Promising Data for Public Empowerment: The Making of Data Culture and Water Monitoring Infrastructures in the Marcellus Shale Gas Rush

by

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LIST OF ABBREVIATIONS AND ACRONYMS

3RQ	Three Rivers Quest
ALLARM	Alliance for Aquatic Resource Monitoring
AMD	Acid mine drainage
C-SAW	Consortium for Scientific Assistance to Watersheds
CCC	Coldwater Conservation Corps
CCCC	Concerned Citizens for Cattaraugus County
CCD	County Conservation District
CCJ	Center for Coalfield Justice
CUAHSI	Consortium of Universities for the Advancement of Hydrologic Sciences
CVC	Conemaugh Valley Conservancy
CVMP	Citizens' Volunteer Monitoring Program
EESI	Earth and Environmental Systems Institute
EIA	United States Energy Information Administration
EPCRA	Emergency Planning and Community Right- to-Know Act
EIS	Environmental Information System
GIS	Geographic Information System
GPS	Global Positioning System
HIS	Hydrologic Information System
IWLA	Izaak Walton League of America
KWMN	Keystone Watershed Monitoring Network
LCHA	Love Canal Homeowners Association
NORMS	Naturally Occurring Radioactive Materials
NPSS	New Political Sociology of Science
NY DEC	New York Department of Environmental Conservation
PA DCNR	Pennsylvania Department of Conservation and Natural Resources
PA DEP	Pennsylvania Department of Environmental Protection
PA FBC	Pennsylvania Fish & Boat Commission
PA FBC	Pennsylvania Fish & Boat Commission
PATU	Pennsylvania Council of Trout Unlimited

PEC	Pennsylvania Environmental Council
PGIS	Participatory Geographic Information System
POWR	Pennsylvania Organization for Watersheds & Rivers
QA/QC	Quality Assurance / Quality Control
QUEST	Quality Useful Environmental Study Teams
RWQMN	Remote Water Quality Monitoring Network
STS	Science and Technology Studies
TDS	Total dissolved solids
THMs	Trihalomethanes
TRI	Toxics Release Inventory
DOJ	United States Department of Justice
EPA	United Sates Environmental Protection Agency
USGS	United States Geological Survey
VEMP	Volunteer Environmental Monitoring Panel
WINS	(Allegheny) Watershed Improvement Needs Coalition
WQN	Water Quality Network
WVU	West Virginia University
WVWRI	West Virginia Water Research Institute

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ABSTRACT

A recent wave of advanced technologies for collecting and interpreting data offer new opportunities for laypeople to contribute to environmental monitoring science. This dissertation examines the conditions in which building knowledge infrastructures and embracing data "cultures" empowers and disempowers communities to challenge polluting industries. The processes and technologies of data cultures give people new capacities to understand their world, and to formulate powerful scientific arguments. However, data cultures also make many aspects of social life invisible, and elevate quantitative objective analysis over situated, subjective observation. This study finds that data cultures can empower communities when concerned citizens are equal contributors to research partnerships; ones that enable them to advocate for more nuanced data cultures permitting of structural critiques of status-quo environmental governance.

These arguments are developed through an ethnographic study of participatory watershed monitoring projects that seek to document the impacts of shale gas extraction in Pennsylvania, New York, and West Virginia. Energy companies are drilling for natural gas using highly controversial methods of extraction known as hydraulic fracturing. Growing evidence suggests that nearby watersheds can be impacted by a myriad of extraction related problems including seepage from damaged gas well casing, improper waste disposal, trucking accidents, and the underground migration of hydraulic fracking fluids. In response to these risks, numerous organizations are coordinating and carrying out participatory water monitoring efforts.

All of these projects embrace data culture in different ways. Each monitoring project has furthermore constructed its own unique infrastructure to support the sharing,

aggregation, and analysis of environmental data. Differences in data culture investments and infrastructure building make some projects more effective than others in empowering affected communities. Four key aspects of these infrastructures are consequential to data culture formations and affordances: 1) the development of standardized monitoring protocols, 2) the politics of data collection technologies, 3) the frictions of database management systems, and 4) the power dynamics of organizational partnerships that come together around water monitoring efforts. Lessons from this analysis should inform future efforts to build infrastructures that address problems of environmental pollution in ways that also generate long-term capacity for empowering at-risk communities.

1. INTRODUCTION

"Mankind has gone very far into an artificial world of his own creation. He has sought to insulate himself, in his cities of steel and concrete, from the realities of earth and water and the growing seed. Intoxicated with a sense of his own power, he seems to be going farther and farther into more experiments for the destruction of himself and his world. There is certainly no single remedy for this condition and I am offering no panacea. But it seems reasonable to believe—and I do believe—that the more clearly we can focus our attention on the wonders and realities of the universe about us, the less taste we shall have for the destruction of our race. Wonder and humility are wholesome emotions, and they do not exist side by side with a lust for destruction."

- Rachel Carson

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Across the United States, energy companies are drilling for natural gas using highly controversial methods of extraction known as hydraulic fracturing. Growing evidence suggests that nearby watersheds can be impacted by a myriad of extraction related problems including seepage from damaged gas well casing, improper waste disposal, trucking accidents, and underground migration of hydraulic fracking fluids. In the Marcellus Shale, one of the most active drilling formations in the country, nongovernmental environmental advocacy groups have developed surface water monitoring programs to assess potential changes in water quality that might result from shale gas extraction.

Portions of this chapter previously appeared as: Jalbert, K. (2015a). Fracking in the Coalfields: Community-Based Monitoring in Greene County, PA. *The FracTracker Alliance*. Retrieved July 27, 2015, from http://www.fractracker.org/projects/water-monitor/fracking-coalfields/

In the broadest sense, *Promising Data for Public Empowerment* is a study of civic science—a science enacted by grassroots community groups, political advocacy organizations, academic researchers, and private foundations (Fortun & Fortun, 2005). In the context of this dissertation, civic science denotes science done outside the walls of regulatory institutions. Civic science is also the umbrella under which different formations of citizen science live. Citizen science designates a science in which nonprofessionals are enlisted to collect scientific data. These efforts can range from projects driven by academic researchers to those established independently by grassroots environmental groups. *Promising Data for Public Empowerment* focuses in on citizen science efforts that materialize in the realm of civic science. In particular, projects that emerge to forward the needs of the Marcellus Shale water monitoring community.

In the literature on citizen science and environmental justice, scholars argue that grassroots environmental movements can alter the balance of power between lay citizens, regulators, and scientists. However, recent studies also suggest that concerned citizens are not necessarily empowered simply by having access to sophisticated monitoring tools, or by aggregating large pools of data, as many who are involved in these projects assume. *Promising Data for Public Empowerment* builds on this work to explore the complexity of claims that citizen engagement in environmental monitoring naturally leads to public empowerment. This study interrogates a contradiction that exists where proponents of citizen science emphasize the value of local perspectives on environmental risk while also investing in data "cultures" that prioritizes the production of quantifiable data. Most often these decisions are being made in order to appeal to scientific experts and regulators. However, such choices can come at a cost when also trying to use data to address politically situated concerns.

The relationship of data cultures to empowerment is explored in this dissertation by analyzing the ways that people participate in environmental science. In particular, this dissertation looks at the practices of nongovernmental water monitoring efforts in the Marcellus Shale. The dissertation identifies four dimensions of "knowledge infrastructures" that support water monitoring research: standardized data collection protocols, data collection technologies, database management systems, and the organizational partnerships that come together around environmental monitoring efforts.

I disentangled the problems of promising data for public empowerment by asking four important questions. First, what are the discursive contexts in which data cultures influence monitoring practices? Second, how do different stakeholders imagine the affordances of data cultures for the future of watershed protection? Third, how does each of the four components of citizen science water monitoring infrastructures fortify the logics of different data cultures? And fourth, how can data cultures that shape these infrastructures be constructed in a way so that it empowers, rather than disempowers, communities investing resources in water monitoring?

To answer these questions I build on recent STS research pointing to the likelihood that nongovernmental environmental monitoring movements are unlikely to shift scientific thinking or regulatory oversight simply by amassing data on the health of their communities. I look closer at this realization by drawing on STS investigations into the applications of appropriate technologies, as well as into the participation structures that emerge from citizen environmental monitoring. Literature from the information sciences informs the project by probing the costs and benefits of data management systems that pull together stakeholders with different kinds of data and expertise. Finally, studies in critical geography are used to assess dimensions of empowerment and disempowerment revealed by this dissertation research. In total, the contributions of this dissertation offer a much-needed application of scholarship at the intersection of these fields in an empirically grounded ethnographic study.

1.1 The Risks of Shale Gas Extraction

The Marcellus Shale is a sedimentary rock layer created during the Devonian geological period over 350 million years ago. It is the largest shale formation in the US, lying at depths of 4,000 to 8,500 ft. below what is the present-day Appalachian Mountain chain. It's range covers nearly 95,000 underground square miles stretching across southern New York, much of Pennsylvania, eastern Ohio, West Virginia, and northwest Maryland (Ground Water Protection Council, 2009).

The US Geological Survey (USGS) estimated that the Marcellus Shale might contain as much as 85,000 billion cubic feet of recoverable natural gas, and nearly 3,500 million barrels of liquid gas. These vast energy resources are fueling a wave resource development often touted as a new era of US energy independence. As of 2013, the US Energy Information Administration (EIA) reported that shale gas extraction had surpassed all other sources of gas production in the US. Nearly 80% of this new shale gas came from four states: Texas, Pennsylvania, Louisiana, and Arkansas. At present, the

Marcellus Shale produces more cubic feet of gas per day than any other formation in the US (Figure 1).

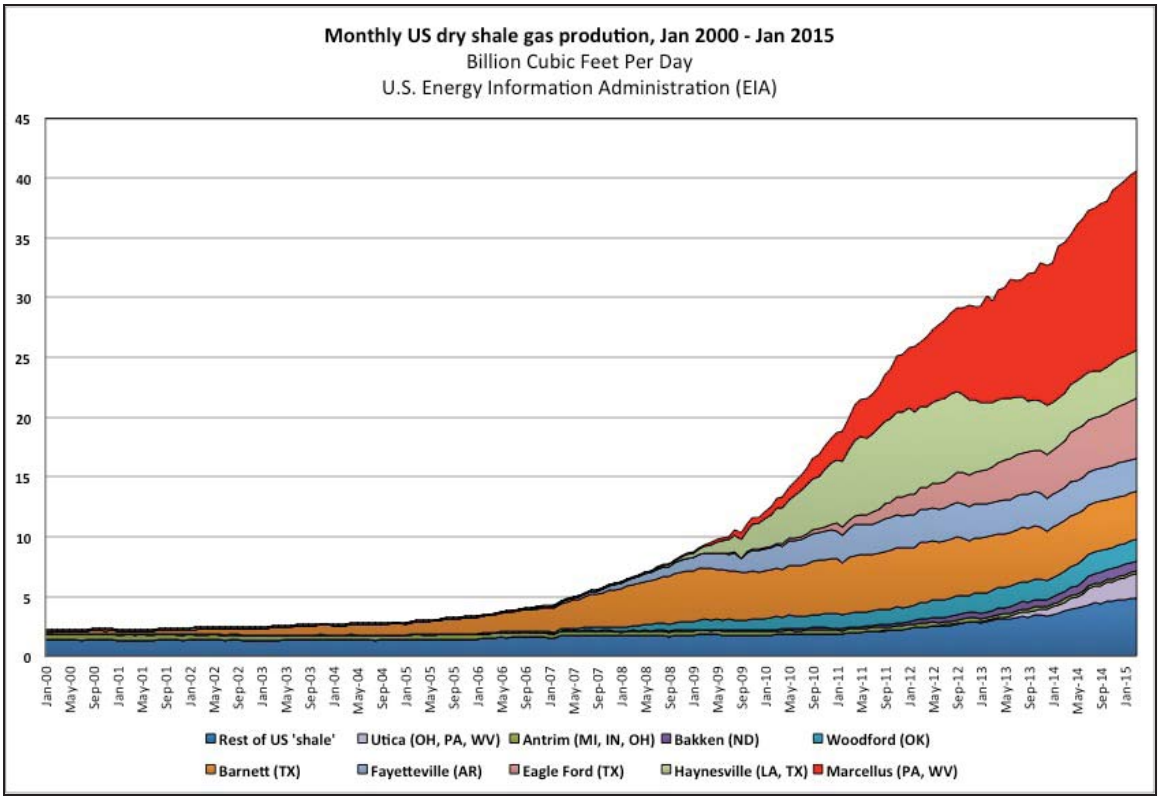

Figure 1. Marcellus Shale production (in red) compared to other shale plays in the US[1]

Geologists have known for decades that shale formations contained extensive gas deposits, but the technologies needed to retrieve trapped shale gas only became commercially available in recent years. Traditionally, gas wells are drilled using "conventional" methods, where operators drilled vertically a few thousand feet into the subsurface to release pooled pockets of oil and gas. Drilling for shale gas, however, is

[1] Chart generated using data obtained from the US Energy Information Agency. Retrieved July 27, 2015, from http://www.eia.gov/petroleum/drilling/

very different from what occurs at a conventional well site. “Directional drilling” technologies now allow operators to send their drilling bits vertically as well as horizontally to follow the contours of particular rock formations. “Unconventional” drilled horizontal wells can reach as far as two miles in any direction, also making it easier to concentrate multiple wellheads at a single location (US Energy Information Agency, 1993) (Figure 2).

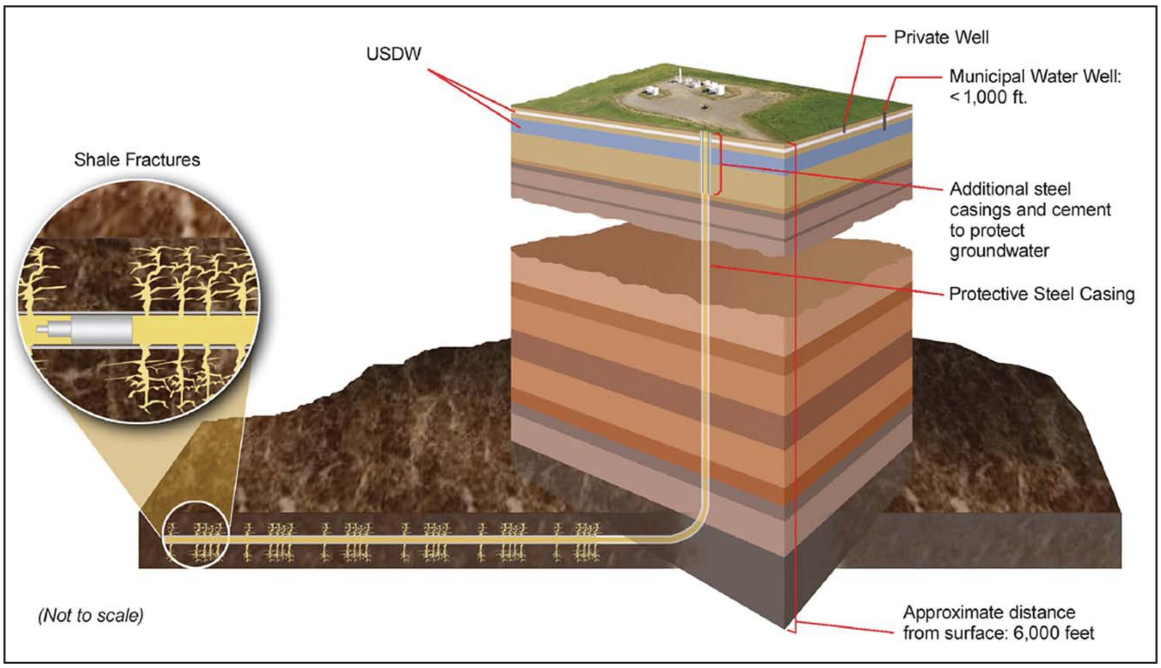

Figure 2. A horizontally drilled gas well, illustrated by the US Department of Energy[2]

Range Resources was the first company to drill horizontally in the Marcellus Shale beginning in 2005 (US Energy Information Agency, 2013). Some well pads in the Marcellus Shale are now known to have as many as 10 wellheads per pad (Figure 3). The

[2] Image included under fair use licensing, obtained from the US Department of Energy. Retrieved July 27, 2015, from http://energy.gov/fe/hydraulic-fracturing-technology

ability to concentrate numerous wellheads on a one drilling site is viewed by the industry as beneficial for minimizing surface level impacts compared to traditional drilling methods. However, the combined footprint of a multiple wellhead drilling site can extent to nearly 10 acres, posing many challenges for private landowners (McGowan, 2011).

Figure 3. A West Virginia shale gas well pad with 8 wellheads

But differences in drilling methods are only part of the story with shale gas extraction. The second major technology ushering forth the shale gas revolution is hydraulic fracturing, often referred to as hydrofracking. Hydrofracking involves the high-pressure injection of water, chemicals, and sand into a well to open new fractures and release trapped gas from shale rock formations. As much as 2.8 million gallons of water can be used to frack a single well. A well may be fracked again numerous times in the future to re-stimulate trapped gas (Figure 4).

Figure 4. A network of pumps hydrofack a well in West Virginia

Although the precise contents of fracking fluids are largely unknown due to the industry's protection of its commercial processes, substances are known to include surfactants, friction reducers, biocides, and corrosion inhibitors (Vidic, Brantley, Vandenbossche, Yoxtheimer, & Abad, 2013). Recently revealed industry documents show that some mixtures contain traces of kerosene, benzene, toluene, xylene, diesel fuel, and formaldehyde (Steinzor, Subra, & Sumi, 2013).[3]

In addition to industrial pollutants, wastewater that returns to the surface can be extremely salty due to the Marcellus Shale being an ancient underground seabed. Compared to freshwater's total dissolved solids (TDS) ratio (a measure of water salinity) of roughly 5,000 ppm, fracking wastewater's TDS can be as high as 100,000 ppm. Other elements that can come up from the shale bed with flowback wastewater can include heavy metals, barium, strontium, and radionuclides such as uranium, radium and radon. These radionuclides are referred to as NORMs, or naturally occurring radioactive materials (Ground Water Protection Council, 2009).

Proper disposal of flowback wastewater is therefore a major concern for those living in shale gas extraction communities. However, many of the chemicals used by drilling companies are not regulated by the U.S. Safe Drinking Water Act, or the Clean Water Act, or were made exempt from these regulations in what many call the 2005 Energy Policy Act's "Halliburton Loophole" introduced by the then US vice-president, and former Halliburton CEO, Dick Cheney (Soraghan, 2011). Halliburton happens to be the leading service provider and manufacturer of shale gas extraction equipment in the world, and was the first company to successfully frack a well in 1949 (Montgomery & Smith, 2010).

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[3] Some states have approached this issue by requiring the gas industry to report the chemicals they use through projects like FracFocus.org. The logic of this method is derived from success stories of similar industry databases such as the Toxic Release Inventory. However, whereas the TRI is a government run system, the Groundwater Protection Council and the Interstate Oil and Gas Compact Commission oversee FracFrocus.org. Furthermore, in many states, gas companies report their chemical uses on a voluntary basis.

Another major concern related to hydraulic fracturing is the risk of unrecovered fluids used in the drilling process. While the amount of "flowback" wastewater recovered from a hydraulic fracturing operation varies by shale play, on average only 30% of fluids injected into the ground are recovered from a typical well drilled in the Marcellus Shale. The remaining 70% remains trapped underground (Ziemkiewicz, Quaranta, & McCawley, 2014). Unrecovered fluids can migrate through existing or industry-made fractures into aquifers, private drinking wells, and eventually into neighboring streams, lakes, and rivers.

1.2 A Scientized Response to Pollution Threats

As the gas industry expanded across the Marcellus Shale, a number of prominent pollution incidents alerted residents to the potential risks of shale gas extraction. One of the earliest and most significant events was the Dunkard Creek fish kill. Dunkard Creek winds along the Southern Pennsylvania border of West Virginia through some of the densest coal and natural gas mining fields in the United States. In 2009, watershed specialists in the region were alarmed to discover the creek, claiming one of the most diverse ecosystems of the Monongahela River watershed, had suffered a massive and devastating fish kill. Some studies estimate that nearly 20,000 fish and other aquatic species were lost in the ecological disaster that may take decades to reclaim.

In 2011, the US Environmental Protection Agency (EPA) determined that an invasion of golden algae was to blame, caused by stagnant rivers from lack of rainfall, excessive water withdrawals for energy extraction processes, and unchecked discharges of acid mine drainage (AMD) from legacy coal mines. CONSOL Energy, the predominant coal company in southwestern Pennsylvania, ultimately agreed to pay $5.5 million, limit their water use, and build a better AMD treatment facility (Federman, 2012).

However, some residents living along Dunkard Creek, as well as a few outspoken scientists, suspected a more sinister chain of events was to blame. Golden algae only thrive in highly brackish waters. TDS levels in Dunkard Creek registered nearly 100 times higher than would be associated with AMD waste, even during periods of extremely low water. But these measurements were very characteristic of wastewater produced in the processes of hydraulic fracturing. Many believed these waste fluids were illegally dumped into abandoned mines or active mining waste pits, and subsequently migrated into their watershed. The true cause of the fish kill continues to be disputed today.

Following the high profile Dunkard Creek fish kill, a rapid series of news headlines featured spills at drilling sites, well pad blowouts, accidents involving trucks hauling fracking chemicals, and illegal midnight dumping into local streams (Donlin, 2010; Puko, 2010; S. Wilson, 2009). Stories of groundwater contamination emerged from Dimock, Pennsylvania, and featured heavily in the popular documentary film *Gasland*.[4] The city of Pittsburgh's Water and Sewer Authority found high concentrations of trihalomethanes (THMs) in drinking water supply intakes—a carcinogenic byproduct of bromide interacting with organic matter in chlorination processes. Sources of bromide

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[4] Information about the *Gasland* is available at http://www.hbo.com/documentaries/gasland (Last accessed July 27, 2015).

were later traced to poorly equipped upstream treatment plants accepting fracking wastewater along the Allegheny River (Brantley et al., 2014).

A number of efforts managed by federal, state, and local government agencies were in place to monitor surface water quality during these years. However, due to shrinking resources in these agencies over recent decades, the overall capacity to track water quality had failed to keep pace with the rapid rise of the industry. Some estimates calculate the Pennsylvania Department of Environmental Protection's (PA DEP) general fund had been cut by nearly 30% from 2002 to 2011 (PA Environmental Digest, 2011). Meanwhile, more than 7,000 unconventional gas wells were drilled in Pennsylvania between 2004 and 2013. Similar trends were found in neighboring states of West Virginia, and Ohio. Strained regulatory programs focused their limited resources on monitoring major water bodies, leaving the vast majority of smaller tributaries—where most shale gas drilling occurred—relatively unchecked.

Environmental disasters like the Dunkard Creek fish kill became rallying points for concerned citizens living in the Marcellus Shale. They are also fundamental to the origin story of the nongovernmental water monitoring community. Following these pollution incidents, many people went looking for reliable information to fight back against a new industry sweeping the region. Representatives from environmental advocacy groups recalled, in my interviews, having to field hundreds of phone calls from residents who were concerned about threats to their personal health and environment and noticeable absence of regulatory oversight.

One form of response that emerged from the confusion began in 2009. A number of service providers, who had worked with community-based water monitoring groups in the past, developed new protocols specific to tracking shale gas pollution. Training programs were organized to propagate standard practices and to establish larger monitoring networks. Private foundations offered grants to purchase more monitoring equipment and to build complex data management systems. Meanwhile, academic researchers became interested in working with this growing monitoring community to do long-term, watershed-wide ecological assessments.

Proponents of the growing nongovernmental monitoring community emphasized the value and importance of local environmental knowledge. Claims that individuals and communities could be empowered by participating in water monitoring programs were abundant. However, those who designed these monitoring programs also magnified the importance of adopting protocols and technologies that would produce science built on objective data. This "culture" of data was fed by a desire to gain the respect of watershed experts and regulators who controlled discussions about proper environmental governance.

While nongovernmental water monitoring efforts have been active in the region since the early 1970s, this groundswell of new monitoring activities in response to shale gas development was significant. In only five years, the field matured from a dispersed collection of site-specific efforts into a diverse infrastructure of organizations and technologies (Figure 5). As the water monitoring community continued to build alliances, accumulate resources, and develop expertise believed necessary for filling gaps in—or questioning of—regulatory science, this data culture proliferated.

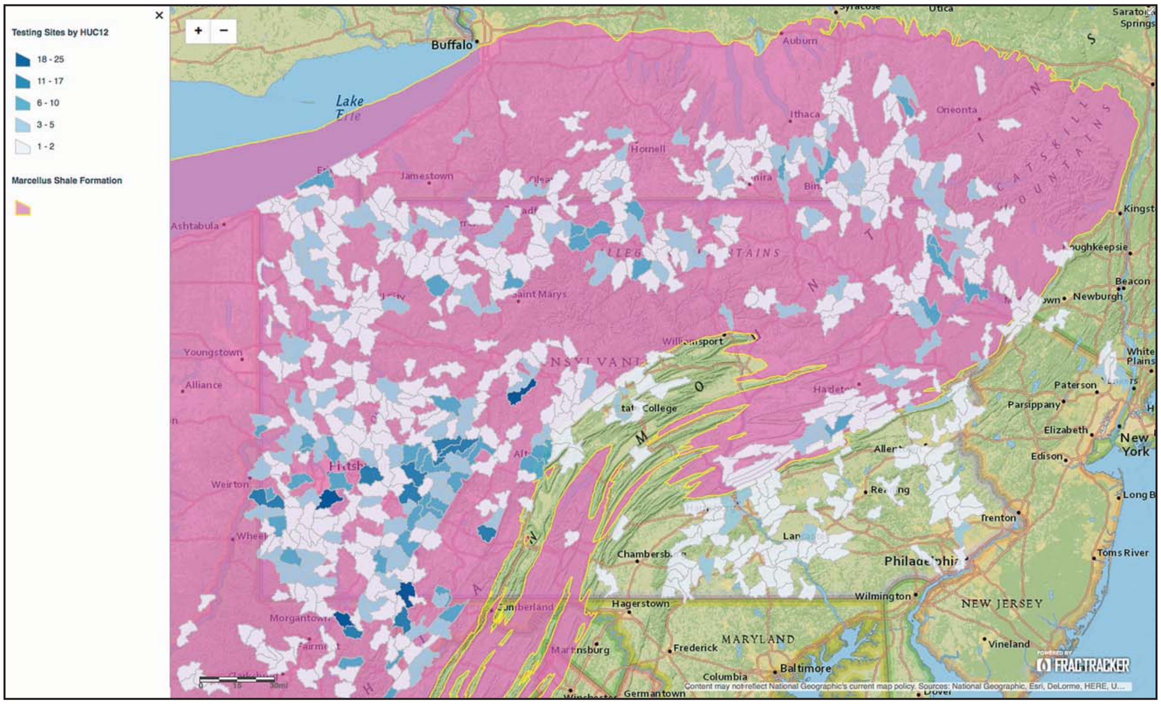

Figure 5. Watersheds in West Virginia, Pennsylvania and New York monitored by civil society organizations as of January 2015[5]

In this study, I find that data cultures are distinct from more broadly conceived scientific cultures in that they create the settings necessary for stakeholders to gather, manage, and utilize knowledge in ways that make sense across diverse communities of scientific practice. Data cultures give people new capacities to understand their world and to formulate powerful scientific arguments. They furthermore make possible the conditions for managing knowledge in anticipation of future scientific questions unknown to those collecting data in the present. In these ways, data cultures provide many "critical" tools to the water monitoring community—data consciousness, data

[5] This map was generated using data from the Watershed Knowledge Mapping Project and from data collected for this dissertation. It appears in the FracTracker Alliance's Knowing Our Waters Project, retrieved July 27, 2015, from http://www.fractracker.org/projects/water-monitor

literacy, and data “wisdom”—that cut through the tropes of “more data is better data” and other simplified assertions about science.

However, I also find that data cultures, when narrowed by decisions to use overly quantifying protocols and technologies, have made many aspects of social life invisible. Narrowed constructs of “data” can exclude situated, subjective, and perceptive observations that might afford other kinds of environmental understandings. Data cultures can therefore have both empowering and disempowering qualities depending on the logics that create them.

This dissertation illustrates how the qualities of data cultures are deeply bound to infrastructures assembled to do scientific research and, by extension, how these infrastructure empower and disempower those who invest in environmental monitoring work. This study also shows that participants in collaborative research programs can advocate for more nuanced data cultures, ones that account for a diversity of knowledge. Ultimately, I argue that multifaceted data cultures allow for structural critiques of status-quo environmental assessments of polluting industries, and it is these orientations around scientific data that bring long-term capacity for empowering at-risk communities.

1.3 Research Methods

To understand the complexities of promising data for public empowerment, the dissertation drew upon a number of distinct research methods at different phases of the research. Its early stages employed “field studies” methods, inspired by those working in the new political sociology of science (NPSS). For NPSS researchers, a field studies approach to studying scientific communities illuminates the everyday engagements "connecting science and science policy to political, economic, educational, and other fields and on the *institutional logics* of scientific fields that pattern expert discourses, practices, and knowledge and shape relations of the scientific field to the rest of the world" (D. J. Hess & Frickel, 2014, p. 1). Field studies methods were used heavily during preliminary fieldwork conducted from 2011 to 2013 as research assistant for Professor Abby Kinchy's Watershed Knowledge Mapping Project. These methods helped to characterize the makeup of the water monitoring community.

A few important findings emerged from these early years that set the foundation for this study. First, monitoring groups were shown to have wide variations in their technical practices. Second, observations of service providers revealed many contentious discussions about how to manage increasing complicated data. Third, trends across the field pointed to a major shift in how monitoring groups were beginning to collaborate and streamline their practices to find a common means to bring their data to the public. Finally, an emerging family of data management projects was quickly changing the character of the field. These trends all pointed to growing tensions amongst the water monitoring community about how their data should be used and what it should represent. In many ways, these observations pointed to a field coming into maturity and now reflecting upon what exactly it had created—a field in the midst of an existential crisis.

In its middle stages, the study became deeply ethnographic in the vein of multi-sited anthropological engagements with science studies. It borrowed from George Marcus' (Marcus, 1995a) considerations of the many tactics of multi-sited research where answers can be found by "putting questions to an emergent object of study whose contours, sites, and relationships are not known beforehand, but are themselves a contribution of making an account that has different, complexly connected real-world sites of investigation" (p. 102). For Marcus, multi-sited research can be contoured around the people, the things, the metaphors, or the conflicts. My objective in executing this phase of the dissertation was to encircle data cultures by spanning their multiple emergences (standards, technologies, databases, partnership alliances) through an observational study of intersecting water monitoring efforts. During this phase I relocated to Pittsburgh, Pennsylvania, to immerse myself in the research and would remain there for more than two years.

Near the end of the study, I adopted engaged research practices common to the field of community-based participatory research (Minkler, Vásquez, Tajik, & Petersen, 2008). I did this by establishing myself as a resource for groups working to understand the effects of data culture. Engaged research provided a deeper understanding of the issues at hand more than any other employed method. It also opened doors to bring the knowledge acquired in this study back to my interlocutors and to inform technical practices in the water monitoring community.

1.3.1 A Visual Perspective

As a final note to the methods used in tis study, it is worth commenting on the many inclusions of visual images dispersed throughout the dissertation. Visual anthropologist Sarah Pink asks the question, "Why, if the visual is so central to everyday narratives and provides us with such great opportunities to evoke something of the sensory embodied experiences of research, does so much ethnographic research rely on aural narratives, or written accounts of people's multisensory experiences?" (Pink, 2008, p. 135). Why indeed.

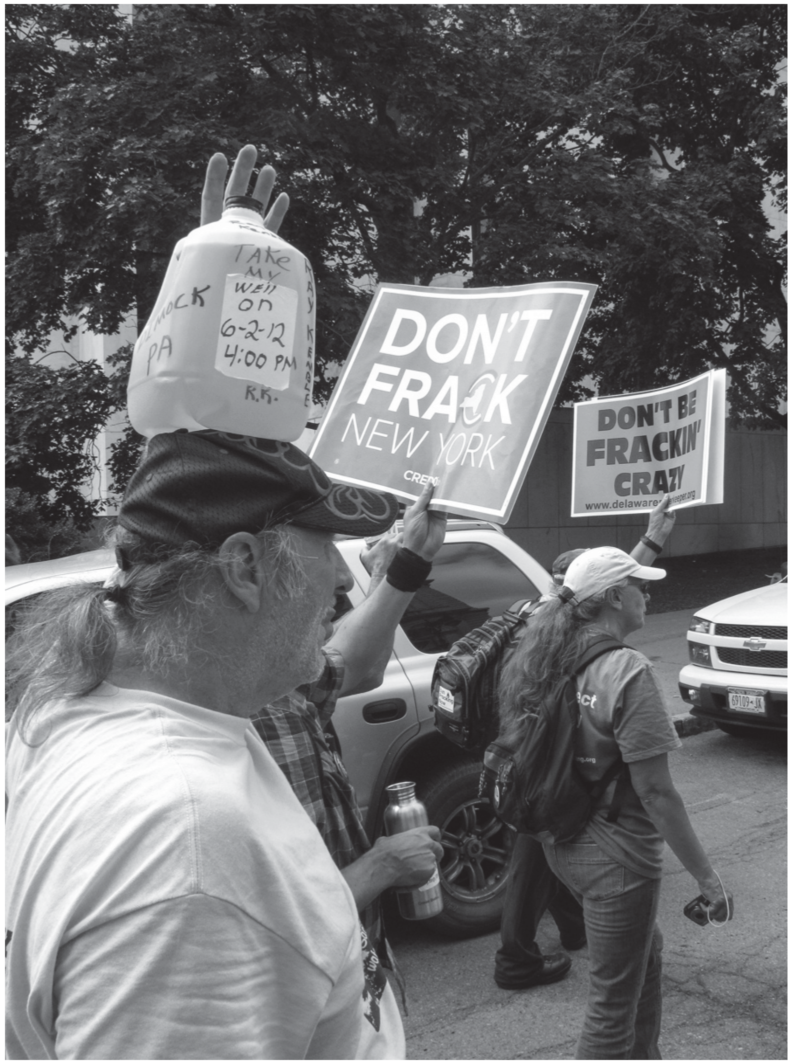

Figure 6. Anti-fracking protesters at a 2012 rally in Albany, New York

Visual documentations are an important method for relating data collected in this study to the reader. The photographs make the dilemmas the water monitoring community deals with more human and serve to draw out the complexities of material presented in textual form. These photographs included here are only vignettes of a larger collection of work that has appeared in community monitoring newsletters, published articles, and elsewhere. I hope that these images contribute to the historical archive and give future readers a window into the lives of those who struggled with some of the most challenging issues of our time (Figure 6). Prior to coming to the social sciences I was a documentary photographer for more than ten years. Many of the pseudonyms used in this dissertation hint to artists who have influenced my work.

1.4 Field Sites

Field sites for this study were selected such that they would reveal the four dimensions of knowledge infrastructures that support water monitoring research: standardized protocols, data collection technologies, database management systems, and organizational partnerships. In each of these cases, the "emergent objects" of study in these spaces were both social and technical in nature. For instance, service providers and academic researchers are critical in supporting the water monitoring community. They are also instrumental in shaping what kinds of data citizen science monitoring networks collect, what technologies they deploy, and how their data will be used. As such, service providers were important field sites for this study.

This dissertation also attempts to represent the diversity of monitoring groups in the field. Some of these efforts are managed by a centralized organization that acquires resources and establishes outside assistance on behalf of its network's members. Other efforts derive from coalitions of many smaller organizations that pool their knowledge and resources. Others still are only a single organization operating with relative independence. Field sites were chosen in order to understand water monitoring activities across this spectrum.

Finally, field sites for the dissertation were selected in order to shed light on the spaces where data collection technologies and data management systems are developed. In many instances, these field sites mirrored where I studied service providers and academic researchers. However, "following" the technologies also lead in unexpected directions. For instance, nonprofessional groups were also found to have a significant hand in influencing data collection and data management technologies.

1.4.1 Service Providers and Supporting Organizations

The primary service provider featured in this study is the Alliance for Aquatic Resource Monitoring (ALLARM), based at Dickinson College in Carlisle, PA. ALLARM has a long history within the Pennsylvania water monitoring community since it began offering training support for acid rain monitoring in 1986. ALLARM rapidly shifted its programming in 2009 in response to the encroaching gas industry and developed its "Marcellus Shale Volunteer Monitoring Manual." This monitoring protocol was vetted by contacts in regulatory agencies with which ALLARM had developed long-standing relationships. Since 2010, ALLARM has trained nearly 700 volunteers throughout Pennsylvania, New York, and West Virginia. Meanwhile, their monitoring protocol has become a key reference for many of the watershed protection groups throughout the region.

Another service provider highlighted in this study is Three Rivers Quest (3RQ), based at West Virginia University's Water Research Institute (WVWRI). 3RQ is the result of a major grant awarded in June 2011 by the Colcom Foundation to expand the Institute's support for water monitoring into the Allegheny, Monongahela, and Upper Ohio River watersheds of West Virginia, Pennsylvania and Ohio.

Organizations like ALLARM and 3RQ are used as focal points in this study to reveal the social relations and technical practices that shape data cultures in the Marcellus Shale water monitoring community. Service providers play a significant role in determining the partnership structures of water monitoring networks, which are found to lie along a spectrum of bottom-up grassroots driven efforts and top-down academic led researcher programs. Service providers also play a key role as mediators between nonprofessional monitoring networks and regulatory agencies when determining how to navigate the expectations of watershed experts. As such, service providers must often make compromises between guiding monitoring networks into data-centric practices for doing "professional" science, and those that might provide tools more in-line with community-based research.

1.4.2 Monitoring Organizations and Networks

Numerous monitoring organizations and networks are mentioned in this dissertation, however a few are featured in great detail. One monitoring larger network featured in this study is the NY Water Sentinels, a subprogram of the Sierra Club's Atlantic Chapter, which began mobilized monitoring volunteers in 2011. The NY Water Sentinels now have over 150 volunteers monitoring in thirteen counties throughout the

Southern Tier of NY State. The NY Water Sentinels are the most explicit example in this dissertation of a monitoring network built from the ground up, and illustrates how concerned citizens can retain a high degree of agency in determining how resources in their monitoring network are applied to address issue that concern them.

The Harry Enstrom Chapter of the Izaak Walton League of America, located in rural Southwestern Pennsylvania's Greene County, manages a second monitoring effort featured in this study. Unlike the more expansive networks, the Harry Enstrom Chapter is the only chapter in the IWLA monitoring for shale gas impacts. The story of the IWLA is quite different from other monitoring efforts featured in this dissertation because of their willingness to take advocacy positions through the practices of water monitoring. The IWLA is used in this study as a counter-argument to assertions that influencing environmental decision-making requires data cultures devoid of political advocacy.

A third monitoring network important to the research is the Pennsylvania Chapter of Trout Unlimited (PATU), a state-level branch of the nation-wide Trout Unlimited advocacy organization. The primary mission of PATU is to serve their member base of sporting enthusiasts by protecting high-quality fishing habitats in thousands of minor tributaries of Pennsylvania's six large watersheds. PATU oversees 50 local chapters and 12,000 members across the state. A number of chapters began water monitoring in 2010 as part of their Coldwater Conservation Corps (CCC). While the PATU are not featured in their own case study in the dissertation, observing the PATU revealed a great deal of information about how the Marcellus Shale monitoring community works.

1.4.3 The Many Technologies of Water Monitoring

STS scholars are quick to note that no technology is neutral. Each is the manifestation of social and political forces that can have long-lasting effects. In other words, technologies have their own politics and agencies based on who build them (Feenberg, 1999; Latour, 2009; Winner, 1980, 1986). Such is the case with the technologies used for gathering water monitoring data and making sense of it. Different types of technologies are rapidly shaping the character of the Marcellus Shale water monitoring community. The first are the technologies of data collection, which begin with the standardized protocols that define what, when, and where water quality data will be gathered. The politics that inform the processes of writing protocols determine what kinds of knowledge monitoring programs will produce. Protocols are therefore the foundations of data cultures.

In addition to focusing on the importance of standardized protocols, this study concentrates on the physical technologies of water monitoring. In some instances volunteers are deployed with handheld, manually operated monitoring equipment. In other instances, monitoring groups have obtained sophisticated data loggers to automatically monitor their streams. Proponents of data loggers believe they are more precise than the work of volunteers, and that these devices appeal to watershed experts and regulators. Data loggers are analyzed in this study for how they deeply reflect ideas about scientific objectivity in data cultures.

A third kind of technology featured in this study are the data management systems used by monitoring groups for aggregating and interpreting water quality data. Service providers and academic researchers are increasingly amplifying the importance of bringing data together in centralized databases and geographic information systems (GIS). These systems are sold as a way to engage the complexity of gas extraction by situating water monitoring data alongside other forms of information, such as the precise locations of dispersed well pads, government water monitoring sites, and detailed watershed maps. The first data management system featured in this study is the Shale Network. Shale Network was introduced in 2011 by Pennsylvania State University in collaboration with ALLARM, the University of Pittsburgh, and the Consortium of Universities for the Advancement of Hydrologic Sciences (CUAHSI). The second data management system featured in the dissertation is the QUEST Data Management Tool, developed by WVWRI as part of their 3RQ program.

These two systems offer sophisticated data archiving, analysis, and map generating tools. In some cases, developers and proponents are quick to note that the systems are not built to accommodate nonprofessional users. In other instances, these systems are touted as a way to empower monitoring groups to use their data for addressing shale gas impacts in their communities. This study focuses on the motivations behind the two data management projects in order to demonstrate how different stakeholders come together to negotiate with their data, and to illustrate how diverse data cultures can be.

1.5 Data Sources and Analysis

Data for this study consists of semi-structured interviews, participant observation, visual documentation, as well as primary and secondary document analysis. Significant contributions to data also derived from a number of opportunities to conduct participatory "engaged" research. Each of these data collection methods offered different perspectives on how people come together to shape data culture and find empowerment through water monitoring.

Data analysis for the research was an iterative process conducted throughout the data collection timeline. Nearly all recordings of interviews were professionally transcribed using funds from the NSF grant. Other interview audio was reviewed for important segments and selectively transcribed for further analysis. Primary documents, interview transcripts, field notes, and other research data was then entered into Atlas.ti and analyzed with a three-tiered coding structure: 1) auto-coding for common keywords, 2) topical coding to draw out themes in the work, and 3) conceptual coding to draw out the theoretical underpinnings of the research. Using this method I was able to interrogate my research questions, test hypotheses, and generate findings for the research.

1.5.1 Semi-Structured Interviews

Between September 2011 and January 2015, 62 semi-structured interviews were conducted with a wide range of stakeholders including members of grassroots water monitoring groups (20), government agencies (7), capacity building and service provider organizations (10), nonprofit watershed associations (10), academic research programs (6), data management projects (8), as well as at one of the field's major funding foundations (1). Of these 62 interviews, 20 were conducted as research assistant to the Watershed Knowledge Mapping Project.

In some instances, I identified interview subjects early in the project due to their key positions in the field. In other cases, subjects were discovered in the course of fieldwork. I extended my interactions with these individuals through dozens of follow-up discussions, correspondences, and by tagging along with them as they went about their work in the monitoring community. The organizations in the dissertation are identified by name in order to maintain the accuracy and usefulness of the data and findings of the study. In a few instances, the names of organizations are omitted when the identity of individuals can easily be traced to their origins. Pseudonyms are used in place of some real names in order to protect personal privacy. However, in most instances individuals preferred that I use their real name for accuracy purposes. The majority of interviewed subjects requested the right to review their quotations through informed consent forms. These individuals provided clarity and context on their quotes prior to inclusion in this dissertation.

1.5.2 Participant Observation

Sources of data also include over 1,000 hours of participant observation in many different contexts. Much of this time was spent on the ground with concerned citizens who participate in water monitoring projects. Fieldwork at this level involved attending seven training sessions where volunteers learn the processes of using water monitoring protocols and technologies, and an eighth session where volunteers learn to use automated data logger monitoring equipment. I attended three additional training sessions where volunteers worked through the process of analyzing their data with the assistance of service providers. Follow-up meetings with individuals in these contexts afforded opportunities to work further with water monitoring groups in their streams, collecting data and installing equipment.

Participant observation was applied to the capacity building organizations and service providers who work with watershed groups. This work occurred during visits to their offices and facilities, by accepting invitations to participate in strategic planning sessions, and by attending many regional conferences where capacity building organizations interact with their constituents. Data collection at this level consisted of documenting how people conceptualized their project designs in planning meetings, but also observing how people used monitoring and data management technologies in working with their data. In effect, observations at this level included an analysis of how data moves throughout the information cycle (Dalcanale, Fontane, & Csapo, 2011; Timmerman, Ottens, & Ward, 2000), as well how social relations and technologies come together as complex infrastructures.

1.5.3 Document Analysis

In addition to many hours spent with interlocutors, primary documents published by capacity building organizations, citizen groups, database projects, and regulatory agencies were analyzed for key themes. These documents were generally available to the public through government agency websites, organizational archives, or were obtained by personal request. Primary documents specific to the Marcellus Shale water monitoring community assisted in situating the history of the field and how it evolved alongside the controversies of natural gas development. Primary documents also allowed for comparisons between the public statements of research subjects and their observed behaviors in the field. Secondary documents published by social scientists and water quality experts were used to contextualize the field within the bigger story of grassroots environmental monitoring nationally. These documents were obtained from peer-reviewed academic journals and through requests made to the authors.

1.5.4 Data from Engaged Research

A significant amount of data collection for this study was acquired through "engaged" research. This work emerged from a number of opportunities extended by my interlocutors. First, as an invited member of the NY Water Sentinels' science advisory committee, I participated in the network's weekly planning calls. Second, as an unofficial advisor to Penn State's Shale Network, I was afforded opportunities to understand the inner workings of the project by contributing to strategic planning meetings. Third, by becoming a member of the IWLA Harry Enstrom Chapter, I was able to participate in ongoing discussions about chapter's strategies for engaging the scientific and regulatory community.

A fourth opportunity came from my co-convening a series of meetings in October 2013, March 2014, and April 2015 called the Water Quality Data Coordinator Group. This planning group brought together more than 20 representatives from across the monitoring community for the purpose of building synergies across their programs. Participants included representatives from ALLARM, Delaware Riverkeeper, Kiski-Conemaugh Stream Team, Mountain Watershed Association, Shale Network, 3RQ, PA Trout Unlimited, Western Pennsylvania Conservancy, and the US Army Corps of Engineers.

Finally, data collected in engaged research evolved from my work with the FracTracker Alliance, where I was a visiting researcher from 2013 to 2015. In 2014 I assisted FracTracker in establishing the “Knowing Our Waters” project.[6] This project focused on the efforts of monitoring programs throughout Pennsylvania, New York, West Virginia, Maryland, and Ohio by utilized rich-media digital storytelling methods. Knowing Our Waters is intimately linked to the dissertation research and has served as a venue to communicate my findings to a wider audience of non-academic readers.

1.6 Funding Sources

This dissertation is based upon work supported by the National Science Foundation while research assistant to the Watershed Knowledge Mapping Project from 2011-2013 (Award #1126235), and later from a National Science Foundation Doctoral Dissertation Improvement Grant from 2013-2014 (Award #1331080). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author and do not necessarily reflect the views of the National Science Foundation. Funding from the RPI Humanities, Arts, and Social Sciences (HASS) Fellowship supported this work from 2013-2015. Additional sources of funding include the Colcom Foundation, which supplied $50,000 to launch the FracTracker Knowing Our Waters Project, and the Foundation for Pennsylvania Watersheds, which sponsored the Water Quality Data Coordinator Group meetings.

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[6] Additional information on the Knowing Our Waters Project is available at http://www.fractracker.org/projects/water-monitor/ (Last accessed July 27, 2015).

1.7 Outline of the Text

Promising Data for Public Empowerment continues from this introductory chapter by reviewing literature foundational to the study, then applies concept from this literature in four empirical chapters. Each of these empirical chapters reveals a different component of knowledge infrastructures that support water monitoring: standards, data collection technologies, data management systems, and partnership structures. Across these chapters I explore how these components contribute to the evolution and influences of data cultures, and how data cultures are subsequently tied to matters of empowerment.

Chapter 2 introduces the key conceptual and theoretical themes explored in the dissertation. It situates the study within the STS literature examining changing relationships of power between citizens and institutions of expertise. A second theme addresses how scientific knowledge is produced through technologies and social partnerships. This literature provides insight into the ways that scientific communities define standards for generating objective science, as well as how scientific communities delegate who is eligible to proclaim matters of fact. Research in the burgeoning field of infrastructure studies is used to explain how environmental science movements employ technologies and social partnerships to assemble resources for sustained research. How environmental science groups mold their work around data culture is then drawn out from these observations. Finally, in order to understand emergent forms of political organizing that happen around data management systems, I turn to literature from the fields of information sciences as well as from the critical geography community.

Chapter 3, "Defining a Science for Marcellus Shale Water Monitoring," highlights the patterns of decreasing regulatory oversight at a time of increasing environmental risk that spawned the Marcellus Shale water monitoring community. In this chapter I argue that understanding the characteristics of nongovernmental monitoring programs takes on increased importance in the absence of state resources. The chapter begins with an analysis of the Pennsylvania Department of Environmental Protection's Water Quality Network and the Susquehanna River Basin Commission's Remote Water Quality Monitoring Network, two influential governmental monitoring programs that have set the tone for how the shale gas industry should be monitored. This is followed by an analysis of how service providers such as ALLARM assisted nonprofessional groups to develop monitoring programs. This chapter reveals how regulators, industry, and the civic science community responded to each other's work to shape the standards by which water quality indicators should measured. I find that technical standards, and the data collection protocols built on such standards are foundational to data cultures.

In chapter 4, "The Politics and Technologies of Data Collection," I argue that there are different logics within the water monitoring community about what methods of data collection will influence environmental governance. In some instances, monitoring groups have deployed networks of volunteers with handheld meters. In other cases, organizations have invested heavily in automated monitoring equipment, also called data loggers. I find that many established watershed protection organizations believe data loggers increase the credibility of monitoring programs by replacing the subjective observations of volunteers. However, I argue that automated data loggers are also constraining the extent to which nonprofessionals can participate in water monitoring programs. The politics of data loggers are then compared to the work of the Izaak Walton League's Harry Enstrom Chapter to illustrate how water monitoring can also be used for political advocacy, and how data cultures can incorporate diverse other ways of making knowledge claims with data.

Chapter 5, “Building Infrastructures for Empowerment,” characterizes the partnerships structures that bring together different stakeholders to do watershed science. The chapter details the infrastructure building activities of two distinct water monitoring networks working across large geographic regions. The first is the NY Water Sentinels, a grassroots coalition of community-based advocacy groups. The second is West Virginia University’s Three Rivers Quest, a large research network managed by an academic institution. In both cases infrastructures were built to support affiliated groups, to distribute resources across the network, and to assist members in using their data to produce scientific knowledge. However, I find variations in how different stakeholders retain control over research programs across the spectrum of possible partnership formations. The primary purpose of this chapter is to offer a better understanding of empowerment in water monitoring research infrastructures.

Chapter 6, “Data Brokers, Data Wranglers, Data Culture(s),” explores the attractions and hesitations within the water monitoring community to build a centralized water quality database. I find that data management projects are where stakeholders with different interests in the water monitoring community come to negotiate with their data. In this chapter, I look at how the desire for a centralized database took root. I then explore interactions of data and people in one of the more prominent data management projects in the field, Penn State University’s Shale Network. I use this example to illustrate how the desire to find relevance in data has, in many ways, become more powerful than the database itself. Shale Network has become a space where people from across the Marcellus Shale water monitoring community come together with different data cultures. In doing so, they are negotiating what kinds of knowledge and technical practices the water monitoring community should account for.

The last chapter concludes the dissertation by bringing together the themes explored throughout the text. It reassesses why people organize, how they form identities, and how they express their concerns through data. This chapter also returns to reflect upon the central dilemma of the dissertation: how we might we rethink data cultures, such that civic science research infrastructures empower citizens to overcome the environmental threats posed by shale gas extraction.

1.8 Conclusion

Little attention in STS research has been paid to the ways in which citizen science groups seek empowerment by utilizing bigger and more complex data in their knowledge claims. In the absence of such research, it is difficult to understand the tensions that arise when claims of empowerment emanate from these projects. Participatory environmental monitoring projects are an important way that the public can assess these risks, and potentially influence environmental governance of the shale gas industry. However, the discourses of objectivity are strong within scientific, regulatory, and industry circles. As water monitoring groups across the Marcellus Shale adapt their technical practices to align with data cultures dominated by these watershed experts, it remains to be seen whether or not their data will be enough to penetrate this wall of science.

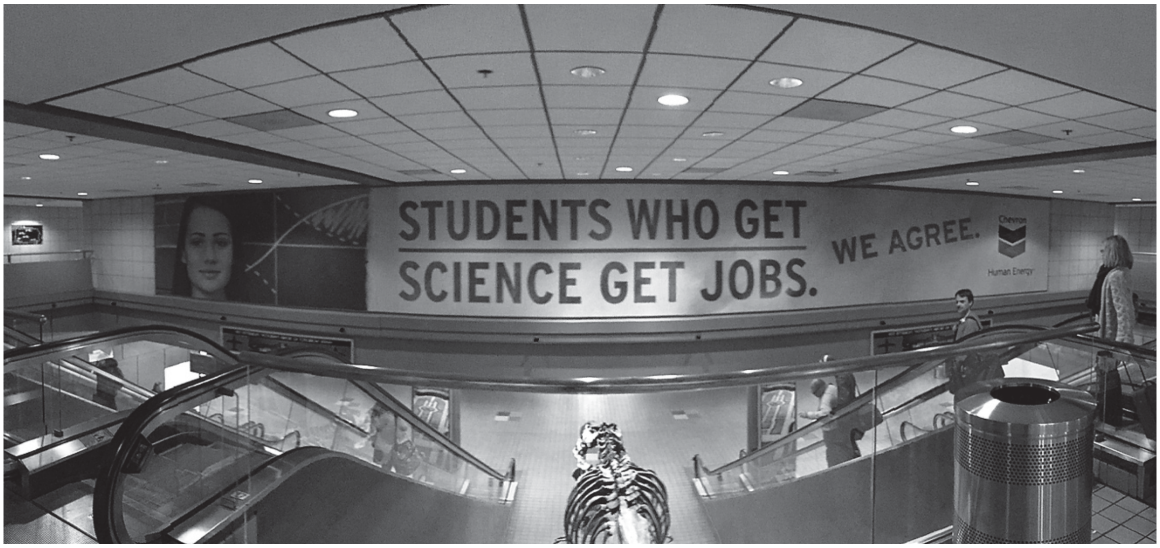

Figure 7. A billboard at the Pittsburgh International Airport illustrates the importance of science in debates about shale gas extraction

This study, therefore, concerns itself with the important question of why these monitoring groups are increasingly persuaded to make their claims through data-intensive protocols, technologies, and data management systems. It furthermore suggests that there are other data cultures worth attending to. This dissertation therefore offers a much-needed application of recent scholarship in STS by exploring the relationship of data cultures to empowerment in a series of empirically grounded case studies.

The implications of this research are significant. If, as this study suggests, wholesale investments in objective data offer only limited success for environmental advocacy, then it is important understand how these notions are established and put into practice. The summation of these findings inform the construction of more informed research infrastructures, ones that bring resources to bear on the problems of environmental pollution while also remaining attuned to the concerns and needs of people living in threatened communities.

2. LITERATURE REVIEW

Much effort has been spent in science studies detailing the practice of knowledge production in professional contexts (Knorr-Cetina, 2009; Latour & Woolgar, 1979; Pickering, 1995; Rheinberger, 1997). However, studies of civic engagements in science have moved this field beyond the laboratory to also grapple with the work of practitioners who self-educate, self-organize and, in the process, bridge institutional boundaries to enlist unexpected partners. Civic participation in science is an increasingly indispensable source of knowledge in scientific debates. This shift challenges former concepts that suggest scientific problems are identified and solved by experts who, in the process, must deal with the problems of accounting for the needs of the public. This literature review brings this shift into context with concepts and theories at the intersection of STS and neighboring disciplines in order to illuminate changing relationships of power that play out in civic engagements with scientific knowledge production. In turn, this literature is used to build a case for how data cultures are formed in these interactions.

2.1 Civic Science and the Questioning of Expertise

STS scholars offer several explanations for the rise of civic science in environmental health research (Kinchy, Jalbert, & Lyons, 2014). Historical perspectives point to the rise of neoliberalism in environmental governance throughout the 1980s. Just as the “environmental decade” of the 1970s—marked by frustrations over national-level, top-down conservation policies—was reaching its end, neoliberal policies encouraging local governance and privatization gained traction in the US (Griffin, 1999; Western &

Wright, 1994). In the 1990s, scientific agendas at academic institutions were similarly challenged by pressures to commercialize research and to develop closer relationships with industrial partners. The results of these changes meant that "mainstream research agendas tend to reflect the priorities of political and economic elites" (D. J. Hess, 2009, p. 306).

Those who study citizen science projects suggest that they may develop when individuals and public interest groups feel they have been denied access to valuable information for assessing risks, or demand greater transparency regarding how decisions are being made within governing institutions (Collins & Evans, 2002; Durant, 2008; Wynne, 1992, 2006; Yearley, 2000). In other instances, the public may use citizen science to produce independent knowledge or to contest the claims of officially sanctioned scientists (Allen, 2003; F. Fischer, 2009; Irwin, 2002; Ottinger, 2009). In these cases, concerned citizen groups may use information as a tactic to force relationships of accountability between "the regulated and regulators" (Overdevest & Mayer, 2008, p. 27).

Citizen science efforts can thus challenge conventional thinking on expertise. Rebecca Lave (2012) notes that some efforts, "have been able to establish serious scientific credibility in startling upsets of the traditional construction of scientific legitimacy," and are increasingly, "accorded a place at the table in many regulatory decisions" (p. 28). In the field of citizen science environmental monitoring, mobilizing volunteers to gather independent data is one way that concerned citizens can address the problem of "undone science" or, "areas of research that are left unfunded, incomplete, or generally ignored but that social movements or civil society organizations often identify as worthy of more research" (Frickel et al., 2009, p. 444).

A noteworthy example that illustrates these points is an environmental justice organization called the Louisiana Bucket Brigades, who use plastic buckets to measure air quality along industrial fence-line communities. As opposed to regulatory monitoring techniques that averaged air pollution over a duration of time, this form of citizen science based air monitoring enabled communities to collect data on shorter durations of intense air pollution. Gwen Ottinger's (2009) study of these practices suggests that Bucket Brigade monitoring was "grounded in activists' understanding of health effects—which differs significantly from that of regulators" (p. 252). Therefore, she suggests, "bucket monitoring not only departs from regulators' standardized practices but also represents a critique of them and the scientific claims that lie at their core" (Ottinger, 2009, p. 255). Through citizen science air monitoring, environmental activists were able to transform their personal experiences of environmental risk into data collection in order to articulate their grievances and, ultimately, forced regulators to take action against the polluting facilities.

By asking whose questions are prioritized in different formations of environmental science research, we begin to recognize the tacit or "situated" knowledge of nonprofessionals as an alternative to authoritative knowledge claims (Haraway, 1988; Harding, 2008). Jason Corburn (2005) describes this process as "street science" in a case where residents of New York City neighborhoods used community asset maps, health registries, and oral testimonies to contest cumulative exposure models in collaboration with the EPA. Immigrant communities complained the methods for establishing their typical eating habits did not take into consideration the daily practices of fishing from the heavily polluted East River. A locally formed Watchperson Project was established to train citizens as epidemiologists. By placing data collection and analysis into the hands of the community, they discovered how anglers had actually learned to identify fish most likely to be contaminated. In other instances, anglers had learned to remove section of the fish known to accumulate pollutants. These findings then assisted the EPA in refining its assessments of pollution risks and public health standards.

Although these and numerous other case studies have demonstrated the proficiency of nonprofessionals trained to do science, the effectiveness of citizen science can also be limited by their inability to meet the expectations of expert scientists. For instance, government agencies often view nonprofessionals as useful for pointing out issues for later investigation, but raise doubts about the quality or political bias of their data. As a result, they can remain hesitant to incorporate citizen science into regulatory management practices (Nerbonne & Nelson, 2004, 2008; Pfeffer & Wagenet, 2007; Wagenet & Pfeffer, 2007).

2.2 Infrastructures and Data Culture(s)

A growing body of research suggests that citizen scientists can prove adept at overcoming the difficulties of recognition and legitimacy by building alliances with experts in professional organizations and universities. These partnerships can coalesce resources, improve data collection efforts, open doors to laboratories, and enlist specialists who assist groups in solving technical issues often at the heart of disputes over the credibility of citizen science (Savan, Morgan, & Gore, 2003). These partnerships also provide scientific literacy opportunities, or what Steven Epstein (1996) calls the "expertification" of nonprofessionals, who are then able to engage scientists more effectively in public debates.

The field of "infrastructure studies" in STS offers valuable insights into how these alliances assemble resources for sustained research without the support of regulatory institutions. Foundational research in infrastructure studies focused on the development of large-scale technical systems, such as electrical grids and hydroelectric dam projects, and how these projects tend to homogenize technical practices (Bijker, Hughes, & Pinch, 1987; Hughes, 1987; Winner, 1986). Meanwhile, research in the information sciences found that computing infrastructures can emerge from complex webs of independent systems and push out other possible architectures (Bowker, Baker, Millerand, & Ribes, 2010; Edwards, 2003; Star & Ruhleder, 1996). Recent work brings these two applications of infrastructure studies together to understand the processes of knowledge-making, where "knowledge infrastructures" are defined as the, "robust internetworks of people, artifacts, and institutions which generate, share, and maintain specific knowledge about the human and natural worlds" (Edwards et al., 2013, p. 23).

Susan Leigh Star noted that the politics that define such infrastructures are often invisible; they are taken for granted precisely because their construction is deeply embedded in the tactics of local practice (Star, 1999). Geoffrey Bowker and others (Bowker et al., 2010; Bowker, 1994; Ribes & Finholt, 2009) suggest that any understanding of knowledge infrastructures must therefore come from attending to the sense-making activities that establish their technosocial relationships: "the political, ethical, and social choices that have been made throughout its development" (Bowker et al., 2010, p. 99). Paul Edwards has used the concept of "data friction" to describe the kinds of negotiations that occur, "where data move between people, substrates, organizations, or machines," and when research communities try to make sense of the knowledge they produce through these infrastructures (Edwards, Mayernik, Batcheller, Bowker, & Borgman, 2011, p. 669).

In the case of environmental monitoring networks, I argue that infrastructures that facilitate the creation of scientific knowledge consist of the four components: standardized protocols, data collecting technologies, data management systems, and the partnerships structures that bring these various components together. Like other infrastructures, these can also emerge from complex webs of independent systems, and can sometimes homogenize technical practices. However, in other instances, these knowledge infrastructures are found to be amazingly fluid. The remaining portion of this literature works to explicate the relationship between the four components of environmental monitoring infrastructures. In each case I illustrate their importance in shaping data cultures, and ultimately how data cultures relate to empowerment when the public uses to to engage scientific debates.

2.2.1 The Authority of Scientific Standards

Standards established by scientific research communities shape how knowledge is represented, communicated, and used, both within and beyond their borders (Gieryn, 1999; Proctor, 1991). Bowker and Star (1999) argue that standards are knowledge-categorizing systems that allow people to organize and make sense of their world.

Standards, when applied to data, can also assist in forming common ground for collaboration when disparate communities of practice work together to define scientific problems and find agreeable solutions. In other words, data derived from standards-based scientific processes can work as a boundary object, “both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites” (Star & Griesemer, 1989, p. 393). However, when standards become a source of tension between scientific collaborators, a great deal of work must be done to make sense of discrepancies. These tensions can impact what kinds of knowledge are included as valid data, and can inhibit mechanisms to share robust data within a larger research community.

One illustration of frictions that occur around standards can be found in Zimmerman’s (2007) study of how ecologists gather and share data. Wide variation in historical data collection techniques over decades of ecological research introduced great diversity in how data was characterized across research sites. Ecologists in isolated research communities were adept at dealing with issues of data variability within their small circles of similarly trained scientists. However, when a wave of new data sharing technologies emerged, the standards imposed by these systems made common understandings of data difficult across these research communities. This not only had an effect on how ecologists could use each other’s data, it also impacted their ability to gain credibility outside the boundaries of their profession.

In similar respects, the Bucket Brigades story points to an important problem that occurs when nonprofessionals use data to participate in scientific discussions. Ottinger (2009) also noted in her research that, despite the fact that citizens convinced regulators to deal with pollution emanating from specific industrial facilities, they were “unable to change how overall air quality was ultimately assessed” (p. 246). Ottinger attributes this failure to the “boundary-policing role” of standards that “provided regulators with a ready-made way to dismiss activists’ data as irrelevant to air quality assessment” (p. 246). Like Zimmerman’s ecologists, this example illustrates the power of standards, and the importance of adhering to standardized data collection protocols if people intend to use data to participate in broader scientific conversations.

2.2.2 The Affordances and Limitations of Monitoring Technologies

Data collection technologies are tightly bound to standardized protocols. Choice to use a particular kind of data collection technology can cement notions of what counts as good science and useful data. In some cases, citizen science efforts have independently developed and disseminated their own monitoring technologies, such as with the aforementioned Bucket Brigades, for capturing evidence of environmental pollution. Comparable approaches have led to deploying radiation detectors in the wake of Japan’s Fukushima nuclear reactor meltdown, and infrared photographing kits for aerial mapping water pollution sources along the Gowanus Canal in Brooklyn, New York (Dosemagen, Warren, & Wylie, 2011; Hemmi & Graham, 2013).

In other instances, professional scientists have partnered with small bands of citizens to develop experimental projects for reporting data about environmental and personal health using mobile phones, sensor devices, and handheld GPS units (Burke & Estrin, 2006; Campbell et al., 2008; Miluzzo et al., 2008). These technologies are typically developed in academic settings and deployed into participating communities.

For example, the University of California-Berkeley developed one early project called "Common Sense" with Intel Labs to produce mobile air monitoring technologies for residents to carry throughout the city of San Francisco (Aoki et al., 2009). A more recent project, initiated by Carnegie Mellon University's CREATE Lab, uses low-cost sensors to detect changes in water quality by measuring conductivity and temperature fluctuations. One model, the Catfish, is even designed to sit in a toilet's flush tank, warning residents if their well water becomes contaminated by nearby extractive industries.[7]

However, STS research has shown that some types of monitoring technologies are more compatible with the communities in which they are deployed than others. The expertise and financial resources of monitoring groups may be insufficient to maintain monitoring equipment offered by professional organizations in the long-term. Sheila Jasanoff (2002) observed one such example in India:

> Once, in a relatively well-appointed regional environmental agency in India, I saw a set of instruments for measuring water quality that had been donated some years before by the World Health Organization. At the time, these grey metal boxes, offered as a reward for the Indian agency's superior technical ability, no longer functioned. Parts were missing or broken and could not be replaced locally. Possibly, the expertise required to use them had also vanished. The instruments were lined up against a wall, occupying space and gathering dust. (p. 262).

Indeed, one of the downsides of projects like Catfish is its dependence on a university laboratory to repair its custom-built components. Meanwhile, projects based on research grants or industry-lab partnerships rarely expand beyond proof of concept stages. This

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[7] Additional information on the Catfish and other CREATE Lab projects is available at http://www.cmucreatelab.org/ (Last accessed July 27, 2015).

was the case with Common Sense, which was discontinued in 2011 with the closing of Intel's university research labs (Mims, 2011).

Environmental monitoring devices, and automated monitoring technologies in particular, can also reduce perceptions of environmental complexity down to what can be represented in quantitative measurements. Jackson and Barbrow (2013) evaluated the reduced importance of personal experiences in a study that examined the pervasiveness of remote sensor networks, satellites, and modeling tools used by field ecologists. Whereas ecologists previously were required to engage in field research in order to do ecological work, Jackson and Barbrow (2013) note:

> New techniques, practices, norms and mandates for data sharing have begun to erode the one-to-one relation between collection and analysis, giving more ecologists access to data they had no hand in producing…increasingly easy access to data means that ecologists can pursue their work without getting the least bit muddy, wet, bug-bitten or sunburned. These are important and justly celebrated accomplishments. But they may also radically change what it means to be an ecologist and to do ecological work (p. 6).

Additional consequences stem from cases in which monitoring technologies are the enforcers of standards. A recent study of response to the BP Deepwater Horizon oil spill in the Gulf of Mexico found that a wide spectrum of scientific inquiries eventually converged on questions that could be addressed using deep-sea sensors deployed in the aftermath of the disaster. David Bond (2013) explains:

> The materiality of the oil spill was redrawn around the technical capacity of select devices. This technological consensus transformed the varied scientific inquiries that gathered around the oil spill into a 'science for policy' of the oil spill…Scientists who wanted their work to be relevant to the emergency response (and the enormous resources it offered) had to discipline their questions and findings into the technical configuration of facts deemed legitimate by the state. (p. 705).

The arrival of sophisticated technologies for doing civic science is a significant contribution to a field often hindered by the limitations of finding effective tools to collect evidential data. However, lessons from the literature point to the importance of also building local capacity—including an education in the underlying scientific concepts, the skills necessary to interpret and negotiate data, and the expertise required to maintain equipment—in order to sustain monitoring programs. These studies also emphasize the dilemmas present when environmental monitoring projects fail to recognize the power of technologies with deeply embedded assumptions about what constitutes good science, and how these politics can shape what kinds of knowledge technologies produce.

2.2.3 Participatory Environmental Information Systems

Technologies developed for use in doing science produce new technologies to represent and communicate the findings of science (Pickering, 1995; Rheinberger, 1997). These can take shape as conceptual models, visual displays, schematics, and databases. One of the more significant shifts in the field of ecological management in recent decades is the turn to use environmental information systems (EISs), such as databases and geographic information systems (GIS), to make sense of complex datasets.

The widespread use of EISs first emerged in the 1980s from the realization that informed decision-making required new tools for interrogating large pools of data made available by digital technologies. For environmental regulators, this surge in EIS use also stemmed from widespread calls to modernize scientific research into the impacts of industrial development in complexities ecosystems (Goodchild et al., 1996; Haklay, 2003). Research in critical geography, informed by feminist post-colonial theory, points to the fact that academic researchers and NGOs have worked to incorporate mechanisms for greater public engagement in EIS driven studies, particularly by using the capabilities of “participatory” GIS (PGIS) projects (Baumann, 2010; Elwood, 2006a, 2007, 2008; Flanagin & Metzger, 2008; Yang, Raskin, Goodchild, & Gahegan, 2010). In some instances, these projects have even assisted grassroots groups in developing their own independent systems.

A central debate in the field of critical geography revolves around the political equality and social justice dimensions of data sharing and visualizing projects, and how they may assist marginalized communities in changing relationships of power (Corbett & Keller, 2005a, 2005b; Elwood, 2006b; Schuurman & Leszczynski, 2006; Schuurman & Pratt, 2002). Many believe that PGIS projects can provide fresh opportunities for overcoming the digital divide—or as others have called it, the “data-rich/information-poor” syndrome—where the inability of the public to use data on their own terms creates wide gaps in how marginalized groups understand environmental issues (Timmerman, Beinat, Termeer, & Cofino, 2010; Ward, Loftis, & McBride, 1986).

But complex technologies that help to make sense of data have many disadvantages as well. As with monitoring technologies, groups that invest in PGIS projects can be forced to manipulate their data to fit categorizing standards established by system developers or must acquire expensive equipment in order to connect with technical infrastructures (Sieber, 2000). Additional challenges to building PGIS projects include having to overcome barriers of access, providing adequate training to learn how to work with data, as well as in building tools for sharing data across diverse research communities (Delborne & Galusky, 2011; Gouveia & Fonseca, 2008). Nonprofessional groups that wish to participate in these projects may ultimately be forced to undergo organizational and ideological changes, ceding authority individuals in their network with adequate skills for interfacing with the expert community.

2.2.4 Civic Science Partnership Structures

Standards, data collection technologies, and data management systems define the physical contours of knowledge infrastructures. Equally powerful are the partnership structures formed between experts and nonprofessionals that bring these resources to bear in defining the parameters of research programs. Social science researchers have developed an entire family of frameworks to describe new forms of scientific engagement that come together in these partnerships, including citizen science, community-based science, street science, and crowdsourcing science (Corburn, 2005; F. Fischer, 2000; Irwin, 2001; Minkler & Wallerstein, 2003; Moore, 2006).

Each of these frameworks seeks to illustrate the ways in which nonprofessionals are involved at different levels of scientific research, from asking basic research questions, to shaping data collection strategies, to analyzing and disseminating results. Many of these studies have shown that nonprofessional engagement at each of these levels of research can vary significantly. However, Shirk et al. (2012) also note that studies of public participation in science often focus too much on *outcomes* as measures of success, such as the number of people who become involved in programs or how much data they produce, at the expense of evaluating the "social and interactional dimensions" that determine how participatory processes function.

Shirk et al. (2012) offer a spectrum model to explain the interactional dimensions of participatory science projects. On one end of Shirk et al.'s (2012) spectrum are "contributory" projects, where the public collects data for research programs designed by scientists (in cases where the public asks researchers to do such work the authors call this a "contractual" model). On the other end of Shirk et al.'s (2012) spectrum are "co-created" projects, designed in partnerships with equal distributions of power between scientists and the public. In this model, nonprofessionals are present in all aspects of research, from question setting to disseminating findings. In the middle of the spectrum are hybrids, or "collaborative" projects, where the public may assist in refining study designs, by doing data interpretation and dissemination for instance, but do not set the initial scope of research.

Looking at the quality of participation in this way highlights some of the tradeoffs that occur when nonprofessionals partner with experts and professional institutions. The spectrum model illustrates how enlisting powerful partners can come with certain liabilities for grassroots science movements, particularly in how much control they may relinquish when managing their research programs. For instance, academic researchers increasingly recognize the value of using volunteers to gather data in a wide variety of fields. However, as Lave (2012) notes, this "new wave of appropriation of labor and knowledge" is not necessarily out of a sense of public duty, as much as it is out of necessity, as researchers search for low-cost methods when collecting data for their studies. The objectives of professional scientists in these collaborations may differ from what concerned citizens see as the core issues.

Despite the liabilities of relinquishing some control over their research programs, for citizen groups that must operate under the skepticism of regulatory institutions, building alliances within experts can bring additional credibility to their science (Brown et al., 2004; D. J. Hess, 2005, 2007; Morello-Frosch et al., 2006). The spectrum model therefore allows for a definition of participation as having a range of "social and interactional" qualities, with varying consequences for addressing the concerns of nonprofessionals.

2.3 Measures of Empowerment

Bowker et al. (2010) have noted that, "if participants have been active in the formation of infrastructure elements, they are more likely to have a deeper awareness of alternatives and have had a voice in mediating choices inherent to issues such as standards formation and community goals" (p. 106). Other researchers in infrastructure studies have drawn similar lines between participation in infrastructure building and empowerment (Anand, 2011; Dantec & DiSalvo, 2013; Elwood, Goodchild, & Sui, 2013). Most often, empowerment implies a rearrangement of power that occurs where marginalized people and communities struggling against social, political and environmental injustices. However, like Shirk et al.'s (2012) concerns for the poorly defined parameters of participation, empowerment is also a weakly defined concept. In this study I draw upon the contributions of critical geography to look more deeply at empowerment in order to effectively understand its relationship to public participation in science.

2.3.1 Metrics of Empowerment

Investigating the dynamics of public empowerment can help illuminate concentrations and redistributions of authority and expertise in environmental science. Corbett and Keller (2005a, 2005b) offer a two-dimensional framework to complexify empowerment in the context of PGIS projects. First, they make the distinction between empowerment—"a tangible increase in social influence or political power"—and empowerment capacity—"aspects of the deeper process of change in the internal condition of an individual or community that influence their empowerment" (Corbett & Keller, 2005b, p. 28). They suggest that catalysts for empowerment can come from gaining access to new information, learning new skills, and acquiring tools to forward a person or group's agendas. This framework makes the further distinction that empowerment and empowerment capacity can occur differently at the scale of the individual versus that of the larger community.

To illustrate this framework, Corbett and Keller (2005a) suggest that empowerment of an individual might be evaluated on their ability to tangibly influence decisions related to an issue that concerns them, whereas increasing their empowerment capacity may lead to a greater awareness of power structures, and their subsequently working to transform those structures. Similarly, a community that changes the outcome of regional political decisions could be evaluated as having been empowered. They then argue that increasing a community's capacity for empowerment comes from aggregating resources and forming a collective identity in order to remain a constant force in long-term political debates. It is important to note that building capacity for empowerment does not necessarily result in tangible changes to the conditions that set the stage for disempowerment. Instead, changes in empowerment capacity affect the likelihood that the actions of an individual or community will yield long-term change.

When Corbett and Keller (2005b) applied their framework to analyze the outcomes of PGIS projects, they made some interesting discoveries. Catalysts that increased empowerment capacity at the community level were overwhelmingly credited to groups participating in the processes of acquiring new information and gaining access the tools necessary to produce that information. This finding is highly relevant to the topics of the dissertation. It gives credence to the possibility that enabling communities to produce data and utilize data-making technologies can be a pathway to enacting social and political change.

2.3.2 Imagining Empowerment

George Marcus (1995b) notes that science is unique in that its task is to "understand the present by borrowing from a cautiously imagined emergent future, filled with volatility, and uncertainty, but in which faith in practices of technoscience become even more complexly and interestingly constructed in new locations of doing science" (p. 4). One of the lesser assertions of this dissertation is that, in addition to evaluating the processes and outcomes of empowerment, we can also assess how individuals and communities feel inspired to imagine alternative arrangements of power that might come from collecting scientific data. To understand these emergent visions of empowerment, I briefly review the writings of those who have conceptualized social imaginaries in scientific research communities.

Social imaginaries explain how people perceive the present and possible future states of society, as well as how people envision their interests intersecting with those of others (Taylor, 2002). STS has worked to explicate the intricacies of how imaginaries are formed within research communities through similar concepts like scientific imaginaries, technoscientific imaginaries, and sociotechnical imaginaries (M. M. J. Fischer, 2005; Fortun & Fortun, 2005; Fujimura, 2003; Jasanoff & Kim, 2009; Marcus, 1995b).

Scientific imaginaries can be quite powerful in determining the course of what methods, tools, and organizational partnerships come together to produce new knowledge. For instance, in a study of Japanese geneticists, Joan Fujimura (2003) noticed multiple imaginaries in what researchers believed their DNA research might do for the future of science. One school of thought envisioned a future of genomics that would have greater respect for Asian culture, by connecting science to holistic discourses in Shintoism and Buddhism. A second school of thought used the language of futurism in a dream of positioning Japan as the center of a new era of intelligent systems, robotics, and synthetic human organs.

Both of these imaginaries were formidable in mobilizing scientists to act upon particular ideologies in changing the nature of research. Joan Fujimura (2003) notes that scientific imaginaries are thus:

> Visions of future possibilities around which scientific practices and communities are organized…they are the products and producers of networks of humans that include cultural intellectuals and writers, government bureaucrats and politicians, molecular biologists, artificial intelligence researchers, robotics engineers and designers, business executives and long-range planners and the public. These networks also can be said to include technologies—nonhuman actors, in Bruno Latour's words—without which scientific imaginaries cannot be made into projects and actions (p. 192).

The scientific imaginary is a useful concept for making sense of the complex beliefs of those who participate in citizen science data collection efforts. Fortun and Fortun (2005) have noted of the concept's application to civic science that:

> The study of imaginaries has allowed us to examine how large-scale change happens and is understood at the local level. Focusing on imaginaries is a way to study the forces constitutive of subjectivity and how subjects negotiate those forces. And it is also a way to study how people shape and are shaped by complex technical, social, and political-economic systems. (p. 44).

Reflecting on Corbett and Keller's (2005b) concept of empowerment capacity as the, "aspects of the deeper process of change in the internal condition of an individual or community that influence their empowerment," the scientific imaginaries of citizen scientists are also intricately tied to the deeper processes of envisioning present states of disempowerment. People who live in communities threatened by environmental pollution face many challenges in voicing their concerns. Those who invest in water monitoring must deal with additional difficulties in proving the worth and credibility of their science. In many cases, what sustains these people is the imaginary that environmental monitoring will change the power structures that allow for pollution in their communities. These scientific imaginaries, in turn, come to define which practice and technologies will be used to change those conditions.

2.4 Conclusion

The processes of establishing standardized protocols, selecting monitoring technologies, designing database projects, and forming partnerships structures are crucial topics for understanding how data cultures affect power structures in scientific research.

As the credibility of citizen science data becomes one of the most contested aspects of environmental monitoring studies, the infrastructures built to manage and manipulate their data become complicit in how citizens might be empowered to influence environmental debates.

Systems that aggregate and leverage volunteer collected data may indeed create new dialogues by connecting the dots between nonprofessional science and that of experts. Nevertheless, incorporating data-intensive workflows also implies conforming to data cultures that can limit the long-term empowerment capacity of individuals and communities. Systems that promise access to vast quantities of objective data may not always equate to having better data. Furthermore, one of the interesting side effects of investing in data-intensive science is a tendency to forget why people collect data in the first place or, as Boyd and Crawford (2011) have noted, “why people do things, write things, or make things is erased by the sheer volume of numerical repetition and large patterns” (p. 3).

This review of existing literature in STS and critical geography reveals a large body of research focusing on themes of public empowerment and the changing role of participatory technologies in environmental science. Meanwhile, literature in the information sciences illustrates how the amplified use of data-intensive science is changing how meaning and importance is attached to knowledge that emerges from these infrastructures. However, less attention has been paid to how civic science movements build alliances and develop data-intensive infrastructures to influence how regulatory agencies respond to scientific controversies. There also remains a relative vacuum of theoretical work for understanding the struggles of grassroots groups that compete for influence in shaping the parameters of knowledge infrastructures.

A closer examination might explain the enabling and constraining parameters of infrastructures that support civic science. Additional research may also illustrate how building infrastructures that retain the agencies of nonprofessionals can be paramount in asking questions, gathering useful data, and making arguments to support the claims of those living in at-risk communities. This dissertation, therefore, seeks to contribute to the literature by conducting this research. In doing so, it works to reveal and understand the deeply intertwined relationship between data cultures, knowledge infrastructures, and empowerment.

3. DEFINING A SCIENCE FOR MARCELLUS SHALE WATER MONITORING

This chapter addresses the origins of civic science water monitoring in the Marcellus Shale, and how relationships built over time between regulators and nonprofessionals have shaped its data cultures. In my research I found that efforts managed by regulators and watershed experts have set the tone for how the shale gas industry's impacts on watershed should be monitored. I also find that these standards are influencing how citizen science monitoring groups develop their own programs in order to meet the expectations of the regulatory community.

Adherence to these expectations is driven by the belief that volunteer groups that follow established standards will gain greater say in determining the nature of regulatory oversight. Monitoring protocols built on these beliefs are found to have empowering and disempowering qualities. Standardizes protocols help nonprofessionals make sense of the complex problems of watershed protection. However, standardized protocols also limit the scope of monitoring programs in order to collect data considered relevant to a specific group of potential data users.

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3.1 The Roots of Civic Science Water Monitoring

Civic science water monitoring has a long history in the United States. As far back as 1926 the Izaak Walton League of America (IWLA) recognized that organizing local residents was the best way to protect fishing habitats, and launched the first major effort to survey the quality of surface waters in the Upper Mississippi River. By 1969 the "Save Our Streams" program had expanded nationally (Firehock & West, 1995). Many additional water monitoring programs began in the late 1960s as lake and river associations formed around the country to address declining water quality. Following the Clean Water Act in 1972, which required states to implement surface water quality assessment programs, volunteer-based monitoring programs were seen as one way to augment limited resources and meet federal reporting requirements (Lee, 1994).[8] These needs were amplified in the 1980s during a decade of withdrawing government resources at the federal and state levels (Nerbonne & Nelson, 2004; Weber, 2000).

Virginia Lee, a long-time coordinator of citizen water monitoring programs at the University of Rhode Island Coastal Resource Center, noted that, prior to state recognition of the value of volunteers, "most people in the water quality business were chemists and engineers who believed testing needed to be done by professionals. It was like being a heretic to suggest volunteers could collect data" (Lee, 1994, p. 30). Nevertheless, she also suggested that, during those early decades, government agencies and volunteer monitoring programs "grew together." Volunteers became more aware of the importance

[8] This growth was augmented by the US government's General Accounting Office findings in 1981 that suggested states eliminate or reduce previous monitoring programs dependent on fixed-station monitoring, in favor of short-term rotating studies of river basins. Two years later the EPA suggested to states that one way to do this was to enlist regional volunteer groups to assist with these studies (Ward, 1996).

of quality assurance and quality control (QA/QC) and the value of producing standardized data. Meanwhile, agencies began to recognize the value of having additional labor to collect water quality data. In 1990, the EPA released a series of guidance manuals to assist states in promoting these co-evolving benefits. The EPA also established networking resources such as the National Directory of Volunteer Environmental Monitoring Programs and the Volunteer Monitor (US Environmental Protection Agency, 1997). By 1994 the EPA reported listing more than 500 programs in the National Directory (Pfeffer & Wagenet, 2007).[9]

The story of civic science water monitoring's growth in the US is echoed in states within the boundaries of the Marcellus Shale formation. The Pennsylvania Department of Environmental Protection (PA DEP) setup an advisory group called the Volunteer Environmental Monitoring Panel (VEMP). This then panel established the PA DEP's Citizens' Volunteer Monitoring Program (CVMP) in 1996. Among many early accomplishments, CVMP is credited with having coordinated an annual "Water Quality Snapshot" with volunteer-based organizations spread throughout the state's watersheds. Most of these groups drew upon the expertise and resources of several organizations that had experience working with volunteers in environmental stewardship projects (D. Wilson, 2002). In 2000, PA DEP established the Consortium for Scientific Assistance to Watersheds (C-SAW) to coordinate these support services.

[9] Both the Volunteer Monitor and the National Directory still exist as resources for the water monitoring community, and can be found at (http://water.epa.gov/type/rsl/monitoring/index.cfm). However, the Volunteer Monitor ceased publication in 2012 after the death of its long-time editor Eleanor Ely. Meanwhile, the National Directory (last estimated to contain information on nearly 1,000 monitoring groups) is poorly managed, and many groups no longer exist. The Watershed Knowledge Mapping Project research team learned this after corresponding with the EPA offices in charge of the directory.

C-SAW brought together Pennsylvania's most prominent watershed science service providers to offer free technical support to community groups. Members of the consortium included the Alliance for Aquatic Resource Monitoring (ALLARM), an outreach program of Dickinson College, the Conemaugh Valley Conservancy (CVC), the Delaware Riverkeeper Network, the Pennsylvania Lake Management Society, the Stroud Water Research Center, and the United States Geological Survey (USGS) (C-SAW, 2014). A major milestone for the partnership was in publishing the "Technical Handbook for Community-Based Monitoring in Pennsylvania" in 2001. This handbook was authored to guide monitoring program in selecting "monitoring methods appropriate to meet the goals of the individual group" (D. Wilson, 2002, p. 1).

From 2001 to 2009, DEP funneled more than $1.6 million to monitoring organizations through CVMP, the C-SAW service provider network, and through their Growing Greener Environmental Stewardship Grants program (Vastine, 2008). A 2005 study of Pennsylvania watershed associations (regional nonprofit organizations dedicated to protecting a particular water body) found that 40% of surveyed groups were established in these early years, many of which used volunteers for collecting watershed data (Stedman, Lee, Brasier, Weigle, & Higdon, 2009).

3.1.1 Retracting Essential Resources

Shrinking resources for surface water monitoring in the past decade have created many challenges at the critical moment of gas industry expansions in the Marcellus Shale. More than 10,000 unconventional gas wells were drilled between 2004 and 2013 throughout Pennsylvania, West Virginia, and Ohio. Nearly 7,500 of these were in

Pennsylvania alone (Figure 8). Over the same time period, the PA DEP's operating budget was reduced from $728 million to $689 million, and its staff was cut by 17%. The Pennsylvania Department of Conservation and Natural Resources (DCNR), the agency tasked with conserving the state's 2.2 million acres of forest, saw its budget stagnate at around $320 million over the same period (PA Environmental Digest, 2014).

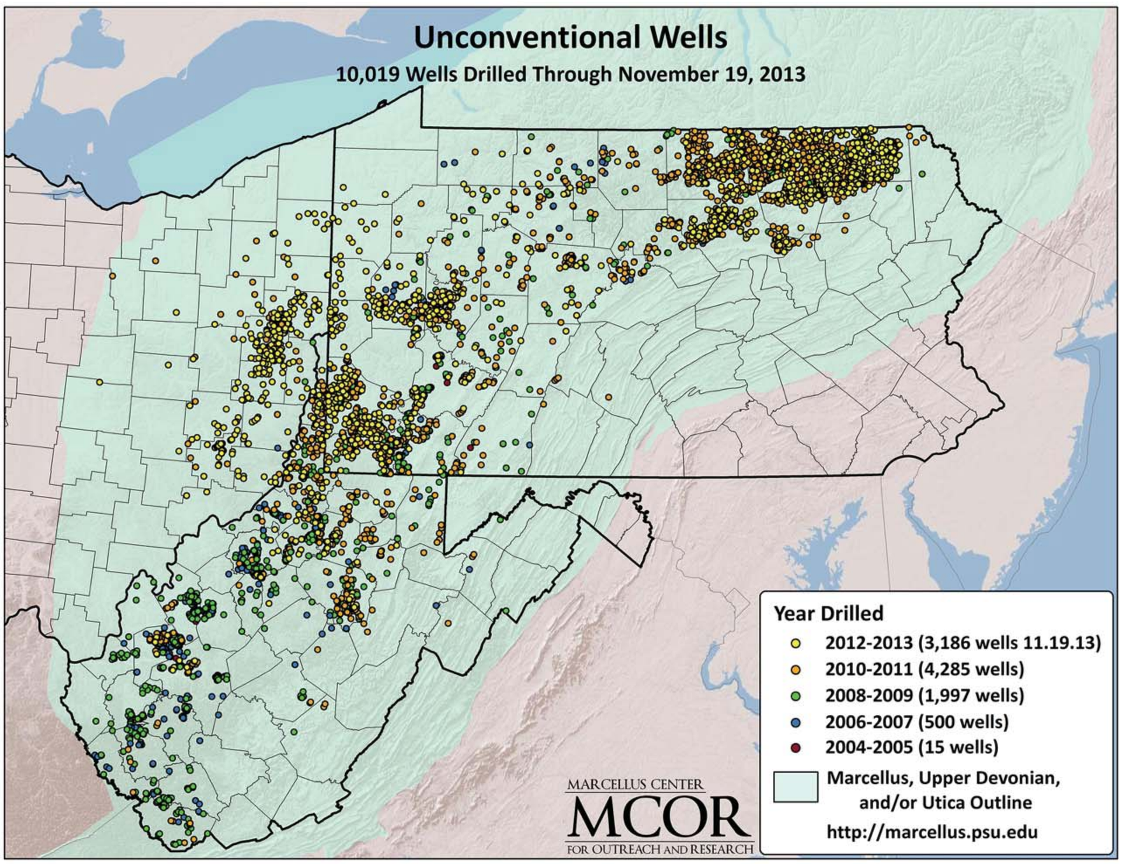

Figure 8. More than 10,000 gas wells have been drilled in the Marcellus Shale[10]

[10] Map used by permission of Pennsylvania State University's Marcellus Center for Outreach and Research (MCOR). Retrieved July 27, 2015, from http://www.marcellus.psu.edu/

Similar cuts were seen in neighboring states. New York's Department of Environmental Conservation (NY DEC) witnessed a 25% drop in its operating budget. The U.S. Environmental Protection Agency (EPA) reduced its support for state-level environmental conservation projects by approximately $1 billion due to the financial meltdown of 2008 (Environmental Advocates of New York, 2009). These cuts subsequently forced the federal government to push a larger load of regulatory oversight on to already overwhelmed state agencies.

The explosive growth of the shale gas industry combined with declining resources for regulatory oversight complicated regional watershed management strategies. Nearly 1,400 drilling violations were reported in Pennsylvania between 2008 and 2010, with more than half of these related to surface water contamination incidents (Entrekin, Evans-White, Johnson, & Hagenbuch, 2011). Meanwhile, since 2001, the PA Fish & Boat Commission (PA FBC) tripled the number of oil and gas well permits it had to review in a typical year. In 2010 alone, PA FBC made 175 field sites visits to observe water quality impacts at shale gas extraction these facilities. The mounting problem of inadequate oversight led the PA FBC director to conclude in a public hearing: "This limited field presence is completely inadequate if we are expected to live up to the charge given to us by the General Assembly in 1909 to enforce water pollution laws and—just as importantly—to work with other agencies and the industry to try to prevent problems before they occur" (PA Fish & Boat Commission, 2010).

3.1.2 Externalizing Civic Participation

For Pennsylvania's nongovernmental water monitoring community, the most painful impact of shrinking budgets came in 2009. Funds allotted to the Growing Greener Environmental Stewardship Grants program were exhausted, and the secretary of the PA DEP opted to cut direct support for citizen science watershed protection projects. In July of that year CVMP was shut down, leaving watershed groups across the state that had relied on state support to fend for themselves.

On a visit to the PA DEP to conduct interviews in the summer of 2012, I accidentally exited the Rachel Carson State Office Building elevator one floor below my intended destination, which was supposed to be the Division of Water Quality Standards. Wandering through rows of empty cubicles, I stumbled on the office of a name I recognized from reading scores of old CVMP newsletters and training manuals. For months leading up to the trip I had tried with no success to locate someone in the PA DEP knowledgeable of CVMP's history. Stunned that a person from legacy monitoring program still worked at the agency, I begged for an interview.

Kelly Cunningham was hesitant at first considering the many years that had passed since her involvement with CVMP, but we eventually sat down together the following day. She told me her feelings about the DEP's decision to cut her program. "I worked with the DEP Citizen Monitoring Program from about 1997 to 2009. I actually was the volunteer monitoring coordinator from 2002 to 2009. In 2009, a decision was made by the department based on budget issues that they were going to discontinue that program; hence they moved me into where I currently am, in the 319 non-point [pollution] source program. So yes, I did work with citizen monitoring for quite a number of years."

I asked, "So is this reason why you ended up moving down here, as opposed to with those folks who are doing water quality standards upstairs?"

"Our citizen program was always in this bureau. We underwent a recent name change, we used to be called the Bureau of Watershed Management, and we are very watershed oriented, and that is where they had placed the citizen program. We work very closely with water quality standards staff, but the program was always here, at least since '97."

"What do you think was behind watershed monitoring not being a critical item anymore? Was there kind of a consensus in the program as to why that was the case?" I asked.

"As far as volunteer monitoring not being a priority anymore? I think that comes from the lack of money and change in administrations," she replied, "You get a new Governor, you get new secretaries, and they just have different priorities. I know at the time of the heyday of our program, which I would say was from about '97 to probably '06—then the administration was really into wanting to do watershed type projects, watershed group work, etc. And then you get a change in priorities, you have less money, issues come up, and new things come up. And, Marcellus Shale was just starting out."

"I was going to say, it seems very untimely, considering—'09 is right about when that started to become a big issue," I noted.

“Yes, and we started discussing it in ’08 or ’09. Well, they dropped the program, basically effective July 1st of ’09. But early ’09 and late ’08, we were talking about how can we do things with watershed groups, related to Marcellus shale.”

“What sort of things did you have in mind?” I asked.

“I was hoping we could provide volunteers with some trainings related to what you would be looking for. What kind of impacts could happen so that you could be monitoring your streams and get a feel for what is happening? I know this is taking place out there. I know that ALLARM and Delaware Riverkeeper are very much into that. Those are the kinds of things that I was originally thinking would be nice to do, but then of course the program was dropped. “

“So do you feel as though those groups have picked up the slack for what DEP was hoping to do?” I inquired.

“Yes, we worked real close with them and still do, on some things, with Delaware Riverkeeper, with ALLARM, with the Pennsylvania Lake Management Society, with Stroud Water Research. They have had a number of Growing Greener Environmental Stewardship Grants that have gone to—it’s called C-SAW, Consortium for Scientific Assistance to Watersheds—to work with volunteers and watershed groups and we were all for it. Because we know, and knew at that time, and still know, that not any one of our individual groups could cover everybody’s needs across the state of Pennsylvania.”

She continued, “When we first started the program, there were a lot of people—general statement—many people in the department who thought volunteer monitoring was not going to provide very good information and it was a fluff program. And I think that we set our program on the right track to show that volunteers can and do provide quality assured information, and can partner with the department in many avenues, in many different ways to help provide needed information. So I thought our program was headed in the right direction and I got that read from a lot of people in other states when I used to go conferences and meetings. They always thought we had a really good program."

"But lack of money was the big issue, and something had to give and the decision was made to drop the CVMP. They didn't understand the interconnections that we had, and the partnerships that we had, and I truly feel that if it came back, with the staff cuts that we have taken and other things that the department has had to deal with in the last few years, we could get a lot of good information in partnering with groups."

Kelly's memory of the C-SAW/CVMP/PA DEP partnership is accurate. The partnership was often cited as an important model for other states in the region that were developing community-based environmental stewardship programs at the time. This service provider model also prioritized the needs of communities working on local watershed issues. A 2002 survey of CVMP assisted programs noted:

> Ensuring that volunteer collected data is put to some use is often the dilemma for coordinators of community based monitoring programs. The last thing volunteers wish to do is collect endless mountains of data that will grace the shelves of storage sheds for years to come. Discussion of volunteer data use often turns to identifying data users outside the organization such as the state and federal government. Yet this survey indicates that the groups themselves are using the data and in large part to educate themselves and their communities (Snyder & Wilson, 2002, p. 3).

The survey observed that the primary use for community-based monitoring data was for local stewardship projects. However, other functions of monitoring data identified in the survey included its use for watershed-wide trend analysis, and periodically contributing to state environmental management programs. These findings are noteworthy. The C-SAW/CVMP authored Technical Handbook was not intended to establish standardized protocols, but to guide monitoring groups in selecting processes appropriate to their needs. The C-SAW/CVMP/DEP service provider model illustrated how a range of possible technical practices could be used to address watershed problems across a diverse region, while also retaining the support of state agencies.

Reflecting on this I asked Kelly, “so what would be needed in order for it to come back? Would it just be more money, or a changed perception as to the value of volunteer monitoring?”

“What would it need to bring it back?” She stated emphatically, “I think the only way, at least the way things are now and in the near future, if money doesn’t get any better especially, would be for a broad group of volunteer organizations, to come in and talk to people in the administration and say, hey look, we were involved for ten years. And give them lists of things that were achieved, because there were many things that were achieved—whether it be monitoring an AMD project, or collecting all this baseline data, or leading to bacteria data being provided, whatever it might be. If they can make such a strong case about the data helping the department meet department goals, and money would be available, maybe they would listen and consider starting the program again.”

We also talked about what community monitoring groups would need to do in order to convince people in the PA DEP that their data could be used for environmental management. “I mean the big things that we always dealt with was QA/QC, quality assured data, making [monitoring groups] understand that sometimes you had to follow specific protocols.” She clarified, “Trying to relate the science, I guess is the way I’m going to say it, to some of the volunteers who had no scientific background, wasn't always the easiest thing to do. We had volunteers who were retired professors. We also had volunteers who never set foot in a science lab since high school or whatever. So I guess we always strived to have them understand the overall picture, to understand the need for quality assurance, but to also understand that data has certain uses."

My conversation with Kelly highlights the present state of relationships between government agencies and a once robust network of state-supported volunteer monitoring efforts in Pennsylvania. These efforts, once free to define the parameters of programs that informed local stewardship projects, now must justify their existence not only on terms of financial need but also on the merits of their science. Indeed, the major barrier to reestablishing public partnerships appears to hinge on the perceived efficacy of their data. This is a radical shift from the days when state agencies sought out volunteer monitoring groups to fill in the gaps of federally mandated watershed assessments.

A second, but less explicit, narrative that can be drawn from Kelly's story is the political sensitivity of endorsing a new generation of monitoring programs targeted at the region's growing shale gas industry. The oil and gas industry carries a great deal of power in Pennsylvania and insists that they are capable of self-regulation. This influence has made an impact on budget allocations over the years and shapes the nature of regulatory oversight. The political weight of the oil and gas industry may explain why the PA DEP is hesitant to again support volunteer monitoring programs.

3.2 Standards: The Agents of Credibility and Expertise

Despite declining resources for state-based, a number of efforts run by federal, state, and regional government agencies were active when unconventional gas extraction came to the Marcellus Shale region. Nongovernmental monitoring efforts also persisted even after the loss of state support. However, no official procedures for how one might monitor water quality impacts from shale gas drilling really existed. The suite of parameters that became the default for these monitoring programs came about through consensus, built up from the many daily decisions made by watershed specialists over the years, particularly in regulatory agencies.

Detailing the full extent of these programs is beyond the scope of this study, but characterizing those that have had most impact on decisions regarding how the shale gas industry should be monitored is useful for understanding the present state of public engagements with these expectations. For this purpose I will illustrate two. The first is the Water Quality Network (WQN), co-operated by the PA DEP and the US Geological Survey (USGS). WQN existed prior to shale gas extraction and is used as a primary tool for enforcing water quality standards and the Clean Water Act in Pennsylvania. The second is the Susquehanna River Basin Commission's (SRBC) Remote Water Quality Monitoring Network (RWQMN), established in January 2010 specifically for the purposes of tracking shale gas water quality impacts.

The historical development of these two programs reveal how some testing procedures became cemented into what now serves as the standard for enforcing watershed protection laws related to shale gas. By extension, they also explain why these choices propagated to influence nongovernmental monitoring programs.

3.2.1 Setting Expectations: The Water Quality Network

Pennsylvania has an estimated 86,000 miles of streams in six major river basins, 161,455 lake acres, and 403,924 freshwater wetlands—a watershed portfolio second only to Alaska in magnitude in the United States (PA Department of Environmental Protection, 2014). The Pennsylvania Water Quality Network (WQN) is the statewide water quality monitoring program, operated by the PA DEP, assigned to assess the health of this vast network of Pennsylvania's surface waters (Figure 9). Tony Shaw, one of WQN's project directors, explained the program's history:

> The Water Quality Network was formalized pretty much back in the early mid-70s, building on old stations that had been in place back to 1950. That was the precursors of our department. And in the early '70s, when we became an official regulatory agency to enforce the Clean Water Act, we got a huge chunk of federal funds that helped support the monitoring network.

WQN consists of more than 100 "standard" and "reference" monitoring stations (PA Department of Environmental Protection, 2015c). Standard stations are measured bi-monthly for physical and chemical analysis, and every other year for a biological evaluation (including algae, plankton, e-coli and macroinvertebrates). Reference stations are similar to standard stations, but located closer to the headwaters of major streams, where their purpose is to determine "normal" conditions prior to incursions from known pollution sources (PA Department of Environmental Protection, 2005a).

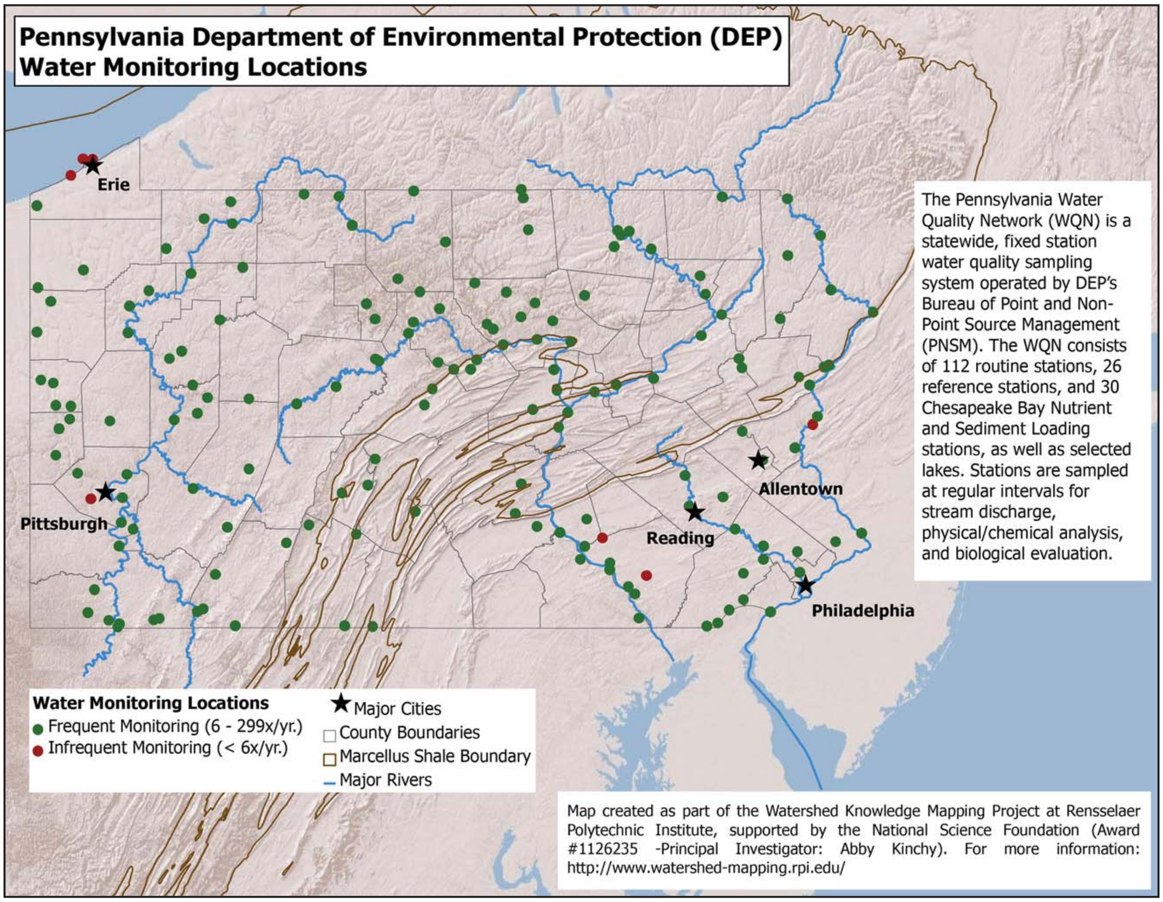

Figure 9. PA DEP's WQN water monitoring station locations[11]

The most common data collection technique used at these stations is "grab" or "field" samples (a single water measurement taken at a specific time and place), which is later analyzed in a laboratory for a full suite of organic and inorganic indicators. For standard stations, the base indicators that are measured at the time of collection are pH, temperature, dissolved oxygen, and specific conductance. Once samples are taken to the PA DEP's laboratories, a full suite of tests can be run to measure additional indicators including barium, strontium, and bromide—indicators that also happen to be detectible in

[11] Map generated by the Watershed Knowledge Mapping Project. Retrieved July 27, 2015, from http://www.watershed-mapping.rpi.edu/

more than 90% of Marcellus Shale flowback wastewater. In fewer instances, WQN samples are subject to alpha and beta radiological examinations, which provide a more detailed level of radiation analysis that might confirm the presence of shale gas pollutants.

Stream flow (the volume of water in a stream) is measured at each station using a variety of techniques in order to determine the relative dilution of these indicators. Because WQN is co-managed by the USGS, most often flow is checked against USGS stream gauge stations, which are typically located in major waterways. When no USGS station is available, volume and steam velocity is measured using electromagnetic sensors and by calculating a stream's cross section depth (PA Department of Environmental Protection, 2014).

The scientific rigor of WQN is well known within the watershed management community and has become the touchstone for determining best practices. However, Tony Shaw explained that PA DEP's data collection methods were not always so meticulous:

> The science became more rigorous, more detailed, a more automated machine with better detection limits. Standards improved, finding that there are impacts at lower concentrations. So you had ten or twenty staff of varying level of care and expertise and diligence—sometimes they were not consistent. When that came to light, my former supervisor said, enough of that, we are going get consistency here. So he spearheaded an effort with several prongs. One, we were going to adopt ultra-clean sampling techniques. Which means metals-free models, metals-free acid for fixatives—everything has to be metals-free. Sampling had to be done away from the road. Sometimes people take a bucket of water and take it over the bumper of the truck and start filing bottles up, so you get road dust. Sometimes there were smokers in the area and you get cigarette smoke and contamination. So it was more rigorous pond and stream processing—that was back in 2001 or 2002.

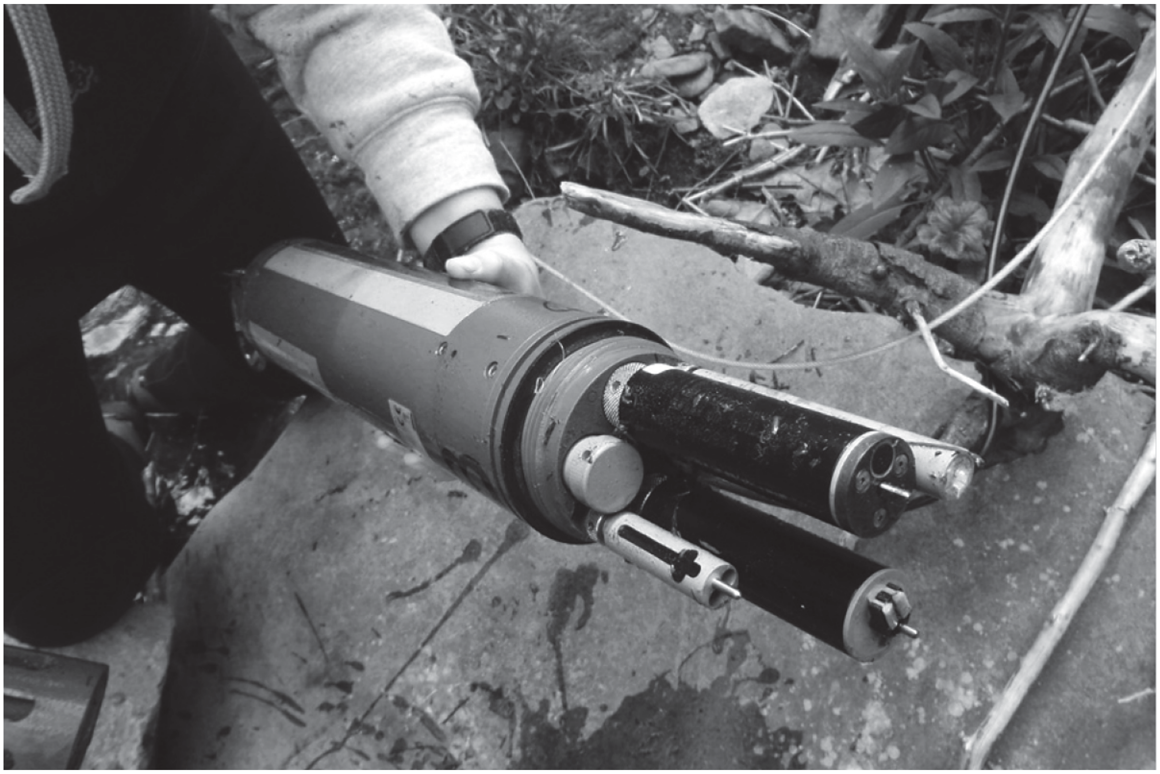

Figure 10. A typical sonde data logger used by the PA DEP[12]

Besides improving quality control procedures, one of the more significant changes to WQN in recent years has ben to use more automated monitoring equipment. These high-end instruments, often called sondes (French for "probe"), can cost upwards of $10,000 (Figure 10). "These stations are designed for a one year data record," Dustin Shull, one of PA DEP watershed specialist, told me, "So that paints a really solid comprehensive picture for one year. After that year, they are pulled and they go to another site with those similar characteristics that we are looking for."

Automated monitoring devices are now central to an evolving PA DEP strategy to monitor large watershed regions with limited personnel. This turned out to be particularly

[12] Photograph obtained from the 2014 SRBC annual report and duplicated under fair use. The report is available at http://mdw.srbc.net/remotewaterquality/ (Last accessed July 27, 2015).

important with the rise of the shale gas industry. When I asked Dustin how their program had changed with the introduction of shale gas drilling in Pennsylvania, I was told that one major change was in doubling the number of sondes:

> In response to the Marcellus? We enhanced the Water Quality Network, we have added stations, we have activated some old monitor stations, upgraded some stations, and in all of the stations in the Marcellus region we added new chemical parameters that have been targeted specifically for Marcellus signatures. Some of our staff, they coordinated and installed the data sonde, or data logger networks of ten plus sondes that were targeting watersheds where Marcellus activities were expected to increase. Those locations are primarily selected based on a set of pre-conditions. We want to go in and characterize based on conditions before activity goes in."

While baseline grab sampling continues to be the staple of PA DEP's monitoring efforts, the increasing use of automated technologies is significant. Remotely installed sondes are restricted in what indicators they can measure. Often they are programmed to collect the core measurements of pH, temperature, dissolved oxygen, specific conductance, and stream flow. More advanced testing would require watershed specialists to visit these sites and bring samples back to the PA DEP's laboratories. Automated monitoring technologies essentially set a de-facto standard for what kind of data the PA DEP might accept in absence of more in-depth testing procedures. These indicators became symbolic reference points for those who went looking for a standard to monitor shale gas pollution events. Indicators like barium and strontium, identified by the PA DEP as likely to be present in shale gas wastewater, also played an important role as the inexpensive, broad-sweep indicators nonprofessionals might use to pinpoint the presence of radionuclides in their water samples.

The PA DEP has thus spent more than four decades establishing protocols, indicators, and technologies believed to be appropriate for enforcing the Clean Water Act and other state regulatory laws governing Pennsylvania's watersheds. Decisions made during the rise of shale gas extraction eventually set the baseline for how the industry might be monitored. For instance, a 2012 PA DEP report titled, "Recommended Basic Oil and Gas Pre-Drill Parameters," suggests residents signing gas leases might consider monitoring pH, total dissolved solids, iron, manganese, sodium, methane, and ethane (PA Department of Environmental Protection, 2012). While the report lists these indicators as "high priority" it also notes that the list does not indicate a standard for how the PA DEP assesses gas drilling. Nevertheless, anyone who wished to interface with the PA DEP on issues of water quality monitoring—whether it be the shale gas industry, other government agencies, or the concerned public—feel obliged to acknowledge the PA DEP's authority, and the implied standards embedded in these statements.

3.2.2 Honing in on Shale Gas: The Remote Water Quality Monitoring Network

The Susquehanna River begins in Otsego Lake near Cooperstown, New York, and empties into the Chesapeake Bay more than 400 miles downriver. Its hundreds of tributaries are spread over parts of New York, Pennsylvania, and Maryland. Because the Susquehanna River flows through three states, the Clean Water Act mandated a joint-agency effort for managing the watershed. In December 1970, the Susquehanna River Basin Compact was signed into law, establishing the Susquehanna River Basin Commission (SRBC) as the agency designated to coordinate watershed management projects at the federal, state, and municipal levels (Susquehanna River Basin Commission, 2014a).

While the SRBC is a non-regulatory agency, the commission is nevertheless instrumental in shaping watershed protection in the three states that contain the Susquehanna River's waterways. The SRBC is the primary agency responsible for issuing water withdrawal permits, which can determine where drilling companies can operate. The SRBC also oversees a number of water quality monitoring efforts that feed data into state and federal regulatory management programs, including those of the PA DEP.

The core of the SRBC's water monitoring program consists of grab samples collected in one of six sub-basins, rotating on a three-year basis. However, critiques of rotating sub-basin studies argue that they can leave large gaps in data for areas experiencing intense gas drilling that may not have been tested in years. For instance, the Middle Branch and West Branch of the Susquehanna River, two of the densest drilled watersheds in the state, were last surveyed in 2009/2010, and prior to that in 2002/2003.[13]

In 2010, the SRBC added a second water monitoring program called the Remote Water Quality Monitoring Network (RWQMN) to compensate for these gaps (Figure 11). This monitoring network was born from a prior group of sampling stations meant for collecting real-time data on drinking water quality. With $200,000 in funding allocated by the Commission's members, and an additional $750,000 in industry donations from East Resources (a subsidiary of Shell Oil) and Chesapeake Energy, the network was rebuilt from the ground up to track water quality impacts related to shale gas

[13] These studies are available at http://www.srbc.net/programs/subbasinsurveyyear1.htm

development (Susquehanna River Basin Commission, 2014b). RWQMN now consists of 51 sondes spread throughout the Susquehanna River basin.[14]

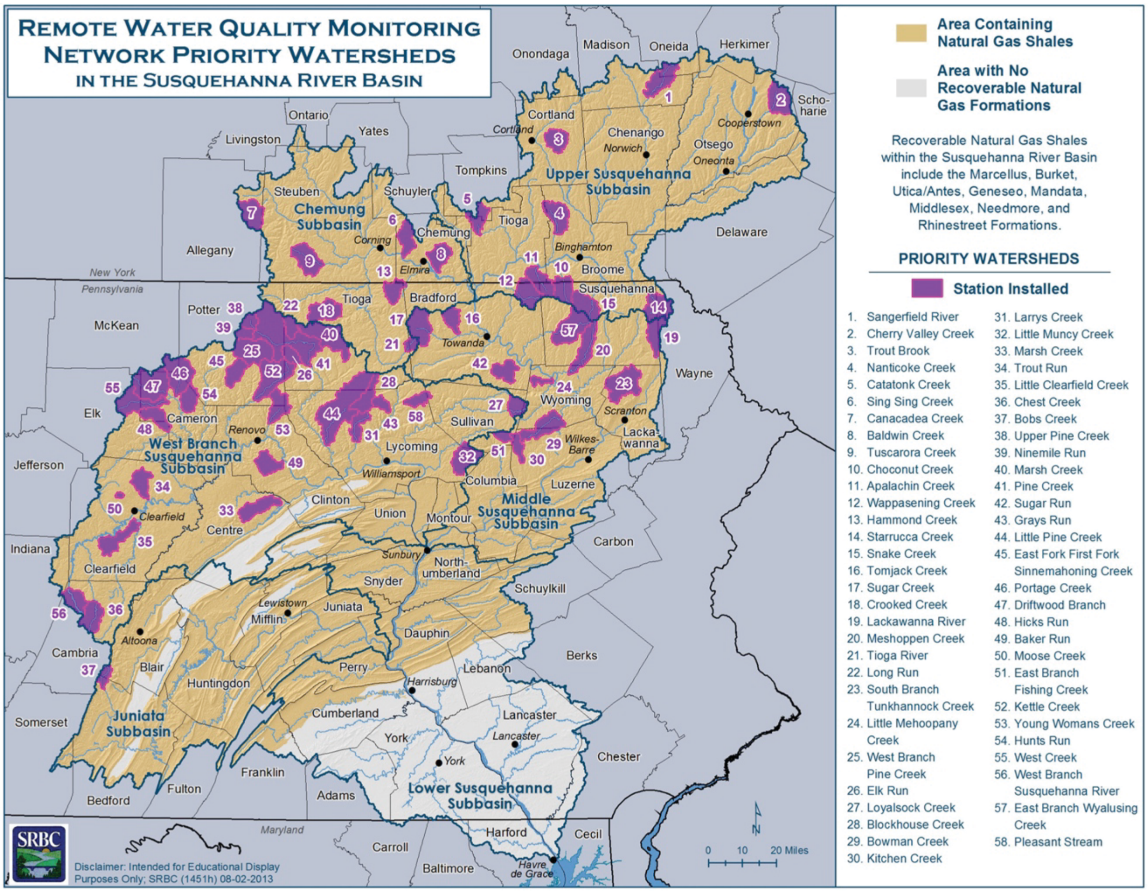

Figure 11. SRBC RWQMN water monitoring station locations[15]

Like the PA DEP's WQN's data loggers, the RWQMN's stations are equipped to automatically measure the core indicators of temperature, pH, conductivity, and water depth. The RWQMN differs in that its sondes also monitor turbidity, a key measure of

[14] Additional information on the RWQMN is available at http://mdw.srbc.net/remotewaterquality/ (Last accessed July 27, 2015).

[15] Map obtained from the 2014 SRBC annual report and duplicated under fair use. The report is available at http://mdw.srbc.net/remotewaterquality/ (Last accessed July 27, 2015).

sedimentation loads and erosion impacts. A second variation in RWQMN's sondes is their ability to measure dissolved oxygen, an important indicator of a stream's capacity to sustain aquatic life. These two indicators were selected specifically to target some of the known pollution threats of the gas industry. For instance, many watershed experts assert that they may have been able to intervene at Dunkard Creek if they had known the relative concentration of dissolved oxygen leading up to the fish kill. Jonathan Friedlander, a staff member at the SRBC recalled:

> I know early on there was a lot of concern about frack water, flowback, and wastewater—we also were concerned about turbidity. Because we knew, when the industry moves in, it's not just the handling of those chemicals, it's the road building, the pipelines, and all of those similar activities that would yield sediment.

The RWQMN is unique among the region's monitoring networks in that all of its logger stations transmit data real-time by cellular or satellite connections to SRBC's headquarters. In the event of a pollution spike, the SRBC's staff receives a warning notification of the precise time, location, and measured indicators at their desk. Because of its purpose as early warning system, some of the RWQMN's sondes differ in their locations from those of the PA DEP's WQN in that they are located where Marcellus Shale gas drilling is most active, or in locations planned for future development.

Some of the criteria that determine the exact siting of stations can include whether or not the water body is impaired by other pollution sources that could confuse detection of gas related activities, the locations of important drinking water facilities, as well as based on input from local interest groups concerned about protecting a particularly sensitive watershed. Another factor determining station placement is the SRBC's preference for waterways that present a goldilocks scenario for detecting potential pollution events. Jonathan mentioned this consideration in our interview:

> One of the first things we did was recognize the limitations of the instruments with detecting subtle shifts—we don't want to put these in areas where there is too much flow, we won't be able to pick up on anything; it's a waste of money. We didn't want to put them in areas too small either, so that we weren't maximizing the investment. So we actually ran bench tests in a lab, where we had results from what flowback wastewater would look like. We generated a simulated flowback based on conductance and dilution from flow. We ran different dilutions to sort of get the right flow range and that is how we came about with siting monitoring station locations.

In many ways the RWQMN is a concentrated version of the PA DEP's strategies for monitoring shale gas impacts. The SRBC's RWQMN mirrored the PA DEP's WQN logger network in its technical designs and selection of relevant monitoring parameters. With the addition of turbidity, dissolved oxygen, and station placements based on simulated releases of flowback wastewater, the RWQMN now functions as the region's only agency-based monitoring system built for the explicit purpose of tracking the shale gas industry's impacts on watersheds.

These decisions were fundamental to SRBC's desire to see their data used, not only as an early warning system, but also to inform regulatory oversight of the industry. However, despite the fact that the RWQMN tightly aligns with the PA DEP's own design standards, the SRBC's data is still considered "provisional" by the PA DEP. I am told that one reason for this is that real-time data lacks the same level of quality assurance as laboratory-tested field samples. Jonathan noted:

> They are working at how to refine that data, and have it in a more defendable format, and collect it in that sense. So we are talking to DEP about if there are any adjustments, and recognizing that they are still developing their protocols on how to deal with continuous data, and if

> there is a way we can align our process of evaluating how our data is being collected and analyzed.

The SRBC has published periodic reports after passing data through quality controls, but this process can take staff as much as a year to complete. Even in this more rigorous analysis of their data, the SRBC has found only a few incidents of suspected pollution events.

The conundrum revealed by the SRBC's RWQMN is an interesting one. On one hand, an agency-based program has been tailored to monitor the shale gas industry using standards suggested by the PA DEP's technical practices. The SRBC's monitoring efforts are widely respected in this respect by the civic science monitoring community. Some monitoring groups even use RWQMN's real-time data, which is streamed live on the SRBC's website, to corroborate their own findings in those same watersheds. Data from the PA DEP's stations are not available in this way. On the other hand, the SRBC's data lacks the same level of authority as the PA DEP's data. While the SRBC is working with the PA DEP to make data from both of their programs align and become more accurate for regulatory purposes, the PA DEP's data carries greater weight simply for political reasons. The SRBC is a non-regulatory agency.

This presents a problem for other programs looking to ride on the coattails of technical practices established by agency-based programs. If the SRBC's data comes with only conditional influence due to their position as a non-regulatory agency, one can imagine the difficulties nongovernmental monitoring groups have in getting their data recognized by regulators. In this way, the story of the SRBC's RWQMN illustrates very clearly who holds the power to define credibility and expertise in the Marcellus Shale water monitoring community.

3.3 A Rebirth of Civic Science Water Monitoring

STS research suggests that citizen science movements materialize for different reasons. People may believe they have been denied important information for assessing risks to their health and well being, or protest the idea of experts managing risks on their behalf (Epstein, 1996; F. Fischer, 2000; Wynne, 1996). Studies of citizen science also find that people who collect their own data may do so in order to ask different questions than those of expert scientists, bringing an outsider's perspective to scientific research. In many cases these public engagements are viewed as a way to generate forms of knowledge that might not have otherwise been considered relevant by experts (Allen, 2004; Brown, 2007; Corburn, 2005).

In similar respects, proponents of citizen science efforts in the Marcellus shale argue that people should have access to tools for assessing risks, for participating in regulatory decision-making processes, and for voicing their personal concerns about the gas industry. Volunteers are most often viewed as "first responders" in these efforts, ready to notify regulators of possible violations. Others see monitoring efforts as a way to promote long-term community-based environmental stewardship. Regardless of their intentions, Kinchy and others (Jalbert, Kinchy, & Perry, 2014; Kinchy et al., 2014; Kinchy & Perry, 2012) suggest that water monitoring efforts in the Marcellus Shale are filling important knowledge gaps by working to collect data independent of, or in partnership with, the state.

However, the processes of designing rigorous monitoring programs can be overwhelming for nonprofessionals. When concerned citizens went looking for allies to help them assess watershed impacts from gas extraction, C-SAW and other long-standing service providers in the region stepped in to help these groups build new monitoring programs. As one service provider's outreach coordinator put it bluntly:

> Since the DEP really didn't give a shit about volunteer data in the water quality enforcement divisions, it has resulted in having to have a network of organizations working together. The fact that C-SAW has federal and counties and universities and NGOs as a part of a coordinated technical assistance umbrella, that was really powerful.

In this capacity, service providers guided groups through identify appropriate parameters, tools, quality controls, and data management strategies. Ultimately, these service providers envisioned a new era of water monitoring that would not only help citizens understand the risks of shale gas extraction, but also empower participants in monitoring programs to change how the industry was managed.

3.3.1 Designing Standardized Protocols for Volunteers

As the primary organization in C-SAW with extensive experience working with volunteers, ALLARM took on new importance in building out this network of monitoring programs. ALLARM was central to developing the original C-SAW/CVMP "Technical Handbook for Community-Based Monitoring" in Pennsylvania, and is widely credited with establishing and propagating the first volunteer monitoring protocols tailored to shale gas extraction impacts.

Founded in 1986, ALLARM's original mission (then the "Alliance for Acid Rain Monitoring") was to study the impacts of acid rain by training volunteers across the state to gather pH and alkalinity samples in their watersheds. Using the study design outlined in the Technical Handbook, participants in these programs selected their own stream sites and did sampling using equipment supplied by ALLARM. These efforts proved for the first time that a comprehensive network of volunteers in Pennsylvania could assess conditions related to a particular watershed issue. ALLARM's volunteers also contributed to one of the most extensive state-managed datasets on acid rain impacts at that time. This data was later used in lobbying efforts to amend the Clean Air Act in 1990 (Wilderman, Barron, & Imgrund, 2004).

Beginning in 1996, ALLARM shifted its resources to become a regional service provider for local watershed groups dealing with a wider range of water quality issues from agricultural runoff to acid mine drainage to point-source industrial pollution. ALLARM modified the Technical Handbook to write its own "Study Design Manual" with the goal of aligning their services to support what Shirk et al. (2012) call "co-created" models of participatory science. ALLARM wanted groups to retain full control over the processes of research, from asking basic research questions to identifying how to use resulting data.

Everything changed for ALLARM in 2008 with the introduction of Marcellus Shale gas extraction. Julie Vastine, a staff member at ALLARM, explained why:

> I was first introduced to shale gas extraction at the December 2008 Campaign for Clean Water Meeting, which is held in Wildwood Education Center in Harrisburg. The Campaign for Clean Water has all these different work groups. So we were on the exceptional value stream work group, and then there would be like storm water work group, and I can't remember all the other ones. Then someone from Clean Water Action did a presentation on what is Marcellus shale and fracking and things like that. And it was the type of thing where, at the time, I think there was only 25 organizations represented in the room and we were all like—wait a second, what in the heck is this? And I think that was my first introduction to shale gas. And then in 2009, as it started to pick up a little bit more in the media, we were like, huh, and we starting to explore that question of what is ALLARM's role with this.

Julie recalled that ALLARM's staff quickly realized that their program would need to adapt to the new, but also unknown, pollution threats associated with shale gas extraction. They also began fielding dozens of requests from watershed groups asking ALLARM to help them monitor watersheds around gas wells.

The following summer ALLARM's science director spent her entire seven-month sabbatical researching a protocol for shale gas monitoring that would be practical for volunteers, yet rigorous enough to detect shale gas contaminations. ALLARM also sought the guidance of watershed specialists with whom they had developed long-standing relationships in the past. These included consultations with staff in the EPA, USGS, SRBC, PA DEP, PA FBC, the Delaware Riverkeeper Network, and in numerous County Conservation District (CCD) offices dealing with the rise in shale gas extraction activities.[16] Julie noted of this process:

> When we launched our protocol in 2010, we made a concerted effort to get everyone to read it and to do as many presentations as we could in front of agencies. So SRBC has given us a great big thumbs-up, EPA Region 3 has given us a nice thumbs-up, and the DEP thinks it works.

These conversations assisted ALLARM in understanding how shale gas impacts might occur, as well as in identifying how agencies were ramping up their own monitoring programs to prepare for the gas industry's growing presence. Indicators selected by ALLARM staff would eventually fall in line with the widely accepted standards propagated by watershed experts in these agencies—conductivity (TDS),

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[16] Pennsylvania's County Conservation Districts are the county government offices devoted to natural resource management and mitigation projects. Every county with the exception of Philadelphia has a CCD office. Responsibilities of CCDs include erosion and sedimentation control programs, nutrient management, water monitoring, pollution reduction, and invasive species control. CCDs are tasked with making sure the oil and gas industry complies with state and federal laws regarding these issues, but otherwise have no regulatory authority or the ability to issue violations.

temperature, and stream flow all became central to volunteer-based monitoring protocols.[17] Julie clarified that the new protocol was built upon a "pollution response" model:

> People wanted to get out there fast and start monitoring. So we developed a tailored training tool. We also needed to make sure what they were collecting was consistent. In the older study plan, where ALLARM would do the longer planning meetings, groups would often end up wanting to monitor very different things depending on their situation.

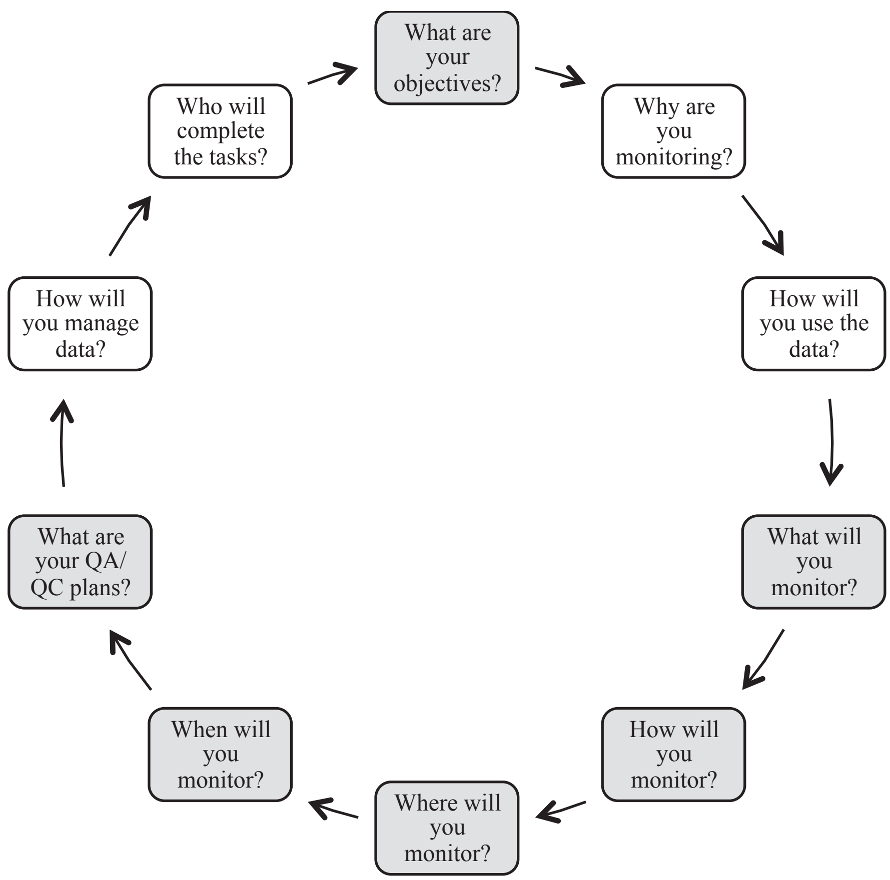

Figure 12. ALLARM's study design wheel—boxes in gray denote predetermined components for shale gas monitoring (gray shading added by the author)[18]

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[17] In some instances groups who would work with ALLARM added pH and dissolve oxygen to the protocols.

Similar decisions were made regarding where to monitor and which tools were found to be appropriate to the budgets and skills of most volunteers. This approach differed greatly from ALLARM's earlier model of assisting groups in open-ended programs to address a wide range of watershed issues. Whereas the previous study design model promoted by ALLARM worked in full partnership with monitoring groups in implementing the many steps of a participatory science project, when ALLARM released their "Marcellus Shale Volunteer Monitoring Manual" in 2010, many stages of the volunteer monitoring study design were pre-set by ALLARM (Figure 12) (Alliance for Aquatic Resource Monitoring, 2012a).

ALLARM's tightening of their study design to accommodate shale gas monitoring might be interpreted as a shift away from what Shirk et al. (2012) call the "co-created" model of participatory science towards a "contractual" model for doing science in partnership with an academic service provider. However, ALLARM's decision to retain greater control over the shale gas monitoring protocol was, by many, seen as critical to the success of the program. ALLARM realized the terms of engagement for collecting, managing, and using data would be different for shale gas compared to other water quality issues.

[18] ALLARM's study design wheel is explained in greater depth in their training manual titled "Marcellus Shale Gas Extraction: A Study Design and Protocol for Volunteer Monitoring" (Alliance for Aquatic Resource Monitoring, 2012a).

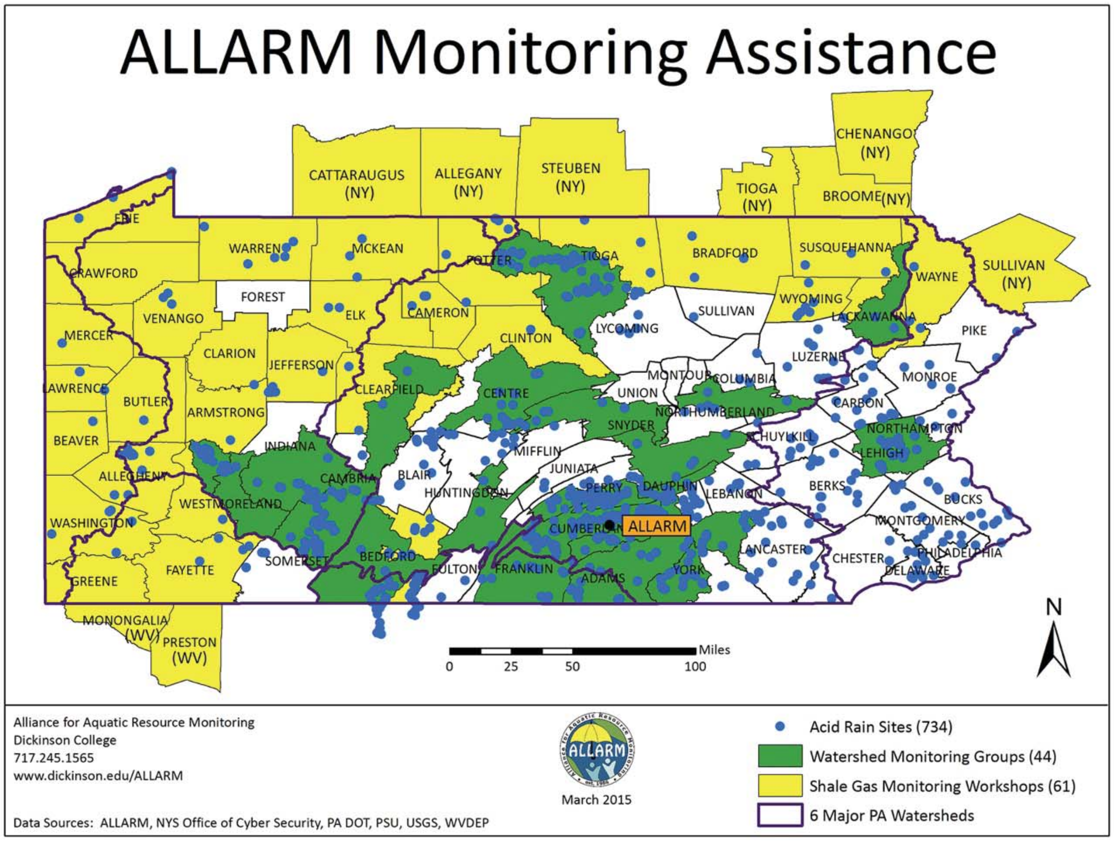

Figure 13. Map of ALLARM training workshops in West Virginia, Pennsylvania, and New York by county 2010-2015[19]

Those who oversaw the program's development argued that, if monitoring groups had any chance of influencing government oversight of the industry, these groups must first adopt a widely recognized standardized protocol. Second, they believed this protocol must also be consistent across monitoring groups in order to facilitate comparisons of data from different watersheds. Many scientists in the field still did not understand what the broader impacts of shale gas extraction to watersheds might look like. If volunteer groups intended to see their data used for scientific assessments of shale gas impacts,

[19] Map of training programs supplied by ALLARM and used by permission.

they would need to think beyond local uses of data to also appeal to the interests of the larger research community. Finally, a uniform protocol also meant that individual monitoring groups could work together on the singular issue of shale gas extraction. This was a radical departure from historical formations of volunteer-based monitoring in the region, where groups operating in relative isolation.

Since introducing their shale gas monitoring protocol in 2010, ALLARM has used this model to train more than 700 people in 40 workshops across Pennsylvania, New York, West Virginia, and Maryland (Figure 13) (Alliance for Aquatic Resource Monitoring, 2012b).

3.3.2 Turning Citizens into Scientists

The pollution response model behind ALLARM's protocol shaped its training program. Training manuals emphasized two primary objectives. The first was to collect data for early detection of contamination in small-stream headwaters. The second was to prevent future impacts by being the "eyes and ears" on the ground to observe industry practices. ALLARM conducts all of its training for a particular group in a one-day six-hour workshop with three modules. Each of these modules is designed to bring the volunteer through the different stages of the study design process: understanding the basic research questions, learning how to collect and interpret water samples, and deciding what to do with the data.

The first portion of a typical day of training is an educational session that provides workshop participants with the basic background knowledge needed to understand the relationship between the gas industry, environmental impacts, and regulatory oversight.

ALLARM's trainers walk volunteers in this first module through the geography and hydrogeology of the Marcellus Shale and how gas is extracted. Examples of questions often asked in these sessions include, "Why is there limited drilling in the Northeast part of state compared to other areas of Pennsylvania?" Realizations like, "So the gas is in the shale itself! How do they keep the shale fragments from getting into the gas when extracted?" And, "Isn't hydrofracking exempt from the Clean Water Act?"

Volunteers are also taught the differences between fluid mixtures used in the process of drilling, the waste byproducts retrieved from the well after it has been stimulated, and the signatures of chemicals used in the drilling process. They learn about the potential environmental and personal health effects of these chemicals, as well as the water quality standards enforced by state and federal agencies that exist to protect communities from exposure.

The second training module guides participants through the process of collecting, measuring, and recording water samples (Figure 14). Volunteers are supplied with a LaMotte Tracer PockeTester, a handheld electronic meter selected by ALLARM staff for its relatively high accuracy and low cost of about $100. The PockeTester measures the conductivity of a water sample by way of calculating its total dissolved solids (TDS).[20] Volunteers are also instructed in how to measure a stream's depth and do cross-sectional analysis to calculate changes in water level. ALLARM's trainers explain how determining the water level of a stream is critical for the accuracy of their data. Streams can change seasonally, or due to water withdrawals by the extraction industry. Any

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[20] For additional information on the LaMotte Tracer PockeTester see http://www.lamotte.com/en/water-wastewater/instrumentation/tracer-pocketesters (Last accessed July 27, 2015).

pollutants that might be present would occur in different dilutions depending on the relative volume of a stream.

Figure 14. Volunteers are trained to calibrate their conductivity meters[21]

It is this second module where volunteers are taught the importance of adhering to ALLARM's protocol if their data is to being taken seriously. Volunteers are shown how to follow quality assurance and quality control (QA/QC) procedures by calibrating their meters, duplicate their measurements in the field, and sending "split" samples bi-annually and to a laboratory to verify the precision of their instruments. Sending samples to a laboratory gives monitoring groups the ability to run more extensive tests, such as for concentrations of barium and strontium. The presence of these substances could help

[21] Image provided by ALLARM and used with permission

determine if a particularly high conductivity reading came from shale gas wastewater, or if it was due to other causes such as the spreading of road salts in winter.

In the final module of training, participants are transitioned to think about the applications of ALLARM's protocol in their community. Volunteers are supplied with a sample map of "Cherry Creek" with markings to denote extraction-related infrastructures that may be present in a watershed such as well pads, wastewater treatment plants, holding ponds, or land permitted for future development.[22] Participants used these maps to learn the terrain of gas development and where to monitor in threatened streams. For instance, in one session, the ALLARM trainer asked, "So where do we think we want to start monitoring?"

A volunteer responded, "It seems like it's important to see the topographical map to know where they would be likely to drill. You know, to help in seeing if it is a good site geographically."

"Not really," the trainer responded, "No rules apply for gas pads. They go wherever they need to go, regardless of how complicated access might be."

Volunteers are then supplied with a new map of their own watersheds to replicate the exercise. They are told to follow the above golden rule, as well as to take into consideration where drilling may occur relative to areas of special interest such as high quality streams, swimming and fishing areas, or streams they already know of that introduce other pollutants. To procure this information, volunteers are shown how to find well pad locations, drilling permits and water discharge reports published by the PA DEP and various river basin commissions.

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[22] I later discovered Cherry Creek was based on an actual watershed in Bradford County, PA, one of the hardest hit by gas development in the state

Monitoring groups work with ALLARM at the end of the training sessions to develop a strategic plan and evenly distribute their resources throughout a watershed. One approach to doing this is to determine where the SRBC's or PA DEP's monitoring stations are located, then to place their monitoring sites above or below those stations in order to triangulate the source of potential spills. This strategy also allows groups to leverage the credibility of agency-managed stations to confirm the quality of their data.

However, volunteers also tend to select places with which they have a strong personal connection. One volunteer noted they chose their site, "quite honestly, because it's in my backyard, and I did want to know about my backyard. We have quite a few wells. We have about 100 acres of land and there are quite a few wells that are visible." By assisting groups to develop a strategic plan for monitoring their watershed, while also taking into consideration individual concerns for particular waterways, the final module of the ALLARM training helps participants to realize connections between the local and the larger story of shale gas development.

3.4 Water Monitoring and the Potential for Empowerment

In my fieldwork I have found that the demographics of those who attend training workshops are fairly consistent. Most are older adults, often retired seniors, with spare time to take on new projects. Rarely does one find a volunteer under the age of 30. Gender representations can be relatively even, with the exception of efforts sponsored by sporting advocacy organizations that can be overwhelmingly male. The racial makeup of groups is overwhelmingly white, reflecting the overall racial composition of the region.[23] In other ways monitoring volunteers do not reflect the region's population. Those who show up for training typically come from middle or upper middle class families. Often these people have degrees in higher education, some in chemical, biological, and environmental science.

Despite coming from seemingly advantaged backgrounds, ALLARM's training sessions are often the places where these people first come into contact with the details of how the shale gas industry operates, as well as the complex political relationships that define how watersheds are managed. This is true even of those who have scientific and political backgrounds. In fact, over the course of this study, I found it was not uncommon to see many people attend a training session and, in the end, choose not to become a volunteer monitor. These individuals explained in conversations that their motivations for coming were to learn about gas drilling from sources other than public relations campaigns funded by gas companies.

ALLARM's training programs thus serve a multiple purposes. First, they propagate tools for collecting water quality data. Second, they encourage participants to recognize present and future pollution risks, and to take up water monitoring as a means to become involved in discussions about environmental protection. Third, they create a space for bringing people in the community together around common cause. ALLARM's staff believes that their monitoring program can empower concerned citizens to influence

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[23] As of the last US census, 81% of Pennsylvania's population was white. Some of Pennsylvania's most heavily drilled regions like Greene County, Bradford County, and Potter County were 94%, 97% and 98% white respectively. Similar numbers reflect the composition of northwest West Virginia and counties in the Southern Tier of New York. Additional information on these statistics is available at http://www.census.gov/2010census/data/ (Last accessed July 27, 2015).

management of the shale gas industry for these reasons. For instance, an ALLARM training handout claims: "Data will give the monitors a powerful presence that gas companies will have to respect, and will therefore become more careful with their practices. These groups will be raising the red flag by performing the roles of early detection and thus prevention of widespread contamination" (Alliance for Aquatic Resource Monitoring, 2010).

Furthermore, ALLARM insists that their close working relationship with the PA DEP gives volunteers more credibility when interacting with regulators on water quality issues. An ALLARM staff member stated as much in a training session: "We have a good relationship with DEP. They get over 100 calls a day. We've been told to mention the caller has been ALLARM-trained and they bump that call to the top—the reason our data is getting attention and respect is because of our QA/QC."

However, the entanglements of learning how to monitor and being empowered through water monitoring are complex. The remainder of this chapter, and the breadth of this dissertation, reflects on a basic question: to what extent have protocols, tailored to the resources of nonprofessionals but also adhering to the de-facto standards established by the regulatory community, empowered individuals and communities?

3.4.1 Capacities for Empowerment

Corbett and Keller (2005a, 2005b) found in their studies of participatory GIS projects that empowerment can occur at two scales: at the level of the individual and at the level of the community. They also identify the difference between changes in social or political conditions that result from an individual or community's empowerment, versus changes in an individual's or a community's capacity for attaining future empowerment. Applying this framework, there are clear indications that individuals do increase their capacity for empowerment by learning the processes of water monitoring. Jinnie Monismith, ALLARM's Director of Technical Assistance, reflected on the thrill of watching this process unfold:

> I can literally see someone's confidence grow through participating in different elements of stream monitoring and learning new techniques. For instance, watershed groups often learn how to monitor water chemistry first. When they are comfortable with those methods, they may incorporate monitoring macroinvertebrates or visual assessment to their monitoring program. This allows the monitor to build on his or her understanding and their skill set of how different elements influence each other and ultimately impact the stream. You can see the monitor get excited on an individual level, and then they meet as a group and talk with each other and there's a whole sense of additional empowerment. We've seen groups use their data and be able to go to town meetings and say: this is what we have found from monitoring our streams. It really is empowering.

This sense of empowerment is echoed in the voices of those who take up monitoring. Gail, a volunteer trained by ALLARM, commented on her personal experiences:

> When I'm going out there and I tell my friends what I'm doing, they say, well, why are you doing this? I can say, well, to get a baseline for these activities, like fracking in this case. And I say, what we do affects waters and streams. If you are spilling something out, whatever you are doing—motor oil, when you are changing your motor in your car or something—it goes somewhere and it doesn't necessarily all dissipate. Maybe if you are monitoring the water, you monitor soil as well, monitor your tree growths, look at the insect population. I mean, these are environmental changes that take place over time. What I'm doing has this long-range impact.

Changes in an individual's empowerment capacity can also come from the structures of monitoring programs, or when ALLARM encourages volunteers to take on different leadership roles. For instance, a volunteer might take on the tasks of checking in with fellow volunteers and organizing meetings. Data management coordinators ensure

QA/QC procedures are being met. Another role volunteers often step into is that of an industry-watch coordinator, whose responsibilities are to make regular trips to the county offices to keep track of new drilling permits, or read through the details of new regulations. Other roles filled by volunteers include outreach coordinators, newsletter writers, and people selected to attend public hearings and regional conferences to bring additional information back to the group.

Changes in an individual's empowerment capacity can also be found in how volunteers continue to educate themselves beyond initial training sessions. Volunteers seek out the locations of gas extraction infrastructures, information about at-risk habitats, and data generated by other water monitoring groups. Often this means developing skills to navigate the bureaucracies of local, state, and federal agencies. This process can change how volunteers understand the political landscape of watershed management. For instance, Hank Eggleston, a PATU chapter leader, reflected on what their group had learned about the PA DEP:

> Government will never have the resources—recall, we talked earlier, this is a diffuse industrial activity, scattered all over the place. Collectively, it's humongous, it's huge, but very difficult to deal with because it is scattered. There are small facilities that are very diffused, scattered all over the place. That presents really difficult detection and enforcement challenges and, as a practical matter, we realize that DEP, or any regulatory agency, can't have people everywhere. So the public can serve as eyes and ears and report to DEP when things go amiss.

One of the arguments of this research study is that evidence of empowerment may also be found in the scientific imaginaries of those who take up water monitoring. This assertion is based on the idea that volunteers not only come to understand how their work relates to the power structures governing the shale gas industry, they also develop a sense of confidence that water monitoring contributes to a science that will give people greater voice in environmental governance. An early indication of this possibility came from asking a watershed specialist who works with trained volunteers, “Do you think that volunteers sees themselves as doing science?”

She responded, “Yeah, I do. I had a lady tell me not long ago, she actually had turned in her kit because she was moving and she was unable to continue monitoring the place where she had been monitoring and it had nothing to do with shale gas, it was a job change, she moved away. But she told me that she felt like when she brought these samples back, she was wearing a lab coat.”

“She felt like she was wearing a lab coat?” I asked again.

“Yeah. She said she wished she was wearing a lab coat, because she felt like a scientist, which was funny.”

The summation of these findings suggests that water monitoring does lead to increased capacity for empowerment at the level of the individual. Volunteers experience water monitoring as empowering, and they develop this capacity for long-term empowerment by becoming scientific citizens. These two forms of empowerment also set the foundation for how volunteers imagine themselves as part of a larger movement to shape an alternative future for watershed science.

Figure 15. Concerned citizens can become empowered by becoming scientists

However, there are also many disempowering aspects to using water monitoring as a tool for empowering individuals. Volunteers sometimes find it hard to follow strict guidelines outlined by their monitoring protocols. These problems became comically evident while I was observing a follow-up meeting between a service provider and a group of volunteers. Sitting around a long table in a local town hall, the service provider asked, “So, to begin, how are we all doing? How often are you all going out?”

“The best I’ve been doing is monthly. I missed October. Then this week I waded out into the creek in my boots. They were too short, and I got wet and caught a cold as punishment I suppose,” one woman said, “I feel guilty about that, but my husband says not to feel bad—you do your best. I guess it's good to encourage each other to go out when you can. I find I need a partner."

"Yes, don't ever feel guilty. You are all volunteers!" the staffer emphasized.

Another woman in the group confessed, "Well, I've been doing weekly. But then my husband had a heart attack so that changed everything for a while. You know, doing flow measurements takes two people. Also, last time I went out someone had pushed a bunch of rocks into the stream, which changed the flow and messed up my baseline. So I spent days pushing all the rocks out. It's on state land, by a favorite camping spot. I've been getting people who run the camp to help me out and they really enjoy that."

The monitoring group's leader then inquired, "Have you asked the forest ranger?"

The volunteer responded, "Yes, but he's out for deer season now. Also, I haven't entered my data into the database since the link went bad. I've just been adding it to an excel spreadsheet on my computer."

A theme that emerges from these comments is that volunteers have other pressing matters to attend to in their lives besides water monitoring. Limited time and resources put volunteers in a position of being expected to produce useful data, while also struggling to keep up with the standards put in place by ALLARM's protocol. Evidence of disempowerment in this example can therefore be traced directly to frustrations over an individual's inability to fulfill their imagined duties as scientific citizens. Over time, frustrations and reduced self-esteem can cause major problems for monitoring groups such as low volunteer retention rates and large gaps in their data.

3.4.2 Ambiguous Outcomes of Empowerment

At the 2014 National Water Monitoring Conference in Cincinnati, Ohio, ALLARM presented, for the first time, a detailed report on the data collected by their volunteers since 2010. Compiling this report took ALLARM staff more than a year of work in contacting watershed groups, getting their data out of notebooks into spreadsheets, and teasing out trends. Out of 4,220 samples collected at 280 sites in Pennsylvania and New York, 3,000 samples from 116 sites had complete data for analysis—characterized by having at least 8 observations per site. Nearly 80% of monitoring sites were located in the headwaters of larger watersheds, most often in places with no active drilling. This aligned with ALLARM's objectives to use the protocol for baseline monitoring, but less so as a "red flag" mechanism assumed in the protocol's "pollution detection" model (Wilderman & Monismith, 2014).

For ALLARM, these findings were encouraging. It showed their volunteers were being proactive in selecting sites that would provide reliable datasets, and that volunteers were also filling gaps left by regulatory monitoring programs focused on larger water bodies. I argue that these findings are also evidence of increasing empowerment capacity at the community level. Monitoring groups were indeed using information, tools, and new social connections to build a larger presence in environmental debates.

Finding clear indications that empowerment capacity garnered from water monitoring programs lead to tangible outcomes in environmental governance is less clear. ALLARM's analysis found that volunteers occasionally discovered high conductivity readings due to excessive road salt use, or because of the presence of limestone streams in Northwestern Pennsylvania. But no conclusive evidence of contamination due to gas extraction had been found using the protocol's water monitoring techniques. During the conference, ALLARM's science advisor noted: "We think we found some in the data. But we've found the volunteers are very conservative in reporting. They don't cry wolf like people think."

Nevertheless, many incidents had been detected using the ALLARM visual monitoring protocol. More than 200 incidents had been sent to the PA DEP based on testimonies and observations of poor erosion control, bubbles in streams from methane migration, illegal dumping, and suspected chemical spills. The PA DEP almost always insisted on sending their scientists to reevaluate the situation. In many cases the PA DEP took days or weeks to arrive in the field. These findings presented a dilemma for the monitoring community, as articulated by one service provider who said:

> We're not seeing much with conductivity, and we have how many people monitoring it? Yeah, I think that a lot of people think that, at least with conductivity data, that it's not showing shale gas impacts…are we monitoring for the right parameters? The visual data being collected is where we're seeing more people reporting violations than we've ever had with conductivity. I think that a lot of times people focus on conductivity because there's a meter, and it's a little more sexy because it's chemistry.

One of the founding ideas instilled in the minds of monitoring volunteers is that standardized protocols would empower them by generating data for better environmental governance. Yet, volunteer monitoring groups were not finding evidence of gas extraction impacts in their data, or were hesitant to report incidents due to a lack of confidence in their science. Isolated events that were being reported are based on circumstantial evidence, such as photographs and verbal testimony. These techniques were useful for getting the attention of regulators, but this form of "data" did not comply with standards established by agency-based monitoring programs ALLARM consulted when developing their protocols.

Some watershed experts suggested that these findings proved that volunteers were inadequate to the task of assessing the dangers of shale gas extraction. Questions have also centered on why service providers instructed volunteers to collect data for broad-brush indicators like conductivity, which cannot rule out other pollution factors. Or why barium and strontium are sold to monitoring groups as the signature indicators of gas extraction when other, more expensive, radionuclide tests were far more accurate. In my interview with Tony Shaw at the PA DEP I got a glimpse of why regulators felt this way:

> Volunteer monitoring data frequently was a sample here, a sample there, three weeks later there would be another one. A couple months later, something else. Six or seven samples maybe, so to speak. So the datasets were not up to the rigor of what we required. We could use data when it's fitting our methodology requirements, but very little data does. So the volunteer monitors, obviously, would get frustrated and say, what is the purpose of it? But aside from that, as an agency, whether we use a volunteer monitoring group or not, we would say that we believe and support volunteer monitoring efforts. We believe there is a function and a place for them—it can be the sentinel, the warning. I think that is a good volunteer monitoring purpose.

This statement illustrates that, despite the fact that ALLARM built its protocol based on the suggestions of regulatory experts, those who define the standards ultimately have the power to determine who is qualified to collect data with those standards. These people are the guardians of what others kinds of knowledge might count as "data" in making claims about pollution events. Converting empowerment capacity into tangible influence in regulatory governance is therefore tied to the problems of overcoming these boundaries of expertise.

3.5 Conclusion

In this chapter I have introduced how standardized protocols were developed for assessing gas extraction’s impacts to watersheds in the Marcellus Shale. I also demonstrated how civic science groups responded to those standards when building their own monitoring programs. In doing so, this chapter reveals a number of important findings about the dilemma of promising that data will lead to public empowerment.

First, I find that the extent to which citizen science projects gain credibility can greatly depend on how they respond to practices accepted by those with scientific authority. Regulatory agencies hold the power to determine credibility. When service providers developed shale gas monitoring protocols they felt obligated to align their study designs with regulatory practices in order to provide effective tools to the volunteer community.

Technical standards are therefore at the heart of how a particular kind of data culture was established in the Marcellus Shale water monitoring community—one dominated by the views of regulators and watershed experts. This data culture was important for creating a science that made sense across a diverse field of practitioners. As was seen in how the PA DEP’s WQN program evolved over time, data culture is about care, diligence, discipline, and consistency when doing science, not doing the “easier” thing. These skills, often associated with experts, were taught to people who enlist in volunteer training sessions. Volunteers become intimately familiar with the science of water quality protection through training modules, and discover what is expected of them if they wish to produce high-quality data.

The data culture introduced to the water monitoring community also helped people anticipate data they didn't yet know they needed, and to want more data than they presently knew what to do with. This was evident in how SRBC selected additional indicators when setting up the RWQMN, and how service providers trained monitoring groups to think about how their data might be used, not just in the present, but also in the future. In these ways, the data culture established by standardized practices produced confidence in volunteers that they could participate in science and make a difference with their data.

However, the state of the water monitoring community's data culture at the time was disempowering as well. When dominated by the views of experts, data culture can exclude other kinds of knowledge that do not fit easily into scientific categorization schemes. Examples of this can be found in how volunteers have used the tools of visual monitoring and oral testimonies to communicate shale gas extraction's environmental impacts. These forms of local, situated, or subjective, knowledge found no place to live in data management schemes meant to attract regulatory agencies. Service providers have attempted to organize qualitative data on numerous occasions, but the very nature of this kind of environmental knowing evades easy classification. As a result of these difficulties, an expertise unique to those who live in gas extraction communities is ignored.

This points an important aspect of data culture that will be explored in later chapters. For reasons of simplicity I have in some instances of this chapter referred to "the water monitoring community's" data culture. This is a misnomer. Data culture is not singular, but plural. This chapter has shown how regulators, service providers, and volunteers all have different ideas about what water monitoring data should do. Regulatory agencies may have set the tone for data culture, but there are many unresolved disputes about how to account for and make “data” from other kinds of knowledge.

A service provider once commented in an interview that, “One of the things that we are always talking about is what would advanced shale gas monitoring look like? We need to be asking the right questions, and then make sure there's some kind of reportable outcome that's going to happen with the data.” This supports the STS literature that find it is unlikely that changes in policy, or a revised understanding of a scientific problem, could ever be directly attributed to the deployment of monitoring protocols or technologies, no matter how rigorous or sophisticated they may be. I extend this argument by suggesting that translating empowerment capacity into tangible empowerment rests not on better monitoring, but on developing data consciousness, data literacy, and data wisdom in order to challenge the idea that there can only be one data culture.

4. THE POLITICS AND TECHNOLOGIES OF DATA COLLECTION

There are different logics within the water monitoring community about the purposes of collecting water quality data (Kinchy et al., 2014). Some imagine data should contribute to long-term ecological research projects. Others want data to prompt regulatory action or to support litigation against the industry. In the case of many service providers, collecting data is viewed as a way to engage the public through science and encourage people to take stewardship over their environment. In this chapter, I illustrate how these different logics play out when monitoring protocols are applied in the field. In particular, this chapter looks at how ideas about the purposes of data affect which technologies monitoring groups deploy, as well as what political choices they must make when implementing protocols and technologies.

The chapter begins by evaluating how many organizations in the Marcellus Shale water monitoring community are now investing in automated monitoring devices under the belief these devices are they key to collecting data that will be respected by regulators. Rather than relying on field measurements made by nonprofessional volunteers, scientific claims made with these devices can be based on the readings of seemingly objective instruments that align with the practices of agencies like the PA

Portions of this chapter previously appeared as: Jalbert, K. (2015a). Fracking in the Coalfields: Community-Based Monitoring in Greene County, PA. *The FracTracker Alliance*. Retrieved July 27, 2015, from http://www.fractracker.org/projects/water-monitor/fracking-coalfields/.

Portions of this chapter are also to appear in: Jalbert, K. & Kinchy, A. J. (n.d.) Sense and Influence: Environmental Monitoring Tools and the Power of Citizen Science. *Journal of Environmental Policy & Planning*.

DEP. These ideas are particularly strong within well-established watershed associations and in Pennsylvania's many County Conservation Districts.

I find that data loggers can be empowering for watershed specialists looking to make sense of complex environmental problems. However, as David Bond's (2013) noted of the Deepwater Horizon oil spill, automated technologies can also limit environmental understandings—not only by narrowing the range of measurements scientists might use to assess pollution, but also by constraining the range of political options that become available to people dealing with environmental hazards. This chapter demonstrates how data loggers can impact the work of water monitoring groups in similar ways.

The second half of this chapter tells the story of volunteers who monitor on behalf of the Izaak Walton League of America's Henry Enstrom Chapter in Greene County, Pennsylvania. This example is used to illustrate some of the tradeoffs that exist between monitoring programs that rely on automated monitoring technologies and those that enlist highly engaged volunteers. In this story, a water monitoring organization is shown to use water quality data as a tool for political action.

In looking at these two case studies together, I find that support for data loggers is tightly bound to notions that data culture should adhere to the authority of scientific experts. By comparison, the work of the Izaak Walton League strongly supports my arguments about the importance of reevaluating who has the right to make scientific claims. And that it is necessary to broaden ideas on what kinds of knowledge count as worthwhile data, and of how water monitoring data can be used. However, I also argue that data loggers and data advocacy reveal equally important approaches to data collection that ought to be respected if we are to promote more inclusive data cultures.

4.1 Data Loggers, the Technologies of Objectivity

It was a chilly November morning on my drive through rural southwest Pennsylvania. Soon I came across the pull-off for the bridge where my contact suggested we meet. Melissa Reckner was already suited up in a pair of waist-high waders when I arrived. Melissa works for the Kiski-Conemaugh Stream Team, a sub-program of the C-SAW affiliated Conemaugh Valley Conservancy (CVC), and grew up along the Stonycreek River, a tributary of the Conemaugh River. Not having waders of my own, Melissa loaned me a pair of vinyl boots that clipped onto my belt like a pair of hip-hugging cowboy chaps. I made a point to wear thermal underwear, knowing that we would be standing in hip-deep water most of the day, collecting baseline water quality samples and benthic macroinvertebrates, or “macros.” Macros are the tiny living things in streams that have no backbone, but can still be seen with the naked eye, such as insects, fresh-water clams, and snails. Macros can be very sensitive to changes in habitat. The absence of some, or the encroachment of others, can indicate subtle changes in water quality.

Figure 16. Outflow pipe at Hutchinson Hollow Rd. with a data logger (on right)

While Melissa took a call on a potential funding opportunity, I decided to wander across the road to look down upon the stream where we would take our first samples of the day. To my surprise, a 5-foot diameter pipe spilled water into a drainage pool, which then flowed under the road and into the Kiski-Conemaugh River. I realized this was not a high quality stream. The water was tinged orange with metals. I am told that the pipe is actually the juncture of a naturally flowing stream and discharges from the Hutchinson

Hollow coal treatment facility up the road. I asked Melissa why an automated data logger was placed here (Figure 16). She told me that data loggers, in combination with macroinvertebrates, are considered the one-two punch for determining long-term stream health. The plant's lease is coming up for renewal in a few months and the Stream Team hoped that their water monitoring data would be used by the PA DEP to establish new discharge standards.

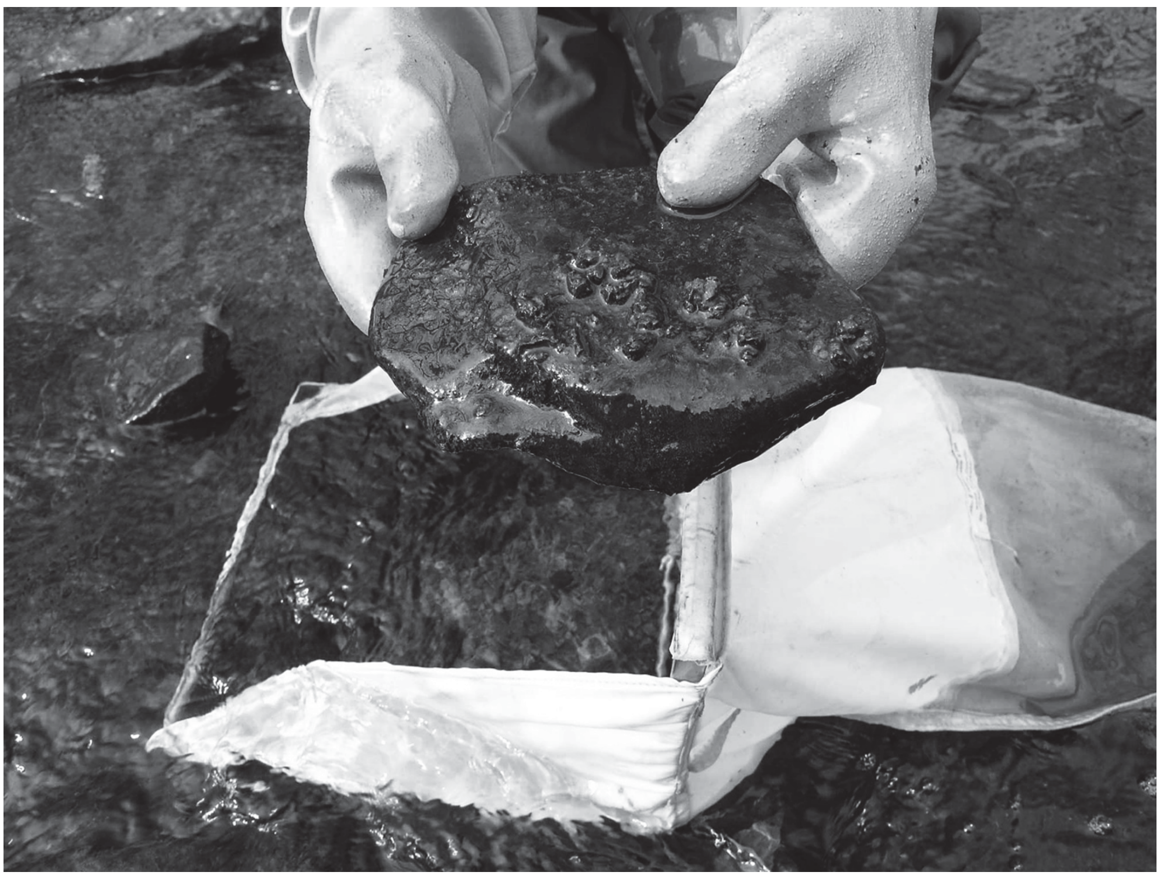


Figure 17. Collecting benthic macroinvertebrates is one method for assessing stream health in addition to collecting data with loggers

Our second monitoring location was a 15-minute drive north, taking us by farmlands dotted with gas pads, and even a wastewater holding pond just alongside the main road. This monitoring site was much deeper and murkier than the previous. As I stepped down the embankment, what looked like a shallow stream was actually three feet of water with another two feet of thick mud and settled leaves. Compared to the heavily degraded waters of Hutchinson Hollow, this water was teeming with fingernail clams, caddisflies, crayfish, and other species. Melissa's favorite is a shell-encased worm that will soon hatch into a moth. She found it fascinating how the bulky worm could become something so delicate (Figure 17).

Melissa retrieved the data logger at this second site and showed me how it works. Data loggers are installed inside a PVC tube, staked to the streambed and cabled to a nearby tree to prevent losing the sensor in the rougher waters of spring or the thick ice flows of winter. Melissa removed the unit from its housing, brought it back to the car, and plugged the logger into an optical reader connected to her laptop. We used the data logger's software to look at trends in water conditions, downloaded the data to the laptop, and wiped the logger's memory before placing it back in the stream.

"I was the little tomboy playing in the local tributary, collecting crayfish, walking in the woods, doing the things kids do," Melissa explained while we tinkered with the data logger. She continued to recall her childhood:

> I was fortunate that woods and this clean tributary surrounded my house. It was a small thing that you could literally hop across, but then I had the Stonycreek River not far from my house. When I was a kid, of course, the Stonycreek was lifeless; it was the color of your orange shirt. Every time we went in there, we would come out stained orange. But we were kids, we didn't know what was going on, or we didn't know any better. Mom used to make us keep a pair of clothes down on the rocks down there that we would change into, play in the stream, and change out of, because we

> were ruining too many t-shirts and shorts. But the encouraging part is that here, 20 years later, I can go back to our old swimming holes and you can go fishing because they've made such a remarkable recovery.

This particular monitoring site hadn't been visited in a number of weeks. But, for Melissa, collecting this data was not so much for immediate use, as much as it was for keeping track of the long-term health of the watershed. Melissa had many years of experience and knew how complicated watershed management could be. Melissa's story is but one of many instances that illustrate how automated monitoring devices have become an important tool for watershed specialists who must make sense of these complex, long-term environmental issues.

4.1.1 More Data, Better Data

Like the volunteer monitoring community, the history of how data logger monitoring materialized in the Marcellus Shale can also be traced to the Dunkard Creek fish kill. In the months following the fish kill, a number of watershed groups began exploring how they might have done a better job of early detection. Elliot Curtis is an aquatic biologist who was employed by one of the County Conservation Districts (CCD) coping with the fallout of Dunkard Creek. Elliot recalled that the biggest problem with understanding the event was in having no reliable data on watershed conditions leading up to the fish kill. A big reason for this was that many of the region's CCDs had limited staff trained in water monitoring. Elliot's supervisor instructed him to find a better solution:

> I was tasked with trying to come up with a way we could rapidly monitor the streams and get a good baseline from the streams before drilling was

permitted. So I worked through the winter of 2008 and 2009 researching this. I knew what my choice was—long term data loggers. And I knew there were tons of different ones out there. I didn't realize how many, but after months of research, and countless calls to different companies that manufactured different loggers, I had it narrowed down. We needed something that was accurate enough to give us a good picture of what our streams were, but easy enough to work with that anyone could work with it.

Figure 18. The Solinist Level logger LTC data logger, tethered to a stream anchor

Elliot's eventual choice was the Solinist Level logger LTC, a temperature, conductivity, and stream-flow sensor with a 5-year battery life that sells for about $1,300 (Figure 18). Elliot explained how he came to his decision:

> I liked the price of it. I liked the housing. I liked how tough they looked built. And you know, their advertising of the accuracy is nice, but what really sold me on them was: one, the calibration, and two, they export to CSV and Excel. And everything on the software was in pictures. So literally I had a guinea pig, an AmeriCorps intern who was a retired English literature teacher—real nice guy, hard worker, scared to death of technology. So I said, ok, we've got these loggers. Let me show you how to use the software. And literally this guy was scared to turn a computer on. Within 10 minutes he was in the field downloading loggers flawlessly—I said, that's the loggers you have to go with.

For Elliot, the Solinst data logger was the answer to collecting high quality data in a timely manner without having to rely on the availability of trained personnel. Elliot now regularly consults with watershed groups throughout the Marcellus Shale to bring these data loggers online. [24]

The first installation of data loggers in Western Pennsylvania was launched with only $7,500 in private donations in 2009, but the technology quickly gained the attention of other CCDs, watershed associations, and even volunteer-based groups in the region. Some of these groups were looking for a tool to gather data in streams threatened by natural gas development. Others hoped to augment existing watershed management projects dealing with agricultural runoff, sewer treatment plants, and discharges from coal processing facilities. The multi-use capabilities of data loggers attracted organizations that had not historically invested in water monitoring programs in the past, or those that were questing the worth of their existing programs. “We were about to cancel our monitoring program last year,” one County Conservation District manager told me, “but having purchased some data loggers, now we see it as an invaluable process.”

[24] For additional information on the Solinist Level logger LTC see http://www.solinst.com/products/dataloggers-and-telemetry/3001-levelogger-series/levelogger-junior-edge/ (Last accessed July 27, 2015).

Significant financial investments in data loggers would come from the Colcom Foundation's Marcellus Environmental Fund beginning in 2010. The Colcom Foundation was established in 1996 by an heir to the Mellon family fortune to fund land conservation and habitat restoration projects across the US, but particularly so in its own backyard of Western Pennsylvania. In December 2010, Colcom announced it would award $1.3 million through a new Marcellus Environmental Fund—a one-time dispersal of grants dedicated to addressing the impacts of gas drilling. In the first five months of the program, Colcom received over 80 requests for more than $7 million in funding. Many of the groups that would receive Colcom grants expressed a need for baseline water monitoring programs.

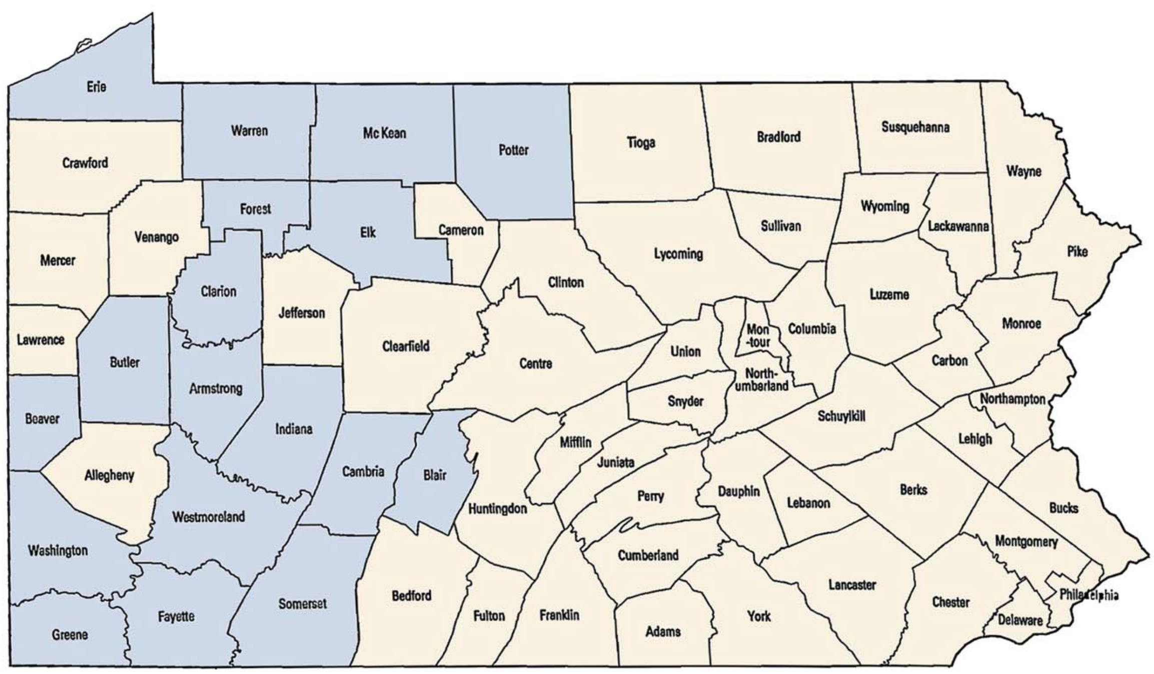


Figure 19. Pennsylvania counties (in blue) with data loggers as of May 2014[25]

[25] This map was created by the author based on paper maps and records obtained from The Colcom Foundation.

Colcom consulted with numerous watershed experts who suggested funding automated monitoring equipment rather than volunteer monitoring programs. They took these suggestions seriously. In less than two years Colcom would underwrite the installation of more than 200 data loggers across 17 counties in western Pennsylvania (Figure 19). Carol Zagrocki, a staff member at Colcom, explained why the foundation chose to invest so heavily in data loggers:

> Realistically, it's not easy for a volunteer to be out there at the exact moment as an impact on a waterway. We realize that. But they can see things. They can be our eyes and the ears, even if they have their own reason for being there. A data logger, to me, is maybe a little more important for really establishing detailed baseline data.

Colcom's substantial financial support stands in stark contrast to the days when PA DEP's Growing Greener Grants sustained many of the region's nongovernmental water monitoring programs. In many respects, the Marcellus Environmental Fund made Colcom the new steward for watershed protection funding in the region. Pollution threats from shale gas extraction radically altered ideas about how data ought to be collected during these transitional years. These ideas subsequently shaped how monitoring technologies were selected when building new infrastructures for water monitoring.

4.1.2 Bridging Political Boundaries

Data loggers do things that volunteers armed with handheld meters cannot. Mainly, they produce large volumes of data about a stream, complete with precise time and location records that appeal to watershed scientists. Data loggers are also well attuned to the standards established by monitoring programs such as those managed by the PA DEP and SRBC. In fact, because of expanding interest in data loggers by the state's CCDs, the PA DEP's Division of Water Quality Standards was motivated to publish a data logger monitoring protocol in 2013. This protocol did not formally establish mechanisms for shuttling data into regulatory management projects, but it did outline steps for proper site selections, calibrating equipment, maintenance procedures, and decision trees for reporting data to the PA DEP (PA Department of Environmental Protection, 2013). This document reinforced the belief that regulators would pay greater attention to data collected with loggers.

A number of examples suggest that data loggers can create boundary-bridging opportunities for environmental protection organizations to work directly with regulatory scientists. The data logger program operated by the Kiski-Conemaugh Stream Team detected regular conductivity spikes at their Hutchinson Hollow monitoring station beginning in 2012. After reporting their findings to the PA DEP, further investigation identified the Hutchison Hollow coal treatment plant as its source (PA Department of Environmental Protection, 2010). Kiski-Conemaugh Stream Team's data is now part of the docket for review in the plant's permit renewal process as Melissa had hoped (Kiski-Conemaugh Stream Team, 2013).

A second example grew out of relationships formed in the Allegheny Watershed Improvement Needs Coalition (Allegheny WINS). Established in 2007, Allegheny WINS brought together members of federal and state agencies to manage the half-million acre Allegheny National Forest. Members of Allegheny WINS also include a number of

CCDs, watershed associations, oil and gas companies, the Seneca Nation of Indians, as well as advocacy groups such as local chapters of PATU (Allegheny WINs Coalition, 2011; Western Pennsylvania Conservancy, 2008). In 2010, the Pennsylvania Department of Conservation and Natural Resources (PA DCNR) asked a PATU chapter to place their data loggers in Cornplanter State Park where PA DCNR suspected incidents of illegal dumping of shale gas wastewater. Data over the next three months showed irregular conductivity spikes in the vicinity of a high quality trout stream called Cafferty Run. PA DCNR installed remote cameras on the site and the PA DEP successfully caught the violators shortly thereafter.

This example is fairly unusual, however. In many conversations with watershed specialists I discovered that data loggers had led to inconclusive findings when suspected shale gas pollution events occurred. When asked about this problem, Monica Porter, a specialist at a Pennsylvania-based watershed association, expressed her frustrations. “I personally have fallen out of love with the data logger,” she told me.

“Why is that?” I asked.

“They take an enormous amount of staff time. They require an enormous amount of travel, just in terms of getting our people out there to download the information. And I find that the time lag in getting the data oftentimes is so great that it keeps you from identifying potential issue. We have a logger, and we saw, back in May, the conductivity go up to like 20,000 from 300 in a matter of 30 minutes. This wasn’t a watershed that was at the time being actively drilled, so we weren’t trying to get down there more often. You know, we were just kind of regularly downloading it every two weeks and by the time we got the data, of course that flush was gone and aside from looking at land use upstream, it didn't really provide us with a whole lot of information. And subsequent samples have shown that the level of conductivity has gone back down. So it's really frustrating in that sense."

"So it was never a traceable event?" I inquired.

"We never found out what it was," Monica replied, "but data loggers have helped us identify some really interesting things, for the most part unrelated to shale gas. We had one downstream of a mine drainage discharge system that we have been in active litigation over since 2006. We put this logger in the stream only because we thought there was the potential for a shale gas wall to be drilled in the headwaters. But the water was downstream from the discharge, from the treatment system. And we found that they were manipulating the system to avoid using expensive treatments in a very regimented way. We would see conductivity go up a couple days a week—always on Monday, or like Thursday at 1:00, and then all weekend, and then it would come back down. We found a lot of weird stuff like that."

"What sort of action were you able to take on that?" I asked

"We brought that up in our settlement conversations. The company, of course, denies that they were doing that, but we were able to get DEP—rather than coming out and doing routine scheduled inspections—to do more pop-in inspections. And they have been sampling a little more, but I think that once we brought it up, we saw the conductivity levels kind of level off, which is really interesting."

Other watershed specialists echoed Monica's story. These findings suggest that data loggers do appear to work for confirming extraction related problems in specific scenarios, such as with the Allegheny WINS example. However, data loggers are less effective in accomplishing the bigger task of monitoring the shale gas industry's impacts to complex watersheds. Even when sudden pollution events are detected, data loggers are not generating the kind of bulletproof data many project designers and funders anticipated. Furthermore, most data logger programs are managed by organizations that have relationships with regulatory agencies predating the arrival of these technologies. This opens up the possibility that boundary-bridging success stories related to data loggers may not be due to the loggers themselves, but due how credibility was already established through these relationships.

4.1.3 Implications for Public Participation

Data loggers are permeating into many corners of the water monitoring community because of their perceived effectiveness in attracting the attention of regulators, including into groups sustained by volunteers. However, many people who witnessed smaller watershed groups investing in data loggers expressed concern about the long-term viability of their programs. I discussed the implications of smaller groups becoming attracted to data loggers with staff at a prominent service provider organization. One staff member reflected on how many data logger based monitoring programs were missing important lessons learned in the past:

> My thing with data loggers is it's a quick way to generate lots of data. But I think one of the things that I find challenging about a funder giving out lots of money for a tool is the same challenge that we ran into in 2000 when DEP's Growing Greener Grant program put all this money into watershed associations to do monitoring. People dove into monitoring, buying all this different kind of equipment, not thinking through how they are going to use their data, not thinking about 'what is your question' and matching the parameters to that question. I think people latched on to an

> easy way to collect data without thinking about what the long-term view of that is.

These observations point to a number of side effects when monitoring groups, especially those that rely on nonprofessionals, invest in data loggers. For starters, data loggers are expensive devices. A single data logger may cost $1,300, while the same amount could fund monitoring kits and training programs for dozens of volunteers. Many people I spoke with who worked with loggers also felt overwhelmed by having to download, archive, and manage the massive amounts of data. Some of the earliest installed data loggers have accumulated more than 60,000 measurements *per logger*. One volunteer who maintains loggers for a small watershed group commented, “we have these 12 or 14 data loggers out there that are generating reams of data that has never been analyzed.”

A second problem is that nonprofessional groups lack the expertise to wade through this data to identify pollution events and tease out longer-term trends. A watershed specialists who consults with monitoring groups spoke about the implications of this problem. “We're at a stage right now where there's a lot of people collecting stuff, and they're doing it the right way with the right equipment,” he explained, “but as a community we're at the point right over here where 'what does it mean' and nobody still knows.”

Disconnects between the technical affordances of data loggers and the ability to maintain them are thus problematic for small watershed groups that lack expert staff and resources. These barriers also make it difficult for watershed groups to make sense of how data loggers might fit within the goals of their water monitoring programs. Questions posed in ALLARM’s study design such as, “How will you manage your data?”

"How will you use the data?" and "Who will complete the tasks?" have no easy answers. As a result, smaller monitoring groups that deploy data loggers have become dependent on the expertise and resources of well-established outside groups that assist them with these tasks.

The limitations of these alliances quickly become evident. In many instances, organizations that oversee data logger projects have taken neutral political stances toward managing shale gas development. Elliot Curtis, the aquatic biologist who was instrumental in bringing data loggers to the region, noted that many larger environmental protection groups are attracted by the idea that:

> This is not an activist, or a 'say no to Marcellus' thing. This is what we can use to lead us into the future of water quality monitoring, to get more bang for our buck on projects, to centralize pollution, to find where the pollutants are coming from and what they are. You know, this does the work of a hundred volunteers and all we need is one person to download them.

These political positions can influence what kinds of questions are asked in monitoring programs based on data loggers. They can also have the effect of prioritizing the needs of watershed specialists over those who are primarily concerned about shale gas extraction. The monitoring objectives of smaller monitoring groups that depend on outside groups to maintain their data loggers can succumb to these powers. For example, one organization that assists with loggers requires groups to sign a liability waiver that states:

> I hereby state that all data and logger locations will remain confidential. I will not disseminate data acquired by verbal, written, or electronic means unless I obtain written approval from [the service provider]. I will not divulge any logger location unless written approval is obtained from [the service provider organization] Director. I will only e-mail data and related information to [service provider] staff. I understand that acquired data

> must be interpreted by individuals designated by the [service provider's] Director before the data and resulting information may be disseminated to the public to avoid false reports.

The cautious position laid out in this contractual agreement is understandable. The justification for the document is that false reporting could undermine the entire field of nongovernmental monitoring in the region, or put place hard-won relationships between professional environmental organizations and regulators in jeopardy. However, these contracts leave little room for water monitoring groups to use data in other ways, such as in advocacy campaigns or lawsuits that outside groups might not be on board with.[26]

Data loggers are also changing how service providers view the future usefulness of nonprofessionals in collecting data. Many who support data loggers believe that removing the human element from the tasks of data collection is makes for rigorous science. Melissa Reckner, who assists County Conservation Districts with data loggers as well as programs that utilize volunteers, suggested that data loggers should make us rethink the purposes of nonprofessionals:

> I love volunteers, but I don't necessarily agree with some organizations' use of their time. They are sending people out once a week to get the field meter into a stream. That is awesome; eyes in the field. But one, you suffer volunteer burnout. Especially if they are not seeing any change over time. They are like, why am I still doing this? Also, if a volunteer goes out on a beautiful day like today, and an episode happens this evening, they are not going to know about it because it's going to dissipate by the time they go out next Wednesday. Also, it's weather dependent. If it's rainy, or really bad snow and ice, a volunteer isn't going to go out, which is why we decided we wanted to develop our shale gas monitoring program around loggers. They are out there 24/7 and they are very accurate. So there is no question about protocols or anything.

[26] For reasons of confidentiality, I have intentionally omitted the source of this document.

These views on the relative affordances of data loggers versus volunteers are common. Proponents of data loggers argue that they should allow concerned citizens to put down their conductivity pens and leave monitoring to the experts. “Just because fewer people aren’t in the field doesn’t mean people can’t be volunteering in other capacities,” this service provider suggested, “like maintaining a website or Facebook account, compiling a newsletter, staffing booths at events, providing educational programs, fundraising, and things like that.”

Indeed, when I asked a member of a local PATU chapter why they shut down their volunteer monitoring program in favor of purchasing data loggers, I was told that volunteers were eager to put aside their testing kits. Chapter members felt data loggers did a better job of monitoring and would free up time for members to work on other conservation projects. For instance, some volunteers have since expanded the chapter’s “Trout in the Classroom” program, which works with the PA FBC to educate school groups about coldwater fisheries and the importance of watershed conservation.[27]

Removing volunteers from the process of water monitoring could have serious implications for how average citizens retain a voice in steering projects meant to protect their communities. Replacing volunteers with data loggers can close down opportunities for nonprofessionals to ask questions ignored or overlooked by experts. The political restrictions that come with data loggers also mean that attempts to change environmental governance must occur on scientific terms, limiting other mechanisms water monitoring groups might use to pressure industry and regulators. In these ways, automated

[27] It is worth noting, however, that this PATU chapter initially installed their loggers with the assistance of their local CCD. Since that time, the CCD has taken control over their loggers. I am told that this happened because the chapter’s members became overwhelmed by the loggers and lost interest in the program.

monitoring technologies can be disempowering for nonprofessionals who view water monitoring as a way to change underlying power structures that dominate ideas about how the shale gas industry ought to be managed.

Ultimately, I argue that data loggers can be empowering tools for professional watershed scientists working in well-established environmental organizations that have established relationships with regulators. However, I also argue that data loggers are ill-suited tools for building empowerment capacity in communities dealing with politically complex environmental threats like shale gas extraction. Melissa Reckner noted in an interview that, “data loggers don’t vote,” suggesting that, beyond arming nonprofessionals with testing kits, volunteer monitoring projects also produce engaged citizens. As will be seen in the second half of this chapter, influencing environmental governance may depend on engaged citizens who put data into action through civil lawsuits, advocacy campaigns, and appeals to the public.

4.2 Advocating with Data: The Harry Enstrom Chapter of the IWLA

Greene County, in southwest Pennsylvania, produces over 12% of the underground mined coal tonnage in the United States (Weir International Inc., 2010). The combined output of three active mines—Bailey Mine Complex (the largest underground mine in North America), Cumberland Mine, and Emerald Mine—produced nearly 20 million tons of coal in 2012 (Center for Coalfield Justice, 2012). These three mines also make Greene County one of only two in Pennsylvania where longwall coal mining is still practiced—a process often considered, along with hydraulic fracturing and tar sands removal, to be an “extreme” form of fossil fuel extraction. The process of longwall mining uses a highly mechanized process to bore out coal bed segments 800 feet wide, 7,000 feet long, and 7 feet high. The residual earth is then allowed to collapse as machinery advances along its path. The fact that two extreme fossil-fuel extraction industries co-exist in Greene County is a rarity in the US. Greene County is also home to many abandoned mines from more than a century of coal extraction.

Figure 20. Abandoned Clyde Mine discharges AMD into Ten Mile Creek

One of the more prominent impacts from legacy coal mining comes from acid mine drainage (AMD) discharges, formed through the chemical reaction of subsurface water entering coal beds that contain sulfur-bearing minerals (Figure 20). This process results in the formation of sulfuric acid – particularly in flooded abandoned mines. AMD fluids are highly toxic when they reach the surface, and can have harmful health effects on humans and ecosystems. The drainage can be treated to neutralize the harmful effects of sulfites and heavy metals (US Environmental Protection Agency, 1994). However, many AMD discharge sites remain under-managed due to a lack of state resources for abandoned mine reclamation projects.

Impacts from active coal mining can also include declining groundwater levels that cause drinking wells to dry up, redirected surface water flows, migration of methane and other gases released in the process of mining, and the discharge of polluted water used in extracting coal. The EPA and the PA DEP require coal-mining operators to limit discharges into surface waters and, in some instances, these regulations have been effective. In March 2014, the EPA and the US Department of Justice (DOJ) indicted Alpha Resources with more than 6,000 discharge violations in Pennsylvania, West Virginia, Tennessee, Virginia, and Kentucky. In addition to a $27.5 million fine, Alpha Resources was ordered to invest $150 million in Greene County to build reverse osmosis AMD treatment plants (US Environmental Protection Agency, 2014).

Shale gas extraction introduces a host of new water quality issues to a region already compromised by active and legacy coal mining. Compared to other Pennsylvania counties in the Marcellus Shale, Greene County is the fourth highest producer of shale gas. From July 2013 to June 2014, extraction companies retrieved more than 330 billion cubic feet worth of gas. Greene County produced more than 4.4 million barrels of liquid waste from these wells over the same time period, making it the second highest county in the state (Kelso, 2014). The three most common methods of shale gas wastewater disposal in the county include sending waste to municipal treatment facilities, to high-pressure injection wells in Ohio and West Virginia, or storing it locally in wastewater impoundments ponds for future disposal or reuse. Each of these disposal methods comes with a host of associated risks.

The majority of wastewater treatment plants in the state of Pennsylvania are not equipped to handle shale gas drilling waste. In 2011 the PA DEP requested that gas companies cease delivering waste to these facilities, but not all facilities complied with the PA DEP's request (PA Department of Environmental Protection, 2011). Holding ponds and waste pits are known to leak. In September 2014, Range Resources was fined $4.15 million by the PA DEP for soil and groundwater contaminations at five impoundments in neighboring Washington County. This is the largest fine to date assessed against the Pennsylvania shale gas industry (Hopey, 2014b). An equally concerning issue is the lack of information on waste handling practices. In March 2014, the Tri-County Municipal Water Authority, which services more than 10,000 customers in Fayette, Greene and Washington Counties, came under investigation by the PA DEP for failing to report its discharges and water quality reports (Jones, 2014).

Besides concerns about legal methods of wastewater disposal, another major issue in Greene County is the illegal dumping of waste. In June 2012, Allan's Waste Water Service Inc. pleaded guilty to 13 counts of discarding millions of gallons of shale gas extraction wastewater into abandoned mine shafts, local streams, and along rural roadsides between 2003 and 2009 (Kelly, 2013). "By illegally dumping these polluted liquids you caused serious injuries to our waterways," a Greene County judge commented in the hearing, “these are dastardly crimes.” To which the operator testified, “I'm sorry for the pollution stuff my company caused” (Krysak, 2012).

What might come from the entanglement of these two industries remains a relative mystery. I visited the Center for Coalfield Justice (CCJ), an environmental justice advocacy organization that works in Greene County to improve policy and regulations for the oversight of fossil fuel extraction, to learn more about these issues.[28] I met with Veronica Coptis, one of CCJ’s directors. Concerns about coal and gas extraction hit home for Veronica. She lives in Greene County, has three gas pads neighboring her property, and a husband who, until recently, worked for the coal industry. She told me:

> If we keep going with the pace that we’re going right now, we’re just treating this region like a grand experiment. What happens when you start plugging a bunch of gas wells near abandoned mine pools? Or what happens when you start long-wall mining close to a shale gas well? If it goes the way it’s going right now, unfortunately, we’re going to see some massive disaster. And then there are other threats to worker safety—if this fracking wastewater is getting into these mines, there are men and women, underground, in that mine working, and what is the exposure to them, as well as to the workers that are dealing with it on the frack sites?

Unfortunately, energy extraction is deeply woven into the fabric of Greene County and those who take aim at the industry can find themselves quickly ostracized. “Its like it’s a big secret, and you are not allowed to take the lid off of it, not even in public meetings,” a long-time Greene County resident explained, “The community members, they are shy, they are bit by coal from a century of repression by the coal industry that ‘thou shall not say too much’ or whatever. I think the gas industry has

[28] CCJ is one of the more established environmental advocacy organizations in Southwestern Pennsylvania. While its initial mission was to assist communities with issues related to coal mining, its mission necessarily expanded when these same residents faced a second wave of energy extraction with shale gas. More on CCJ can be found at: http://coalfieldjustice.org/ (Last accessed July 27, 2015).

followed that model because it has worked for the coal industry. I think, if there is anything that citizens in this county could do, it's to daylight information so these dirty little secrets just can't happen."

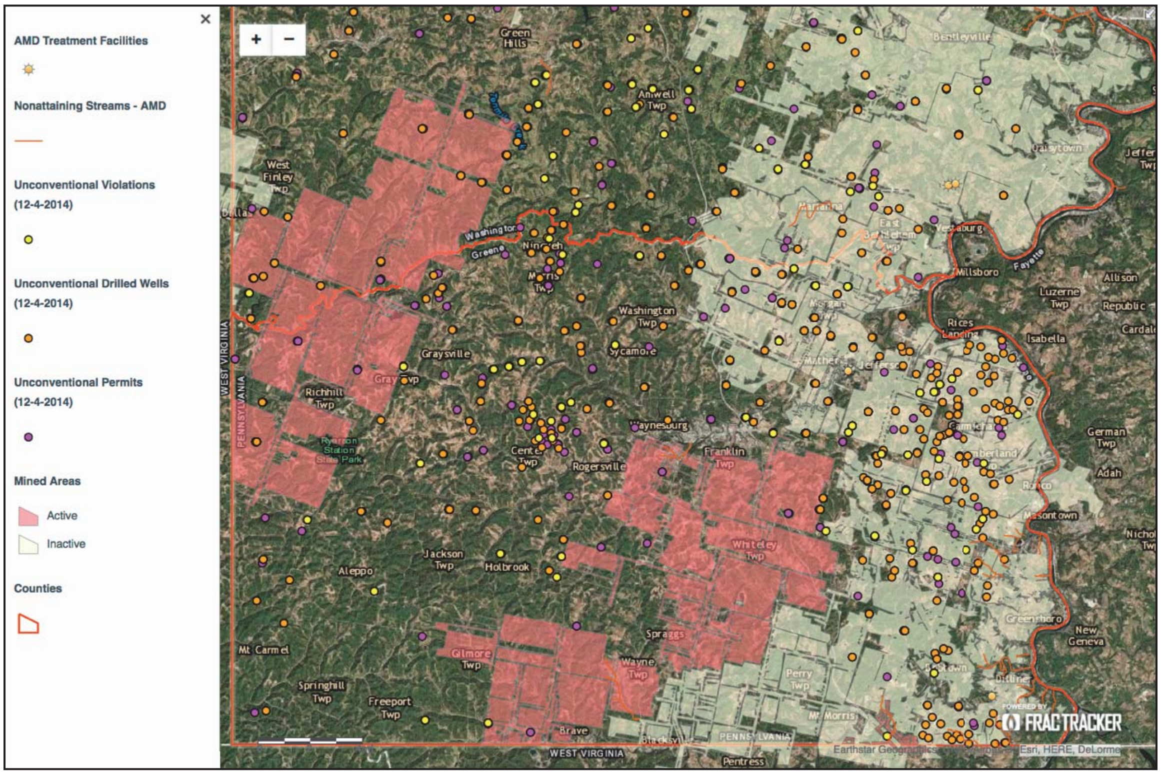


Figure 21. Coal mines and gas wells in Greene and Washington County, PA (pink denote active mines, gray denote abandoned mines, points represent gas wells and permits)[29]

One group that has not been shy about speaking out against the extraction industry in Greene County is the Harry Enstrom Chapter of the Izaak Walton League of America (IWLA). IWLA National does not take an anti-industry position. Their mission states: "The IWLA supports the economic development of mining, drilling and the proper

[29] Map generated by the FracTracker Knowing Our Waters Project. Retrieved July 27, 2015, from http://www.fractracker.org/projects/water-monitor/

use of natural resources."[30] However, members of the Harry Enstrom Chapter are highly dedicated to protecting their community from the impacts of coal mining and gas drilling activities. One member told me:

> We cannot take a position on anything, we have to be neutral, but there is something rotten going on. There are people who are being impacted adversely, people that are dying because our elected representatives. Our DEP, our EPA, they're not protecting the interests of the people. They are protecting the interests of the extraction industry.

Harry Enstrom Chapter's draw as a home for people willing to speak out against the gas industry is strong. Some members trace their involvement back to the Dunkard Creek fish kill which, they say, rocked many residents in Greene County out of complacency. Chuck Hunnell, a retired high school history teacher, explained how he came to be an IWLA member:

> I was having dinner one night in Williamsburg, and the League chapter had a meeting in an adjoining room, and I could hear what they were talking about. They were talking about water quality, talking about Marcellus drilling, talking about the Dunkard Creek fish kill, and I'm sitting there thinking, Lord, I need to be there. Then I saw some people that I knew that came out. And I asked them what the organization was. They said, The Izaak Walton League. I had never heard of them. So I went and introduced myself and the rest is history. I have been involved ever since.

In 2010, the Harry Enstrom Chapter consulted with a local laboratory and developed a protocol for training volunteers to do water monitoring. This program drew additional members to the chapter. "I wasn't involved with any watershed monitoring activities before working with the IWLA," Alex Shields, a local farmer in his 30s explained, "I just saw in the *Observer Reporter* an article that they were doing water

[30] Additional information on the mission and objectives of the IWLA is available at http://www.iwlaharryenstrom.org (Last accessed July 27, 2015).

testing. So I went to a meeting for this chapter and it all started from there." This person now runs the Chapter's monitoring program. The Harry Enstrom Chapter's membership exploded from 27 members in 2010 to over 120 today, making it one of the larger chapters in the Izaak Walton League of America organization.

4.2.1 Contesting Official Assessments of Water Quality

The Harry Enstrom Chapter's growing reputation as a grassroots advocacy group coincided with the expansion of its monitoring program. Beginning in 2011, a number of the chapter's volunteers began to find high levels of bromide at five different water monitoring locations. In each case these were either abandoned coal mining AMD discharge sites, or at points where active coal mining refuse pods discharged treated water into nearby streams. The "hot spots" identified by the chapter included Emerald Mine's refuse impoundment discharge #001 into Smith Creek and #005 into Frosty Run, as well as Cumberland Mine's discharge #014 and #029 into Whiteley Creek (Figure 22). All of these sites are operated by Alpha Resources. #014 and #029 were even included in the 2014 DOJ violations settlement. A fourth site was the Clyde Mine AMD treatment plant, which discharges into Ten Mile Creek. Clyde Mine was abandoned in 2002 after the company filed for bankruptcy. The PA DEP now manages Clyde Mine's discharge treatment plant.

Figure 22. Cumberland Mine's discharge into Whiteley Creek

These findings led volunteers to wonder if the waste products of coal and gas were co-mingling in underground mine shafts, or in refuse impoundments managed by the coal industry. The Harry Enstrom Chapter took this information to Range Resources to learn more about what might be causing high bromide levels. One chapter member recalled of the meeting:

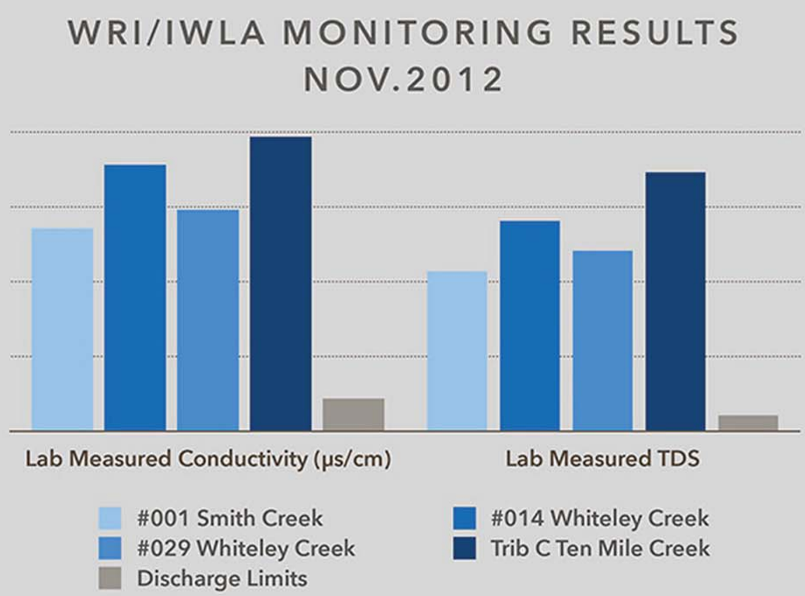
> We had a meeting with Range Resources in 2011. They contacted us, heard about our monitoring program, and eight of us went. They gave a nice presentation about how they're really safe. We said, we would like to help you out with monitoring, but they never contacted us. What we did get out of that meeting was learning that bromides don't come from coal, but from Marcellus Shale drilling. So then why are we getting so much bromide out of coal mining discharge? Are the water pools compromised?

> If so, then we're in trouble. There’s 1.8 trillion gallons of water in the old abandoned mines here in Southwest Pennsylvania. We can treat AMD if it's strictly AMD. But we can't handle flowback water.

The Pennsylvania Oil and Gas Act, Section 78, prohibits the disposal of flowback water or any materials associated with the drilling industry into coal mines, slurry impoundments, coal mine discharges or coal refuse piles. Following their unproductive meeting with Range Resources, the chapter decided to gather as much information as possible, deliver their findings to the PA DEP, and demand that watershed experts from the agency follow up with more comprehensive testing. But determining the co-presence of coal mining discharges and shale gas wastewater can be difficult. Veronica Coptis from CCJ explained the reasons for this:

> You typically see a lot of barium with fracking wastewater. But if fracking wastewater comes into contact with mining wastewater that has a lot of sulfate in it, those two chemicals will combine and settle out. So we’ll see a lot of bromides and we’ll see a lot of chlorides, but we won’t see the barium. Which agencies like to use as a character of fracking. So this complicates the enforcement of trying to get these issues handled. Or, there can be a bunch of fracking waste coming out of a discharge, but the mining permit doesn’t have bromide listed as one of their pollutants that they’re not allowed to discharge.

Harry Enstrom Chapter’s monitoring protocol and data collection technologies were nearly identical to those outlined in the ALLARM shale gas monitoring protocol. Their pocket conductivity meters could easily measured total dissolved solids (TDS). However, determining whether or not high conductivity readings stemmed from bromides or chlorides was beyond the capabilities of volunteer monitoring field kits. Furthermore, the relative presence of barium required samples to be sent to a laboratory for further analysis. The Harry Enstrom Chapter did not have extensive resources to run these tests on a regular basis and they knew their own limited data would be considered circumstantial by regulators. Thus, one strategy the chapter used to bring attention to the significance of their findings was to obtain the PA DEP's own monitoring reports and compare the two datasets at their five suspected hot-spot sites.



Indicator	#001 Smith Creek	#014 Whiteley Creek	#029 Whiteley Creek	Trib C Ten Mile Creek	Discharge Limits
Lab Measured Conductivity (μs/cm)	6,110	8,060	6,690	8,870	1,000
Lab Measured TDS	4,808	6,344	5,432	7,840	500

Figure 23. WVWRI's monitoring results confirmed IWLA's findings[31]

When the Harry Enstrom Chapter obtained reports on the PA DEP's samples collected in 2012, they discovered that Emerald Mine discharge #001 registered conductivity readings of nearly 5,000 microsiemens, and TDS levels of 3,500 milligrams

[31] Data obtained from WVWRI during the process of writing the FracTracker Knowing Our Waters Project article on the IWLA.

per liter. Cumberland Mine's discharge #029 conductivity was as high as 7,500 microsiemens. The chapter also requested the assistance of watershed scientists from the West Virginia Water Research Institute (WVWRI), based at West Virginia University, to corroborate these findings. WVWRI researchers found similarly disturbing conductivity levels at these sites (Figure 23). The PA DEP has no discharge limits for bromide, but standards do require conductivity concentrations to be below 1,000 microsiemens, and TDS concentrations to be below 500 milligrams per liter. In other words the PA DEP's own reports showed these five discharge sites to be far above their allowable limits.

Smith Creek, Frosty Run, Whiteley Creek, and Ten Mile Creek all flow into the Monongahela River. Ken Dufalla, Harry Enstrom Chapter's president, spoke plainly about what this means for Greene County in a packed room of residents in February 2014:

> This is going into your drinking water. It's going into the Mon River. One million people depend on the Monongahela River for their drinking water. When you go to a school district, and you can't drink the water, we've failed our children. We haven't stood up and taken back what's ours. Our state constitution guarantees us clean air and water. We'll go to jail for it.

Another important study supporting the Harry Enstrom Chapter's case was the PA DEP's 2014 Integrated Water Quality Monitoring and Assessment Report, required by the Clean Water Act. This report noted that its measurements of TDS in the Monongahela River watershed had significantly decreased since 2012, with one exception. The report stated that, "statistically significant increasing trends for both SO4 (sulfates) and TDS were observed at one station (Dunkard Creek)" (PA Department of Environmental Protection, 2014). Of more than 100 monitoring stations that make up the PA DEP's WQN, Dunkard Creek was the only station in Greene County included in the report.

Harry Enstrom's members argued that, if abandoned mine discharge sites like Dunkard Creek were experiencing abnormal TDS levels, then other mining discharge sites were as well.

In documents submitted to the PA DEP, in November 2013, the Harry Enstrom Chapter requested regulators run a full spectrum of water quality tests at their hot spot sites to determine the sources of pollution.[32] Similar documents were forwarded to the EPA. Neither of these letters led to further testing. Later in 2013, a Duke University study found radium concentrations were 200 times above normal at a wastewater treatment facility receiving shale gas waste in nearby Indiana County (Cusick & Colaneri, 2013; Warner, Christie, Jackson, & Vengosh, 2013). Documents obtained by the chapter from PA DEP in 2014 showed Smith Creek's discharge #001 had radium 226 levels of 301 PCi/L. The total radium limit for industrial effluent set by the EPA is 60 PCi/L. Harry Enstrom Chapter wrote more letters to the PA DEP and EPA requesting tests for radionuclides, which also led to no further actions.

Despite Harry Enstrom Chapter's concerted efforts to triangulate their findings with data from the PA DEP and WVWRI, the chapter was unable to provoke a response from regulators. Frustrated by the difficulties, the chapter sought out other means of influence. Rather than making their case purely on scientific grounds, chapter members took their data into the political realm. They used their data as a tool for advocacy to change public opinions on the efficacy of regulatory oversight. In doing so, they also increased their capacity for empowerment in the face of mounting risks from shale gas extraction.

[32] These letters are available at http://www.irrc.state.pa.us/docs/3042/COMMENTS_PUBLIC/3042 03-19-14 IZAAK WALTON LEAGUE OF AMERICA DUFALLA ENSTROM.pdf (Last accessed July 27, 2015).

4.2.2 Finding the Capacity to Influence

Harry Enstrom Chapter's official position on extraction related issues remains neutral. However, members in the chapter have developed a reputation in the Marcellus Shale monitoring community because of their willingness to take vocal positions against the gas industry—a stance that many water monitoring groups are hesitant to take in fear of having their science stigmatized as biased. The chapter's work has even garnered the respect of watershed specialists who wish they had access to volunteers like Harry Enstrom Chapter's in their own monitoring programs. Elliot Curtis, the aquatic biologist who commented that data loggers were the future of monitoring because they were not "an activist, or a 'say no to Marcellus' thing," also told me:

> They are the most hardcore group of individuals that I have ever met in my life. I mean, they take on projects that volunteer organizations from anywhere would just be, like, forget that. I would love to see the Izaak Walton League adopt advanced monitoring techniques. They could sell it. Those guys are the most active people you will ever meet. I mean, you look at them, they are not scared, and it's sort of been passed down generation to generation in the Izaak Walton League of America helping the community. If I could get dedication like that in watershed associations, man, there would be no stopping them.

Harry Enstrom members developed this reputation by vigilantly engaging regulators and industry at every turn. For instance, in February 2014, Chevron's LANCO 7H well in Dunkard Township exploded, killing one worker and injuring another. The well blowout would burn for nearly a week before a Houston-based emergency response company, Wild Well Control, arrived at the scene to distinguish the fire. Meanwhile, Chevron set up a command center at the Bobtown Polish Club to address questions from residents.

Figure 24. Chevron's gift certificate for one pizza and 2-liter bottle of soda. Chevron's offer expired on May 1st, 2014[33]

Besides the ill-will triggered by Chevron's forcing the club to cancel its annual Valentine's Day party, the Bobtown well blowout received national attention for a poorly handled public relations campaign. Chevron mailed gift certificates to every Dunkard Township resident for a free pizza and 2-liter bottle of soda (Figure 24). The letter accompanying Chevron's gift certificate read:

> Dear Neighbor. We are sorry to have missed you. We wanted to provide you with a status update on the February 11 incident that occurred on Chevron Appalachia's LANCO 7H well pads in Dunkard Township and see if you had any questions or concerns that we could address. Chevron recognizes the effect this has had on the community. We value being a

[33] Photograph taken by Katie Colaneri, WHYY reporter, and used by permission. This image originally accompanied an article titled, "Chevron Pizza 'Scandal' Leaves Small Town Divided" (Colaneri, 2014).

> responsible member of the community and will continue to strive to achieve incident-free operations. We are committed to taking action to safeguard our neighbors, our employees, our contractors and the environment.

The Bobtown well blowout came up repeatedly at Harry Enstrom Chapter meetings as an example of how the shale industry and regulators ignore their responsibilities to the safety of residents in Greene County. One member told the chapter his story of living near the LANCO 7H well:

> From my property I can see all the different hills. I called up this number at Chevron to get more information. I asked them what kind of testing they are doing after the explosion? They did the two-step shuffle—said they don't have any hard data to report yet. They kept pushing it off. Then I called the DEP. I wanted to know how far out the scorched area of the explosion went. They said it blew straight up. But I said that's not what I've seen in the photos. DEP said they're waiting for info from Chevron. So then I was talking to this guy from the DEP. I told him I did some water monitoring and he said they were trying to get on top of that.

Another chapter member attending the meeting, also an employee in one of the state's environmental protection agencies, chimed in:

> I went to the site when it was still burning. I mirror the same thing that DEP says. We're still waiting for more information. I'm monitoring the area. But, since I wasn't allowed on the site, I don't know how it was contained. So far I haven't seen anything in the monitoring. In my opinion the only thing that would enter the stream is through runoff. I'm still getting bits of information on it. But my biggest concern is the chemicals they used in putting out the fire. Fire suppressants and so on.

"Why are you having a hard time getting that information?" another member asked.

"This is something we're just not used to dealing with," the agency representative responded. "It's different contracting companies coming in to do the cleanup. We get emails about what they're doing and possible impacts."

"That should all be known to the public."

"Well, if people call, then besides the free pizza, maybe they'd put that information out," the representative explained.

The Bobtown well blowout also illustrated how the Harry Enstrom Chapter mobilized residents in Greene County to speak out against the pollution event. One member summarized how they responded to the blowout:

> We brought Chevron a bottle of pop and a pizza to their main office. There were six of us, all over the age of sixty-five, three of us were women, and one was an attorney. Chevron thought we were some kind of radical group. We also brought them a thumb drive with 11,000 names of people who don't want their damn pizza. They physically closed the door in front of us and held it shut so we couldn't enter. So that's what they think about us.

In May 2015, Chevron settled for $5 million in a wrongful death suit of a worker killed during the Bobtown well blowout (Ritenbaugh, 2015a). The following month Chevron was fined $940,000 by the PA DEP (Ritenbaugh, 2015b). However, no data was ever released on water pollution impacts caused by the incident. The extent to which environmental issues were addressed in the settlement are noted in a PA DEP press release that simply stated: "The penalty points to Chevron's failure to construct and operate the well site to ensure that health, safety and environment were protected, as required by the state's Oil and Gas Act" (PA Department of Environmental Protection, 2015a).

Besides taking direct action in moments of crisis, the Harry Enstrom Chapter also has a reputation for instilling a sense of responsibility within its membership to use their painfully acquired knowledge to overcome generations of systemic environmental injustice. To understand this better, I asked a few members of the chapter why they were so personally dedicated to helping residents in Greene County. Chuck Hunnell told me:

> Every little kid that walks down the street, every child that has arsenic in their water, Ken will tell you, it brings tears to your eyes. We had one particular incident, a lady by the name of Stacy who was one of my students when I was teaching. Her son may not live to be 21 because his liver has been contaminated with arsenic. It broke through into the ground from a Range Resources frack pump and they can say, my gas company was Range Resources, in their particular case their arsenic provider is Range Resources. And there are lawsuits about that and we were able to get – we met with Attorney Smith down in Pittsburgh – we have been very active here, we have been all over the place.

Ken Dufalla added to Chuck's comments:

> Their pets died. A horse died. Other farm animals died. And I asked one question at that meeting: did our local politicians, or the EPA, or the DEP assist you in any way? No, not at all, nothing. There was an article in the *New York Times Sunday Magazine* called "The Fracturing of Pennsylvania" – have you read that? That's her. That's about her and her problem. Every time I get so irritated and I'm ready to quit, I think back to that story. [34]

Evidence of Harry Enstrom Chapter's importance to those in their extended community can be heard in the testimonies of residents who rely on their support. During a public gathering in neighboring Washington County, a mother, whose family experienced direct health impacts from gas drilling, explained how important the chapter has been in helping her family cope. She told the group, "The stress has been awful and at first we thought we were alone. But we're not alone. Please support your Izaak Walton League. This hit us all so fast and you have to get educated. These people have helped us." Some residents become members as a result of receiving assistance from the Harry Enstrom Chapter. This form of recruiting expands beyond the borders of Greene County

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[34] This article can be found at http://www.nytimes.com/2011/11/20/magazine/fracking-amwell-township.html (Last accessed July 27, 2015).

into neighboring Washington and Fayette Counties as well. One example is Terry Greenwood of Washington County.

Like many other members, Terry joined the IWLA in order to make sense of the realities of living with the encroachments of shale gas after he fell victim to what is often called "split estate." Terry owned his farm, but a prior owner retained the mineral rights, dating to a land sale made in 1921. When this mineral rights owner signed a lease with Dominion Resources Appalachia, Terry's dairy farm would become one of the first properties in Pennsylvania to be drilled for shale gas.

In 2008, Terry complained to the PA DEP that his well water had been contaminated by gas drilling only a few hundred feet from his home. The PA DEP corroborated Terry's finding and ordered Dominion Resources to temporarily supply a source of water. The following year, Terry's cows began to get sick. In archival footage from an unused interview with *Gasland* filmmaker Josh Fox, Terry explained:

> They was drilling, and all the water was running into the field. And the cattle was right up there in their pasture drinking the water. And I called the DEP and said they shouldn't be drinking that water, what's in that water? Cause I didn't know anything about this at first, you know. And they said, there's nothing wrong with it. Then my cows started having calves. 18 cows had calves and I lost 10 of them. The DEP says, that's just a farmer's luck (Fox, 2014).

Some of Terry's calves were stillborn. Others lived for just a few days. Despite Terry's insistence that his calves had been drinking from the same source of water for 18 years, the PA DEP would tell Terry the cause of his cows' sickness was e-coli. Of the remaining cows on Terry's farm, not one would give a healthy birth the following year (Bloom, 2011).

Figure 25. Terry Greenwood on his cattle farm[35]

In June 2014, Terry died at the age of 66 of glioblastoma, a rare form of brain cancer. One of the places Terry found moral support during his struggles was with his fellow members of the IWLA Harry Enstrom Chapter. The chapter held a memorial for Terry. We were told that, when an IWLA member dies, there is a tradition where the

[35] Photograph by Mark Schmerling and used by permission.

IWLA buys a book on fishing in their honor and donates it to the local library. The memorial ended with a brief comment by Chuck Hunnell:

> We're all aware of what's going on around us. What they are doing with us is they are playing with our lives. We saw what happened to Terry. We have to keep our politicians accountable. I'm concerned about our friends. I am told that the CDC is investigating Terry's death.[36]

4.2.3 Translating Empowerment Capacity into Empowerment

In my observations of the Harry Enstrom Chapter's work, I discovered that its monthly meetings are the heart of the chapter's energy. At the beginning of every meeting members recite the Izaak Walton League of America's pledge, "To strive for the purity of water, the clarity of air, and the wise stewardship of the land and its resources; to know the beauty and understanding of nature and the value of wildlife, woodlands and open space; to the preservation of this heritage and to man's sharing in it. I pledge myself as a member of the Izaak Walton League of America." A Christian prayer then follows this pledge to guide members in honoring the organization's mission and to help them find the strength to protect their community.

The implications of what occurs after this pledge and prayer are significant. It's not unusual to see entire sections of a meeting dedicated to reading through recently acquired reports, or discussing the implications of a published scientific study (Figure 26). Interpreting data and learning the legalities of watershed management as a group

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[36] Terry Greenwood's story is well known to many in the advocacy community. His name has not been anonymized here. More on Terry's case can be found in the Shalefield Stories, an online archive of first-hand accounts from those who have experienced negative health effects from shale gas extraction, at http://www.friendsoftheharmed.com (Last accessed July 27, 2015).

greatly expanded the knowledge of chapter members, which they then took with them into public debates. Evidence of this was found during a series of hearings held by the PA DEP on proposed changes to Act 13, a highly contested legal document that restricts local zoning control of shale gas development. Numerous well-informed members of the chapter provided testimony on issues ranging from the handling of industrial waste, managing abandoned wells, and best practices for preventing chemical spills.

Figure 26. Harry Enstrom members share DEP water quality reports at their monthly meeting

Monthly meetings served as a venue for building alliances with experts in many different fields of potential influence. Guest speakers at chapter meetings have included ornithologists, geochemists, public health providers, environmental attorneys, and social scientists. Connecting with these experts brought additional knowledge to the chapter. These contacts were also valuable for funneling resources to residents who needed assistance in dealing with health and legal issues.

Figure 27. A Russian filmmaker visits the Harry Enstrom Chapter's monthly meeting

The chapter's persistence has also made its monthly meetings and tours of its water monitoring sites an obligatory stop for journalists, politicians, and representatives from state agencies. Coverage of the Harry Enstrom Chapter's work can be found in NBC News, the Huffington Post, Associated Press, and the BBC, and their work is often cited as a prime example of how citizens can mobilizing against shale gas development impacts (Begos, 2011). Representatives from many foreign countries facing the prospects of shale gas exploration, including Germany, Poland, Australia, Russia, and Italy, have met with members to understand the concerns of affected residents (Figure 27). Meanwhile, officers from the PA FB, DCNR, nearby CCDs and local watershed associations regularly attend chapter meetings.

The chapter's growing influence as a group that uses water monitoring for advocacy makes some established environmental protection organizations in the region uncomfortable. "The Izaak Walton League is run completely by testosterone," I was told by a staff member at one watershed association who tried working with the chapter in the past. "I like a lot of the members in the Izaak Walton League, but wow, it was like, holy moly." The chapter's approach has also affected their standings with potential funders who shy away from advocacy-based water monitoring. Carol Zagrocki at Colcom, who initially facilitated a grant to help the chapter setup their monitoring program, told me:

> They do a really good job with what they were doing, with the way they were establishing their volunteers, the way they were monitoring, the data they were collecting, the reports they were putting together for the public on their data, and then the advocacy type of work that they were doing with concerns that they found. They did a really good job. But I heard from others, a lot of grumbling, that they do their own thing. Everybody else tries to work with them, and some do successfully enough. But they are definitely independent. They have not come back for additional funding.

Despite these hesitations, Harry Enstrom Chapter's use of monitoring as a tool for advocacy shows evidence of breaking through the wall of silence about shale gas pollution in Greene County. One measure of the chapter's achievements is seen in increasingly opened channels of communication with regulatory agencies at levels simply unheard of in other volunteer-based monitoring groups. At a March 2014 chapter meeting Ken Dufalla presented an update on ongoing correspondences with different agencies:

> I finally got a letter from the EPA. In it is the details of what happened at Emerald Mine. Some of the info isn't truthful. The settlement is for the $25.5 million dollars and they have to put it in a treatment plant. They're going to shut down the mine, flood it with water and send it through a reverse osmosis plant. That's good. Other mine outputs are going to have to change where they are sending their discharges, away from the smaller streams.
>
> Here's another letter, from the DEP, about our complaints around high bromide levels. The letter argues that discharges are still within allowable limits, and they stand by that statement. Our data shows otherwise. We also got a list of their samples. They all show exceeded levels. This stuff gets us in trouble. The EPA sent me a letter that also argues that the levels DEP gave them seem fine. But the radiation indicators DEP is giving the EPA aren't indicative of Marcellus. They're giving them gross alpha and not radium 228.
>
> Here's the letter we wrote about radiation going into Ten Mile Creek. We sent it to the Soil and Conservation Office of Greene County. The letter we got back says, among other things, that they agree with the chapter that the people have the right to know, and have tests done by the DEP. That letter was sent to a whole list of people, and I got a call from the district attorney's office.

Other accomplishments are more tangible. When I was accompanying a chapter volunteer on a visit to their monitoring sites in December 2014, we happened upon a PA DEP watershed specialist gathering samples at Dunkard Creek. We were told that the agency would be responding to accruing complaints about water pollution in Greene County by returning to the area in 2015 for a comprehensive monitoring study (Figure 28). In June 2015, the PA DEP announced it would begin investigating whether or not radioactive materials were present in stream sediment and water samples at 13 sites along

Ten Mile Creek near Clyde Mine and the Tri-County Municipal Water Authority plant. A PA DEP spokesperson told a local reporter that the agency began its investigation as direct result of the Harry Enstrom Chapter's repeated requests for additional testing (Khan, 2015).

Figure 28. Encountering the PA DEP at Dunkard Creek

Environmental protection groups in Greene County hailed this as a major victory for concerned residents, and credited the Harry Enstrom Chapter with starting a new era of better relations with the PA DEP. Nevertheless, there were many who express concerns about the PA DEP's plans. The PA DEP spokesperson said that the study would only focus on Ten Mile Creek. This would neglect the many other hot spots detected by Harry Enstrom Chapter's monitoring volunteers. Furthermore, all of Ten Mile Creek's suspected discharges come from the abandoned Clyde Mine, meaning that any evidence of pollution would be difficult to trace back to existing companies operating in the region.

A final concern stems from either circumstance or what some people perceive as planned negligence. When the PA DEP came to Greene County to collect its samples Ten Mile Creek was raging with high water due to a particularly rainy weekend. “Any results from the DEP samples today cannot be trusted because of the high water,” a resident of Greene County commented in an email, “It appears that the DEP wants to be able to say that all is just fine after last year's high radiation tests that were buried by the DEP. How many people have to die before the powers in Harrisburg actually admit that there is a massive problem in Greene County streams?”

The WVWRI responded to these complaints by conducting duplicate samples along Ten Mile Creek. “If it were me, I’d immediately redo the tests,” the Institute’s director commented (Haines & Stevens, 2015). WVWRI’s results came back negative for radiation in July of 2015. The Harry Enstrom Chapter president commented on these findings in a local newspaper article. “If the radiation is not there, thank God because we’d have a hell of a time getting it out of there,” he told the reporter. He also reflected on what these findings mean in relation to the PA DEP’s tests at these locations the previous year, “I’m also torn about the fact that this is just one lab saying one thing, and another lab is saying another thing” (Petsko, 2015).

One bit of hope is that, even if the PA DEP’s water tests come back inconclusive, sediment samples collected at those sites will help clarify questions about possible radiation entering Ten Mile Creek. Residents of Greene County await the results of PA

DEP's samples at the time of this writing. Their report is due to be released in September 2015.

4.3 Conclusion

In this chapter I have argued that there are a range of logics within the Marcellus Shale water monitoring community about the purposes of collecting water quality data. When these ideas are applied in the field, they can shape what technologies are used for monitoring and what kinds of questions guide watershed studies. In the case of those who use data loggers, these technologies are being used to support longer-term ecological studies. For the IWLA Harry Enstrom Chapter, basic data collection methods are used as an advocacy tool to prompt immediate regulatory action. I argue that these logics are informed by different ideas about how to define the boundaries of data culture.

I discovered that data loggers are creating opportunities for professional environmental protection organizations to work directly with regulatory agencies. Data loggers are potentially empowering technologies for documenting and solving environmental problems in a spectrum of conservation projects beyond shale gas monitoring. Some of this success is due to the fact that data loggers align well with the standards set forth in governmental water monitoring programs, such as those run by the PA DEP and SRBC.

Another possible factor is that data logger programs are generally run by organizations with pre-existing relationships with regulators. Data loggers might be seen as tools for strengthening these relationships. These findings illustrate some of the benefits of situating monitoring programs in a data culture that respects expert knowledge. One might even argue that the numerous implementations of data loggers is a meaningful response to earlier concerns that institutions tasked with protecting watersheds lacked adequate resources.

Nevertheless, I argue that, without deeper scrutiny of the logics that support the use of data loggers, there is a risk that these devices will fail to have the impact that many of their supporters intend—particularly those who hoped data logger programs would protect watersheds from shale gas development. In practical terms, the usefulness of data loggers is limited because of their expense, inflexibility, and the expertise needed to maintain equipment and interpret data. Data loggers also come with certain obligations that depoliticize environmental monitoring, and can constrain how nonprofessionals participate in determining the direction of water monitoring programs. I therefore suggest that data logger programs, in their present condition, are not well suited to addressing the range of concerns expressed by residents living in shale gas communities. In fact, I argue they may be disempowering because of their imposed restrictions on public participation.

In contrast, models that encourage citizens to retain control over monitoring programs show evidence where nonprofessionals build capacity for empowerment by using basic monitoring tools and bringing attention to gaps in environmental oversight of the shale gas industry. While the Harry Enstrom chapter may have faced difficulty in getting their data recognized by regulators, compared to professional watershed groups using data loggers, the chapter found ways to influenced debates by politically mobilizing with their data.

Those who became involved in the chapter's monitoring programs learned about the science of watershed protection and how to collect data using basic tools and protocols. By encouraging members to extend their work into the community, the chapter also realized it could play an important part in pressuring regulatory agencies to take seriously their responsibilities in protecting the wellbeing of their fellow citizens when, in many instances, more established environmental protection organizations were unwilling to play this role. In other words, the chapter's approach was not only empowering for individuals, but also brought empowerment to the larger community.

I further argue that Harry Enstrom Chapter's work was successful in building capacity for long-term empowerment by creating a body of educated citizens. These citizens were willing to rethink their arrangements with powerful institutions in a region known for complacency with respect to extraction industries. The work of the Harry Enstrom Chapter therefore shows the importance of retaining mechanisms for using data in advocacy if water monitoring programs are to empower at-risk communities.

Nevertheless, the Harry Enstrom Chapter has work to do if they are to grow their influence the region. Reshaping their approach to be more welcoming of other ideas on how to use water monitoring data will be necessary for enlisting the external help of organization, academic researchers, and regulators who view the group as overly confrontational. Harry Enstrom Chapter is also marked as a group that runs "completely by testosterone" due to the fact that its leadership is dominated by outspoken male figures. These leaders are effective in bringing attention to the chapter's work, but their dominance may come at the expense of empowering other individuals in the organization to step into leadership roles and become vocal advocates in their community.

Ultimately, this chapter illustrates certain realities about how scientific arguments are sometimes not adequate on their own when dealing with highly politicized environmental threats. The stories told in this chapter point to the fact that there is no uniform data culture in the Marcellus Shale water monitoring community. There are also data cultures that respect the importance of expertise, while taking into account why people take up water monitoring in the first place.

5. BUILDING INFRASTRUCTURES FOR EMPOWERMENT

In the Marcellus Shale monitoring community, research partnerships have formed between concerned citizens, grassroots advocacy groups, service providers, and academic outreach programs to do watershed science. Research partnerships can assist monitoring groups in improving their protocols, help them to gain entry to certified laboratories, and provide access to tools to analyze complex datasets (Overdevest & Mayer, 2008; Savan et al., 2003). Research partnerships build capacity to empowerment in at-risk communities by mobilizing a broader movement for environmental protections. I argue that these alliances also bring together diverse forms of knowledge about environmental risk and ideas about how to address issues related to shale gas pollution.

This chapter examines the promises of empowerment that permeate the water monitoring community and how they play out in different research partnerships, ranging from top-down expert-led efforts, to grassroots alliances that share resources equally. Like the model proposed by Shirk et al. (2012), these partnerships exhibit a range of ways that nonprofessionals contribute knowledge to research programs, from "contributory" to "co-created" arrangements. I illustrate these points by detailing the activities of two monitoring networks. The first half of the chapter focuses on the NY Water Sentinels, a coalition of concerned citizen groups formed in 2011 and later expanded through affiliations with the Sierra Club Atlantic Chapter. With an annual budget of only $20,000, roughly 150 volunteers now monitor streams in twelve counties across the Southern Tier of New York. The second case study is of Three Rivers QUEST

Portions of this chapter will appear in: Jalbert, K. (n.d.) Grassroots Infrastructures: Making Sense of Resilient Resources for Civil Society Science. *Science & Technology Studies*.

(3RQ), supported by $1.3 million in grants awarded by the Colcom Foundation in 2011 and 2014 to West Virginia University's Water Research Institute. 3RQ supports a variety of water monitoring programs across Pennsylvania, West Virginia, Maryland, and Ohio.

In both case studies, the central questions focus on empowerment, on who maintains control over the different components of knowledge infrastructures. I find that participatory models adopted in these programs can either reproduce or redistribute power, authority, and expertise in ways that can advance the agendas of some monitoring groups more than others. My findings also suggest that partnership structures can change over time. I conclude by arguing that knowledge infrastructures reveal additional dimensions of empowerment beyond what can be described in Corbett and Keller's (2005a) empowerment framework.

5.1 Troubles with Democracy in Bottom-Up Science

"You can see it's kind of gurgling," the person next to me commented as we peered over the edge of the access hatch to a nearly 40-foot tall vat of stewing sludge. The smell is overwhelming, and we felt a bit uneasy about the rope and emergency flotation device hanging beside us on the railing. This particular container was but one in a complex arrangement of pipes, pumps and tanks that processed the regular flow of leachate (liquid waste outflows) from the nearby Steuben County Landfill in Bath, New York (Figure 29). A dozen people stood below us on the next platform, listening intently as the plant manager described how drainage from the landfill entered the system on one end, gets piped through the Village of Bath’s sewage system, and eventually discharged into the Cohocton River, a tributary of the upper Susquehanna River watershed.

Figure 29. A tour the Steuben County leachate treatment plant

The Steuben County landfill is the site of a decades-old township dump, originally constructed without a proper leachate treatment system. In 1995, when the landfill sought expansions, the New York Department of Environmental Conservation (NY DEC) assisted Steuben County in building a treatment plant that would not only have the capacity to process leachate from this landfill, but also wastewater from other sources in response to increasing demands in other parts of the state (Hardman, 2014).

One recent market was Pennsylvania's Marcellus Shale gas drilling industry. Despite New York State's 2008 drilling moratorium, and the more permanent December 2014 ban on hydraulic fracturing (NYS Department of Health, 2014), a recent report calculates that more than 460,000 tons of solid waste and 23,000 barrels of liquid waste has entered the state from shale gas drilling operations in Pennsylvania since 2010 (Moran, 2015).

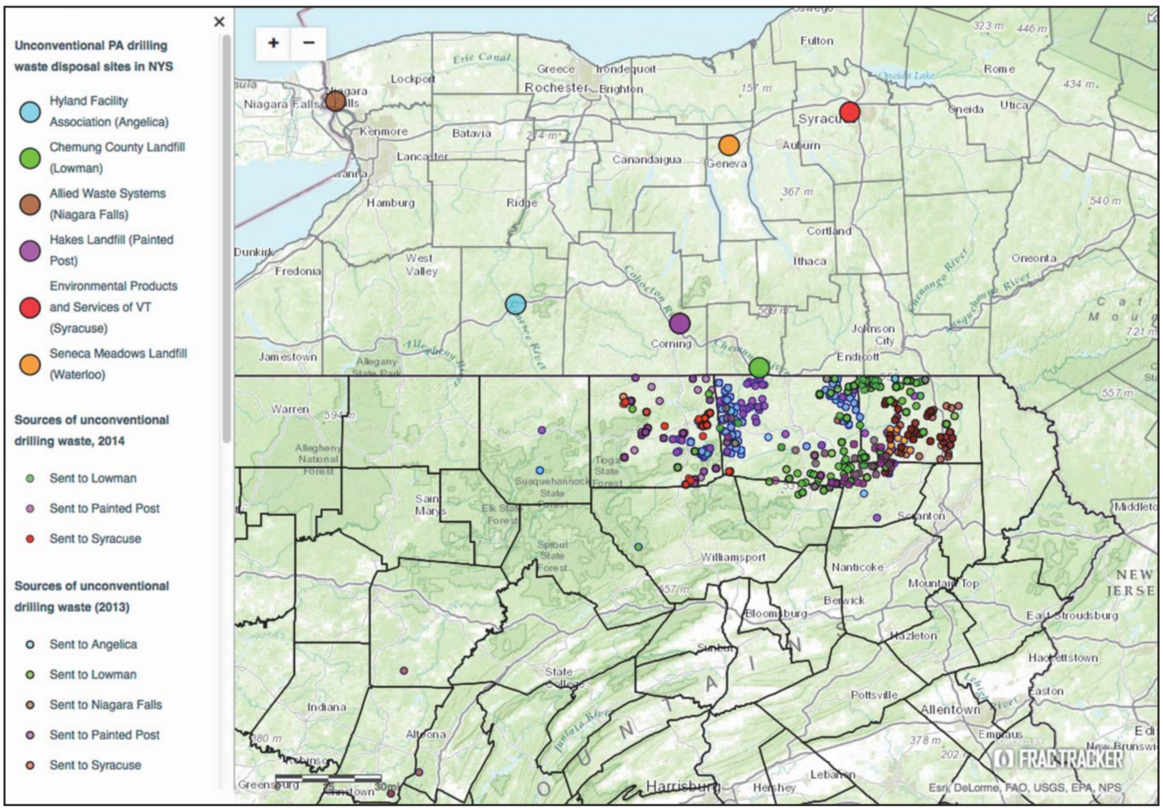

Figure 30. PA shale gas drilling sites and their corresponding NY landfills[37]

[37] Map to appear in Jalbert K. (2015b). Toxic Crossings: Water Sentinels, Waste Flows, and the Southern Tier of New York. *The FracTracker Alliance*. Retrieved July 27, 2015, from http://www.fractracker.org/projects/water-monitor/toxic-crossings/

Landfills in New York State that have accepted shale gas waste from Pennsylvania include the Chemung County Landfill (Lowman, NY), Casella Waste Systems (Painted Post, NY), Seneca Meadows Landfill (Waterloo, NY), Allied Waste Systems (Niagara Falls, NY), Hyland Facility Association (Angelica, NY), and the Hakes Landfills (Painted Post, NY) (Figure 30). Among these facilities, the Chemung County Landfill has accepted the most solid waste, at nearly 200,000 tons. Hyland Landfill and Hakes Landfills have each accepted over 100,000 tons of drill cuttings. These amounts do not include the tens of thousands of tons of drill cuttings used as "daily cover"—the layer of compressed soil placed on top of a landfill's daily waste.

Drill cutting are highly valued by landfill operators. Their density takes about one-forth the space of conventional waste, but can be charged at the same per-ton disposal fee. This new revenue stream persuaded operators to expand their facilities in tandem with Pennsylvania's expanding shale gas industry. For instance, Casella Waste Systems, the largest operator of landfills in New York, requested and received approval from the NY DEC to expand the volume of waste at Chemung County landfill from 120,000 tons to 180,000 tons per year, and began diverting Chemung County's less-valuable township waste to other landfills. A new proposal is now being considered that would expand the landfill's capacity from 180,000 tons to 417,000 tons per year (Mantius, 2013).

A number of loopholes allow shale gas waste to travel into New York, even though much of the gas industry's practices are otherwise limited. According to NY DEC regulations, "drilling fluids, produced waters, and other wastes associated with the exploration, development, or production of crude oil, natural gas or geothermal energy," are not considered hazardous waste in New York State (NYS Department of Environmental Conservation, 2006). Gas drilling waste is also exempt from New York's Low Level Radioactive Waste Laws that govern Naturally Occurring Radioactive Material (NORM) such as uranium, radium 226, and radium 228. Many residents feel this rule fails to acknowledge the fact that Marcellus Shale drill cuttings are known to contain low levels of radioactive materials.

According to a USGS study, NORM levels from the Cambrian-Devonion shale layers (of which Marcellus is one) far exceed those of other shale formations in the United States (Rowan, Engle, Kirby, & Kraemer, 2011). In fact, between 2009 and 2012, radiation alarms at Pennsylvania's landfills were triggered more than 1,000 times due to waste loads from shale gas drilling operations (Puko, 2013). In a more recent incident, Range Resources confirmed that drilling waste was rejected by a landfill in Washington County, PA, due to high radiation levels. This waste is presently being stored at drilling sites until a proper destination can be found (Hopey, 2014a).

Landfill operators assert that waste haulers are only delivering drill cuttings to their facilities, which industry officials argue are unlikely to contain low levels of radioactive materials. However, Casella also operates processing centers at the Hyland Landfill, and another at a landfill in McKean County, Pennsylvania, for solidifying drilling muds and liquids. A common practice at these facilities is to add bulking agents, such as sawdust and wood chips, to turn drilling muds into solids that can then be shipped to New York landfills. Additional materials that fall under "solid waste" include contaminated soil from chemical spills, rubber well pad liners, and other industry-associated materials (Alexander & Shilling, 2011).

The Steuben County landfill does not accept drilling waste of any kind at present. However, one fact is known about the facility—its overbuilt wastewater treatment plant generates revenue for the county by accepting excess leachate from neighboring landfills, including more than 2.2 million gallons worth from Hyland landfill, and nearly 2 million gallons from Hakes Landfill, between July 2012 and April 2013. Both of these landfills accept drilling waste (Mantius, 2013).

Furthermore, in July 2013, a Syracuse-based laboratory pled guilty to falsifying more than 3,300 water tests for the Hyland landfill. This same contractor processed samples for Steuben County's leachate treatment plant up until the laboratory's state certification was revoked (Mantius, 2013). These two facts have many residents in the county worried about the safety of public drinking water supplies and nearby watersheds.

Standing in the treatment plant's control room, my fellow tour members had many pressing questions. Was the facility designed to handle leachate from landfills accepting Marcellus Shale waste? Are there adequate mechanisms in place to prevent pollution of the Cohocton River? Are you testing the leachate from other landfills for radiation? Does this include gamma, alpha, and beta ray monitoring?

Figure 31. An effluent sample gets passed around the treatment plant control room

The plant manager passed around a vial of concentrated leachate to those in the room (Figure 31). Meanwhile the County Waste Commissioner reassured us of the facility's safety:

> Let's say you fill the landfill with it and, when it's done, put on six to ten foot of cover, I can't remember which—the Argonne National Laboratory said you could build a school on top of it. You could put a playground on top of it. You could build houses on top of it, and it would be safe. I've talked to the engineers, I've talked to Casella, and I've talked to the DEC. They are required, and I've been told by everybody, to provide the radioactivity report to DEC.
>
> Now I'm going to carry you through a few different controversies and there's going to be disagreement with what I say. That tanker truck, when it comes in, we send it through our radiation monitors. Up at the landfill

> along with the scales. The only thing that's made those radiation monitors go off is when a truck driver has had some medical treatment. People will say—and what we measure up there are gamma rays, because gamma rays go through the steel boxes. But what is within gamma rays, and radioactivity, is alpha rays and beta rays. Alpha rays, if you breathe them—that would be dangerous. But they don't go through the box. So people say, you're only measuring the gamma. Well, if you see that going up you know the alpha is up. If it's down, the alpha is down. We are getting a real measurement as to whether it's dangerous or not.
>
> Then what we do is we get the leachate in from Hyland—and by the way, Hyland is Marcellus Shale drill cuttings. It's from the Marcellus Shale. So that's real Marcellus Shale leachate. I said, I want to test the truck when it gets here. So you measure the leachate. Bob processes everything, and what's leftover is the sludge from the leachate. This is the concentrate from the leachate. We run a radiation monitor over it. The radiation that comes off of it is less than the radiation in crushed stone on the road or in a concrete base.

One tour member, Gene, took out a Geiger counter and asked. "Well then, can I check your sample? I have a Geiger counter here."

The Commissioner responded, "Uh, yeah. And while you're at it, check your digital watch, check the tiles, check the granite slab on your kitchen counter." Looking defeated, Gene put away his Geiger counter, but on our exit from the facility he takes a moment to test wastewater spilled from a truck at the plant's entry bay (Figure 32). Gene's equipment finds nothing out of the ordinary, but he voiced his suspicions of the Commissioner's claims.

Figure 32. Gene using his Geiger counter at outside the landfill treatment plant

5.1.1 Grassroots Partnerships Structures

The tour of the Steuben County landfill treatment plant was organized by a local chapter of the NY Water Sentinels—a grassroots coalition of environmental advocacy groups that began baseline monitoring in watersheds along the border of Pennsylvania in 2011, where Marcellus Shale drilling was expected to occur if New York State's moratorium was lifted. The origins of NY Water Sentinels can be traced back to the Concerned Citizens for Cattaraugus County (CCCC), an organization that has worked for years on issues ranging from stopping large windmill farms to opposing new landfills. As part of a new initiative to address shale gas issues in New York, the regional Atlantic Chapter of the Sierra Club (representing Northeastern US) became interested in supporting a water monitoring network to prepare for the possibility of shale gas drilling in New York. The Sierra Club approached the CCCC and provided a seed grant through its National Water Sentinels program to assist its members in acquiring monitoring equipment and scheduling training sessions with ALLARM.

Over the next two years volunteers in other regions were brought on board, partly by recruiting Sierra Club members throughout the state, partly by passing out flyers in town meetings and posting in local newspapers. The NY Water Sentinels also enlisted members of other environmental organizations, such as the Coalition to Protect New York, Keuka Lake Watershed Acton Committee, the Federation of Fly Fishers, and the Citizens for Protection of Health and Environment. Their monitoring network now extends into watersheds in Allegany, Broome, Cattaraugus, Chautauqua, Chemung, Chenango, Cortland, Delaware, Otsego, Steuben, Sullivan, Tioga, and Yates Counties.

Using ALLARM's monitoring protocol, 160 NY Water Sentinel volunteers have made more than 1,500 visits to document conditions at 125 stream sites (Figure 33). Samples are also sent every six months to a New York State certified laboratory for testing of barium and strontium levels. NY Water Sentinels data is managed by members in the network, and is also delivered to ALLARM and to Penn State's Shale Network on a regular basis for additional analysis.

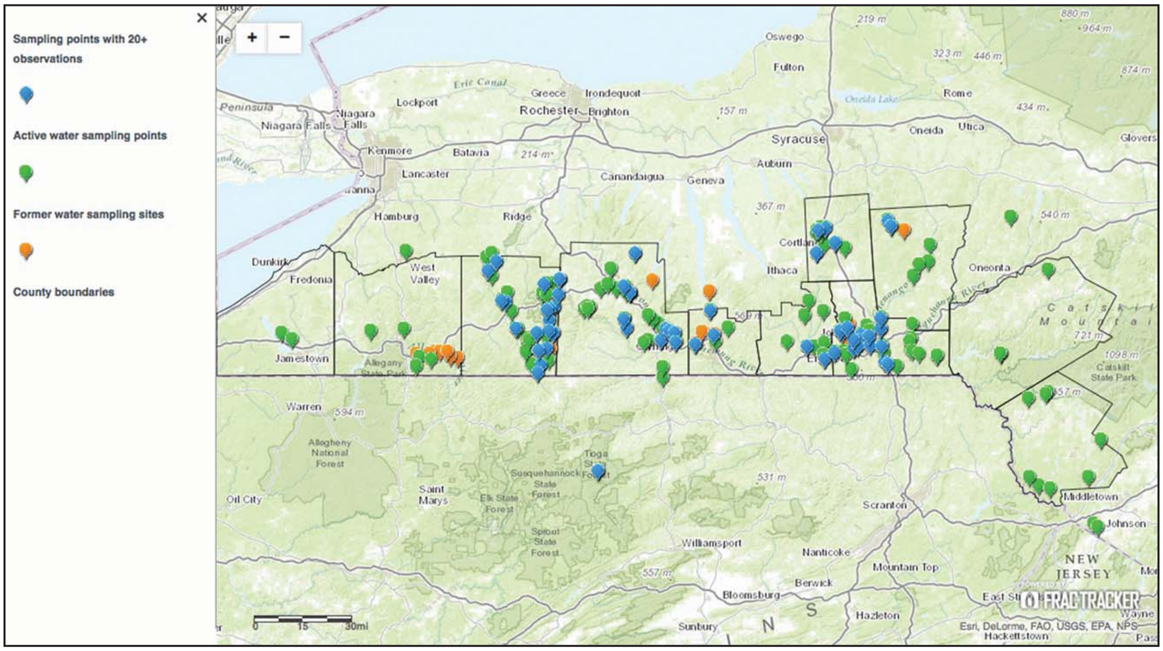

Figure 33. A Map of NY Water Sentinels water monitoring locations in Southern Tier counties of New York State[38]

The NY Water Sentinels have no paid staff or dedicated facilities. Its governing structure is one of overlapping committees, populated by volunteers who participate in the monitoring network. The Steering Committee is the executive body of the NY Water Sentinels, with responsibility for administering the organization and setting the overall agenda of the monitoring network. This includes establishing new affiliations with outside partners, determining where future training will occur, making changes to monitoring protocols and how data will be used, as well as what political or legal initiatives the network may engage. Steering Committee members are elected annually by

[38] Map to appear in Jalbert K. (2015b). Toxic Crossings: Water Sentinels, Waste Flows, and the Southern Tier of New York. *The FracTracker Alliance*. Retrieved July 27, 2015, from http://www.fractracker.org/projects/water-monitor/toxic-crossings/

Water Sentinels chapters, but also consist of members of the Sierra Club Atlantic Chapter office who serve an advisory role.

Day-to-day governance of the NY Water Sentinels falls upon the Coordinators Committee. Its purpose is to implement the directives of the Steering Committee and, in the process, maximize inclusion of the network's volunteers by soliciting input on mission changes and monitoring strategies. The Coordinators Committee meets weekly by phone to discuss topics ranging from recent regulatory reports, equipment maintenance and data management issues, quality assurance updates, and the status of local finances. Other working groups that meet on a semi-regular basis include an External Communications Committee, a Science Committee, a Finance Committee, a Legal Committee, a Fundraising Committee, and a Data Management Committee—all populated by volunteers in the network.

The NY Water Sentinels also retain the help of many outside experts to assist the Steering Committee and Coordinator Committee with different tasks. The Legal Committee is advised by no less than three practicing attorneys, two of which are also members of local NY Water Sentinels chapters. The Science Committee regularly consults with professors of biological science, geology, and environmental studies at three separate universities. A staff member from ALLARM also sits on the Science Committee. I too sit on this committee, periodically offering insights from my observations of the larger water monitoring community. Since 2012, the NY Water Sentinels have hosted annual "summits" at Binghamton University that bring together its committees, members, and advisors to review its accomplishments and determine future endeavors.

At the time of its formation, the NY Water Sentinels defined themselves as a "semi-autonomous" monitoring network, in that they enjoyed relative independence from the Sierra Club. When I asked Miles Coolidge, an advisor from the Sierra Club Atlantic Chapter who sits on the Steering Committee, about how the network evolved, I was told:

> The first year we spent a lot of time getting the QA/QC to work. We built the technical infrastructure. The second year we worked on getting the coordinator groups working—the social infrastructure. Now we need to do more outreach into challenging areas, to develop that sense of community. Our value is to work at the local level. We have to make sure we are embedded in the community.

In my observations, the Sierra Club's finely tuned sense of how to build an environmental advocacy monitoring network significantly shaped how the NY Water Sentinels' infrastructure evolved. Its democratic partnership structures greatly empowered individuals on the front lines by giving them the capacity to ask questions about how shale gas waste was entering their communities. This structure also allowed groups within the network to build capacity within their communities by expanding their monitoring networks and engaging the public.

5.1.2 Internal Frictions and the Tradeoffs of Local Empowerment

The NY Water Sentinels successfully implemented a research program based on a co-created partnership model. However, their governing structure also made the network vulnerable to internal friction and competition for resources. This story begins at the Hyland Landfill in Wellsville, New York. In 2013 Casella Waste Systems applied to the NY DEC to expand Hyland Landfill's annual volume of accepted waste by more than 60% to 153,000 tons per year in order to accommodate Pennsylvania's drilling cuttings

(Donohue, 2015). Two members of the local NY Water Sentinels chapter felt it was important to begin baseline monitoring around the landfill as well as its wastewater treatment plant. "We didn't find any elevated radioactivity from the Wellsville Water Treatment plant discharge, but we did find elevated radioactivity in a stream running off from the landfill at a designated outfall," Gavin Erwitt, the chapter's coordinator, explained, "we didn't have a protocol, we just did it."

Figure 34. Field sampling at a leachate treatment plant outflow pipe

As word spread through the network about the possible risks of shale gas waste, other NY Water Sentinels volunteers began monitoring the outflows of landfills and wastewater treatment plants in their counties. Increased attention to landfills quickly became a contentious issue. Some member groups in the monitoring network felt that chasing landfills compromised carefully laid out technical plans for doing watershed-wide baseline studies. "Rightly or wrongly, they want to expand the program to include more testing like this at Chemung and any of the other six landfills in New York where this is happening. But they are kind of casting about looking for a protocol," Gavin explained (Figure 34).

Proponents of landfill monitoring were quick to point out that the industry may apply enough pressure to the NY legislature to reverse the December 2014 ban on high-volume hydraulic fracturing if natural gas prices rebound from current record lows. In their view, the ban created space to extend the mission of the organization and take action against other sources of known pollution. However, other members believed that straying from their original mission of doing systematic watershed studies would impact their productivity, or dismantle work done to garner the respect of the scientific and regulatory communities. Other concerns were raised as to whether or not taking on advocacy-oriented causes would undermine the NY Water Sentinels' ability to raise funds.

A heated discussion in a Leadership Committee meeting painted the character of this particular debate. "The assumption of our original mission was that fracking would eventually come to New York and we needed to prepare for it," a committee member commented.

Miles from the Sierra Club had a different perspective. "We did originally say that we needed the data to understand baseline. But we need to have the conversation that, now that we have data and we know more, should we expand our mission?"

Miles continued, "Getting people involved at the community level in water quality is an important facet of making a difference. We always incorporated that as part of our discourse. But we haven't been as active in that area as we could be. So the efforts around the Hyland landfill illustrate to me how important outreach is to these areas."

"Well, we should also have a discussion of how this changes the political posture of our groups," the committee member responded with concern, "Our group has a history of 'opposing' things. Baseline monitoring allowed us to get involved in something that was more objective and positive, to just look at possible violations. Landfill monitoring would bring us back to being a bad-boy watchdog. This is a conversation each group will have to have."

Debates would continue in following months and most NY Water Sentinels chapters continued their baseline monitoring work. Others took their landfill data to court with some success. A representative from a chapter that had ben monitoring around Chemung County landfill explained:

> We told them if they keep taking cuttings that the landfill leachate would get progressively more radioactive. They have no way of taking it out of the leachate. Both the DEC and the landfill protested and we were thrown out of court. But the county commissioner asked the DEC to investigate more because they thought we were making a good point. The case was thrown out on a technicality because the subject of proceeding was the volume of drill cuttings being accepted, and not the volume of leachate going out.

NY Water Sentinels groups that did take up the cause of landfill monitoring would eventually influence allocations of resources in the network as well as engagements with outside partners. A dedicated protocol for landfill monitoring was developed with the help of staff at ALLARM. Individual chapters used some funds to purchase new equipment for collecting samples around treatment plants, such as turbidity tubes. The Ithaca, NY, based Community Science Institute, a nonprofit laboratory that also runs a vast water monitoring network in the region, offered to partner with landfill monitoring volunteers to run a full-spectrum analysis of their samples on a trial basis.

These subtle shifts in resource allocations show some of the benefits of grassroots, bottom-up research partnerships. When the NY Water Sentinels program began it emphasized the importance of doing science at the local level. Its resulting governing structure respected input from its individual members. Some monitoring groups were empowered by this governing structure by having the capacity to address new problems discovered in the course of water monitoring. However, for a network with limited resources, increasing empowerment capacity for some came at a cost to other individuals and groups with different ideas about how to influence environmental debates.

5.1.3 Institutionalizing Bottom-Up Infrastructures

Knowledge infrastructures are fluid things. In the case of grassroots-built infrastructures, I find that the internal dynamics of power can change drastically due to their democratic governing systems. I argue that these partnership structures can also change in moments of vulnerability, such as when resources become scarce or when a monitoring network continually struggles for recognition. Monitoring groups may appeal to powerful institutions for financial, political, or scientific support in these instances. However, monitoring networks can become susceptible in this situations if strengthening alliances with institutions also means giving up control over how their network functions. I watched the beginnings of this process unfold with the NY Water Sentinels in the spring of 2014.

By 2014 the NY Water Sentinels had grown into a formidable presence in the Southern Tier of New York. In 2015 the network planned to expand to 150 monitoring sites and offer two new training programs, which they estimated would add 30 new Water Sentinels volunteers. These and other programming expenses, such as public outreach events and laboratory analysis, would be covered by a 2015 budget of roughly $22,000. More than sixty percent of the NY Water Sentinels' budget leading up to 2014 came from seed grants obtained from the Sierra Club as part of its National Water Sentinels program. The rest was made up of private donations and local awards. Unfortunately, the Sierra Club eliminated funding for the National Water Sentinels program at the end of the 2014 fiscal year.

Loss of a major funding source required that NY Water Sentinels find alternative financial support. One possibility was to maintain the status quo as a semi-autonomous affiliate of the Sierra Club. However, the NY Water Sentinels had learned in the past that obtaining funding while under the umbrella of a large institution could be difficult. In December 2013, the Cora Brooks Foundation expressed interest in offering as much as $10,000 to expand the network's monitoring into the Delaware and Susquehanna River watersheds. When they learned in later stages of the granting process that the NY Water Sentinels were affiliated with the Sierra Club the deal fell through. The Foundation had a policy of not funding organizations with budgets greater than $5 million. A similar incident occurred with the Community Foundation of Elmira-Corning and the Finger

Lakes. Heather Mann, a member of the NY Water Sentinels Finance Committee, told members of the network about these lost opportunities at an annual summit:

> We've had some discouraging experiences getting grants. We've been writing grants, but then when we get to the point of submitting grants we have to prove the money will go right into Water Sentinels activities. But the money has to go through Sierra Club and then to us. The accounting there is very opaque, so we can't illustrate to the foundations that the money will only go to the Water Sentinels.

At the time, the NY Water Sentinels did not have a dedicated account with the Sierra Club. Consequently, donations had to be made to the Sierra Club, but could not be specifically allocated to particular programs they supported like the NY Water Sentinels. Donating institutions required detailed reporting and tracking of funds. As the NY Water Sentinels learned more about the Sierra Club's accounting systems, it became clear that no mechanisms existed to track the flow of funds through the Sierra Club.

Another solution for the NY Water Sentinels was to set up as a wholly independent nonprofit, leaving behind the financial, technical, and legal support of their long-time benefactors. This idea did not sit well with those who had been members of the Sierra Club long before the NY Water Sentinels came into existence. These members recognized that there were administrative benefits to being under the Sierra Club umbrella, not to mention potential opportunities in aligning their program with a powerful advocacy organization. As a compromise, "some of us have talked about doing two different structures—one with the Sierra Club and one without," Heather explained to me after the summit. Some proponents of a dual-structured program believed it would present an ideal resolution to issues like the landfill monitoring debate. Some groups could move forward in doing more advocacy work while others continued developing resources for baseline water monitoring.

But the Sierra Club was uncomfortable with the idea of providing assistance to, and taking ultimate responsibility for, half the network without having a say in what happened with the other branch. Heather noted at the summit, “The issue is that the Sierra Club has all these accountants to manage the grant. And they take on the liability since they are tax exempt. If we use it in a way that isn't in-line with how we proposed we can be liable.” The discomfort relates to IRS requirements. The Sierra Club is a 501c3 entity, and must illustrate to the IRS that funds are used for 501c3 eligible activities. The Atlantic Chapter is the borrower of funds from the 501c3 entity and must oversee the uses of such funds. As an independent recipient of funds from the Atlantic Chapter, the NY Water Sentinels agreed to adhere to the limitations of 501c3 status, including using funds for certain kinds of political advocacy. Violating this agreement would make the NY Water Sentinels liable.

Sierra Club advisors instead suggested a third possibility. The NY Water Sentinels could become an official sub-program of the Sierra Club Atlantic Chapter. In doing so, the monitoring network would be able to apply for internal Sierra Club grants and enjoy the protection of being part of a large environmental advocacy organization. The NY Water Sentinels Steering Committee weighed the costs and benefits of their options and, in 2014, elected to remain affiliated with the Sierra Club. The Atlantic Chapter then altered its 501c3 status to create a new designation for the NY Water Sentinels program.

Being part of the extended Sierra Club network has allowed the NY Water Sentinels to apply for new funding lines. One example is the Grassroots Network Grant program, an incubator project for emerging campaigns that awarded the network $4,000 in September 2014. The NY Water Sentinels also worked with the Sierra Club to iron out accounting issues to comply with 501c3 reporting requirements. This made it easier for private foundations wanting to support the network. In September 2014 the NY Water Sentinels received a $4,000 grant from the Hoyt Foundation. These and other funding sources were critical in supporting the NY Water Sentinels monitoring network, and secured its ability to extend programming into the next year.

Nevertheless, the decision to join with the Sierra Club had other implications for a monitoring network built on a foundation of grassroots partnerships. The democratic governing structures of the network are changing. Under the new charter, individual monitoring groups will be required to report their activities to the NY Water Sentinels Steering Committee as before, but also to the Atlantic Chapter Conservation Chair. Groups may make recommendations to the Sierra Club to undertake a legal action, but cannot act independently without a detailed review by the Sierra Club of the legal merits of the case. Financially, the network's assets will be held in a Sierra Club Foundation account. How these changes might affect the day-to-day operations of the NY Water Sentinels in the future remains to be seen. When I asked one Chapter Coordinator, Gene Coplans, how his group felt about these changes, he told me:

> Look, we have meat eaters and hunters and we have—most of our people are Republicans. They don't have any sympathy for the Sierra Club. They are not members of the Sierra Club. I joined the Sierra Club just so I could do this. I wasn't a member of the Sierra Club. There is a difference between grassroots environmentalism, which is what we do, and aesthetic environmentalism, which is what the Sierra Club does. I like to call them 'Rocky Mountain High' environmentalists because their primary interest is in preserving wild lands where no one lives. Our interest is in protecting our backyards. We are NIMBYs and we wear the NIMBY badge with honor. The Sierra Club Atlantic Chapter, of people that are involved here, are paid staff. They seem to have little understanding of what it takes to organize and maintain an entirely volunteer group and so I have just had to

> say repeatedly, no. My people aren't going to do that. You want them to do this, that and the other thing. They didn't agree to do that and I'm not going to ask them to do it, because if I ask them to do it, my group is going to fall apart.

These comments reflect how building closer ties to the Sierra Club made some groups in the monitoring network uncomfortable. As was evident in the landfills story, individuals in monitoring networks wanted to have a say in daily operations and larger mission-related decisions. Furthermore, some member groups like the CCCC have a long history working in their communities. They know what it takes to bring people together in common cause and sustain their membership. Like Gene, people in these groups resented the notion that the Sierra Club might dictate organizing tactics in the future, or change how they might engage water monitoring on their own terms—scientifically, politically, legally, or otherwise. As is the case with many organizations dependent on soft money, the requirements that come attached with new funding also create a framework within which their organizations must define their activities.

Nevertheless, the NY Water Sentinels remain a fully democratic process at this time. The Steering Committee and the Leadership Committee continue to make decisions about how the monitoring network operates, and are committed to keeping the network locally focused. The NY Water Sentinels are now exploring the possibility of further refining the Sierra Club's 501c3 reporting systems so funders can tailor their donations for use in certain zip codes. This altered funding structure would bolster the NY Water Sentinels' ability to work on specific projects without compromising the network's other objectives.

Changing relationships between the NY Water Sentinels, its members, and the Sierra Club illustrate how a monitoring infrastructure can be affected when external pressures force a network to reevaluate its partnership structures. These changes can reveal some of the tensions that exist when different ideas about how to run a monitoring program collide during times of transition. It remains to be seen how these changes may affect members in the network. Additional research may show that building closer alliances with the Sierra Club significantly increased the empowerment capacity of the NY Water Sentinels. This may particularly true at a time when many environmental advocacy organizations see New York State as a "won" cause due to the recent shale gas drilling ban and begin investing their resources elsewhere.

5.2 Uneasy Alliances in Top-Down Science

The United States Geological Survey (USGS) supports a Water Research Institute in each U.S. state and territory, most often located at state land-grant universities. The West Virginia Water Research Institute (WVWRI) is based at West Virginia University and was founded in 1967 to manage many of the state's long-term surface and ground water research studies.

In the fall of 2008, researchers from WVWRI began to notice rising levels of total dissolved solids (TDS) in tributaries of the Upper Monongahela River exceeding EPA secondary drinking water standards. Excess TDS was likely coming from coal and gas extraction activities, but researchers knew little about where and when discharges were occurring. In July 2009, WVWRI received funds from the USGS to gather more data and established 17 monitoring sites for bi-weekly, full-spectrum sampling. Unfortunately, these new resources came into place only one week prior to the Dunkard Creek fish kill

(West Virginia Water Research Institute, 2011a). It was too late to understand the series of events that led to the fish kill, but WVWRI researchers realized similar incidents were bound to happen in other watersheds already impacted by coal mining, and now experiencing a rise in gas extraction activities.

The Monongahela River flows from West Virginia into Pennsylvania, and eventually meets the Allegheny River to form the Ohio River in Pittsburgh. Watershed scientists throughout these river basins agreed that a region-wide strategy was needed to coordinate their individual monitoring programs. The Pittsburgh-based Colcom Foundation came to the same conclusion. "For a year I went around, meeting with people, saying, boy, I need a group to come to the table here and help get all the groups together with their data," Carol Zagrocki from Colcom told me, "When WVU came to us and said that they wanted to do this project, that they wanted to do the outreach to the other groups and kind of guide them, it made sense. Although Colcom's focus is on southwest Pennsylvania, watersheds don't end at state lines. After all, the Mon flows into Pittsburgh, and is major source for our drinking water."

In 2011 the Colcom Foundation awarded the WVWRI $60,000 from its Marcellus Environmental Fund to establish what would become known as Mon River QUEST (Quality Useful Environmental Study Teams). The program was designed to complement WVWRI's USGS-sponsored monitoring program by aggregating and analyzing data from regional watershed protection groups. The director of WVWRI noted at the time that, "by expanding this project to include a network of volunteers, the dataset will be much greater and provide a better overall picture of the health of the Mon River Basin.

This is especially relevant now because of the rise of the gas well drilling activity" (West Virginia University, 2011).

Mon River QUEST received immediate national attention as a research model for using watershed data from multiple sources to address regional water quality impacts (West Virginia University, 2012). As a result, WVWRI received an additional $750,000 from Colcom in 2012 to expand the program into the Allegheny and Ohio River watersheds. Mon River QUEST was renamed Three Rivers QUEST, or 3RQ. 3RQ received a third grant from Colcom for $500,000 in 2013 to develop the QUEST Data Management Tool to help groups store, manage, and map their data (West Virginia University, 2013).

3RQ is a complicated arrangement of organizations with varying resources and objectives. Early on in the project's design WVWRI identified three research partners. Each partner took stewardship over a different watershed: Wheeling Jesuit University for the Ohio River, Duquesne University for the Lower Monongahela and Lower Allegheny Rivers, and the Iron Furnace Chapter of the PATU for the Upper Allegheny River. WVWRI would continue to oversee the Upper Monongahela River. 3RQ's research partners were responsible for managing an extensive bi-weekly water sampling regime.[39] Each research partner also managed the distribution of competitive $3k-$5k QUEST mini-grants distributed to independent watershed groups in their respective regions.

Amongst the three-dozen organizations funded by QUEST mini-grants, one is the Izaak Walton League's Harry Enstrom Chapter. Other mini-grant beneficiaries include established watershed associations with dedicated staff and secondary sources of income.

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[39] Indicators measured in this program include pH, acidity, alkalinity, conductivity, temperature, TDS, TSS, Al, Br, Ca, Cl, Fe, Mg, Mn, Na, $SO4^{-2}$ and S.

Many of these larger groups had received money from the Marcellus Environmental Fund and were brought on board at Colcom's request. In total, 3RQ would bring together a network of some 30 monitoring groups collecting samples at more than 300 sites across the three large watersheds.

3RQ's research partners stressed that the program's diverse partnership structure would bring resources and expertise to bear on problems important to local watershed groups. "3RQ provides a unique opportunity for academic scientists to engage in community based participatory research—that is, water quality issues identified by our community partners helps to prioritize our research efforts," Rick Burrows, a researcher with Wheeling Jesuit University, noted in a Pittsburgh gathering to announce Colcom's 2013 funding extension. Research partners further argued that community groups could become empowered by being part of the research network. "It also provides community members with direct access to academic researchers who have a wide range of water quality expertise," Rick continued, "With this partnership, we can respond rapidly to help solve local environmental issues in a timely fashion" (West Virginia University, 2013).

These statements suggest that, from the research partners' perspective, 3RQ's structure resembles what Shirk et al. (2012) refer to as a "collaborative" project, "designed by scientists and for which members of the public contribute data but also help to refine project design, analyze data, and/or disseminate findings." Nevertheless, as I will demonstrate, 3RQ operated very differently in the field. In truth, research partners controlled many aspects of 3RQ's design, which affected everything from resource allocations to who determined what the data meant when making scientific claims and political statements. Meanwhile, mini-grantees who came on board with 3RQ expected to have a high degree of influence in determining the nature of their participation. Ultimately, disconnects between 3RQ's founding philosophies and how the project functioned in practice would have major implications for water monitoring groups inside and outside the network.

5.2.1 Erecting Boundaries of Power and Expertise

3RQ's research partners possessed a great deal of power when dealing with local watershed groups. One expression of this power was revealed in determining which groups were accepted or rejected from participating in 3RQ's mini-grant program. The Marcellus Environmental Fund cemented Colcom's position as a patron for watershed research at a time when many environmental protection groups in the three-rivers region remained hindered by decades of declining state support. 3RQ's mini-grants became an important tool for bolstering underfunded and understaffed programs. Lisa Greenfield, a watershed specialist in West Virginia, recalled why her organization went for a mini-grant:

> They put an RFP for money and we wanted some of it. We had worked with the Water Research Institute before, but we needed more funding support. We applied to 3RQ, and we chased a little bit of money on our own with Colcom prior to the QUEST program being founded. We were really driven by the need for staff support, and not by the resources that the program was going to offer beyond that.

Lisa's group received funding from 3RQ and became part of the monitoring network. However, not all groups were as lucky. Mandy White, a watershed specialist in a Pennsylvania-based organization, recalled having a different experience. Mandy's organization manages a large network of data loggers in Western Pennsylvania, initially paid for by Colcom. She expected they would also be welcomed into 3RQ:

> At the time we had received some grants from Colcom, and Colcom was talking with 3RQ about becoming the data manager for all the data that was being generated from monitoring, at least Colcom-funded monitoring, in Southwest Pennsylvania. Colcom let us know that, because of this relationship that they had with the WVWRI, they wanted our data in 3RQ. But we did not receive a mini-grant. We applied but we didn't get it. We actually never even got a letter telling us that we didn't receive funds, we just saw the announcement and we were not in it. By that time we had funded the project in other ways, so it wasn't a big deal.

While 3RQ's rejection might not have been a big deal for Mandy's ability to sustain her organization, 3RQ's new position of authority as an obligatory point of passage for watershed data in the region set an expectation that groups would want to partner with 3RQ, regardless of whether or not they had received funding. This assumption turned out to be disempowering for some groups that were important players in the region's water monitoring community, but were denied access to 3RQ mini-grants. For example, Colcom would eventually request that Mandy's send data collected with their loggers to 3RQ's databases. But their exclusion from 3RQ's official partnership structure meant that she would have a reduced role in determining how 3RQ's research team might use her data.

In other instances, groups applied for 3RQ mini-grants for the explicit purpose of getting assistance from 3RQ's watershed scientists in managing their data. Rita Levitt, the director of a Pennsylvania-based watershed association noted:

> I mean, it is good to have your own database, but at the same time, you know, a central repository where hopefully it will never disappear, that was for us, the goal. That whatever we are putting in, somewhere it will be on a big server, even years from now and could be pulled up even if something happened, it would still be there. I mean, we've got a spread

sheet, we've got some things going on, but at the same time, not the—we didn't have the tools, the manpower or the ability to really create a database of any kind.

Decisions to partner with 3RQ on terms of data management were echoed by many who joined the network. Water monitoring groups needed a place to store rapidly accumulating data. Many groups also believed that partnering with a respected research institution would bring legitimacy to data collected by nonprofessionals, or reveal hidden evidence of pollution in water monitoring data.

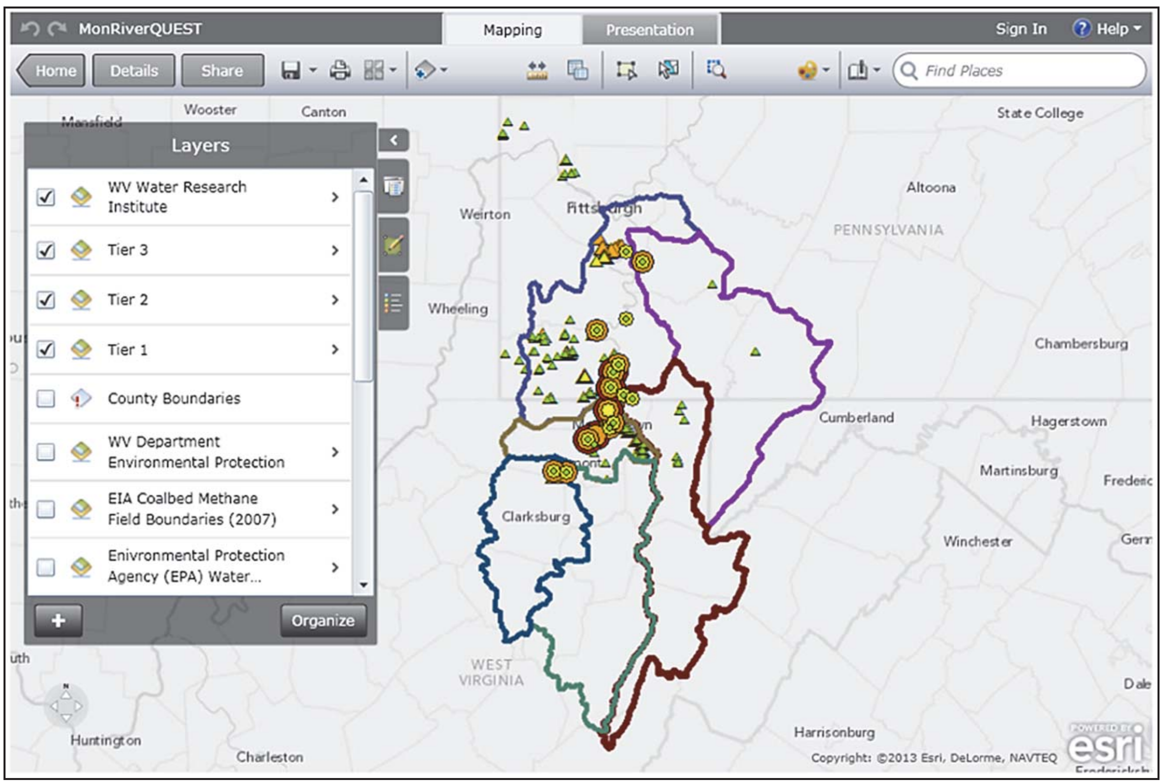

Figure 35. 3RQ's QUEST Data Management Tool (circa 2013)[40]

[40] The current version of the QUEST Data Management Tool can be found at http://3riversquest.org/ (Last accessed July 27, 2015).

Lisa, Mandy, and Rita's data are stored in a database and GIS system developed by WVWRI called the QUEST Data Management Tool. The initial architecture of 3RQ's technical centerpiece mirrored its partnership structure, in that data entering the system was "tiered" to distinguish its source. Within this classification scheme, bi-weekly samples gathered by 3RQ's four research partners were assigned to Tier 1. Tier 2 was reserved for data generated by Colcom-funded automated data loggers. Data from grassroots monitoring programs, like the Izaak Walton League Harry Enstrom Chapter, were placed in Tier 3 (Figure 35).

Tiered data made sense to 3RQ's development team. Melissa O'Neal, 3RQ's program director at WVWRI, noted that the classification scheme was particularly important when having to work with regulatory agencies:

> We actually had conversations with the EPA and with the different state agencies, Pennsylvania DEP and West Virginia DEP, early on during the brainstorming phases of bringing on the volunteer component into the program, and that was one of the things that was identified. Whenever they are looking at the data from our website, they wanted to be able to distinguish between what we are collecting and what volunteers are collecting. And then, further, which volunteers are collecting—how much confidence can we give in this data that is being provided.

The tier system was born out of a need to better define the characteristics and quality of 3RQ's data. It is understandable that 3RQ's certified laboratory testing was deemed of highest quality and given its own layer. Data loggers were placed in a separate category partly because data from these devices was so different that of grab samples. The size of logger-derived datasets also took a toll on QUEST loading time, thus requiring a separate layer.

From the perspective of standards and knowledge categorization, it is also interesting to note how data loggers enjoyed a space of privilege tiered apart (and above) data from the work of volunteers. In many respects, data loggers had fewer quality controls than the protocols established by ALLARM. I suggest that this reflected cascading levels of trust in watershed experts, automated technologies, and finally the work of nonprofessionals. The initial tier system, in essence, drew boundaries around data and reinforced the power structures of authoritative science.

5.2.2 Renegotiating the Terms of Research Partnerships

Representatives from smaller watershed groups I met with argued that 3RQ's partnership structure, and its initial investments in a tiered data scheme, reflected the monitoring network's overall political landscape. They felt as though 3RQ's leaders made demands for their data in order to conduct scientific research, but diminished the importance of using data to address issues in their communities in other ways. These concerns were made plain in my conversations with Lisa Greenfield:

> What I don't see QUEST doing at this time, at least not in the way that maybe I would like to see it done, is then turning around, taking this data, and being the leaders—telling our elected officials that this is happening to our rivers and streams and this is what we need to do to protect them. That gets back into the big questions about the Ivory Tower, and who funds your research. I have opinions about the motivations behind some of this research. We might have all this data on our watershed, but how is that helping improve water quality broadly across the state and across the region? Yeah, we hope that nothing bad ever happens, but if it would, it wouldn't be the researchers marching down to Charleston, it would be us. I don't think they would help us.

3RQ's project leaders countered these claims. They noted that using data for research purposes could produce meaningful changes in environmental governance. Furthermore, since 3RQ is part of West Virginia's designated Water Research Institute, they were not in a position to use data beyond the purposes of research. 3RQ's project director articulated these points at a Pittsburgh gathering of 3RQ's partners in August 2014. During an open Q&A session a member of the audience asked how 3RQ might use data to assist watershed groups in doing advocacy-based work. We were told:

> We get a lot of questions in a lot of places that we go where people look to us and say—what are you doing? Why aren't you out there doing something? We are, but we're not doing it at an advocacy level because that's not our role. That's your role, and that's why we're hoping to empower folks by taking their data. We're helping them manage it, we're helping by meeting with the EPA, and industry, and state agencies, whether they be in Pennsylvania or West Virginia. We are taking on that role. We are getting the data out.

3RQ has found some success influencing environmental decision-making in ways this passage suggests. For example, the WVWRI manages an advisory panel called the TDS Working Group, a partnership between WVWRI, regulatory agencies, and seven coal companies. The TDS Working Group uses 3RQ data to identify locations where excess discharges from coal mining treatment plants contributed to high TDS levels in different watersheds. The TDS Working Group then works with industry through a reporting system to reduce discharges during low water conditions. The idea behind the project was to prevent future incidents similar to the Dunkard Creek fish kill (West Virginia Water Research Institute, 2011b).

Nevertheless, growing discord between what mini-grantees wanted from 3RQ and how 3RQ's research partners envisioned the purpose of the project threatened to unravel the monitoring network. Numerous mini-grantees questioned their commitments to a program that did not help them to address more immediate concerns. Similar complaints came from monitoring groups outside the network, particularly organizations responsible for managing Colcom-funded data loggers, which had been pressured to contribute data to the QUEST Data Management Tool.

These complaints had an interesting effect. At this point, Colcom and WVU had invested more than $1.6 million to establish 3RQ as a regional hub for water monitoring research. It is my belief that 3RQ's leaders and funders took note of dissatisfactions within the network and realized their vulnerabilities. 3RQ then reevaluated the effectiveness of its technical systems as well as its participation structures and made some significant changes.

First, 3RQ's leaders found that the QUEST tier structure was confusing to people. They adjusted the categorization scheme to reflect how data was collected, rather than by what kind of organization. Tier 3 now denotes data verified by an analytical lab, Tier 2 includes data collected with protocols such as ALLARM's, and Tier 1 is for data verified by an individual person. QUEST's GIS system still represents this data on three separate layers—grab samples collected by 3RQ research partners, field data collected by volunteers, and data from automated loggers—but breaking the symbolic link between data source and data quality is significant for monitoring groups who felt disempowered by contributing data to the system.

A second major change came in June of 2015, when Colcom would award WVWRI a fourth grant for $350,000. 3RQ used these funds to establish a new program called REACH (Research Enhancing Awareness via Community Hydrology). REACH will allow each of 3RQ's four research partners to hire a field coordinator to serve as a link between researchers and community groups. Melissa O'Neal from 3RQ explained the purposes of the project in a press release:

> With the REACH initiative, we are able to take the data collected by volunteers a step further. The mini-grant program previously assisted groups with acquiring training, equipment, and staff time. Now that a lot of the volunteers are equipped, we can take a close look at the data they are collecting and identify areas of concern. With this grant we have funding to go in and work with the watershed groups to perform targeted studies…We are not only collecting more data to determine the impairment, but we're working with watershed groups and local entities to improve water quality (West Virginia University, 2015).

3RQ's research partner at Duquesne University put the program in the context of helping monitoring groups to take action with their data:

> This new program, Research Enhancing Awareness via Community Hydrology (REACH), will give people the ability to understand what they are seeing. With this ability to interpret data, it's up to them to take it to the next level and demand action if action is required. It's definitely about citizens taking action and being engaged in the political processes with a firm base of data (Duquesne University, 2015).

The REACH initiative is a breakthrough addition to 3RQ in terms of realizing how network's founding philosophy differed from its day-to-day operations. The initial project promised a partnership structure that would empower communities to draw upon the resources and expertise of research institutions and deal with local watershed issues—particularly those associated with shale gas drilling. In practice, much of the network's activities substantially contributed to watershed projects like the TDS Working Group, but needed to do more when working in local monitoring groups. This was especially true of groups that hoped to use 3RQ's resources to combat the shale gas industry through advocacy.

REACH may change these dynamics. Hiring community outreach coordinators shows an attempt at bi-directionality, or shifting the 3RQ partnerships structure towards a "co-created" model of participation. Furthermore, stating that REACH might help monitoring groups make sense of their data to then “take it to the next level and demand action” suggests that 3RQ’s leaders are beginning to recognize how they might assist groups with advocacy-based work while still adhering to the political restrictions of research institutions.

5.3 Conclusion

On their surfaces, water monitoring networks in the Marcellus Shale are surprisingly similar—they propagate standardized monitoring protocols, provide access to sampling equipment, offer training to new members, develop a means to work data, and create pathways to partner with outside experts. Knowledge infrastructures built by the NY Water Sentinels and 3RQ addressed these needs for their respective member groups. Their infrastructures were also built for similar reasons. Those who invested believed research partnerships would build capacity by bringing together diverse resources and knowledge, and empower their members to gain greater legitimacy when working on complex environmental problems. The case studies in this chapter illustrate how these infrastructures were built using different partnership structures. It shows that participation models adopted in these partnerships impacted how people and organizations retain control over resources and decision-making capabilities that affect the nature of empowerment.

In the case of the NY Water Sentinels, member groups enjoyed a high degree of autonomy to address new environmental pollution concerns as they arose, such as with the problems of landfill waste. Their democratic, bottom-up governing system afforded mechanisms for empowering individuals to influence the operations of the larger network. By comparison, local watershed organizations that aligned with 3RQ gained access to professional-grade resources, and mini-grants brought forth new equipment and staff. However, 3RQ's partnership structure reinforced the authority of watershed experts while claiming to do collaborative research. Mini-grantees were able to hook into a larger monitoring infrastructure, but were disempowered by the constraining needs and priorities of 3RQ's research partners.

Studying the NY Water Sentinels and 3RQ revealed some important discoveries. Dynamics of power in water monitoring infrastructures can change over time. Shifts can occur when resources become scarce and some members of a network gain greater influence. This was seen at two different turning points in the NY Water Sentinels' development. One occurred when a number of individuals inserted new objectives, in this case landfill monitoring, into the network's daily activities. The other turning point coincided with the NY Water Sentinels becoming a sub-program of the Sierra Club. For 3RQ, power shifts occurred for different reasons. Despite being part of one of the most resource-rich water monitoring networks in the Marcellus Shale, many of 3RQ's member organizations felt disempowered an inability to influence 3RQ's research design. Dissatisfaction became visible when members voiced concern about how their data was being managed and how research partners responded to their political needs. The REACH initiative and changes to QUEST's tier structure acknowledged these asymmetries.

Studying the NY Water Sentinels and 3RQ led to a second important discovery on the nature of empowerment. Corbett and Keller (2005a) offered a framework to assess empowerment at two scales, at the level of the individual and at the level of community. My findings suggest that, within the knowledge infrastructures, changes in empowerment can occur at three distinct levels: at the scale of the individual, the monitoring group, and the research community. This third level of empowerment is the result of the heterogeneity and geographic expansiveness of these knowledge infrastructures.

I also found that there are tradeoffs that occur across these three scales of potential empowerment. Individuals who viewed landfill waste as a major threat were empowered by the NY Water Sentinels governing structure, but one might argue that the larger research network suffered due to internal frictions and competing objectives. Aligning with the Sierra Club might have saved the NY Water Sentinels and extended its political influence, but the commitments of this new partnership arrangement may alter the agencies of individual monitoring groups in the future. Whether or not REACH will alter 3RQ's partnership structure to allow greater agency for mini-grantees remains to be seen. Nevertheless, the fact that Colcom awarded 3RQ $350,000 to fund the REACH project illustrates how marginalized groups in hierarchical partnership structures can alter the topology of infrastructures through various forms of resistance.

In summary, this chapter looked at the promises of empowerment often articulated in the processes of building water monitoring research infrastructures. Recognizing how power, authority, and expertise play out in these infrastructures offers a more nuanced understanding of empowerment, as well as some of the tradeoffs that occur at different scales during stages of infrastructure building. This chapter also begins to reveal that shifts in empowerment can hinge on how people rethink the purposes of water monitoring and water quality data. The next chapter builds on these observations by looking at how beliefs on the affordances of data play out in data management systems that bring people together from across the Marcellus Shale monitoring community.

6. DATA BROKERS, DATA WRANGLERS, DATA CULTURE(S)

This chapter examines the emergent forms of collectivity that occur around data, and the conflicts that arise when data cultures meet. It is a story about how members of a diverse scientific research community imagine relationships between how people use data and what that data ultimately means. As many STS scholars have shown, those who make scientific observations must generate new tools to make sense of their findings—such as conceptual models, visual schematics, and data arrays (Crary, 1999; Daston & Galison, 2007; Daston & Lunbeck, 2011). For the Marcellus Shale water monitoring community, the tools of data analysis and communication take shape in a family of shared databases and participatory geographic information systems (PGIS).

Databases and PGIS projects can assist nonprofessional groups with data related issues that they often do not have the capacity to manage themselves. They can create pathways for volunteer-collected data to interact with data from expert scientists, as was seen in 3RQ's QUEST Data Management Tool. In my research I have found that many nonprofessional monitoring groups often believe that participating in shared database projects makes their data more meaningful, more conversant with scientific researchers, and more likely to influence environmental decision-making. Meanwhile, research scientists encourage groups to invest in shared data management projects in order to gain access to data that might otherwise live in isolated notebooks and personal computers.

Like monitoring protocols and data collection technologies, data management systems can have empowering and disempowering qualities. Design choices that shape these systems can favor the objectives of some participants more than others depending on what research questions set the tone of the projects. This chapter shows how data management systems can be complex technologies, often built for the expert community and used by a limited pool of users. Furthermore, those who invest in these projects, particularly volunteer monitoring groups, are often forced to contour their data to expectations of system designers. However, these database projects also reveal possibilities where the situated knowledge and personal concerns of monitoring groups can change how project designers build their systems and conceptualize their uses. This chapter therefore addresses the question of how data cultures can have other orientations beyond ones constrained by standards determined by professional experts.

I begin this chapter by exploring how the dream of a centralized database became such a strong attraction for the region's water monitoring community. This is followed by a close analysis of Pennsylvania State University's Shale Network, one of the most prominent projects that emerged to serve the water monitoring community in recent years. I use this case study to argue that data management projects like Shale Network are also social spaces in which stakeholders from many backgrounds articulate different visions for the future of data culture in the water monitoring community.

6.1 Database Pasts

The centralized database has become a sort of Holy Grail for the Marcellus Shale water monitoring community. Efforts to build a functional system can be traced back more than a decade to the work of the Pennsylvania Organization for Watersheds & Rivers (POWR). POWR is a nonprofit established in 1993 to serve as a mediator between watershed advocacy groups and Pennsylvania's many state environmental protection agencies. In July of 2001, the PA DEP's VEMP, a consulting body of service providers and watershed monitoring groups, expanded its mission statewide and became the Keystone Watershed Monitoring Network (KWMN). One of KWMN's first tasks was to develop a data management system for the nongovernmental water monitoring community. KWMM enlisted the help and resources of POWR, which proceeded to establish a Database Subcommittee to come up with a list of requested features based on consultations with the states' many volunteer programs (D. E. Hess, 2005).

The Database Subcommittee's findings included feature requests for: 1) a web-hosted, user-friendly, point-and-click interface, 2) basic data manipulation capabilities, such as graphing and statistical processing tools, 3) a way to generate standard reports, 4) a GIS component for viewing source locations, 5) a way to import data from other databases in use by KWMN's members, 6) a system with different levels of access and security for different users, and 7) a system that could store "great volumes of metadata" including the quality control plans of different groups. POWR took these suggestions into consideration and signed an exclusive contract with consulting the firm Gannett-Fleming to develop the project.[41] In November 2005, POWR introduced the PA Watersheds Data System to serve as, "a warehouse of watershed monitoring data for Pennsylvania representing the hard work of many volunteer watershed organizations across the Commonwealth" (PAWDS, 2005).[42]

Indicative of a time when Pennsylvania's water monitoring community enjoyed robust support from regulatory agencies, the PA Watershed Data System had many

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[41] This information was obtained from unpublished document supplied by staff at ALLARM titled "Background on the KWMN and Data System."

[42] While a reference has been provided for this quote, it is worth noting that the site "Welcome to the PA Watersheds Data System" is no longer in operation. It was previously accessed on April 17, 2013 at http://www.pawatershedsdatasystem.psu.edu/.

influential proponents including the PA DEP, PA DCNR, and PA FBC. A press release from the PA DEP stated some of its hopes for the project:

> HARRISBURG, PA, Dec. 16, 2005 -- Pennsylvania Organization for Watersheds and Rivers (POWR) has announced the release of an online system that will store data collected by volunteer watershed monitors statewide. This information is currently used to track the impacts that human activities may have on a watershed, but it is stored only locally, without online access. With the advent of the PA Watersheds Data System, thousands of records dating back to the early 1970s can be made publicly available. The system is accessed through POWR's website www.pawatersheds.org, and is designed to place the monitoring groups in charge of their data, including whether they will store their data in it and who they will allow to see it once it is stored there (PA Department of Environmental Protection, 2005b).

The Deputy Secretary for Water Management in the PA DEP also said of the project:

> The PA Watersheds Data System represents an important step forward in Pennsylvania's water resources management toolkit. Among other things, it allows everyone to see where regular monitoring is taking place and where it may not be taking place. This will help governments and private citizens alike understand the condition of the environment as well as fill in gaps where information is lacking. DEP is a strong contributor to the project both financially and in terms of scientific expertise and we're excited to see it come to fruition (PA Department of Environmental Protection, 2005c).

The PA Watersheds Data System was promoted heavily in following months in training sessions and at regional conferences. Advertising flyers associated with the project stated, "We want to help you become a POWRful force in Pennsylvania's watersheds!"[43] By the end of January 2006, more than 100 users from watershed groups, consulting firms, and government agencies, contributing more than 100,000 data points to the system. The system also maintained records on the monitoring protocols for these groups as the Database Subcommittee had hoped (PA Department of Environmental

[43] This information was obtained from POWR flyer supplied by staff at ALLARM titled "Volunteer Monitoring Data System of the Keystone Watershed Monitoring Network."

Protection, 2006). Having realized a fully functioning data entry, data visualizing, and data mapping tool, the PA Watersheds Data System was fairly advanced given the state of technologies available at its time (Figure 36).

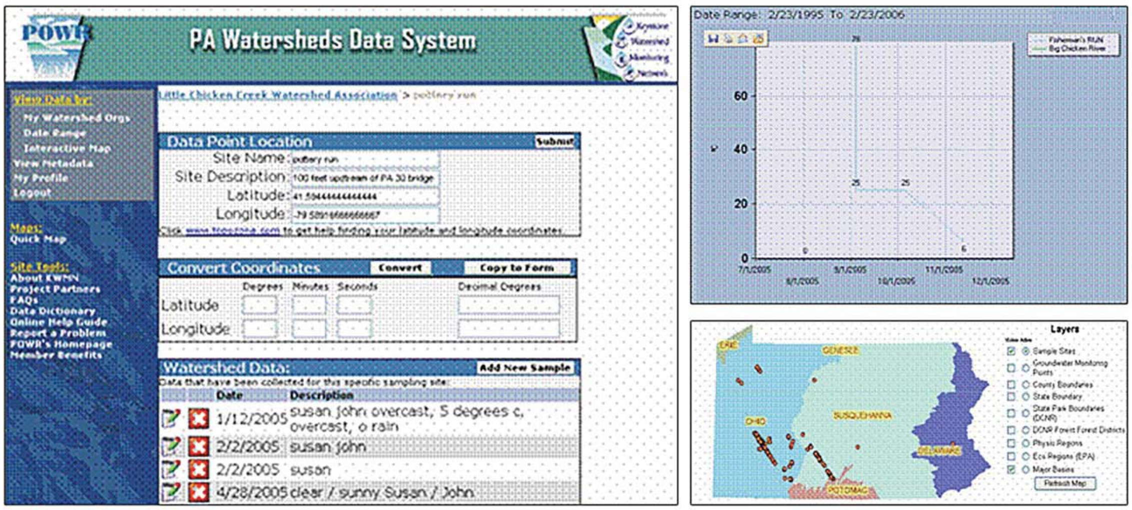

Figure 36. A collection of screenshots of the PA Watershed Data System[44]

The PA Watershed Data System would eventually store data for more than 50 different organizations. However, organizational changes at POWR threatened the system's existence. In 2008, POWR became a subsidiary of the newly formed Pennsylvania Environmental Council (PEC). When restructuring the new organization's priorities, PEC's board noted of the database:

> The incredibly complex online system is a powerful idea, but is a time consuming venture with questionable value. Without an emphasis on advocacy, either at the local or state level, monitoring programs are

[44] Unfortunately, no high-quality screen captures of the now defunct website could be found. However, low resolution screenshots of the PA Watershed Data System, archived from the August 2006 Pennsylvania Statewide Conference on Abandoned Mine Reclamation, are still available at: http://2006.treatminewater.com/B/materials/databases/databases-powr_files/v3_document.html (Last accessed July 27, 2015).

> complex volunteer activities and have little power to address problems in water quality once identified. It is important to note that water quality monitoring is essential to a fully functioning statewide water resource program. However, POWR's best strategy is to help transfer coordination of this program to an organization or entity with large resources and technical know-how, such as Penn State or another university, or even Stroud Water Resources Center (Pennsylvania Organization for Watersheds & Rivers, 2009).

The PA Watershed Data System eventually lost support within the PEC and the database would be transferred to Penn State researchers with the hope it would continue under their stewardship. Ongoing development and maintenance ceased without a steady funding source. In the summer of 2013, the PA Watershed Data System indefinitely went off-line, although most of its users had abandoned the project long before then. Data not kept in the original records of contributing organizations are no longer accessible to the public.

The birth of the PA Watershed Data System set in motion a series of expectations about what an effective database should do for monitoring groups. A lasting impression in the memories of those who were around during the early years of Pennsylvania's water monitoring efforts, long before the threats of shale gas extraction, was the continual loss of data due to having no central repository. The PA Watershed Data System brought data out of local silos and put it into a single location for public use. The system also effectively implemented tools for groups to control how their data was used and provide details on the character of their data. Other requested features did not come to fruition in the PA Watershed Data System. For instance, watershed specialists became the primary users of the system, partly because simplified computing interfaces had not yet evolved to accommodate nonprofessional users. Other features, such as including metadata on quality assurance plans, were partially implemented on a case-by-case basis.

Despite its flaws, the demise of the PA Watershed Data System left a lasting mark on the water monitoring community. “This is why people don’t know about the watershed-based volunteer monitoring movement—we suck at holding onto our data, we suck at using our data, we are horrible at telling our stories,” one service provider close to the project would tell me. This sense of defeat is often cited by people with knowledge of the project’s history as the reason they have deep reservations about investing in shared database projects.

Nevertheless, nearly all of the features explored in the PA Watershed Data System, successfully implemented or otherwise, continued to be top priorities for people working with water quality data. When leaders in the Marcellus Shale monitoring service provider community revisited the idea of building a shared database, the PA Watershed Data System would fundamentally shape how they envisioned what such a system might do for lifting the work of concerned citizen groups. In their view, if a system could emerge that delivered on the technical promises of the PA Watershed Data System, while also allowing groups to mobilize their data in a spectrum of discursive arenas—from science, to policy, to advocacy—then the stories of watershed groups may indeed gain influence in debates about shale gas extraction’s impacts.

6.2 Database Present

The shale gas water monitoring community expanded rapidly in its early years as more groups were brought on board through outreach and training programs. Data accumulated in the notebooks and computers of volunteer groups. Service providers, academic researchers, and volunteers alike again turned to the dream of a centralized system to solve pressing data management, data assessment, and data communication needs. Volunteers and service providers hoped that a next generation of data management tools would do what the PA Watershed Data System could not—bridge the data-rich/information-poor divide by empowering nonprofessionals to use their data for advocacy. Academic researchers were eager to get their hands on large pools of data for doing watershed-wide studies on shale gas pollution. Julie Vastine from ALLARM told me at the time:

> The things that kept me up at night were the fact that we did not have data for the 300 groups throughout the state doing water monitoring. We didn't have their data in a central location. What a missed opportunity. Do you know what I mean? We wanted communities to have complete ownership of the scientific process. If you use the Cornell Lab of Ornithology's metrics for public participation and scientific research, we were an exemplary model of the 'co-created' model, where the communities, through every step of the scientific process, owned the data, housed the data, used the data, designed the study, and did the analysis—the whole nine yards. But the compromise of that is where are the data?

The Marcellus Shale water monitoring community came together at an ideal time for realizing a potentially successful project. Database interfaces had improved significantly since 2005. GIS-based environmental research expanded over the years as more regulators, environmental protection organizations, and academic researchers integrated these tools into their daily work. For the shale gas water monitoring community, the protocols promoted by service providers also meant that data was more uniform and collected with documented quality controls. Service providers had a more mature understanding of data management projects following the demise of the PA Watershed Data System and had prepared monitoring groups for the likelihood that this data would eventually be housed in a central database.

Data management projects that materialized to meet these needs differed from those of the past in that they came out of academic research centers without direct support from regulatory agencies. One prominent project that emerged to serve the monitoring community was 3RQ's QUEST Data Management Tool. Another was a project established by Pennsylvania State University's Earth and Environmental Systems Institute (EESI) called the Shale Network. As was discussed in the previous chapter, QUEST's primary function was to host 3RQ's monitoring data. The same is true of Shale Network. However, Shale Network differs from QUEST in that the project not only produced a shared data management system, it also created a social space that brought people together to talk about data.

6.2.1 Shale Network: The Honest Brokers of Data

Shale Network's stated mission is to bring together a diverse community of stakeholders for the purpose of sharing and using data to better understand the impacts of shale gas extraction. This includes water quality data from nongovernmental water monitoring groups, academic watershed researchers, state and federal agencies, and, to a limited extent, industry. In doing this work, Shale Network billed itself as, "an 'honest broker' that collates datasets and learns and teaches how to synthesize that data into useful knowledge."[45] The core Leadership Team behind the Shale Network included water quality scientists from Penn State and the University of Pittsburgh, as well as staff from ALLARM. Shale Network's genesis can be directly traced to the appeals of service

[45] Additional information on Shale Network's intended mission is available at http://www.shalenetwork.org (Last accessed July 27, 2015).

providers who asserted their need for a centralized water quality database. Sue Brantley, Shale Network's primary investigator at Penn State, noted of their project's origin:

> Penn State was running a series of talks on Marcellus Shale research and ALLARM came and gave a talk. I think I watched it on the web or something. I learned about ALLARM, so I just called them up and I said, I thought it was really interesting what you are doing with ALLARM. Is there some way that somebody like me, that is interested in water and chemistry, could I help you? We chatted and it was actually their idea. They were the ones who were saying, we really needed a database, we need to put data together, and I was working on databases for other kinds of geochemical data and I know a lot about the problems of databases in terms of geochemical data and so I thought, well, that does sound interesting and I knew that our work would fit, so it really was that. I mean, it was ALLARM's idea, and I always like to give them credit.

There were a number of incentives for ALLARM and other service providers to team up with Penn State. Sue Brantley is one of the most respected geochemists in her field. EESI is a well funded department at Penn State, an attractive proposition for service providers struggling to support a network of cash-strapped nonprofits that otherwise have no access to large research grants. EESI is also home to the Marcellus Center for Outreach and Research (MCOR). MCOR provides technical support to state agencies, industry, and environmental groups through environmental impact statements and data mapping projects.[46] Aligning with Penn State promised many new opportunities for the water monitoring community to interact with the scientists and regulators. Partnering with an institution with long-term resources also meant that a centralized database stood a better chance of overcoming the vulnerabilities that led to the PA Watershed Data System's demise.

[46] Additional information about the MCOR can be found at http://www.marcellus.psu.edu/ (Last accessed July 27, 2015).

In 2011, Shale Network's founding partners successfully received a five-year, $750,000, NSF Research Coordination Network grant. As the Leadership Team planned out Shale Network, they made certain choices that would permanently shape its topology as a technical platform for working with data. EESI already had working relationships with a NSF-funded research center, called the Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI), which developed data management tools for more than 100 universities and watershed science organizations around the world. Shale Network contracted with the consortium to design their database and GIS system.

CUAHSI's technical developers delivered a system built upon an open-source data management and GIS toolkit developed by CUAHSI called HydroDesktop. HydroDesktop is the client application for CUAHSI's larger Hydrologic Information System (HIS) project that brings data together from its many consortium members. HydroDesktop allowed users to access publicly available data in HIS gathered from state and federal agencies, including data from the USGS's National Water Information System, the EPA's STORET system (STOrage and RETrieval), as well as from many other nongovernmental water research centers.[47]

6.2.2 The Difficulties of Data Wrangling

While building the Shale Network database was one thing, getting data into the system from the Marcellus Shale water monitoring community proved far more

[47] Additional information on CUAHSI, HydroDesktop, and HIS is available at https://www.cuahsi.org/ (Last accessed July 27, 2015).

challenging. HydroDesktop and HIS were built for watershed scientists, which comes with demanding expectations for how data ought to be managed. David Owens, one of Shale Network's "data wranglers"—a group of Penn State and University of Pittsburgh graduate students tasked with obtaining data—explained some of the standard procedures he follows with when entering data into Shale Network's database:

> We follow a specific format for how the data can be inputted so the programs recognize it. We fill in our "data-value sheet" with all those different values. We give each site a specific site-code, and we fill out the date, the time, the methods, was that data censored, and what that means—this is the description of the site. Like if it was a well, how deep is that well. Units. Description. That will be our data values page. We then fill out a "sites-page" where we provide a site-code with the site name. We do a latitude and longitude. We fill out a "variables-page" with the variable code. So if it's methane, we might call it DEP-Methane. That is just for us—what are the units for the sample medium, was it surface water, ground water. There are a couple other things that I can't remember offhand. And then finally the "source-page"—how will we publish this, how it would be cited, all the information an organization can provide. Like, the organization's description of the data, how it was handed to us, an abstract, a citation if that is provided. Contact information about the person at the time we received the data. Then once we have that, we upload it to the server. Then once it's uploaded, if we have any new variables that we have to add for CUAHSI to recognize, we do that. We have to tag each variable so that Shale Network recognizes what the variables are. So, in a perfect world, if everything went smoothly, there is no reason that, if it was an easy data set, like maybe with 100 datasets, that it couldn't get uploaded by the end of the day.

These expectations can set a high bar for nonprofessional monitoring groups that wish to contribute their data. While some information David required is collected in the course of using standard protocols like those laid out by ALLARM, there is often little motivation for volunteers to collect the breadth of additional background information Shale Network's data wranglers required. One reason for this stemmed from trying to get data from monitoring programs that traditionally emphasized using their data to address local environmental issues and not for scientific research. Another factor was that volunteers simply didn't have the time or energy to take on more tasks than they initially signed up for. Service providers realized they would have to deal with these obstructions if a successful database were to get off the ground.

I witnessed this during a meeting between PATU volunteers and their service provider when discussing what to do next with the chapter's data. For nearly two years this PATU chapter, one of the more methodical monitoring groups in Pennsylvania, had been entering their data into Survey Monkey. Survey Monkey is a website designed for conducting online surveys and polls, but was tailored by the group to manage water quality data in lieu of better options.

Hank Eggleston, the group leader told us, "The problem with Survey Monkey is that nobody is going to take the time to look at all this data. What are we going to do with it all? There are 70 sites in our county!"

The service provider commented, "Well, there are people who are getting very interested in volunteers' data. Academics, government agencies, even industry. So I suggest you all begin to discuss how to share your data."

Hank replied, "Survey Monkey was a stop-gap measure, it's 2-years going, for what to do with the data. Which has put on hold any talks of making a real system."

"Yes, but for the first time, in the whole Achilles heel of the Marcellus Shale data problem, there are projects coming that are viable options. 2013 will be the year of the database," The service provider responded, "so the question is, are people keeping their data? Do you keep track of when you calibrate your meters? Also, how many hours you are monitoring? These are the things people are asking of us as we've been learning about the data sharing process."

Hank, perturbed by the direction of the conversation, interjected, “This is going to end up being a monster with all this data!”

“Hank, I’ve only asked you for three more things!”

Besides the problem of asking volunteers to invest more time and energy recording metadata for data wranglers, impediments can also stem from how volunteers perceive the usefulness of databases in the first place. A volunteer at the PATU meeting interrupted the conversation, “Survey Monkey is better than no monkey. It is a place to put the data to show the county. Otherwise it doesn’t exist if it just sits on our own computers.” But he continued by saying:

> My scare is that these groups are going to get a big grant, and build the databases. Then they don’t maintain it. But down the road, if they don’t work out, we have to chase down our data with someone else. We need to keep that data local for our use most importantly. And there is the privacy issue with sending it all over the state. I think having someplace for our data, only, is important. The problem with Survey Monkey is I can’t see the history of our data, of other’s data. How do we do that? People here want to know how their data compares to others. Do other people out there ask for that as well?

Another volunteer, who expressed concern about losing control of their data, told me on the side, “Do you want to know where all the data is? It’s right here,” pointing to a 2-inch thick white-lined notebook. Retaining local control of data was of great concern to this particular PATU chapter, as well as for many other groups. Why they should trust service providers and academics with their data remained an unanswered question.

Shale Network’s data wranglers hence faced numerous barriers to obtaining usable data from the volunteer community. At a meeting of Shale Network’s contributors in 2012, a representative from a New York based volunteer-based monitoring network summarized what this meant for getting data into databases. “We've found it very difficult to get people to develop a community around collecting data, and then getting that data into a database. People have different interests and concerns than those doing the data collection," this person commented, "it takes time to work out those problems. It's a real hurdle for us getting the data to you." A 2014 review of Shale Network's datasets revealed that, of more than 1 million represented data points collected at 250,000 different monitoring sites, only 5% of that data came from volunteer groups. These were supplied almost exclusively by ALLARM staff or from data funneled through ALLARM's affiliation with other monitoring networks.

Besides troubles encountered with wrangling data from volunteer groups, barriers to acquiring data also extended to the reluctance of regulators and industry. Regulatory agencies typically collect and organize data internally. The dispersion of regulatory responsibilities across agencies like the PA DEP, PA DCNR, and the PA FBC, has caused data to be aggregated using different protocols to suit the particular needs of different environmental management projects. Increasingly scarce resources within regulatory agencies have also limited personnel assigned to manage data and respond to public information requests. Even when people do acquire regulatory data, particularly on shale gas related water quality issues, it is often incomplete due to the fact that gas companies are allowed to submit their reports on paper rather than in digital form (Malone et al., 2015).

For industry, there is little incentive to share robust data, and little industry related data has made its way into the Shale Network system. When I asked a member of the Shale Network data wrangling team about their experiences acquiring industry data, I was told:

> Well, they have probably collected, and I'm just kind of guessing here, but I would guess over a quarter of a million water samples from gas wells across the state. So that is a huge data set. It probably won't see the light of day any time soon. And if it does, it will be pretty fuzzy. So they are not going to say, oh yeah, that was Joe Smith's at 123 Main Street. That was his well. You will never be able to go down to that level with it.

Making this data available to the public increases corporate liability. Acquiring industry-related data from residents who have signed gas leases can be equally difficult. This was noted by a member of a leader from one of Shale Network's data contributing groups: "Private landowners, and farmers in particular, they're worried about being liable for contamination problems related to their business. Or for people who have abandoned wells on their property who would then be required to fix them."

Having realized that acquiring government generated data was far easier than working with volunteer groups or industry, the Shale Network Leadership Team applied a significant portion of their resources to scrubbing through dataset generated by state and federal monitoring programs. Service providers and volunteer groups on the project voiced concerns about the dangers of relying on datasets already believed to be unreliable in assessing the impacts of the shale gas industry. Shale Network's researchers even admitted that, despite the wealth of data available in HydroDesktop, the project has not confirmed any water pollution incidents traceable to shale gas extraction. "We have most of the data that we know we're going to get," David Owens told me in an interview, "and we can just tell there is a lot we don't know, and won't know, unless we go out and collect a lot more data. So that is something we have been grappling with."

In bringing to light the difficulties of data wrangling and sharing, Shale Network revealed what Edwards et al. (2011) described as the data frictions that occur when, "data move between people, substrates, organizations, or machines" (p. 669). Shale Network's academic research wanted a system that would provide access to large pools of data for doing watershed-wide studies. Service providers needed a way to store data collected by the volunteer community before it was lost forever. Volunteers hoped a centralized system would make their data more meaningful, but also one that would respect local needs and personal concerns about the gas industry. Meanwhile, industry and regulators had little investment in sharing their data at all.

The difficulties Shale Network faced in building a "community around collecting data" point to the fact that there were conflicting opinions about the usefulness of the database depending on whom you asked. I argue that feelings about the purposes of Shale Network were rooted in the data cultures stakeholders brought with them when coming together around Shale Network. As the following section will show, frictions between the logics that inform these data cultures would become visible in tensions around the design of Shale Network's technical components. However, these tensions would also reveal the diversity of knowledge representations and applications that were possible in managing and communicating water quality data.

6.2.3 Data-Rich, Information-Poor Users

In December 2013, I travelled to CUAHSI's offices in Somerville, Massachusetts, to find out more about choices made when designing HydroDesktop for Shale Network. During my visit I was told by Harvey Callahan, a lead developer on the project, that:

> I think the Shale Network came in really early on in the development where they said, well, we have HydroDesktop and that is what we are doing. CUAHSI's vision, in terms of how data services should work, and

specifically with the Shale Network, is that we are essentially providing the infrastructure, and it's standardized.

However, HydroDesktop's features were built from the ground up to serve a community of academic researchers and watershed specialists. This was most apparent when users from different backgrounds came together to learn the functions of the system, navigate its interfaces, and work with its data.

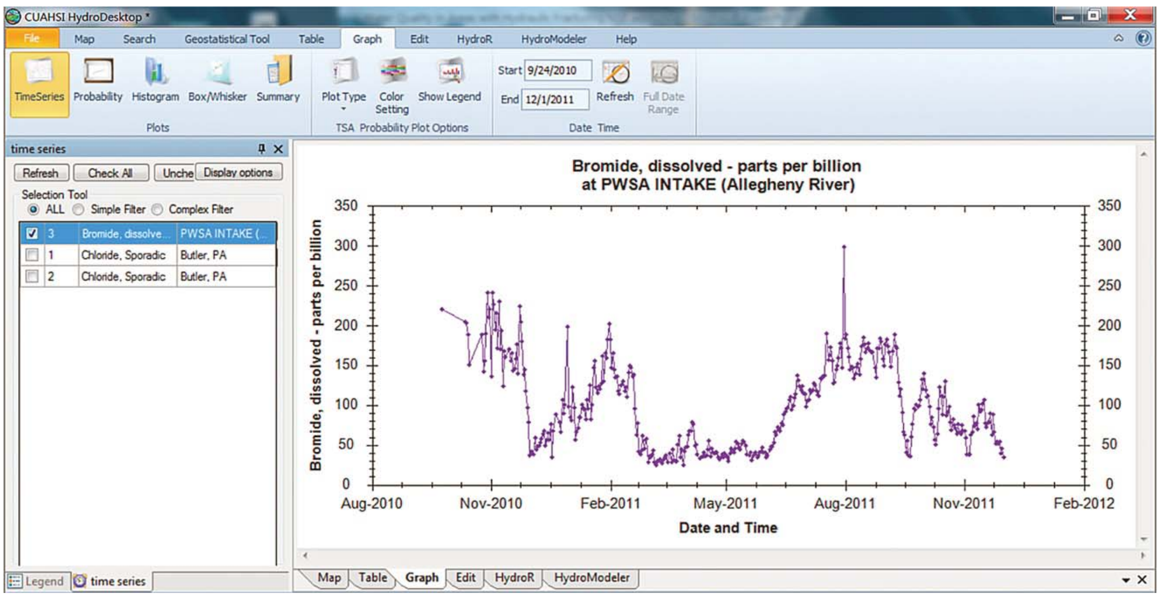

Figure 37. Shale Network's client software, CUAHSI HydroDesktop[48]

The amount of data HydroDesktop makes available to the user is simply astounding. Drop-down tabs in its interface revealed hundreds of possible chemical and biological indicators (Figure 37). Many of these are listed in laboratory-based nomenclatures as opposed to vernacular terms like "conductivity" for instance. In my

[48] Image captured from Shale Network webinar hosted by the EPA. Retrieved July 27, 2015, from http://dels.nas.edu/resources/static-assets/besr/miscellaneous/BESR%20Webinar/Brantley-2014.pdf

observation of Shale Network training sessions I heard many complaints from nonprofessionals that wading through all this data to find a particular water quality indicator of interest was tedious.

HydroDesktop also had no viable way to isolate and view the sites belonging to an individual monitoring group or watershed. Finding this information meant that users had to wade through extensive metadata associated with different datasets. In many cases, this metadata did not correspond to how information was organized by volunteer groups who contributed their data. This was complicated by the fact that HydroDesktop had no way to deal with qualitative information such as photographs, field notes, testimonials, and other forms of "situated knowledge" that often helped volunteers contextualize their data.

HydroDesktop's mapping and data visualization tools were similarly complicated to learn. Graphing features like box plots, time series, histograms, and probability grids, that were familiar to watershed scientists, made little sense to users without environmental science or mathematical backgrounds (Figure 38). These skills were required in order to use HydroDesktop's GIS capabilities. HydroDesktop therefore created a user space that enabled researchers to conduct scientific analysis, but prevented other possible entry points. Its interfaces and functionalities ultimately reintroduced problems of "data-rich/information-poor" syndrome, where nonprofessionals felt powerless to operationalize their data. This creating wide gaps in how nonprofessional users understood the functions of Shale Network.

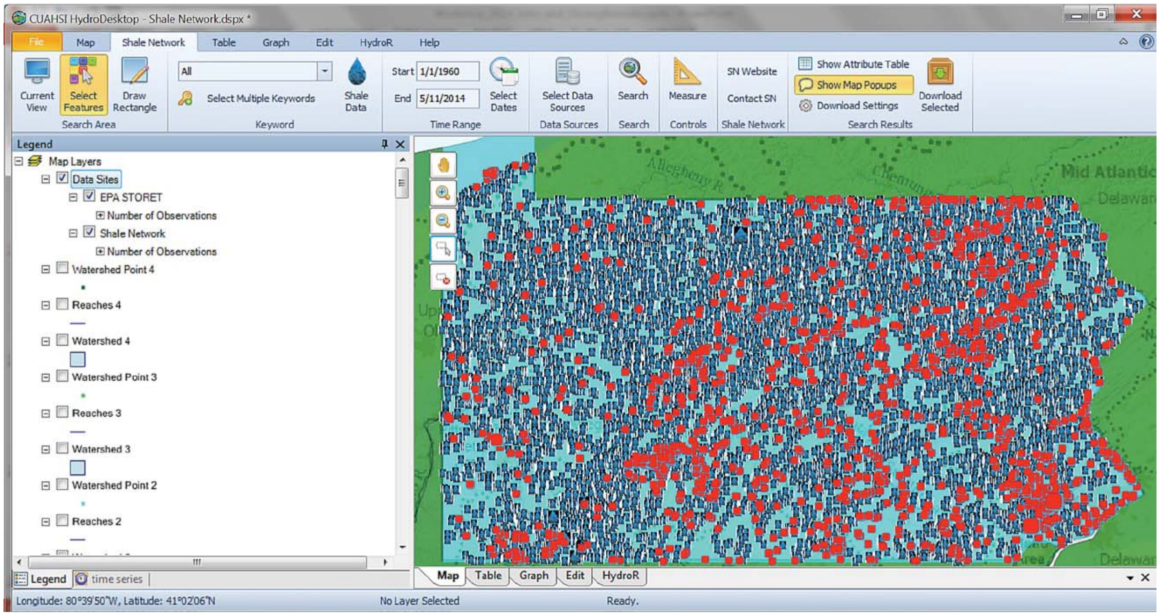

Figure 38. CUAHSI HydroDesktop's GIS mapping features[49]

Even those who did have scientific backgrounds found HydroDesktop daunting at times. Jeremy O'Reilly, a researcher at Penn State, noted of the system:

> Even for me, accessing the data and the database can be a hard climb. Especially if you are just sort of the average Joe and you have an interest in—you are an environmentalist. But that is kind of where it stops, in terms of taking it to the next level, doing research or something like that. And so I think it can be intimidating to try to access it—I don't think it's the most user-friendly interface for the public. I think we all know that. It wasn't developed for the public.

The high level of technical expertise requires to use HydroDesktop constrained Shale Network's ability to serve a broad base of users. Debates concerning what to do about these findings created numerous tensions. Service providers had hoped it would be a participatory GIS system. But the Leadership Team knew their data wranglers were

[49] Image captured from Shale Network webinar hosted by the EPA. Retrieved July 27, 2015, from http://dels.nas.edu/resources/static-assets/besr/miscellaneous/BESR%20Webinar/Brantley-2014.pdf

doing the bulk of the work in aggregating data from different sources, and only a fraction of this data represented the work of volunteers. Shale Network also promised to help groups use their data to make sense of shale gas extraction, but nearly all of HydroDesktop's users were watershed scientists. In fact, a 2014 survey of users found that, despite offering extensive training, none of the volunteer groups that had contributed their data were using HydroDesktop to work with their data. A Shale Network project leader admitted that, "I don't think there's hundreds of people working with Shale Network data. Maybe a few dozen people."

Service providers and volunteer groups became cautious about what Shale Network might ultimately do for their water monitoring community. A staff member from one service provider vented their frustrations in saying:

> A big emphasis is being placed on how can we help volunteers look at their data. How can we create tools to help them? HydroDesktop is not a volunteer-accessible tool. We are eager to see the data become part of this larger data set. That's a powerful contribution of Shale Network. But for the volunteers it needs to be boiled down and simpler. It has to tie into what their interests are.

Shale Network's academic researchers expressed their own vexations. They admitted having little knowledge of how or why volunteers would want to use HydroDesktop. For their part, Shale Network's contribution to the water monitoring community was in managing their data and delivering it to a larger audience of users. "When we wrote the grant, we wanted to concentrate on data wrangling and not writing computer programs," one of Shale Network's researchers explained. Another member of Penn State's researcher team commented, "We never really were funded to make a system friendly to anyone who walks off the street. We were funded to do science." In this view, developing custom tools for nonprofessionals to work directly with their data was not a major component of Shale Network's overall mission.

Applying a "build it and they will come" philosophy did not manifest as intended for Shale Network's Leadership Team. Establishing a community of users proved just as difficult as forming a community around data sharing. For service providers who invested in Shale Network, partnering with academic researches may have brought additional resources and expertise to the water monitoring community, but these resources came with the caveat of entering data into a system primarily built around the needs of researchers and not those of a general public. This put service provider in an awkward position with volunteer groups. Volunteer-based shale gas monitoring was supposed to empower concerned citizens, but the database project they helped create ultimately reinforced disproportionate relationships of power and expertise that had long obstructed the credibility of the volunteer water monitoring community.

6.3 Stretching the Boundaries of Data Cultures

Despite growing frustrations over Shale Network's small number of users, lack of diversity in its data, and inconclusive findings, year after year respondents to annual surveys sent by the Leadership Team expressed a high level of interest in being part of Shale Network's ongoing mission. This points to one of the distinguishing characteristics of Shale Network. Shale Network's data management system is only half of the story. The project also brought together people from all corners of the Marcellus Shale water monitoring community to make sense of the problems of aggregating, sharing, and analyzing data from different origins. I argue that Shale Network created the perfect platform for realizing the range and plurality of data cultures.

Besides building and populating their database, Shale Network hosted a series of annual workshops at Penn State in the springs of 2012, 2013, 2014, and 2015. More than forty representatives from regional universities, government agencies, environmental nonprofits, and volunteer watershed monitoring groups attended the first workshop. By 2014 this number had nearly doubled to eighty groups spanning three states.[50] Workshop attendees included academic researchers, staff from ALLARM, watershed specialists from PA DEP, PA DCNR, PA FBC, SRBC, EPA, and the NY DEC. The gas industry sent representatives from the Marcellus Shale Coalition (a gas industry trade and advocacy group), Shell Oil, and Noble Energy. Numerous volunteer monitoring networks attended as well, including members of PATU, the NY Water Sentinels, volunteers who monitor for the New York based Community Science Institute, and even a few groups who partnered with 3RQ.

Those attending the workshops often talked of coming together to learn what data was being collected by other groups, to determine how others were using data in their watershed studies, and to build partnerships with other monitoring programs. Workshops provided opportunities to listen to individuals' articulations of why, despite so many challenges, they felt invested in being part of a community that might reshape the future of water monitoring in the region (Figure 39).

[50] A complete list of attendees for these two workshops is available at http://www.shalenetwork.org/2012 and http://www.shalenetwork.org/2014 (Last accessed July 27, 2015).

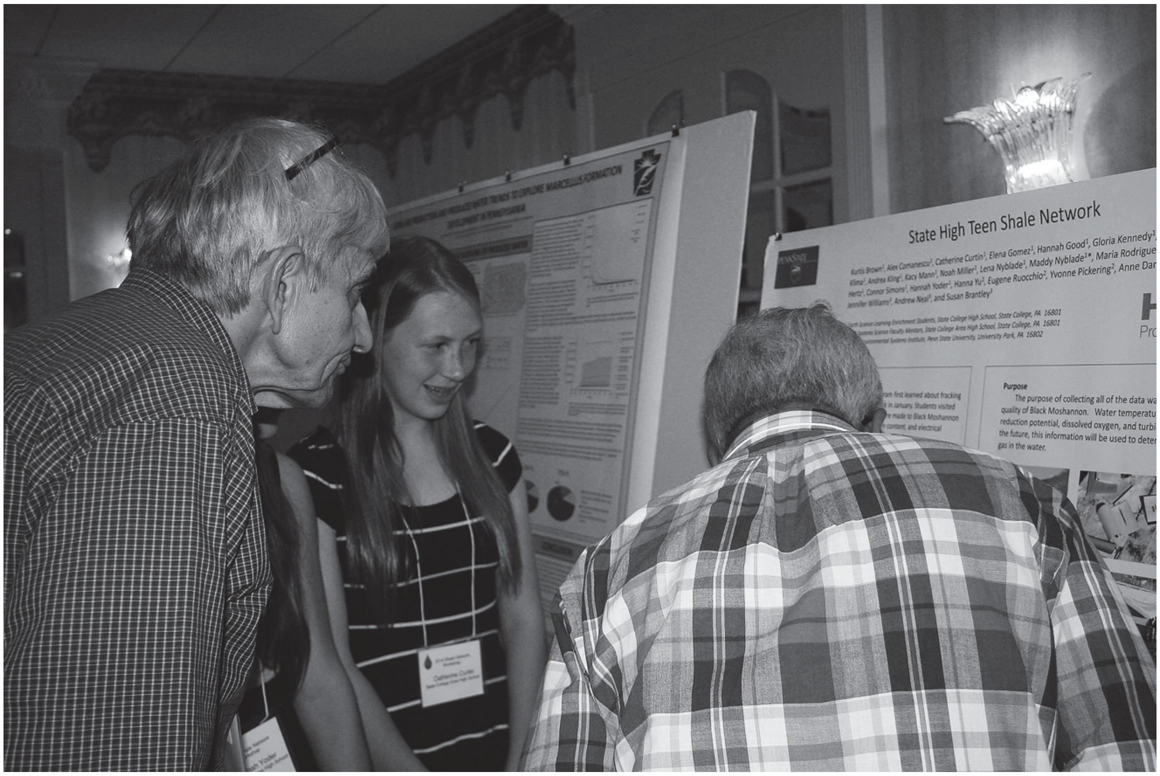

Figure 39. Shale Network attendees share their work at a poster session[51]

Continued confidence on the part of nonprofessionals that Shale Network might help them influence gas industry practices can be credited to the persistent assertion that a centralized database will putt information into the hands of researchers and regulators. This belief also applied to why people participated in annual workshops. Thirteen different government agencies attended Shale Network's workshop in 2014. Many volunteer monitoring and environmental advocacy groups have noted that their primary reason for also attending was to engage regulators in person in order to encourage them to use their data.

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[51] Photograph by Anne Danahy, Penn State staff. Used by permission under creative commons license by-nc-nd 2.0. Retrieved July 27, 2015 from http://news.psu.edu/photo/316327/2014/05/16/shale-network-poster-show.

Approaches to engaging regulators at workshops varied. Some volunteers who attend felt their participation brought a non-scientist's perspective to the room and help raise awareness of the concerns of residents living in gas communities. Others believed they could make the argument that they had a unique understanding of their streams and could help regulators manage the gas industry. These ideas were expressed in some of the presentations held at the workshops. Nancy Goldin, a Pennsylvania volunteer group leader, gave her presentation in 2014. The final PowerPoint slide, titled "helpers in the streams," showed a photograph of her daughter and husband holding a foot-long Hellbender salamander, one of many threatened species living in Pennsylvania's high quality watersheds. She concluded:

> What have we learned? People want to help because they care about their streams, but that they also have to be adaptive to change. Our partnerships with other monitoring groups have been great. We want to keep fostering those relationships. But we also recognize that data management is a balancing act, and we understand it requires time and expertise. I think Shale Network is great. We want to bring that idea back to our volunteers. We want to focus on strengthening our protocols. We want to work with outside agencies to do more data management and analysis. We also want to do more with integrating our data with outside data, and use that help our volunteers engage the public.

Others workshop participants took an advocacy-based approach with regulators. A representative from a New York based monitoring group explained their reasons for participating in annual workshops:

> We've done the workshops, we're out there, we have this data. The reason for wanting to put all the data in one place is so we can do something with it. Now we have a large group of people meeting to do monitoring. We can bring that network to bear by pointing out to the DEC that there are issues to follow up on. We are now becoming a movement, and we know we need to have this community involved. That is what will let us get beyond the power structures that operate at the local level.

Regulators, however, brought a different vision to Shale Network on the purposes of the shared database and the worth of its different datasets. During a 2014 roundtable discussion, Richard Brandt, a data management specialist in the PA DEP's Division of Oil and Gas Management, was asked why the DEP had been reluctant to engage with volunteer collected data collected through Shale Network. He responded:

> Let's go back to proper forensics. Imagine it's a crime scene. Someone steals my computer. So the police come in and they see Air Jordan sneaker prints on the floor. That suggests that someone came in that was wearing Air Jordan sneakers, but lots of people might be wearing Air Jordan sneakers. Then they find a fingerprint associated where the crime was. And that's kind of unique. I've always been struck, and please correct me, but I don't understand how a lot of the parameters that people are concerned about as diagnostics of shale gas fluids—barium, strontium, radium go right down the list—in very small concentrations, could possibly point to pollution from shale gas in the absence of chloride or bromides. Nobody here has told me how one could strip out the chloride and bromide and other halogens along a transport process and suggest flowback spilled at a facility. Without understanding that, the whole thing gets complicated.

Compared to Mark and Nancy's perspective, Richard's comments reflect regulator's insistence that data management must be resolved on the terms of scientific protocols and standards, and is protective over who has the right to define those terms. Industry representatives in the room echo Richard's position. They also go further to take issue with the notion that Shale Network's data should be used as evidence against polluters. A regulatory compliance manager from one company in the room remarked:

> The context of the Shale Network, as I understand it, is about acquiring and sharing data for research. As for data gathering by volunteers, those are decent screening tool. But what if you want to look at the overall issues and want to know its background so you can figure out the impact? If you can even figure out that there is an impact, then the next question is, what caused that impact? The question should not necessarily be "am I looking for a particular group that caused it." So let's put our scientific

> hats on here. Let's use the data in a forensic manner from a scientific standpoint.

The discourse of forensics and of wearing "scientific hats" exemplified in these comments reflects conventional views on maintaining objectivity in environmental science, views that many of Shale Network's academic researchers also share. As I noted in the development of monitoring protocols, insisting that watershed studies adhere to the technical practices of professional researchers can be the key to these protocols being taken seriously. The same can be said of data management systems.

Shale Network's mission and technical architecture adhered to the logics of political neutrality. Shale Network's ability to bring regulators and industry to the table hinged on their ability to convince these people that Shale Network had invested in a data culture that sets a high bar when determining the validity and application of its data. Member groups who come to Shale Network with different data cultures felt constrained by Shale Network's data culture. However, at the same time, they benefit from Shale Network's ability to create a dialogue. I argue that Shale Network's workshops became a space where people came together to expand data-consciousness and data-literacy. Shale Network built bridges between data cultures in ways that allowed for negotiating the terms of knowledge creation and the meaning of expertise.

A number of examples illustrate that bringing these data cultures together changed how stakeholders across the water monitoring community think about data. Shale Network has challenged the idea that government agencies know how to best manage their data. One of Shale Network's researchers explained how people from the USGS benefited from the project:

> You know, the data that the US Geological Survey has is really easy to pull off HydroDesktop, and they didn't even know about that. So some of the people at CUAHSI that work with us, we put them in contact, and they have been showing the USGS people how to pull up the data using HydroDesktop. So that is another impact that we have had, where we have actually—sometimes our teaching the government agency folks—here is a tool that can actually allow you to do things that you didn't know you could do.[52]

Shale Network also broke down notions of expertise by revealing some of the messiness of regulatory science. One of the project's data wranglers commented about her experiences working with the PA DEP:

> I think we are starting to understand a little bit about the kinds of data that they have down there. It is incredibly complex—because they haven't been organizing it across their different branches and things, you know what I mean? We started to get some DEP data from them, and then we will plot it up, and then I will end up calling them up and asking them things about it, and then they don't always have the answer. And I circle around and try to figure out what I think is going on. So you know, we are still very early in the process, but you know, I think we are discovering things about how these government agencies even work.

In other instances, interactions between service providers and Shale Network's system designers helped to reconsider how data management technologies might serve a broader community. In 2015 CUAHSI introduce a stripped down, web-based version of HydroDesktop. CUAHSI's developers noted that they did this in response to concerns that Shale Network and other research programs they supported were inaccessible to most users.

Shale Network's Leadership Team is also working with CUAHSI to incorporate datasets previously not considered pertinent to its overall mission as a platform for

[52] It is important to note in this context that Shale Network regularly populated HydroDesktop's database with updated USGS data. Shale Network's data wranglers noted that this dataset has not been updated for some time. The USGS changed its data processing protocols and the Shale Network team has not revisited how to reintegrate the dataset.

conducting watershed studies. Additional layers of "social" data such as poverty rates, population density, and other demographic information, will be added to HydroDesktop in coming months. Harvey Callahan, one of CUAHSI's developers for Shale Network, noted how this has changed the way CUAHSI sees its responsibilities to research communities beyond Shale Network:

> The development team has been working really hard to provide specific tools to the Shale Network to help them meet their needs. But, at the same time, this project has provided valuable feedback when looking at how to expand, and stretch, and develop the system to meet this broader set of uses. I think it's really important that this has been mutually beneficial. This has helped us reconceptualization the system, and how it's going to grow in the future.

In some ways Shale Network appears to be paying off for the volunteer community as well. Julie Vastine from ALLARM reflected on changes she has witnessed in saying:

> The cool thing about Shale Network, you have all these diverse data producers and users being receptive to volunteer data. And that doesn't happen—it hasn't happened. We can say that, very confidently, that the academic field has not been kind to the volunteer monitoring data—to the point that I have gosh darn professors in our own geology department that have slammed us for years for the work that we do. And it wasn't until we started working with Penn State's geoscientists and Shale Network that they were like, oh wow, that's cool. It's the standard hurdles with volunteer monitoring. We have seen it for four decades. Now people see the value in using the data. Those are things that are really exciting.

These are, without question, exciting advancements for the Marcellus Shale water monitoring community. If people are indeed rediscovering the value of nonprofessional collected data, then one can readily conclude Shale Network has increased the empowerment capacity of the volunteer monitoring community as a whole. Whether or not this kind of empowerment extends to individuals remains to be seen in how later revisions of HydroDesktop, and Shale Network's overall methods for managing data, adapt to the needs of nonprofessional monitoring groups.

In the meantime, one thing is clear about Shale Network's impact. All of the above testimonies point to the fact that Shale Network has transformed people's perceptions of data culture, and it is important to note that all of the above testimonies to Shale Network's successes are not attributable to the project's database per se, but stem from social bonds built during workshops and other opportunities for personal interactions.

6.4 Conclusion

George Marcus (1995b) offered that the scientific imaginary explores, "future possibilities through technoscientific innovations, but is equally constrained by the very present conditions of scientific work. The imaginary fills in the cognitive gap and tension that the widespread perceived inadequacy of working practices and concepts create" (p. 4). In the same way people imagine the possibilities of empowerment, this chapter reveals that they also imagine future rearrangements of data culture.

Shale Network's project designers faced numerous difficulties in meeting their objectives to create a central warehouse for water quality data. And yet, there persisted a mutual desire across the user community to continue investing in the vision of a someday-successful centralized database. Over the course of this five-year study, Shale Network's workshops opened a window to observe why this imaginary endures, and how it has shaped future possibilities for water monitoring science in the Marcellus Shale.

A key discovery that emerges in this chapter is that people invest in data management projects for a variety of reasons. Some believe these projects should be used as a tool for doing scientific research, as in the case of Shale Network's Leadership Team. Others see data management projects as a way to engage and questioning the practices of experts and regulators, or even use these systems for environmental advocacy. PEC's board of directors dropped the PA Watershed Data System because they came to realize that "without an emphasis on advocacy" monitoring programs would have "little power to address problems in water quality once identified." This argument persisted in the promise that gathering water quality data can push back against regulators who insist their management of the shale gas industry is effective. Monitoring groups carried these ideas with them into data management projects like Shale Network.

Shale Network's story illustrates additional ways that data culture can about care, diligence, discipline, and consistency when doing science, not doing the "easier" thing. Shale Network's researchers are carful about making claims with their data. They maintain a level of caution expected of professional scientists who have been trained to not rush to judgment without solid evidence. There are lessons in this level of care for monitoring groups who wish to use data for advocacy. Data will be far more powerful when used in these circumstances if it has been properly vetted and passed through quality control procedures.

In fact, Shale Network's researches are not averse to making claims of pollution when they believe evidence suggests as much in their data. Sue Brantley and her colleagues published a paper in the Proceedings of the National Academy of Sciences in May 2014 detailing how drinking water supplies at three homes in Bradford County, Pennsylvania revealed trace elements associated with drilling for shale gas (Llewellyn et al., 2015). The study was conducted by researchers on Shale Network's Leadership Team, not derived from Shale Network itself, but "This is the first documented and published demonstration of toxic compounds escaping from uncased boreholes in shale gas wells and moving long distances into drinking water," Susan Brantley told the Associated Press (St. Fleur, 2015).

However, I also found key acts of resistance against the protocols, technologies, and data management practices controlled by a data culture defined by scientific experts. Some of the battlegrounds for data culture are found where volunteers resist demands that they share their data, when volunteers refuse to use interfaces that do not accommodate their level of expertise, and when volunteers show up at workshops to debate the meaning of their data with regulators and industry.

These acts of resistance have an impact in that they make service providers and system developers rethink the purposes of their projects. The PA Watershed Data System was a critical project for defining the needs of water monitoring community. Shale Network was a worthy attempt to address these needs in a technical platform but, in the end, had far more success as a space for bridging data cultures. It is hopeful that a next generation database will embody these learned experiences to accommodate a range of data cultures socially and technologically.

2013 may not have turned out to be "the year of the database" that delivered on these promises, but Shale Network does present solid evidence that people who advocate for different orientations of knowledge creation and application can impact the data cultures that steer the direction of water quality science in the Marcellus Shale.

2015 marks the end of Shale Network's grant cycle and no further source of funding has been identified. Users will still be able to access data via CUAHSI's HydroDesktop. However, without its fleet of data wrangling graduate students, additional data will likely never enter the Shale Network system. The more troubling casualty will be the end of its annual workshops, which have served as a venue for the monitoring community to make sense of what water quality data means in the context of present and future impacts of shale gas extraction.

7. CONCLUSION

The nature of public participation in environmental science has changed rapidly in the Marcellus Shale water monitoring community. Over the course of this study I witnessed the field mature through distinct phases. The first emerged in 2009, following a series of high profile pollution incidents. Service providers worked with regulators and watershed specialists to develop monitoring protocols for a movement of concerned citizens motivated to collect water quality data. 2012 marked as second phase with a new emphasis on data aggregating and analysis, leading to the development of data management systems to help make sense of this data. A new phase began in 2014, when the field began reflecting upon its accomplishments and failures, wondering what it all means for the future of watershed science, and whether or not public participation in water monitoring has helped communities living with the daily challenges of shale gas extraction.

Studies show that members of the public participate in environmental monitoring for a variety of reasons. In some instances residents may take up data collection equipment when they believe regulatory institutions are negligent in their responsibilities to protect public safety or the environment (Overdevest & Mayer, 2008). In some situations groups view environmental monitoring as a way to vocalize their opposition to what they feel are unacceptable industrial practices (Ottinger, 2009). In other examples, citizens generate their own knowledge to contest the claims of experts (Epstein, 1996; F. Fischer, 2009; Irwin, 2002). This research often concludes that, thorough participation in environmental monitoring, the public can alter the balance of power between polluting industries, at-risk communities, and institutions of authority (citations).

In this study, I examined the assertion that collecting water quality data will directly lead to public empowerment. I began by asking a number of important questions. First, what are the discursive contexts in which data cultures influence monitoring practices? Second, how do different stakeholders imagine the affordances of data cultures for the future of watershed protection? Third, how does each of the four components of citizen science water monitoring infrastructures fortify the logics of different data cultures? And fourth, how can data cultures that shape these infrastructures be constructed in a way so that it empowers, rather than disempowers, communities investing resources in water monitoring?

To answer these questions I looked closely at four aspects of civic science water monitoring: the influence of standardized monitoring protocols, the politics of data collection technologies, the frictions of database management systems, and the power dynamics of organizational partnerships that come together around water monitoring efforts. I found that proponents of environmental monitoring value highly mechanisms of public participation when building water monitoring infrastructures, but these mechanisms became limited by a need to produce objective data. Lay participants were not typically valued for their situated knowledge or local expertise. These data-centric approaches threatened to disempower at-risk communities in ways practitioners might not have expected.

My analysis of this situation was informed by work from a variety of scholarly disciplines. I began with recent STS studies that point to the likelihood that monitoring movements are unlikely to shift scientific thinking, or regulatory oversight, simply by acquiring technologies and amassing standardized data on the health of their communities

(Ottinger & Zurer, 2011). I looked closer at this realization by drawing on STS research investigating the affordances of data collection technologies and participation structures used in nonprofessional monitoring (Bonney et al., 2009; Ottinger, 2010b; Shirk et al., 2012; Wylie, Jalbert, Dosemagen, & Ratto, 2014). Literature from the information sciences informed the project by probing the costs and benefits of data management systems that pull together stakeholders with different kinds of data and expertise (Bowker et al., 2010; Boyd & Crawford, 2011; Edwards et al., 2013, 2011). Finally, research in critical geography helped me to assess dimensions of empowerment in participatory data collection projects (Corbett & Keller, 2005a, 2005b).

Each of these disciplines deals with different aspects of data handling practices and impact on people willing to engage in science. However, none of these fields of research are able to fully explain how civic science movements might build better data cultures to empower communities facing environmental risks. My aim in this study was to address this research gap. If amplifications of data offer only limited success for concerned citizens who partake in environmental monitoring movements, then it is critical to understand how these notions are established and put into practice. In doing so, I argue that it is possible to formulate civic science research in ways that do offer greater capacity for empowerment and more tangible outcomes of that increased empowerment.

7.1 Rethinking Data Culture

I have argued in this dissertation that a desire on the part of nongovernmental groups to gain the respect of regulatory agencies is one of the primary drivers of a data culture that reinforces traditional structures of power. The roots and effects of this data culture are seen in three main contexts: in the construction of standards when building water monitoring programs, where the technologies and politics of monitoring are deployed in the field, and in the spaces where data comes together in shared data management projects.

In scientific research communities, standards give people the tools to scrutinize complex problems, to narrow a seemingly endless range of possible inquiries into ones that produce meaningful answers. Bowker and Star (1999) noted that standards are useful devices in bringing diverse communities of practice together by finding common ground on the meanings of knowledge. Determining appropriate standards for scientific research is therefore critical for environmental groups hoping to make sense of hydraulic fracturing.

However, standards are the mechanisms of categorization and can render many forms of knowledge invisible. This is particularly true of knowledge that lies outside the parameters of what institutions with scientific authority consider necessary for doing rigorous, objective research. Such is the case with how knowledge became standardized and categorized with the birth of an early data culture in the Marcellus Shale water monitoring community. With the arrival of unconventional gas extraction in the Marcellus Shale, many environmental protection groups—governmental and nongovernmental—sought ways to assess its potential impacts on surface water quality. However, no clear standards existed for which water monitoring indicators or technologies were most appropriate for the task. Standards would eventually be set by the daily choices and practices of regulatory agencies as they built their monitoring programs over time.

The PA DEP's Water Quality Network, established to enforce the Clean Water Act, existed prior to the arrival of shale gas extraction and in many ways became the default touchstone for future monitoring programs. Any organizations in the region planning to engage in debates about water quality were obligated to recognize the authority of the PA DEP's practices, even if the standards set for shale gas monitoring in WQN were developed without clear mandates. This was evident in how the first major non-regulatory water monitoring program dedicated to tracking pollution events shale gas extraction, the SRBC's Remote Water Quality Monitoring Network, came into existence.

The standards set by PA DEP, and propagated by projects like SRBC's highly respected RWQMN, were emulated by civic science monitoring programs seeking to gain a seat at the table of environmental governance. Protocols built by service providers such as ALLARM tightly aligned with these standards out of necessity. These protocols would significantly shape the nature of scientific research infrastructures populated by concerned citizens who were willing to take up the tools of water monitoring.

A poignant example of this was seen in how ALLARM reconfigured its study design around a "pollution response" model. Whereas in the past ALLARM worked closely with communities to think through what a group's objectives were in monitoring, what methods they would use, and how they might use their data, ALLARM's Marcellus Shale Volunteer Monitoring Manual pre-set many of these variables. Rather than determining the nature of their program in a fully participatory process, volunteers would produce data predicated on the expectations of watershed experts who consulted with

ALLARM when building the protocol. However, ALLARM justified this limited the scope of monitoring on the grounds that standardized data had a better chance of being used by the PA DEP and other regulatory agencies. The ability to act on their findings likely depended on how closely they followed carefully designed protocols. Second, promoting a standardized protocol meant that, one day, this data might be pooled together to assess region-wide water quality changes. This would be a radical departure from a past marked by dozens of monitoring efforts working in relative isolation.

ALLARM's reconstructed study design illustrates how powerful standards were in shaping a particular data culture that would dominate the early developmental stages of the Marcellus Shale water monitoring community. This data culture was constructed on a platform that fortified the authority of watershed experts in the region, and narrowed the range of possible questions people might ask in evaluating the state of their environment through water monitoring.

That being said, investments in this particular data culture also helped the monitoring community respond to a complex scientific problem. Standardized protocols gave people new capacities to formulate powerful scientific arguments. They furthermore made possible the conditions for collecting data in ways that accommodated later projects that would arise to serve the monitoring community such as shared databases and watershed-wide studies. In these ways, this data culture made the nonprofessional community aware of critical analysis tools such as data consciousness, data literacy, and data wisdom.

In this dissertation I have also shown how data cultures shape ideas about how the protocols and technologies of monitoring should be applied to influence environmental governance. Choices to use one technology over another are heavily influenced by notions of what constitutes worthwhile science and acceptable uses of data. Data collection technologies, I argue, are the agents of standards. The story of deploying data loggers illustrates this point. Following the high-profile fish kill at Dunkard Creek, professional watershed organizations went looking for a tool that could detect rapidly changing watershed conditions and produce indisputable data. Automated monitoring technologies filled this need to an extent.

I found that data loggers did indeed create boundary-bridging opportunities for organizations to work with regulators in certain kinds of watershed management projects. One example is the Kiski-Conemaugh Stream Team's ability to feed data into the PA DEP's permit review process for the Hutchinson Hollow coal treatment facility. A second example came from partnerships established through the Allegheny WINS coalition, where a collaborative effort between PATU, PA DEP, and PA DCNR successfully stopped illegal dumping at Cafferty Run using data loggers.

Data loggers succeeded in these cases because organizations used the devices in ways the PA DEP and PA DCNR anticipated. Data loggers had become an integral part of regulatory monitoring programs. Nongovernmental monitoring groups that adopted similar technologies paid close attention to how they were being used in these programs. A second factor in the success of these examples may be due to the fact that relationships with regulators predated the arrival of data loggers. This suggests that data may have been deemed credible at least partly on the basis of how watershed protection organizations had developed credibility through the "tools" of social networking and making political alliances.

However, in other instances I discovered that watershed specialists had grown frustrated with the inconclusiveness of data loggers, particularly when trying to assess the impacts of shale gas extraction. Part of this was due to the limitations of a technology that required significant investments of time and resources for equipment maintenance and managing large pools of data. These limitations also meant that suspected pollution events from shale gas extraction came and went without notice.

Many in the field had faith in the idea that automated monitoring technologies were good for science. Data loggers did things that volunteers could not. They generated large volumes of data about a stream in ways that appeal to watershed scientists. Proponents of data loggers felt that removing the human element from the tasks of monitoring would provide more precise data. These viewpoints are manifestations of a data culture that amplifies conservative definitions of expertise, ones that prioritize knowledge emerging from organizations that traditionally enjoy authority in scientific debates. For nonprofessional monitoring groups, the limitations put constraints on how they could participate in programs that relied heavily on data loggers.

I analyzed the effects of a data culture dominated by scientific experts in a third setting, the databases and participatory GIS projects developed to serve the Marcellus Shale water monitoring community. As researchers in critical geography note, PGIS projects can create pathways for nonprofessionals to interact with professionals on around the topic of data (Baumann, 2010; Elwood, 2006a, 2007, 2008; Yang et al., 2010). PGIS projects assist nonprofessional groups in managing their data when they may otherwise not have the resources to do so on their own (Flanagin & Metzger, 2008; Sieber, 2000). Often, groups that participate in these projects hope that experts will help them see through the complexity of their data. Meanwhile, scientists promote the idea of shared databases in order to gain access to data for conducting research studies across broader geographies and timelines.

The shale gas water monitoring community expanded rapidly in its early years. In many instances its data remained stagnant, living only in the notebooks and computers of local watershed groups. Service providers, volunteers, and academic researchers alike became concerned about problems of data management. They looked to databases and GIS projects to solve these problems. The water monitoring community's philosophy about the affordances of databases were set a decade prior to the arrival of shale gas. As far back as the PA Watershed Data System, proponents believed that a centralized database would make data more powerful, more credible, and thus be more likely to have influence in debates about environmental governance not only on scientific terms. But these people also believed that databases should play a role in the bringing data into the political realm.

These ideas persisted a decade later when a new generation of projects emerged to manage shale gas related monitoring data, the most prominent projects being Penn State's Shale Network and 3RQ's QUEST Data Management Tool. New systems under development attracted the attention of service providers and monitoring groups for a variety of reasons. Partnering with Penn State and West Virginia University opened doors to financial and technical resources often only available to large research institutions. As a self-described "honest broker" of data, Shale Network might be capable of building bridges with regulatory agencies with which Penn State had developed rapport.

Meanwhile, the 3RQ was based in the federally recognized West Virginia Water Research Institute.

Like water monitoring protocols and technologies, the values that shaped Shale Network's implementation were deeply contoured by the undercurrents of a particular data culture. When project leaders appointed CUAHSI to develop the system, this decision also invested in a data culture rooted in traditional notions of expertise and scientific authority. CUAHSI was in the business of building tools for hydrogeologists. As such, HydroDesktop is the embodiment of how data is curated, analyzed, and communicated by professionalized researchers. 3RQ's QUEST Data Management Tool may have been developed in-house, but its design expressed many of the same principles.

Shale Network and 3RQ faced many challenges in bringing their vision of a data management to the Marcellus Shale water monitoring community. As was seen in the case of Shale Network, volunteers in the field were not prepared to generate data that fit complex metadata frameworks. In contrast, data from regulatory agencies and scientific researchers did fit these models and ultimately came to represent the bulk of Shale Network's data. 3RQ's research team had fewer struggles obtaining data from monitoring groups, but in many instances data was shared out of obligation.

Shale Network and 3RQ faced additional challenges when monitoring groups became skeptical of contributing their data into systems they found too difficult to use. Shale Network's HydroDesktop is freely available to the public, but the complexity of the software required a high degree of expertise not typically found in many monitoring groups (Figure 40). The QUEST Data Management Tool's initial "tier" structure also isolated many groups that felt the system reflected 3RQ's priorities in serving the needs of the project's research partners.

Figure 40. Nonprofessionals struggled with HydroDesktop during training sessions[53]

Shale Network and 3RQ's data management systems thus served the scientific research community well, but failed to live up to the expectations of those who hoped the projects would serve the needs of a broad base of practitioners. The tenets of the data culture that prompted their development drew boundaries around what was considered acceptable data, and hardened those assumptions when data exited the systems for use in

[53] Photograph by Anne Danahy, Penn State staff. Used by permission under creative commons license by-nc-nd 2.0. Retrieved July 27, 2015 from http://news.psu.edu/photo/316327/2014/05/16/shale-network-poster-show.

scientific research and regulatory contexts. I found this was particularly true when the technologies of data collection and management were propagated and enforced through partnerships structures that built expansive infrastructures for water monitoring research.

7.1.1 Inclusive Development Towards Data Culture(s)

Standardized protocols, monitoring technologies, and data management systems are the components of water monitoring infrastructure that reveal frictions that occur when, as Edwards et al. (2011) note, "data move between people, substrates, organizations, or machines" (p. 669). This study demonstrates how frictions that occurred in alliances formed by water monitoring community—between those who have the power to define the parameters of knowledge work and those who do not—were weighed in favor of dominant ideas about scientific knowledge and expertise. However, I also found seeds of resistance to this dominant data culture.

Those who invested in water monitoring as a means to sway scientific discourse and environmental decision-making have faced many challenges to finding recognition. These disillusionments mirror Ottinger's (2009) observations of Bucket Brigades who were unable to change how air pollution was assessed because, "regulatory standards for air quality, combined with standardized practices for monitoring, provided regulators with a ready-made way to dismiss activists' data as irrelevant to air quality assessment" (p. 246).

Fortun and Fortun (2005) argue that one of the distinct features of civic science is how it forms investigative relationships that "questions the state of things, rather than a science that simply serves the state" (p. 50). A key debate that emerges in this dissertation is whether or not water monitoring should serve the state, or if it should function as a way to challenge ideas about how the gas industry is regulated.

The water monitoring community was built on the idea that arguing their positions on terms set by watershed experts was the surest path to convincing regulators that their data was worthwhile. In many ways the processes and technologies that emerged from this line of thinking have not lived up to these expectations. As a result, some groups are rethinking their relationships to a data culture that systemically limits public participation and narrows what kinds of knowledge can inform official assessments of water quality. In doing so, they are revealing that there is not one, but many data cultures that exist in the water monitoring community.

Resistance to normative data culture is seen in the work of the Izaak Walton League Harry Enstrom Chapter. After numerous failed attempts at getting their own water monitoring data recognized, chapter members turned to a spectrum of other strategies. One method was to use the PA DEP’s own data to contest official claims that AMD waste did not contain evidence of shale gas wastewater. They also enlisted the WVWRI to corroborate their findings. These strategies had limited success and, ultimately, the chapter sought out other means of influence. Rather than making their case purely on scientific grounds, chapter members took their data into the political realm. They used their data as a tool for advocacy to change public opinions on the efficacy of regulatory oversight.

In other instances, monitoring groups reshaped ideas about data culture through their interactions with academic researchers an regulators in social settings. As was shown in the case of Shale Network, workshops afforded opportunities for nonprofessionals to challenge dominant thinking about who had the ability and right to make claims with water monitoring data. Other acts of resistance were evident when volunteers objected to sharing data on the grounds that data should be used to solve local environmental problems, not necessarily serve the needs of researchers in far off institutions. For 3RQ, resistance to a singular data culture was visible in moments when mini-grantees expressed discontent with systems that diminished the value of their data and failed to acknowledge political uses of data when deal with watershed issues in their communities. Mini-grantees pushed back against 3RQ's research team by demanding more from the network in exchange for their participation.

These acts of resistance have had an impact on how service providers, system developers, and even regulators responded to the needs of nonprofessional monitoring groups. In recognizing the limitations of their system, Shale Network's leadership team worked with CUAHSI to develop a lighter version of HydroDesktop so volunteers could work with their own data, rather than having to be dependent on watershed researchers. 3RQ's REACH initiative may resolve some of the issues of imbalanced applications of resources in the their network. 3RQ's soon to be hired outreach coordinators may work as a bridge between academic researchers, regulators, and nonprofessionals to help community groups make sense of and mobilize their data. In the case of the IWLA Harry Enstrom Chapter, the PA DEP did eventually return to Greene County for additional testing in part because of WVRI's assistance when gathering data. This might be a model for how REACH works with other groups in the 3RQ network.

These examples present solid evidence that the water monitoring community can be transformed to accommodate other data cultures, ones that represent the broader range of scientific and political objectives. I argue that these findings challenge ideas in STS, particularly in the knowledge infrastructures literature, that suggest that standards and technologies that establish infrastructures are non-negotiable. The logical question that follows this argument is, do deviations from normative data culture also empower at-risk communities?

7.2 The Empowerments of Environmental Monitoring

Two important conceptual models inform this dissertation's analysis of promising data for public empowerment. The first is Shirk et al.'s (2012) spectrum for evaluating the quality of public participation in scientific research. The second is Corbett and Keller's (2005a, 2005b) framework for examining empowerment. These two models complement each other in interesting ways, but both have remained relatively untested in studies of civic science.

Shirk et al.'s (2012) spectrum is an effective tool for evaluating the costs and benefits of different participation models at various stages of designing a research program. In their spectrum, co-created projects have nonprofessionals involved in all stages of development: setting research questions, selecting technologies, gathering data, analyzing data, and disseminating findings. On the other end of the spectrum, professional researchers can run contributory oriented projects, where volunteers are encouraged to collect data for researcher studies, but have less say in deciding the parameters at other stages. The authors note that their model is a gauge to be tested in future studies. Shirk et al. (2012) also suggest that future studies must go beyond prior appraisals of public participation that "conflate power as a degree of participation—how much or how little a given individual/group 'may' have—with evaluative statements about how much power a group "should" have" (p. 3). This statement implies that future assessments of participation must include ethical considerations of appropriate technologies, what it means to build relationships of trust, and how to define individual agency.

This dissertation makes a contribution by testing Shirk et al.'s spectrum of participation through an empirically grounded study of the Marcellus Shale water monitoring community. [54] The Marcellus Shale water monitoring community emerged in order to deal with scientific problems that have deep implications for personal and environmental health. In studying this community I argue that evaluations of how much power groups "should" have in these research programs requires looking closely at how such programs empower or disempower people hoping to overcome significant threats to their way of life.

Corbett and Keller (2005a, 2005b) outlined a framework for evaluating empowerment nearly a decade ago, at a time of growing interest in using participatory GIS efforts for collaborative scientific research. This framework identified four "catalysts" where changes in empowerment and empowerment capacity occur. The authors found that these changes can be due to having access to new information,

[54] I also think it is important to note that Shirk et al.'s (2012)spectrum misses a kind of science often not recognized by the professional research community. Sometimes nonprofessionals prefer to develop research programs without the help of outside experts. Interestingly, I found very few occurrences of what is often called "guerilla" science in the Marcellus Shale water monitoring community. This itself speaks to the power of authoritative data cultures in defining responses to shale gas extraction. While I did not have the opportunity to explore these ideas in the dissertation, I have dealt with partnership structures that shun expert assistance in prior research dealing with the phenomenon of "civic technoscience" (Ratto, Wylie, & Jalbert, 2014; Wylie et al., 2014).

process, skills, or technologies. While important to the field of critical geography, Corbett and Keller's framework for evaluating empowerment has not found traction in other disciplines. I argue that a second contribution of this dissertation is in bringing this framework into the world of citizen science that I contend has yet to look critically at often-made claims of empowerment.

I find that participation models adopted by water monitoring efforts are rarely mutually beneficial for all involved stakeholders. Research programs can reproduce and redistribute power, authority, and expertise in ways that often advance the agendas of some monitoring groups over others. My findings further suggest that dynamics of power in participatory research projects have deep implications for how individuals and communities access tools to alter the conditions of systemic injustices. In this way, participation structures are intertwined with matters of empowerment.

7.2.1 Partnership Structures and Empowerment

Claims of empowerment are ubiquitous in the Marcellus Shale water monitoring community. ALLARM's shale gas training manual states that one of the program's goals is to "enhance local action for the protection and restoration of Pennsylvania watersheds by empowering communities with scientific knowledge and tools to implement watershed assessments" (Alliance for Aquatic Resource Monitoring, 2012a). As was noted above, ALLARM also asserts that collecting water quality data "will give the monitors a powerful presence that gas companies will have to respect" (Alliance for Aquatic Resource Monitoring, 2010). Similar claims are heard from leaders of Shale Network and

3RQ (Figure 41). Hence, local action, empowerment, and gaining respect are all tied to the rationalities of why concerned citizens should participate in environmental science.

Evidence suggests that concerned citizens can become empowered through water monitoring activities. Volunteers learn about shale gas extraction practices and the complexities of watershed science and the critical tools of data culture. They also acquire skills to understand regulatory frameworks that dictate environmental protection. Volunteers are encouraged to take leadership roles within their monitoring networks that can sometimes lead to taking a more prominent and vocal position in their community. In this respect, water monitoring meets many of the prerequisites for increasing individual empowerment capacity due to the acquisition of new skills and tools to acquire information.

Nevertheless, this potential for empowerment can be dependent on the participatory models of water monitoring research infrastructures. A prime example of this is seen in the work of the NY Water Sentinels. The NY Water Sentinels did deploy ALLARM's protocol, which pre-set some aspects of their monitoring program, but network's governing structure was set up in a way to give volunteers a high degree of agency. This extended to the ways in which resources were applied on the ground and to how volunteers could influence the overall mission of the network. This became evident when a number of volunteers began monitoring around landfills and wastewater treatment plants. The NY Water Sentinels' research process thus afforded a high degree of agency for participants when asking new questions about the impacts of shale gas extraction. This shows evidence of increasing individual empowerment.

The agencies of volunteers may change in the NY Water Sentinels as they grow closer to the Sierra Club. Many members of the network came on board with the belief that they would be in control of their monitoring programs, particularly in cases where more established environmental advocacy organizations chose to align their work with the NY Water Sentinels to do monitoring. Evidence suggests that the NY Water Sentinels are finding ways to tailor their relationships with the Sierra Club to protect this philosophy. However, for groups that "wear the NIMBY badge with honor," and do not share the environmental philosophies of the Sierra Club, these change may be disempowering in more subtle ways. Corbett & Keller (2005b) note that empowerment can also depend on factors such as retaining an organization's cultural identity and a demonstrated independence from external collaborators. I argue that commitments to NIMBYism are real based on these assessments of empowerment.

Similar connections between participation and empowerment are found in the 3RQ's monitoring network. Watershed researchers throughout the three-rivers region recognized that reducing water pollution risks from shale gas extraction required a coordinated monitoring effort. Unlike the NY Water Sentinels, 3RQ came together as a hierarchy, characteristic of Shirk et al.'s (2012) contributory participation model, where the four research partners controlled most aspects of the project's study design.

3RQ's partnership structure dictated the terms of participation for mini-grantees. It also affected empowerment in interesting ways. 3RQ did not necessarily produce disempowerment by preventing groups from monitoring or acting on their findings. More so, 3RQ instilled a feeling of disillusionment amongst members who invested time and resources in a project that promised to be collaborative, but ultimately serviced the needs of academic researchers. A primary contributor to growing pessimisms came from the sense that project leaders were unlikely to help them use water monitoring data when advocating to change structures of systemic environmental injustice. I argue that 3RQ's partnership structure reduced the capacity for empowerment within these groups. However, 3RQ's effective engagements with regulators also show evidence that the project is translating the network's science into tangible increased in empowerment for the region. This is evident in how the TDS Working Group has changing some watersheds management practices.

Figure 41. 3RQ 3RQ's Convergence at the Confluence conference gift bags (the caption reads "Citizens and scientists making a difference in the Upper Ohio Basin")[55]

[55] Photograph captured from a WVWRI press release and included under fair use. Retrieved July 27, 2015, from http://3riversquest.org/convergence-at-the-confluence/.

The NY Water Sentinels and 3RQ case studies reveal dimension of empowerment not explored in prior research. Corbett and Keller (2005a) offered a framework to assess empowerment at two scales—at the level of the individual and at the level of community. My findings suggest that changes in empowerment actually occur at three distinct levels: at the scale of the individual, the monitoring group, and the research community. This third level of empowerment comes into play because knowledge infrastructures built by the water monitoring community come together as diverse partnerships of individuals, organizations, and institutions spread across large geographies.

I also found that there are tradeoffs that occur across these three scales of potential empowerment. In the case of the NY Water Sentinels, individuals who took up the cause of landfill monitoring were empowered by democratic governing structure, but one might argue that other groups in the network suffered as a result of resulting frictions. Similarly, the network's closer relationships with the Sierra Club has opened doors to new funding opportunities, but this new arrangement may affect how the NY Water Sentinels' larger research community applies its resources to deal with environmental issues. Future research should revisit the network's evolution.

3RQ's recent announcement to do community outreach through its REACH initiative also illustrates the tradeoffs of empowerment. I argue that REACH is a direct response to members of the network demanding greater agency in doing more than just collecting data for its research partners. It is likely that mini-grantees will become empowered by working with 3RQ's new community outreach coordinators in some way. This empowerment may take shape as increased capacity at the group level to influence the nature of 3RQ's research. It may extend further to empower communities in which these groups operate to deal with environmental threats by steering resources from the network to address local issues. At the same time, increased empowerment at these levels would mean that academic researchers would have to give up some of their own power in order to accommodate more inclusive participatory models.

7.2.2 Technologies and Empowerment

In this dissertation I argue that the partnership structures and participatory models factor into how individuals and communities experience empowerment in citizen science. I also contend that empowerment is intertwined with technologies deployed in the field of water monitoring community. Choices concerning data collection, data management, and data analysis technologies impact how people in water monitoring programs influence scientific discourse and environmental governance. For instance, data loggers are potentially empowering devices for scientists in need of highly detailed data. In the case of data management systems, researchers who work with Shale Network and the QUEST Data Management Tool have used the wealth of data accumulated in these systems to do complex watershed studies. However, as David Bond (2013) noted, such technologies can narrow how pollution is assessed. They also constrain the range of political options that become available when working to change underlying conditions that lead to environmental risk.

Figure 42. A chapter of Trout Unlimited installing their own data loggers in lieu of launching a volunteer monitoring program

I found that data loggers pose many logistical challenges for concerned citizens who want to play a greater role in water monitoring studies. Data loggers are high-priced, complicated, devices that require extensive resources and expertise if they are to be use properly. Established environmental organizations with the ability to maintain data logger networks increase their capacity for empowered when using these devices. For nonprofessional groups, however, the tradeoffs that occur around data loggers are significant. Professional watershed groups take relatively neutral positions on the threats posed by shale gas extraction. The shale gas industry is something to be managed through water monitoring, and not necessary combatted. In this view, data loggers are the key to generating data that regulators will take seriously. However, for groups who work with these institutions, data loggers can limit their capacity for empowerment. Data may be used for making scientific arguments, but less so as a means of political resistance.

Data loggers have secondary implications for empowerment when they replace the work of volunteers. Taking people out of the streams also means disconnecting pathways for individual empowerment gained in learning how to monitor. This point is driven home by the comment that "data loggers don't vote," meaning that volunteer monitoring efforts also educate the public on what it means to have shale gas extraction in their communities, and create the conditions necessary for mobilizing citizens to use that knowledge to increase their capacity for long-term empowerment.

Data management systems have their own empowering and disempowering qualities. HydroDesktop and 3RQ's QUEST Data Management Tool systematically excluded all but the few users who had the skills to operate technologies designed for watershed scientists. This had the effect of replicating the disempowering relationships to knowledge that make people data-rich but information-poor.

The demise of the PA Watershed Data System brought to light important non-technical requirements when building a data management system to support civic science initiatives. The system must also resolve the problem that the water monitoring groups "suck at" holding onto their data, using their data, and telling their stories. A database with long-term purchase must therefore function as a repository and a mouthpiece for water monitoring groups. I argue that the social network established by Shale Network is a striking example of how this might occur.

A line of argument threaded throughout this dissertation is that empowerment can also be evaluated based on whether or not people feel inspired to imagine alterative arrangements of power in scientific research. As George Marcus (1995b) noted, the imaginary "fills in the cognitive gap" when the present conditions of scientific work prevent future possibilities. Shale Network's workshops turned out to be far more empowering than its data management tool. Annual workshops provided opportunities for nonprofessionals to engage scientists, regulators, and industry to discuss the terms of meaningful data.

These gatherings created a platform where stakeholders from many backgrounds discussed what the water monitoring community should strive for in shaping the future of water quality science in the region. Shale Network's workshops thus increased the capacity of nonprofessionals, not only by giving them a seat at the table, by opening the door to introduce different the scientific imaginaries of those who work with data in different ways. Although I argue that more work must be done in the Shale Network to translate gains made its workshops over to its technical architecture. [56]

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[56] A line of argument I was unable to explore in this study is that the water monitoring community not only develops scientific imaginaries around how data can be used to change regulatory oversight, it also constructs alternate visions of what kind of knowledge should inform governing systems in general. In this way, I argue that the civic science water monitoring community has formed a unique counter-public to how environmental data has historically been handled. This "data public" utilizes environmental information to forward open government agendas. The concept of publics has become a useful scaffold for those who study communities of practice in STS. Chris Kelty (2008) uses the term "recursive publics" to grasp the complexities of how open-source software programmers work to police the technical, cultural, and legal boundaries of their community in order to maintain an identity apart from commercial enterprises. Carl DiSalvo (2009) writes about the publics of participatory design when people come together to imagine alternative technologies. For environmental health issues, a public may look similar to the American breast cancer movement, where Phil Brown and others observed that activists from

7.3 Imagining the Future of Civic Environmental Science

I conclude this dissertation by considering one of the major turning points in the history of the US environmentalism movement—the story of Love Canal. The Hooker Chemical Company dumped more than 20,000 tons of toxic chemicals into an abandoned canal in Niagara Falls, New York, buried it, and sold the land to the city for development. Decades later, when women experienced disproportionate numbers of miscarriages and children were born with physical and mental defects, working-class mothers in the neighborhood rose up, brought national attention to their story, and forced the federal government to relocate their families (Center for Health Environment and Justice, 2013). One of the greatest aftereffects of Love Canal tragedy was the creation of the 1980 Comprehensive Environmental Response, Compensation, and Liability Act, also known as Superfund. A second significant outcome was the passing of the Emergency Planning and Community Right- to-Know Act (EPCRA), which required the EPA to track industrial chemical releases in a database. EPCRA made way for designing the publicly

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many backgrounds rallied around their shared experience as cancer sufferers in an "embodied" health movement (Brown et al., 2004; Morello-Frosch et al., 2006). Each of these examples illustrate how publics unite people not necessarily according to geographic proximity, political affiliations, or socioeconomic status, but in how they experience their common identity as a group in forwarding agendas. Evelyn Ruppert (n.d.), a sociologist working on topics in open government, suggests that "data publics" are provoked by the lack of transparency in how state institutions share information used in decision-making processes. She argues that the recent push for open government in the past decade requires new arrangements of public participation, where concerned citizens not only obtain data, but also work to analyze and reuse this acquired data to deal with issues that concern them (Halford & Savage, 2010; Ruppert & Savage, 2011). Data publics are, furthermore, evolving entities as newly revealed information spawns fresh inquiries and allegations. Ruppert observes that process of opening up government is therefore always evolving rather than being a singularly defined event.

available Toxics Release Inventory (TRI) database, which became an important resource for evaluating pollution loads in at-risk communities.[57]

Love Canal also gave rise to the modern environmental justice movement. According to the EPA, environmental justice means that “no group of people, including a racial, ethnic, or socioeconomic group, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies” (US Environmental Protection Agency, 2015b). The EPA began addressing the problems of enironmental justice in 1999 by assigning “EJ zones” to census tracts where more than 20 percent of the population living below the poverty line, and/or in communities where more than 30 percent were minorities.

These designations require federal and state agencies to “consider, in addition to enhanced public participation, other options to address EJ concerns in the initiation, processing, and resolution of an enforcement matter” in these communities (US Environmental Protection Agency, 2015a). Some of the mechanisms outlined in the EPA’s policies necessitate holding public meetings to provide opportunities for residents to question government officials, publishing documents to share information with the community, and offering workshops “to build a community's capacity to better understand the technical and complex issues surrounding their concerns, the roles of the

[57] Additional information on the Comprehensive Environmental Response, Compensation, and Liability Act is available at http://www.epa.gov/superfund/policy/cercla.htm (Last accessed July 27, 2015). Additional information on the Emergency Planning and Community Right- to-Know Act and the Toxics Release Inventory is available at http://www2.epa.gov/epcra/what-epcra (Last accessed July 27, 2015).

various government agencies, and the policies that may impact those issues" (US Environmental Protection Agency, 2015a).[58]

More than two-thirds of Greene County's population lives in an EPA designated EJ zone (PA Department of Environmental Protection, 2015b). Census tracks down river from the Hakes Landfill in Painted Post, New York are EJ zoned, as are the communities around the Chemung Landfill in Lowman, New York. An Allied Waste Systems facility in Niagara Falls, located only three miles from Love Canal, also lies in an EPA designated EJ zone (NYS Department of Environmental Conservation, 2015).

These statistics raise some important question. The Marcellus Shale water monitoring community's achievements are remarkable given the scope of the shale gas industry's reach and the complexity of mitigating environmental impacts. Monitoring groups continue to enlist new volunteers, acquire resources, build alliances with powerful institutions, and revise their monitoring strategies to adapt to rapidly changing conditions in scientific and politic arenas. So then, why do residents in communities that experience disproportionate impacts from shale gas extraction continue to feel so disempowered by how state and federal agencies manage the gas industry? Why are so few of the EPA's EJ enforcement mechanisms utilized in these areas? Furthermore, why has it fallen on organizations like the IWLA Harry Enstrom Chapter, the NY Water Sentinels, and other grassroots organizations to push for levels of public participation required in EJ zones?

Many battles fought in the decades since Love Canal have struggled against the problems of environmental racism. In low-income, majority white, communities these fights are often referred to antitoxics movements (Schlosberg, 2007). It is my belief that

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[58] Additional information on the EPA's policy on environmental justice is available at http://www.epa.gov/environmentaljustice/plan-ej/ (Last accessed July 27, 2015).

the Marcellus Shale water monitoring community's sustained efforts meet many of the criteria environmental justice scholars use to identify an antitoxics movement.

Research has shown that the problems that led to Love Canal resulted from two kinds of knowledge deficits. First, residents were unaware of buried waste in their community. The second was a lack of understanding the negative health effects of these chemicals (Delborne & Galusky, 2011; F. Fischer, 2000). These knowledge gaps were eventually overcome for two reasons. First, Delborne and Galusky (2011) notes:

> With the help of scientific researchers such as Beverly Paigen and external environmental groups including Environmental Defense, Lois Gibbs and the Love Canal Homeowners Association (LCHA) conducted their own toxicological surveys and formulated exposure rates and theories on the flow of toxics…The LCHA had limited success in generating politically viable scientific information, but they did manage to create enough data and attention to galvanize a public perception that something was wrong (p. 68).

Fischer (F. Fischer, 2000) argues that scientists who were willing to help residents interpret government reports subsequently built their capacity to obtain more information. Residents then used this knowledge when advocating for their cause with regulators and in national media. In other words, one of the worst environmental disasters in US history led to two of the greatest achievements in environmental justice—the enacting of the Federal Superfund Act and the creation of the TRI. These accomplishments came as a result of binding political advocacy to the processes of overcoming information deficits in partnership with scientific experts.

This is a lesson the Marcellus Shale water monitoring community must learn. One of the reasons why the IWLA Harry Enstrom Chapters' story is so powerful in this study is because it shows people questioning the state of science while also reaching for empowerment at multiple levels. Members of the chapter are unabashed about taking political positions with their data in a region historically disempowered by the powers of extraction industries. They are also unyielding in their belief that the concerns of impacted residents trump all other considerations when debating the relative affordances of water quality science done by volunteers, universities, or regulators.

Figure 43. Members of Harry Enstrom Chapter present their work in Washington County, Pennsylvania[59]

However, unlike many stories in the antitoxics literature, the political and geographic landscape that the Marcellus Shale antitoxics movement occupies is incredibly vast. Research infrastructures built by the water monitoring community struggle to mirror an industrial infrastructure that consists of a seemingly ubiquitous

[59] The full video of this presentation, as well as presentations done by public health workers, legal experts, and watershed scientists attending the public outreach event, is available at https://www.youtube.com/watch?v=Wgi7yVmziBY (Last accessed July 27, 2015).

network of well pads, pipelines, and other resource flows that reach far beyond the Marcellus Shale. Just as there is no one shale gas community, there is also no single strategy for how to fight pollution threats associated with shale gas industry across this vast landscape. The challenge for a civic environmental science movement operating in this climate is how to deal with a problem of many Love Canals. They must also develop strategies to unify a distributed antitoxics movement, find common identity, and welcome different ideas about how to use the tools and processes of water monitoring in local contexts.

Gwen Ottinger (2010a) commented in her studies of bucket brigade communities that, in addition to considering where data comes from in grassroots monitoring programs, "We must also ask how their data are translated into action or intervention; what kinds of intervention are made possible by various interpretations; and, to the extent that studies of surveillance and empowerment incorporate a normative project, how adequate the forms of empowerment enabled by various interpretations are to reducing social inequality" (p. 232).

In this dissertation I have sought to answer this question. I have noted that there are different logics within the Marcellus Shale water monitoring community about the purposes of collecting water quality data, and that these logics define the parameters of water monitoring science in the region. My challenge to the water monitoring community is to suggest that these logics do not need to be mutually exclusive. I suggest that one way to reconcile the divisions that separate these ideas is to build infrastructures that allow for diversified objectives and applications when collecting and mobilizing water quality data. Projects like 3RQ's REACH, the NY Water Sentinels' working to retain local control with the Sierra Club, and Shale Network's retooling of HydroDesktop suggest that the monitoring community is coming to this realization.

Nevertheless, overcoming systemic environmental injustice across large geographies and diverse scientific research communities will require creating new partnerships that not only generate and curate knowledge, but also help people mobilize knowledge in the many communities facing pollution threats of shale gas extraction. Using data in these many locations and contexts will inherently require different scientific and political strategies. The research community must become comfortable with the idea that science does not exist in a bubble. It is also a social and political endeavor. Translating capacity for empowerment into real influence will ultimately require changing the hearts and minds of scientists, politicians, and the public alike. This, I argue, is how we can deliver on the promise that data can lead to public empowerment.

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