fracture equipment to attach to the well
Fracturing Pumps	Heavy duty pumps that take the fluid from the blender and pressurize it via a positive displacement pump
Blender Pumps	Takes fluid from the fracturing tanks and sand from the hopper and combines these with chemical additives before transferring the mixture to the fracturing pumps
Transfer Pumps	A trailer-mounted pump and manifold system that transfers fluid from one series of fracturing tanks to another, or from ponds to the manifold
Sand Storage Units	Large tanks that hold the proppant and feed the proppant to the blender via a large conveyor belt
Fracturing Tanks (Supply and Receiving)	Water containment tanks for supplying water required for stimulation and receiving produced water after fracture stimulation
Chemical Storage Trucks	Flatbed trucks used to transport chemicals to the job site may contain a pump to transfer chemical additives from the onboard storage tanks to the required equipment (i.e. blender)
Technical/Data Monitoring Vehicle	The work area for Engineers, Supervisors, Pump Operators, Company Representatives, and Regulatory Personnel
Acid Transport Trucks	Used to transport acids to job sites; a truck has separate compartments for the transport of multiple acids or additives
Manifold Trailer	Large manifold system that acts as a transfer station for all fluids; mixed fluids from blender pumps move through the manifold on the way to the pump trucks

c) Hydraulic Fracturing Fluids

Following drilling, the formation is ready to be hydraulically fractured by injecting the well with a fluid under high pressure in a controlled, engineered, and monitored process. While the casing and cement are installed, petroleum engineers and geologists are often working to perfect the fracturing fluid composition and calculate the hydraulic pressures needed to fracture the target formation (ALL Consulting, 2012). The composition of fracturing fluids must be altered to meet specific reservoir and operational conditions (ALL Consulting, 2012). As such, fracturing fluids are mixed on-site right before their use in fracturing and can continually be modified to meet the fracturing needs.

The prevalent type of fracturing fluid used for modern UOGD is known as slickwater. Slickwater refers to the addition of friction reducing agents to the water supply, which allow the fluid to be pumped into the target formation at a higher rate and reduced pressure than by using water alone (ALL Consulting, 2012). Other additives, all with an engineered purpose, are included in the fracturing fluid in addition to friction reducers. Figure 4 provides an example of the composition of a typical fracturing fluid.

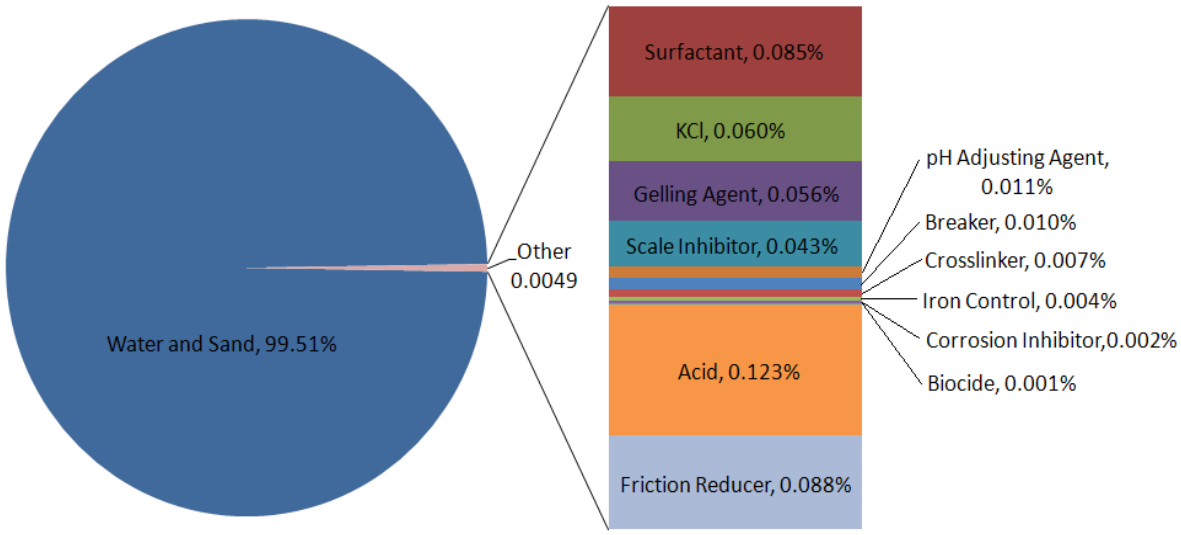


Figure 4: Example of Volumetric Composition of Typical Hydraulic Fracturing Fluid (adapted from Arthur et al., 2008)

Figure 4 was derived from data collected by ALL Consulting in 2008 from a hydraulic fracturing operation of the Fayetteville Shale in Arkansas. The Figure shows that water makes up the bulk of the fracturing fluid, with about 0.5% coming from other additives. Table 2 details the types of additives and their function in hydraulic fracturing.

Although there are more than a thousand chemicals used as additives in hydraulic fracturing fluids, only a limited number get routinely used, as not all chemical functions are necessary for every fracturing job.

As a result of concerns about fracturing fluid constituents, US industry teamed up with the Ground Water Protection Council and the Interstate Oil and Gas Compact Commission to create a voluntary disclosure and information website called FracFocus, with the purpose of standardizing and increasing accessibility to chemical information (ALL Consulting, 2012). However, depending upon the jurisdiction's regulations and company practice, information about hydraulic fracturing fluid additives used in an individual well is often, but not always, obtainable (Goldstein et al., 2014).

There are other fluids, besides water, that have been used to fracture unconventional formations. About 1000 wells in Canada and the United States were stimulated using propane-based liquefied petroleum gas (LPG) from 2009 to 2012 (ALL Consulting, 2012). The base of this fluid is approximately 90% propane and 10% gelling agent and other additives that help the fluid transport the proppants. The main advantage of this technique is that the LPG returns to the surface after fracturing as propane gas. The recovered propane is either re-used in subsequent operations or sold with the natural gas. Also, since there is no water required, there is also no need for water storage ponds and water disposal costs possibly reducing truck traffic. Other compounds used as a base for fracture fluids include carbon dioxide (CO_2) and nitrogen gas (N_2). Both of these compounds form foams that transport the proppant into the formation, thereby leaving less fluid in the formation and creating very rapid recovery times (ALL Consulting, 2012). However, the use of CO_2 and N_2 is limited as they are not always readily available or appropriate for every formation. LPG, N_2, and CO_2 are not discussed further in this review as the majority of the literature references hydraulic fracturing where water is the base of the fracturing fluids. However, it is important to note that technologies are always evolving and improving, and these changes may impact regulations, environmental public health concerns, and investigations approaches.

Table 2: Fracturing Fluid Additives, Examples and their Function in Hydraulic Fracturing (adapted from ALL Consulting, 2012)

Additive Type	Examples	Function
Acid	Hydrochloric acid	Dissolve minerals; clean cement from casing perforations; initiate cracks in the rock
Biocide	Glutaraldehyde	Eliminate bacteria that can break down organic gelling agents
Breaker	Ammonium persulfate, Sodium chloride	Introduced toward the end of the frac job to break down the gelling agent; decrease viscosity and help release the proppant from the fluid
Corrosion Inhibitor	N, n-dimethyl formamide	Used when fluid contains acid; Prevents corrosion of tubing, tanks, casings, and tools
Crosslinker	Borate salts	Maintain fluid viscosity as temperature increases
Friction Reducer	Polyacrylamide, Mineral oil	Minimizes friction to allow injection of fluids at optimal rates and pressures
Potassium chloride		Creates a brine carrier fluid
Gelling Agent	Guar gum, Hydroxyethyl cellulose	Increases fluid viscosity to suspend more proppant
Iron Control	Citric acid	Prevents precipitation of metal oxides
pH adjusting agent	Sodium or Potassium carbonate	Maintain the effectiveness of other components
Proppant	Silica, Quartz sand	Hold the fractures open to allow gas flow out
Scale Inhibitor	Ethylene glycol	Prevents scale deposits in the pipe
Surfactant	Isopropanol, Naphthalene	Increases the viscosity of the fluid

d) Fracture Treatment

The following five general steps are involved in the fracturing of a well:

Step 1: Perforate the well casing

Following drilling, a perforating gun is sent down the wellbore and activated. Activation of the perforating gun creates a series of holes in the casing to allow fluids to flow outward to the formation during the fracture treatment and also allow gas or oil to flow inward from the formation into the wellbore during the production phase (ALL Consulting, 2012). In some cases, the lateral lengths, which can be hundreds to thousands of metres, hinder the ability to maintain adequate downhole pressures to successfully fracture the entire horizontal well in a single process (ALL Consulting, 2012). To overcome this barrier, fracture treatments in horizontal wells are done by isolating portions of the laterals with a liner, cement, and a plug/isolation packer and fracturing these individually isolated sections called stages.

Step 2: Create fractures by pressurizing the reservoir rock using a fluid

Stages are fractured sequentially beginning with the interval at the furthest end of the wellbore. The first sub-stage is primarily fresh water that is pumped to flush any residue in the wellbore from the drilling and perforation processes and to clean the lines of the fracturing equipment. Acid flush typically follows the initial fresh water flush and is designed to clean cement from the perforations and any residue surrounding the wellbore. The acid flush provides a clean pathway for the fracture fluids to reach the formation when pressurized. The next sub-stage is a water spacer, which pushes the acid into the formation to begin the propagation of fracturing. This water spacer facilitates what is called a “mini-frac” and generates accurate data regarding reservoir parameters used to verify the fracture job design.

Step 3: Grow the fractures by continuing to pump fluids into the fractures

Next, the well is shut-in to determine the fracture gradient and to verify the wellbore design. The fracture gradient is a measure of the strength of the rock compared to the pressure necessary to initiate fracturing at a specific depth. When the well is re-opened, fracture fluid without proppant is injected into the formation to extend the fractures (ALL Consulting, 2012).

Step 4: Maintain the fracture by pumping proppant materials into the fracture

The sub-stages that follow are a series of pumping events in which proppant volume is increased to create and sustain the fractures. In some treatments, the proppant size may be increased

during the sub-stages to optimize the permeability in the fracture, and thus maximize the flow of hydrocarbons to the wellbore (ALL Consulting, 2012).

Step 5: Isolate stage and repeat until all stages have been fractured

Once the prescribed volumes of fluid and proppant are applied to the wellbore, a final flush removes remaining proppant from the well. A packer is then used to isolate this zone, sealing it from an intrusion of any additional fluids during subsequent fracturing stages. After this zone is isolated, a new zone in the wellbore gets prepared for fracturing starting with Step 1: perforation of the casing. The process described above continues for each stage of the fracture treatment in the wellbore (ALL Consulting, 2012).

A multi-stage slickwater hydraulic fracture treatment of a horizontal gas shale well can have as few as two or as many as 100 stages for one well treatment and each stage may include 16 or more sub-stages (ALL Consulting, 2012). The time to complete a multistage fracturing job is dependent on some parameters including lateral length, target formation, number of stages, fracturing technology, etc. For example, in the Horn River Shale in British Columbia, where horizontal wells are, on average, drilled approximately 2,000 metres in length and hydraulically fractured using the general method described in the steps above, it took 274 fracture stages over 111 days to complete the well stimulation (ALL Consulting, 2012).

e) Monitoring

Monitoring activities are performed on-site in a technical monitoring vehicle (TMV) as well as by the personnel operating the equipment during the job. Monitored aspects include treatment pressures, chemicals, proppant density, fluid velocity, and pressure (ALL Consulting, 2012). Monitoring and assessment of this data help the on-site personnel assess whether the fracturing job is performing as expected and provides them the ability to make changes in the treatment to ensure a successful well completion. In the rare case of a failure, activity can be stopped to prevent an environmental incident, safety hazard or health hazard (ALL Consulting, 2012).

f) Water Considerations

The volume of water that is necessary to hydraulically fracture a well varies from one basin to another, but also depends on the composition of the fracture fluid and the number of stages anticipated per wellbore. Unlike conventional oil wells, which may produce oil and gas at fairly consistent rates over relatively long time spans, production levels in fracking wells drop off with

alarming speed, and thus sustained production from these formations requires repeated fracturing (Lave & Lutz, 2014). A single-stage horizontal shale gas well can use between 3,500 cubic metres and 15,000 cubic metres of water. A multi-stage well uses even more, and a slickwater fracture treatment can use more than 20,000 cubic metres of water (ALL Consulting, 2012). Other estimates have noted that between 7500 cubic metres to 53000 cubic metres of water are required for each well over its lifetime (Vengosh et al., 2014). Water for hydraulic fracturing frequently comes from surface water bodies such as rivers and lakes, but can also come from shallow groundwater containing potable water, deep groundwater containing saline water, municipal water, re-used produced water sources and other industrial sources (ALL Consulting, 2012).

2.1.5 Fluid Recovery and Management

Reversal of the flow of fluids occurs when the hydraulic fracturing process has ended, and pressure is released. On average, between 30% and 50% (although a range of 10% to 80% has been reported) of the injected water and fracturing fluids flow back to the surface relatively quickly (Lave & Lutz, 2014; Shonkoff et al., 2014). Flowback water is the term used to describe the water that flows back at a high rate. Water that does not quickly return to the surface is absorbed by the source rock. Produced water is the term used to describe the water that continues to flow to the surface at a slow rate over the lifetime of the well. The produced water contains variable concentrations of chemicals used in the fracturing fluids, reaction products, and dissolved contaminants from the target formation, which can include heavy metals, volatile organic compounds (VOC) and naturally occurring radioactive material (NORM) (Finkel & Hays, 2013). The produced and flowback wastewaters can be stored temporarily in surface reserve pits or tanks and then disposed of in several ways. The wastewaters may be injected back underground through underground injection control (UIC) wells, if permitted, treated and then discharged to a surface water body, or applied to land surfaces (Rahm, 2011).

2.1.6 Oil and Gas Production

Upon completion of the drilling and stimulation activities, removal of much of the equipment and construction of semi-permanent surface facilities begins (CSUR, n.d.). Partial site reclamation starts with dewatering surface pits that are no longer needed and filling-in and re-graded the land. In most cases, the surface footprint of the wells and the surface facilities is much smaller than the original drilling footprint.

For natural gas wells, the produced gas gets separated from the water or any liquid hydrocarbons using a flow line and is then sent to a compressor station, which can be located on the pad or offsite, to become liquefied natural gas (LNG) that can be sent through a pipeline for sale (USEPA, 2015). For oil wells, production is similar to gas wells although separation occurs on the well pad without the need for a compressor station. The oil is then either hauled by truck or train or sent through a pipeline for further processing or sale.

The duration that a well stays in the production stage depends on some factors, such as the amount of hydrocarbons in place, the reservoir pressure, and the production rate (Patzek et al., 2013). Some wells stay in production for short periods of three to four years, while others, such as onshore tight gas reservoirs, are predicted to produce for as long as forty to sixty years. Since most modern fractured wells in unconventional formations are less than a decade old, there is limited data to determine the full extent of the production decline and to ultimately determine how much they will produce and for how long (Patzek et al., 2013).

2.1.7 Well and Site Closure

Abandonment of a well occurs once it reaches the end of its production life. The abandonment process starts with cement integrity testing followed by cleaning of the wellbore then plugging the wellbore with cement (AER, 2015b). The cement plug isolates all porous formations from one another and any groundwater zones from the wellbore (AER, 2015c). Finally, the well casing is cut off below the surface and capped with a steel plate or cap. All wellhead and surface equipment is removed, and the site is restored to its predevelopment conditions to the best extent possible, as per specific regulations (AER, 2015b).

Inadequate execution of the abandonment process may cause fluids from higher pressure subsurface zones to potentially migrate through the wellbore to the surface or other zones, such as fresh water aquifers (USEPA, 2015). Issues can also arise if corrosion or damage during excavation occurs. Gas detection tests can be used to identify any leaks, which are then repaired (AER, 2015c).

2.2 Environmental Public Health Review of Unconventional Oil and Gas Development

As previously described, UOGD involves highly engineered, modeled and monitored processes. Despite the regulatory oversight, there have been accidents in the past that have created the potential for human exposure to environmental health hazards. Public concern about adverse health impacts has followed (Bamberger & Oswald, 2012; Shonkoff et al., 2014; Werner et al., 2015). The following section

presents a scoping-level review of the current literature that discusses environmental impacts and potential human health risks of UOGD, along with how these two intersect.

2.2.1 Scope of Review

The focus of this review is to understand the EPH risks associated with UOGD. The review includes publications sourced from peer-reviewed scientific literature, including commentaries, and grey literature, like government reports. Although UOGD involves an array of processes, the focus is on the chemical and physical EPH risks of the same upstream activities reviewed in Section 2.2 including well pad infrastructure, drilling, hydraulic fracturing, fluid recovery and oil and gas production. Evidence suggests that parts of these processes present the greatest risks to EPH and therefore have received the most attention in the scientific literature (Goldstein et al., 2014; Shonkoff et al., 2014).

The review is organized into environmental public health concerns noted in the literature (Witter et al., 2013) by media type (namely water, air, and land), followed by other nuisance conditions (like noise and lighting), and ending with a review of the literature on the current health studies not previously discussed. Each public health concern contains a summary of the main hazards, exposure pathways, and potential public health effects. Risk mitigation strategies and related public health research needs are also discussed where appropriate.

Aspects of UOGD that are out of scope of the review include:

- Socioeconomic risks and benefits
- Psychosocial impacts
- Relationship to climate change and global warming
- EPH risks associated with downstream activities like pipelines and refineries

2.2.2 Water

The two main concerns raised about UOGD and water resources are a) water quality and b) water quantity. The following section describes these aspects using risk assessment methodology as a guide.

a) Water Quality

Water quality concerns stem from uncertainty about the effects on groundwater from injecting hydraulic fracturing chemicals into the wellbore and the effects on surface water and groundwater from mismanaged wastewater (Lave & Lutz, 2014). The following section will review the hazard

sources, potential human exposure pathways, including potential contamination pathways, evidence of water quality contamination and a summary of environmental health studies.

(i) Hazard Assessment

Flowback and produced water, collectively termed wastewater, along with the extracted hydrocarbons from UOGD are the main hazards that can potentially contaminate groundwater and surface water, including water used for drinking. These fluids contain compounds that have known adverse human health effects at specific exposure levels. Wastewaters contain the chemicals used in the fracturing fluid as well as naturally occurring compounds found deep in the geological formations. The type and concentration of such compounds vary with the geologic formation, the fracturing fluid composition, and the time since drilling. Table 3 summarizes the types of compounds found in oil and gas bearing rock along with examples.

Many of these naturally occurring compounds are associated with human health effects at specific exposures levels (Shonkoff et al., 2014). The USEPA reports that produced water can contain some of these chemicals at concentrations that exceed drinking water standards (Goldstein et al., 2014). Also, the mixing of these compounds under conditions of high pressure and high heat may create additional potentially toxic compounds (Shonkoff et al., 2014). Compounds found in these mixtures may pose risks to the environment and public health through numerous environmental pathways, including water, air, and soil.

Table 3: Common Naturally Occurring Compounds Found in Oil and Gas Formations (adapted from Goldstein et al., 2014; Stringfellow et al., 2014)

Type of compound	Examples
Inorganics (or common ions)	Brine (e.g., sodium chloride, bromide)
Gases	Natural gas (e.g., methane, ethane), carbon dioxide, hydrogen sulfide, nitrogen
Heavy metals	Mercury, lead, arsenic, cadmium, strontium, sulfur
NORM	Radium, thorium, polonium, and uranium
Organic compounds	Organic acids, polycyclic aromatic hydrocarbons, BTEX

A study by Colborn et al. (2011) identified 632 chemicals used in shale gas operations. Systematic searches were conducted to determine potential health effects of 353 of these chemicals based on their Chemical Abstract Service numbers. The results showed that 75% of the chemicals could potentially have some adverse effect on the body. For example, over 50% of the substances can affect the brain and nervous system, about 25% of these compounds are known carcinogens or mutagens and almost 40% are considered endocrine disrupting compounds (EDC), which affect the endocrine system including reproductive organs (Colborn et al., 2011). However, the review by Colborn et al. (2011) did not consider the estimated or measured concentrations found directly in fluids, wastewater nor the environment, which are necessary to understand the dose and subsequent health effects and public health risks (Shonkoff et al., 2014). Similarly, a study by Stringfellow et al. (2014) identified 81 common chemical additives in hydraulic fracturing fluids and categorized them according to their functions. Here, 45 of the compounds were organic, and 27 of these were considered biodegradable. Most of the hydraulic fracturing chemicals that were evaluated by Stringfellow et al. (2014) were considered non-toxic or of low toxicity and only three were classified as Category 2 oral toxins according to standards in the Globally Harmonized System of Classification and Labeling of Chemicals. Both Stringfellow et al. (2014) and Colborn et al. (2011) both acknowledged that toxicity information for many chemicals they researched was lacking. Poorly characterized compounds include biocides, corrosions inhibitors, scale inhibitors, and iron control agents. Biocides as a group are of concern, as they contain the highest number of toxic compounds (Stringfellow et al., 2014). Gaps in toxicity and other chemical properties suggest deficiencies in the current state of knowledge, highlighting the need for further assessment to understand potential issues associated with hydraulic fracturing chemicals in the environment (Stringfellow et al., 2014).

The make-up of flowback waters collected from multiple drilling sites in the Marcellus Shale was characterized by compiling and analyzing sampling data from four different databases (Abualfaraj et al., 2014). Based on 35,000 entries, the descriptive statistical analysis revealed high concentrations of chlorinated solvents, disinfectants, dissolved metals, organic compounds, radionuclides, and total dissolved solids. The following constituents were found to have mean concentrations over ten times greater than the maximum contaminant limit (MCL) for drinking water: 1,2-dichloroethane, antimony, barium, benzene, benzo(a)pyrene, chloride,

dibromochloromethane, gross alpha, iron, manganese, pentachlorophenol, radium, thallium, and vinyl chloride. There was a tight correlation between the concentrations of anthropogenic chemicals with each other, but not with chloride concentrations, and not with naturally occurring inorganics and radionuclides (Abualfaraj et al., 2014). Among the four different databases, there was a significant difference detected between the mean concentrations of 60% of the constituents of the flowback water (Abualfaraj et al., 2014). Like flowback water, produced waters are typically composed of naturally occurring hypersaline formation water and organic chemicals, like solvents, biocides, and scale inhibitors, but can also contain oil, bitumen, and hydrocarbon condensates with high concentrations of total dissolved organic carbon (Vengosh et al., 2014). The total dissolved salts (TDS) content of produced water ranges from below seawater, like in the Fayetteville Shale (25 000 mg/L) to seven times more saline than seawater, like in the Marcellus Shale (up to 180 000 mg/L) (Vengosh et al., 2014). The variations observed in the flowback water analysis and the TDS values from produced waters iterates wastewater composition and concentration depends on the regional shale composition and chemical additives used in the fracturing fluid (Abualfaraj et al., 2014; Vengosh et al., 2014).

(ii) Exposure Assessment

It is evident that numerous hazards exist in the fracturing fluids and wastewaters associated with UOGD; however, for there to be an environmental public health risk, these hazards need to be released into an environmental media for there to be an exposure. Contamination of groundwater aquifers overlying shale formations or nearby surface water is particularly problematic if the water is a drinking water source for nearby communities. Five main pathways of water contamination during UOGD have been identified using probability bounds analysis (Rozell & Reaven, 2012). These pathways, along with their likelihood of occurrence and examples, have been summarized below.

Well casing leaks

Well casing leaks, mainly due to structural impairment of cement and casings used to prevent gas and fluid migration in the wellbore, is one of the most commonly cited mechanisms through which water can become contaminated (Davies, 2011; Shonkoff et al., 2014). Poor casing and cement quality can lead to wastewater constituents being released in groundwater during flowback and production events (Werner et al., 2015). Studies conducted by independent scientists, as well as researchers from the oil and gas industry, suggest that between 6% and

75% of wells experience zonal isolation or structural integrity failures and that unconventional wells used for UOGD may fail at a higher rate than conventional vertical wells (Hays et al., 2015). Rahm & Riha (2014) cited a much smaller estimate of cementing and casing problems in about 1 to 3% of wells drilled. These leaks have implications for air quality as well, which is discussed in Section 2.3.3.

Wastewater disposal

Wastewater disposal is also a potential water contamination risk, mainly for surface water, that is several magnitudes larger than other pathways (Rozell & Reaven, 2012). In regions that do not use or limit the use of IUC, wastewater is often transported by hauler or pipeline to off-site treatment facilities, which eventually discharge the treated water to surface water (Lave & Lutz, 2014). Treatment options include publicly owned treatment plants, municipal wastewater treatment plants (WWTP), or commercially operated industrial wastewater treatment plants (Vengosh et al., 2014). As there is the potential for a large contaminant load, concerns have been raised as to whether or not treatment facilities can effectively remove or transform chemicals to safe levels using common treatment technologies (Warner et al., 2013a). For example, of the 81 hydraulic fracturing chemicals studied by Stringfellow et al. (2014), which can end up in wastewater, 17 had high theoretical chemical oxygen demand and are used in concentrations that present potential treatment challenges. If the wastewater treatment process does not remove contaminants to acceptable levels, and the effluent is discharged to a surface water source, it is possible that drinking water quality and the treatment processes at public water systems downstream from the effluent discharge might be negatively affected (Warner et al., 2013a).

Warner et al. (2013a) studied water quality and isotopic compositions of discharged effluents, surface water, and stream sediments associated with a brine treatment facility in Pennsylvania. They found that the chloride concentrations 1.7 kilometres downstream of the treatment facility were 2 to 10 times higher than background levels. Bromide levels in the water were also elevated even with the 500 to 3000 dilution of the wastewater effluent. Stream sediments tested at the point of discharge showed Radium-226 at concentrations about 200 times greater than upstream and background sediments. The concentrations found were above radioactive waste disposal threshold regulations, posing potential environmental risks of radium bioaccumulation in localized areas of UOGD wastewater disposal (Warner et al., 2013a). Surface

water was also studied by Olmstead et al. (2013) who examined how the release of treated Marcellus Shale gas wastewater affected observed downstream concentrations of chloride and total suspended solids (TSS). Like Warner et al. (2013a), Olmstead et al. (2013) also found that treated shale gas wastewater increased chloride concentrations in the watershed. The elevated levels of halides in surface water have important implications for downstream municipal water treatment plants, as they can react with disinfection chemicals during treatment to form disinfection byproducts (DBP) at a greater concentration than during normal sewage treatment (Rahm & Riha, 2014).

With inadequate disposal options available, industry has developed methods to recycle wastewater for subsequent well stimulations. Recycling the wastewater helps to decrease the amount of potentially poorly treated effluent discharged into river systems (Vidic et al., 2013). The use of alternative non-water based stimulation techniques, such as CO_2, LPG and N_2 could also help to limit the volume and toxicity of waste (Rozell & Reaven, 2012).

Drilling site discharge

Surface water and shallow groundwater aquifers can potentially become contaminated by untreated drilling site discharge. The USEPA undertook a study to answer questions about the frequency, severity and causes of drilling site spills (USEPA, 2015). They estimated that one spill occurs for every 100 wells in Colorado and between 0.4 and 12.2 spills for every 100 wells in Pennsylvania. Their research also found that between 2006 and 2012, 151 spills of hydraulic fracturing fluids and chemicals and 225 spills of produced water occurred in 11 states. The median spill volume for fracturing fluids and chemicals spills was 1600 litres and for produced water spills was 3750 litres. The most common cause of fracturing fluid and chemical spills was equipment failure (blowout preventer failure, corrosion, and failed valves). Container integrity failure caused the most volume of produced water to be released (USEPA, 2015). Leaks, spills, and releases of hypersaline flowback and produced waters are expected to impact the inorganic quality of surface water because these brines contain elevated concentrations of salts, alkaline earth elements, metalloids, and radionuclides (Vengosh et al., 2014).

On container integrity, field evaluations on a subset of reserve pits indicated several construction and maintenance deficiencies related to the containment systems, some that could lead to spills and leaks and eventual contamination of water if allowed to progress (Ziemkiewicz

et al., 2014). Although these ponds are often lined to protect against leakage, case studies have documented reported ruptures of these liners that may have led to water and contamination and possibly contributed to fish and livestock deaths (Bamberger & Oswald, 2012).

Groundwater contamination can also result from surface spills at active well sites. Gross et al. (2013) analyzed data from the Colorado Oil and Gas Conservation Commission (COGCC) and found 77 reported surface spills at storage and production facilities in Weld County, Colorado. From this database. A review of the BTEX concentrations from the groundwater samples found that concentrations of benzene, toluene, ethylbenzene and xylenes exceeded the USEPA National Drinking Water MCLs in 90, 30, 12 and 8% of the samples, respectively (Gross et al., 2013). Because baseline sampling data (pre-development) were not available, the background BTEX concentrations remain unclear. However, natural groundwater concentrations of BTEX are typically low near deposits of crude oil, coal, and natural gas (Gross et al., 2013). Following remediation of the spills, there was an 84% reduction in BTEX levels in the affected groundwater.

After complaints about the taste and odour of well water from residents of Pavillion, Wyoming, the USEPA initiated a groundwater investigation (DiGiulio et al., 2011). The study found increased concentrations of benzene, xylenes, gasoline range organics, diesel range organics, hydrocarbons, and high pH in two shallow monitoring wells (DiGiulio et al., 2011). Although this study was scrutinized for adequate sampling protocols, a follow up study by the U.S. Geological Survey (USGS) found similar elevated levels of specific conductance, pH, methane, ethane, and propane, but low levels of organic compounds (Vengosh et al., 2014). The shallow groundwater contamination was linked in part to surface reserve pits used for the storage of drilling wastes and produced and flowback waters (DiGiulio et al., 2011).

Transportation spills of wastewater

Surface water and groundwater can also become contaminated as a result of spills during the transportation of chemicals and wastes to and from the well pad (Rozell & Reaven, 2012; Vidic et al., 2013). Spills are unintended releases of chemicals, wastewater, or other hazardous materials, and can result from accidents, poor planning, and illicit dumping. They can range in severity from a relatively small release of a few litres to a major event that can pollute nearby surface water (Rahm & Riha, 2014).

Migration through fractured rock

Vertical fractures created during hydraulic fracturing are often cited as being able to act as conduits between the production zone and a fresh water source (Vengosh et al., 2014). However, debate around the ability of fluids to migrate upwards through fractured rock is strong; one model has suggested that contaminants could flow through fractures and reach overlying aquifers in six years or less (Vengosh et al., 2014). Other studies have suggested that the upward flow rate of fluids is highly improbable because of the low permeability of rocks overlying the shale formations, low upward hydraulic gradients, and high density of fluids (ALL Consulting, 2012; Engelder et al., 2014; Schon, 2011).

The USEPA/USGS investigation in Pavillion, Wyoming, also cited migration of fluids through fractures or natural faults as a possible reason for contamination (DiGiulio et al., 2011). In this case study, the contamination occurred in an area where UOGD occurred in tight sand formations located only 130 metres below drinking water aquifers. This depth is unlike most unconventional plays, which typically exist several thousand feet beneath the surface (Lave & Lutz, 2014). However, the findings show that shallow aquifers could potentially be contaminated by the migration of hypersaline water or hydraulic fracturing fluids through conductive faults or fractures (Vengosh et al., 2014).

(iii) Other Environmental Health Studies

One of the main components assessed in the literature concerning water samples, especially groundwater samples, is methane, the main component of natural gas. In certain regions, methane can naturally occur in aquifers, and there are conflicting scientific opinions about whether its presence is caused or exacerbated by UOGD (Davies, 2011; Saba & Orzechowski, 2011; Schon, 2011). Osborn et al. (2011) and Jackson et al., 2013 both examined groundwater wells and found that water sourced from wells closer to shale gas developments contained higher concentrations of methane gas compared to groundwater wells farther away. More specifically, Osborn et al. (2011) analyzed water from 68 wells and found communities in the Marcellus Shale in Pennsylvania with active shale gas development (one or more gas wells within 1 kilometre) had significantly higher concentrations of methane in their water wells compared with non-active sites (no shale gas wells within 1 kilometre). The chemical signature

of the methane found in drinking water wells in the active area indicated that it was thermogenic methane typical of oil and gas hydrocarbons. In contrast, the methane from the non-active sites had signatures of biogenic methane, which is associated with bacteria and not oil and gas hydrocarbons, and suggests that shale gas production processes were the source of the methane contamination (Osborn et al. 2011).

The work by Osborn et al. (2011) prompted three replies criticizing the claims that hydraulic fracturing caused methane contamination. One criticism pointed out issues with comparing data from different formations to support the claim of thermogenic methane in wells in the vicinity of gas extraction (Saba & Orzechowski, 2011). Another criticized the authors for attributing the presence of methane directly to drilling, as this misrepresents potential risks of modern drilling and completion techniques used to develop UOG resources and does not fully consider geological history (Schon, 2011). Similarly, the third reply did not agree with implicating a specific process as the main reason for contamination and criticized the small, non-random sample that covered a diverse geological area (Davies, 2011). Also, several of the wells sampled with high methane levels were located in Dimock, Pennsylvania, an area previously studied where issues of improper well casings were found to potentially cause aquifer contamination in at least three wells (Davies, 2011; Lave & Lutz, 2014). Further, there were no data to demonstrate that methane contamination did not pre-exist hydraulic fracturing, which is particularly important given that natural seepage of methane to groundwater has been observed throughout this region for many decades (Lave & Lutz, 2014).

Building on previous work by Osborn et al. (2011), Jackson et al. (2013) analyzed methane concentrations in drinking water wells across northeastern Pennsylvania. The researchers found methane in 82% of the 114 samples, with average concentrations six times higher for homes that were less than one kilometre from natural gas wells. For the wells in the same area, the average concentration of ethane was 23 times higher compared to those greater than one kilometer away from gas extraction sites. These data, based on isotopic signatures and gas ratios, suggest that a subset of homeowners living less than one kilometre from shale gas wells had drinking water that was contaminated with stray gases associated with gas development activities (Jackson et al. 2013).

Unlike Osborn et al. (2011) and Jackson et al. (2013), Boyer et al. (2012) did not find significant well water impacts from UOGD. Here, 233 private water wells in Pennsylvania at both active sites and non-active control sites were sampled and analyzed for methane and numerous other compounds. The results showed that approximately 40% of the pre-drilling water samples exceeded at least one Safe Drinking Water Act (SDWA) water quality standard, mainly for coliform bacteria, turbidity, and manganese and about 20% showed the presence of methane, although concentrations were far below health guidelines. However, one drinking water well had slightly elevated concentrations of bromide, chloride, sodium, barium, TDS, and hardness, which could possible indicate mixing of the well water with wastewaters or naturally occurring brine. The analysis of pre-drilling versus post-drilling water samples did not show any statistically significant increases in dissolved methane concentrations, nor a significant correlation to the distance from drilling (Boyer et al., 2012). Warner et al. (2013b) conducted water analyses of major ions, trace metals, methane, methane carbon isotopes, and select isotope tracers on 127 drinking water wells in the Fayetteville Shale in north-central Arkansas. The results indicated that the methane detected in the samples was mainly biogenic in nature with a possible minor contribution of thermogenic methane. The comparison of multiple geochemical and isotopic proxies from well water and flowback water showed no direct evidence of contamination in shallow drinking water aquifers in the Fayetteville Shale (Warner et al., 2013b). Fontenot et al. (2013) also studied water quality in private drinking water wells near natural gas operations but in the Barnett Shale formation in northern Texas. They found levels of arsenic, selenium, strontium, and TDS that exceeded the USEPA's MCL for drinking water for some samples located within three kilometres of active gas wells. The same metals were also found in other samples outside the Barnett region and within the region more than three kilometres from UOGD sites but at lower levels. 29% of the samples had varying levels of detectable methanol and ethanol. Although Fontenot et al. (2013) tried to establish baseline concentrations using historical data, without actual pre-drilling information, it is very difficult to conclude that the elevated levels were a result of drilling and extraction. This study was criticized for concluding the elevated levels were a result of UOGD even though no evidence of BTEX compounds or other indicator compounds were found and for using inadequate comparisons of total metals in the active site versus dissolved metals in the reference data.

Another potential drinking water contamination hazard is the presence of NORM that is co-extracted during drilling activities. To test the hypothesis that groundwater aquifers used for drinking water may be contaminated by NORM during UOGD, Nelson et al. (2015) conducted a small-scale pilot study. Here, they monitored radionuclides (natural uranium, lead-210, and polonium-210) in three private drinking wells within 2 kilometres of a large-volume hydraulic fracturing operation before and approximately one-year following the fracturing activities. The radionuclide concentrations in well waters did not exceed maximum contaminant levels indicated by state and federal agencies. Also, the researchers did not find any statistically significant differences in radionuclide concentrations in the samples before and after fracturing. Although there was a slight increase in lead-210 at one residence, the small number of samples and large uncertainties limit any definitive cause of the increase (Nelson et al., 2015).

Lastly, EDCs have been cited as a potential hazard of UOGD if water contamination occurs. Kassotis et al. (2014) measured estrogen and androgen receptor activity in surface and groundwater samples in Colorado using reporter gene assays in human cell lines. The water samples collected from the drilling-dense region exhibited statistically higher levels of estrogenic, antiestrogenic, or antiandrogenic activity compared to references sites with limited nearby drilling (Kassotis et al., 2014). Kassotis et al. (2014) indicated that potential release of EDCs into the environment during UOGD at levels that are a potential health concern.

Apart from industrial incidents, such as the loss of well integrity or a storage pond breach, researchers have been challenged in their ability to link associations between water contamination and a particular UOGD process (Shonkoff et al., 2014). Furthermore, environmental studies have been hampered by many methodological limitations resulting in difficult interpretations about hazards and potential exposures. The discrepancies between study findings point to a need for research investigating what the best indicators of potential water quality impacts from UOGD are. For an indicator to be effective, it must meet three criteria: (i) association with shale gas development, (ii) observed at high enough concentrations and with enough spatial and temporal variation to support statistical analysis, and (iii) known to cause water quality damage (Olmstead et al., 2013). Based on the research of Olmstead et al. (2013), chloride and TSS meet the criteria to be indicators of water contamination.

Although the studies reviewed have resulted in conflicting findings, several of the recommendations made by the researchers have been consistent with each other. One common suggestion is to find or produce appropriate background information to be able to compare findings at the same sites during UOGD. Many authors also recommend an expanded monitoring program of private drinking wells to better understand the potential for drinking water resource contamination from UOGD (Nelson et al., 2015).

b) Water Quantity

Water quantity concerns come from questions about how the large volumes of water required to stimulate each UOGD affect local and regional water quantity and quality (Lave & Lutz, 2014). The following section assesses the potential hazards from using large volumes of water, evidence of adverse effects, potential human exposure pathways and a summary of environmental health studies related to water quantity.

(i) Hazard Assessment

Although the large number of hydraulically fractured wells, coupled with the high water volume use per well, creates the perception of large rates of water use, compared to other industries like irrigation, agriculture, and municipal activities, water use for UOGD is relatively minor. For example, in Texas, 56% of water consumed is used for irrigation practices, 26% for municipal purposes and only 1% for UOGD (Nicot & Scanlon, 2012). However, the small amount of water consumed compared to other industries doesn't preclude assessing potential hazards of water withdrawal.

When water withdrawal from surface streams, rivers or lakes and groundwater aquifers leads to exceedances of natural recharge rates, water quality can be adversely affected (Rahm & Riha, 2012). Some potential consequences include mobilization of naturally occurring substances, promotion of bacterial growth, and mobilization of lower quality water from surrounding areas (USEPA, 2015). Similarly, surface water effects include altering stream flow and reducing water volume, which can potentially reduce the capacity of surface waters to dilute municipal or industrial wastewater discharges (Cooley & Donnelly, 2012).

(ii) Exposure Assessment

If groundwater or surface water sources have been adversely affected by quality or quantity issues, there is the potential for human exposure through ingestion of drinking water. However,

the exact impact that water withdrawals will have on local water resources is dependent on many factors that need to be assessed on a regional basis (USEPA, 2015). Areas with large amounts of sustained groundwater pumping are most likely to experience impacts, particularly in regions where freshwater sources are scarce, like those with drier climates and higher aquifer consumption. Here, the amount of water used during UOGD can put extra stress on water resources (Rahm & Riha, 2014; Vengosh et al., 2014).

(iii) Environmental Health Considerations

A literature review was conducted by the USEPA (2015) to address the potential effects of water withdrawals, and they did not find a single case where water use or consumption caused a drinking well or stream to run dry. Assessing the risks related to water withdrawals for UOGD is challenging in part because water quantity impacts result from the combination of water use and water availability at local scales, and not directly from withdrawals related to energy development (USEPA, 2015). Complicating the assessment further is the use of technological advancements that alter fresh water needs (ALL Consulting, 2012). Increased water demand is driven by the ability to drill deeper wells, with longer laterals and a greater number of fracturing stages; while the reuse of wastewater decreases demands on fresh water and reduces other impacts associated with transportation (Rabinowitz et al., 2015; Rahm & Riha, 2014).

Another aspect to consider when assessing water quantity is the numerous regulatory requirements designed to ensure that water withdrawals do not adversely affect the environment. The regulatory oversight makes it possible to monitor and coordinate water withdrawals from all interests so that they occur in a sustainable manner. Sustainable withdrawal practices include use of large rivers, continual but low rate pumping, and seasonal timing so as to acquire water when supplies are plentiful (Rahm, 2011).

2.2.3 Air

There are two main categories of air pollution from UOGD: a) emissions from well-site activities and b) emissions from off-site transportation (Shonkoff et al., 2014). Each category contains a summary of the hazard sources and potential human exposure pathways. Section c) contains a review of the environmental health studies related to air quality.

a) Well Pad Activities

The on-site activities considered for this section include drilling, well stimulation, and gas production, along with any associated equipment that may emit air pollution, like diesel compressors and retention ponds.

(i) Hazard Assessment

Sources of air pollution during various UOGD activities can be either point sources or fugitive sources. Below are some examples:

- venting excess gas at well head,
- controlled burning of natural gas (flaring),
- diesel engines for drilling and natural gas compressor stations,
- mixing of hydraulic fracturing fluids, and
- aeration and evaporation of retention ponds (Field, Soltis, & Murphy, 2014; Goldstein et al., 2014).

The potential emissions from the above sources are listed below:

- methane
- non-methane volatile organic compounds (VOCs) including BTEX, formaldehyde, methylene chloride, trimethylbenzenes, acrylonitrile
- nitrogen oxides (NOx)
- hydrogen sulfide
- particulate matter ($PM_{2.5}$ and PM_{10})
- polyaromatic hydrocarbons (PAHs)
- silica dust
- sulfur dioxide
- formaldehyde

Most of the air quality concerns addressed in the literature are related to venting and fugitive gas emissions (Werner et al., 2015). Petron et al. (2012) conducted a pilot study to characterize emissions of methane and non-methane hydrocarbons in the Denver-Julesburg Basin in Colorado in 2008. Automobile-based surveys found a mix of venting emissions (leaks) of natural gas and flashing emissions from condensate storage tanks. They estimated that approximately 4% of all natural gas produced is accidentally leaked or purposefully vented to the atmosphere.

A more recent study conducted in 2012 found even higher methane leaks in Uintah Basin shale gas field in Utah (Karion et al., 2013). Karion et al. (2013) estimated 6.2–11.7% of total gas production was leaking into the atmosphere.

Many of the common petroleum hydrocarbons measured in and around UOGD sites, such as BTEX, have been thoroughly studied with information readily accessible in toxicity databases and associated health and environmental standards. On the other hand, available information for some of the other compounds, like heptane, octane, and diethylbenzene, is more limited (Adgate et al., 2014). Emissions can potentially contain both carcinogenic and non-carcinogenic compounds. For the non-carcinogenic compounds, possible health effects though inhalation can range from nose and throat irritation from VOC exposure and asphyxiation from methane in confined spaces to silicosis from silica dust and death from hydrogen sulfide exposure (Goldstein et al., 2014; Shonkoff et al., 2014).

Some compounds associated with the petrochemical industry are also associated with pungent odours, leading to health concerns (Werner et al., 2015). Types of odours reported include rotten eggs, burnt butter, sulfur, sickly sweet smells, chemical-like smells, and propane (Steinzor et al., 2013; Subra, 2009). Headaches, nasal congestion, eye, nose, and throat irritation, cough, chest tightness, wheezing, nausea and drowsiness are associated with noxious odours (ATSDR, 2015).

(ii) Exposure Assessment

The following assessment is divided into occupational exposures and community-level exposures to air contaminants related to UOGD.

Occupation exposures

UOGD workers are at risk from exposure to air pollution because they work in proximity to on-site emission sources and can potentially be exposed to elevated levels of chemicals. Allen et al. (2013) studied methane emissions at 150 production sites and found a wide variation of emissions from site to site, including in adjacent sites drilled by the same company. There was about a 100-fold variation in emissions during uploading events in which the producing well is subject to relatively sudden hydrocarbon releases (Allen et al., 2013). Some researchers have suggested that the same variability would be anticipated for BTEX and other VOCs (Goldstein et

al., 2014), however, without direct measurements of other compounds this conclusion is not appropriate.

Occupational exposures to respirable crystalline silica, a proppant, has been studied for workers (Esswein et al., 2013; Korfmacher et al., 2013; Witter et al., 2014). Silica dust can become airborne during transportation in trucks and trains, mechanical handling on conveyor belts, and mixing into fracturing fluids with the blender hopper (Adgate et al., 2014). Esswein et al. (2013) collaborated with the National Institute for Occupational Safety and Health (NIOSH), to study worker exposure to respirable crystalline silica during UODG operations. The researchers collected 111 full shift personal breathing zone samples at 11 sites in five states. They found that 51.4% of samples showed silica exposures greater than the Occupational Safety and Health Administration (OSHA) permissible exposure level (PEL) and 68.5% of samples showed exposures greater than the NIOSH recommended exposure limit (Esswein et al., 2013). Certain workers, such as sand movers and blender operators, had the highest exposures (Esswein et al., 2013). Although exposures can be partially controlled through the use of personal protective equipment (PPE), the researchers noted that the type of respirators worn by workers was not sufficiently protective in some cases, given the magnitude of silica concentrations (Esswein et al., 2013).

Apart from silica, there is relatively little published research on other direct occupational exposures associated with UOGD development. One mitigating factor is that employees are required to wear PPE to reduce exposure to possible contaminants or fire hazards associated with methane and H_2S. For H_2S specifically, workers are also required to wear alarmed personal monitors to prevent fatalities (Adgate et al., 2014). Another consideration when discussing on-site emissions is the role of the USEPA in reviewing technologies and updating regulations to minimize emissions. The USEPA signed new regulations in 2012 requiring oil and gas operators to use reduced emissions completions, called “green completions,” which utilize equipment to minimize the loss of methane, VOCs, and other atmospheric pollutants during well construction. These regulations are to be fully implemented by early 2015, and they are expected to reduce well site emissions by 95% (Lave & Lutz, 2014).

Community-level exposures

Residents in communities neighboring UOGD sites can potentially be exposed to chemical or physical hazards generated at the well site (Adgate et al., 2014). While workers on-site are at a higher risk of being exposed to elevated concentrations of emissions, ambient concentrations in the environment are likely to be much lower, depending on the distance to development, wind direction, wind speed, and weather factors. However, it has been hypothesized that the continuous operation of UOGD sites means that cumulative exposures may be of concern for those residing near developments (Adgate et al., 2014).

In one of the most cited UOGD studies, McKenzie et al. (2012) estimated community health risks for exposures to air emissions from well sites located in Garfield County, Colorado in the Piceance Basin. The authors monitored air quality at four well sites during well completions and at a fixed station representative of the community. They found that residents living less than half a mile from wells were at greater risk for health effects from UOGD than residents living more than half a mile from wells. In addition, subchronic exposures to air pollutants during well completion activities presented the greatest potential for health effects. However, the data evaluated were limited in terms of the number of chemicals analyzed, size of data set, and short time period over which samples were collected (Bunch et al., 2014). The risk assessment aspects of the study by McKenzie et al. (2012) are further discussed in Section 2.3.7. Another study that conducted a quantitative analysis of community-level exposures found that UOGD activities did not result in community-wide exposures to concentrations of VOCs at levels that would pose a health concern. Bunch et al. (2014) evaluated VOC concentrations in the Barnett Shale region using data from a monitoring network established by the Texas Commission on Environmental Quality (TCEQ). Data was collected from seven monitors, with abilities to measure up to 105 VOCs/monitor, over a period dating back to 2000. A total of 4.6 million data points were collected and compared to federal and state health-based air comparison values (HBACVs) to assess potential health effects. None of the measured VOC concentrations exceeded applicable acute HBACVs.

Paulik et al. (2015) used passive sampling to assess the association between PAHs and natural gas extraction in Carroll County, Ohio. Passive air samplers were deployed on 23 properties in February 2014 in a rural community with extensive UOGD. Samplers were analyzed for 62 PAHs and results were grouped based on three distance categories from each sampler to the nearest

active well. The general trend observed was that levels were highest for samplers closest to active wells. The researchers also calculated sourcing ratios and found that PAHs were predominantly petrogenic, as opposed to pyrogenic, suggesting that PAHs originated from the earth. The results were also used to estimate lifetime cancer risk from exposure to known carcinogens, which is discussed Section 2.3.7.

In the symptom survey conducted by Subra (2009), most of the participants (28 out of 31) experienced odours at a frequency ranging from one to two times per day to 24 days per month, while the survey by Steinzor et al. (2012) noted that 81% of respondents reported noxious odours either sometimes or constantly, while 18% reported odours every day. Section 2.3.7 further discusses symptom surveys.

b) Off-site Transportation

Contaminants can become airborne not only from well-site activities, but also from transportation of water, sand, chemicals, and equipment to and from the well pad. This air pollution can potentially impact local and community air quality (Hays et al., 2015).

(i) Hazard Assessment

The main hazard associated with transportation to and from the well pad is emissions of diesel exhaust. With each well requiring approximately 2,300 trips by heavy-duty trucks during early stages of UOGD, levels of diesel associated air pollution will increase near the well pad but also throughout the development region (Shonkoff et al., 2014). Diesel exhaust is a mixture of gases and diesel particulate matter (DPM), produced during the combustion of diesel fuel (OSHA, n.d.). DPM contributes to cardiovascular illnesses, respiratory diseases, atherosclerosis, and premature death. It also can contain associated products of incomplete combustion including polyaromatic hydrocarbons (PAHs), some of which cause cancer when tested in animals, along with a myriad of other adverse health effects (Goldstein et al., 2014).

In addition to DPM, NOx and VOCs are other pollutants prevalent in diesel exhaust. When VOCs react with NOx in the presence of sunlight, ground-level ozone forms (Goldstein et al., 2014; Ratner & Tiemann, 2015). There is concern that in high volume UOGD regions, the level of ozone may exceed ambient air guidelines (Goldstein et al., 2014). Ozone is a strong respiratory irritant and has been associated with increased respiratory and cardiovascular morbidity and

mortality (Shonkoff et al., 2014). NOx and VOCs can be generated from both transportation emissions and the on-site emissions discussed in part a).

(ii) Exposure Assessment

The literature review did not result in any documents specific to exposures from traffic emissions. The lack of studies is likely because diesel exhaust is ubiquitous in nature. Instead, literature discussing air quality in UOGD regions was found and is reviewed in part c). Another consideration is that much of the research about diesel engines is likely for machines that were made before 2007 when there was a transition to new, less polluting diesel technology, as well as to alternative fuels (Goldstein et al., 2014).

Concerning ozone concentrations, study results have been conflicting. An increase in ozone levels attributable to UOGD has been projected using environmental modeling in the Haynesville Shale in Arkansas by Kemball-Cook et al. (2010). Likewise, modeling was also used in Pennsylvania and predicted an increase in ozone precursors and exceedances of the ozone standard during the winter in rural areas (Goldstein et al., 2014). However, in the Barnett Shale area of Texas, there has been a decline in ozone levels from 1997 to 2011 despite the increases in the number of shale gas wells during this time (Honeycutt, 2012). Despite there being many studies documenting the potential of UOGD to contribute to ground-level ozone, Adgate et al. (2014) found only one study that looked at community-based ozone levels and health in a region with UOGD in their comprehensive review. That study found that between 2008 and 2011 in Sublette County, Wyoming, there was a 3% increase in the number of clinic visits for adverse respiratory-related effects for every 10 ppb increase in the eight-hour ozone concentration the previous day (Adgate et al., 2014).

c) Environmental Health Studies

Emission sources can be spread over thousands of acres of a production area, which can complicate the assessment of local and regional air quality (Field et al., 2014). Despite the challenges, researchers have made an attempt to quantify air impacts. The majority of these studies conducted air sampling or used available data from air monitoring networks, then compared measured air concentrations to some air contaminant compliance values. This section will review relevant literature related to air quality and UODG that was not previously discussed.

A case study was conducted by the CDPHE (2012) to measure air emissions in Erie, Colorado that may be associated with well completions during UOGD. Air samples were taken at two locations adjacent to an UOGD site. Results were consistent with what would be expected; concentrations of oil and gas related compounds, including methane, were found to be slightly higher than in downtown Denver, but much lower than in Platteville where greater oil and gas activity is taking place (CDPHE, 2012). The concentrations of benzene and most other chemicals were within the acceptable USEPA health guidelines. However, this study only represents emissions from one well site over a very short time period so very little about community exposures and health impacts can be concluded (Bunch et al., 2014).

Another study conducted by Titan Engineering on behalf of the Barnett Shale Energy Education Council, as described by Bunch et al. (2014), investigated emissions from UOGD in 2010 and came to a similar as the CDPHE (2012). Here, air samples near eight well sites in the production stage and two compressor stations were collected and analyzed for a broad range of VOCs and reduced sulfur compounds (Bunch et al., 2014). The results indicated that the monitored facilities had negligible to minimal impact on ambient air concentrations of the compounds measured (Bunch et al., 2014). There were a few instances where some compounds were present above the applicable air monitoring comparison value (AMCV), but at the measured levels they did not pose a significant risk to human health (Bunch et al., 2014). In another study, conducted in Fort Worth, Texas (ERG, 2011), air samples were collected at eight locations over two months and samples were analyzed for approximately 140 VOCs and carbonyls. None of the measured air concentrations exceeded the short-term health benchmarks used by the investigators to assess the potential for health risk (Bunch et al., 2014). Zavala-Araiza et al. (2014) also assessed emissions from an UOGD region. Here, the researchers collected and analyzed ambient air samples taken from three sites in the Barnett Shale: a site in the geographical centre of the natural gas production region; a rural/suburban site at the periphery of the production region, and an urban site. From April 2010 to December 2011, hourly ambient hydrocarbon concentration data were collected using automated gas chromatography. The results showed that the dominant hydrocarbon species observed were light alkanes and little variation in the composition of samples was observed (Zavala-Araiza et al., 2014).

Taking a bit of a different approach, Caulton et al. (2014) employed an aircraft fitted with a specialized spectrometer in southwestern Pennsylvania in 2012 to identify and quantify methane

emissions from UOGD. The researchers identified a large regional flux of methane emissions over the Marcellus Shale region covering approximately 2800 square kilometres. Seven well pads were identified as being in the drilling stage and had emissions that were two to three orders of magnitude greater than the USEPA's estimates for this phase (Caulton et al., 2014). However, more work is needed to determine all of the sources of methane emissions, to ascertain why these emissions occur and to evaluate if the plumes contain other emissions associated with UOGD (Caulton et al., 2014).

2.2.4 Land

The three main concerns raised about UOGD and land resources are a) land contamination, b) land erosion and c) induced seismic activity. These aspects are discussed below using risk assessment methodology as a guide.

a) Land Contamination

Contamination concerns stem from the uncertainty of how spills and releases can potentially affect land and human health. The following section will assess the hazards and potential exposure pathways and end with a summary of environmental health studies related to land contamination.

(i) Hazard Assessment

The main hazard sources with respect to land contamination are similar to those identified in the water quality hazard assessment in Section 2.3.2(a)(i); land can become contaminated by spills, leaks, or other incidents involving hydraulic fracturing fluids and wastewater generated from UOGD. Contaminants can also end up on land when drilling muds are spread onto soil on areas known as land farms (Finkel & Hays, 2013). Some states also allow operators to spread wastewater onto roads for dust suppression or de-icing, which could potentially lead to land contamination (Vengosh et al., 2014). Another hazard is particulate matter that can become deposited on land from diesel exhaust and wind erosion from drill cuttings (Werner et al., 2015).

(ii) Exposure Assessment

When pollutants, such as petroleum hydrocarbons and heavy metals from wastewaters, end up on land through various means, they can be absorbed in or adsorbed to soil. Pollutants that stay associated with soil can then be ingested accidentally or purposefully (i.e., pica), inhaled if they become airborne, and absorbed through the skin should contact occur (Werner et al., 2015). These exposure pathways would be the most relevant near residential areas as opposed to

remote rural areas where community exposures would be unlikely. Animals living near UOGD or near accidents and releases are also at risk of exposure. The deaths of 17 cattle were attributed to exposure to hydraulic fracturing fluids that leaked onto an adjacent pasture in Louisiana in 2009 (Rahm, 2011). However, studies on land contamination in relation to UOGD, exposure pathways, and human health are limited.

Another possible exposure route is through ingestion of surface water that has been impacted by contaminated land via runoff or floods or shallow groundwater that has been impacted through leaching. Whether or not the contamination is transported from the soil to a nearby drinking water resource depends on the mobility, solubility and volatility of the compound or mixture, as determined by the various physicochemical properties (ATSDR, 1999). In general, organic chemicals tend to be less mobile in the environment and usually remain in soils or sediments (ATSDR, 1999). Low mobility may result in smaller dissolved contaminant plumes in ground water, although these chemicals can be transported with sediments in surface water or small particles in ground water. Organic chemical properties vary with salinity, and effects depend on the nature of the chemical (USEPA, 2015).

(iii) Environmental Health Studies

Werner et al. (2015) conducted a literature review of pollutants in soil and their effect on soil quality as a result of UOGD activities and found a very limited number of studies. The only study they discussed was an Australian study from 2013 that analyzed environmental monitoring data and found no evidence of an association between soils sample results, emissions from conventional shale gas operations and reported symptoms from residents in a nearby community (Werner et al., 2015).

b) Land Erosion

Apart from land contamination concerns, there is also a concern raised about how the changes in the land surface from UOGD can affect public health. The following section will assess the hazards and potential exposure pathways related to land erosion.

(i) Hazard Assessment

Although UOGD typically requires fewer well pads and fewer access roads compared to conventional oil and gas developments and the overall land impact is small relative to other human land uses, there are still land aspects that are worth discussing (Lave & Lutz, 2014; USGS

2012). Land clearing and construction, which contribute to erosion, have been identified in the literature as being one of the main hazards of development. Land erosion has been shown to increase TSS in local water bodies, particularly when coupled with the effects of precipitation on transporting sediments, increasing flow rates so that water carries more and larger sediments, and re-suspension of sediments (Olmstead et al., 2013; Rahm & Riha, 2014). The effect of TSS in surface water is a reduction in sunlight, increase in temperature, decrease dissolved oxygen and clarity, and ultimately poorer water quality for aquatic systems and downstream users (Olmstead et al., 2013).

(ii) Exposure Assessment

Exposure to hazards associated with land erosion is difficult to assess directly. The impact to drinking water sources as a result of land erosion have not been studied well. However, there is information available on spills associated with surface water impacts from UOGD, which is presented in the water quality Section 2.3.2(a). As hazards associated with land erosion are not unique to UOGD, best management practices from other industries can be used to mitigate risks. Some of these management practices include, but are not limited to well pad setbacks to surface waters, runoff flow paths, and infrastructure to control stormwater, erosion and sediment impacts (Olmstead et al., 2013; Rahm & Riha, 2014).

c) Induced Seismic Activity

In recent years, the number and frequency of induced seismic events in oil and gas rich regions have increased public concern about the effects of UOGD (AER, 2015d; Taylor et al., 2015). This Section discusses the potential hazards and how they translate into human exposure.

(i) Hazard Assessment

In Canada and the US seismic events have been claimed to be associated with UOGD on numerous occasions (Hays et al., 2015). There are three main mechanisms that are thought to cause seismic activity in oil and gas regions. These mechanisms are:

- underground injection control (UIC) wells,
- well stimulation, and
- hydrocarbon extraction (Atkinson et al., 2015).

The main hazard is the ability of seismic events to damage infrastructure and injuries to workers and community residents. Table 4 outlines the possible effects experienced based on the magnitude of the seismic event.

Table 4: Earthquake Magnitude Scale (MTU, 2007)

Magnitude	Earthquake Effects
2.5 or less	Usually not felt, but can be recorded by seismograph
2.5 to 5.4	Often felt, but only causes minor damage
5.5 to 6.0	Slight damage to buildings and other structures
6.1 to 6.9	May cause a lot of damage in very populated areas
7.0 to 7.9	Major earthquake, serious damage
8.0 or greater	Great earthquake, can totally destroy communities near the epicentre

(ii) Exposure Assessment

Some examples of seismic activity include:

- 4.6 magnitude earthquake in 2015 in the Fort St. John, British Columbia was potentially attributed to well stimulation (Atkinson et al., 2015).
- 3.9 magnitude earthquake in 2014 near Rocky Mountain House, Alberta caused a power outage (Atkinson et al., 2015).
- Since the installation of seismometers, there have been hundreds of earthquakes recorded near Fox Creek, Alberta, mostly 2.5 or less, but ranging up to 4.4. (AER, 2015b).
- In 2011, three moderate earthquakes of magnitude 5.0, 5.6, and 5.0 in Oklahoma were reported to be from injection of wastewater into deep disposal sites near shale gas operations. The largest earthquake in this series destroyed 14 homes and injured two people (Ellsworth, 2013).

Taylor et al. (2015) conducted a seismic risk analysis and concluded that the communities most at risk of seismic hazards from nearby UOGD are those that have been previously aseismic or minimally seismic. In these regions, the hazard potential for a much larger seismic event, like one more than 5.0, is elevated due to the increased energy from UOGD. As a result of not having experience with seismic events, these regions have not had to incorporate seismic stressor into building codes, leaving infrastructure more vulnerable to impacts. While the documented seismic activity has captured substantial public attention, some argue that the mechanisms attributed to causing the seismicity are well understood and that strategies exist for identifying, monitoring, mitigating seismic risks (Lave & Lutz, 2014).

2.2.5 Traffic

The abundant amount of traffic required for UOGD raises concerns over air pollution (previously discussed in Section 2.3.3(b)) and accidents and injury resulting from the high volume of trucks traveling to and from the well sites. The latter is discussed below.

(i) Hazard Assessment

The phases of development that require the most traffic load are well pad construction, drilling and well completion (Witter et al., 2010). It has been suggested that industrial traffic can pose an increased risk of motor vehicle crashes, which could result in injury or death (Werner et al., 2015).

(ii) Exposure Assessment

Occupational exposures

Safety issues are a major concern for oil and gas workers, including traffic accidents (Goldstein et al., 2014). NIOSH research found that between 2003 and 2009, 716 oil and gas extraction workers were fatally injured on the job, resulting in an annual occupational fatality rate of 27 per 100,000 workers, more than seven times as high as in all U.S. industries. Of these fatalities, motor vehicle crashes were the leading cause of death to oil and gas extraction workers accounting for nearly 30% of all work-related fatalities (Goldstein et al., 2014).

Community-level exposure

Graham et al. (2015) examined the association between UOGD and motor vehicle accident rates in Pennsylvania. The researchers used publicly available data on all reported vehicle crashes and compared accident rates in counties with and without shale gas development from 2005 to 2012. Through a matched analysis, the results indicated that vehicle accidents have measurably increased in conjunction with shale gas drilling but differences in fatalities and major injury as a result of the crashes were not detected. One example is that counties with high drilling rates in the north experienced 15–23% higher vehicle crash rates in 2010 to 2012 and 61–65% higher heavy truck crash rates in 2011–2012 than control counties (Graham et al., 2015).

2.2.6 Nuisance Conditions

Two nuisance conditions that are a source of individual and community concern are noise and light pollution. Hazard sources and exposures associated with each nuisance are discussed below.

a) Noise

Although noise generation from UOGD has not been systematically studied, it has been reported as a health concern in the literature (Goldstein et al., 2014).

(i) Hazard Assessment

There are many sources of noise that are associated with UOGD. These include, but are not limited to:

- construction,
- vehicles,
- diesel generators,
- drilling, and
- compressors (Werner et al., 2015).

Loud continuous noise, like that experienced by workers at the well site, has been associated with temporary or permanent hearing loss, whereas low-frequency noise exposure has been associated with stress, annoyance, irritation, fatigue, headache, unease, and sleep disturbance (Werner et al., 2015).

(ii) Exposure Assessment

Workers are at the greatest risk of being exposed to noise at levels that may cause hearing impairment due to their proximity to the hazard sources. However, occupational noise exposures can be mitigated by the use of PPE.

For community noise, health impacts are likely to result from annoyance and stress due to noise above background levels. It is not likely that medical attention will be necessary for most people, although some may seek medical assistance (Witter et al., 2010). A biomonitoring study from Texas found residents reporting concerns about noise related to shale gas wells and compressor stations. Staff visiting the sites also noted similar noise during site visits before sampling (TXDSHS, 2010). However, at no point was sufficient noise data collected to be able to draw conclusions about possible impacts.

Noise abatement strategies include de-centralized compression stations (centralized compression stations are a significant noise source), noise suppression equipment, use of hay bale walls around the pad, noise blankets for diesel engines, and electric grid power for drilling

(Witter et al., 2010). Local regulations distinguish between maximum decibels for day and night, while others distinguish between maximum decibels for certain phases of the operation such as drilling, fracturing, and production; however, there is often variability, and sometimes the setback distances are meant to be monitoring points and are not necessarily locations indicative of being protective of health (Werner et al., 2015).

b) Light

Light pollution is best described as ongoing exposure to light after dark. A review of the pollution sources, potential health effects, and exposure aspects is provided below.

(i) Hazard Assessment

UOGD operations are typically conducted on a 24-hour basis meaning as operations are occurring in the night, lights are needed to illuminate the well sites (Werner et al., 2015). The two main types of light pollution that these developments can cause are sky glow and light trespass. Sky glow is the bright halo that appears over urban areas at night and could occur with larger unconventional developments (Chepesiuk, 2009). Light trespass occurs when unwanted artificial light from, for instance, a floodlight, spills onto an adjacent property, lighting an area that would otherwise be dark. Light pollution can contribute to stress and sleeping disorders amongst those living in nearby communities (Korfmacher et al., 2013).

(ii) Exposure Assessment

Very few studies, as reviewed by Werner et al. (2015), discuss or research light pollution caused by UOGD activities and the potential for community exposure and health impacts. Some studies recommended measures that can be taken to reduce light pollution such as directional lighting, glare restrictions, sodium vapour lights, and light shields (Witter et al., 2010).

2.2.7 Health Impact Assessments

The number of studies and reviews on UOGD and environmental health is large. Despite there being hundreds of chemical and physical hazard sources, known emissions and releases of contaminants, measured environmental concentrations in the environment, and potential exposure pathways, very little is known about the dose, toxicity, metabolic pathways and actual human health effects of UOGD as evident by the inference of health impacts rather than strong epidemiological evidence of health effects from UOGD (Lave & Lutz, 2014; Werner et al., 2015). This is likely because whether or not an exposure leads to a disease or a measurable health effect depends on factors that are difficult to quantify and not

routinely reported in environmental health studies. The few epidemiological studies published, whether or not reporting an association of adverse consequences with UOGD, are hindered by a lack of methodological rigor or study design power (Goldstein et al., 2014; Werner et al., 2015). Regardless of the limitations, these epidemiological studies have been reviewed, along with some symptom surveys and articles that used health risk assessment or health impact assessments.

a) Symptom Surveys

Some of the studies reviewed examined health symptoms reported by residents living near UOGD. In general, some of the symptoms reported include short-term impacts like nose, eye, and throat irritation, respiratory tract ailments, nausea, nosebleeds, sleep disturbance, rash, headaches, abdominal pain or cramping, diarrhea, dizziness, fatigue, and weakness (Rabinowitz et al., 2015; Saberi et al., 2014; Steinzor et al., 2013; Subra, 2009). While these studies lack scientific rigor because they use convenience sampling, the reported symptoms are consistent with known health effects associated with petroleum hydrocarbons exposure.

Subra (2009) surveyed 31 individuals from DISH, Texas, located in the Barnett Shale area. 19% of the surveyed population considered themselves to be sick, or both healthy and sick, reporting a total of 130 medical conditions. The authors compared the reported symptoms to measured ambient air contaminant concentrations and found that 61% of the reported symptoms were known health effects of exposure to the contaminants in the air. Similarly, Steinzor et al. (2013) conducted a self-reporting survey and environmental testing project in Pennsylvania between 2011 and 2012. The survey was completed by 108 individuals from 55 households across 14 counties in rural and suburban residential communities. A key finding was that as the distance from oil and gas facilities increased, the percentage of respondents reporting the symptoms generally decreased (Steinzor et al., 2013). Rabinowitz et al (2015) also conducted a health symptom survey of 492 individuals in 180 randomly chosen households with groundwater wells in an area of active gas drilling in Pennsylvania. Here, the number of reported health symptoms per person was higher among residents living less than 1 kilometre compared with greater than 2 kilometres from the nearest gas well (Rabinowitz et al., 2015). Unlike Steinzor et al. (2013), there were no environmental samples were taken which could have been a very simple and cost-effective measurement to use in the analysis. Saberi et al (2014) explored a similar topic by administering a questionnaire to adult volunteers with medical complaints in a primary-care medical office in Pennsylvania in the Marcellus Shale area. Of the 72 respondents, 22% perceived UOGD as a health concern and 13% attributed

medical symptoms to UOGD exposures. Overall, 42% attributed one or more of their medical symptoms to environmental causes, of which UOGD was the most frequent. The results of this pilot study suggest that there is a substantial concern about adverse health effects of UOGD among Pennsylvania Marcellus Shale residents, and that these concerns may not be adequately represented in medical records (Saberi et al., 2014).

For the environmental testing portion of the Steinzor (2013) paper, the researchers collected 34 air samples for VOC analysis and nine water samples at 35 households. Concerning the air sample data, very little information about public health risk can be concluded due to the limited number of samples over a short 24-hour time frame. For the water testing, again, very little can be concluded due to the limited number of samples and no background data to compare the results to. The finding of high levels of heavy metals that exceeded MCL in the water is potentially a public health concern that warrants further investigation, even though the metals are likely not be related to UOGD (Steinzor et al., 2013).

None of the symptom survey studies presented evidence that the reported symptoms were a result of exposure to the hazards associated with UOGD. Although the intent of the surveys and associated environmental monitoring was not to find a cause and effect relationship, the findings are further limited by the absence of in-depth health history, little consideration given to indoor air exposures and other possible ambient air exposures, and reporting of nonspecific symptoms that were not medically verified (Adgate et al., 2014).

b) Cancer Studies

Two studies examined cancer incidence in Pennsylvania (Fryzek et al., 2013) and Texas (TXDSHS, 2014). Fryzek et al.'s study compared childhood cancer incidence before and after UOGD between the years 1990 and 2009 (Fryzek et al., 2013). They obtained data on childhood cancers from the Pennsylvania cancer registry for this time period. The authors found the total number of cancers observed was close to expected before drilling began and after drilling and concluded that communities exposed to UOGD are not at an increased risk of childhood cancer, childhood leukemia, and childhood CNS tumours (Fryzek et al., 2013). Although the authors admit some limitations, like no individual-level information on environmental, lifestyle, or medical characteristics, there are many other flaws associated with the study design. Goldstein & Malone (2013) have argued that the study does not include the appropriate epidemiological consideration

of the lag period between the exposure to a carcinogen and the eventual development of a clinically observable cancer. The lag period for childhood cancers can be 4 years period before an appreciable increase in risk can be observed and as many as 15 years before all of the cases accumulate (Goldstein & Malone, 2013). Also, within the time frame studied, only a small number of wells had been drilled in the Marcellus Shale, and even fewer were horizontally drilled and hydraulically fractured, as development in the region only started in 2006 (Shonkoff et al., 2014). The study by Fryzek et al. (2013) suggested the need for more rigorous assessments that pay close attention to the epidemiological factors for cancer studies, like latency periods of environmentally mediated diseases (Shonkoff et al., 2014).

The second cancer study was conducted by the TXSDHS as a result of public concerns in the community of Flower Mound, Texas, that possible exposures to UOGD emissions were causing cancer in the area. In 2010, the TXSDHS conducted a cancer cluster investigation (CCI) in two zip codes, updated their findings in 2011, and again revisited the CCI in 2014 by using updated cancer and population information (TXDSHS, 2014). Cancer data obtained from the Texas Cancer Registry for leukemia, liver, brain/central nervous system (CNS) childhood cancers (0–19 years), as well as leukemias, non-Hodgkin's lymphomas, and breast cancers for all ages were evaluated. Investigators calculated standardized incidence ratios (SIRs) as the number of observed cases divided by the number of expected cases in the area of concern for a ten year time-period (January 1, 2002 – December 31, 2011). Both 95% and 99% confidence intervals (CIs) were calculated for each SIR. Female breast cancer was the only type of cancer where the number of observed cases in the two postal codes was significantly higher than the expected number of cases. The same result was found with the previous CCI's conducted in 2010 and 2011. Given the high level of concern in the community, TXDSHS plans to continue to monitor cancer incidence in the Flower Mound area.

c) Biomonitoring

Most of the studies reviewed concentrated on environmental measurements of water and air quality. While this type of information provides a tool for estimating potential human exposures, there is a lot of uncertainty in how these measurements translate into exposure and uptake into the body (Bunch et al., 2014). The best tool for actually measuring an individual's exposure is biomonitoring, which involves the collection of blood and/or urine, which is then analyzed for chemicals of interest. One study that employed this method was conducted by the TXDSHS (TXDSHS, 2010). Here, the researchers aimed to address health concerns from residents' in DISH, Texas, who

were concerned about the potential impact of nearby shale gas wells and compressor stations. In this study, blood and urine samples were collected from 28 residents in the community and analyzed for VOCs and VOC metabolites, respectively. The TXDSHS concluded that the levels of VOC metabolites in the urine of most DISH residents were not different from typical background levels in the general US population. Some of the VOCs in blood samples were found at levels higher than expected levels in the general US population. However, it was noted that the pattern of VOC values was not consistent with community-wide exposure to contaminants, such as those that might be associated with shale gas drilling operations (TXDSHS, 2010). One of the limitations of biomonitoring is that multiple exposures to contaminants are reflected in the results making identification of the sources difficult. The authors hypothesized that the high levels of some VOCs in the blood were likely from other sources of exposure like smoking and household cleaners. Another limitation of biomonitoring noted by the authors is that VOCs only stay in the body for a very short period of time, meaning that the measurements reflect recent, short term exposures and not long-term exposures. This was also just single sampling event and it may be worthwhile to explore more comprehensive biomonitoring studies to assess exposures.

d) Health Risk Assessments

The Colorado School of Public Health worked in collaboration with Garfield County Public Health to conduct a qualitative and quantitative analysis of existing environmental, exposure, health, and safety data pertinent to the Battlement Mesa community, who expressed concern regarding future land use decisions around natural gas development (Witter et al., 2010). A health impact assessment (HIA) was conducted to address eight areas of health concern identified through stakeholder consultation and a literature search. Within the HIA, health risk assessments were used to determine the potential for air, water, and soil compromise. Although the results of the HIA were very general, it provides baseline information for use future prospective exposure studies and more comprehensive health risk assessments.

McKenzie et al. (2012) conducted a human health risk assessment for exposures to air emissions in an area of Colorado with UOGD. Based on air quality monitoring data, the researchers used U.S. EPA guidance to estimate chronic and subchronic non-cancer hazard indices (HIs) and cancer risks from exposure to hydrocarbons. The results of their study are summarized below.

	Proximity to well	
	≤ ½ mile	> ½ mile
Subchronic non-cancer HI	5	0.2
Chronic HI	1	0.4
Cumulative cancer risk	10 in 1,000,000	6 in a 1,000,000

The main compounds that contributed the majority of the subchronic non-cancer risk were trimethylbenzenes, xylenes, and aliphatic hydrocarbons. For cancer risks, benzene was the major contributing factor (McKenzie et al., 2012). However, there were many limitations and criticisms of the health risk assessment. First, there were no baseline air quality data available before development to compare the results to. Also, the fixed point monitors used to estimate community exposures are intended to measure regional atmospheric concentrations (Werner et al., 2015). Therefore, point sources could not be identified, and it is likely that some areas will have higher or lower concentrations of pollutants to which residents could be exposed, but this study could not detect these differences (Bunch et al., 2014). The authors acknowledge that accurately estimating exposure rates over multiple decades is extremely difficult.

A similar group of researchers conducted a retrospective cohort study to examine associations between maternal residential proximity to natural gas development and a number of adverse birth outcomes from over 100,000 births between 1996 an 2009 in rural Colorado. The authors did not find an association between density and proximity of wells within a 10 mile radius of maternal residence and the prevalence of oral clefts, pre-term birth, or term low birth weight (McKenzie et al., 2014). However, they did observe a positive association between density and proximity of pregnant mothers to shale gas development and the prevalence of congenital heart defects and possibly neural tube defects in their newborns (McKenzie et al., 2014). The main limitation noted by the researchers was that they could not fully adjust for socioeconomic status, health, nutrition, prenatal care, and pregnancy complications that may have resulted in confounding. They also did not have information on maternal folate intake and genetic anomalies, which are both independent predictors of our outcomes, and also may have resulted in confounding. Another limitation of the study was the lack of temporal and spatial specificity of the exposure assessment. Because there was no maternal residential history, it was assumed that the address given was also the address during the first trimester of pregnancy, which is the critical time period for formation of birth defects. Another issue related to the exposure assessment was the lack of information on the phases of UOGD activities that were occurring during the first trimester. Fedak et al. (2014)

criticized that using proximity to wells was a weak proxy for exposure and that no true exposure to any chemical was actually measured or modeled (Fedak et al., 2014). They took the assessment a step further and analyzed the results by restricting the radius to wells within a closer proximity. This resulted in no association between found between density and proximity of wells to maternal residence and the prevalence of any birth defects.

The passive sampling study by Paulik et al. (2015) was previously discussed in Section 2.3.3. The researchers also used the air monitoring results to conduct a quantitative human health risk assessment. Here, the average benzo(a)pyrene equivalent concentrations for the close, middle and far air sample collection locations were used to calculate the excess lifetime cancer risks (ELCR) associated with exposure to the measured PAHs. Closest to active wells, the ELCR for maximum residential exposure (24 hours per day) was 290 in 1,000,000, which is above the U.S. EPA's acceptable risk level (Paulik et al., 2015), but also a very conservative estimate. Although risk estimates decreased 30% when comparing results from close samplers to farther samples, no comment was made on the statistical significance of the difference but the authors did acknowledge that the risk estimates they made depend heavily on exposure frequency and duration. Another limitation of the study was the time of year that the air sampling was conducted. Sampling was only done during February, when the ambient temperatures are usually colder and there maybe temperature inversion events that can lead to poorer air quality (Fort Air Partnership, 2015).

2.2.8 Summary

The scientific literature contains some evidence of potential public health risks from UOGD but contains just as much evidence to suggest risks are minimal. The studies that aimed to quantify the potential risks were not objective and evidence-based, lacked methodological rigor and contained too many limitations to conclude with any certainty that a human health risk exists or does not exist. Therefore, it is imperative that well-designed empirical research is conducted to quantify the potential risks to the environment and human health, both in the short-term to assess acute effects and long-term since many diseases appear years after exposure (Finkel & Hays, 2013).

Some of the studies reviewed were initiated as a result of public concerns and complaints to government agencies (CDPHE, 2012; TXDSHS, 2010,2014; Witter et al., 2010). These complaint investigations from state agencies have added to the current body of knowledge and findings from

future investigations can help inform the complex assessment of potential environmental public health risks from UOGD.

CHAPTER 3 – METHODOLOGY

The main technique to collect primary data to accomplish the research objectives outlined in Section 1.5, was survey research. However, through researching survey methodologies, it became apparent that a less standardized approach would be required as the goal was to describe a set of organizations and not to collect data of a personal, self-reported nature (Rea & Parker, 2014). Therefore, conducting less formal case studies of different jurisdictions using survey techniques as a guide was the best method to collect data. The following chapter outlines how the case studies were prepared (Section 3.1) and implemented (Section 3.2).

3.1 Research Preparation

To prepare for conducting the case studies, methodologies were explored to determine who and how to sample (Section 3.1.1) and how to develop the content of the questionnaire (Section 3.1.2).

3.1.1 Survey Methodology

There were several important aspects to consider when selecting the most appropriate survey research methods. The following section will discuss (a) the sample population, (b) the sampling design and (c) the data collection mode, as described by Fowler (2009) and Rea & Parker (2014).

a) Sample Population

The first consideration in deriving a sample is specifying the unit of analysis. The unit of analysis is the individual, object, or institution (or group of individuals, objects, or institutions) that bears relevance to the study (Rea & Parker, 2014), in this case, the agencies that are responsible for investigating complaints related to oil and gas. In the US, State agencies are the primary regulators of oil and gas production on non-federal lands and are therefore the jurisdictions that should be identified to narrow down specific agencies that investigate complaints (Ratner & Tiemann, 2015). In the literature review conducted in Chapter 2, there were three States that were often referred to: Colorado, Pennsylvania, and Texas. North Dakota was also identified as a potential state to study since the recent boom of UOGD has brought media attention. Table 5 summarizes the oil and gas activities in these states.

Table 5: Summary of Unconventional Oil and Gas Development in Colorado, Pennsylvania, Texas and North Dakota (adapted from Ratner & Tiemann, 2015; Rahm & Riha, 2014; Rahm, 2011)

State	Unconventional Oil and Gas Plays		History
Colorado	Niobrara Pierre Hillard-Baxter-Mancos		- Output of crude oil doubled from 2012 to 2014 - Approximately 2 billion barrels of oil could be recoverable from the Niobrara Shale
Pennsylvania	Marcellus Utica Devonian		- In 2014, Marcellus Shale was the single largest gas producing play
Texas	Barnett Eagle Ford Haynesville-Bossier	Bone Spring Delaware Spraberry Granite Wash	- One of the world's largest producers of oil and gas - Technologies in hydraulic fracturing and horizontal drilling were pioneered in the Barnett Shale
North Dakota	Bakken		- Increase in US crude oil production between 2008 and 2014 from tight oil in Bakken Shale

The next step was to identify the agencies responsible for investigating oil and gas complaints within the four states. The results are summarized in Table 6.

Table 6: Summary of Regulatory Agencies Responsible for Conducting Complaints related to Oil and Gas Development

State	Regulator		
	Oil and Gas	**Environment**	**Health**
Colorado	Colorado Oil and Gas Conservation Commission (COGCC)	Colorado Department of Public Health and Environment (CDPHE)	Colorado Department of Public Health and Environment (CDPHE)
Pennsylvania	Pennsylvania Department of Environmental Protection (PADEP)	Pennsylvania Department of Environmental Protection (PADEP)	Pennsylvania Department of Health (PADOH)
Texas	Railway Commission of Texas (RRC)	Texas Commission on Environmental Quality (TCEQ)	Texas Department of State Health Services (TXDSHS)
North Dakota	North Dakota Industrial Commission (NDIC)	North Dakota Department of Health (NDDOH), Environmental Health Section	North Dakota Department of Health (NDDOH), Environmental Health Section

The third step was to choose individuals from each agency to survey. Sections 3.2.1 and 3.2.2 describe the process of selecting individuals from each agency. Differences in the organizational structure of the government of each State and the availability of web-based information about the sample population had a direct impact on the choice of sampling design discussed in the next section.

The sample size is another consideration of the sample population. For these case studies, the researcher did not know how many individuals needed to be interviewed to meet the research objectives. Instead, the judgement of the researcher and the referrals made at the end of each interview drove the sample size. The main indicator of success was that at least one individual from each agency identified as having direct involvement in complaint investigations was represented.

b) Sampling Design

The two sampling methods for survey research are probability sampling and non-probability sampling (Fowler, 2009). Probability samples have the following two common characteristics:

- An equal probability of selection for all members of the population at all stages of the sampling process and
- elements of the sample are selected independently of one another (Rea & Parker, 2014).

Examples of probability sampling include simple random sampling, systematic random sampling, stratified random sampling, and cluster (multistage) sampling. All of these sampling designs permit the researcher to use a variety of statistical tools to calculate the precision of sample estimates (Rea & Parker, 2014). Although the use of one type or a combination of these types of probability sampling are common in survey research when a given population in known, there are occasions when the goal of information gathering is not to generate statistics about a population but to describe a set of people in a more general way (Rea & Parker, 2014), as is the case with this research thesis.

Non-probability sampling design, on the other hand, is used when the researcher does not know the probability of selecting a particular respondent as part of the sample (Rea & Parker, 2014). Therefore, there is no certainty that the probability of selection is equal among the potential respondents and as such, the researcher cannot analyze the sample in the context of the normal distribution and apply simple statistics. Some examples of non-probability samples are convenience sampling, chain referral sampling (or snowball sampling) and purposive sampling. An example of

convenience sampling is a sidewalk survey where interviewers survey people walking by, usually at a public place. Snowball sampling is particularly beneficial when it is difficult to identify potential respondents, such as populations that are relatively specialized or localized (Biernacki & Waldorf, 1981). Here, once a few respondents are identified and possibly interviewed, they are asked to identify others who might qualify as respondents.

In purposive sampling, professional judgement, rather than random sampling, is used to identify key respondents. Key respondents, whom the researcher considers to be particularly knowledgeable about the subject, may be selected for interviews (Rea & Parker, 2014). Benefits to purposive sampling include the ability to focus the survey on individuals that, in the judgement of the researcher, are suitable candidates. Another advantage to this sampling method is the capacity to incorporate chain referral methods. Since the target population is a specialized and small group of individuals and some contact information for potential respondents is lacking, the sampling design employed a combination of both purposive and chain referral methods.

c) Information Collection Methods

Aspects of the sample population, sample design, desired response rates, and budget, were used to determine the best information collection methods. The common methods used to collect survey research information, along with the advantages and disadvantages of each, are summarized in Tables 7 and 8, respectively.

Given that the sample population is a relatively specialized group of individuals, the intercept method would not be an appropriate way to conduct the interviews as there isn't a location appropriate to intercept respondents. Achieving the desired response rates and needed referrals would likely not be possible through the mail-out questionnaires since the response rates are typically lower than other methods and the time to receive referrals may be too long. In-person surveys would be the best way to collect data based on the advantages provided in Table 8 and the ability to build rapport with the respondents. However, there wasn't a budget to travel to four different states to conduct in-person interviews. Therefore, the most feasible approach to administering the survey was through telephone interviews. Telephone interviews were chosen over web-based surveys because telephone surveys can integrate open-ended questions with follow-up questions, allow flexibility to explain and clarify questions, are low cost, lead to data and referrals in a timely manner, and readily available contact information is accessible from websites.

Table 7: Descriptions of Information Collection Methods (adapted from Rea & Parker, 2014; Fowler, 2009)

Survey Method	Description
Mail-Out	Dissemination of printed questionnaires through the mail (e.g. postal service) to the sample population.
Web-Based	An alternative to the traditional mail-out questionnaire; individuals are contacted by e-mail and asked to participate in a survey that is completed and submitted online.
Telephone	Information is collected through the use of telephone interviews between a trained interviewer and the sample population.
In-Person	In-person, or face-to-face, interviews permit an interviewer to conduct interviews directly with a respondent.
Intercept	A variation of the in-person interview whereby information can be obtained from respondents as they pass by a populated public area such as a mall. The interviewer actually "intercepts" individuals and asks them to participate in the survey.

Table 8: Advantages and Disadvantages of Five Information Collection Methods (adapted from Rea & Parker, 2014; Fowler, 2009)

Survey Method	Advantages	Disadvantages
Mail-Out	- Convenient - Reduced interviewer-induced bias	- Time to respond - Low response rate - Incomplete open-ended questions
Web-Based	- Rapid data collection - Cost-effective - Confidential and secure	- Limited to populations that have access to e-mail and a computer - Incomplete open-ended questions
Telephone	- Rapid data collection - Lower cost compared in-person interviews	- Less complexity - Less appropriate for personal or sensitive questions
In-Person	- Greater complexity - Ability to contact hard-to-reach populations	- High cost - Interviewer-induced bias - Lack of anonymity
Intercept	- Complexity - Used to inform questionnaires for larger surveys	- Low response rates - Lack of anonymity - Interviewer-induced bias

Although open-ended questions and question clarification are forbidden in a standardized interview, conducting case studies relies on some flexibility to elaborate on the subject matter (Fowler, 2009). The majority of surveys utilize a single data collection method, but it is not uncommon for combinations of methods to be used (Fowler, 2009). Here, telephone interviews with potential respondents were the preferred choice of information collection. However, due to the availability of a contact email addresses, some contact with agencies and individuals was likely to occur through email but with the goal of conducting the interview via telephone.

3.1.2 Questionnaire Development

Designing a sound questionnaire involves a) establishing an information base, b) selecting questions needed to meet the research objectives, c) organizing the questions into a form to maximize the ease of use for both the interviewers and respondents, and d) testing the questions to make sure they can be asked and answered as planned (Fowler, 2009). These four steps are outlined below.

a) Information Base

Preliminary information about issues of importance from interested parties and key individuals was gathered through professional contacts at AHS, AH and the Office of the Chief Medical Officer of Health. A 2012 briefing note developed by the Provincial Scientific Advisory Team of AHS listed many of the same questions noted in the introduction (N. Fok, personal communication, 2012). Another interagency committee comprised of members from AH and AHS developed a document outlining specific issues and questions based on an investigation of health concerns at a southern Alberta residence in proximity to a UOG facility (A. Torng, personal communication, 2014). The information base for the question selection process came from the two documents mentioned above, along with discussions with professional contacts, and personal experience working as an Environmental Health Officer for AHS.

b) Question Development

To maximize the advantages and minimize the potential limitations inherent with telephone interviewing, questions that could easily be delivered over the phone to collect the desired information were developed. The questions were mainly aimed to collect descriptive and behavioral data on the roles, responsibilities, and experiences that the different agencies have had regarding oil and gas complaint investigations. For these purposes, the format of the questions,

namely closed-ended and open-ended, was researched. Table 9 discusses the advantages and disadvantages of these two question formats.

Table 9: Advantages and Disadvantages of Open-Ended and Closed-Ended Questions (adapted from Rea & Parker, 2014; Fowler, 2009)

Question Format	Advantages	Disadvantages
Closed-Ended	- Uniform answers can be used for comparison - Greater response rate	- Insufficient options for respondents to select from - Limited or erroneous information
Open-Ended	- Can provide rich qualitative data - Unrestrained answers	- Subjective and time-consuming categorization for analysis - Time commitment may lead to high refusal rate

Open-ended questions were adopted to allow respondents to have the opportunity to expand on their organization's role in complaint investigations freely. Since the sample population was relatively small and there was no need for statistical analysis on the collected information, the disadvantages mentioned in Table 9 could be overcome.

c) Questionnaire Organization

The goal of formatting the questionnaire was to make the tasks of the interviewer and the respondent as easy as possible (Fowler, 2009). The questions were arranged in a clear and logical order with introductory questions being those that were relatively easy to answer. The focus of the initial questions was to elicit straightforward factual information about the organization's role with oil and gas activities. Sensitive or complicated questions were placed near the end of the questionnaire so that a rapport was established before asking questions that took more knowledge of examples of actual investigations. Lastly, related questions were grouped together into four main sections so that the respondent could focus and concentrate on the specific issues without distraction. Appendix A contains the first questionnaire along with an explanation of why each section or question was included.

d) Testing Phase

The purpose of the testing phase, i.e. testing the questionnaire, was to detect any flaws in the questionnaire's clarity, comprehensiveness, and acceptability. The state of North Dakota was surveyed first to test the first draft of the questionnaire based on the following considerations:

- North Dakota has a relatively short history of UOGD

- North Dakota had one main agency identified as investigating UOGD complaints

Appendix B1 and B2 contain the completed questionnaires from two respondents from the NDDOH, Environmental Health (EH) Section.

Since the objectives of this research were a result of collaboration with AHS and AH, the draft questionnaire (Appendix A) was also reviewed by AHS and AH for content and to ensure that the questions were consistent with the objectives of the study (K. Thomas, personal communication, 2014; R. Musto, personal communication, 2015).

The interview experience with the North Dakota respondents and the feedback from AHS and AH were used to fine-tune the questionnaire for use in the surveys that followed. Appendix C contains the final questionnaire template and the rationale for any changes.

3.2 Survey Implementation

Implementing the survey consisted of selecting respondents from the three US jurisdictions (Section 3.2.1) and developing a standardized implementation procedure (Section 3.2.2).

3.2.1 Respondent Selection

After the unit of analysis was defined and researched (Section 3.1.1), the working population was generated by listing contactable members identified through a web-based search of the different jurisdictions of interest. It was critical that the sample population be those with the most familiarity with the complaint system. Identifying these individuals for some jurisdictions was very easy, as some State Department websites include comprehensive organizational charts with names and contact information. However, some agencies only listed general contact phone numbers for offices and departments. Section 3.2.2 outlines a flexible system of implementation to accommodate for the variability in available information.

3.2.2 Survey Administration Protocols

To build an enhanced rapport with the respondents, the researcher reviewed existing sources of information for each agency to become familiar with the appropriate terms, oil and gas history, industry jargon, and complaint information. This information was gathered through reviewing website content and government publications. Once this secondary research was compiled, the following steps were taken to enlist participation and administer the survey for each jurisdiction identified in section 3.1.1:

Step 1: Identification of the most appropriate respondent from the working population

- When names and titles could be found, preference was given to those in a leadership role, such as Directors and Managers.
- When names could not be found, phone calls to the agencies were made, and contact information was gathered and incorporated into the working population list.
- When phone calls did not result in the required contact information, emails were sent to general information email addresses.

Step 2: Enlisting participation in the survey was accomplished by introducing the study through email and telephone communication:

- Email was the preferred method for initial contact, as more detail about the study objectives could be given. For case studies, a typical approach is to enlist respondents as collaborators in the research, explaining to them what is wanted and asking them to provide the needed information (Rea & Parker, 2014).
- A sample email is provided in Appendix D. All emails contained the following:
  - the purpose of the research,
  - the topics to be covered,
  - a request to respond to the email to set up an interview,
  - the researcher's contact information, and
  - the names of the those that made the referral, where appropriate.
- When telephone contact was used, a script very similar to the email was employed.
- The process was repeated for members of the working population but did not exceed more than two emails or two telephone calls depending on the contact information provided.

Step 3: Setting up interview dates and times

- Surveys were planned during the working hours of the respondents, based on where they were located.
- For dates that were scheduled more than one week in advance, a confirmation email was sent before the interview.

Step 4: Conducting the survey

- Surveys were administered via telephone except where the respondent requested

the survey to be sent through email. Interviews included:

- Introduction of researcher
- Purpose of the research
- Assurance that the research was not meant to make any organization look bad to alleviate any potential concerns

- Telephone conversations were recorded with participant consent using an Olympus WS-700M Digital Voice Recorder and an Olympus TP-7 Telephone pick-up for note taking purposes only
- Interviews were approximately 45 minutes to 1 hour in length

Step 5: Transcription of interview

- Recordings were used to transcribe the summary of the interviews
- Recordings were destroyed following transcription

For each state, the agency that was identified as playing the larger role in complaint investigations was ideally surveyed first. This agency was mainly the oil and gas regulator, as opposed to the health and environmental regulators.

The process was repeated until a representative sample from each state was surveyed, or information collected became repetitious, based on the judgement of the researcher (Biernacki & Waldorf, 1981).

CHAPTER 4 – RESULTS

The results of the surveys from all four States are summarized in this the following sections. The summaries are organized by each State and then by topic discussed in the interviews, as per the final version of the survey template. The Chapter ends with a brief overview of the current situation in Alberta.

For each survey that was completed, detailed responses can be found in the following Appendices:

- Appendix B – North Dakota
- Appendix E – Colorado
- Appendix F – Texas
- Appendix G – Pennsylvania

The results for each State also include information from the relevant agency websites and also from documents that were discussed and referenced during the interviews.

4.1 North Dakota

The results for the State of North Dakota include the responses from the North Dakota Department of Health (NDDOH), as this was the agency that was of main interest, as they investigate all health and environmental complaints.

4.1.1 Respondents

To find respondents from the NDDOH, the Department's website was searched. The State Health Officer was contacted via email and responded to verify that two potential survey participants would be appropriate to contact (T. Dwelle, personal communication, 2014). These two individuals were contacted, and interviews were arranged. A referral to a local health unit, but an interview could not be arranged. A summary of the survey participants is provided in Table 10.

Table 10: North Dakota Survey Participants

Appendix	Title	Organization
B1	Manager, Air Quality Division, Permitting and Compliance	Environmental Health Section, NDDOH
B2	Director, Water Quality Division	Environmental Health Section, NDDOH

4.1.2 Role in Oil and Gas

In general, the role of the NDDOH, Environmental Health (EH) Section, is to implement EH laws that pertain to air, water, and land. Concerning oil and gas, the Department's role is the same but with some restrictions. For water, if the issue or concern occurs within the boundaries of the oil and gas development, the NDIC has jurisdiction. If the issue occurs beyond the boundary of a development, then the NDDOH has jurisdiction. For air, issues and concerns are in the jurisdiction of NDDOH because emissions cannot be held within the development boundary. Here, the NDDOH regulates the emissions, even though they are on-site. The Department is not directly involved in responding to emergencies or reviewing emergency response plans related to oil and gas, but they do act as a science tool that first responders can engage if needed. The main responder to oil and gas emergencies is the NDIC.

For EIAs, the NDDOH is typically not involved, as individual wells are seen as a minor source of air impacts. However, they can be called upon to develop, review or comment on Environmental Impact Statements (EIS). Similarly, for HHRAs, the EH Section is not directly involved, but they do work with other sections that have HHRA specialists, and if they need further help on complex issues, they can call upon the State Epidemiologist and State CDC. The Air Quality Division registers oil and gas wells and permits tank batteries, compressor stations, and other oil and gas production related facilities, a process that allows estimation of emissions through modeling or measuring air impacts. Based on these assessments, the estimations or direct measurements are then compared to other studies, reports, and legislation. In other words, they have very little to do with exposure assessments and focus on doing comparisons air quality values to health standards that have already incorporated a risk assessment.

Lastly, the NDDOH's role in oil and gas legislation was discussed. As the NDDOH is in the purview of the government, they can submit proposed legislation. The Water Quality Division also reviews and develops water quality standards, whereas the Air Quality Division uses the Clean Air Standards from the USEPA. The one exception to this is for hydrogen sulfide, which the USEPA does not have a standard for. As a result, NDDOH has a specific hydrogen sulfide standard.

4.1.3 Types and Nature of Complaints

The NDDOH does not have a report that summarized the types and nature of complaints related to oil and gas. The respondents indicated that the types of complaints that are received are widely ranged and unique. They do not distinguish complaints by type of oil and gas development (i.e. unconventional versus conventional). The Water Quality Division responds to water and soil complaints, such as spills

and releases that impact private property. The Air Quality Division responds to general air contamination complaints, such as odours and dust. Complaints about traffic, noise, and lights are not investigated by the NDDOH. Neither the Air nor Water Quality Divisions spoke about general health complaints being an area that was of much concern as they were noted to be the minority of the complaints that are received.

4.1.4 Investigation Response Approach

The approach of the NDDOH to investigate complaints related to oil and gas does not differ from their approach to investigating any other public health complaint; all complaints are investigated, even anonymous ones, with the goal of finding issues and resolving them without any pre-determined ideas. There is a high priority put on complaint investigations, and it is acknowledged that often a multimedia approach is needed, along with consideration of the medical side of the issue.

The main agencies that the NDDOH collaborates with are the NDIC, State Water Commission, and the oil and gas companies. Complex complaints usually involve a concerted effort by all parties to plan a comprehensive investigation.

North Dakota has several ambient environmental monitoring networks. There is a surface water program that identifies sites and samples at a frequency based on risk. The groundwater program has recently expanded in western North Dakota where UOGD has increased, and concern over point and non-point sources of pollution has also increased. There was also a shallow well sampling program to identify GUDI wells. For air quality, the Department owns and operates a network of eight ambient air quality monitoring sites stationed throughout the state (NDDOH, 2014). In addition to the ambient air quality monitoring sites operated by the Department, the owners of certain industrial sources of air emissions also operate air quality monitoring sites within their immediate spheres of influence. The site locations selected are based on computer dispersion modeling and prevailing wind directions. Although these networks are necessary for understanding possible water and air impacts from both human and natural sources, the ambient monitoring data is not very useful for investigating complaints. The data from the air monitoring network is constantly being assessed, and North Dakota has consistently met the National Ambient Air Quality Standards (NAAQS). If a widespread issue were to occur, the department would likely already know about it before any complaint came in.

For water sampling, North Dakota has a state lab with water chemistry and biological capabilities, which is part of the EH Section. Air sampling requires more tools and equipment; apart from the ambient

monitoring stations, the air quality program has additional monitoring equipment like mobile, relatively simple handheld tools. These additional tools can be used right on top of a source, in a house, or outside of a house. There is an increasing number of mobile truck mounted monitoring systems but the NDDOH currently does not have access to any of these systems.

4.1.5 Examples of Investigations

Two examples of successful investigations were given by the NDDOH. For the Air Quality Division, the successful investigation example had to do with the ability to investigate a complaint by using resources that are already in the field (either NDDOH employees or the oil and gas companies themselves). The Water Quality Division gave an example regarding possible contamination of a water well following UOGD. The investigation did not find contamination related UOGD, but it did find a deficiency in the structure of the well, coupled with rain and heavy equipment that could have created a situation where the well was susceptible to contamination.

Although no example of an unsuccessful investigation was given by the Air Quality Division, factors that could impede an investigation's success were discussed and are included in Table 11. The Water Quality Division gave a general example of a health complaint that was received, but even after a thorough investigation involving the HHRA team and physicians, no source could be identified.

For both the successful and unsuccessful investigations, summaries of the possible reasons leading to each investigation outcome are summarized in Table 11.

Some of the challenges raised by the NDDOH included lack of reporting findings from investigations when complaints are settled between an oil company and the complainant, as well as the inability to share or publish data from private wells. Finding definitive causes of reported health symptoms was also noted as a challenge, as was risk communication to the public of what an acceptable level of risk means and how that translates into actions taken by the regulator or health agency. Risk communication is also complicated by the unknown health effects of chemical mixtures. Here, the public often thinks the cause and effect relationships are direct, but the negative impacts are often only discussed and not the possible hormetic effects.

Concerns were also raised about the EH Section of the North Dakota government being encompassed within the NDDOH. The disadvantage of having EH as part of the Health Department is that the EH

section is focused on the environment is comprised of scientists and engineers, not doctors nor nurses that can do health and medical assessments.

Table 11: Summary of Reasons Leading to Successful and Unsuccessful Investigations in North Dakota

Successful Investigations	Unsuccessful Investigations
- Good working relationship with industry to help solve problems together promptly with two-way communication. - Established policies to guide investigations and assessments with flexibility. - Visual issues (smoky flare) can be resolved quickly through photographs. - Available field staff to start an investigation in a timely manner. - Capacity to investigate beyond sampling, such as the possible physical issues like well integrity/damage. - Capacity to assess indoor air quality (IAQ) as part of a complaint investigation.	- Vague complaints or those that come from second-hand information. - Lack of cooperation from complainants, such as gaining access to private homes for IAQ investigations. - Lack of health guidelines for a large number of potential chemicals. - Existing poor groundwater quality (high in sulfates). - Shallow gas deposits which can result in methane in groundwater.

In general, concerns about specific environmental contamination have been validated by complaint investigations. The State Water Commission has documented impacts from surface activities where localized groundwater contamination occurred, but they have not seen direct contamination of drinking water supplies. On the other hand, general health complaints, like UOGD causing asthma or cancer, have not been validated but the NDDOH recognizes that just because no association has been found, it does not mean that adverse effects are not being seen at the community level.

4.2 Colorado

The two main agencies identified as playing a role in complaint investigations in Colorado were the Colorado Oil and Gas Conservation Commission (COGCC) and the Colorado Department of Public Health and Environment (CDPHE). The results of the interviews have been summarized in this Section.

4.2.1 Respondents

To enlist respondents from Colorado, the CDPHE website was searched, and the first email was sent to a representative of the inspections and enforcement division, but no response was received in return

(J. Mattox, personal communication, 2014). Next, an email was sent to a representative of the Air Pollution Control Division who responded by indicating that he would look into who would be best from his Department to respond to the survey (M. McMillan, personal communication, 2014). A few months later, a referral to M. Van Dyke was made (M. McMillan, personal communication, 2015) and an interview was scheduled (M. Van Dyke, personal communication, 2015). An email was also sent to a general CDPHE email that belonged to the Water Quality Control Commission, who then forwarded the request for survey participation and an interview was scheduled (D. Kurz, personal communication, 2015).

The COGCC was contacted through a search of the agency's website, and an interview was arranged (D. Kulmann, personal communication, 2015). Following the advice from the CDPHE, the COGCC was contacted and an interview was arranged before the CDPHE interviews were held (D. Kulmann, personal communication, 2015). Table 12 summarizes the survey participants from Colorado.

Table 12: Colorado Survey Participants

Appendix	Title	Organization
E1	Deputy Director	Department of Natural Resources, COGCC
E2	Lead Wastewater Engineer	CDPHE, Water Quality Control Division
E3	Chief, Environmental Epidemiology, Occupational Health, and Toxicology Section	CDPHE, Air Pollution Control Division

4.2.2 Role in Oil and Gas

The COGCC oversees the responsible development of Colorado's oil and gas natural resources in a manner consistent with the protection of public health, safety, and welfare, including the prevention and mitigation of adverse environmental impacts (COGCC, 2016a). The CDPHE is comprised of several different divisions, many of which are involved at some level with oil and gas complaints (CDPHE, 2015a). Within the Department, the health and regulatory sections are split in that they focus on different areas, but they do work together. One of the main roles of the CDPHE is to take in and coordinate investigations of oil and gas related public health complaints, which often involve both the health and regulatory sections (COGCC, 2016c). Table 13 summarizes the role that each agency plays with respect to oil and gas development in Colorado.

4.2.3 Types and Nature of Complaints

Complaints are received by the State government by phone using a toll-free number managed by the CDPHE's Emergency Preparedness Division. Here, the complaints are triaged to discern what the issue is and then emailed to all departments that may be affected, including COGCC. There is currently no report that summarizes the complaints received by the State of Colorado; there are internal statistics, but the data is not up to publication standards. As such, the types and nature of the complaints received by both the CDPHE and COGCC, based on the knowledge of the survey participants and some internal statistics, have been summarized in Table 14. It should be noted that this summary is not specific to unconventional oil and gas complaints, as the statistics at the time of the survey did not differentiate to this level.

4.2.4 Investigation Response Approach

Both the COGCC and CDPHE investigate all regulatory complaints to ensure compliance with regulations, with the exception of complaints that simply express concern about oil and gas developments but do not specifically have a concern about the environment or health impacts. The COGCC implemented a new complaint process on January 9, 2015. It is possible to go on their website to file a complaint, look up types of complaints and actions taken (COGCC, 2016c). For health complaints investigated by the CDPHE, there is always contact made with the complainant, but a full investigation is not necessarily always conducted.

Non-specific concerns are investigated in the same manner as environmental and health complaints. The new complaint process will help bring more transparency to oil and gas investigations, which will help with the perception of oil and gas industry by a public body that is very active, being both in favor and against oil and gas industry. Another aspect that helps with public perception issues is that the COGCC has developed public documents that explain, in plain language, unfounded concerns about oil and gas development and unconventional oil and gas. An example is the document produced about some of the errors made in *Gasland* documentary (Ritter, 2010).

Table 13: Summary of the Roles and Responsibilities of COGCC and CDPHE in Oil and Gas Development in Colorado

Role in Oil and Gas	COGCC	CDPHE
Regulate and Permit	- Main regulator of the extraction of oil and gas - Permits oil and gas operations, including drilling of new wells - Environmental group investigates spills and reviews remediation plans. - Conducts inspections to ensure compliance with oil and gas regulations	- Under the Water Quality Control Act, the CDPHE has authority to regulate anything related to water. However, there is a patchwork of other departments that also regulate water, mainly the Department of Natural Resources that contain the COGCC and the Division of Reclamation, Mining and Safety. From CDPHE (2015b): - Air Division: Administers air emissions requirements. - Water Division: Issues stormwater discharge permits. - Solid and Hazardous Waste Division: Administers solid and hazardous waste requirements.
Emergency Preparedness	- Recently developed an ERP on how the COGCC responds to emergencies, like the 2013 flood near Denver, that impact oil and gas operations. - The plan outlines how the COGCC coordinates with first responders like State Emergency Officials and Local Governments.	- CDPHE has a Division of Emergency Preparedness and Response on the environmental side. - CDPHE does not have first responders; their role is to find out the details of the emergency and to notify the appropriate people and agencies.

Table 13: Summary of the Roles and Responsibilities of COGCC and CDPHE in Oil and Gas Development in Colorado (cont.)

Role in Oil and Gas	COGCC	CDPHE
HHRA	- HHRAs are not typically done by COGCC. - CDPHE have done about 3 HHRAs - An oil and gas task force was appointed by the Governor to develop recommendations on how to improve regulations in Colorado. One of the recommendations was to come up with health studies related to oil and gas. The majority of this work would be done by CDPHE (Keystone Center, 2015). - Another recommendation was to make a health complaint phone line related to oil and gas. It is expected that implementation will begin in the next couple of months (Keystone Center, 2015).	
Legislation review and development	- COGCC plays a large role in the legislation review process. - There was a recent increase in the penalties and fines for violations of the oil and gas rules, which involved changes to legislation and the COGCC helped draft these changes.	- Regulatory side of CDPHE is involved in legislation development and review. - Health side of CDPHE is not directly involved but have provided technical advice/data from HHRAs that has been used to inform legislation

Table 14: Summary of the Types and Nature of Complaints Investigated by COGCC and CDPHE

Types of Complaints	COGCC	CDPHE
Air	- In 2013, air complaints topped the list. - In 2014, air complaints were second after noise. They made up 11.5% of all complaints. - In 2015, 7% of complaints received between January 1 and March 5, 2015. - Nature of the complaints: odours and visual concerns (see flare/flame).	- All complaints (except for one related to air) received by the Health section have been related to air and health. When the regulatory side does their investigation and health concerns remain, the complaint gets passed onto the health section.
Water	- One complaint received between January 1 and March 5, 2015, that was related to a drinking water well issue.	- Two program areas: Surface water and Drinking water - For drinking water, the CDPHE only regulates public drinking water systems, not private systems. - Nature of complaints: water is dirty, smells, aesthetic issues, secondary treatment issues, water line breaks, loss of pressure to drinking water system.
Land	- Concerns related to land fall within the jurisdiction of the Solid and Hazardous Waste Division. - When these agencies are involved, it mainly has to do with spills on land.	
Traffic	- Neither agency commented on traffic complaints.	

Table 14: Summary of the Types and Nature of Complaints Investigated by COGCC and CDPHE (cont.)

Types of Complaints	COGCC	CDPHE
Noise	- Consistently one of the most frequent complaints received. - Seeing more complaints as oil and gas developments are getting closer to residential areas. - In 2013, noise was the second most received complaint after air concerns. - In 2014, noise was the 33% of all complaints - In 2015, 46% of complaints between January 1 and March 5 were related to noise.	- No response
Lights	- Light complaints were not a category in the older complaint system. - 10% of total complaints received between January 1 and March 5, 2015, were related to lights.	- No response
General health complaints	- There is very little information available on general health complaints from both the COGCC and CDPHE because these types of complaints were previously classified under the potential source of the issue, like air, water, etc. - New complaint system now has a Health and Safety category - In 2015, all complaints have been specific to the environment and not general health/safety complaints - Examples of these types of complaints are nose bleeds, asthma, generally not feeling well.	

Regarding who investigates complaints, the law has defined the roles, responsibilities, and authority for each department within the State of Colorado. Almost all complaints related to oil and gas become multi-agency; the CDPHE and COGCC rely on each other for help in many ways. An example of how the CDPHE and COGCC work together is when a tank overflowed and spilled produced water into a dry gully. Here, the COGCC took the lead on the investigation and clean-up, but the CDPHE Water Quality Control Division observed to see if downstream water users may be affected. The majority of complaints start at the COGCC, and when there is a need for further expertise, they engage the appropriate agencies. For example, all air and odour complaints get referred to the CDPHE because they have the most expertise, especially in interpreting air sampling results. Local health agencies at the County or city level are also called upon to collaborate, as they know the local situation and context and have resources dedicated to oil and gas. The oil and gas companies themselves can also be called upon to help with complaints. However, they usually play a passive role, like providing data or information about a specific oil and gas development to the COGCC or CDPHE.

State regulators have the scientific expertise to conduct investigations, but they do not have a lot of resources to contribute. For water and land, there is an expectation that the company who is at fault for spills or other incidents remediate the issue and this is usually done through third party consultants. The role of the State agencies would then be to review the actions and any reports from the oil and gas company and to communicate and provide information to address public concerns. If there was a large incident where a responsible party could not be identified and/or the incident covered too many jurisdictions (e.g. crossed state lines), then the federal regulator (USEPA) may get involved as they can hire contractors to do any clean-up, and they can legally pursue people to make them financially responsible. For health complaints related to air, sometimes air monitoring is involved by the CDPHE, but this would be the exception. Air monitoring is very resource intensive, and there are many limitations to collecting samples and interpreting results. With that said, some tools and equipment were identified as being very helpful to complaint investigations. These tools, along with their function, have been summarized in Table 15.

Table 15: Summary of Equipment Used for Oil and Gas Complaint Investigations in Colorado

Equipment/Tools	Function
FLIR camera	- The most powerful tool for initial investigations of air complaints on the regulatory end. They can determine if VOCs are being emitted from flares/other devices. - COGCC owns 5 and CDPHE has more.
Noise survey equipment	- Critical device as noise complaints are number one in term of frequency. - Allow for real-time monitoring over a specified period. - COGCC owns five noise metres.
Ambient air monitoring networks	- Only measure four criteria pollutants. - Some areas of the State have an enhanced monitoring program (Garfield County). - Neither are the most helpful to detect more specific, local concerns unless there is a huge spike. - Can be used to address community concerns, but these are not the norm.

4.2.5 Examples of Investigations

All three survey participants gave an example of a successful investigation or what would be an ideal investigation for their department. The COGCC described a noise concern at a residence that was experiencing night and day noise from a distant oil and gas facility in 2015. To investigate, one noise metre was placed 25 feet from the residence, and another was placed half way between the house and the development. The metres were the same brand and were calibrated and run at the same time. The results were that the average noise levels measured at the residence exceeded the noise levels as outlined in the oil and gas rules and were greater than the readings measured closer to the facility, which did not exceed the noise rules. A site investigation showed that there were many other closer noise sources that were likely contributing to the high noise levels, such as a nearby gravel pit and interstate, as well as new home construction in the neighborhood.

The CDPHE used an example where exploration and production materials were going to a purification plant where all lines entering the building were regulated by the COGCC. The finished product exited the building via a CDPHE regulated pipeline that went under a stream to an outlet that connected to trucks for transport. Through the spill reporting line, it was determined that oil was present in the

stream that crossed over the outlet pipe. The COGCC took the lead in the investigation because they had staff on-site, even though CDPHE had jurisdiction. A general example of a successful investigation from a health perspective was given by the CDPHE. The best outcome or goal for a health investigation is that following a complaint, a potential source is identified and subsequently modified by the operator and the complainant no longer has health symptoms. Another example of a successful investigation is when the CDPHE provides the resident with all of the appropriate health and risk information based on measured exposures ifor them to make their own personal health decisions.

Next, examples of unsuccessful investigations were discussed. The COGCC gave an example of a noise, lighting, and dust concern that was received before the new complaint process was implemented. When the inspection was arranged, there was miscommunication over the township, so the initial investigation was conducted in the wrong location, and since there were no remarkable findings, the file was closed. When the mistake was realized, and the area of concern was confirmed and investigated, there was nothing found as drilling was completed. It is now the process to confirm location with complainant before starting an on-site investigation. Another example was given by the CDPHE from training in a different state. Here, oil spilled into a creek and investigators started to follow back to determine source and cause. Following calls made to a particular oil and gas operator, the entity kept denying being at fault and would not cooperate with the investigation but it ended up that they were responsible for the incident.

For both the successful and unsuccessful investigations, summaries of the possible reasons leading to each investigation outcome are summarized in Table 16.

In the past, there was no established process to follow up with complaints, which may have contributed to the loss of credibility of State agencies. The new process implemented in early 2015 requires formal communication to be sent to the complainant following an investigation. Results are communicated back to complainants to give them as much information for them to make decisions about their health. Acceptable communication includes formal reports, summary letters, inspection reports, etc., sent by email or regular mail. If an issue, like an oil spill affecting a drinking water source, can potentially impact a larger community, then the CDPHE has a responsibility to communicate to all those that may be adversely impacted, not just the complainant. With the new complaint system, some of this information will be publically available.

Table 16: Summary of Reasons Leading to Successful and Unsuccessful Investigations in Colorado

Successful Investigations	Unsuccessful Investigations
- Clear roles and responsibilities. - Appropriate equipment and resources to conduct a thorough investigation. - Cooperation of complainant to set up monitoring equipment at residence. - Quick reporting thought emergency response line. - Close coordination of investigations between the two main regulators (COGCC and CDPHE).	- Alternative complaint process that bypasses the COGCC. - Lack of resources to fully investigate to the complainant's satisfaction. - Temporal and spatial nature of air quality - Lack of cooperation between oil and gas operators and investigative agencies.

Related to the factors that hindered investigations, some challenges were identified. These were mainly related to the investigation of health concerns and air quality impacts. These challenges stem from intermittent exposures, non-specific symptoms, sparsely populated communities and trying to identify rare outcomes.

Some of the needs that were identified to improve investigations included:

- Dedicated complaint person to receive, route, follow-up, close and send formal communication.
- More sophisticated tools for ease of use and more robust and consistent reporting capabilities.
- Sampling methods: need to determine the best time to take air samples, like peak samples as opposed to long-term average samples, as these appear to be the biggest health concern (short-term, high exposures).
- Address gaps in science (not specific to oil and gas): translation of an exposure to something meaningful; many chemicals do not have reference values, and the process of doing an HHRA that was historically based mainly on hazardous waste sites may not be the right process for oil and gas.
- Relationships with other States to work together on the difficult health risk assessments.
- Resources to be able to do more specific monitoring over longer periods of time to explore different locations.

4.3 Texas

The three main agencies responsible for complaint investigations related to UOGD in Texas are the Railway Commission of Texas (RRC), Texas Commission on Environmental Quality (TCEQ), and TXDSHS. The results from the surveys and relevant websites have been summarized in this Section.

4.3.1 Respondents

The search for survey participants in Texas started with emails sent to general information addresses at the TXSDHS, TCEQ, and RRC. An email response was received from the TCEQ following a telephone call, which stated that the Legislature was in session and resources were not available to participate in the survey (C. Gandee, personal communication, 2015a). A similar response was received from the RRC (G. Greever McElwain, personal communication, 2015). Both responses included web links to valuable information around each agency's role in oil and gas development, including complaint investigations. In September 2015, both agencies were contacted again, and the TCEQ agreed to participate in the survey (M. Honeycutt, personal communication, 2015; C. Gandee, personal communication, 2015b).

To find survey participants from the RRC, a professor who co-authored an air monitoring study in Texas was contacted and suggested to contact the TCEQ Regional Offices, as opposed to their central office (D. Sullivan, personal communication, 2015). Telephone calls were made to two offices located in the Barnett Shale, but survey participants could not be confirmed. To expand on the search for RRC survey participants, numerous other emails were sent to academic researchers from Texas that had published papers on the topic of unconventional oil and gas development (D. Burnett, personal communication, 2015; D. Rahm, personal communication, 2015; A. Rich, personal communication, 2015; B. Shaw, personal communication, 2015). None of the researchers that were contacted were able to provide potential RRC survey participant information.

No response was received from the TXSDHS from the initial email and phone calls made in December 2014. The City of Plano Environmental Health, a local public health organization that is located in an intense oil and gas development area, was contacted in September 2015. Through email, it was communicated that this organization is not involved in oil and gas (J. Dingman, personal communication, 2015). Further attempts to contact the TXDSHS in 2016 resulted in a phone conversation (T. Ellerbee, personal communication, 2016) and subsequent interview. There were no referrals to other potential survey participants provided at the end of the interviews. A summary of the survey participants from Texas is provided in Table 17.

Table 17: Texas Survey Participants

Appendix	Title	Organization
F1	Air Program Liaison	Office of Compliance and Enforcement, TCEQ
F2	Manager	Health Assessment & Consultation Program, TXSDHS

Although the RRC did not participate in the study, information from their website and some information given from the other study participants are included in the results Section.

4.3.2 Role in Oil and Gas

The oversight of oil and gas activities (exploration, production, and transportation) in Texas falls primarily under the jurisdiction of the RRC (RRC, 2015). The TCEQ is the environmental agency for Texas and works to ensure clean air, clean water, and the safe management of waste, which involves a role in oil and gas activities. An explanation of each agency's jurisdiction over various oil and gas activities is summarized by the TCEQ based on a Memorandum of Understanding (MOU) between the RRC and TCEQ (TCEQ, 2015a). The TXDSHS does not play a direct role in oil and gas, but has been involved in investigations and reporting, which is further explained in Section 4.3.3. A summary of the specific roles of the TCEQ and RRC has been provided in Table 18.

4.3.3 Types and Nature of Complaints

Complaints to the TCEQ are received via phone, email or an online form (TCEQ, 2015b). The public is given all of the needed information for filing a complaint via the TCEQ's website, including, but not limited to, what is needed to submit a complaint with and without information and evidence and how to preserve information and evidence. Complaints to the RRC are submitted to district offices (RRC, 2016b). Both websites offer information about each agency's role in conducting complaint investigations, including links to one another's sites. The TXDSHS receives complaints via phone call or email and typically gets involved in investigations when there is the potential for a larger community exposure, not individual complaints. A summary of the types and nature of complaints received by each agency has been provided in Table 19.

The TCEQ noted that in some areas of Texas with a long history of oil and gas development, complaint numbers are low, likely because people who have resided there for a long time have become accustomed to the activities and are likely familiar with the complaint processes and who needs to be

contacted. In areas where oil and gas operations are new, residents are more likely to have concerns, resulting in increased complaints.

4.3.4 Investigation Response Approach

The TCEQ investigates all reportable incidents and complaints. Their legislation mandates a responsible party to report exceedances of reportable quantity thresholds within 24 hours, regardless of whether or not there was a complaint. Complaints are responded to in a prioritized manner, with some complaints receiving a very quick response (within one working day) when:

1. health effects are being alleged, or
2. a facility had a complaint confirmed (i.e. odour) within the last 12 months.

For the TXDSHS, all health complaints are investigated, but only two of their investigations have been specific to oil and gas. Therefore, the following Sections include information from responses by the TXDSHS about general complaints investigated by the Health Assessment & Consultation Program. When a complaint comes in, it is reviewed and further researched, if needed. The type of expertise required by each agency to conduct their respective investigations is summarized in Table 20.

For the areas with which the TCEQ has jurisdiction, parallel investigations are not conducted or collaborate in the actual investigative efforts unless it requires a large emergency response effort. For complaints that are not within the TCEQ's jurisdiction, they get referred to the appropriate agency.

The TXDSHS receives some complaints through referrals from the TCEQ, and they also collaborate with:

- USEPA
- OSHA when occupational exposures have occurred
- Local Universities
- Texas Department of Agriculture
- City and County Local Health Departments

Table 18: Summary of the Roles and Responsibilities of TCEQ and RRC in Oil and Gas Developments in Texas

Role in Oil and Gas	TCEQ	RRC
Regulate and Permit	- Issues air permits to set emission limits for oil and gas facilities. - Enforces air, waste, and water regulations and associated permitting. - All of the rules and regulations are geared towards protecting public health	- Main regulator of all activities associated with the exploration, production, and transportation of oil and gas activities (RRC, 2015) - Issues permits for exploration/drilling
Emergency Preparedness	- Has ERP staff at the agency. - For emergencies, they would collaborate with ERP staff to have an all hands on deck response.	- Responds to emergencies related to fires, leaks, spills, or pipeline failures.
HHRA	- TCEQ has a toxicology division that assesses health impacts. - Can conduct modeling for air contaminants in relation to receptors. Modeling results are assessed for health impacts by toxicology division. - Permitting process also involves modeling and review by the toxicology group to assess health impacts.	- It is unknown if the RRC is involved with HHRAs.
Legislation review and development	- TCEQ participates in the process of legislation review and development. - Agency determines if a Bill will have an impact to the TCEQ. If there is an impact, the Bill is analyzed and they present analysis to the author of the Bill for consideration. - When reviewing, some considerations include: o Does Bill require more regulating and will this require more staff and a budget enhancement? o Will laws conflict?	- As the RRC is a regulatory body, they play a very large role in legislation development for the oil and gas industry. - Have numerous Rules available on the website that cover all areas related to oil and gas exploration, drilling, production and transportation (RRC, 2016a).

Table 19: Summary of the Types and Nature of Complaints Investigated by TCEQ, RRC and TXSDHS

Types of Complaint	Responsible Agency	Nature of Complaints
Air	TCEQ	- Odour (1) and Dust (2) are the most common complaints received by the TCEQ. However, it is difficult to separate complaints of oil and gas sources from other industrial sources. - In the Barnett Shale region, air quality complaints are number 1 - Between September 2014 and August 2015, about 1/5 of air complaints in the Barnett Shale were related to oil and gas - The peak of air complaints related to oil and gas (was between 2010 and 2011, but are now seeing a downward trend after focusing on this area with a specialized team they were able to ramp up compliance and enforcement activities.
Water	TCEQ	- Suspected contamination of drinking water from a public system. - Water rights issues or unauthorized discharge of wastewater and are related to oil and gas activities but not a direct result of the explicit operations.
	RRC	- Suspected contamination of drinking water from a private system from oil and gas
Land	TCEQ	- TCEQ is the lead on hazardous substance, refined petroleum products, and abandoned containers.
	RRC	- RRC has jurisdiction over spills associated with exploration, development, and production.
Traffic, Noise, Lights	Local Law Enforcement	- Noise, traffic and other nuisance related issues are governed by local ordinances.
General Health Complaints	TCEQ	- Health complaints come second to air complaints (odour and dust). - Reported symptoms include headaches, eye irritation, sinus pain.
	TXDSHS	- Health Assessment & Consultation Program has only been involved in 1 or 2 exposure investigations related to oil and gas. Not a lot of complaints because they go to other agencies first (TCEQ, RRC), depending on what the concerns is. - The TXDSHS receives a wide variety of general health complaints but statistics and information are only kept about notifiable diseases. - Cancer cluster investigations are usually a result of concerned citizens who feels like there are too many cancer cases in community and reports concern. TXDSHS can then do an epidemiological investigation.

Table 20: Summary of the Expertise Required to Investigate Oil and Gas Complaints in Texas

TCEQ	TXDSHS
- Degree in natural or physical science, engineering, environmental studies - One year of full-time experience in the field of environmental activities directly related to the examples of work performed may be substituted for each year (30 semester hours) of the required education.	- Biology - Regulatory Public Health Investigation Experience - Environmental health - Toxicology - Epidemiology - Medical doctors

An interagency collaboration that was identified as being beneficial to the overall operation of Texas State agencies was the Toxic Substances Coordinating Committee. This Committee, which is comprised of representatives from TXDSHS, TCEQ, Department of Agriculture, RRC, Department of Public Safety, Parks and Wildlife, works together to coordinate regulation development, risk assessments, cooperative studies, information dissemination, and public education efforts about toxic substances and harmful agents (Government of Texas, 2014). They meet quarterly to discuss their work and any issues they have encountered, as well as what each agency's roles and responsibilities are for the different issues, including health and oil and gas files. The meetings have been very helpful to facilitate building the necessary relationships to openly discuss concerns and figure out best management practices.

The TCEQ utilizes their ambient air monitoring network data to try to narrow down any potential sources that are causing public concern when a specific time and date can be given. The network is also used to look for trends (i.e. elevated readings during a certain time of day) and give background air quality information, which can help to focus when a complaint investigation may want to be conducted.

Other equipment and tools used by the TCEQ to investigate air quality complaints, along with their function, have been provided in Table 21.

Table 21: Summary of Equipment Used for Oil and Gas Complaint Investigations in Texas

Equipment/Tools	Function
Optical/infrared gas imaging camera TVA (toxic vapor analyzer) RAE and Jerome	- Imaging Camera and TVA are very useful for imaging VOCs - RAE and Jerome are used to image/detect H_2S - These instruments are all owned by the TCEQ and are used to narrow down where a plume is.
Summa Canister	- Used to take a sample of plume, which goes to a lab for analysis.
Mobile monitoring unit	- TCEQ owns a monitoring division that can respond with mobile monitoring unit – bus is equipped with all sorts of equipment, have ambient air monitoring equipment (gas chromatograph) and investigative equipment at their disposal.
Labs	- Depending on the required analysis, different labs are utilized. - State Lab and Federal CDC Lab. - Private labs have been used on occasion. - Analyze environmental samples. - Analyze blood samples.

Equipment or samples are not typically utilized by the TCEQ when they investigate water concerns. This is because most of the issues, like wastewater discharge, can be observed and photographed and/or the entity has admitted to the practice. The TXDSHS does not typically collect many environmental samples, apart from some drinking water samples. They have contracted out work to a local university that had the equipment and expertise to do indoor air, ambient air and soil gas sampling for a complaint investigation.

Both the TCEQ and TXDSHS respond to non-specific concerns in the same manner as they would respond to any other issue. The TCEQ responds to all alleged health impacts within one day and investigations are continued until the agency is satisfied that there is not a risk by using all of their tools, resources and knowledge.

4.3.5 Examples of Investigations

For an illustration of a successful investigation, the TCEQ gave a general example of an alleged odour complaint being worse at night. For this type of investigation to be successful, it was noted that timing the investigation for non-routine business hours would be important. To identify the emission source(s), an investigator may take one or all of the following actions: conduct a night investigation; utilize air sampling equipment; conduct an odour survey of the area; and conduct an on-site survey. Either during

or following the investigation, company personnel would be informed of findings so that repairs could be made. Sample results could be used to assess impacts to public health and the environment, and determine the proper level of enforcement.

The TXDSHS gave an example of the DISH, Texas biomonitoring study that was briefly reviewed in Section 2.3.7.c. In this study, blood and urine samples were taken from 28 individuals, as a result of health concerns stemming from potential exposures to VOCs from nearby compressor stations (TXDSHS, 2010). This investigation was deemed successful because it was able to fill a data gap. Through the biomonitoring, and all of the associated available tools and resources, they were able to determine if an exposure was occurring, and if so, at what levels were a health concern.

Next, the TCEQ gave an example of an unsuccessful complaint being when a complainant has an allegation of a health concern from an oil and gas facility, like a malodour, and the TCEQ investigates but finds that the company is properly authorized and has proper controls in full compliance with the standards. These situations are challenging because the complainant can become very frustrated if they are feeling health impacts every day, making it difficult to provide good customer service to someone who is not satisfied with the outcome of an investigation. All that can be done at that point is to explain the procedures that were used and the conclusions of the investigation but they are not always satisfied.

In general, the TXDSHS has always been able to fill a data gap though their investigations of assessing exposure and potential health impacts. However, sometimes they are not given enough information by the complainant, like missing name and/or number, wrong number, making follow-up difficult. In these instances, every effort is made to confirm complaint details but sometimes the person cannot be reached. The reasons leading to all of the successful and unsuccessful investigations described above have been summarized in Table 22.

Table 22: Summary of Reasons Leading to Successful and Unsuccessful Investigations in Texas

Successful Investigations	Unsuccessful Investigations
- Clear roles and responsibilities. - Cooperation from the complainant to assist in the investigative process. - Appropriate timing of investigation (night vs. day). - Ability to quickly respond to health issues. - Appropriate equipment to do site assessment, take samples, analyze samples - Established procedure to assess odours. - Ability to enforce regulations and correct hazard. - Comprehensive complaint reporting system and clear intake process, like through website, email, and hotline. - Ability to contact oil company quickly. Owner, operator contact info must be posted on signage at facility. - Appropriate expertise available to review analytical results and make a health based determination. - Current reference information.	- Lack of health information, like pre-existing health conditions, other exposures, etc. to conduct a full assessment. - Anonymous complaints make complaint follow-up difficult. - Lack of complaint details (time, date, frequency, and duration of an issue) makes it difficult to isolate/locate a source. - Temporal and spatial variation of exposures from changes in weather and stages of development.

In general, both the TCEQ and TXDSHS indicated that they do not need anything in particular to help them respond better to concerns and complaints around oil and gas development in Texas. However, they both identified better communication and cooperation between all stakeholders as always being beneficial to identify and resolve concerns and complaints. The TXDSHS also identified the need for more studies and knowledge around sampling and results. In the past they have done investigations and received results for which there was no standard or guideline to compare them to, resulting in meaningless and/or difficult to interpret measurements.

For every investigation, a letter describing what actions were taken and what the findings were, along with a copy of the investigation report, is sent to the complainant at the conclusion of the investigation. Reporting helps in the risk communication process and is a benefit to both the complainant and the agency. Additionally, throughout the investigation, it is possible to track the status of a complaint through the TCEQ's online reporting system (TCEQ, 2015c). In addition, there is also an expectation that the field staff are in frequent communication with the complainant throughout the entire process, as long as it is not an anonymous complaint. Results of all investigations are also communicated back to the responsible company in order for them to focus their maintenance efforts. The TCEQ also reports on all of its activities, including complaint investigations through their biennial reports available on their public website (TCEQ, 2014).

The TXDSHS communicates all results back to the complainant via a letter with results and an explanation of the findings. For larger community concerns, a public meeting is typically held to present findings and answer any questions or concerns, with keeping in compliance with confidentiality laws. All documents that can be public record are posted on the website.

4.4 Pennsylvania

The two agencies responsible for complaint investigations related to UOGD are the Pennsylvania Department of Environmental Protection (PADEP) and the Pennsylvania Department of Health (PADOH).

4.4.1 Respondents

Finding survey participants from Pennsylvania began with a phone call to the PADEP. During the phone call, it was suggested to contact the PADEP through a general oil and gas email, which was done and resulted in a scheduled interview (J. Ryder, Personal communication, 2015). At the time of the interview, the respondent asked to have the survey sent via email instead of conducting a telephone

interview so that the most appropriate people within the Department could have an opportunity to provide input. The survey template was then modified to ensure the questions being asked were clear to someone besides the researcher in order to obtain the most appropriate information. The survey was sent via email and responses were received via email. After reviewing the responses, it was indicated that the Bureau of Air Quality investigates air complaints, not the Division of Oil and Gas. The PADEP's Bureau of Air Quality was subsequently contacted and an interview was arranged (S. Foster, personal communication, 2016). During this interview, the survey participant referred Section 3 of the questionnaire to a field inspector who specializes in oil and gas air quality. An interview with the air quality specialist was arranged via email (M. Beacker, personal communication, 2016).

Before scheduling an interview with the PADOH, it was the judgement of the researcher to first receive the initial responses from the PADEP. After the PADEP's responses were received, the PADOH was contacted and an interview was arranged via email (F. Ahmed, personal communication, 2016). A summary of the survey participants is provided in Table 23.

Table 23: Pennsylvania Survey Participants

Appendix	Title	Organization
G1	Bureau Director	Bureau of District Oil and Gas Operations, PADEP
G2	Acting Division Director & Health Assessment Section Chief	Bureau of Epidemiology, PADOH
G2	Epidemiology Research Associate	Bureau of Epidemiology, PADOH
G3	Chief, Division of Compliance & Enforcement	Bureau of Air Quality, PADEP
G4	Air Quality Specialist	Bureau of Air Quality, PADEP
G4	Supervisor	Bureau of Air Quality, PADEP

4.4.2 Role in Oil and Gas

The PADEP is the main regulator of oil and gas and the environment in Pennsylvania, whereas the PADOH is a health advisory agency, which gives advice on health related issues, including any related to oil and gas development. A summary of the roles and responsibilities of each agency have been summarized in Table 24.

4.4.3 Types and Nature of Complaints

Complaints are submitted through a form on the PADOH's website that allows submission of health complaints to the PADOH or environmental concerns to the PADEP. Both agencies also receive complaints via direct calls, emails, and written correspondence or from referrals from one another or other agencies. The PADOH Environmental Health website outlines how to report environmental concerns, including the types of complaints that go to each Department, and provides public information pertaining to oil and gas and health (PADOH, 2016). Complaints received by the PADEP are entered into a complaint tracking system (CTS) and subsequently managed by complaint coordinators in the six regions. The PADOH is looking to create a health registry based on their investigations that can potentially tie into the current PADEP's database. Although neither agency has published data on the types and nature of complaints, it is possible to pull complaint reports from the CTS upon request. The survey participant responses to the types and nature of complaints received by their Departments concerning oil and gas developments have been summarized in Table 25.

4.4.4 Investigation Response Approach

Both the PADEP and PADOH investigate all complaints in the areas they are each responsible for. The form and degree of response can be highly variable depending on the nature of the complaint and the facts associated with it. For non-specific concerns, an educational approach is taken, where the Departments provide the public with factual information that may be beneficial to the specific issue they are dealing with. There are guidelines that outline timeliness for responding to complaints. In general, it takes less than 24 hours to make contact with complainant to confirm that concerns have been received and to gather more information, when needed.

After complaints are received by the PADEP, a site visit is conducted to do a visual assessment (take photos, talk to facility operators, review record). Complaint investigations may result in violations and/or enforcement actions and penalties. The PADOH starts with conducting a detailed health intake and sometimes go into the field to speak directly people at their home. The length of each investigation varies depending on the nature of the concern. For water quality complaints, it takes about three weeks to a month to close a case, as the standard water test done by the PADEP takes three weeks to complete. The type of expertise indicated by each Department as being beneficial to investigating complaints is summarized in Table 26.

Table 24: Summary of the Roles and Responsibilities of COGCC and CDPHE in Oil and Gas Development in Pennsylvania

Role in Oil and Gas	PADEP	PADOH
Regulate and Permit	- The primary regulator of oil and gas operations. - Conduct widespread inspection, compliance, and enforcement actions for various development activities. - The Office of Oil and Gas Management permits various oil & gas development activities such as well pads, oil & gas wells, and pipeline infrastructure development. - Bureau of Air Quality permits oil and gas emissions for midstream activities.	- Do not have regulatory authority for any oil and gas operations.
Emergency Preparedness	- Active Emergency Response Program that coordinates the departmental response to each incident. - The Bureau of District Oil & Gas Operations does not actively engage in ER planning but they do have Oil & Gas Employees that are members of three regional emergency response teams. - Oil & gas operators must develop and submit ERPs for the operations they are conducting throughout Pennsylvania. - Permitting process also outlines what a company needs to do if an emergency, which is typically a notification to appropriate agency.	- Have had very few instances that have needed an emergency response. - If an emergency were to happen, PADOH would not be a first responder; that would be FEMA or other first responders. - PADOH gives experts opinion and advice on whether or not there are any health implications on people who live nearby based on data collected during emergencies.

Table 24: Summary of the Roles and Responsibilities of COGCC and CDPHE in Oil and Gas Development in Pennsylvania (cont.)

Role in Oil and Gas	PADEP	PADOH
EIA	- Environmental impacts of major contamination sources (potential or actual large emissions) are addressed in the permitting process, as many forms of environmental data and associated technical information are required for these various permits and authorizations. However, they are not referred to as EIAs.	- Not applicable to the PADOH.
HHRA	- Within the PADEP there is an air toxics and risk assessment group. But this is usually only utilized if there is a major air contamination source identified. - For complaint investigations, The PADOH is the main agency responsible for HHRAs.	- HHRAs are conducted when there is a known exposure to a chemical. - Data collection is typically done by the USEPA or PADEP. - PADOH then assesses whether there is a human health risk. The document that would be generated from this is called a "Health Consultation." - Communities have requested a health assessment prior to a potential environmental impact coming to the community. However, a request for a community health assessment for new well, like an unconventional gas development, has never been requested.
Legislation review and development	- Development of new regulations focusing on oil & gas development activities is one of the primary functions of the Central Office Bureau of Planning and Program Management. - The Bureau of Air Quality reviews Federal air quality regulations to determine if the program will be impacted.	- Legislation can be reviewed with a health lens through the Environmental Quality Board (EQB), which has representation from PADOH (Director, Bureau of Epidemiology) with voting rights. - The EQB meets on a monthly basis.

Table 25: Summary of the Types and Nature of Complaints Investigated by PADEP and PADOH

Types of Complaints	PADEP	PADOH
Air	- In 2015, 53 complaints were received about air quality and unconventional oil and gas development. The majority of these complaints were related to odours. - Air quality program also addresses road dust, fugitive dust and fugitive emissions (fugitive meaning anything not coming directly from a stack). - Community concerns (silica and diesel emissions) from a crystalline silica facility development near a daycare centre and baseball fields spawned a large ambient air study conducted by the PADEP (Bureau of Air Quality, 2016).	- The nature of air complaints has been changing; - In 2008/2009 there were a lot of air quality complaints (noxious odours) from flaring. - In 2012, flaring was no longer permitted except for in certain circumstances when the driller could get a waiver. - There have also been other technological advances that have reduced the need for flaring. It is far more desirable to capture natural gas emissions from an economical standpoint. - Now many complaints are related to odours from compressor stations. - Nature of complaints includes upper respiratory issues, eyes, nose and throat irritation, aggravation of asthma and emphysema.
Water	- The Bureau of District Oil & Gas Operations responds to water-related complaints that are related to oil & gas activity. - Get complaints and requests to investigate whether or not private water supplies have been impacted by oil and gas related activity. - The Department also investigates complaints related to surface water impacts where spills or releases have potentially entered waters of the Commonwealth.	- Water is the number one type of complaint investigated by the PADOH, followed by air complaints. - Biggest complaint is water quality, not quantity. - Can also be odours from the water from methane migration.

Table 25: Summary of the Types and Nature of Complaints Investigated by PADEP and PADOH (cont.)

Types of Complaints	PADEP	PADOH
Land	- Land issues and complaints are investigated by the Oil and Gas Division. - Many of these types of complaints are a result of storm water runoff from well sites or access roads or well site restoration issues.	- Rarely involved in complaints related to land.
Traffic	- Neither Department responds to traffic complaints; they are handled by the municipality or the Pennsylvania Department of Transportation.	
Noise	- PADEP does not have any regulations that specifically address noise. Local government entities usually have zoning or other ordinances to control for noise.	- Not involved in complaints related to noise.
Lights	- The Bureau of District Oil & Gas Operations rarely receives light related complaints.	- If a lighting complaint is received, it is usually in combination with other complaints like noise, odours, nuisance issues, etc.
General Health Complaints	- Refer health complaints to PADOH	- Skin issues, like rashes, are the primary complaint when there is a water concern, but also for air concerns. - Also receive complaints about headaches, nosebleeds, respiratory issues. - Have received blood tests from individuals concerned about oil and gas exposures.

Table 26: Summary of the Expertise Required to Investigate Oil and Gas Complaints in Pennsylvania

PADEP	PADOH
- Several years of oil and gas industry related experience - Environmental science degrees - Environmental engineering - Geology - Licensed professionals through the Commonwealth of Pennsylvania	- Toxicology - Epidemiology - Medical doctors - Public health - Mining engineering - Environmental health - Health education

The PADOH and PADEP often work very closely when complaints involve environmental health concerns. Table 27 summarizes the agencies that are called upon for complaint investigation collaboration, along with a description of when the agency may be involved in an investigation.

Pennsylvania has environmental monitoring networks for air quality (PADEP, 2015b) and water quality (PADEP, 2016). The purpose of the air quality monitoring network is to ensure areas are in compliance with the NAAQS. For complaint investigations, the data gathered through this network helps to inform where there may be trouble spots with complying with the Standards. However, the information is typically not specific enough to aid in individual contamination source complaints. Despite this, citizens have requested more ambient air monitoring but there haven't been any changes to legislation that would increase the reaches of the network. The water quality network is designed to assess both the quality of Pennsylvania's surface waters and the effectiveness of the water quality management program (PADEP, 2016). The use of this network to investigate complaints was not specifically mentioned by any of the survey participants but it has been used to monitor temporal surface water quality trends, which could include trends in oil and gas development areas.

Table 27: Complaint Investigation Interagency Collaboration Summary for PADEP and PADOH

PADEP	PADOH
Depending on the nature and severity of the incident, the PADEP may collaborate with a variety of agencies. The individual fact pattern associated with each investigation dictates what additional agencies may be involved. Some of these include: **Oil and Gas Companies** (responsible party): **Municipalities**: When field staff responds to noise-related complaints in a jurisdiction that has a noise ordinance in place, local code coordinate with local codes enforcement officers to address the issue. **Non-Governmental Organizations:** NACAA (National Association of Clean Air Agencies): Consolidates and communicates Federal regulation updates and changes to all states to keep them informed. Ozone Transport Region: Coordinate the way air programs are run and ensure the regulations are similar for similar facilities and pollutants so facilities aren't significantly subject to different requirements in different states. ECOS (Environmental Council of the States): Similar to NACAA; Committees made up of State representatives. MARAMA (Mid-Atlantic Regional Air Management Association): Collaborative organization made up of 8 states in the area who give air quality training. NESCOM (Northeast States for Coordinated Air Use Management): PADEP does not belong to this organization, but they participate with them on other levels.	**USEPA**: The USEPA is called upon to assist with investigations (testing and monitoring) when there is potential for a large population to be impacted and if there is really strong evidence of exposure. **County Health Departments** that are not affiliated with the State have helped to coordinate investigations but still rely on PADOH for their help to interpret any findings. **Universities**: PADOH collaborates with the Universities like the University of Pittsburg and Penn State. **CDPHE**: PADOH has monthly conference calls with CDPHE. They try to learn from each other, despite their organizational structures being vastly different. **Independent non-profit stakeholders**: These are groups that are geared towards the Marcellus Shale region and have shared information with the PADOH. One particular group is so well known that sometimes the public reports complaints to them first. From there, the group can point the person or group towards the right resources to help with concern. These groups sometimes do their own monitoring and projects, usually with the affiliation of the University. **CDC:** Summits are held where agencies from across the country come together to discuss investigations and other issues around oil and gas development.

Within the PADEP, there is a centrally located accredited laboratory facility that analyzes and processes all samples collected as part of an investigation. Apart from the main laboratory, there are also four mobile analytical laboratories (mobilabs) available to provide on-site environmental testing throughout Pennsylvania (PADEP, 2015a). The mobilabs have the capability to analyze air, water, soil, as well as other matrices for both organic and inorganic contaminants. The mobilabs are capable of quick turnaround times and are ready to respond to environmental emergencies around the clock (PADEP, 2015a). The only samples that the PADEP does not have the ability to analyze are isotopic gas samples, which are sometimes useful when trying to determine the potential source of methane contamination in water. However, a private lab in the State is available to do this analysis. Another piece of equipment useful for initial and follow-up air quality investigations is the FLIR camera. Each of the six PADEP regions owns one of these cameras.

The PADOH does not require any equipment for their involvement in complaint investigations. They rely on other governmental and outside agencies for data collection and subsequently provide health assessments based on the environmental findings. An example where the USEPA was involved in a complaint investigation involving air quality from a compressor station was discussed. Here, the USEPA was called upon because they have very sophisticated mobile monitoring equipment called an E-Van that can be set up for a period of time to analyze the air and monitor trends. Clinical laboratories provide blood analysis, usually as requested by a primary care physician in response to a potential harmful exposure, and the results of these analyses are often shared with the PADOH and used as part of their health assessment.

Following a complaint investigation, the results are always communicated back to the original complainant and to any agency that helped with the investigation. An official response letter is sent with recommendations and any resources that may be helpful for every complaint. There is also telephone communication throughout complaint. The public can also request information from complaint investigations through the State's Right to Know Laws but any personal information is redacted. There is some complaint information readily available on each agency's public website; The PADEP lists water supply complaint investigation letters and the PADOH posts their environmental health studies, like the silica monitoring project.

4.4.5 Examples of Investigations

Examples of successful complaint investigations that each Department played a role in were discussed. The PADEP gave an example related to fugitive dust created from traffic. The Bureau of Air Quality addresses these concerns by contacting both the township where problem is occurring and the oil and gas company. The two latter entities would then work together to ensure the dust was mitigated through whatever means was decided (sometimes calcium, paving, water). Confirmation that the issue is resolved is done through either follow-up with the complainant or an on-site inspection by the PADEP. If the issue gets resolved, the complaint investigation is deemed a success. Another investigation involving a malodour complaint in 2015 was given. Here, the Bureau of Air Quality coordinated with an oil and gas water quality specialist within the PADEP to conduct an on-site investigation. An odour, but not a malodour, which imparts a physical response prompting illness, was noted on-site. Through the investigation and follow-up with the oil and gas program, it was determined that flooding of the dehydrator with glycol, which caused glycol to burn off in the reboiler, resulted in a chemical smell in the ambient environment. As this was a onetime malfunction, they were able to communicate to the complainant what had happened and let them know it would not be an ongoing issue.

The PADOH also gave a couple of successful investigation examples. The first involved a person, who worked at a company that handled shale gas wastes but was not coming into direct contact with products, and was concerned about high barium levels in a blood sample. Prior to the complaint, the concerned individual had blood tested and provided results to the PADOH. Following a detailed health survey, the blood sample results were reviewed and barium levels were noted to be within acceptable limits. Next, the toxicologist communicated findings to the complainant and provided a fact sheet on barium from a study done in Pennsylvania. The complainant was then referred to OSHA and they are currently conducting an investigation.

The second example was from a drinking water complaint from parents with six children, ages 2-11, who lived in a pre-1978 farm home in the Marcellus shale region. Following an extensive health history, it was suggested that the children get their blood tested, as lead exposure from lead paint could have been another source leading to symptoms. The results were that three children had high lead levels in their blood. The drinking water was also tested and results were within acceptable health limits. Although the complaint was related to Marcellus shale and drinking water, the role of the PADOH is also to take care of other environmental risks that are identified.

Similarly, both Departments were asked to describe examples of complaint investigations that were not successful. The PADEP used malodours as a general example for unsuccessful complaints, as these investigations, whether related to oil and gas sources or not, present the greatest challenge. Resolution of a malodour complaint is difficult because their nature is very subjective and intermittent, making it very hard to pinpoint and rectify the source. The PADOH gave examples of a couple of different kinds of complaints that have been unsuccessful. The fist was a general situation that has been encountered where an activist group had called to make a complaint but they make it sound like it is coming from a private citizen. Distorted information from the complaint and investigation correspondence were subsequently put on the internet or shared with media, which can do damage to the trust in the government. Another example was given about the regulation of compressor stations. If one operator has three or more compressor stations within a localized area, they are required to do cumulative readings of emissions that combine all operations. However, if they only have one or two stations then they only need to do single readings from each station. This makes it difficult to get a true cumulative reading for areas with multiple operators and a high density of compressor stations.

Based on both types of examples of investigations, along with other responses given throughout the survey, summaries of the reasons leading to a successful or unsuccessful complaint investigation were compiled and are provided in Table 28.

All investigations are challenging in some respect. Managing the complaint process and the many forms of data that are collected, sometimes from multiple agencies, as part of an investigation require specialized skills and expertise. One of the needs identified by both the PADEP and PADOH is to develop better technology and database functionality to capture a wider range of data that is collected during complaint investigations. The PADOH would like to be able to build a health registry that could tie into the comprehensive system already developed by the PADOH so all complaints and issues could be managed in one location. This would improve surveillance, especially considering the untapped resources in the Marcellus shale and the possibility of development occurring for >40 more years. However, upgrading the current system and developing a health registry requires fiscal resources and possibly people to manage the systems. There is no lack of expertise within either Department to get this work accomplished. A larger budget and more staff would also aid in a quicker complaint response times.

Table 28: Summary of Reasons Leading to Successful and Unsuccessful Investigations in Pennsylvania

Successful Investigations	Unsuccessful Investigations
- Prompt response. - Technically accurate sample and field data collection methods. - Expert analysis of the entire body of collected data and associated field information. - Timely resolution of any documented impacts or violations. - 'Multiple lines of evidence' approach where many different forms of both field and laboratory data are compiled and analyzed to make a defensible and credible decision on the investigation. - Timely communication with all involved citizens regarding the status of the investigation. - Interagency collaboration with multiple stakeholders. - Clear of roles and responsibilities of each stakeholder in the investigation process. - Health-based or risk-based regulations. For example, regulations that require groundwater testing for wells within a certain distance to drinking water well (e.g. pre-drilling, drilling, and post-drilling water quality results from the drilling companies) that can be used as a comparison. - Comprehensive complaint tracking/documentation system. - A proactive approach to communicating the regulations and expectations during complaint investigations to oil and gas operators when development began in Pennsylvania.	- Remote locations of oil and gas sites can make it challenging to observe issue in a timely manner. - Intermittent exposure that can potentially cause a wide array of non-specific symptoms. - Temporal and spatial variation of noise, odour, and other air quality concerns - Non-feasible laboratory methods to conduct the most acceptable analysis of environmental samples (e.g. isotope testing for methane in water samples is very expensive).

The PADOH would also like to receive more environmental and biological samples to assist in health assessments. They currently get lots of water quality results, rarely get air quality results, once in a while will get soil results, and only a handful of blood results. They do not get as many blood samples as they would like because many people do not visit a physician when they have symptoms or their physician does not relate symptoms to potential environmental exposures and does not order a blood test.

Complaint investigations of non-specific concerns have been validated by investigations indicating that following up on these concerns is important and can produce important information. However, there are instances when this is not the case; sometimes sampling data is within acceptable ranges or when the sampling does match the reported symptoms it can be difficult to conclude an association with health the symptoms, as there are grey areas in the science. Therefore, to validate concerns, the PADOH would like to see the science to continue to improve, more testing where there are more signatures from contaminants.

4.5 Alberta

Although Alberta was not included in the formal survey process, it is beneficial to include a brief summary of the regulatory agencies' roles in oil and gas development and their complaint investigation approaches.

4.5.1 Role in Oil and Gas

As discussed in the introduction, there are four main agencies responsible for conducting complaint investigations related to oil and gas developments. The AER is the main regulator of oil and gas activities but is not a government agency. The AEP is a ministry within the GOA and plays both a regulatory and advisory role for environmental issues. The health agencies, AH (GOA agency) and AHS (operates at an arm's length from AH), play an advisory role in oil and gas operations but have regulatory authority under the *Public Health Act* to address health concerns.

The majority of the work around public health and oil and gas developments has been in relation to emergency preparedness. AHS reviews ERPs developed by oil and gas companies, participates in emergency simulation exercises, provides guidance on potential exposures to harmful substances and responds to health complaints or concerns following an incident (AHS, 2016). When energy

developments are required to conduct an EIA, the health agencies are invited to review the EIA based on a GOA guidance document (GOA, 2010).

4.5.2 Investigation Response Approach

In general, the AER and EAP respond to all public complaints related to operational or environmental concerns. To aid in the clarification of roles and responsibilities, the two entities have signed an MOU addressing the management of monitoring and reporting information (AER, 2016). This agreement has been established to ensure the continued collection of monitoring and reporting information, including data collected during complaint investigation, and the seamless continuation of data management practices during the regulatory transition. As part of the MOU, AEP will continue to provide support to industry on data submission processes and will continue to interact with industry on behalf of the AER for any additional inquiries specific to monitoring and reporting submissions covered by the MOU.

How the health agencies fit into the complaint investigation process is less clear than the relationship between AER and AEP. A very important multi-agency, cross-jurisdictional committee, the Technical Advisory Committee on Public Health and the Oil and Gas Industry (TACPHOGI), exists in Alberta with the goal of building coherency and alignment in public policy. This committee created a resource manual to assist EPH field staff in addressing and mitigating health concerns around oil and gas development, but focused on the risks associated with sour gas development (Jensen, 2015). This committee was re-established in 2014 and now has the opportunity to expand to include UOGD issues and concerns.

CHAPTER 5 – DISCUSSION

Chapter 5 includes a discussion of both the methodology used to conduct the case studies of North Dakota, Colorado, Pennsylvania and Texas (Section 5.1), as well as an analysis of the survey findings and how they relate to the research objectives (Section 5.2 to 5.5).

5.1 Research Methodology

Conducting case studies of experienced jurisdictions using survey methods proved effective to meet the objectives of this research. Despite no formal analysis of the findings through statistical methods, complaint management and investigation strategy themes appeared throughout the research. The sampling methods (Section 5.1.1), survey participants (Section 5.1.2), questionnaire (Section 5.1.3), and the quality of data collection (Section 5.1.4), all of which have the potential to affect the quality of the resulting survey data, are discussed below.

5.1.1 Sampling Methods

The methods used for obtaining a sample of survey participants from the selected states involved two approaches: purposive sampling and chain referral sampling. 7 out of the 13 survey participants were recruited using the purposive sampling method using information available on agency websites. In North Dakota, contacting an individual in a senior leadership position who referred the two survey participants used a top-down approach to finding participants. In Colorado, Texas, and Pennsylvania, the use of general department emails proved very useful to get the research information and interview request to the most appropriate people in a timely manner.

Chain referral sampling was used to recruit 6 out of the 13 survey participants. Originally, it was expected that sample participants in one jurisdiction, would also provide referrals in the other jurisdictions, but this did not occur; referral chains stayed within each State agency. Therefore, new contacts and referrals had to be initiated for each State, which wasn't difficult, as online contact information for each agency of interest was available. Another problem that must be addressed when using the chain referral sampling method is that of limiting the number of cases within any subgroup in the sample (Biernacki & Waldorf, 1981). The number of cases was limited by considering if there was any information missing and who else could add value to the information that had already been collected. The decision to continue or to stop was left up to the judgement of the researcher and was based on whether the sample was representative of the agency being studied and whether the data collected was being repeated. For example, the first CDPHE interview was with a Wastewater Engineer

in the Water Quality Control Division. Although many relevant answers were given about the regulatory environmental investigations, in the judgement of the researcher, it was necessary to recruit another CDPHE participant to comment on the health investigations. The answers given by the health representative were mainly novel but also provided some repetitive information given by both the COGCC and CDPHE participants, so it was decided to stop recruiting participants from Colorado after the second CDPHE interview.

5.1.2 Survey Participants

Participants from government agencies from four states were sought to provide facts and opinions about their agency's experiences with investigating complaints related to oil and gas development. All relevant agencies identified in Table 6 had at least one representative in the survey, except for the RRC and NDIC. However, the latter was not included in the research study. The response rate of survey participants was 87% (13 participants responded to 15 requests), which does not include the numerous screened units who were contacted to try to find members of the sample population (Fowler, 2009). To gain support from some of the agencies and participants, it often took a couple of emails, mainly as reminders of the initial request, before getting a commitment to participate. Striking the right balance between persistence and responsiveness to reluctant respondents led to a successful response rate.

To ensure the most appropriate participants were selected from each of the chosen agencies, a detailed description of the research objectives and sample questions were used in the screening process. The test to determine that the most appropriate participants were chosen was to assess their ability to answer all of the questions during the interview or find the answers through a different means. All survey participants were able to either answer all of the questions, provide answers from other colleagues at a later date (TCEQ and the Division of Oil and Gas, PADEP) or refer the researcher to someone who could give an answer (Bureau of Air Quality, PADEP).

5.1.3 Questionnaire

Although the questionnaire was reviewed by Alberta stakeholders and tested using North Dakota survey participants, there were some issues identified regarding clarity, but not acceptability or comprehensiveness. Lack of clarity resulted from poorly defined terms, like the use of the words successful and unsuccessful when asking about examples of complaint investigations. Many participants pointed out that a successful investigation to their agency is sometimes not considered a successful investigation by the complainant. The question was reworded to include what their agency, as opposed

to the complainant, would consider a success/unsuccessful investigation. Another issue identified was the use of double-barreled questions. In Section 2 of the survey, the first question asked, "who investigates and when?" which led to respondents answering when complaints were investigated, but not who investigates. At the time of the interviews, the interviewer did not notice the missing answers to the questions, and therefore, follow-up emails had to be written to ensure survey completeness. To overcome these clarity issues, the survey could have been tested on another jurisdiction or reviewed with a focus group.

The use of an open-ended question format was critical for getting information from specialists in a field that the researcher was less qualified in. This format allowed for each interview to be conducted more like a conversation, with flexibility to explain and clarify questions and plenty of questions and comments going back and forth, resulting in valuable qualitative input from each respondent. The only downfall of this format was that it resulted in each interview varying in length. On average, the interviews took between 40 to 60 minutes, except for the PADOH, which took 90 minutes, likely because there were two participants answering open-ended questions at the same time.

5.1.4 Information Collection

Telephone surveys were chosen as the main information collection mode, due to their low cost, rapid data collection, and ability to use open-ended and follow-up questions. The one exception to the telephone survey was an email survey that was created from the final survey template (Appendix D) at the request of the PADEP's Division of Oil and Gas. The request was made so that the respondent could use additional personnel from the PADEP to help answer the questions to the fullest extent possible. This survey was sent via email and responses were received via email in an attempt to minimize non-response from this agency. The answers that were received via email were reviewed to ensure they were comparable to the other answers received via telephone. They were found to be of a comparable nature but lacked some details that could have been included if there was the ability to ask follow-up questions.

With telephone interviews, it is possible to introduce bias in the interview process. Bias was minimized by not expressing any opinions on oil and gas development or making extraneous comments in reaction to statements made by the respondent.

5.2 Roles and Responsibilities in Oil and Gas Developments

According to the roles and responsibilities around oil and gas developments, the agencies that were surveyed were classified into three types:

1. Regulatory Agencies: COGCC, PADEP, RRC[2]
2. Advisory Agencies: PADOH, TXDSHS
3. Regulatory and Advisory Agencies: CDPHE, TCEQ, NDDOH

A discussion of the various roles and responsibilities of each type of agency is provided in this Section.

5.2.1 Regulating and Permitting

The regulatory agencies play the biggest role in regulating and permitting oil and gas operations, including exploration, drilling, production, and transportation. These agencies operate to protect the environment, public health, and public safety through inspection activities, compliance monitoring, and enforcement actions. The agencies that are considered both regulatory and advisory in nature regulate and permit the environmental factors associated with air emissions and water and waste discharges associated with oil and gas developments that the sole regulatory agencies do not oversee. It is worth noting that the CDPHE and NDDOH both noted that within their departments, the health or advisory component is a separate entity from the regulatory or environmental component, although they do collaborate when necessary. The advisory agencies do not have the authority to participate in the regulation or permitting of oil and gas developments.

5.2.2 Legislation Development and Review

The extent of each agency's role in regulating and permitting oil and gas activities feeds into their role in legislation development and review. Since the regulatory agencies, including those that are also advisory agencies, play a key role in regulating the oil and gas industry, they also help develop and review the applicable State legislation like Rules, Regulations, and Standards. They can also be involved in reviewing federal legislation that impacts the regulation of oil and gas at the State level, such as the *Clean Air Act*.

The advisory agencies can also play a role in legislation review, but typically not in the direct development of the laws. The PADOH reviews legislation with a health lens through participation and voting rights on the EQB. The health side of the CDPHE plays a similar role in that they have provided

[2] Although the RRC was not surveyed, information about their role in oil and gas developments was available on the agency's website and is included in Section 5.2.

technical advice and data from HHRAs that have been used to inform legislation. This is relevant because current state regulations have been criticized for not fully considering the long-term and compounding public health effects potentially posed by UOGD (Goldstein et al., 2012).

5.2.3 Emergency Preparedness

Another part of the core work for the regulatory agencies involves preparing for and responding to emergencies like spills, fires, and explosions caused by oil and gas operations or other events, like floods, that may affect oil and gas operations. Some of the roles they play in emergency response are notification to appropriate agencies and coordination with other stakeholders, such as first responders and local governments. The advisory agencies act as an environment and health science resource by giving expert opinions on the potential or actual environmental health implications of the emergency.

5.2.4 Environmental Impact Assessments

EIAs are an important part of a planning process to determine environmental effects of a proposed project and to mitigate adverse effects. Their use in the oil and gas industry has been criticized for not involving health experts or for ignoring health aspects (Werner et al., 2015). In Pennsylvania, major contamination sources require an environmental assessment, which is addressed through the permitting process. The PADEP relies on their air toxics and risk assessment group to provide input into reviewing these assessments. The permitting processes used by the COGCC and NDDOH do not require EIAs, as the facilities are too small to be considered major sources of pollution. However, the COGCC has voluntary drilling plans that include aspects of an EIA, and the NDDOH can be called upon to develop, review or comment on EISs. The other agencies do not have any involvement in EIAs. Human Health Risk Assessments

Regulatory agencies are usually not involved in conducting HHRAs as they mainly focus on comparing measured values or estimates to established standards set out in applicable legislation. When there is a need to conduct a more in-depth assessment, these agencies can reach out to the health agencies in their State who have personnel with risk assessment expertise. In Colorado, the CDPHE has conducted around three HHRAs but mentioned that there might be a need to re-evaluate how HHRAs for oil and gas are conducted, as they were historically based on hazardous waste sites, which might not be the right process to assess health risks of oil and gas operations. The PADOH has received requests from communities to conduct an HHRA before a development comes to their community; however, an HHRA related to oil and gas has never been requested.

5.3 Types and Nature of Complaints

Complaint histories were discussed with the survey participants to understand the types of issues that Alberta's health, energy, and environmental regulators may respond to concerning UOGD. The agencies surveyed do not distinguish between the type of oil and gas operation, such as unconventional versus conventional developments, apart from PADEP's Bureau of Air Quality. Therefore, the types of complaints that were described were more about oil and gas operations in a general sense.

Although the types of complaints investigated are widely varied and unique, the most commonly raised concerns pertained to air quality, water quality, and health impacts. These issues are consistent with the findings of the National Research Council (Goldstein et al., 2014).

5.3.1 Air

Odour complaints were identified as being one of the most common air quality concerns by all four states. The symptoms that have been reported about odours include upper respiratory problems, eyes, nose throat irritation, and aggravation of asthma and emphysema. Other types of air concerns include dust, silica, diesel emissions, and visual concerns, such as black smoke. A general trend observed has been a reduction in air quality complaints, likely as a result of technological advances, regulatory changes and compliance and enforcement activities.

5.3.2 Water

Water quality concerns from suspected contamination of both public and private water systems and spills entering waterways are common complaints. The concerns can range from odours and other aesthetic issues to water line breaks and loss of water pressure. The regulatory agencies responsible for permitting water usage also respond to concerns regarding water rights issues or unauthorized discharge of wastewater. Water quantity was not raised as a concern by any of the survey participants possibly because stringent water withdrawal oversight is designed to ensure that water withdrawals do not adversely affect the environment (Rahm, 2011). If there were to be a water quantity issue, it is likely that the result would be a concern regarding water quality and not water availability (Rahm & Riha, 2012).

5.3.3 Land

The main concerns around land include spills of hazardous substances and refined petroleum products, as well as stormwater runoff from well sites onto private land. Well site restoration issues were also raised as a potential public concern.

5.3.4 Nuisance Conditions

Concerns about noise, lights, and traffic are investigated by local government entities through zoning or other ordinances that address these concerns regardless of whether or not they are potentially related to oil and gas developments. The PADOH has investigated light complaints, but these are usually in combination with other health or nuisance complaints. The COGCC was the only agency that actively investigates noise and light concerns. Noise in Colorado is one of the most frequent complaints received, likely as a result of oil and gas developments encroaching on residential areas. Lighting concerns are also frequently raised, as they made up 10% of the total complaints received by the COGCC in the first two months of 2015.

Although local governments respond to these concerns, if health complaints are alleged, and oil and gas facilities are nearby, the advisory and regulatory agencies may be more involved. Other jurisdictions can potentially learn from the experienced agencies who respond to nuisance complaints, because as UOGD activities are now moving closer to residential areas and schools, there could be an increased number of complaints that need to be investigated.

5.3.5 General Health Concerns

General health concerns were noted to be the most common issue that the advisory agencies respond to. Some of the symptoms that have been reported by concerned individuals include headaches, nosebleeds, eyes, nose and throat irritation, sinus pain, skin rashes, respiratory issues like asthma and aggravation of asthma and emphysema, and a general indication of not feeling well.

TXDSHS's Health Assessment and Consultation Program noted that they do not receive many oil and gas related health complaints as they have only been involved in a couple of exposure investigations related to energy development. However, the lack of complaints does not mean there are no health concerns; it is just indicative of issues being addressed by the TCEQ who is responsible for investigating oil and gas complaints that are related to environmental media, which includes health complaints. The TXDSHS typically gets involved in investigations when there is a potential for a larger community exposure, not for individual complaints. For example, they responded to community concerns about cancer cases being elevated in a region with oil and gas development. The NDDOH also does not get many health complaints without some other kind of associated environmental concern.

On the topic of complaint numbers, the TCEQ noted that in some areas of Texas with a long history of oil and gas development, complaint numbers are low. Low complaint numbers in these areas may be

because people who have resided there for a long time have become accustomed to the activities and are likely familiar with the complaint processes, like who needs to be contacted and when to contact them. In areas where oil and gas operations are new, residents are more likely to have concerns, resulting in increased complaints.

5.4 Complaint Investigation Response Approach

In general, the approach to responding to oil and gas complaints does not differ from investigating any other public concern. The regulatory agencies indicated that all complaints that are received and are in their purview get investigated. For health concerns, all complaints, including non-specific complaints, are also investigated but the form ad degree of response depends on the nature of the complaint and the facts associated with it. Sometimes, an educational approach is taken, where the agency provides the public with factual information that may be beneficial to the specific issue they are concerned about. The goal of investigating complaints is to find potential issues and resolve them without any pre-determined ideas.

With the type and nature of oil and gas concerns constantly evolving, as technology changes, regulations adapt to technology and development expands, there is a need to be equipped with the appropriate resources, tools, and equipment needed to respond appropriately to concerns and complaints with a multimedia approach and consideration of the medical side of the issue. The investigation methods identified by the different agencies, including how complaints and concerns are received, what type of expertise is needed, and what tools are necessary, are discussed in this Section.

5.4.1 Complaint Intake Processes

Complaints and concerns are reported through numerous means, such as toll-free numbers, email, web-based intake systems and referrals from other stakeholders. At the time of the surveys, the CDPHE was working on the implementation of a health complaint phone line related to oil and gas to improve the intake process since the main role of the CDPHE is to take in and coordinate investigations of oil and gas related public health complaints, which often involve both health and regulatory sections. Shortly after this time, the CDPHE had an established complaint phone line and associated website that both allow for easy online complaint submissions. The website is comprised of a simple form to fill out that guides the user to the correct agency based on their concern(s) (CDPHE, 2016a). For example, after asking a yes or no question about whether or not the complaint is related to health symptoms, the second question asks the user, “do you have a complaint that is not health related about oil and gas?” If yes,

the form then prompts the user to select their concern from a drop down menu. The options include, but are not limited to air quality, well water, spills, noise, and property damage. If air quality concerns are chosen, further details are gathered and then the form states who the complaint will be sent to, namely, the Oil and Gas Air Pollution Control Team at the CDPHE. If water quality concerns are noted, the form states that the COGCC responds to these types of complaints and following submission of the form, the user is directed to the COGCC's complaint website (COGCC, 2016b). If the user is guided to the COGCC's website, there is another complaint intake form that allows for streamline complaint submissions. The complaint categories match those found on the CDPHE website, with a few others added, like royalty payments that are unrelated to health. These complaint intake systems were praised by other agencies for being the gold standard.

To inform the public about how to report a concern, including what information they should be prepared to provide, the COGCC, PADOH, and TCEQ provide a comprehensive list of requirements on their respective websites and provide information about the partner agencies that also investigate complaints. In Pennsylvania, complaints received by the PADEP, are entered into their CTS and are subsequently managed by complaint coordinators. The PADEP's Bureau of Air Quality has two complaint coordinators who specifically manage all oil and gas concerns for the two regions with the most oil and gas activity. Many of the public websites also provide educational resources, such as CDPHE's *Oil and Gas and Your Health* website (CDPHE, 2016b).

5.4.2 Who Investigates Oil and Gas Complaints

Typically, laws have defined the jurisdiction of each agency and their specific role in complaint investigations related to oil and gas activities. Clear roles and responsibilities are critical to ensuring complaints are managed in a timely and consistent manner. In Texas, the TCEQ and RRC have a publically available MOU that explains each jurisdiction's roles and responsibilities pertaining to oil and gas complaints (TCEQ, 2015a).

As the regulatory agencies are mainly concerned with the operation of the oil and gas facilities, they typically respond to public complaints and incidents that take place at a well site or oil and gas facility. Most complaints start at the regulatory agency and if everything is in compliance and a health or environmental issue has been indicated, the complaint flows to the public health or environmental side, respectively. Over the last couple of years, the role of health agencies has been evolving; they are now playing a much larger part in complaint investigations.

5.4.3 When Complaints are Investigated

Most of the agencies have guidelines that outline timeliness for responding to complaints. Like with any complaint, contact with the complainant usually occurs within 24 to 48 hours to confirm concerns and gather more information, if needed. When health effects are being alleged or if a facility has had confirmed complaints, the investigation process is expedited in many cases.

5.4.4 Training, Education, and Expertise

The regulatory and advisory agencies indicated that they have the knowledge and expertise to effectively investigate complaints. The regulatory agencies were mainly comprised of licensed professionals like engineers and geologists and others with environmental science backgrounds and experience in the oil and gas industry. The health agencies identified expertise in science fields, like medicine, toxicology and epidemiology, public health, environmental health, biology and health education. The PADOH was the only advisory agency that identified expertise in engineering and experience in oil and gas. The differences in the types of expertise means both the regulatory and advisory often work in collaboration to conduct multimedia investigations that incorporate the health side of a complaint.

As health investigations of oil and gas concerns have the potential to increase, and this is potentially a newer area of involvement for EPH departments who would likely be responsible for conducting investigations, it is necessary for additional training or expertise to be made available.

5.4.5 Interagency Collaboration

Although there are main agencies that are required to investigate complaints, it is sometimes necessary to use other government and non-governmental organizations to assist when issues arise that are outside of the main expertise present within each organization. The surveyed agencies identified two types of stakeholders they collaborate with; agencies used directly to help with complaint investigations and agencies used indirectly to help with investigations and other departmental functions.

Agencies used directly to help with complaint investigations include the USEPA, local health departments, municipalities and counties, oil and gas companies, third party consultants, universities, and OSHA. The reason for using these agencies is for their additional expertise, knowledge, and equipment they can lend to the investigation.

Agencies used indirectly to help with complaint investigations include intrastate agency collaborations, non-government organizations, interstate agency collaborations, like that between the PADOH and CDPHE, non-profit stakeholders, USGS, and the CDC. The purpose of building these relationships and working together is to share and discuss findings and learn from each other's experiences in investigating complaints.

In Alberta, some of the agencies that can be used directly to assist in complaint investigations may include: AER, AH, AEP, AHS, Albert Agriculture and Rural Development (AARD), airsheds, oil and gas companies, municipalities and counties, Alberta universities, and environmental consultants.

Some of the agencies that can indirectly help with investigations in Alberta include Health Canada, Clean Air Strategic Alliance (CASA), Environment Canada, Alberta Geological Survey (AGS), Watershed Planning and Advisory Councils (WPAC), and other States and Provinces with UOGD.

5.4.6 Tools and Equipment

Since the majority of complaints identified pertained to air quality, it follows that the tools needed for investigations also relate to air quality measurement. The Forward Looking Infrared (FLIR) camera was a tool owned by the regulatory agencies and identified as being critical to investigate air complaints, as it detects VOCs using a relatively simple handheld tool. The TCEQ also identified the RAE and Jerome as tools that they own and use to detect hydrogen sulfide. Since the COGCC investigates noise complaints, it is necessary for them to have noise survey equipment with real-time monitoring.

There were mixed responses as to whether or not the ambient air monitoring networks are beneficial to complaint investigations. The air monitoring networks can be used to help address community air quality concerns or help find potential trouble areas, depending on the locations of monitors, but the information they gather is not specific enough to aid in individual contamination source investigations. Some areas in Colorado with heavy oil and gas activity have enhanced monitoring and owners of certain industrial sources of air emissions in North Dakota operate additional monitoring sites within their immediate spheres of influence. These additional measures may be more helpful to detect spikes and narrow down an area for further investigation. For water investigations, apart from some water sampling equipment to collect drinking water, no other tools are necessary. Water monitoring networks are useful for establishing background conditions and detect trends but data has not been used for complaint investigations. Some agencies have contracted work to Universities who also have equipment and expertise to take samples and interpret results.

Having access to appropriate labs to analyze air, water and soil samples is critical to help with investigations. State labs are the most commonly used for environmental analysis, clinical labs provide blood analysis, and private labs are used to fill any gaps, like isotope testing in water. Mobile labs are an invaluable resource for complaint investigations as they can do on-site testing and monitoring of an extensive list of compounds with a quick turnaround time. For jurisdictions that do not have their own mobile lab, the USEPA has sophisticated E-vans available under certain circumstances. Advisory agencies do not have any ambient air monitoring equipment, but they do have the capacity to do water sampling. These agencies rely on other governmental and outside agencies for data collection and provide health assessments based on the environmental or biological sample results.

5.4.7 Reporting

Reporting of investigation findings is critical to maintaining credibility and public trust. Following investigations, all results are communicated back to the original complainant, usually in the form of a formal letter, apart from anonymous complaints. Any other agency that is involved in the investigation is also included in the results dissemination. The communication contains the following: summary of findings, recommendations, actions taken and any other resource that may be helpful. Throughout the investigation, there is an expectation that the field staff are in frequent communication with the complainant throughout the entire process. For health investigations, it is important to provide as much relevant information as possible to the complainant to help them make decisions about their health. Results are also reported back to the responsible company for them to focus their maintenance efforts.

The new complaint system developed by the COGCC allows the public to search all complaints, including a newly added category to capture health and safety concerns. This easy to access system, which contains complaint summaries, will help bring more transparency to the activities of the COGCC and can potentially help to address future concerns. The current perception is that there are thousands of complaints about oil and gas operations, but this is not the reality.

Complaints received by the PADEP are entered into a CTS and subsequently managed by complaint coordinators in the six regions. There are two dedicated complaint coordinators who solely manage oil and gas complaints in the regions where there is greater oil and gas development. Although neither agency has published data on the types and nature of complaints, it is possible to pull complaint reports from the CTS upon request.

When an issue has the potential to impact a larger community, findings are communicated to all people affected, not just the complainant. This is sometimes done through a public meeting to present findings and answer any questions or concerns. Many public websites also contain complaint information, such as water supply complaint information and environmental health studies. In Alberta, The Government of Alberta has taken a similar approach by authoring and posting The Alberta Oil Sands Community Exposure and Health Effects Assessment Program in 2000 and the Wood Buffalo Environmental Association Human Exposure Monitoring Program in 2005 and 2006 (AH, 2016).

The regulatory agencies often collect and report data on violations of oil and gas operations that result from routine inspections or complaint violations, such as the TCEQ's Biennial report (TCEQ, 2014). This reporting is important to discern whether activities at gas wells might be altered, restricted, or monitored to reduce spills, mishaps, and accidental releases of pollutants. The PADOH is looking to create a health registry based on their investigations that can potentially tie into the current PADEP's database of violations on oil and gas facilities.

5.4.8 Non-specific Concerns

Some concerns have been validated through complaint investigations, specifically the environmental contamination incidents. However, many of the non-specific health complaints, like UOGD causing asthma or cancer, have not. This does not mean that the health effects are not real, it just means that no significant association could be determined based on the evidence. Despite mixed results, following up on these concerns is important and can produce valuable information to inform investigative methods, policies and knowledge about UOGD and health.

A factor that complicates the investigation of non-specific health concerns is that many of the symptoms associated with UOGD development may reflect psychosocial stress, and not an environmental issue that can be investigated (Adgate et al., 2014). Contributing to this stress is a lack of trust and transparency concerning industry and government action. Better reporting of investigation actions and results, through multiagency collaboration, can help manage the concerns around the lack of transparency and help with risk communication when an issue is found.

5.5 Examples of Investigations

The survey participants were asked to provide examples of investigations that their agency had participated in to help identify the factors that were associated with successful and unsuccessful investigations, the challenges faced and the needs to improve investigations. Many of the investigation

examples given pertained to air quality complaints, like dust and odours, which are the most common. Water quality, noise, lighting, and general health complaint investigations were also described.

5.5.1 Factors Leading to Successful and Unsuccessful Investigations

The factors identified as having an impact on whether or not the investigation was considered successful or unsuccessful can be classified into five categories:

Personnel and Knowledge

Having the appropriate personnel with the right experience and knowledge to investigate complaints was identified as a major contributing factor to a successful investigation. All agencies said they have personnel with the right knowledge but they could use more personnel to respond to complaints in a timelier manner. For this to happen, these people need to be situated in the right locations, like in denser oil and gas developments. The PADEP identified that their two dedicated complaint personnel are essential to coordinate a response to complex oil and gas concerns. The same can be said for the CDPHE that has one main person to take in and coordinate all health complaints.

Interagency Collaboration

Apart from their own personnel, the ability of agencies to reach out to other agencies was also important, especially the relationship between the health and regulatory agencies, who play the largest role and have different but complementary expertise and equipment. Other important relationships include a good rapport with the complainant who can assist in many ways, such as providing health information and giving access to the indoor environment, if necessary. Another critical collaboration is with the oil and gas company itself. Having two-way communication with the industry can help to mitigate any issues in the timeliest manner. Regulatory agencies can proactively communicate regulations and expectations when a complaint investigation is started directly to oil and gas operators to aid in collaborative efforts. All of the interagency collaborations and communications can help ensure all stakeholders learn from the mistakes and successes of each unique investigation.

Equipment

To conduct thorough regulatory and environmental investigations, having the right equipment or a means to acquire the right equipment is essential. This includes any equipment necessary to do a site assessment, take samples, and analyze samples with a multiple lines of evidence approach. Along with the equipment, there must also be technically accurate sample and field data collection methods.

Complaint Intake and Reporting Processes

Having enough of the right information before a complaint investigation starts, like the name, phone number of complainant, right location and proper complaint details is essential to start the investigations properly and be able to follow-up later on any details that were missed. Whatever the system is, a clear, publically available intake process that ties into all of the main agencies is essential for quick intake and subsequent triaging of concerns. An online complaint tracking system was also identified as adding to the transparency of the actions taken to investigate complaints, especially on the regulatory side.

Laws, Policies and Procedures

Legislation and other associated policies can help or hinder complaint investigations. Laws around pre-drilling water sampling have helped health assessments, but some laws around air quality monitoring have hindered cumulative impact assessments. Having advisory agency input into laws that can affect public health investigations is critical to ensure that legislation does not impede environmental and health assessments. Given that many issues and complaints are regional, it follows that governance and regulatory approaches may also be regional. It is critical for decision makers at all levels to understand what aspects of UOGD may represent universal risks present anywhere drilling occurs, and what aspects may be caused or influenced by regional geology, hydrology, etc.

Policies and MOUs can delineate roles and responsibilities of all stakeholders, making investigation processes streamlined. Legislation that gives power to regulators to enforce laws and correct hazards can lead to the swift resolution of any documented impacts or violations. Another factor related to policies and procedures is the ability of agencies to go beyond the alleged complaint and conduct a multimedia investigation. This is where EPH departments have an advantage over the oil and gas and environmental regulators. They have the ability to assess other exposure aspects beyond the regulatory side, like indoor air quality and water treatment systems, that can lead to similar symptoms, and conduct health studies through biomonitoring or epidemiological assessments.

5.5.2 Challenges

Management of UOGD, like many complex activities, is a challenge and all complaints bring with them some level of difficulty. Managing the complaint process and many forms of data that are collected, often from multiple agencies, requires expert organization and analysis. This is especially difficult when there are vague, fake, anonymous, or second-hand complaints that do not provide correct or substantial

information. Related to this is that some oil and gas companies have their own complaint processes that the public can access to raise concerns. This creates a situation where the regulator or health agency is made unaware of the issue and cannot report on or confirm any potential problem, except where the company is required by law to provide notification of reportable exceedances.

One of the recurring challenges was the temporal and spatial variation associated with air quality complaints, like dust and malodours. These issues, coupled with the remote locations of oil and gas sites, make it very difficult to capture the worst-case scenario, like the peaks of higher levels of contaminants, to be used in a health assessment. The variation also makes it difficult to pinpoint a potential source, especially when concerns arise from the interaction of multiple activities taking place over time and space. Therefore, risks and impacts associated with UOGD must be analyzed within the context of other activities that are or could be conducted. For example, road salt application, and industrial activities, including construction, agriculture, and coal mining, all have potential environment impacts similar in some ways to UOGD. It is likely that any assessment of risk will be either incomplete or applicable to a limited set of contextual conditions. Still, governments and regulators must make decisions about how best to assess risk and follow-up on concerns.

Related to the difficulty of pinpointing a potential source and conducting a risk assessment, is when individual activities are assessed to be within the bounds set out by regulations but health concerns are still alleged. This issue can arise from the intermittent exposures from a variety of sources that cause an array of subjective symptoms. When this happens, complainants can become emotional if they are not satisfied with the outcome of an investigation.

In some regions, there are areas that have naturally poor water quality, such as the high sulfates and shallow hydrocarbon reservoirs that can cause methane in groundwater, in North Dakota. Similarly, Pennsylvania, which is part of the Ozone Transport Region, has struggled to keep ozone levels within Federal guidelines as a result of many anthropogenic sources not related to oil and gas activities. These situations make complaint investigations difficult if the poor background conditions are unknown to the public and have not been adequately documented by the investigators.

Most agencies identified they have laboratories available to analyze a myriad of environmental and biological samples for compounds of interest. However, one challenge raised was the feasibility of some methods, such as isotope testing. Another challenge was getting biological samples prescribed from

primary care physicians and analyzed by the State health departments to conduct an exposure assessment through biomonitoring.

Lack of complete chemical disclosure was identified in the literature as a potential challenge, as the missing information complicates interpretation of public complaints about health impacts (Goldstein, Kriesky, & Pavliakova, 2012). However, this concern was not raised as an issue by the survey participants, likely because the regulatory and health agencies usually have a means to obtain the chemical data when needed and companies have been cooperative in revealing additives used in fracturing fluids (Rahm, 2011).

When all of the above challenges are considered, it results in a difficulty to communicate risk to the public and a subsequent need to improve risk communication strategies. An interesting point was raised by the NDDOH: chemical risks are taken very seriously by the public and workers, but traffic accidents are the largest contributor to fatalities in the oil and gas sector in North Dakota. This raises the issue of what topics educational and risk communication messages should focus on.

Risk communication around chemical exposure information can be overwhelming for the general public to use and make decisions. It is necessary to translate exposure information into something meaningful, but many chemicals do not have reference values.

5.5.3 Needs

Many needs to improve complaint investigations were identified through numerous questions on the survey. One common need identified was improving current complaint databases. The CDPHE indicated that they needed one dedicated complaint person to receive, route, follow-up, close and send formal communication on the health complaints. Both the Colorado and Pennsylvania agencies need more sophisticated tools for ease of use and more robust reporting capabilities to capture a wider range of data that is collected during complaint investigations. The ability to connect both the regulatory and advisory systems to have all complaint information in one accessible place was also a need to systematically collect and analyze data. This would improve surveillance over the next few decades, while developments are occurring.

There was also a need for better communication and collaboration between all stakeholders, which is always beneficial to identify and resolve concerns and complaints. Clear, definable roles of all stakeholders who actively investigate complaints is critical to help streamline investigations.

Collaboration needs include sending more biological and environmental samples to advisory agencies to aid in their complaint investigations, as they rely on others for data collection.

Lastly, some gaps in science were identified as having to be filled through future research. This additional research can help the science continue to improve and aid in complaint investigations to be more thorough. Some of the research needs include better sampling methods to capture acute exposures, long-term monitoring to assess chronic exposures, expansion of analytical methods to include more signatures from contaminants and establishment of guidelines or standards for compounds that currently do not have them. Many of these needs relate to finding better tracers and indicators used to track UOGD wastes and differentiate it from other sources of contamination. This will be especially helpful in regions with existing water quality issues, like high TDS and acidity in the Marcellus Shale and sulfates in North Dakota. Future health studies were suggested to help fill the gaps on health guidelines for a large number of chemicals in the environment that do not have any.

CHAPTER 6 – CONCLUSION

Conducting case studies of agencies experienced in investigating oil and gas complaints using telephone survey methods was an effective means of achieving the two research objectives, which were to 1. Identify the types of issues health and environment regulators respond to in relation to unconventional oil and gas developments and 2. Identify the investigation approaches that are required to respond appropriately to these issues. The conclusions for each objective, based on the survey results, are summarized below.

Objective 1 conclusions and recommendations include:

1. Air concerns, such as odours and dust, were cited as the most frequent and also the most difficult to investigate.
2. Water concerns were also prevalent in some regions, and the response was complicated by poor underlying water chemistry.
3. General health concerns were cited by advisory agencies as having many challenges. Challenges associated with addressing health issues stem from a combination of intermittent exposures, non-specific symptoms, sparsely populated areas, rare health outcomes, plus external social and economic factors. It is recommended to use monitoring and education to address these concerns with the acknowledgement that these issues may never be resolved to the satisfaction of the complainant.
4. In areas with a long history of oil and gas development, the general trend has been towards decreasing complaint numbers. In areas where oil and gas operations are new, residents may be more likely to have concerns, which may result in increased complaints.

Objective 2 conclusions and recommendations:

5. Intake and coordination of complaints are best done by the main oil and gas regulator with the assistance of a complaint tracking system. Ideally, the different agencies directly involved in the complaint investigation could use a similar tracking system to allow for comprehensive reporting. Using complaint coordinators, who solely manage oil and gas complaints in the regions where there is greater oil and gas development, was identified as a factor contributing to successful investigations.
6. Together, a system of complaint prioritization, along with field staff readily available to start investigations quickly in remote locations, contributed to successful investigations.

7. Owning or having access to the appropriate tools and equipment to collect systematic data from multiple lines of evidence for rigorous analysis facilitated investigations. It is common for those agencies that played the larger role in regulating the different aspects of oil and gas operations, such as being responsible for permitting, owned the equipment since it is also used for routine inspections, as well as complaint investigations.
8. A publically accessible database of complaints has helped to bring transparency to the complaint investigation processes and has helped to clarify the current public perception of the unconventional oil and gas industry by reporting the nature and number of complaints, outcomes of investigations, and some sense of the magnitude of risk.
9. Collaboration between the main regulatory and advisory agencies is essential to building a coordinated response to address health and environmental concerns.
10. Proactive legislation that addresses both public health and environmental protection aspects was identified as a factor leading to successful investigations. More specifically, advisory agencies need to play a larger role in development and review of oil and gas policies using a health lens, especially for those areas that have a direct impact on the public health aspects of an investigation, such as emission standards and water testing requirements.

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APPENDIX A – Survey Template (Version 1)

DATE		TIME	
CONTACT		AGENCY	
DEPARTMENT			

1. **Background Information**
   a. *General information on their department's role in oil and gas developments*
      - *Emergency Response Plans?*
      - *Environmental impact assessments?*
      - *Human health risk assessments?*
      - *Legislation review/development?*
   b. *What is the nature of complaints received by your department? What types of complaints are received most often?*
      - *Environmental contamination (air, water, soil)*
      - *Traffic, Noise, Lights*
      - *General health complaints*

2. **Investigation Response Approach**
   a. *How are complaint investigations conducted?*
      - *Inter-agency collaboration?*
      - *Environmental monitoring?*
      - *Equipment (type, who owns it, etc.)*
      - *How do you respond to non-specific (vague) issues*

3. **Results**
   a. *Examples of successful investigations*
      - *what has worked well/best practices*
   b. *Examples of unsuccessful investigations*
      - *what hasn't worked or what has posed a challenge*
   c. *Have non-specific concerns been validated by investigations*

4. **Others to contact for interview**
   a. *Oil and Gas Regulator*
   b. *Health and/or Environmental Regulator*
   c. *Other Health Agency*
   d. *Other*

Rationale

Question 1a: These questions were asked to gain further understanding into the general roles that the organization played with respect to oil and gas development. The activities that are listed are complimentary to complaint investigations. The bullets were used as prompts if the respondent did not mention them.

Question 1b: Answers to this question around types of complaints were important to document as there may be different approaches used to investigate different types of complaints. The bullets were used as prompts if the respondent did not mention them.

Question 2a: This general question would provide the respondent the opportunity to discuss their complaint investigation process. Again, the bullets were used as prompts if the respondent did not mention them.

Question 3a and 3b: The question was used to gain further insight into the complaint investigation process using a "what worked, what didn't work and why" approach, as suggested by K. Thomas (personal communication 2014).

Question 3c: Non-specific concerns are typically the most difficult to address, based on the researcher's professional experience. It was therefore important to ask if investigations have resulted in validation of the complainant's concerns.

Question 4: As part of the chain referral sampling methodology, respondents were asked if they knew anyone within their organization or other agencies that would be appropriate for participating in the survey.

APPENDIX B1 – North Dakota Telephone Survey (Health and Environment Regulator - Air)

DATE	Dec. 18, 2014	TIME	1:00pm MST
CONTACT	Manager, Air Quality Division, Permitting and Compliance	AGENCY	North Dakota Department of Health
DEPARTMENT	Environmental Health Section		

(Note: Questions posed to respondents are italicized and responses are in brown)

1. **Background Information**

a. General information on their department's role in oil and gas developments

- Hard to distinguish the two (unconventional oil and gas versus conventional) fracking is a very short part of the well life cycle. Are emissions that come after the frack any different from emissions from conventional oil and gas? Some people consider just the emissions that are released during the frack and some would consider the entire process.
- For water, everything within those bounds is not under water's jurisdiction, unless it is beyond the boundary. Dykes can contain spills and DNR. For air it is a bit different, as the emissions cannot be held within the boundary, cannot capture it. And cannot measure it.
- Emission points are regulated by health, even though they are on-site.
- Ambient standards look at quality outside of sites.
- Upgraders/refineries. One large refinery that was existing from the 50s (70,000 barrels/day) and a new refinery to make diesel in the SW from Bakken crude. Remaining component goes off to different refineries. Bakken crude is so sweet, looking at more smaller (pre-processing/stage 1) refineries

• *Emergency Response Plans?*

- ERPs: no
- Emergencies: can lend expertise to first responders, EH section acts as a science tool that they can engage

• *Environmental impact assessments?*

- EIA: not directly, individual wells are seen as minor sources only.

• *Human health risk assessments?*

- If clean air standards/ambient standards were exceeded, or monitoring/modeling showed problems, then EH section would address where the problem came from, and get very involved with an Environmental Impact Statement (EIS).
- Who does the risk assessment? Not within EH. Basically they measure or model numbers and are making sure that they are below guideline health standards. Not really needing to do an assessment. Relying on information from other studies/reports to compare values to, not generating values.

• *Legislation review/development?*

- Permitting and registration process estimates registered oil well emissions (tonnes/year emitted) and EH section then assesses/compares with regulations.
- Written guidance document provides a clear pathway for industry to comply with regulations (conservative). It is not the only way to comply, as they can take a much more detailed approach.
- If they install the state of the art pollution control equipment, then the permitting process is much easier and makes any investigation related to a specific operation more straightforward.

- Legislation review of AQ by Department: Clean air standards are taken from EPA except for H_2S since EPA does not have a standard for this. ND has a specific H_2S standard. Old wells have H_2S. Beyond that, air pollution rules are in addition to EPA and some come from EPA

b. What is the nature of complaints received by your department? What types of complaints are received most often?

- *Environmental contamination (air, water, soil)*
- General environmental/air contamination
- Odours (usually in relation to older wells, the Bakken doesn't have appreciable amounts of H_2S)
- Dust
- *Traffic, Noise, Lights*
- Noise\truck traffic: do not have a direct issue with these complaints as it is a part of ongoing activities related to all kinds of industrial development.
- Lights: no complaints
- *General health complaints*
- E.g. "I'm not feeling well since the well was drilled"
- Cannot look into the medical part, but more so what emissions are coming off of the well.
- Complainant needs to do own follow up with medical professionals.

2. Investigation Response Approaches

a. How are complaint investigations conducted?

- Complaints are not distinguished by type of oil and gas development (Unconventional vs. Conventional)
- Air contamination (odours, not feeling well): first step: assess/inspect area itself for number of wells and ensuring that each well is operating within compliance.
- High priority put on complaints.
- *Inter-agency collaboration?*
- 2 complementary groups:
    - Department of Health: from the well beyond.
    - North Dakota Industrial Commission, Department of Mineral Resources, Oil and Gas Division: cover what is within the bounds of the fenced site/pad.
- Collaborate with industries/companies to gain access to areas and/or information.
- Inspections/assessment might mean taking equipment out to conduct measurements. Sometimes before even leaving the office (when they have a sense of what the problem might be) they contact the company directly for them to do an inspection/assessment for speed/efficiency purposes.
- Example: smoky flare – citizen sends in picture, they can just forward email to industry contact to investigate and they request a response. Typically that same day (very often) they do an investigation and respond back to the DoH with what actions were taken (e.g. fixed the flare) and what time the actions were taken. This is a simple case. More difficult cases would involve a concerted effort – plan a day to go inspect.
- *Environmental monitoring?*
- Ambient monitoring network throughout North Dakota. Ambient monitoring data is not really necessary to review in the event of a complaint because the whole state has always met all clean air standards on a consistent basis, plus it is consistently being assessed.

- When a complaint comes in, the department likely already knows if it is a widespread ambient problem but history says that it wouldn't be.
- Ensure air quality is compliant and pollution control is working properly, there may still be ultra sensitive so complainants need to seek further medical help.

• *Equipment (type, who owns it, etc.)*

- Inspectors in the field: related to o and g: spills, compliance for a different reason (new wells or company review).
- Additional monitoring: mobile, relatively simple handheld tools. Seeing more and more truck mounted systems but the DoH does not have access/own any of these.
- Monitors can be put right on top of source, or in house or outside of house. This is like an extension of the ambient monitoring network.

• *How do you respond to non-specific (vague) issues*

- Cannot look into the medical part, but moreso what emissions are coming off of the well.
- Complainant needs to do own follow up with medical professionals.
- Department ensures that ambient clean air standards are met and that there are no non-compliant operations occurring.

3. **Results**

a. Examples of successful investigations

• *what has worked well/best practices*

- Already in area and get complaint or see issue before complaint comes in and they can proactively investigate in a timely manner. Can get a hold of the company and mitigate complaint.
- Really great working relationship with industry. Some people see this as a weakness/negative as in industry has health in their "back pocket." Health sees this as a positive in that when you have a good working relationship with industry you can solve problems together through a gained respect for each other.
- Work hard at being flexible.
- Air toxics policy (on website).

b. Examples of unsuccessful investigations

• *what hasn't worked or what has posed a challenge*

- Vague complaints are the most difficult and least successful to investigate. People tend to blame a new industrial development for adverse health effects. This can include a new factory, agricultural (grain bins), oil and gas.
- Regardless of how vague the complaint is, the department is still required to investigate. They require this of themselves. Because even vague complaints can lead to problem identification and the DoH can help to mitigate the issue(s).
- Indoor air quality (IAQ): DoH has a small group that specializes in IAQ to help with investigations. When the public has a preconceived notion that the new industry is the cause, it is very difficult to get cooperation to investigate their private home. This is unfortunate because it halts the investigation. Sometimes complainants have said that they need to escape the problem by going outside but are still convinced the problem originates from the industry.
- Causation is very difficult to determine.
- There are often no health guidelines for the large number of chemicals in the environment. OSHA standards are often used with an applied divisor (Different TWA makes a common divisor hard to apply to all).

- Synergies (+/-) are unknown for compound mixtures. Public often think the cause/effect relationships are direct but they aren't. Tend to look at the negative but forget about hormetic effects.
- Hard to communicate an acceptable level of risk: take the safety training around chemicals very seriously! But remember that the main way a person would be harmed/dies in the oil field is from a driving accident (i.e. huge traffic fatalities since Oil and Gas boom)

c. *Have non-specific concerns been validated by investigations*
- The difficult ones, like asthma, cancer, community concerns have not been validated
- Specific complaints have been validated by investigations.
- Suggest adding section on organization of department and how Enviro and Health are related:
- Department of EH is encompassed within the Health department.
- Disadvantage of having health and environment together: The State EH Section is focused on environment and they cannot do a health/medical assessment. These are scientists and engineers, not nurses and Drs.

4. **Others to contact for interview**
   a. *Oil and Gas Regulator*
   b. *Health and/or Environmental Regulator*
   c. *Other Health Agency*
   d. *Other*

APPENDIX B2 – North Dakota Telephone Survey (Health and Environment Regulator - Water)

DATE	Dec. 19, 2014	TIME	8:00am MST
CONTACT	Director, Water Quality Division	AGENCY	North Dakota Department of Health
DEPARTMENT	Environmental Health Section		

(Note: Questions posed to respondents are italicized and responses are in brown)

1. **Background Information**

a. General information on their department's role in oil and gas developments

- Environmental Health Section: Implements environmental health laws that pertain to air, water and land.

- *Emergency Response Plans?*
- Emergency response – not first responders, more involved on clean-up aspects
- *Environmental impact assessments?*
- Can be asked to review "Environmental Impact Statements (EIS)"
- *Human health risk assessments?*
- Not directly involved in HHRAs but they do work with other sections like the lead group (air quality) that has HHRA specialists. They can also use the expertise of the State epidemiologist and State CDC.
- *Legislation review/development?*
- Agency is in prevue of government
- They can submit proposed legislation
- They review/develop Water Quality Standards

b. What is the nature of complaints received by your department? What types of complaints are received most often?

- Complaints are widely ranged and unique

- *Environmental contamination (air, water, soil)*
- Media: mainly water and soil (in conjunction with waste management)
- Most common: spills, releases, activity that has affected private property
- *Traffic, Noise, Lights*
- N/A
- *General health complaints*

General health complaints are the minority

2. Investigation Response Approach

a. How are complaint investigations conducted?

- Goal of complaint investigation is to find the problem and fix it. There needs to be no pre-determined ideas.
- Department of Health investigates all complaints, including anonymous ones
- With Oil and Gas complaints there is often the need for a multimedia approach
- Also need to consider the disease control/medical side
- Mentality has changed prior to oil and gas activity

- *inter-agency collaboration?*
  - State Water Commission
- *Environmental monitoring?*
  - Ambient monitoring – broad brush
    1. Surface Water: Sites identified and sampled on a regular basis. Frequency and site is based on risk/type/level
    2. Ground Water
       a. There has been an increase in the ambient GW monitoring in western ND
       b. Sampling shallow wells, GWUDI (2 year project).
  - Take pre-samples
  - Review private well data but cannot share/publish

- *Equipment (type, who owns it, etc.)*
  - State Lab – EH section
  - Water chemistry and Biological capabilities
- *How do you respond to non-specific (vague) issues*
  - Goal of complaint investigation is to find the problem and fix it. There needs to be no pre-determined ideas.
  - Department of Health investigates all complaints, including anonymous ones

3. **Results**
   - Can't prove a negative: can take sample and a given point in time
   - Contamination of GW crosses jurisdictions if it occurs on the O&G site

a. Examples of successful investigations

- *what has worked well/best practices*
  - Complaint from neighbor about a change in his well water quality with an O&G development nearby. O&G commission did not respond. Owner tried to work with O&G company with no luck. Eventually passed to Department of Health. Water samples analyzed in EH lab. Also took water from other private wells nearby. No contamination related to O&G found but there was a failure in the structure of the water well and the aquifer was possibly contaminated by shallow well.
  - Equipment sitting on surface (traffic, drilling heavy water trucks) may have jiggled the wells loose.
  - Problem: Climate since it had rained, making the ground soft and damaged well susceptible to contamination.
  - Health spoke with company and the issue was settled between the company and the complainant.
  - Potential contamination was in the first couple hundred feet and from surface.
  - Reference to review: National USGS study on deep wells (published in Oct or Nov 2014) showed no contamination in areas where hydraulic fracking of unconventional oil and gas took place.

b. *Examples of unsuccessful investigations*

- *what hasn't worked or what has posed a challenge*

- Getting cooperation from complainants can pose a challenge.
- Example: general complaint came to health department (i.e. something nearby impacting health). HHRA was involved, including physicians, but nothing/no source was identified even after a thorough investigation.
- Another problem: Western ND has poor GW quality, in general, that is naturally high in sulfates. ND also has documented cases of shallow gas deposits which can result in methane in GW.
- Get a lot of complaints from second hand information, not direct calls from those in the vicinity of the potential problem. These are very difficult to determine where to start an investigation.

c. *Have non-specific concerns been validated by investigations*

- Have documented impacts from surface activities, including localized GW contamination but have not documented DW supplies being affected.

4. **Others to contact for interview**

a. *Oil and Gas Regulator*
b. *Health and/or Environmental Regulator*
c. *Other Health Agency*
   - S. Adams, SW Health District
   - (701) 483-0171
d. *Other*

APPENDIX C – Survey Template (Final Version)

DATE	
TIME	
CONTACT	
AGENCY	

(Note: Questions posed to respondents are italicized, telephone responses are in brown and email responses are blue)

(new additions to the survey are in red)

1. **Background Information**

a. General information on their department's role in oil and gas developments

- *Regulate/Permit?*
- *Emergency response planning?*
- *Environmental impact assessments?*
- *Human health risk assessments?*
- *Legislation review/development?*

b. What types of complaints are received most often? What is the nature of these complaints?

- *Air*
- *Water*
- *Soil*
- *Traffic*
- *Noise*
- *Lights*
- *General health complaints*

2. **Investigation Response Approach**

a. How are complaint investigations conducted

- *Who investigates and when? (all complaints?)*
- *Inter-agency collaboration? What are the triggers used to decide when to call upon other agencies/make referrals?*
- *Environmental monitoring versus reactive investigation?*
- *Equipment (type, who owns it, etc.)*
- *How do you respond to non-specific (vague) issues?*

3. **Results**

a. Examples of successful investigations

- *Possible reasons why the investigation was successful (clarity of roles and responsibilities, resource needs met, etc.)*

b. Examples of unsuccessful investigations

- *Possible reasons why the investigation was unsuccessful (lack of complaint details, not the right equipment, etc.)*
- *what hasn't worked or what has posed a challenge (i.e. non-disclosure agreements?)*

c. *Ask about what the respondents need in their own jurisdictions to help with complaint investigations*
d. *Are investigation results communicated to complainants or to the public? How is this accomplished? (aside: if complaint investigated by another agency, are results communicated back to original agency?)*
e. *Have non-specific concerns (as noted in 1. b.) been validated by investigations?*

4. **Others to contact for interview**

a. *Oil and Gas Regulator*
b. *Health and/or Environmental Regulator*
c. *Other Health Agency*
d. *Other*

Rationale

The additions to the survey template were made as part of the pre-test interviews with the State of North Dakota (Appendix B1-B2), as well as consultation with AHS (R. Musto, personal communication, 2015)

Question 1a: Regulation and permitting roles were added to the bullet points for prompting as this is a critical role in how investigations are conducted. Although this information was available through the gathering of secondary research, this gave the respondent an opportunity to expand on the specifics of this role.

Question 1b: Types of possible complaints were separated to make it easier to document responses.

Question 2a: Two more prompts were added that were both probing further into investigation details that will be very useful for AHS to know.

Questions 3a and 3b: Prompts were clarified as this section was difficult for pre-test respondents to answer.

Questions 3c: General question offered to respondents to gain further insight into the needs that even established agencies have to investigate complaints.

Questions 3d: AHS asked for this information to be included, as risk communication and transparency have been identified as issues in past investigations.

APPENDIX D – Sample Email

Dear Mrs. ABC,

My name is Jessica Ponto and I am an Environmental Health Officer working in Alberta, Canada. Apart from my job as an EHO, I am also pursuing my MSc in Environmental Science through the University of Alberta. Here, my research is focused on the role of government departments in conducting investigations relating to oil and gas developments, specifically, unconventional developments. In order to explore this topic I am conducting telephone surveys and I am looking for participants from the [insert agency name] to partake in the survey.

The survey will look at:

- Nature/types of complaints (air, water, soil, noise, general health complaints)
- How investigations are conducted (equipment/labs/contracts/etc)
- Successes and failures
- Validation of complaints

I was hoping that you would be able to participate in this survey on behalf of your organization. If you are interested, please respond at your earliest convenience and we can schedule a time for the survey. If you are not the appropriate person to contact for this information, would you be able to point me in the direction of someone who could participate?

Thank you very much for your time. I look forward to hearing back from you.

Kind regards,

Jessica Ponto

_____

Jessica Ponto, B.Sc., BEH(AD), CPHI(C)
Environmental Health Officer and Executive Officer
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APPENDIX E1 – Colorado Telephone Survey (Oil and Gas Regulator)

DATE	March 5, 2015
TIME	9:00am MST
CONTACT	Department of Natural Resources Deputy Director
AGENCY	Colorado Oil and Gas Conservation Commission

(Note: Questions posed to respondents are italicized and verbal responses are in brown, email responses are in blue)

1. **Background Information**
   a. *General information on their department's role in oil and gas developments*
   - *Regulate/Permit?*
     Main regulator for any extraction of oil and gas out of the ground
     Permitting all oil and gas operations, including drilling of new wells
     Inspections/Compliance
     Has an environmental group that reviews/investigates spills, remediation plans, pits that were used, etc.

   - *Emergency response planning?*
     Recently developed an ERP on how the COGCC responds to emergencies (like the 2013 flood near Denver) that impact oil and gas operations. This is basically a plan that says how the COGCC coordinates with the state emergency officials and local governments (first responders).

   - *Environmental impact assessments?*
     No, this is done mostly by the Federal Bureau of Land Management
     EIAs are done for major projects/large scale assessments, whereas the permitting done by the COGCC is mainly done on a site by site basis.
     In their rules they have a comprehensive drilling plan, but it is not a requirement, it is voluntary. To date, only 1 filed.

   - *Human health risk assessments?*
     No
     Just had an oil and gas task force that was appointed by the Governor that made recommendations on how to improve regulations in Colorado. One of the recommendations was to come up with health studies related to oil and gas. The majority of this work would be done by CDPHE.

     Another recommendation was to make a health complaint phone line related to oil and gas. It is expected that implementation will begin in the next couple of months.
     Recommendations are available from: http://dnr.state.co.us/ogtaskforce/Documents/finalrecsogtf.pdf and the final report: http://dnr.state.co.us/ogtaskforce/Documents/OilGasTaskForceFinalReport.pdf

- *Legislation review/development?*
  Yes, especially in the reviewing process. Recently they increased the penalties and fines for violation of the rules, which involved changes to legislation and the COGCC helped to draft these changes. An elected official needs to introduce it, but the COGCC significantly help the legislature to write the laws.

b. *What types of complaints are received most often? What is the nature of these complaints?*
No report for 2014, there are internal stats that could be published but feel the data collected is not up to par.
2014 – noise and air are the top two, in that order
2013 – air and noise are the top two, in that order

New complaint process implemented on January 9, 2015. It is possible to go on their website and file a complaint, look up types of complaints and actions by visiting: http://cogcc.state.co.us/Complaints/Complaints.html

- *Air*
  2014 – 11.5% of all complaints
  2015 – 7%
  Nature of the complaints: odours, see flare/flame and get worried

- *Water*
  1 related to water well issue this year

- *Soil*
  Spills

- *Traffic*
  n/a

- *Noise*
  Consistently one of the biggest complaints received, seeing more complaints as oil and gas developments are getting closer and closer to residential areas.
  2014 – 33% of all complaints
  2015 – 46% of complaints to date

- *Lights*
  2014 – not a category for older complaint process
  2015 – 10% of complaints to date

- *General health complaints*
  When department receives general health complaints, like nose bleeds, etc:
  - Might think it is air impacts from oil and gas, they typically go out first to conduct investigation to see if they notice anything out of the ordinary and then make appropriate referral, if deemed necessary. Complaints are not ignored. They may then classify it as an air complaint or possibly health/safety.

- They have another category called Health/Safety but no complaints in this section have been filed in 2015
- New phone line will be a better avenue for these kinds of complaints – will act as a triage essentially.

- *Access*
  This involves complaints related to access roads not being maintained or tracking mud from access roads to main roads, etc.

2. **Investigation Response Approach**
   a. *How are complaint investigations conducted*
   - *Who investigates and when? (all complaints?)*
     COGCC takes in all complaints and generally investigates all complaints. Exception – I hate fracking, you should ban it. There is nothing that can be investigated here.
     Spill complaints are investigated by environmental department

     Below is a list of expertise within the CDPHE:
     toxicologist/ risk assessor
     toxicologist/ environmental health professional
     oil and gas public health expertise
     medical physician in public health and preventative medicine
     atmospheric chemist with oil and gas expertise
     http://www.oghir.dphe.state.co.us/

   - *Inter-agency collaboration? What are the triggers used to decide when to call upon other agencies/make referrals?*
     All complaints start at the COGCC and when they feel they need more expertise, they will engage the appropriate agencies, mainly the CDPHE.
     If COGCC goes on-site and smells an odour, they immediately contact the CDPHE because they have the expertise, especially in interpreting any results.
     CDPHE – triggers to know when to call? Air and Odour always go to CDPHE (air quality division)
     Smell is a trigger. IR Camera showing something is a trigger.

     Oil and gas companies – passive role. Sometimes they will have to go to the companies and ask questions about complaint. But they do not have an active role. Some operators have developed their own complaint process to encourage the public to call them with any concerns. They do not want the COGCC involved because of a violation of the *Rules* is found then that can result in fines and penalties.

     Spills and water concerns are investigated by environmental group.

   - *Environmental monitoring versus reactive investigation?*
     n/a

   - *Equipment (type, who owns it, etc.)*
     Air – FLIR camera has been the most powerful tool (they have 5 of them and CDPHE has more). It can determine if VOCs are being emitted from flares/other devices.

Noise survey equipment: have certain noise standards that operations need to comply with. Real time monitoring over a specified period. Owned by COGCC. Have 5 noise meters, these are critical as noise complaints are #1.

Contaminated water – environmental group (COGCC) would get these. Very few complaints related to water.
GW wells, Surface water - Either one would go to environmental consulting firms who are specialized in testing water wells. Then they contract out to the appropriate third party to do the actual testing. Enviro group acts as a project manager for that investigation.
COGCC – have a lot of expertise in house but not the expertise to perform the detailed scientific tests to distinguish between biogenic methane (natural) versus thermogenic methane (non-natural). They can't fingerprint the source. Resources are a limitation. But the role of the COGCC does communicate/supply info to address public concerns.

- *How do you respond to non-specific (vague) issues?*
  New complaint process will help to bring transparency to the bigger picture and this will help with the public perception of oil and gas industry. Public in Colorado is very active (in favor and against) regarding the oil and gas industry.

  COGCC has developed public documents that explain, in plain language, some of the perceived concerns with respect to oil and gas development and unconventional oil and gas. An example is the document produced about some of the errors made in *Gasland* documentary.

3. **Results**
   a. *Examples of successful investigations*
      - *Possible reasons why the investigation was successful (clarity of roles and responsibilities, resource needs met, etc.)*
        Noise complaint - 2015

        Night noise/day noise from a distant oil and gas operation from his house

        Used two noise meters (Same meter, same brand, calibrated, run at exact same time). One that was ~25 feet from his house and the other that was half way between his house and the oil and gas development. Average noise readings were greater at this house than the readings taken closer to the development. Noise levels (as outlined in the *Rules*) at his house were exceeded but not exceeded at the monitor that was put closer to the development.

        Conclude – oil and gas operation was not the problem. There was a gravel pit nearby, new home construction in neighborhood, interstate closeby.

        Had right equipment and resources to conduct a thorough investigation and come to a strong conclusion.

        Complainant will not agree that this is a success

        This took 6 separate inspections to make sure we got it right that were all generated and sent to him via email and regular mail, along with a summary report.

b. *Examples of unsuccessful investigations*
   - *Possible reasons why the investigation was unsuccessful (lack of complaint details, not the right equipment, etc.)*
   - *What hasn't worked or what has posed a challenge (i.e. non-disclosure agreements?)*

   Before new process, a complaint was received via fax from an attorney's office for noise, lighting and dust concerns. Inspection supervisor was asked to conduct an investigation. Thought complaint was sent but there is no proof it was sent. There was some miscommunication over a township. Ended up finding one well in the location where he thought the complaint was concerned with but it ended up being in a different location. Investigation found nothing of concern and was closed. Complainant not communicated with because that was not the standard process at the time.

   One week later, it was discovered that the wrong location was inspected. Went out to the right location on same day to conduct investigation and nothing was found. Operation was done, drilling was done. 6-7 days person had to live with issues. It is now the process to confirm location with complainant before starting on-site investigation.

   Speaks to the temporal issues associated with air quality and how quickly it can change, or operations stopping. Even an hour later, odour can be gone because the wind changes.

c. *What does the respondent need in their own jurisdictions to help with complaint investigations?*
   1 Dedicated complaint person or people. Receive, routing, follow-up, closing and sending formal communication (hopefully this can be done by July).

   Current reporting uses very simple tools, need more sophisticated tools for ease of use and more robust reporting capabilities.

d. *Are investigation results communicated to complainants or to the public? How is this accomplished? (aside: if complaint investigated by another agency, are results communicated back to original agency?)*
   General reporting is done through new complaint process implemented in 2015.
   In the past they never used to follow up with complaints and it is felt that they may have lost some credibility here. New process says that formal communication must be sent back. Formal reports, summary letters, inspection reports, etc are usually sent by email or regular mail.
   They reach out with literature and research to nearby residents.

e. *Have non-specific concerns (as noted in 1. b.) been validated by investigations?*
   General health concerns – opportunity to improve here with the new process/complaint line

4. **Others to contact for interview**
   a. *Oil and Gas Regulator*
   b. *Health and/or Environmental Regulator*
   c. *Other Health Agency*
   d. *Other*

APPENDIX E2 – Colorado Telephone Survey (Health and Environment Regulator - Water)

DATE	April 1, 2015
TIME	9:00am MST
CONTACT	Water Quality Control Division Lead Wastewater Engineer
AGENCY	Colorado Department of Public Health and Environment

(Note: Questions posed to respondents are italicized and verbal responses are in brown, email responses are in blue)

1. **Background Information**

   a. *General information on their department's role in oil and gas developments*

Within the CDPHE, the health and environment sections are split. Focus of the work is different and they are located in different buildings but they do work together and interact. So for a drinking water issue, the environment's DW group may call upon the epidemiology group in health or vice versa.

- *Regulate/Permit?*

  Within environmental section there are 3 main divisions: air pollution, solid/hazardous waste and water

  Within water quality control division there are two programs:

  1. Surface water (streams and river systems): permitting for wastewater discharges
  2. Drinking water system

  Under the main statute, the Water Quality Control Act, the CDPHE has authority to regulate anything related to water. However, there is a patchwork of other departments that also regulate water, mainly the Department of Natural Resources that contain: COGCC and the Division of reclamation mine safety.

  Ground water issues: if it has to do with a mine – goes to mining, CDPHE would regulate if there was a pipe discharging to a steam outside of stream.

  If it has to do with an oil and gas facility, COGCC has jurisdiction. Where the CDPHE gets involved is if they are taking water (like a produced water) and they are going to haul it to a facility for treatment – that's COGCC. But if they are going to discharge into a stream, then that would be CDPHE (they would permit the discharge)

- *Emergency response planning?*

  CDPHE has an Emergency response division on the regulatory side. This division has a toll –free number for the public to call and report environmental concerns.

  CDPHE not first responders, their role is to find out what they are doing and to notify the appropriate people/agencies.

- *Environmental impact assessments?*

  n/a

- *Human health risk assessments?*
  n/a

- *Legislation review/development?*
  CDPHE is involved in legislation development and review many years ago when it was developed.

b. *What types of complaints are received most often? What is the nature of these complaints?*
   n/a

- *Air*
  n/a

- *Water*
  2 program areas:
  1. Surface water
  2. Drinking water
  - Only regulate public drinking water systems, not private systems
  - water is dirty, smells, aesthetic issues, secondary treatment issues
  - water line breaks, loss of pressure to a drinking water system
  - complaints come to department through toll-free number (separate office that triages these calls) through emergency preparedness group located within the Environment department. They discern what the issue is and email out to departments that may be affected like COGCC.

- *Soil*
  Jurisdiction of solid and hazardous waste division
  Deal mainly with spills

- *Traffic*
  n/a

- *Noise*
  n/a

- *Lights*
  n/a

- *General health complaints*
  Typically this division does not receive health-based complaints directly from public. These complainants usually go directly to doctor. If the doctors report something back to the health department, then health may call upon environment.

2. **Investigation Response Approach**

a. *How are complaint investigations conducted*

- *Who investigates and when? (all complaints?)*

Law has defined roles and responsibilities/authority for each department:
Spill oil and gas produced water (exploration and production waste) – still jurisdiction of COGCC. But CDPHE would be made aware and can support them.
If spill impacted water course, the CDPHE would be in touch with downstream water users.
But the spill/complaint itself is handled by the COGCC.

Eg. tank overflowed and produced water was lost into dry gully, 1-800 team gets call and forwards email water quality and COGCC. COGCC takes lead and water quality observes to see if downstream water users may be affected.

- Where it could become CDPHE, pipeline owned by company A and it ruptures/cracks, it could be Oil and Gas, maybe another company joins in and the pipeline is heading towards a refinery. At some point it enters a different jurisdiction (not considered exploration and production) and COGCC says it is no longer their jurisdiction. A stream discharge would be water quality, but into soil it would become solid water/hazardous waste group.
- But 95% of oil and gas incidents or complaints occur at the facility (at well head, near well head).

- *Inter-agency collaboration? What are the triggers used to decide when to call upon other agencies/make referrals?*
  No third party collaboration
  Some level of coordination with the local county/city level health department as they are often close by and know the local situation/context and can help to confirm details.

- *Environmental monitoring versus reactive investigation?*
  n/a

- *Equipment (type, who owns it, etc.)*
  State regulators do not have a lot of resources. There is an expectation that the oil and gas company at fault for spills or other incidents will remediate issue or hire consultant. The CDPHE would then review actions and report.
  If there was a big spill or big issue where the responsible party cannot be identified – covers too many jurisdictions, this is when the USEPA (federal regulator) may get involved. Because they can hire contractors to do clean up and they will legally pursue people to make them pay.

- *How do you respond to non-specific (vague) issues?*
  n/a

3. **Results**
   a. *Examples of successful investigations*
      - *Possible reasons why the investigation was successful (clarity of roles and responsibilities, resource needs met, etc.)*

Oil and gas exploration/production materials went to a purification plant near oil well heads. All of the pipes coming into that building were regulated by COGCC. Pipeline coming out of that building was a finished product that was buried and went under a stream to a spout that would connect to trucks to haul product off to market. It was determined that something was leaking and oil was in the creek. Got reported through spill line and all agencies were notified. Downstream water users were made aware. COGCC staff started the investigation as they were the main regulator and already had staff present at the site. Pipeline coming out of the building

was regulated by soild and hazardous waste group within CDPHE so they were responsible to ensure that the clean up was done correctly. Ended up being a close coordination between both departments with COGCC taking the lead even though it wasn't directly under their jurisdiction.

b. *Examples of unsuccessful investigations*
Cannot think of an unsuccessful investigation in Colorado but gave an example learned at training in a different state. Oil spill into creek and investigators started to follow back to determine source/cause. There were calls made back to a particular oil and gas operator and that entity kept denying being at fault but it ended up that they were responsible for the incident.

- *Possible reasons why the investigation was unsuccessful (lack of complaint details, not the right equipment, etc.)*
If there was a failure, the entity did not step up and admit. Comes back to cooperating with the oil and gas companies.

- *What hasn't worked or what has posed a challenge (i.e. non-disclosure agreements?)*
n/a

c. *What does the respondent need in their own jurisdictions to help with complaint investigations?*
We have clear oil and gas roles
Every incident is different and it is necessary to learn from each one.
Start with the general principles
Who can support them?
Is the entity cleaning up the mess/rectifying the complaint.
Can't do a flow chart, principles and procedures maybe
Need to confirm details of accident/conditions – is it what we think it is?
Is someone acting responsibly? Is incident controlled, risk being minimized?

d. *Are investigation results communicated to complainants or to the public? How is this accomplished? (aside: if complaint investigated by another agency, are results communicated back to original agency?)*
COGCC would have the main contact with the public
CDPHE mainly communicates to downstream water users in the event of surface water contamination.

e. *Have non-specific concerns (as noted in 1. b.) been validated by investigations?*
n/a

4. **Others to contact for interview**
   a. *Oil and Gas Regulator*
   b. *Health and/or Environmental Regulator*
   c. *Other Health Agency*
   d. *Other*

APPENDIX E3 – Colorado Telephone Survey (Health and Environment Regulator – Air)

DATE	April 8, 2015
TIME	11:00am MST
CONTACT	Chief, Environmental Epidemiology, Occupational Health, and Toxicology Section
AGENCY	Air Pollution Control Division, Colorado Department of Public Health and Environment

(Note: Questions posed to respondents are italicized and verbal responses are in brown, email responses are in blue)

1. **Background Information**
   a. *General information on their department's role in oil and gas developments*
   Regulatory side: complaints start here. Initial reaction is to go make sure that all of the regulations are being complied with.
   Public health side: If everything is in compliance and there is a health issue, then the complaint flows to the public health side. M. Van Dyke is then tasked with managing the health issues. Health role has been constantly evolving, especially over the last 2 years. Refer to the Oil and Gas Task Force Report mentioned by D. Kulmann. This is just a proposal and it is contingent upon getting resources to make changes (ie. larger role for Health).

   - *Regulate/Permit?*
   No role on the public health end of things

   - *Emergency response planning?*
   No role with Emergency response planning

   - *Environmental impact assessments?*
   No response

   - *Human health risk assessments?*
   Yes, in the past they have done about 3.

   - *Legislation review/development?*
   Have been involved in giving technical advice/data from HHRAs to inform legislation but not directly involved in development.

   b. *What types of complaints are received most often? What is the nature of these complaints?*

   - *Air*
   All complaints received by this Division have been related to air and health. This is because the other types of complaints (noise, water, traffic) are taken care of before they reach this Division.

   - *Water*
   1 water complaint

- *Soil*
  n/a

- *Traffic*
  n/a

- *Noise*
  n/a

- *Lights*
  n/a

- *General health complaints*
  See a)

2. **Investigation Response Approach**
   a. *How are complaint investigations conducted*
   - *Who investigates and when? (all complaints?)*
     All complaints get investigated on the regulatory side of things to ensure compliance. When it gets to be a health complaint, there is always contact made with the complainant but a full investigation is not necessarily always conducted.

   - *Inter-agency collaboration? What are the triggers used to decide when to call upon other agencies/make referrals?*
     Collaborate with their own regulatory side at CDPHE as well as COGCC to conduct investigations
     Also reach out to operators
     Any complaint related to oil and gas becomes multi-agency
     Have collaborated with Garfield County in the past and other local health departments, as they have resources dedicated to oil and gas where there is this kind of development.

   - *Environmental monitoring versus reactive investigation?*
     Use ambient air monitors but these only measure 4 criteria pollutants
     Some areas of the State have an enhanced monitoring program (Garfield County)
     Neither are the most helpful to detect more specific, local concerns unless there is a huge spike.

   - *Equipment (type, who owns it, etc.)*
     Regulatory perspective: Conduct site visit to do a visual site assessment and look for leaks using IR cameras.
     Health perspective: sometimes air monitoring is involved but this would be the exception. It is very resource intensive to do this and there are so many limitations to collecting samples and interpreting results.

   - *How do you respond to non-specific (vague) issues?*
     It is a true issue. Respond to every issue as though it is a health complaint and they are all handled the same way.
     If concerns are raised about not liking oil and gas development, these are usually weaned out and would not get to the investigation level.

3. **Results**

a. *Examples of successful investigations*

- *Possible reasons why the investigation was successful (clarity of roles and responsibilities, resource needs met, etc.)*
  Success in their mind is that the operator is in compliance with all of the regulations and the resident gets all of the appropriate health information from the CDPHE in order to make their own personal health decisions. The CDPHE can explain the risk based on measured exposures and then it is their decision to determine whether it is safe or not for them.

  The best outcome/goal is that following a complaint, a potential source is identified and subsequently modified by the operator and the complainant no longer has health symptoms. Has seen situations where a situation gets better but maybe not completely resolved.

b. *Examples of unsuccessful investigations*

- *Possible reasons why the investigation was unsuccessful (lack of complaint details, not the right equipment, etc.)*
  In general, the reason that an investigation is not successful is due to lack of resources to fully investigate to the complainant's satisfaction.

- *What hasn't worked or what has posed a challenge (i.e. non-disclosure agreements?)*
  Challenge: Health issues around oil and gas are really difficult. You have an exposure that is intermittent and changing based on the stage of development. And you have that development surrounded by a mixture of people with an economic incentive to appreciate that development and another group of people who are resentful because they don't get the economic benefit and then some people who may have a true health issue. Then you must try to separate all of the external factors out to address a health issue in a sparsely populated community thinking about rare outcomes. In the epidemiology world, this makes for an almost impossible situation to address health issues and fix potential problems. On top of it all, the exposures of concern are really not specific to oil and gas, as hydrocarbon exposure can occur in many different ways. To determine whether or not these exposures increase risk of a particular outcome is incredibly difficult. Need to work together with other States to figure out how to tackle this problem.

  In Marcellus Shale region, there is a huge focus on water and exposures through contaminated water. In Colorado, aquifers are very separated from the deep production zones, and they have not been seeing the same sorts of issues. Also, a large proportion of the people in Colorado are on public water so the concern about drinking water aquifers is removed.

c. *What does the respondent need in their own jurisdictions to help with complaint investigations?*
Biggest weakness of sampling is the temporal/spatial nature of ambient air: wind changes, temperature changes, etc. All sorts of factors affect exposure and the ability to take a sample at the right time is fairly limited. Sampling technology: need to determine the best time to take samples, like peak samples as opposed to longer term average samples, as these appear to be the biggest health concern (short term, high exposures).

Gaps in science (not specific to oil and gas): translation of an exposure to something meaningful; don't have reference values for many chemicals, process of doing an HHRA that was historically based on hazardous waste sites mostly and may not be the right process for oil and gas. With the implementation of the oil and gas task force, this will bring in more consistent reporting: a single place where health concerns can be reported with the ability to systematically collect and analyze data. Perception right now is that there are 1000s of complaints but the CDPHE doesn't know how many without a better reporting system.

Also need the resources to be able to do more specific monitoring where needed over time to explore different locations.

d. *Are investigation results communicated to complainants or to the public? How is this accomplished? (aside: if complaint investigated by another agency, are results communicated back to original agency?)*
Results are communicated to complainants to give them as much information for them to make their own decisions about their health. With the new complaint system, some of this information will be publically available.

e. *Have non-specific concerns (as noted in 1. b.) been validated by investigations?*
The best outcome/goal is that following a complaint, a potential source is identified and subsequently modified by the operator and the complainant no longer has health symptoms. Has seen situations where a situation gets better but maybe not completely resolved.

4. **Others to contact for interview**
   a. *Oil and Gas Regulator*
   b. *Health and/or Environmental Regulator*
   c. *Other Health Agency*
   d. *Other*

APPENDIX F1 – Texas Telephone Survey (Environment Regulator)

DATE	September 30, 2015
TIME	10:00am MST
CONTACT	Air Program Liaison, Office of Compliance and Enforcement
AGENCY	Texas Commission on Environmental Quality

(Note: Questions posed to respondents are italicized and verbal responses are in brown, email responses are in blue)

1. **Background Information**
   a. *General information on their department's role in oil and gas developments*
   - *Regulate/Permit?*
     2 state regulators – RRC issues permits for exploration/drilling

     TCEQ issues air permits to set emission limits for o and g facilities and they respond to complaints

     Link to public webpage that is focused on o and g – Who regulates o and g in Texas – one stop shop. The public wants to know who is in charge for what concerns.

     https://www.tceq.texas.gov/assets/public/assistance/sblga/oil-gas/statewide_oilgas_prog_info.pdf

     Air regulations and permitting, Waste regulations and permitting, Water regulations and permitting

     TCEQ's Small Business and Local Government Assistance Program: www.TexasOilandGasHelp.org

   - *Emergency response planning?*
     TCEQ has ERP staff at agency
     If an emergency were to happen, they would collaborate with TCEQ to have an all hands on deck response

   - *Environmental impact assessments?*
     n/a

   - *Human health risk assessments?*
     TCEQ has a toxicology division that assesses health impacts. For example, if there was a large release at o and g site and the potential to impact people, the responsible party would be required to do modeling for air contaminants in relation to receptors. Modeling results would then go to toxicology division to assess health impacts by comparing modeling results to the National Ambient Air Quality Standards and other limits in the Texas Rules depending on location.

Also, when company gets a permit, they have to do modeling and the permitting group often calls upon the toxicology group to assess health impacts.

- *Legislation review/development?*
  TCEQ participates in this process. When a Bill is filed, agency determines if there is an impact to the TCEQ or not. If there is an impact, the Bill is analyzed and describe impact to agency and present analysis to the author of the Bill to consider. Will look at things like: does Bill require more regulating and will this require more staff that will need a budget enhancement. Will laws conflict?

b. *What types of complaints are received most often? What is the nature of these complaints?*
   Refer to annual report

- *Air*
  Odour (1) and Dust (2) are the most common complaints

  Difficult to separate out the oil and gas complaints from other industrial areas.

  In the Barnett Shale region, air complaints are number 1

  Between (premilim data) sept 1 2014 to august 31, 2015 fiscal year:

  Air in Barnett shale area – about 1/5 of complaints were related to oil and gas, peak of oil and gas complaints (2010 2011) now seeing a downward trend. They really focused on that area with a specialized team. Ramped up compliance and enforcement activities and have began to see a steady decline in complaint numbers. Economic factors as well?

  In some areas of Texas (midland area) – very long history of oil and gas, prevalent industry in that area. Low complaint numbers

  People who have lived there for a long time, they have become accustomed to these activities and likely are familiar with complaint processes and who needs to be contacted.

  Where oil and gas operations are new likely have more concerns, general trend in complaint numbers.

- *Water*
  Most of the water-related complaints for oil and gas operations that the TCEQ investigates pertain to water rights issues or unauthorized discharge of wastewater and are related to oil and gas activities but not a direct result of the explicit operations.

- *Soil*
  RRC has jurisdiction over spills associated with exploration, development and production
  TCEQ is the lead on hazardous substance, refined petroleum products and abandoned containers.

- *Traffic*
  Investigated by local law enforcement

- *Noise*
  Investigated by local law enforcement

- *Lights*
  n/a

- *General health complaints*
  Health complaints come second to air complaints (odour and dust)
  Headaches, eye irritation, sinus pain

2. **Investigation Response Approach**
   a. *How are complaint investigations conducted*
   - *Who investigates and when? (all complaints?)*
     TCEQ investigates all reportable incidents (responsible party is required to report exceedances of reportable quantity thresholds within 24 hours) regardless of whether or not there was a complaint.

     Prioritization of complaints is outlined on TCEQ website
     Oil and gas complaints do not get special priority
     There are two things that trigger quick response:
     1. If health effects are being alleged, investigation occurs within 1 working day (immediate response priority)
     2. Expedited response if facility had complaint confirmed (ie odour) within the last 12 months. Would bypass routine priority and investigate within 1 day.

     Environmental Investigator
     qualifications: http://www.tceq.state.tx.us/adminservices/employ/jobs.html)

     Minimum qualifications: A bachelor's degree from an accredited college or university, with a major in a natural or physical science, engineering, environmental studies, or related field. One year of full-time experience in the field of environmental activities directly related to the examples of work performed may be substituted for each year (30 semester hours) of the required education.

   - *Inter-agency collaboration? What are the triggers used to decide when to call upon other agencies/make referrals?*
     Typically do not conduct parallel investigations or collaborate in the actual investigative efforts unless it requires a big emergency response effort.

     But if a complaint comes in and it is not within the TCEQ's jurisdiction, then it would be referred to appropriate agency.
     Complaints for exploration, production, transportation to RRC.
     Odour: TCEQ
     Noise, Dust, Traffic: local law enforcement

Drinking water: suspected contamination of private system from o and g: RRC
Drinking water: suspected contamination of public system: TCEQ

For general health complaints about oil and gas operations, are the local health units ever called upon? Not aware of any collaboration with the health department.

TCEQ does not have jurisdiction over indoor air quality and not too sure if the state or local health departments would look into these issues.

Although, not regulatory, the USGS has conducted some studies on background conditions with the focus on O&G activity. Here is an example (http://pubs.er.usgs.gov/publication/ds836) and I can provide contact information for study participants if needed.

- *Environmental monitoring versus reactive investigation?*
  Used as a resource but it would depend on the specific nature of the complaint.
  If a complainant calls with a very specific concern (like an odour at a particular time/date), the ambient monitoring network data can be accessed and reviewed to try to narrow down a potential source.

  Also allows investigators to use monitoring networks to give background air quality information to help focus when you might want to conduct a complaint investigation, like looking for trends (high readings during a certain time of the day).

- *Equipment (type, who owns it, etc.)*
  Monitoring instruments for air: (all owned by TCEQ)
  Optical/infared gas imaging camera that is very useful for imaging VOCs
  TVA (toxic vapor analyzer) for VOCs
  RAE and Jerome for H_2S
  These instruments can be used to narrow down where a plume is, once plume is identified, a canister (SUMMA) can be used to take a sample which goes to lab for analysis. Results will show what is in the plume and from their public health risks can be assessed.
  Instruments and results are also used to communicate to company where they can focus their maintenance efforts.

  TCEQ has a monitoring division that can respond with mobile monitoring unit – bus is equipped with all sorts of equipment, have ambient air monitoring equipment (gas chromatograph) and investigative equipment at their disposal.

  With respect to water issues, equipment or samples are not typically utilized. Wastewater complaints within the Agency's jurisdiction that water staff have responded to are mostly related to ancillary facilities and are not at the drill site. The complaints tend to revolve around equipment and vehicle wash water being discharged. Typically, it is not necessary for our investigators to collect samples as the discharges can be observed and photographed and/or the entity has admitted to the practice. We have also had a few complaint issues at lease sites, but those are referred to the Railroad Commission of Texas with notice to the complainant.

- *How do you respond to non-specific (vague) issues?*
  All alleged health impacts are responded to within 1 day and investigations are continued until the agency is satisfied that there is not a risk by using all of the above equipment and resources to identify and assess emissions. It can be very difficult to determine is air emissions cause health impacts without knowing pre-existing health conditions, other exposures, etc. Can quickly assess wind direction and whether emissions are typically blowing towards house/residential area.

3. **Results**
   a. *Examples of successful investigations*
   - *Possible reasons why the investigation was successful (clarity of roles and responsibilities, resource needs met, etc.)*
     All health issues are responded to within 1 day and investigations continue until the agency is satisfied that there is not a risk.

     An example of a successful complaint investigation would include a complainant that is willing to assist the investigative process with good communication. The level of detail a complainant provides impacts the success of the investigation. For example, if complainants allege odours being worst at night, timing the investigation for non-routine business hours becomes important. In this case, an investigator may take one or all of the following actions: conduct a night investigation; utilize equipment such as an AreaRae, Toxic Vapor Analyzer, Optical Gas Imaging Camera, and/or SUMMA Canister to monitor downwind of the site; conduct an odour survey of the area; and conduct an on-site survey. Once on-site, the investigator would attempt to identify the emission source(s). Either during or following the investigation, company personnel would be informed of findings so that repairs could be made. Sample results could be used to assess impacts to public health and the environment, and determine the proper level of enforcement.

   b. *Examples of unsuccessful investigations*
   - *Possible reasons why the investigation was unsuccessful (lack of complaint details, not the right equipment, etc.)*
   - *What hasn't worked or what has posed a challenge (i.e. non-disclosure agreements?)*
     In general, when a complainant has an allegation of a concern, like an odour at their home coming from an oil and gas facility and they are frustrated because they are living in it every day and they feel an impact. An investigation is started and TCEQ finds out that the company is properly authorized and has proper controls and they are in full compliance with standards. This poses a challenge to provide good customer service because the complainant is not satisfied with hearing that the company is in compliance. All that can be done at that point is to explain the procedures that were used and the conclusions of the investigation but they are not always satisfied.

     A simple question that gets asked a lot, “Is the air in my neighborhood safe?” Very difficult to answer and use risk communication because the information can often be overwhelming for the general public to use and make decisions. Permit application process involves modeling and all of the rules and regulations are all geared towards protecting public health – this is the mission of the TCEQ.

Anonymous complaints are challenging because the investigator cannot obtain further details by asking follow-up questions. Without the time, date, frequency, and duration of an odour, it can be more difficult to isolate/locate a source. Another challenge is if the alleged source of the complaint is no longer at the site when we arrive (pulling unit, frac job, etc.).

c. *What does the respondent need in their own jurisdictions to help with complaint investigations?*
Needs to effectively respond to an oil and gas complaints:
- Procedures to ensure an appropriate response, therefore, you need a mechanism to get complaint to person responding in a timely manner (website, email, and hotline).
- Established procedure to assess odours.
- Equipment mentioned earlier. At a minimum you need a way to evaluate VOCs (IR Camera TVA). Need to be able to identify plume and assess what's in it by sampling or equipment.
- Ability to contact company quickly. Owner, operator contact info must be posted on signage at facility.
- The more cooperation there is between all parties, including the gas companies, the quicker any issues or problems can be identified and fixed.

d. *Are investigation results communicated to complainants or to the public? How is this accomplished? (aside: if complaint investigated by another agency, are results communicated back to original agency?)*
Tracking the status of a complaint: http://www.tceq.state.tx.us/complaints/waci.html
For every investigation, a letter plus a copy of the investigation report is sent to complainant at the conclusion of the investigation. These describe what was done and what was found.

Reporting helps in the risk communication process and is a benefit to both the complainant and the agency.

In addition to the complainant being able to check the status on website and receiving the investigation report at the conclusion, there is also an expectation that the field staff are in frequent communication with the complainant throughout the entire process, as long as it is not an anonymous complaint. With non-anonymous complaints, complainant's identity is protected.

e. *Have non-specific concerns (as noted in 1. b.) been validated by investigations?*
Yes, investigations have found issues related to public concerns.

4. **Others to contact for interview**
   a. *Oil and Gas Regulator*
   Suggested contacting RRC district offices for details on field investigations.
   b. *Health and/or Environmental Regulator*
   c. *Other Health Agency*
   d. *Other*

APPENDIX F2 – Texas Telephone Survey (Health Regulator)

DATE	May 2, 2016
TIME	1:00pm MST
CONTACT	Health Assessment & Consultation Program Manager
AGENCY	Texas Department of State Health Services

(Note: Questions posed to respondents are italicized and verbal responses are in brown, email responses are in blue)

1. **Background Information**
   a. *General information on their department's role in oil and gas developments*
   - *Regulate/Permit?*
     The TXDSHS does not regulate or permit any activities related to oil and gas development. This is the role of the RRC and TCEQ.

   - *Emergency response planning?*
     n/a

   - *Environmental impact assessments?*
     n/a

   - *Human health risk assessments?*
     TXDSHS has been involved in cancer cluster investigations (different group) and biomonitoring studies related to oil and gas developments.
     Mainly involved in exposure assessments/investigations.

   - *Legislation review/development?*
     The Health Assessment & Consultation Program has not been involved but the Commissioner of Health does go in front of the State Legislature when they ask for information, but unknown if there is anything specific to oil and gas.

   b. *What types of complaints are received most often? What is the nature of these complaints?*
     Complaints received by TXDSHS are not organized by media type.
     Health Assessment & Consultation Program has only been involved in 1 or 2 exposure investigations related to oil and gas. Not getting these complaints come through the TXDSHS. Does not mean there are not health concerns, they may be being handled by other agencies (TCEQ, RRC), depending on what the concerns is.

   - *Air, Water, Soil, Traffic, Noise, Lights*
     Sampling is involved in investigations, like private tap water. However, this is not specific to oil and gas operations.

- *General health complaints*
  The TXDSHS receives a wide variety of general health complaints but statistics and information are only kept with respect to notifiable diseases.
  Cancer cluster investigations are usually a result of concerned citizens who feels like there are too many cancer cases in community and reports concern. TXDSHS can then do an epi investigation.

2. **Investigation Response Approach**
   Since only a couple of investigations are specific to oil and gas, this next section is with respect to general complaints that come to the Health Assessment & Consultation Program.

   a. *How are complaint investigations conducted*
   - *Who investigates and when? (all complaints?)*
     Complaints are received via phone call or email and all complaints are investigated. Complaint is reviewed and researched (if needed) and response back to original complainant within 24 hours.

     The TXDSHS typically gets involved in investigations when there is the potential for a larger community exposure, not individual complaints. However, they typically do not get involved in oil and gas complaints because the operations are usually a far enough distance away from communities that the risk of exposure to any hazards is minimal.

     Expertise:
     - 2 health assessors for the State of Texas. Both have biology/degrees and a lot of experience doing public health investigations on the regulatory side (restaurants, drinking water, asbestos, lead poisoning, etc.)
     - Environmental Health
     - Toxicologist, epidemiologist and medical doctor that are part of a different program but can be pulled into investigation and consulted with if necessary.
     -
   - *Inter-agency collaboration? What are the triggers used to decide when to call upon other agencies/make referrals?*
     TCEQ has made referrals
     USEPA
     OSHA has been involved if occupational exposures have occurred
     Receive information about pesticides (illegal spraying) from Texas Department of Agriculture
     City and County Local Health Departments

   - *Environmental monitoring versus reactive investigation?*
     n/a, TXDSHS does not do any monitoring

   - *Equipment (type, who owns it, etc.)*
     Have contracted out work to a local university that had the equipment and expertise to do indoor air, ambient air and soil gas sampling for a complaint investigation.
     TXDSHS can collect drinking water samples
     Have capabilities to do biomonitoring: requires urine cups, blood sampling, etc.

Depending on the required analysis, different labs are utilized. Have used State Lab, Federal CDC Lab, private labs on occasion.

- *How do you respond to non-specific (vague) issues?*
  Addressed the same way that any other concern or complaint is addressed.

3. **Results**
   a. *Examples of successful investigations*
   - *Possible reasons why the investigation was successful (clarity of roles and responsibilities, resource needs met, etc.)*
     DISH, Texas Biomonitoring Study: Resulted from concerns around exposures to VOCs from a compressor station. This investigation was a success because it filled a data gap. They were able to determine if an exposure was occurring, and if so, at what levels were a health concern. It was successful because all needed resources were available:
     - funding, equipment,
     - personnel to collect samples, personnel to review analytical results and make a health based determination.
     - Lab had methods to analyze components.
     - Current reference information was available: there were previous studies and standards available to compared study participant results to a health based standard.

     Texas has a Toxic Substances Coordinating Committee: Different State agencies meet quarterly. Has State representatives from RRC, fish and wildlife, agriculture that meet to discuss work and any issues, as well as what each agencies roles and responsibilities are. This has been very helpful in that it builds relationships to be able to discuss concerns and figure out who should respond.

   b. *Examples of unsuccessful investigations*
   - *Possible reasons why the investigation was unsuccessful (lack of complaint details, not the right equipment, etc.)*
   - *What hasn't worked or what has posed a challenge (i.e. non-disclosure agreements?)*
     There has not been an unsuccessful investigation with respect to assessing exposure. The TXDSHS has what they need to conduct Health assessments on the complaints they have received. They have always been able to fill a data gap by collecting samples and provide the individuals with the results and an explanation.

     Sometimes not enough information is given by complainant (missing name, number, wrong number) and follow-up with them is difficult. Every effort is made to confirm details but sometimes the person cannot be reached.

   c. *What does the respondent need in their own jurisdictions to help with complaint investigations?*
     Better communication between all stakeholders is always beneficial: getting the right information to the right people as soon as possible.

More studies/knowledge about sampling and results. Example: questions about black tar used to seal payment and PAHs. At the time there was no standard to compare the results to, making them somewhat meaningless/difficult.

d. *Are investigation results communicated to complainants or to the public? How is this accomplished? (aside: if complaint investigated by another agency, are results communicated back to original agency?)*
   All results are communicated depending on situation.
   Exposure investigation (medical confidentiality): responds to original complainant via letter with results and explanation of results.
   Larger community concerns: would hold a public meeting to present findings and answer any questions.
   All documents that can be public record are posted on website.
   Documents are tailored to the audience.

e. *Have non-specific concerns (as noted in 1. b.) been validated by investigations?*
   n/a

4. **Others to contact for interview**
   a. *Oil and Gas Regulator*
   b. *Health and/or Environmental Regulator*
   c. *Other Health Agency*
   d. *Other*

APPENDIX G1 – Pennsylvania Email Survey (Oil and Gas and Environment Regulator)

DATE	Received on March 9, 2016
TIME	Sent via email
CONTACT	Bureau Director, Division of Oil and Gas
AGENCY	Pennsylvania Department of Environmental Protection

(Note: Questions posed to respondents are italicized and email responses are in blue)

Objectives:

- To identify the types of issues health and environment departments respond to in relation to unconventional oil and gas developments.
- To identify methodologies/needs/capacities that are required to be in place to respond appropriately to these issues.

Instructions:

- Please fill in boxes as best as possible.
- If there is a document that can supplement your answer, please provide a web link or name of the document.

1. **Background Information**
   a. *General information on their department's role in oil and gas developments*
      - *Do you Regulate/Permit oil and gas operations? Please expand on this role.*
        Yes. The Office of Oil and Gas Management permits various oil & gas development activities such as well pads, oil & gas wells, and pipeline infrastructure development.

        The Pennsylvania Department of Environmental Protection also is the primary regulator and conducts wide spread inspection efforts, compliance, and enforcement actions for these various development activities.

      - *Are you involved in emergency response planning? Please expand on this role.*
        The Department of Environmental Protection has an active Emergency Response Program. Each of the six Regional DEP office has an Emergency Response Team as well as an Emergency Response Manager. The Bureau of District Oil & Gas Operations does not actively engage in ER planning but we do have Oil & Gas Employees that are members of three regional emergency response teams. The Department requires oil & gas operators to develop and submit emergency response plans to our Central Office Bureau for the operations they are conducting throughout Pennsylvania.

- *Does you department conduct Environmental impact assessments? Environmental Impact Statements? Please expand on this role.*
  The Department issues various permits and authorizations according to current statutes and regulations. Many forms of environmental data and associated technical information are required for these various permits and authorizations. We do not call these data Environmental Impact Assessments but this information provides essential environmental data vital to our permit review process.

- *Does you department conduct Human health risk assessments? Please expand on this role.*
  As part of the complaint investigation process, this role is filled by the Pennsylvania Department of Health. When a citizen makes reference to their personal health, staff refer that individual to the appropriate contact with the Pennsylvania Department of Health.

- *Is your department involved in legislation review and/or development? Please expand on this role.*
  Yes. One of the primary functions of the Central Office Bureau of Planning and Program Management is development of new regulations focusing on oil & gas development activities.

b. *What types of complaints (types are listed below) are received most often by your department? What is the nature of these complaints?*

- *Air*
  The Department of Environmental Protection's Air Quality program responds to air related complaints.

- *Water*
  The Bureau of District Oil & Gas Operations respond to water related complaints that are related to oil & gas activity. Primarily we deal with private water supply complaints and requests for investigations into whether or not private water supplies have been affected or impacted by oil & gas related activity.

  The Department also investigates complaints related to surface water impacts where spills or releases have potentially entered waters of the Commonwealth.

- *Land*
  The Oil & Gas Program also investigates complaints related to land issues. Many of these types of complaints are a result of storm water runoff from well sites or access roads or well site restoration issues.

- *Traffic*
  We do not handle or respond to traffic complaints. These issues can wither be handled by the appropriate municipality or the Pennsylvania Department of Transportation.

- *Noise*
  In Pennsylvania, there are no noise related regulations or statutes that the Department of Environmental Protection routinely enforces. Certain municipalities do have noise related ordinances in place that are enforced at the local level. When field staff respond to noise

related complaints in a jurisdiction that has a noise ordinance in place, we typically coordinate with local codes enforcement officers to address the issue.

- *Lights*
  There are no light related citations in the Oil & Gas related statutes and regulations that the Department of Environmental Protection routinely enforces. The Bureau of District Oil & Gas Operations rarely receives light related complaints.

- *General health complaints*
  When we receive a complaint where a citizen is making claims about their personal health, we refer that individual to the appropriate Pennsylvania Department of Health contact.

2. **Investigation Response Approach**
   a. *How are complaint investigations conducted*
   - *Who investigates and when? (Are all complaints investigated?)*
     All complaints are investigated. The form and degree of response can be highly variable depending on the nature of the complaint and the facts associated with it.

     I would refer you to the document at the link below for complaint response information.
     http://www.elibrary.dep.state.pa.us/dsweb/Get/Document-105828/820-4000-001.pdf

     Our inspectors that conduct investigations have a wide variety of environmental backgrounds. All of our environmental inspectors (Water Quality Specialists) have a bachelors degree in an environmental field as a starting point. All of our Oil & Gas inspectors have several years of industry related experience as a starting point and many also have bachelors degrees in geology or another environmental field. We also employ both environmental engineers and geologists. Some of these individuals participate in certain investigations. Many of these folks have bachelors or masters degrees and are also licensed professionals through the Commonwealth of Pennsylvania.

   - *Does your department collaborate with other agencies/companies to conduct complaint investigations? Who are these other agencies/companies and what are the triggers used to decide when to call upon other agencies or to make referrals?*
     Yes. Depending on the nature and severity of the incident, the Department may collaborate with a variety of other resource and regulatory agencies at the local, state, and federal level as well as the responsible party or their designated contractors. The individual fact pattern associated with each investigation dictates what additional agencies may be involved.

   - *Are the environmental monitoring networks in your state (air and water) used to help with complaint investigations? Please expand on this role.*
     When appropriate, we can use environmental monitoring data to aid in an investigation.

   - *What types of equipment/labs are used to investigate complaints (type, who owns it, etc.).*
     All samples collected by the Department as par tof an investigation are analyzed and processed by the Departments own centrally located accredited laboratory facility. More information on the Department's Bureau of Laboratories can be found here:
     http://www.dep.pa.gov/Business/OtherPrograms/Labs/Pages/default.aspx#.VuAqRxwo5D8

The only samples that the Department does not have the ability or specialized equipment to analyze are Isotopic gas samples.

Currently those samples are analyzed by Isotech Labs.
http://www.isotechlabs.com/

- *How do you respond to non-specific (vague) issues?*
  Typically, we try to inform and educate members of the public to provide them factual information that may be beneficial to the specific issue they are dealing with.

3. **Results**
   a. *Example(s) of successful investigations*
   - *Can you please give an example (general description) of a successful investigation (an investigation that your department deemed successful or complete) and possible reasons why the investigation was successful (clarity of roles and responsibilities, resource needs met, etc.)*
     The Department conducts many hundreds of successful investigations each year. Successful investigations are characterized by prompt response, technically accurate sample and field data collection, expert analysis of the entire body of collected data and associated field information, and swift resolution of any documented impacts or violations.

     For many of our investigations, the Department stresses a 'multiple lines of evidence' approach where many different forms of both field and laboratory data are compiled and analyzed in an effort to make a defensible and credible decision on the investigation.

     Timely communication with any involved citizens regarding the status of the investigation are vital to the process.

   b. *Examples of unsuccessful investigations*
   - *Can you please give an example (general description) of an unsuccessful investigation (an investigation that your department deemed unsuccessful or incomplete) and possible reasons why the investigation was unsuccessful (lack of complaint details, not the right equipment, etc.)*
     The Department does occasionally receive complaints that are vague or that do not produce any credible information during the Department's follow up response. The Department also documents these cases as they may be important if the complainant continues to engage the Department over time.

   - *What hasn't worked or what has posed a challenge to completing investigations (i.e. non-disclosure agreements)*
     All investigations are challenging in some respect. Managing the complaint process and the many forms of data that are collected as part of an investigation require specialized skills and expertise.

   c. *Can you please explain what your jurisdiction feels they need to help improve complaint investigations? (Note: this is a very broad question and could include anything from more human and non-human resources, better studies on oil and gas in relation to public health and the environment, etc.)*

The Department has been working to develop better technology and database functionality to capture a wider range of data that is collected during complaint investigations.

d. *Are investigation results communicated to complainants or to the general public? How is this accomplished? (aside: if complaint investigated by another agency, are results communicated back to original agency that took the complaint?)*
Investigation results are communicated to the original complainant. The Department also responds to a variety of Right to Know Law (RTKL) requests from the public regarding complaints that are filed with the Department. Personal information regarding complainants is redacted when providing this information to the public. The Department has also made a list of water supply complaint investigation letters available to the public on its public website.

e. *Have complaints and non-specific concerns (those noted in 1. b.) been validated by investigations? Please expand*
Complaints have been validated by investigations. An easy example is when a resident notices a change in their water and private water supply and requests an investigation be conducted by the Department. The Department investigates and ultimately makes a determination that the water supply has been impacted by Oil & Gas related activities.

Following up on perceived concerns can sometimes produce important information.

4. **Others to contact for interview**
   a. *Oil and Gas Regulator*
   b. *Health and/or Environmental Regulator*
   c. *Other Health Agency*
   d. *Other*

APPENDIX G2 – Pennsylvania Telephone Survey (Health Regulator)

DATE	February 26, 2016
TIME	8:00am MST
CONTACT	Acting Division Director & Health Assessment Section Chief
CONTACT	Epidemiology Research Associate
AGENCY	Bureau of Epidemiology, Pennsylvania Department of Health

(Note: Questions posed to respondents are italicized and verbal responses are in brown, email responses are in blue)

1. **Background Information**
   a. *General information on their department's role in oil and gas developments*
   - *Regulate/Permit?*
     No, not a regulatory agency, this falls in the hands of the PADEP.

     PADOH is a health advisory agency, roles include consultation with the public and physicians, give advice on health related issues. Do not have regulatory authority to fine operations.

     There are a lot of states where their department of environmental protection and department of health are together under the same umbrella/one agency.

     PA has two separate agencies but both under the government.

   - *Emergency response planning?*
     Have had very few instances that have needed an emergency response.
     If an emergency were to happen, PADOH would not be a first responder, that would be FEMA or other first responders.
     DEP would collect data (i.e. from a spill), share with PADOH and give expert opinion/advice on whether or not there are any health implications on people who live nearby.

   - *Environmental impact assessments?*
     See HHRA response

   - *Human health risk assessments?*
     Yes, it would depend on the situation. These would mainly be conducted if there was a known exposure to a chemical. They would reply on data collection form USEPA or PADEP but would then assess whether there was a human health risk. The document that would be generated from this is called a "Health Consultation."

     Communities have requested a health assessment prior to a potential environmental impact coming to the community but they have never received a request for a community health assessment for new well, like an unconventional gas development. Could potentially be due to the financial gain to the community and property owners. But many communities are split, there is not much middle ground.

- *Legislation review/development?*
  A high level body, the Environmental Quality Board (EQB), meets on a monthly basis and has representation from PADOH (Director, Bureau of Epidemiology) with voting rights. Here the laws that are passed can be reviewed with a health lens.

b. *What types of complaints are received most often? What is the nature of these complaints?*

- *Air*
  Nature of complaints have been changing:

  2008/2009 when Pennsylvania was doing a lot of flaring, there were a lot of air quality concerns raised by the public. It could be quite nauseous. Since that time, regulations have changed. In 2012, flaring no longer permitted except for in certain circumstances when the driller could get a waiver. There have also been other technological advances that have reduced the need for flaring. It is far more desirable to capture natural gas emissions from an economical standpoint.

  Now many complaints are related to odours from compressor stations: upper respiratory, eyes, nose throat irritation, aggravation of asthma and emphysema.

- *Water*
  Water is the number 1, followed by air.
  Biggest complaint is water quality, not quantity. Can also be odours from the water from methane migration.
  Very difficult to substantiate a complaint against a well pad if water becomes contaminated. It is nice if you can do isotope testing (very expensive) but not done routinely by PADEP due to cost. It is done when there is a spill or incident reported by the drillers (self reporting) that water may have been impacted.

- *Soil*
  Are only sometimes involved in land complaints.

- *Traffic*
  Investigated

- *Noise*
  PADEP has a separate division that looks into noise and air quality. Respond to complaints within 24 hours. They do not do routine, regular sampling.

- *Lights*
  A lot of operations go through the night. They have had some complainants send in pictures of how bright the lights can be at night. If a lighting complaint is received, it is usually with a combination of complaints, like noise, odours, nuisance issues.

- *General health complaints*
  Have a grouping of signs and symptoms:
  Skin, rashes are number 1 mainly when there is a water complaint, but also for air concerns.
  Headache
  Nosebleeds

Respiratory
Have received blood tests from concerned individuals. Not as much as they would like because most people do not go to doctor if they have symptoms or their primary care physician does not relate symptoms to potential environmental exposure and does not order test.

2. **Investigation Response Approach**
   a. *How are complaint investigations conducted*
   - *Who investigates and when? (all complaints?)*
     See http://www.health.pa.gov/My%20Health/Environmental%20Health/Pages/default.aspx#.VyG32NQrL4Y for information

     All complaints are received and investigated.

     Complaints come in 3 ways:
     1. Form on website to submit either a health complaint to PADOH or environmental concern directly to PADEP.
     2. Call directly
     3. Referred from PADEP who got the complaint first and during the investigation health concerns were noted.

     Contact takes <24 hours. Urgent matters are responded to promptly, like a dangerous level of chemical or biological water test result. Have a detailed health intake, takes an hour. Sometimes they have gone into the field and sat down with people at their home. It usually takes about 3 weeks to a month to close a case. Standard water test done by PADEP takes 3 weeks. But some can go on for months.

     Expertise within the PADOH:

     - Toxicology
     - Epidemiology
     - Medical doctor
     - Public health
     - Mining engineering
     - Environmental health
     - Health education

   - *Inter-agency collaboration? What are the triggers used to decide when to call upon other agencies/make referrals?*
     PADOH and PADEP often work very closely. They will collaborate on a complaint like noise or dust if it is causing a health issue, like respiratory concerns.

     Have collaborated with the USEPA on a few complaints. Here, the USEPA did some testing and monitoring. The main trigger to ask for assistance is how many people are getting impacted, if there is really strong evidence of contamination/exposure, media involvement. The latest investigation was from a compressor station. The USEPA has very sophisticated monitoring

equipment (E-vans). These can be set up for a period of time to monitor trends. This is a rare occasion and this kind of testing (equipment, labs, people) is incredibly expensive.

Local state health departments that are County based (6 of them in total) and not facilitated with State. They usually help to coordinate investigations but still rely on PADOH for their help to interpret any findings.

There are many independent non-profit stakeholder groups that are geared towards the Marcellus Shale region (NE and SW areas). The PADOH and these stakeholders have shared information between each other. There is a high volume of complaints that can come out of specific regions and one particular group is so well known that sometimes the public reports to them first. From there, the group can point the person or group towards the right resources to help with concern. These groups sometimes do their own monitoring and projects, with the affiliation of the University.

PADOH collaborates with the Universities. e.g. University of Pittsburg, Penn State
PADOH has monthly conference calls with CDPHE. They try to leatn from them, even though their organizational structures are vastly different.

CDC summits were mentioned where several agencies from across the country come together to discuss investigations and other issues around oil and gas development.

- *Environmental monitoring versus reactive investigation?*
  Have an Ambient Air Monitoring Network and Water Monitoring Network in specific areas
  Not really used for complaint investigations as information is limited. Citizens have requested more ambient monitoring but there haven't been any changes to legislation.

- *Equipment (type, who owns it, etc.)*
  Bureau of Epidemiology does not own any equipment. They rely on sister agencies and outside agencies for data collection.

- *How do you respond to non-specific (vague) issues?*
  n/a

3. **Results**
   a. *Examples of successful investigations*
      - *Possible reasons why the investigation was successful (clarity of roles and responsibilities, resource needs met, etc.)*
        Complaint about high barium levels in blood. Began investigation with a phone conversation with concerned individual. Person worked a company that handled shale gas wastes but was not coming into direct contact with products. Person already had blood tested and provided results to PADOH. Levels were within acceptable limits. Toxicologist communicated findings: FAQ sheet on barium from a study done in PA. Referred her to OSHA and they are currently conducting an investigation. No other person in home had problems, so the house was not inspected.

Water complaint from parents with six children, ages 2-11. Extensive health history was taken. Age of home was pre-1978 farm home. Suggested getting blood tested, as lead paint could have been another source. Three children had a high lead level. Although the complaint was related to Marcellus shale and drinking water, their role is also to take care of other environmental risks that are identified or seen. Water tests came back within acceptable limits. EH departments have an advantage in that they can look beyond just the regulatory side of oil and gas development.

For water: Have one of the best toxicologist in the country to help with interpretation of well water results from PADEP or owner of well. Also, will get pre-drilling, drilling, and post-drilling water quality results from the drilling companies (required by state regulations if they are within a certain distance) that can be used as a comparison. Pre-drilling tests are useful for all parties. Team can look at results to see if there are any levels that cause harm or any trends that are being observed.

b. *Examples of unsuccessful investigations*

- *Possible reasons why the investigation was unsuccessful (lack of complaint details, not the right equipment, etc.)*
- *What hasn't worked or what has posed a challenge (i.e. non-disclosure agreements?)*

A public member calls to make a complaint but the motive is not to remedy issues around water, air quality or personal health reasons. Activist groups sometimes call and make is sound like a private complaint. Then group put information on the internet or shared with media that was not truthful and distorted. This can do damage to the trust in the government.

An example was given about regulation of compressor stations. If one operator has >3 stations within a localized area, they have to do cumulative readings that combine all operations. If they only have 1 or 2 then they only need to do single readings. This makes it difficult to get a true cumulative reading for areas with high density of compressor stations. Compressors are offsite of a well pad, but still nearby. When some of these stations start up, they sound like a jet engine.

Even though some complaints are responded to within 24 hours, the issue/problem, like noise or odour could have already dissipated. This can be very frustrating for residents. Would like bigger budget, bigger staff to be able to respond to concerns quicker.

To validate perceived concerns, need the science to continue to improve: more testing where there are more signatures from contaminants. Related to best indicator to use.

c. *What does the respondent need in their own jurisdictions to help with complaint investigations?*
Are limited in the environmental/scientific information that they are given to do an assessment (get lots of water quality results, rarely get air quality results, once in a while will get soil results, and only a handful of blood results). Don't get as many blood results as they would like.

Need resources: Money, people.
Looking to develop a health registry but need more financial support. This would improve surveillance, especially considering the untapped resources in the Marcellus shale and the

possibility of development occurring for >40 more years. Need to start collected data as soon as possible. Have the expertise they need to get this going. PADOH will never be a regulatory/investigative agency linked to the PADEP.

d. *Are investigation results communicated to complainants or to the public? How is this accomplished? (aside: if complaint investigated by another agency, are results communicated back to original agency?)*
Once file is closed, an official response letter is sent with recommendations and any resources that may be helpful for every complaint. There is also telephone communication throughout complaint.
PADEP and PADOH share their responses with each other, except when complainant asks that information not be shared.
PADEP has an oil and gas map on their website, that has every unconventional oil and gas well mapped. You can see which wells have violations and what these violations are. The PADOH would like to use this resource to map health investigations.

e. *Have non-specific concerns (as noted in 1. b.) been validated by investigations?*
Not in every case, vague complaints.
Data often comes back as being within acceptable ranges, but sometimes the complaint information does match the data. Even in these instances a clear cut link or causation can usually not be concluded, as there are grey areas in the science. The DEP has because they have clear regulations and standards to compare data to. One time they were able to write in a response letter that "it appears XYZ caused ABC."

4. **Others to contact for interview**
   a. *Oil and Gas Regulator*
   b. *Health and/or Environmental Regulator*
   c. *Other Health Agency*
   d. *Other*

APPENDIX G3 – Pennsylvania Telephone Survey 1 (Oil and Gas and Environment Regulator)

DATE	April 26, 2016
TIME	9:00am MST
CONTACT	Chief, Division of Compliance & Enforcement
AGENCY	Bureau of Air Quality, Pennsylvania Department of Environmental Protection

(Note: Questions posed to respondents are italicized and verbal responses are in brown, email responses are in blue)

1. **Background Information**
   a. *General information on their department's role in oil and gas developments*
   - *Regulate/Permit?*
     Responsible for permitting oil and gas emissions for midstream activities (called a general permit). If you meet applicability, the general permit is a list of conditions that must be complied with. There are also Federal regulations as well for these operations that include other conditions that also have to be complied with. Mainly, this division deals with unconventional oil and gas through the permitting and inspection of facilities that require the general permit.

     There is a conditional exception for facilities that are not eligible for a general permit. These are typically the drilling sites. If you comply/report with certain items then these facilities can avoid the permitting process.

   - *Emergency response planning?*
     No, there is a separate emergency response program within the PADEP that coordinates the departmental response for each incident.

     There are conditions in the permitting process that outlines what a company needs to do if an emergency (explosion, spill), which is typically a notification.

   - *Environmental impact assessments?*
     Potentially part of the permitting process if there is a major air contamination source (potential or actual large emissions) identified.

   - *Human health risk assessments?*
     Have a air toxics and risk assessment group with the PADEP. But this is usually only utilized if there is a major air contamination source identified.

   - *Legislation review/development?*
     Review Federal air quality regulations to see if program will be impacted.
     Has a section that writes and develops regulations.
     Pennsylvania is part of a group of 13 states called the ozone transport region. All states struggle to comply with the National Ozone Standards (mainly due to transport and other reasons, not oil and gas). These states are required to more stringently regulate VOC and other ozone

precursors. When EPA writes a guideline that affects these states, the ozone transport region jurisdictions need to address this.

b. What types of complaints are received most often? What is the nature of these complaints?
PADEP has a database (for air and water) for all complaints. In the 6 regions there are complaint coordinators. But typically complains are anonymous. Reports can be pulled for each complaint but there isn't a report that is publically available right now with complaint details.

- *Air*
  S. Foster specifically deals with air complaints, not just those related to oil and gas.

  2015: 53 complaints were received pertaining to air quality and unconventional oil and gas development. Majority of these complaints were related to odours. Air quality program also addresses road dust, fugitive dust and fugitive emissions (fugitive meaning anything not coming directly from a stack).

  A large ambient air study (baseline crystalline silica monitoring) was done by the PADEP in an area with significant development. Available from: http://files.dep.state.pa.us/Air/AirQuality/AQPortalFiles/Monitoring%20Topics/Toxic%20Pollutants/Docs/Final_Tunkhannock_Report.pdf.

  There was another ambient air study done related to oil and gas.

- *Water*
  n/a

- *Soil*
  n/a

- *Traffic*
  n/a

- *Noise*
  PADEP does not have any regulations that specifically address noise. Local government entity usually has zoning or other ordinance to control for noise.

- *Lights*
  n/a

- *General health complaints*
  Refer these to PADOH

2. **Investigation Response Approach**
   a. How are complaint investigations conducted
   - *Who investigates and when? (all complaints?)*
     Receive complaints mainly through toll-free hotline or sometimes a direct call comes in. They are then put into the complaint tracking system.

All complaints are investigated in the most appropriate way, including referrals for areas that are not addressed by the bureau of air quality. There are guidelines that outline timeliness for responding to complaints. After complaint is made and further information is gathered, a site visit is conducted to do a visual assessment (take photos, talk to facility operators, review record). Complaint investigations may result in violations and/or enforcement actions and penalties.
Air inspectors, Permitting engineers, and other air field staff are responsible for responding to air complaints. College degrees are required.

- *Inter-agency collaboration? What are the triggers used to decide when to call upon other agencies/make referrals?*
  Collaborate with NACAA (National Association of Clean Air Agencies): Federal regulations impact all state air programs; NACAA consolidates and communicates this information to all states to keep them informed. Great tool to help agencies keep up with numerous updates and changes required by many different levels.
  Make referral to PADOH when health concerns are raised.
  Ozone Transport Region (see above). Trying to coordinate the way air programs are run and ensuring the regulations are similar for similar facilities and pollutants so facilities aren't significantly subject to different requirements in different states.
  ECOS (Environmental Council of the States): like NACAA. Committees made up of State representatives.
  MARAMA (Mid-Atlantic Regional Air Management Association): Collaborative organization made up of 8 states in the area. They give a lot of training.
  NESCOM (Northeast States for Coordinated Air Use Management): PADEP does not belong to this organization but they participate with on other levels.

- *Environmental monitoring versus reactive investigation?*
  Ambient air monitoring network is used to ensure areas are in compliance with the National Ambient Air Quality Standards. Helps to inform where there may be trouble spots with complying with the Standards. Typically is not used to look at an individual contamination source.

- *Equipment (type, who owns it, etc.)*
  FLIR (Forward looking infrared camera): Each of the 6 regions has one.
  Use their own environmental laboratory to submit samples to. Lab also had a mobile analytical unit.
  Can arrange specialized monitoring
  SUMA canisters

- *How do you respond to non-specific (vague) issues?*
  All complaints and concerns are addressed; investigations depend on available credible evidence.

3. **Results** (Referred to Field Inspector)
   a. *Examples of successful investigations*
      - *Possible reasons why the investigation was successful (clarity of roles and responsibilities, resource needs met, etc.)*

A successful complaint investigation would be one where a problem is verified and can address it or to verify that there isn't a problem.

b. *Examples of unsuccessful investigations*
   - *Possible reasons why the investigation was unsuccessful (lack of complaint details, not the right equipment, etc.)*
   - *What hasn't worked or what has posed a challenge (i.e. non-disclosure agreements?)*
     For remote locations, it could be a challenge to get an inspector at the right place at the right time to observe issue.

c. *What does the respondent need in their own jurisdictions to help with complaint investigations?*

d. *Are investigation results communicated to complainants or to the public? How is this accomplished? (aside: if complaint investigated by another agency, are results communicated back to original agency?)*
   Environmental studies like the silica monitoring project are conducted and published on government website.
   Investigation results are always communicated back to complainant.

e. *Have non-specific concerns (as noted in 1. b.) been validated by investigations?*
   Yes, investigations of perceived concerns have resulted in regulatory actions, fines, etc.

4. **Others to contact for interview**
   a. *Oil and Gas Regulator*
      For Section 3, S. Foster is going to ask if one of the two field inspectors that focus solely on oil and gas operations can answer these questions.
   b. *Health and/or Environmental Regulator*
   c. *Other Health Agency*
   d. *Other*

APPENDIX G4 – Pennsylvania Telephone Survey 2 (Oil and Gas and Environment Regulator)

DATE	May 2, 2016
TIME	11:30am MST
CONTACT	M. Beacker
JOB TITLE	Air Quality Specialist
CONTACT	A. Ryder
JOB TITLE	District Supervisor
AGENCY	Bureau of Air Quality, Pennsylvania Department of Environmental Protection

(Note: Questions posed to respondents are italicized and verbal responses are in brown, email responses are in blue)

3. **Results**

a. Examples of successful investigations

- *Possible reasons why the investigation was successful (clarity of roles and responsibilities, resource needs met, etc.)*

  Complaints of dust created from traffic (fugitive dust) have been the number one complaint received by this department. These complaints typically come through the Bureau of Air Quality. These are addressed by contacting both the township where problem is occurring and the oil and gas company. These two entities would then work together to ensure the dust was mitigated through whatever means was decided (sometimes calcium, paving, water). If complainant says the problem has stopped, then the investigation was successful. Or if an inspector went on-site to confirm actions were taken, then investigation was a success. Public may not agree that the investigation was successful.

  Malodour complaint in 2015. Coordinated with an oil and gas water quality specialist to investigate the site. Malodour insights a physical response prompting illness and odours do not. Odour, but not a malodour, was noted on-site. Through the investigation and follow-up with oil and gas program they were able to determine that there was an instance when the dehydrator was flooded and the glycol was burning off in the reboiler, causing a chemical smell. It was a onetime malfunction and they were able to communicate to the complainant what had happened and let them know it would not be an ongoing issue.

  Also receive complaints about diesel idling. PADEP plays a similar role in these investigations as with dust complaints: contact company and go on-site to verify actions.

b. Examples of unsuccessful investigations

- *Possible reasons why the investigation was unsuccessful (lack of complaint details, not the right equipment, etc.)*
- *What hasn't worked or what has posed a challenge (i.e. non-disclosure agreements?)*

  Although a successful malodour complaint is described above, malodours present the greatest challenge (not specific to oil and gas either, they are difficult to investigate regardless of the potential source). These types of complaints are very difficult to successfully resolve because their nature is very subjective and intermittent. This makes it very hard to pinpoint the source or cause. It is sometimes hard to know if it is legitimate concern or not. Odours also have a

tendency to bring out emotions because the range of health effects is large and varies from person to person.

c. *What does the respondent need in their own jurisdictions to help with complaint investigations?* Nothing is needed that would help air quality investigate oil and gas complaints. Are seeing a significant decrease in numbers of complaints and are able to address the ones that they do receive. Most complaints are related to the construction phase of development.

When oil and gas activity began in Pennsylvania, the PADEP, Air Quality, was very proactive in communicating expectations/regulations to oil and gas companies coming into the area, through a letter. So when complaints did come in, it was much easier to get cooperation from oil and gas companies since they already knew expectations.