Water Data to Answer Urgent Water Policy Questions: Monitoring design, available data, and filling data gaps for determining whether shale gas development activities contaminate surface water or groundwater in the Susquehanna River Basin

Executive Summary

Throughout its history, the United States has made major investments in assessing natural resources, such as soils, timber, oil and gas, and water. These investments allow policy makers, the private sector and the American public to make informed decisions about cultivating, harvesting or conserving these resources to maximize their value for public welfare, environmental conservation and the economy. As policy issues evolve, new priorities and challenges arise for natural resource assessment, and new approaches to monitoring are needed. For example, new technologies for oil and gas development or alternative energy sources may present new risks for water resources both above and below ground. There is a need to evaluate whether today's water monitoring programs are generating the information needed to answer questions surrounding these new policy priorities.

The Northeast-Midwest Institute (NEMWI), in cooperation with the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program, initiated this project to explore the types and amounts of water data needed to address water-quality related policy questions of critical concern to today's policy makers and whether those data are currently available. The collaborating entities identified two urgent water policy questions and conducted case studies in the Northeast-Midwest region to determine the water data needed, water data available, and the best ways to fill the data gaps relative to those questions. This report details the output from one case study and focuses on the Susquehanna River Basin, a data-rich area expected to be a best-case scenario in terms of water data availability.

1.1 Case Study Question

The policy question that frames this case study evaluating water monitoring capacity is: ***Do shale gas development activities contaminate surface water or groundwater in the Susquehanna River Basin?*** This question is of urgent importance to decision-makers in the Marcellus Shale region. The number of unconventional wells in Pennsylvania grew from less than 200 in 2007 to greater than 9,300 as of August 2015 (Pennsylvania Department of Environmental Protection, 2015a). The Susquehanna River Basin has 63 percent forest cover, a population of more than 4 million people, and more than 49,000 miles of rivers, streams, creeks, and brooks (Susquehanna River Basin Commission, 2014a). The rapid growth of high-volume hydraulic fracturing (HVHF) in the Susquehanna River Basin has raised concerns about the potential for degraded surface-water quality and potential impacts on drinking water aquifers throughout the basin. Because hydraulic fracturing involves injection of high volumes of water and chemicals deep underground at high pressures, it has raised questions about potential contamination of surface water and groundwater and human and environmental health and safety implications. A divisive debate has emerged between citizens who support shale gas development and the economic development it brings, and others who oppose the practice based on water-quality and other environmental concerns. This conflict remains unresolved among the public due in part to a lack of information regarding water-quality and other potential environmental impacts.

Understanding the water-quality impacts of shale gas development is also a priority for the Northeast-Midwest region, generally, as evidenced in an informal project survey of Northeast-Midwest Congressional

Coalition member offices where many asked whether contaminants from shale gas development are reaching surface water or groundwater. Member offices want this information to inform appropriate decisions about regulation and management of shale gas development, and so they can inform their constituents about the impacts of development. It is clear that understanding the potential impact of unconventional oil and gas development and hydraulic fracturing on water quality is an emerging national concern. A recent draft report by the U.S. Environmental Protection Agency (USEPA) studying the impacts of hydraulic fracturing on drinking water resources nationwide generated significant interest and concern from both sides of the debate with its major conclusions: the draft report did not find evidence of widespread systemic impacts on drinking water in the United States; however, the limited amount of data collected before and during hydraulic fracturing activities reduced the USEPA's ability to determine whether hydraulic fracturing affected water quality in cases of alleged contamination (U.S. Environmental Protection Agency, 2015a).

Despite this high-profile interest, the question of whether shale gas development contaminates surface water or groundwater remains largely unresolved. Government agencies, academia, and volunteer groups have worked to collect water-quality data as they are able since shale gas development started in the Susquehanna River Basin in 2007, but it is not clear whether the systematic effort necessary to generate answers to questions surrounding shale gas development and water quality has been made. In summary, this case study topic represents an urgent environmental and public health priority for the Northeast-Midwest region, a national energy policy priority, and an issue for which a comprehensive and analytical look at water-quality data needs and data availability has the potential to create a consensus regarding the data needed to inform future management actions and policy solutions.

1.2 Case Study Approach

The case study approach consisted of three main tasks:

1. Describe the water-quality data, both types and amounts, needed to answer the case-study policy question,
2. Assess the extent to which those data are available and usable, and
3. Identify the additional data that would be needed to more effectively answer the case-study policy question, and estimate the level of effort to collect those data.

For the first task, the project team and technical advisory committee (TAC) identified the data types that were most critical for measuring water-quality change related to shale gas development for both surface water and groundwater, and analyzed available data to determine the quantity of data needed to detect statistically significant changes in water quality. The project team collected data available from agencies and organizations that monitor water quality within the Susquehanna River Basin, evaluated those data against the data needed, and reviewed the usability of those data to help answer the policy question. Once data availability and usability were determined, the project team assessed data gaps and made recommendations for collecting needed data to answer the policy question.

This report identifies the minimum amount of water data needed to detect statistically significant change in water quality related to shale gas development in the Marcellus Shale region, given certain study design assumptions; identifies available water data; and makes recommendations for filling the information gaps.

1.3 Case Study Findings

The case study findings relative to water data needed, water data available and usable, and approaches to filling the data gaps are summarized below.

1.3.1 Water data needed to answer the policy question

The following criteria were used to identify the most important water-quality data needed to answer the case-study policy question:

- **Water data must satisfy study design criteria to be used to answer the case-study policy question.**

It is not possible to identify water data needs for answering the case-study policy question without an initial discussion of an appropriate study design (Figure ES-1). The right water data must be available in the right locations with the right supporting information to detect water-quality change and identify the cause of that change.

The TAC decided to focus on the ability to detect the cumulative effects of shale gas development because water-quality monitoring is critical to identifying this type of contamination. Cumulative effects of shale gas development are defined in this study as the combination of the long-term impacts of the individual steps of shale gas development and the associated potential contamination pathways taken together, and the cumulative impacts of multiple well pads within a geographic area. Short-term spills of concentrated brines are likely to be ephemeral, with spikes in concentrations. Acute incidents are best detected through on-site monitoring, accident reporting with targeted response monitoring, and through continuous water-quality monitors in receiving streams. Cumulative effects of shale gas development were selected as the study focus because these are more subtle to detect and water-quality monitoring is the only path to identifying low level and long-term changes. In the absence of water-quality data, the long-term cumulative effects of shale gas development on water quality will be unknown.

The location of monitoring sites in the right places for answering the case-study policy question is critical. Surface water monitoring sites must be located in each of the four ecoregions with active or planned shale gas development, because stream chemistry in each ecoregion is unique and will respond differently to disturbances or changes in land use. Monitoring sites must be located in watersheds with HVHF wells and in reference watersheds in each ecoregion. In this context, reference watersheds are areas with no HVHF well development. Monitoring sites in these types of watersheds allow for the detection of water-quality changes in watersheds with HVHF well development and comparison with undeveloped watersheds to identify whether water-quality changes are resulting from HVHF development. Ideally, monitoring sites will measure water quality in watersheds smaller than 70 square miles. Small watersheds provide the best opportunities to identify pollutants that are primarily derived from a single source. Monitoring in larger watersheds can provide opportunities for nested monitoring with smaller watersheds that quantifies the

transport of pollutants downstream and pollutant inputs from multiple small watersheds with active shale gas development.

Water-quality and streamflow data at these monitoring sites must be available with sufficient sampling frequency and duration to evaluate trends in concentration over time. Finally, data on shale gas development, geology, climate, and other changes in land use throughout the monitored watershed must be available to correlate water-quality change with shale gas development activity. Without this information, the relationship between shale gas development and water quality cannot be evaluated, even if shale gas development is causing water-quality change.

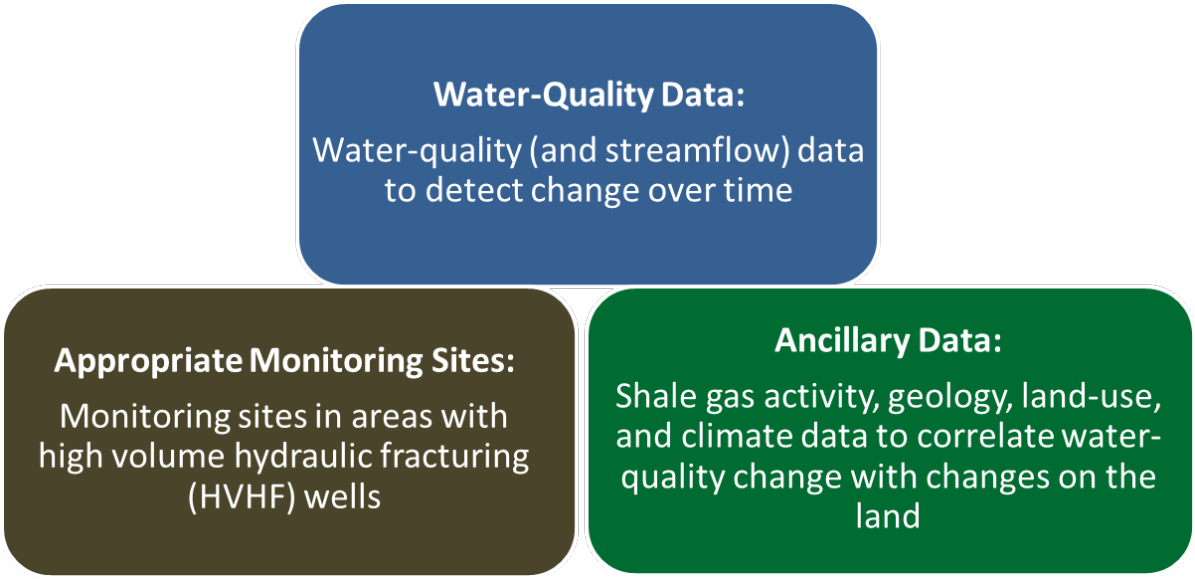


Figure ES-1. Study design needed to answer "Do shale gas development activities contaminate surface water or groundwater?"

The study design for groundwater again requires monitoring sites in the right places: networks of groundwater sampling sites are needed with each sampling site located within 1 mile of an HVHF well. Water-quality data collected before and after shale gas development at the nearby HVHF well sites are necessary to identify groundwater quality change. Again, information on the shale gas development, geology, other changes in land use, and climate near those sampling sites must be available to correlate water-quality change with shale gas development activity.

- **Multiple lines of evidence, using a suite of priority monitoring parameters, are needed to identify shale gas development as the source of water-quality change.**

No one parameter can identify whether shale gas development is the source of contamination if a change in that parameter concentration is detected. By monitoring a suite of parameters, more information is available to identify the likely source of contamination. Each shale gas development activity, from initial well pad development to production of gas from a completed well is associated with different pathways that contribute different potential contaminants, so monitoring for just one of the parameters would miss multiple types of potential contamination.

Suite of priority parameters

Parameters recommended for both surface water and groundwater: alkalinity, dissolved barium, bromide, calcium, chloride, dissolved oxygen, gross alpha, gross beta, lithium, magnesium, nitrate, pH, potassium, radium-226 and -228 (but only if there are changes in gross alpha and gross beta), sodium, specific conductance, strontium, sulfate, total dissolved solids, uranium, and water temperature.

Additional parameters recommended for surface water only: total barium, suspended sediment concentration, total organic carbon, total phosphorus, turbidity, and streamflow.

Additional parameters recommended for groundwater only: benzene, toluene, ethylbenzene, xylene, and methane.

Consequently, a suite of water-quality parameters is needed to determine if contamination from the cumulative impact of shale gas development activities has occurred in the Susquehanna River Basin. The suites of priority parameters for surface water and groundwater are based on the specific hydrology, geology, past and current land use, and other environmental concerns expressed in the Susquehanna River Basin.

- **The sampling frequency and duration of monitoring must meet minimum requirements to adequately characterize and detect changes in priority monitoring parameters related to shale gas development.**

Assuming that monitoring sites located in watersheds with HVHF wells and in reference watersheds and the needed ancillary data are available (Figure ES-1), surface-water quality and streamflow data requirements can be characterized as shown in Table ES-1. As mentioned above, the entire suite of surface-water parameters is needed to identify whether shale gas development is the source of water-quality change. Monthly sampling frequency is needed to detect changes in water quality year round and to minimize the time needed to detect statistically significant water-quality change at each monitoring site (see section 6.4). A minimum of eight surface-water monitoring sites are needed: one monitoring site in a watershed with HVHF wells and one reference watershed monitoring site is needed in each of the four ecoregions with active or predicted HVHF development. Additional monitoring sites will provide critical information regarding the scope and magnitude of potential water-quality change associated with shale gas development, especially in watersheds with the highest density of HVHF wells and nested watershed monitoring sites.

The minimum monitoring duration must be sufficient to characterize background surface-water concentrations for each parameter and detect statistically significant change over normal background fluctuations. The minimum monitoring duration to detect change varies by ecoregion and is discussed in detail in section 6.6. Because the purpose of the monitoring described in Table ES-1 is to detect whether the cumulative effects of shale gas development are resulting in water-quality change, monitoring should continue at selected monitoring sites for the long-term, as long as shale gas development activities continue in the Susquehanna River Basin. The magnitude of water-quality change that could occur from contamination related to shale gas development is unknown, but it would take 3-6 years of monthly monitoring to detect a 20-percent change in median specific conductance or total barium in the Susquehanna River Basin.

Table ES-1. Summary of surface-water data needed to detect water-quality change resulting from cumulative shale gas development activities in the Susquehanna River Basin. Analysis supporting these findings is presented in Chapter 6. [Abbreviations: HVHF, High-volume hydraulic fracturing]

Criteria	Surface-water data needed
Monitoring parameters	• Suite of priority surface-water parameters from Table 3 and streamflow at each monitoring site
Sampling frequency	• Monthly
Locations of monitoring sites	• Monitoring sites in each of the ecoregions with active or predicted HVHF activity, including: o Northern Allegheny Plateau, o North Central Appalachians, o Central Appalachians, and o Ridge and Valley.
Watershed characteristics	• Watersheds smaller than 70 square miles. • Medium and high density and reference watersheds: o Watersheds with greater than 0.5 HVHF wells per square mile, and o Watersheds with 0 HVHF wells per square mile and no significant shale gas development expected. • Watersheds larger than 70 square miles that offer opportunities for nested monitoring (i.e. one or more small watersheds that are being monitored for change are nested within the larger watershed)
Number of monitoring sites	• Minimum of 1 monitoring site in a high density watershed per ecoregion. • Minimum 1 reference monitoring site per ecoregion.
Duration and timing of monitoring	• At least 36 samples collected at monthly or longer intervals over 3-4 years including data collected after shale gas development (post-2007) • Minimum duration of monitoring to detect water-quality change varies by ecoregion • Ideal monitoring sites will have: o Data collected before shale gas development (pre- 2007), o An uninterrupted data record, o Current/ongoing data collection (2009 or later), and o Plans for long-term monitoring.

Groundwater data requirements can be characterized as shown in Table ES-2. Again, the entire suite of groundwater parameters is needed to identify whether shale gas development is the source of groundwater quality change. The study design for groundwater that is most applicable for existing groundwater data requires networks of 25-30 groundwater sampling sites in each of the primary drinking water aquifers in the Susquehanna River Basin, each site located within 1 mile of an HVHF well. Five priority spatial networks were identified for groundwater monitoring. Water-quality data should be collected at those sampling sites before and after shale gas development, with sampling events separated by approximately 10 years. Long-term monitoring would require that additional sampling be done every 10

years into the future. A subset of 5 sampling sites in each network should be sampled every 2 years to identify interim water-quality changes.

Table ES-2. Summary of groundwater data needed to detect water-quality change resulting from cumulative shale gas development activities in the Susquehanna River Basin. Analysis supporting these findings is presented in Chapter 9.

Criteria	Groundwater data needed
Monitoring parameters	• Suite of priority groundwater parameters from Table 3 at each monitoring site.
Spatial networks	• Minimum of 5 networks in each of the major drinking water aquifers with shale gas development, distinguished by topography: o Upper Devonian Lock Haven aquifer with upland topography, o Upper Devonian Lock Haven aquifer with valley topography, o Upper Devonian Catskill aquifer with upland topography, o Upper Devonian Catskill aquifer with valley topography, and o Pleistocene deposits aquifer.
Number and location of sampling sites	• For each network: o 25-30 sampling sites o Each site within 1 mile of a HVHF well
Duration, frequency, and timing of monitoring	• Two samples at each site, separated by approximately 10 years and taken: o before shale gas development, and o after shale gas development • Additional long-term monitoring, in subsequent 10 year increments, • A subset of 5 sites per network sampled every 2 years.

1.3.2 Availability and usability of existing water data to answer the policy question

This investigation found more than 960,000 surface-water records collected at about 14,700 monitoring sites over the last 85 years in the Susquehanna River Basin (Figure ES-2 (A)). However, Figure ES-2(B) shows there are only 10 monitoring sites in the Susquehanna data set compiled for this study that meet most of the criteria summarized in Table ES-1 for barium, an indicator closely associated with HVHF development, and none of these sites are located in watersheds with a high density of HVHF wells. There are no monitoring sites that meet all the criteria in Table ES-1.

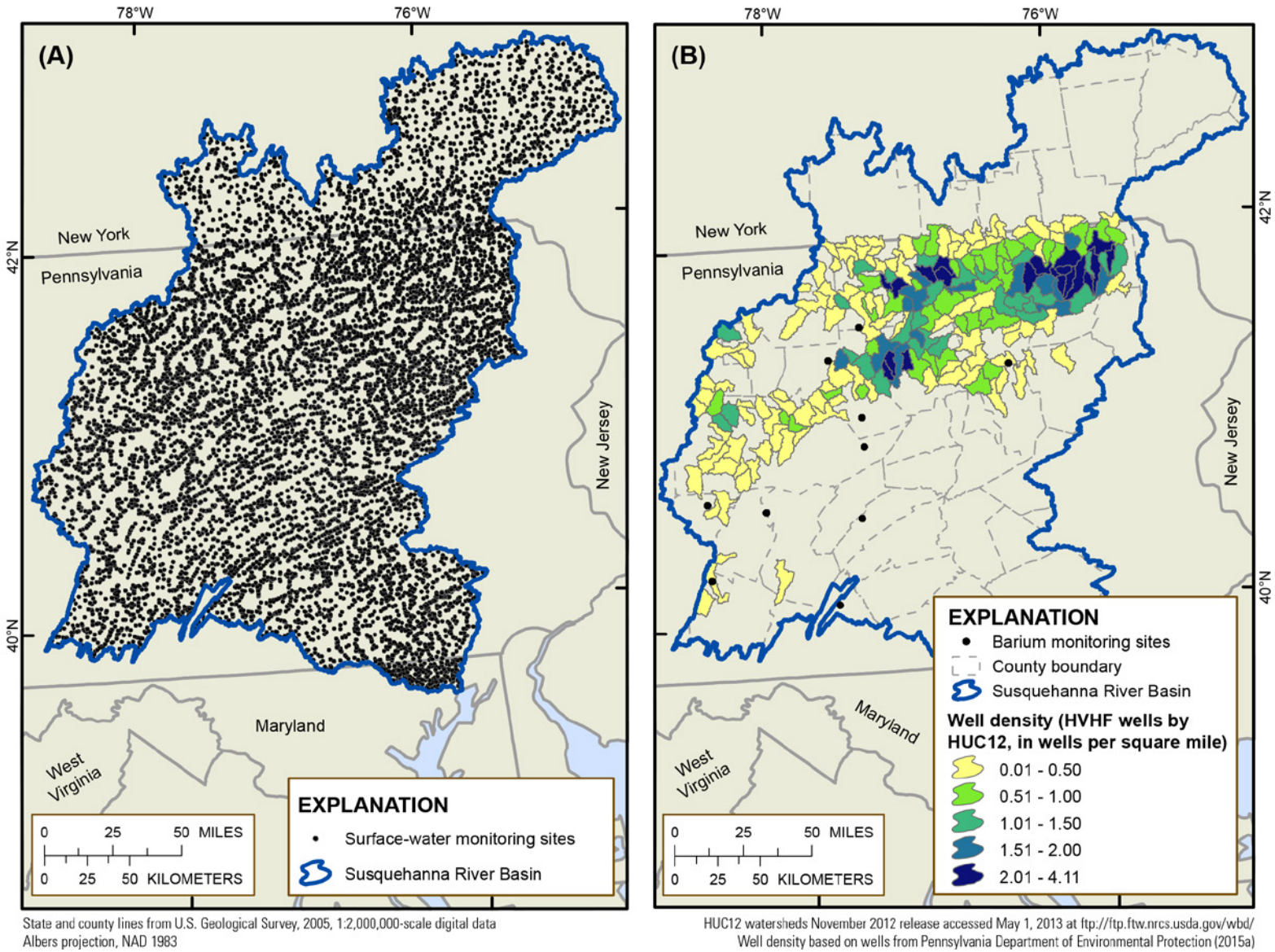


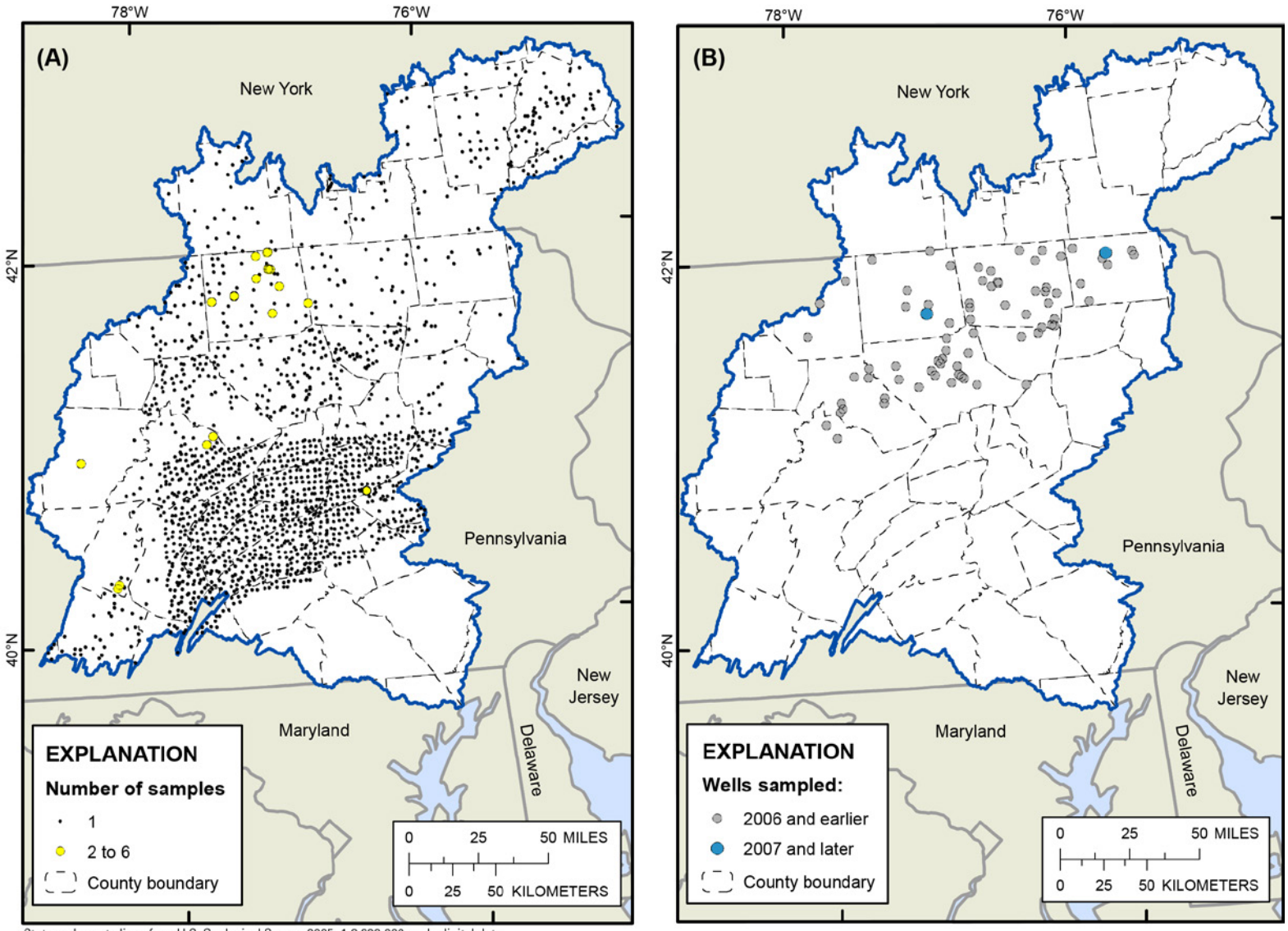
Figure ES-2. (A) Surface-water monitoring sites in the Susquehanna River Basin with water-quality records for at least one of the comprehensive list of surface-water parameters selected by the Technical Advisory Committee (n=14,730), and (B) Surface-water monitoring sites where the minimum data for detecting changes in barium concentration (total or dissolved) have been collected (n=10). None of the 10 monitoring sites are located in a watershed with a high density of HVHF wells.

- **The surface-water data needed for answering the case-study policy question are not currently available in the Susquehanna River Basin.**

While there are some applicable surface-water data available, each of the existing monitoring sites does not meet at least one of the criteria for location, parameters analyzed, frequency of monitoring, or duration of monitoring to detect statistically significant change associated with cumulative effects of shale gas development. Monitoring sites that have used an appropriate sampling plan for answering the case-study policy question are not in the right locations for detecting water-quality change related to shale gas development. Only 4 of 22 surface-water monitoring sites in the Susquehanna River Basin with enough existing data for a water-quality trend analysis for barium or specific conductance are located in watersheds with active HVHF wells, and few of the 26 recommended surface-water monitoring parameters are available for those sites. Only one of those monitoring sites is in a watershed with an HVHF well density greater than 0.5 HVHF wells per square mile. The existing surface-water data in the Susquehanna data set are not sufficient to detect whether the cumulative effects of shale gas development are resulting in water-quality change.

- **The groundwater data needed for answering the case-study policy question are not being collected.**

There is no systematic, large-scale, long-term monitoring effort underway to assess the effects of shale gas development on groundwater quality in the Susquehanna River Basin, and from the data sources that do exist, Figure ES-3 shows that limited groundwater data are publicly available to answer the policy question. The groundwater sampling sites with existing data are rarely located within 1 mile of an HVHF well, but even when they are in the right locations the sites lack data for most of the priority groundwater parameters. The available groundwater data lack the sampling frequency needed for a water-quality trend analysis and lack the number and location of sampling sites needed for a spatial water-quality network analysis. Selecting appropriate groundwater sampling sites is a major challenge for monitoring agencies because they do not have access to information on the location of future HVHF wells. Sampling sites within 1 mile of an HVHF well are due more to coincidence than due to planning.



State and county lines from U.S. Geological Survey, 2005, 1:2,000,000-scale digital data
Albers projection, NAD 1983

Figure ES-3. (A) Groundwater sampling sites with bromide data in the Marcellus and Utica Shale area of the Susquehanna River Basin (n=1,686), and (B) Groundwater sampling sites located within 1 mile of an HVHF well (n=74). None of the 74 sampling sites have data available both before and after shale gas development, and few of the suite of priority groundwater parameters were measured before shale gas development.

- **Current water data usability for answering the policy question is limited by insufficient data documentation and availability.**

Water-quality monitoring programs are usually designed to meet a stated objective or follow a historical precedent. Data collected for one monitoring objective may not be directly applicable to another objective, due to the location of monitoring sites, frequency of monitoring, parameters measured, and analytical methods used. The surface-water data identified through this case study were generated by 35 organizations, and groundwater data were collected by 10 organizations that collect water-quality data for parameters related to shale gas development in the Susquehanna River Basin. Insufficient and inconsistent documentation of available data limited the utility of these existing data sets. Substantial project time and effort over the course of this multi-year project were required to locate, obtain, and consistently format data. Missing information that is particularly important for this case study includes specification of whether water-quality samples were filtered or unfiltered, and information on the aquifer from which groundwater samples were taken.

Data sharing and data accessibility were also limiting factors in data availability in this case study. It is possible that despite the work completed for this case study, additional relevant data that are not being shared or are not available in electronic format may exist. The Water Quality Portal (National Water Quality Monitoring Council, 2014a), a cooperative service that provides publicly available water-quality data from Federal databases, including data collected by more than 400 State, Federal, Tribal, and local organizations, was established to facilitate water data sharing. Data collected at only 19 percent of the surface-water monitoring sites identified through this case study in the Susquehanna River Basin are available through the Water Quality Portal, but 85 percent of the water-quality data records are available through the Portal. This finding indicates that the monitoring sites from the Susquehanna data set that are available through the Water Quality Portal are sites with longer data records, monitoring sites that are more likely to have the data necessary to identify a water-quality trend. Still, important data sets are missing from this collection including data collected by volunteer organizations, local governments, and academia. The Water Quality Portal includes data collected at 45 percent of the groundwater monitoring sites identified through this case study, and 61 percent of the groundwater quality records are available through the Portal. The most important groundwater data sets, those collected by industry, are not available through data sharing systems and access to those data sets is limited.

1.3.3 Approaches for filling data gaps to answer the case-study policy question

- **Increase monitoring at a minimum of 8 targeted surface-water monitoring sites; additional monitoring sites are highly recommended. The water data identified in Table ES-1 must be collected for each of these sites.**

A recently established surface-water monitoring program at the Susquehanna River Basin Commission (SRBC) called the Remote Water Quality Monitoring Network (RWQMN) is designed to collect surface-waterquality data related to shale gas development, and recent updates to a monitoring program at the Pennsylvania Department of Environmental Protection (PADEP) collect data more closely associated with shale gas development than previous monitoring efforts. Many of the monitoring sites for these programs

are in the right locations, but additional sampling frequency, parameters, and streamflow data are needed. For SRBC monitoring sites, a minimum of 4 additional years of monitoring are needed at current sampling frequencies before water-quality trends can begin to be detected. Increased monitoring at a subset of priority monitoring sites would start generating answers to the case-study policy question in a time-frame that is useful to decision makers and would provide the water data needed to identify whether shale gas development is contaminating surface water in the monitored watersheds.

A minimum of 8 monitoring sites are needed, 2 in each of the ecoregions with active or planned HVHF development. Additional monitoring sites will provide critical information regarding the scope and magnitude of potential water-quality change associated with shale gas development, especially in watersheds with the highest density of HVHF wells and nested watershed monitoring sites. An example set of 17 priority surface-water monitoring sites is presented in Chapter 8. The following list includes several site characteristics that could make an individual monitoring site a priority site for increased monitoring:

- History of water-quality data available at the site
- Variety of priority surface-water parameter data available at the monitoring site
- Density of HVHF wells in the monitored watershed
- Availability of existing continuous monitors or streamgages at the monitoring site
- Availability of nested monitoring sites
- Current or long-term funding source available for the monitoring site
- History of cooperation with shale gas development companies that are active within the monitored watershed

The increased monitoring must include analysis for the full suite of priority surface-water parameters, increased frequency to monthly sampling, and addition of streamgages where needed. An example of data needs is presented in Table 19.

- **Maintain data collection and analysis at enhanced surface-water monitoring sites for a minimum of 10 years and as long as shale gas development activities continue in the Susquehanna River Basin.**

Monitoring at enhanced priority sites should continue for more than 10 years to determine whether cumulative shale gas development activities are resulting in water-quality change over the long-term. Monitoring to fill the data gaps should be implemented using an adaptive-monitoring approach and coordinated among monitoring agencies. Care should be taken to coordinate closely among participating monitoring programs so that data collection can be planned for compatibility, sharing, and easy analysis. The data should be evaluated on a regular basis so the monitoring program can be adjusted as necessary to adapt to a changing understanding of shale gas development and water quality.

- **Design and implement a systematic, long-term groundwater monitoring program for detecting groundwater quality change related to shale gas development in the Susquehanna River Basin, building on data collected by the shale gas industry, if appropriate.**

There is no groundwater monitoring equivalent to the SRBC RWQMN that is investigating the potential for shale gas development to change groundwater quality across the Susquehanna River Basin, and the

groundwater data compiled for this study cannot be used as the foundation of a new groundwater monitoring program as described above. The groundwater data summarized in Table ES-2 must be collected through a systematic monitoring program to be able to answer the case-study policy question.

The shale gas industry has collected the most comprehensive set of groundwater data that pre-dates development at HVHF wells in the Susquehanna River Basin. The use of these existing data sets as the foundation of a new long-term groundwater monitoring program would result in the most cost-effective and most timely approach for collecting groundwater-quality data to answer the case-study policy question if the data sets meet minimum requirements for statistical analysis. Most of the priority groundwater parameters would need to be available for each sampling site (Table 3), the source aquifer identified, and the filtered/unfiltered status specified for each parameter.

If access to industry data cannot be obtained, a completely new groundwater monitoring program must be initiated that would also require industry participation to identify appropriate sampling sites based on plans for future shale gas development.

- **Establish a coordinating entity to develop and implement surface-water and groundwater monitoring plans in the Susquehanna River Basin, with representation from water monitoring organizations, shale gas industry, domestic well owners, and public citizens.**

To answer the case-study policy question, the right water-quality data must be collected in the right locations with the right supporting information. Water monitoring organizations and academia are tasked with collecting the right water-quality data, but industry involvement is necessary to identify the right monitoring locations and provide the right supporting information. Industry cooperation is needed to provide access to existing data and to identify locations of new HVHF wells so appropriate sampling sites can be identified. Ongoing coordination between water monitoring agencies and the shale gas industry will provide the necessary updates on locations of active production and technological advances in shale gas extraction practices that may affect water monitoring strategies.

Because domestic wells are the most accessible locations for monitoring groundwater quality related to shale gas development, it is critical to include domestic well owners in the process to obtain access to domestic wells for sampling before and after new shale gas development. To gain public trust, water monitoring programs should engage the people living in affected areas in addition to independent experts. According to the Council of Canadian Academies (2014), citizens will have greater faith in water monitoring results if they can influence the design, access the results, and comment throughout the process.

Engagement of all the critical stakeholders (water monitoring organizations, shale gas industry, citizens, and domestic well owners) will improve water data coordination, sharing, and analysis to better understand the water-quality impacts of shale gas development in the Susquehanna River Basin. Stakeholder participation will promote confidence in the analytical results and lead to a better understanding of the risks to water resources in the Susquehanna River Basin. With this information, real policies and regulations can be implemented to protect water resources in the Susquehanna River Basin.

A coordinating entity is needed to facilitate coordination of sampling plans among water monitoring organizations so data collection, analysis, and interpretation will be compatible and comparable across monitoring sites. Improved data documentation and data sharing will facilitate the use of water data for answering the case-study policy question. Tools such as the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. HydroDesktop (Consortium of Universities for the Advancement of Hydrologic Sciences, Inc., 2014), Water Quality Exchange (WQX) (U.S. Environmental Protection Agency, 2014) and the Water Quality Portal provide the infrastructure for organizations to format and share their data, but greater participation is needed. Consistent, thorough data documentation and wider availability of data sources through these services will increase the value of water-quality data from all monitoring agencies and reduce the amount of time needed to access and prepare data for new applications. A continued commitment to water-quality data-sharing systems is essential for maximizing use of existing water-quality data.

1.4 Conclusion

Targeted, robust monitoring networks for both surface water and groundwater are critical for identifying whether the influx of shale gas development activity in the Susquehanna River Basin is generating adverse changes in water quality. The existing water-quality data in the Susquehanna River Basin are inadequate to serve this purpose. This report presents strategies for collecting the water data needed to detect whether shale gas development activities are contaminating surface water or groundwater in the Susquehanna River Basin in a policy-relevant time frame. Key steps to generating the needed information include increased monitoring in strategic locations, design and implementation of a systematic groundwater monitoring program, and a long-term commitment to water-quality monitoring in the Susquehanna River Basin supported by a coordinating entity. Water-quality data collection and analysis, with participation from the key stakeholders, can answer this urgent policy question of critical importance to the Northeast-Midwest region and prepare for the questions that will emerge with further growth of the shale gas industry. The sooner the region gets started, the better.

Summary of information needs to answer "Do Shale Gas Development Activities Contaminate Surface Water or Groundwater in the Susquehanna River Basin?"

- Increase monitoring at a subset of targeted surface water monitoring sites.
- Maintain data collection and analysis at enhanced surface water monitoring sites for a minimum of 10 years and as long as shale gas development activities continue in the Susquehanna River Basin.
- Design and implement a systematic, long-term groundwater monitoring program, building on data collected by shale gas industry, if appropriate.
- Establish a coordinating entity to develop and implement surface water and groundwater monitoring plans in the Susquehanna River Basin, with representation from water monitoring organizations, the shale gas industry, domestic well owners, and public citizens.