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Washington County, Pennsylvania Retrospective Case Study Characterization Report

Submitted to:

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EXECUTIVE SUMMARY

The U.S. Environmental Protection Agency (EPA) is conducting a retrospective case study in Washington County, PA to determine if there is a relationship between hydraulic fracturing and drinking water resources. EPA selected this site "in response to complaints about appearance, odors and taste associated with water in domestic wells. To investigate these complaints, EPA is collecting data on groundwater, surface water, and spring water quality (EPA, 2012b).

An understanding of background water quality conditions prior to or in the absence of hydraulic fracturing is required to determine if a relationship exists between hydraulic fracturing and drinking water resources. Absence of background water quality necessitates a rigorous investigation of potential sources for any observed impacts prior to source attribution. This report is intended to provide an initial understanding and characterization of water quality conditions in Washington County based upon publically available information on land use, known surface water impairments, and water quality data from the U.S. Geological Survey (USGS), EPA, and state of Pennsylvania. Key findings from this report include:

- **Pennsylvania has one of the most rigorous regulatory programs for oil and gas development of any state**. Casing and cementing standards for oil and gas wells have been robust since passage of Pennsylvania's Oil and Gas Act in 1984, and have been enhanced by changes to Chapter 78 of Pennsylvania's environmental regulations in 2011 and recent changes to the Oil and Gas Act in Act 13 of 2012. Because of these standards, risk of groundwater contamination from poor construction of oil and gas wells is lower now than at any time in Pennsylvania's history.
- **Groundwater, surface water, and spring water quality in Washington County have been significantly impaired by historical land uses**. Historical activities that occurred long before shale gas drilling began in 2005 could provide sources for a large number of pollutants that may exist in groundwater and/or surface water in the study area. The most significant causes of water quality impairments in Washington County are acid mine drainage (AMD) and agriculture. Other land uses known to impact water quality in the county include urban, residential, and road runoff; habitat modification; and municipal and industrial wastewater discharges. Land uses and parameters commonly associated with these land uses include:
    - ***Coal mining and AMD***. Constituents associated with coal mining include metals, ions, sulfate, and general water quality (i.e., total dissolved solids [TDS], pH). Approximately 53% of the county has been mined using underground mining methods. Coal mining activities have had widespread and well documented impacts on both surface water and groundwater within Washington County.
    - ***Agricultural runoff***. Constituents associated with agricultural activities include insecticides, herbicides, fungicides, fertilizers (e.g., nitrogen and phosphorous), metals (e.g., arsenic), and other constituents (e.g., dissolved solids, bromide, selenium). In addition, algal blooms caused by agricultural runoff of nitrogen and phosphorous can be a source of organic carbon that promotes the formation of disinfection byproducts (DBPs) upon chlorination of surface water in water treatment plants (EPA, 2005). Agricultural and livestock activities can also be a source of methane (King, 2012).
    - ***Non-point sources, stormwater runoff, and industrial activities***. Constituents associated with these sources include polycyclic aromatic hydrocarbons (PAHs), polychlorinated

biphenyls (PCBs), metals; salts, pH; siltation; suspended solids; and nutrients depending upon the specific activities in the area.

  - ***Conventional oil and gas development***. Constituents associated with this activity include petroleum hydrocarbons, benzene, toluene, ethylbenzene, xylene (BTEX), salts (sodium and chloride) and methane. Over 11,600 oil and gas wells have been drilled over the past 130 years in Washington County, many of which were drilled prior to the existence of modern techniques or regulations.
  - ***Surface water impairments***. Total maximum daily loads (TMDLs) have been established due to known surface water quality impairments for over 690 miles of impaired streams and rivers in Washington County, representing approximately 35% of the total stream length. Most impaired streams are located in the northern part of the county where historic surface and subsurface coal mining activities have taken place. The entire length of the Monongahela River along the eastern boundary of the county is also listed as impaired. The chemicals that have caused these surface water impairments in Washington County including chlordane and pesticides; PCBs; metals; pH; siltation; suspended solids; nutrients, organic enrichment and low dissolved oxygen (DO); and turbidity.

- **Historical data on water quality within the study area are extremely limited**. Of the 261 parameters that EPA describes in its quality assurance project plan (QAPP), 196 are identified as either critical analytes or measured parameters. Less than 30 are included in enough historical samples to establish any statistically meaningful background water quality for groundwater or surface water. These data are limited to inorganic and general water quality parameters.

- **Difficulty of establishing cause and effect**. Determining a relationship between hydraulic fracturing and drinking water will be difficult given both the known impairments from other activities and the lack of adequate data to characterize background water quality conditions. Without adequate background water quality, impacts observed as part of the EPA study will require a rigorous investigation before relating those impacts to hydraulic fracturing.

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ABBREVIATIONS AND ACRONYMS

AMD	abandoned mine drainage
ANGA	America's Natural Gas Alliance
ANOVA	analysis of variance
AST	above ground storage tank
API	American Petroleum Institute
bgs	below ground surface
BOD	biochemical oxygen demand
BOGM	Bureau of Oil and Gas Management
BTEX	benzene, toluene, ethylbenzene, and xylene
CA	critical analyte
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CSO	combined sewer overflow
CWA	Clean Water Act
DBP	disinfection byproduct
DCNR	Department of Conservation and Natural Resources
DO	dissolved oxygen
DOI	U.S. Department of the Interior
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FSP	Field Sampling Plan
gpm	gallons per minute
HUC	Hydrologic unit code
IOGCC	Interstate Oil & Gas Compact Commission
M	measured
MCL	maximum contaminant limit
MTBE	methyl tert butyl ether
NORM	naturally-occurring radioactive materials
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NURE	National Uranium Evaluation
NWIS	National Water Information System
PADEP	Pennsylvania Department of Environmental Protection
PA GWIS	Pennsylvania Groundwater Information System
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PENNDOT	Pennsylvania Department of Transportation
PGWA	Pennsylvania Groundwater Association

POTW	publically owned sewage treatment work
PPC	Preparedness, Prevention, and Contingency
PSU	Pennsylvania State University
PWS	public water system
QA	quality assurance
QAPP	Quality Assurance Project Plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RPD	relative percent difference
SDWA	Safe Drinking Water Act
SMCL	secondary maximum contaminant limit
SRBC	Susquehanna River Basin Commission
STORET	EPA STOrage and RETrieval Data Warehouse
STRONGER	State Review of Oil and Natural Gas Environmental Regulations
SVOC	semivolatile organic compound
TDS	total dissolved solids
TMDL	total maximum daily load
TRI	Toxic Releases Inventory
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UST	underground storage tank
VOC	volatile organic compound
WSIP	Southwestern Pennsylvania Water and Sewer Infrastructure Project Steering Committee
WWTP	wastewater treatment plant

1.0: INTRODUCTION

The U.S. Environmental Protection Agency (EPA) has initiated five retrospective case studies as part of the agency's evaluation of the potential relationships between hydraulic fracturing and drinking water resources (EPA, 2011).

One of the retrospective case studies selected by EPA is located in Washington County, Pennsylvania (EPA, 2012a). According to the EPA Quality Assurance Project Plan (QAPP) for the Washington County Retrospective Case Study, this area was selected "in response to complaints about appearance, odors and taste associated with water in domestic wells" (EPA, 2012b). To investigate these complaints, EPA is collecting samples from domestic wells, springs, and surface water bodies in the study area and analyzing them for a range of water quality parameters.

To enable evaluation of the EPA case study water sampling and analysis results within the context of regional spatial and temporal variability, American Petroleum Institute and America's Natural Gas Alliance requested that Battelle characterize land use, groundwater quality, spring water quality, and surface water quality in Washington County using readily available data that predate unconventional oil and gas development in the area. This report summarizes historical water resource quality data within the Washington County study area for use in comparing the future data to be generated as part of EPA's retrospective case study.

Based on information contained in the EPA QAPP and on more recent discussions with Range Resources, Inc. (Carl Carlson, personal communication, November 2012), EPA collected water samples from 14 locations in July 2011; EPA performed additional sampling in March 2012 from 11 locations. EPA may have collected samples at additional locations within Washington County, but the location and number of these additional samples is unclear. These data have not been made available to the public to date.

1.1 Scope of Work

The primary objective of this report is to develop an understanding of and characterize background groundwater, spring water, and surface water quality conditions within the study area prior to the onset of unconventional oil and gas development, and highlight potential adverse impacts that may have resulted from former land use activities. This was accomplished by:

- Defining the spatial and temporal boundaries and attributes of the Washington County study area.
- Identifying land use and water quality data that could be used to provide historical context for characterizing water resources in the defined study area, along with identifying associated analytical parameters that could be used to evaluate potential impact on drinking water resources.
- Developing a list of available chemicals and water quality parameters monitored in the study area, and comparing them to EPA QAPP requirements.
- Developing and applying quality assurance (QA) criteria to assess the quality of the historical water quality data.
- Conducting summary statistical analyses on the water quality data and comparing the results to state and federal screening criteria.

Battelle utilized EPA's data quality objective (DQO) process to help ensure that an appropriate type and quantity of data needed to meet the study objective was collected (EPA, 2006). An in-depth evaluation of water quality data by individual surface water bodies, springs, aquifers, or wells is beyond the scope of this report.

1.2 Report Organization

Section 2 of this report discusses the technical approach to defining the study area boundaries; identifying, collecting, and organizing the secondary data; QA procedures for data assessment; and relevant regulations and screening criteria applicable to the water quality parameters of interest. Section 3 provides an analysis of the land use, groundwater quality, spring water quality, and surface water quality data collected for this report. Key conclusions and findings are presented in Section 4.

1.3 Site Description

Figure 1-1 shows the EPA sampling locations in the Washington County retrospective case study area, including 11 known current sampling locations (eight groundwater monitoring wells and three springs) and nine estimated (from the EPA QAPP and lacking coordinate data) sampling locations (six groundwater monitoring wells and three surface water bodies). These locations were compiled using the EPA Washington County QAPP (EPA, 2011) and coordinate information provided by Range Resources, Inc. These sampling locations are situated primarily near towns and villages as:

- Near Bulger in Smith Township,
- Near Avella in Independence Township,
- Near Hickory in Mt. Pleasant Township,
- Near West Middleton in Hopewell Township, and
- Near Amity in Amwell Township.

Although the locations for this case study were selected "in response to complaints about appearance, odors and taste associated with water in domestic wells" (EPA, 2011), no rationale was provided in the EPA QAPP for selecting the specific sampling locations. As determined by Battelle, several alleged incidents have been identified in the vicinity of some of these sampling locations, including inspection reports issued by the Pennsylvania Department of Environment (PADEP) and unofficial citizen complaints, including calls to the U.S. Coast Guard National Response Center.

Complaints to the National Response Center included allegations of impacts to water wells, odors and sheen, release of fluids into nearby streams, holding pond overflows, reports of oil leaks from a separator tank and a hydraulic fracturing pit fire. A review of unofficial National Response Center citizen complaints included the following inorganic constituents: arsenic, barium, hydrogen sulfide, iron, manganese and strontium, which are naturally occurring constituents in the shallow groundwater of the region. Several organic constituents also were mentioned, including: acetone, acrylonitrile, benzene, 1,4-butanediol, ethylbenzene, glycol, methanol, naphthalene, pesticides, styrene, trimethylbenzene, toluene and trichloroethylene. No readily available public records were found to indicate PADEP made determinations that these constituents were found in drinking water supplies in the region or were related to drilling of wells in the Marcellus Shale.

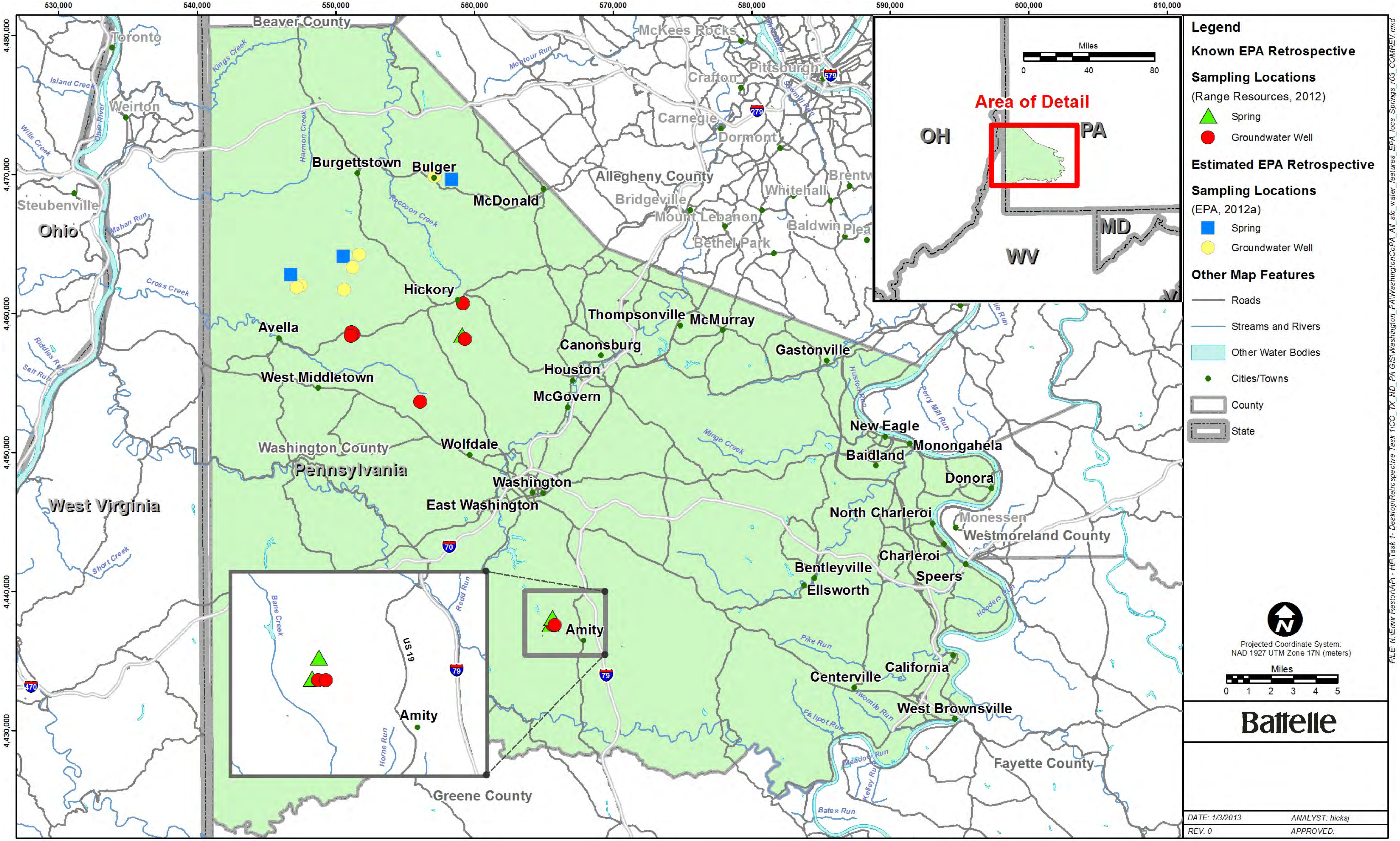

Figure 1-1. EPA Retrospective Sampling Locations in Washington County, PA

2.0: TECHNICAL APPROACH

This section provides the technical approach to defining the study area boundaries, data collection, QA processes, and applicable environmental regulatory framework.

2.1 Retrospective Case Study Area Boundaries

The subject study area of interest is in Washington County, Pennsylvania, which is located in southwestern Pennsylvania within the Marcellus Shale play. The county itself encompasses approximately 857 square miles and has a current population of over 200,000 (U.S. Census Bureau, 2010). Figure 1-1 shows the known and estimated EPA sampling locations for springs and groundwater for the Washington County retrospective case study.

Physiographically, Washington County is located in the Appalachian Plateau Province. The northern portion is within the Pittsburgh Low Plateau section and the southern portion is within the Waynesburg Hills section. The topography is characterized by rolling hills in the north and by sharper ridges and steeply chiseled stream valleys in the south.

From a hydrological standpoint, the county is located within the Ohio River Basin. In the northern portion of the county, the streams and tributaries drain directly to the Ohio River, whereas in the southern portion, surface water drains into the Monongahela River, which then flows into the Ohio River near Pittsburgh (Washington County, 2005). Surface water bodies included in this investigation are those that may be considered drinking water resources or contribute to surface water bodies that may be drinking water resources; this translates into essentially all rivers and streams present in Washington County.

The study area of interest is vertically constrained by near-surface geologic aquifer formations in Washington County that serve as drinking water resources. Where utilized for drinking water supply, these aquifers are generally within 300 feet of the ground surface, based upon groundwater well and groundwater quality data collected during this investigation and subsequently stored within the Washington County database. Water resources below this depth are commonly present as brine, which is not used for drinking water due to high salt content. The underlying Marcellus Shale ranges from roughly 5,000 ft bgs in the northwest corner of the county to 7,500 ft bgs in the southeastern portion of the county.

All groundwater, spring, and surface water data collected prior to 2005 represent conditions prior to significant development of the Marcellus Shale through hydraulic fracturing, and serve to define the temporal boundary for background conditions discussed in this report.

2.2 Data Sources, Collection, and Organization

The data contained in this report are secondary or historical data obtained by Battelle from publically available U.S. federal government and state of Pennsylvania records that were available in accessible, electronic format. Secondary data are defined as “data that were originally collected for another project or purpose.” This section describes the sources of the secondary land use and water quality data and how the data were collected and evaluated by Battelle. The data collected focused on the following:

- Land uses potentially contributing to water quality conditions;
- Groundwater quality conditions;
- Surface water quality conditions; and
- Spring water quality conditions.

2.2.1 Land Use Data Collection. The land use data collected are qualitative in nature and rely upon the original quality and documentation of the primary source of the datasets. The primary sources of the land use data are summarized in Table 2-1. Both historic and current land use information was collected to evaluate conditions associated with water quality within Washington County. This information also provides a context within which to evaluate both the water quality for spatial and temporal changes and for future comparison with data collected for the EPA retrospective case study.

Table 2-1. Summary of Land Use Data Sources

Data Source	Timeframe	Type of Data
PADEP[1]	1991 - 2012	Storage tank cleanup locations
PASDA/Environmental Resources Research Institute[2]	1996	Historic conventional oil and gas fields
EIA[3]	2009	Historic conventional oil and gas fields
PA DCNR[4]	2007	Historic conventional oil and gas fields
PASDA/PADEP[2]	2012	Total maximum daily load (TMDL) impaired waters
PASDA/PADEP[2]	2011-2012	Coal mining operations data including surface mines, underground mines, mined out areas, and other data.
PASDA/PADEP[2]	2012	Land recycling cleanup location divided into sub-facilities categorized: air, contained release or abandoned container, groundwater, sediment, soil, surface water, and waste
USDA[5]	2011	Cropland information for Washington County
EPA Envirofacts[6]	2012	Recognized pre-existing environmental activities that may affect air, water, and land resources
Range Resources	Various	Locations of historic oil and gas wells
PA DCNR[7]	2012	Locations of historic oil and gas wells
Washington County Planning Commission[8,9]	2005	Land use map and Washington County Comprehensive Plan including historical chronology, land use, and economy
USGS[10]	1986	Land use map

2.2.2 Water Quality Data Review. Data were collected from U.S. federal government and state of Pennsylvania sources to characterize groundwater and surface water quality. The spatial boundaries for the data collection effort were hydrologic unit code (HUC) 8 watershed boundaries for the three HUC 8 watersheds present in Washington County, including the Upper Ohio, Upper Ohio-Wheeling, and Lower Monongahela. This larger dataset was then down-selected based on longitude and latitude values to only include data located within Washington County, Pennsylvania.

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1 http://www.portal.state.pa.us/portal/server.pt?open=514&objID=589714&mode=2
2 http://www.pasda.psu.edu/
3 http://www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/maps/maps.htm
4 http://www.dcnr.state.pa.us/topogeo/maps/map10.pdf
5 http://nassgeodata.gmu.edu/CropScape/
6 http://www.epa.gov/enviro/index.html
7 http://www.dcnr.state.pa.us/topogeo/econresource/oilandgas/resrefs/wis_home/index.htm
8 http://www.co.washington.pa.us/generalpage.aspx?menuDept=19&genPageID=162
9 http://www.co.washington.pa.us/maindepartment.aspx?menuDept=19
10 http://water.usgs.gov/GIS/dsdl/ds240/index.html

Groundwater, surface water, and spring water quality data were collected from the following sources:

- U.S. Geological Survey (USGS) National Water Information System (NWIS),
- EPA STOrage and RETrieval Data Warehouse (STORET),
- USGS National Uranium Evaluation (NURE), and
- USGS Report - PADEP Ambient and Fixed Station Network (compilation of USGS and EPA databases).

Table 2-2 provides an overview of the types of water quality data that were collected. The data were then subsetted or further divided to those stations within Washington County and used to characterize water quality for the retrospective case study location. In each of these cases, the siting of the sampling locations and the types of analytes measured were developed to meet specific objectives. The data sources listed in Table 2-2 are considered secondary data, and by definition were not originally collected for the specific purposes of this report. However, these databases are commonly used to define background or baseline groundwater or surface water quality.

Table 2-2. Summary of Complete Water Quality Data Sources for Washington County

Data Source	Timeframe	Number of Monitoring Locations	Parameters
USGS National Water Information System (NWIS)[11]	1926-2004	95 wells 46 surface water 6 springs	Major Ions, Minor Ions, Nutrients, PAHs, Pesticides, Radionuclides, VOCs, Water Characteristics
EPA STOrage and RETrieval Data Warehouse (STORET)[12]	2002-2004	2 surface water	Major Ions, Minor Ions, Nutrients, PAHs, Pesticides, Radionuclides, VOCs, Water Characteristics
USGS National Uranium Resource Evaluation (NURE)[13]	1978	107wells 108 surface water 47springs	Major Ions, Minor Ions, Radionuclides, Water Characteristics
USGS report - PADEP – Ambient and Fixed Station Network[14]	1989	5 wells	Major Ions, Minor Ions, Nutrients, Water Characteristics

Historic water quality data are available from several sources. For example, the USGS monitors groundwater and surface water at a number of locations throughout Pennsylvania; however, the frequency of the measurements and the time period when they were taken vary. Although there have been a number of academic research studies in which data were collected for a short period of time for a specific purpose, these data sources were not pursued for this database due to QA/quality control (QC) issues with the data and/or lack of publically available documentation of QA/QC procedures.

A reference sheet was used to document the data collected by file name, type of data, data source, date of downloading, hyperlink to the source Web site, storage location on the project network drive, and any

[11] http://waterdata.usgs.gov/nwis/qw
[12] http://www.epa.gov/storet/
[13] http://tin.er.usgs.gov/geochem/doc/nure_analyses.htm
[14] http://pubs.usgs.gov/ds/314/

relevant comments. The data were subsequently uploaded into a Microsoft® SQL Server database, processed, assessed according to the QA procedures described in Section 2.3 and qualified, as necessary, based on the results of the QA assessment.

2.2.3 Data Management. Groundwater, spring and surface water data collected prior to 2005 represent conditions in Washington County prior to substantial development of the Marcellus Shale through hydraulic fracturing and serve to define the background conditions discussed in this report.

Summary tables were prepared for groundwater, spring and surface water data for a range of parameters. For the purposes of this evaluation, a minimum of one result from eight discrete locations was selected as the criterion for the minimum number of results needed to characterize water quality for a given parameter. When evaluating the quantity of water quality data, it is noted that EPA's guidance on statistical analysis of Resource Conservation and Recovery Act (RCRA) groundwater monitoring data (EPA, 2009) recommends that a minimum of at least eight to 10 independent background observations be collected before running most statistical analysis methods. Although still a small sample size by statistical standards, these sample requirements allow for minimally acceptable estimates of variability and evaluation of trend and goodness-of-fit. This approach is not meant to imply that eight sample location results are sufficient to characterize water quality for Washington County, only to note that this number was selected as the lower bound for the number of results included. Notwithstanding, it should be taken into consideration that larger sample sizes still may not necessarily constitute a representative dataset for characterizing background water quality for specific formations or locations. Additional evaluation of spatial and temporal conditions should be performed prior to completing quantitative comparisions with other (e.g., EPA or operator) collected water quality data. Parameters with results at fewer than eight locations were excluded from the summary data tables and associated discussion, but are included in Appendix B.

Two separate sets of summary data tables were produced for groundwater and surface water. One set of data tables includes applicable data from the databases identified in Table 2-2. A duplicate set excludes the STORET data because these data may be indicative of environmental impact monitoring that could potentially skew the dataset, and other data with data location issues as summarized in Table 2-3. The spring water quality database did not include data from the STORET database, so only one summary data table was produced.

Within each dataset, summary statistics (mean, median, standard deviation) were derived. To ensure that spatial locations receive equal weighting and that locations with multiple results over time are not weighted higher, the average of parameter-specific multiple temporal results were used to represent the specific parameter at that location. In the event that duplicate sample results exist, the duplicate sample is included as a separate result and included in calculating the average for the sampling location. Two separate sets of summary statistics are calculated: one set includes all available data, with non-detect values included in the calculations at half of the detection limit; the second set includes only detected values.

Groundwater and surface water quality screening criteria were compiled and used for comparison against the assembled water quality characterization data; surface water screening criteria were used for comparison against the spring data. When making these comparisons, only detected values are included when calculating the number of sample results above a screening criteria; non-detect values were excluded. A summary of the water quality regulations that were utilized to compile selected screening criteria are summarized in Section 2.4.1.

Table 2-3. Summary of Data Included in Reduced Washington County Water Quality Dataset

Data Source	Initial Number of Monitoring Locations	Reduced Number of Monitoring Locations	Reason for Removal
NWIS	95 wells 46 surface water 6 springs	95 wells 46 surface water 6 springs	No locations removed
STORET	2 surface water	0 surface water	Data may be indicative of environmental impact monitoring
NURE	107 wells 108 surface water 47 springs	104 wells 107 surface water 47 springs	Latitude and/or longitude coordinate was reported with ≤2 decimal places
USGS Report – PADEP Ambient and Fixed Station Network	5 wells	3 wells	Data may be indicative of environmental impact monitoring

2.3 Quality Assurance Procedures

A systematic approach was used to assess the quality of secondary analytical data in accordance with EPA QA/R-5 which requires that data be reviewed and acceptance criteria and limitation of use be defined (EPA, 2001). To this end, prior to initiating the site characterization study, Battelle developed overall DQOs to establish the study objective, problem being investigated, study goals, data input, boundaries, analytical approach, plan for obtaining data, and data acceptance criteria. The DQOs established the following criteria for data acceptance:

- Data were collected by an agency and organization known to have a rigorous quality system.
- Data were collected under an approved QAPP/Field Sampling Plan (FSP).
- Data were produced by laboratories known to implement a rigorous quality system.
- Analytical methods were identified and appropriate.
- For non-detect values, the detection limits were defined and sensitive enough for each parameter.
- If QC data were available, accuracy was demonstrated to be ≥80% and precision was demonstrated to be ±30%. Accuracy is determined using the results of spiked sample analysis where percent recovery can be quantified. Precision is determined using field or laboratory duplicate samples by calculating the relative percent difference (RPD).

Due to the nature of the source Web sites and the lack of available QC data and metadata, many of these criteria could not be directly assessed. An exhaustive review of comment fields was conducted to determine if the comments provided additional information such as sample preservation or processing procedures, such as holding times or titration endpoints, or other data quality issues. In some cases, Battelle was able to assign the following data qualifiers based on the comments:

- U qualifier was assigned if the comment indicated that the value was less than a specific value inserted as the detection limit (e.g., “<0.05 µg/L”)
- J qualifier was assigned if the value was deemed an estimate. Data were classified as estimates if they were less than the reporting limit, if samples did not meet holding time or holding condition requirements, or a QC failure was noted. This is consistent with national validation guidelines (EPA, 2002).
- S qualifier (suspect) was assigned if the data entry comment indicated that it was suspect, if the parameter was marked as a highly variable compound, if the method high range was exceeded, or if processing errors were noted.

However, the lack of metadata left the majority of data without clear “proof” of quality using the DQO criteria. Although the DQOs specified that such data be flagged as estimated values to be used with caution, the study team determined that too much data would be lost using this approach. Therefore, data were evaluated using the approach described in Appendix B. The results of the data quality review are presented in Appendix A.

Based on the data quality assessment, groundwater, surface water and springs data should be used with caution for the following reasons: the analytical laboratories, laboratory quality control data, quality-related qualifiers, and analytical methods were not reported for most data. Quality system elements that support the data include collection organizations with known quality systems and acceptable laboratory detection limits with one exception. For surface water, laboratory detection limits were acceptable with the exception of selenium, for which all reported detection limits were greater than the Clean Water Act (CWA) chronic value.

2.4 Applicable Statutory and Regulatory Framework

A brief discussion of federal and state statutes and regulations is relevant because of their role in setting water quality standards and criteria. A chronology of relevant laws and regulations related to groundwater quality, surface water quality and environmental restoration is provided in Figure 2-1. The statutes and regulations in place in Pennsylvania to regulate oil and gas activities are also discussed. It should be noted that Pennsylvania has no statutes or regulations that apply to the drilling, completion, or operation of private water supply wells.

2.4.1 Relevant Water Quality Statutes, Regulations, and Guidance. For comparison purposes, historical data are compared to water quality criteria from various sources. Although these values may not be directly relevant or applicable, they are used in this document as screening values. Results above screening criteria do not indicate that corrective action (e.g., remediation) is required, but may suggest that water quality is different from what would be expected, possibly due to anthropogenic or natural conditions. A detection above water quality criteria should not be interpreted as indicative of an impact. In order to assess if an impact has occurred, or if corrective action is suggested, a thorough investigation would have to be performed; this is beyond the scope of this desktop study. Relevant water quality statutes, regulations and guidance are listed and summarized below.

Pennsylvania Clean Streams Law. Enacted in 1937, the Clean Streams Law regulates the discharge of sewage, industrial waste or any substance which causes or contributes to pollution, into the waters of the Commonwealth of Pennsylvania. It also regulates the impact of mining operations upon water quality, supply and quantity. The law was last amended in 1987 to align with requirements of the CWA. The Clean Streams Law is one of the oldest pieces of legislation in Pennsylvania with provisions regulating discharges from oil and gas well drilling activities. The law requires operators to have a plan to prevent accelerated erosion due to drilling activities.

PENNSYLVANIA OIL AND GAS STATUTES AND REGULATIONS

Year	Statutes and Regulations
1984	• Pennsylvania Coal and Gas Resource Conservation Act • Pennsylvania Oil and Gas Act
1987 to 2011	• Pennsylvania Code 25 § 78 Oil and Gas Wells*
2010	• Pennsylvania Code 25 § 95.2 and 95.10 (surface water discharge)
2012	• Act 13 Pennsylvania Statute 58 §§ 23, 25, 27

Notes: *PA Chapter 78 regulations were first adopted July 31, 1987; there have been several amendments to these regulations, the most recent being February 5, 2011. Chapter 95 was originally adopted on September 2, 1971; Sections 95.2 and 95.10 were amended effective August 21, 2010.

ENVIRONMENTAL STATUTES AND REGULATIONS

Year	Statutes and Regulations
1937	• Pennsylvania Clean Streams Law
1948	• United States Water Pollution Control Act
1972	• Federal Water Pollution Control Act of 1972 (Clean Water Act)
1974	• United States Safe Drinking Water Act
1980	• Comprehensive Environmental Response, Compensation, and Liability Act
1984	• Pennsylvania Safe Drinking Water Act
1995	• Act 2: Land Recycling Program (Voluntary Remediation Program)
2007	• Pennsylvania Code 25 § 93.7 (Updated Water Quality Requirements)

Figure 2-1. Timeline of Statutes and Regulations Related to Oil and Gas Activities

U.S. Clean Water Act. The CWA is the common name for the Federal Water Pollution Control Act of 1972 [33 U.S.C. §1251 et seq. (1972)]. It established the basic structure for regulating the discharge of pollutants into U.S. waters and setting water quality standards for surface water. It expanded upon the original 1948 law called the United States Water Pollution Control Act. Under the authorities granted by the CWA, EPA has implemented the National Pollutant Discharge Elimination System (NPDES) permit program. It also established the concept of TMDL, which is a calculation of the maximum amount of a pollutant that a water body can receive and still meet designated water quality standards. TMDLs are specific to the impaired water body and regulate the maximum amount of contaminant loading from both point and non-point sources.

U.S. Safe Drinking Water Act. The Safe Drinking Water Act (SDWA) was enacted in 1974 and amended in 1986 and 1996. Under SDWA, EPA established maximum contaminant limits (MCLs) and secondary maximum contaminant limits (SMCLs). MCLs are established to protect public health from contaminants in drinking water by balancing potential health risks and the cost of treatment. An MCL represents the maximum allowable amount of a contaminant that can be delivered to a consumer by a public water system (PWS). An SMCL is a non-enforceable water quality standard for constituents that may cause taste, odor, or color concerns in drinking water. These non-mandatory levels are established as guidelines for PWSs to address aesthetic and taste issues and do not represent a health risk.

EPA Region 3 Mid-Atlantic Regional Screening Levels for Chemical Contaminants at Superfund Sites. Under the authority of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, screening levels were established for carcinogenic and non-carcinogenic human health effects in tap water. Although these levels are only guidance, this can be a useful reference for compounds that do not have established MCLs or SMCLs.

Other Relevant State Environmental Regulations. Several other environmental laws have been enacted by the state of Pennsylvania. However, this discussion is limited to those laws which include provisions that set water quality standards and/or screening levels. The Pennsylvania SDWA was passed in 1984 to establish provisions for safe drinking water, including enacting drinking water quality standards. Pennsylvania has established surface water quality standards through Title 25 Environmental Protection, Chapter 93, Water Quality Standards (25 Pa.C. § 93.7). 25 Pa.C. §§ 93.7-93.8, established state surface water quality standards for the protection of water resources, wildlife, and industrial water. The Land Recycling Program (Voluntary Remediation Program), commonly known as Act 2, is a Pennsylvania program designed to encourage the voluntary remediation of contaminated areas. The Act was passed in 1995 and established uniform cleanup standards, reviews, and time-tables, as well as financial assistance and the chance for liability relief for property owners who voluntarily remediate. Although Act 2 has not historically been applied to the oil and gas industry, the Act 2 water quality standards are included in this review of background water quality in the region.

2.4.2 Oil and Gas Related Statues, Regulations and Guidance. State laws regulating the oil and gas industry in Pennsylvania have been in place since 1961; those with provisions having to do with environmental protection of water resources are briefly summarized here. Several amendments to the framework of applicable laws and regulations have been passed since the start of unconventional oil and gas development in the Marcellus Shale and further regulations are expected in 2013.

In 2010, PADEP requested to have its oil and gas regulatory program reviewed by the non-profit, multi-stakeholder organization named State Review of Oil and Natural Gas Environmental Regulations (STRONGER). This was the latest of four STRONGER reviews of the PADEP's program and the first to focus on hydraulic fracturing. Overall, the report concluded that the framework in place in Pennsylvania was well-managed, professional and meeting its stated objectives (STRONGER, 2010).

Coal and Gas Resource Coordination Act. Passed in 1984, this act controls potential interference between coal mining and oil and gas activities. The act states that there must be a minimum of 1,000 ft separating gas wells that penetrate a workable coal seam; it also provides recourse for owners of active coal mines to object to proposed gas wells that would penetrate their seam. The Coal and Gas Resource Coordination Act was amended effective May 13, 2011 by Act 2 of 2011.

Pennsylvania Oil and Gas Act. This act was first passed in 1984 and amended most recently in 2012 (Pennsylvania Statute 58 §§ 601.101-601.607). The chapters of the Oil and Gas Act include Chapter 1 (definitions of commonly used terms in the Act); Chapter 2 (provides general requirements of well permitting and reporting, notification of drilling activities, well location, well site restoration, well casing, well plugging and the use of safety devices); Chapter 3 (confining the activities of underground gas storage); Chapter 4 (defining the conditions of eminent domain); Chapter 5 (elucidating enforcements and remedies); and Chapter 6 (miscellaneous provisions in the Act). A summary of key sections of Chapter 2 and recent amendments are summarized below.

- Chapter 2, Section 205 (Pennsylvania Statute 58 §§ 601.205) of the law provides restrictions on the location of oil and gas wells. The construction of an unconventional well, which includes wells drilled to the Marcellus Shale and other gas shales, within 500 ft of a building or water supply is prohibited without permission from the owner; this was increased from 200 feet for conventional wells by Act 13 (see below). As established by Act 13, unconventional wells may not be constructed within 1,000 feet of a public water supply well, surface water intake, reservoir, or other water intake point without written consent from the water purveyor. An unconventional oil or gas well may not be drilled within 300 ft of a surface water body or wetland greater than 1 acre in size. Impacts to public parks, national or state scenic rivers, national natural landmarks, habitats of rare or endangered species and historical or archaeological sites are also considered by the provisions of this section.
- Chapter 2, Section 206 (Pennsylvania Statute 58 §§ 601.206) provides requirements for site restoration after drilling is completed. The section requires the oil or gas well owner or operator to: (1) restore the land surface within the drilling area; (2) remove all drill pits, drilling supplies and equipment not needed for well operations within 9 months of drilling completion; (3) remove all production and storage facilities and equipment within 9 months of plugging the well; and (4) follow all requirements of the Clean Streams Act of 1937.
- Chapter 2, Sections 207 and 208 (Pennsylvania Statute 58 §§ 601.207-601.208) relate to the protection of water resources. Section 207 establishes requirements for protective casings on wells. Casings meeting regulatory standards provided by the Bureau of Oil and Gas Management (BOGM) must be installed in the vertical distance that a gas well penetrates a freshwater-bearing strata or mined coal seam. This casing must prevent the migration of all gases or fluids into the strata or seam. In locations where a coal seam has not been mined, a casing that prevents the migration of gases or fluids into the seam (except those found to be naturally occurring before drilling activities began) must be installed. Section 208 provides for landowner recourse and compensation in the event of an alleged contamination incident, as well as the process for operator rebuttal to an accusation. If the owner of a water supply located within 2,500 ft of an unconventional well (amended from 1,000 ft for conventional wells by Act 13) makes a contamination complaint within 12 months of completion of the oil or gas well (updated from 6 months for conventional wells by Act 13), the well operator is presumed to be responsible, unless:

- The pollution existed before drilling as determined by operator commissioned pre-drilling water surveys carried out by an unbiased, accredited laboratory;
- The landowner or purveyor complaining did not allow operator access for a pre-drilling survey;
- The complaint does not satisfy the location or temporal requirements above, or the pollution occurred as the result of some other cause.

- Recent provisions of the 2012 amendment to the Oil and Gas Act (Pennsylvania Statute 58 §§ 23, 25, 27) commonly known as Act 13 include:
  - Allowing for the assessment of unconventional oil and gas impact fees
  - Strengthening the PADEP's authority to deny permit applications to operators in continuing violation
  - Instituting separate standards for unconventional oil and gas development
  - Increasing the setback distance of a vertical wellbore to 300 ft from any surface water body ("solid blue line" stream, spring, wetland, or other body of water) with the potential for additional protective measures on wellbores located closer than 750 ft to a water body
  - Increasing or establishing setback distances to 500 ft for unconventional wells from existing buildings and water supplies (without owner consent)
  - Increasing or establishing setback distances to 1,000 ft for oil and gas wells from existing public water wells, surface water intakes, reservoirs, or other water intake points
  - Establishing requirements for the construction and maintenance of containment pits and requiring the submission of a waste containment plan
  - Requiring unconventional well sites be constructed to prevent spills either onto the ground or off the well site
  - Codifying as law chemical disclosure obligations
  - Requiring notices of well permit applications to be disclosed to nearby municipalities
  - Extending notification of drilling activities to property owners up to 3,000 ft from the vertical well bore
  - Prohibiting drilling in floodplains if the site will have a pit or impoundment
  - Increasing the distance and duration to which the rebuttable presumption of damage to a water supply to 2,500 ft and 12 months of drilling completion
  - Establishing the State Natural Gas Energy Development Program.

- In 2008, PADEP had issued a policy requiring an approved Water Management Plan as a condition of drilling permits for shale gas wells. This requirement has been codified in Pennsylvania Act 13 of 2012. For the Ohio River Basin, PADEP's review of water management plans follows established practices utilized by the Susquehanna River Basin Commission (SRBC). Water withdrawals from streams are generally approved if they meet either of the following criteria:
  1) withdrawal rate does not exceed 10% of the 10-day, 7-year expected low flow rate, or
  2) withdrawal is regulated to ensure a pass-by flow of not less than 20% of the stream's average daily flow.

Title 25 Environmental Protection, Chapter 78, Oil and Gas Wells (41 Pa.B. 805).

- In 2011, this amendment updated the provisions of Pennsylvania Code 25 §§ 78.81-78.89 and § 78.122 as follows:
  - Casing requirements
    - Requires operators to condition a wellbore to enhance bond between cement, casing and formation
    - Requires the use of centralizers to ensure proper placement of casings
    - Requires better quality cement
    - Necessitates an on-site casing and cementing plan
  - Specifies the actions operators will take if gas migration is detected
  - Clarifies how and when blowout prevention equipment is to be installed and operated
  - Requires a pressure barriers plan to minimize well control events
  - Requires disclosure of hydraulic fracturing fluids to the PADEP
  - Requires operators to keep a list of emergency numbers at the well site.
- Pennsylvania Code 25 §78.53 requires operators to design, implement and maintain best management practices related to erosion and sediment control. There are also rules requiring a Preparedness, Prevention and Contingency (PPC) Plan (Pennsylvania Code 25 § 78.55) for oil and gas operations and for regulating the application of residual waste of the drilling, production and plugging of an oil or gas well (Pennsylvania Code 25 § 78.63). Pennsylvania 25 §78.89 requires the operator or owner to conduct an investigation of potential natural gas migration incidents. The purpose of the investigation is to determine the nature of the incident, assess the potential for hazards to public health and safety and mitigate any hazard posed by the concentrations of stray natural gas.

Title 25 Environmental Protection, Chapter 95, Wastewater Treatment Requirements (40 Pa.B. 4835). In 2010, this amendment updated surface water discharge requirements defined in Pennsylvania Code 25 § 95.2 and 95.10. These provisions apply to new and/or expanded discharges, not those previously permitted. Effluents must comply with the following standards:

- pH: no less than 6 and no more than 9
- Oil: no effluent may have a sheen, no more than 15 mg/L oil as a daily average and no more than 30 mg/L at one time
- Iron: no more than 7 mg/L dissolved iron
- Total dissolved solids (TDS): no more than 500 mg/L (monthly average)
- Chlorides: no more than 250 mg/L (monthly average)
- Barium: no more than 10 mg/L (monthly average)
- Strontium: no more than 10 mg/L (monthly average).

3.0: DATA ANALYSIS

The quality of groundwater, surface water, and spring water is affected by a range of factors including land use patterns, watershed characteristics, hydrology, geohydrology, and water resource management practices. The role of land use is discussed below, along with a review of historical groundwater, surface water, and spring water quality in Washington County.

3.1 Land Use

The total population of Washington County is 207,820 within 857 square miles, which yields a population density of 242.5 persons per square mile (U.S. Census Bureau, 2010). This represents a 2.4% increase from the population of 202,897 in 2000 and a 4.3% decrease from the population of 217,271 in 1960. Land use maps for the county were available for 1986 and 2005. Figure 3-1 shows the land use map for Washington County from 2005. Table 3-1 provides the most recent (2005) and historic (1986) land use statistics for Washington County to illustrate changes in land use over time. As shown in Table 3-1, mixed forest remains the predominant land use in 1986 and 2005. Farmland (e.g., cropland, pasture, and orchards) is second, representing 29.5% of the total land area in 2005. This is a decline in the amount of land dedicated to agriculture in 1986. The total county-wide land use for residential, urban, industrial, commercial and services and transportation combined is 16.1% (Washington County, 2005).

Table 3-1. Summary of Land Use Statistics for Washington County

Category	Percentage in 2005	Percentage in 1986
Mixed Forest	47.10%	36.40%
Agriculture (Crop, Pasture, Orchard)	29.50%	51.10%
Residential	12.50%	7.70%
Mixed Rangeland	4.90%	-
Industrial, Commercial and Services	1.40%	1.20%
Urban	1.30%	0.50%
Transitional	1.10%	0.40%
Transportation and Communication	0.90%	1.00%
Water Bodies	0.80%	0.40%
Surface Extraction (Strip Mine, Gravel Pit, Quarry)	0.50%	1.30%

Historically, agriculture, mining, steel production, and manufacturing have been important industries in Washington County from the 1800s to 1900s (Washington County, 2005). Conventional oil and gas extraction has been ongoing since the late 1800s. According to a study of Southwestern Pennsylvania (including Washington County), the National Research Council (NRC) found that the major causes of water quality impairment in the region were: (1) abandoned mine drainage (AMD); (2) agriculture; (3) urban and stormwater runoff; and (4) human waste handling (NRC, 2005). These widespread land use activities have influenced water quality in Washington County as discussed below.

3.1.1 Coal Mining and Abandoned Mine Drainage. Historically, AMD has been the primary cause of impairment to the Monongahela River watershed (PA Department of Conservation and Natural Resources [DCNR], 1998). As of 2006, AMD and surface/subsurface mining was responsible for over 946 miles of impaired streams in the watersheds in Washington County (EPA, 2012c).

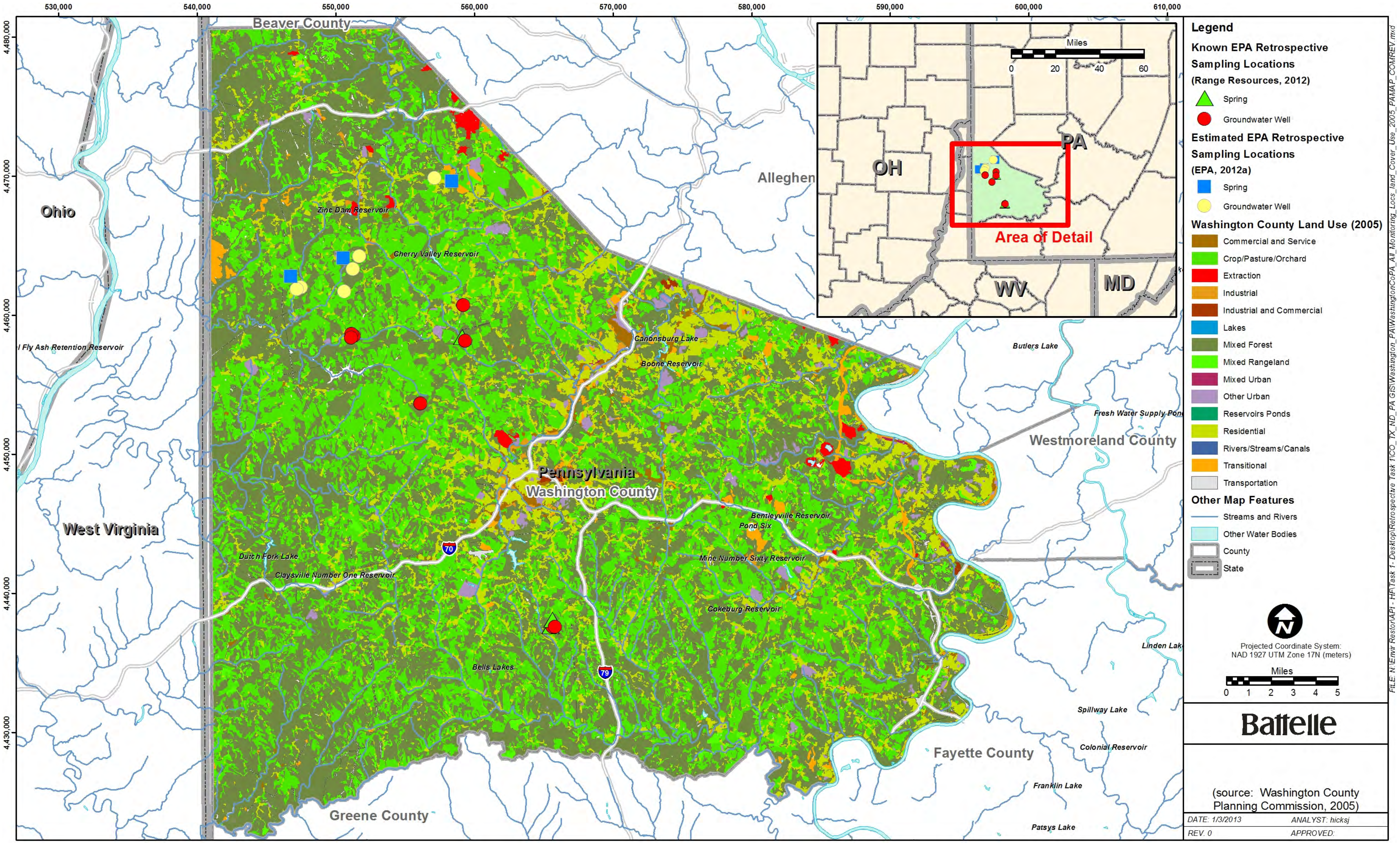

Figure 3-1. Land Use Map for Washington County (Washington County, 2005)

Groundwater quality can also be affected by AMD as demonstrated by a USGS study, which compared groundwater in mined and unmined areas of Appalachian coal fields. Domestic wells located in mined areas were found to have significantly higher levels of sulfate, iron, manganese, and TDS with 20% to 70% of wells exceeding the SMCLs (Anderson et al., 2000).

In the early 1800s, the first commercial coal mining operations began in Washington County. By the early 20th century, coal companies in Washington County were producing over 14.5 million tons of coal, which represented the most significant industrial activity in the region at the time (Washington County, 2005). Mining in Washington County is conducted via both surface mining and underground mining. Figure 3-2 shows the extent of mining operations in Washington County. Surface or strip mining removes soil to expose coal near the land surface, therefore potentially causing habitat modification that can lead to accelerated erosion. Surface mining may also impact shallow groundwater in areas around the mining operations. In 2005, surface extraction covered 0.5% of the landscape in Washington County (Figure 3-1), although in 1986 surface mining covered over 1% of the landscape (USGS, 1986). It was most widespread in the northern portion of the county where the Pittsburgh coal seam outcrops extensively above the drainage base. As shown in Figure 3-2, the Pittsburgh coal seam has been deep mined in approximately 53% of Washington County. Deep mining involves tunneling into underground coal formations. In Washington County, a method referred to as longwall mining was used extensively to remove a large panel of coal, and has been connected with subsidence issues. The “room-and-pillar” approach also was implemented in Washington County, in which it was common to remove pillars once a section of coal was fully developed, achieving well over 90% recovery and subsequently introducing the potential for issues associated with subsidence. Subsidence can cause changes in water levels in deep aquifers and near surface water supplies through dewatering and/or hydrogeologic changes, resulting in overall lower water levels. The quality of the groundwater may be altered even after groundwater levels recharge. Subsidence can also impact surface water quantity and quality by changing surface elevations and drainage patterns within a given watershed (NRC, 2005).

Iron sulfides in coal and other rocks break down in the presence of water and oxygen to form sulfuric acid and iron hydroxides (the orange deposits in streams impaired by AMD). AMD may include iron, nickel, copper, zinc, sulfate, along with lead, arsenic, aluminum, and manganese. Sulfate can be used as a relatively non-reactive tracer of AMD impacts on a watershed (NRC, 2005). As coal production has declined, AMD discharges have decreased over time in Washington County. However, it will take decades for some sites to recover and active AMD reclamation is ongoing in some locations within Washington County. This treatment process can involve the addition of lime, which may increase calcium levels in the treated water that is discharged. Various discharge points from mining activity and reclamation are shown in Figure 3-2.

Fractures (termed cleats) in near surface coal seams above the drainage base may provide the necessary permeability to achieve flow volumes that could serve as a water supply. Drawdown from fresh water wells not isolated from coal seams may liberate methane into the water well (King, 2012). Methane also can be liberated from underground mining that has occurred nearby to water wells and this has been shown to occur within Washington County (U.S. Department of the Interior [DOI], 2001).

3.1.2 Agriculture. Over 162,000 acres of Washington County were dedicated to agricultural activities in 2005. This is a decline of 70% compared to the acreage devoted to agriculture at the turn of the 20th century (Washington County, 2005). This includes land dedicated to crop production where herbicides, insecticides, fungicides, and fertilizers are applied, as well as pastures for livestock production where manure serves as a source of both nutrients and pathogens. Crops in Washington County, predominately alfalfa and hay, represent over 99% of the agricultural land production (U.S. Department of Agriculture [USDA], 2011). Livestock production primarily compromises sheep, cattle, poultry, and hogs (Washington County, 2005).

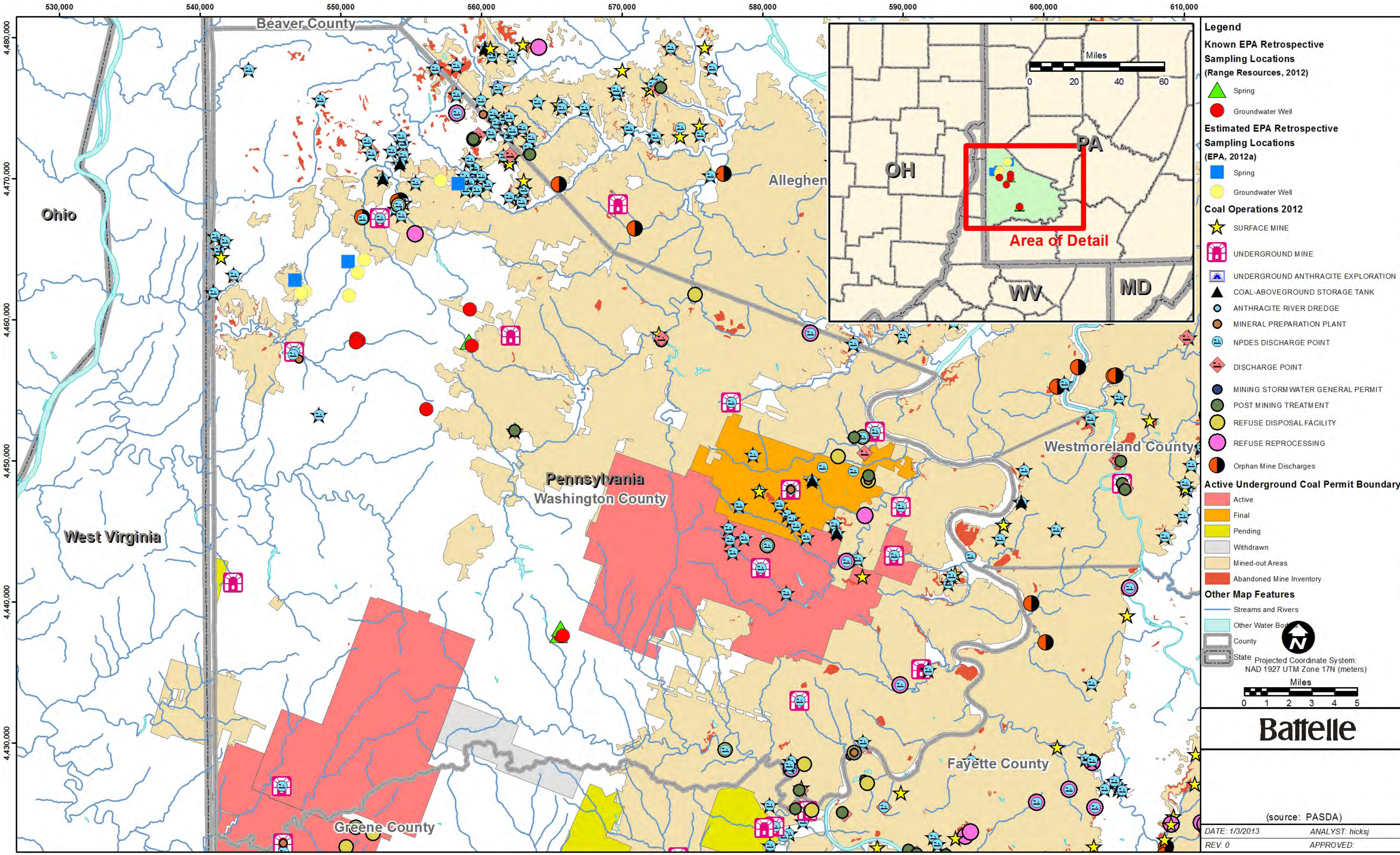

Figure 3-2. Extent of Surface and Underground Coal Mining Activities

As part of the *Draft 2012 Pennsylvania Integrated Water Quality Monitoring and Assessment Report* (PADEP, 2012a), PADEP listed pollution from agriculture to be within the top five activities causing groundwater and surface water contamination. Over 423 miles of streams are documented to be impaired by agricultural runoff (including crop and grazing activities) in the watersheds in Washington County (EPA, 2012c).

Agricultural runoff may include insecticides, herbicides, fungicides, fertilizers (e.g., nitrogen and phosphorous), metals (e.g., arsenic), and other constituents (e.g., dissolved solids, bromide, selenium). In addition, algae blooms caused by agricultural runoff of nitrogen and phosphorous can be a source of organic carbon that promotes the formation of disinfection byproducts (DBPs) upon chlorination of surface water in water treatment plants (EPA, 2005). Agricultural and livestock activities can also be a source of methane (King, 2012).

3.1.3 Other Non-Point Sources and Stormwater Runoff. Runoff from impervious surfaces and other non-point source discharges can affect the quantity and quality of surface water and groundwater recharge. Stormwater runoff from urban areas, suburban residential areas, and roads are known to have caused surface water impairments in the watersheds in Washington County. These include 331 miles of stream impairments caused by urban runoff/storm sewers, 216 miles of stream impairments caused by road runoff, and 176 miles of stream impairments by residential runoff (EPA, 2012c). In addition, habitat modification and uncontrolled runoff from construction sites may cause soil erosion and sediment pollution in nearby streams.

Urban runoff may contain suspended solids, nutrients (e.g., phosphorous), heavy metals (e.g., arsenic, cadmium, mercury), organic contaminants (lawn pesticides, chlorinated solvents), and pathogens. Road runoff from road salt application may contain chloride and bromide (Solars et al., 1982) along with sodium. Washington County hosts nine Pennsylvania Department of Transportation (PENNDOT) salt stockpiles and numerous others in local townships and municipalities. In Washington County, PENNDOT salt usage was 31,311 tons and brine usage was 213,799 gallons in the Winter of 2010 to 2011 (PENNDOT, 2012). Runoff from impervious roadways can also be a source of heavy metals (e.g., iron, lead, zinc) and volatile organic compounds (VOCs; e.g., benzene, toluene, ethylbenzene, and xylene [BTEX]) related to automobile use (EPA, 1995). These inputs occur with rainfall and the concentrations have been found to be dependent on the length of the preceding dry period (Hewitt and Rashed, 1992).

3.1.4 Municipal and Other Wastewater Discharges. Several organizations have noted the impact of inadequate sewage treatment on southwestern Pennsylvania's streams, rivers, and groundwater (Southwestern Pennsylvania Water and Sewer Infrastructure Project Steering Committee [WSIP], 2002; NRC, 2005). Wastewater treatment methods include centralized wastewater treatment plants (WWTPs), decentralized small systems, or on-site sewage disposal. In Washington County as of 2002, approximately 60% of the residences and facilities were connected to public or private WWTPs. In 2005, there were over 40 townships in Washington County identified as high priority areas for sewerage remediation efforts (Washington County, 2005). It was noted that 79 combined sewer overflows (CSOs) existed in Washington County where wastewater would be directly discharged without treatment during storm events (WSIP, 2002). In rural areas and older homes, on-site sewage treatment and disposal may include septic systems, cesspools, or "wildcat" sewers, which are straight pipes that discharge directly to surface water or groundwater (NRC, 2005). The presence of wildcat sewers is a known problem in Washington County (Makin Engineering, 1997).

In the absence of adequate treatment, these wastewater disposal methods may discharge pathogens, household and industrial chemicals, suspended solids, excessive biochemical oxygen demand (BOD), and nutrients into receiving waters. This sewage may contain various household and industrial chemicals and it is estimated that 25% of these chemicals may pass through in the discharge to receiving waters even after treatment at a WWTP (EPA, 1997). Septic systems and on-site disposal can also directly impact water quality in nearby downgradient drinking water wells.

3.1.5 Industrial, Manufacturing, and Commercial Activities. Several types of industrial and manufacturing activities have occurred in Washington County over the years including stone-clay-glass production, steel production, metal fabrication, industrial machinery, and equipment (Washington County, 2005). As a result of these activities, there are over 1,900 facilities or locations with recognized environmental impacts and/or sites that are subject to applicable federal and state environmental regulations. Figure 3-3 shows the location of these facilities in Washington County, and includes over 1,500 sites subject to environmental regulations, 348 storage tank incident sites (both above ground and underground), 86 land recycling cleanup locations, and 13 brownfield sites. It includes facilities that handle wastes subject to RCRA and the Toxic Releases Inventory (TRI) regulations. In addition, this includes NPDES permits in Washington County with allowable discharges of industrial effluent such as a paper mill and other sources; publically owned sewage treatment works (POTWs), active mining operations, stormwater discharges from industrial activities; and discharges from AMD treatment and land remediation systems. Although these are permitted discharges, violations of these permits can occur along with accidental releases above regulatory levels.

In 2010, 58,200 tons of chemicals regulated under the TRI program were discharged into the environment in Washington County from 33 facilities (primarily steel, polymer, and fabrication companies) through on- and off-site disposal or other forms of releases (EPA, 2012d). Between 1988 and 2010, 197 different organic and inorganic chemical constituents were discharged. Chemicals from these types of industrial operations commonly include metals (e.g., aluminum, arsenic, barium, cadmium, chromium, lead, mercury), acids, caustics, cyanides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and chlorinated solvents. In addition, leaking underground storage tanks (USTs) and above ground storage tanks (ASTs) may be associated with contamination of soil and groundwater by petroleum hydrocarbons, BTEX, and oxygenates. Petroleum hydrocarbons released from storage tanks can degrade to methane, but methane is not routinely included in groundwater investigations at USTs and ASTs. Therefore, methane is typically lacking in the secondary data at these sites.

One last note regarding documented releases, the National Academies (2012) estimates that there are at least 126,000 known hazardous waste sites across the U.S. including Superfund sites. It also estimates that approximately 10 percent of Superfund facilities impact public water supply systems, but similar information for other programs is largely not available. Therefore, there is also the potential for existing impacts to water quality from industrial, manufacturing, commercial or other activities that have not yet been documented.

3.1.6 Conventional and Unconventional Oil and Gas Development. Pennsylvania has a rich history of oil and natural gas production, dating back to 1859 when Colonel Edwin Drake drilled his discovery well in Venango County, near the town of Titusville. The Drake well was located approximately 150 ft from the banks of Oil Creek, which was named for the presence of oil from natural seepages. As with most discoveries of this kind, drilling for oil quickly spread over much of western Pennsylvania (Roen and Walker, 1996).

In Washington County, most of the early drilling occurred in the late 1800s and early 1900s. The most prolific oil and gas production occurred at depths of 2,000 to 2,500 ft. The first producing Venango sandstone well in Washington County was drilled in 1882 on the McGuigan farm in the Hickory-Buffalo Consolidated field (Ashley and Robinson, 1992). This initial well was followed 4 years later by the Gordon farm well, which drilled into the Venango sandstone at a depth of 2,392 ft and was the world's deepest oil well at the time (Clapp, 1907). Washington County has two large oilfields, the McDonald Field in the northern part of the county, and the Washington-Taylorstown Field west of the city of

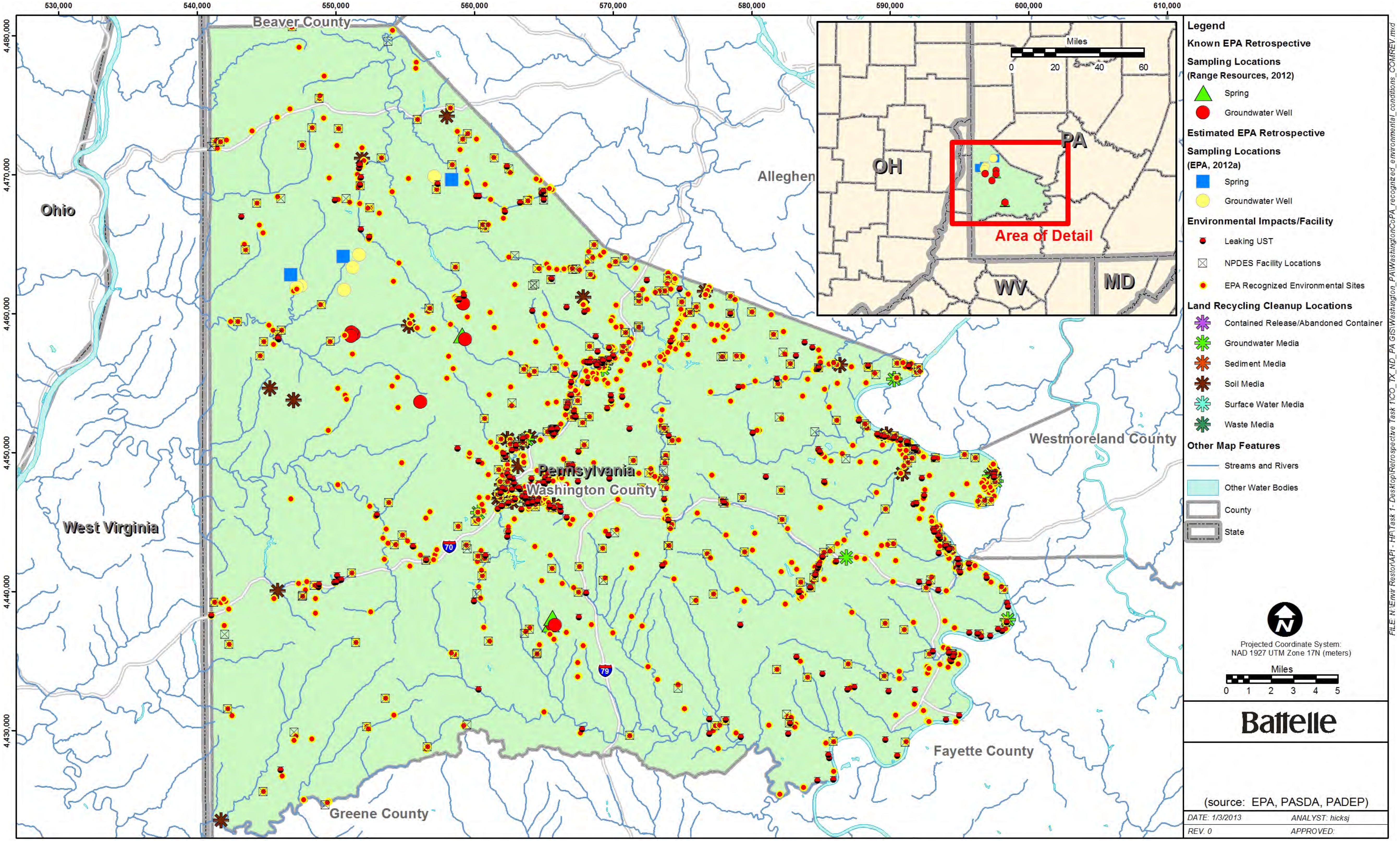

Figure 3-3. Recognized Environmental Impacts/Facilities in Washington County

Washington. The McDonald oilfield may have been the world's largest producing field in the late 1800s until subsequent finds in Texas. Drilling in Washington County has expanded to other oil and natural gas producing intervals including: the Middle Pennsylvanian aged Allegheny sandstone; the Lower and Middle Pennsylvanian Pottsville Group (Pottsville sand, First Salt sand, Second Salt sand, Third Salt sand and Sharon sand); the Lower Mississippian Big Injun sand; and the Upper Devonian Berea sand. In addition, seven natural gas fields were converted to underground natural gas storage areas including six of these storage fields that are still active today.

Figure 3-4 shows the locations of over 11,600 conventional oil and gas wells drilled in Washington County including 6,600 from PADEP records and 5,000 from industry and other historic records. Because of incomplete historic records, well numbers and locations have some inherent uncertainty and many early wells are undocumented. Permitting and registration were not required by the state of Pennsylvania until the 1960s. Little is known about the construction, production, and abandonment procedures for these historic oil and gas wells. It is important to note that although many of these early oil and gas wells have been abandoned, some remain in production today. Additionally, a portion of the Washington-Taylorstown oilfield, located west of the City of Washington, Pennsylvania, has been redeveloped for secondary recovery and is currently under waterflood. Pennsylvania had no official plugging regulations for oil and gas wells until the passage of Act 223 in 1984. It is also known that casing from many wells was removed during World War II to support the country's steel requirements. Moreover, the construction of these older wells (i.e., lack of cemented casing) may be a factor in subsurface migration of methane, crude oil and other constituents. Wells have been hydraulically fractured in Washington County since the 1960s. From 1970 to April 2012, over 900 oil and gas wells were drilled in Washington County to produce formations above the Marcellus (from 2,000 to 5,000 ft) with the majority of these vertical wells having been hydraulically fractured. The Marcellus wells are typically deeper than these shallower conventional wells, being between 5,000 to 7,000 feet in depth.

Figure 3-5 shows the location of unconventional shale gas wells drilled into the Marcellus in Washington County. The first producing Marcellus shale well in Washington County was completed by Range Resources in 2004. The Renz #1 was drilled in 2003 and the first hydraulic fracturing event occurred in October of 2004 (Universal Well Services, 2004). Between 2003 and 2011, 559 wells were drilled in the Marcellus formation in Washington County (PADEP, 2012b). Only a portion of wells have been hydraulically fractured to date due to an inherent lag time in well completion activities. Approximately 50% of these drilled wells were in active production in 2011 (PADEP, 2012b).

Petroleum hydrocarbons can migrate in the environment in close proximity to oil and gas deposits and seeps, whether such migration is naturally occurring or caused from abandoned or poorly constructed wells that penetrate hydrocarbon-bearing zones. Metals, salts, and naturally-occurring radioactive materials (NORM) also may be present in the environment near these deposits or seeps. Due to the high level of historic oil and gas drilling in Washington County, migration pathways may exist from the historic producing horizons to shallow groundwater aquifers. The oil and gas industry is aware of the potential pathways associated with historic oil and gas wells, and has identified several approaches for evaluating these pathways (e.g., using remote sensing technologies and on-the-ground field surveys [e.g., McKee, 2012]). Oil and gas regulatory agencies in producing states proactively manage orphan wells within their jurisdiction, generally evaluating the potential risk posed by each identified well, and mitigating the highest risk wells first. The Interstate Oil & Gas Compact Commission (IOGCC) formed an Orphan Well Task Force to address the requirements in Section 349 of the Energy Policy Act of 2005. This Task Force provides for the establishment of a program to provide technical and financial assistance to oil and gas producing states to deal with environmental issues associated with abandoned or orphan wells. In summary, although the potential for pathways exists, industry and state agencies are well aware of the situation and are taking steps to mitigate those risks.

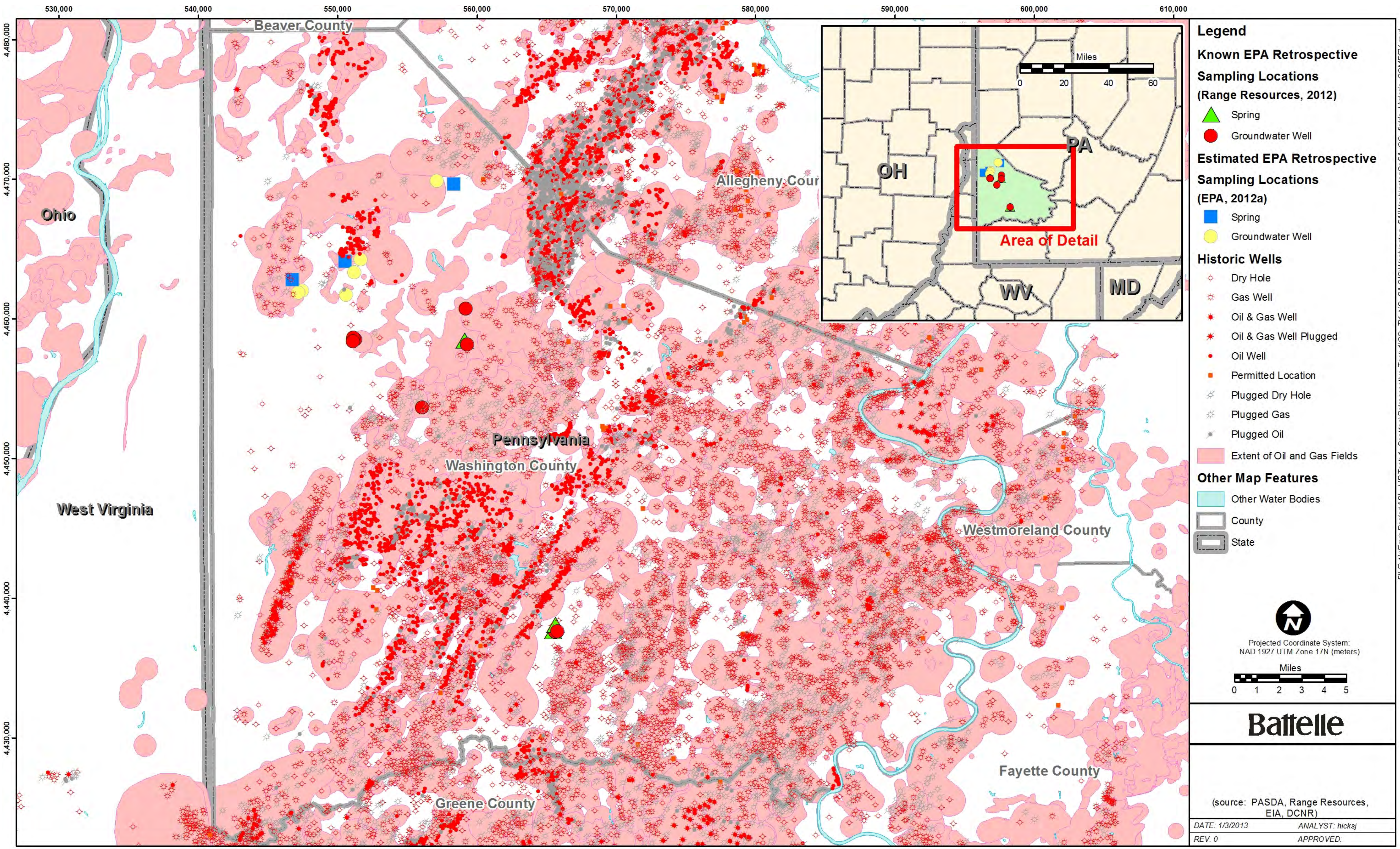

Figure 3-4. Historic Oil and Gas Fields and Conventional Oil and Gas Well Locations

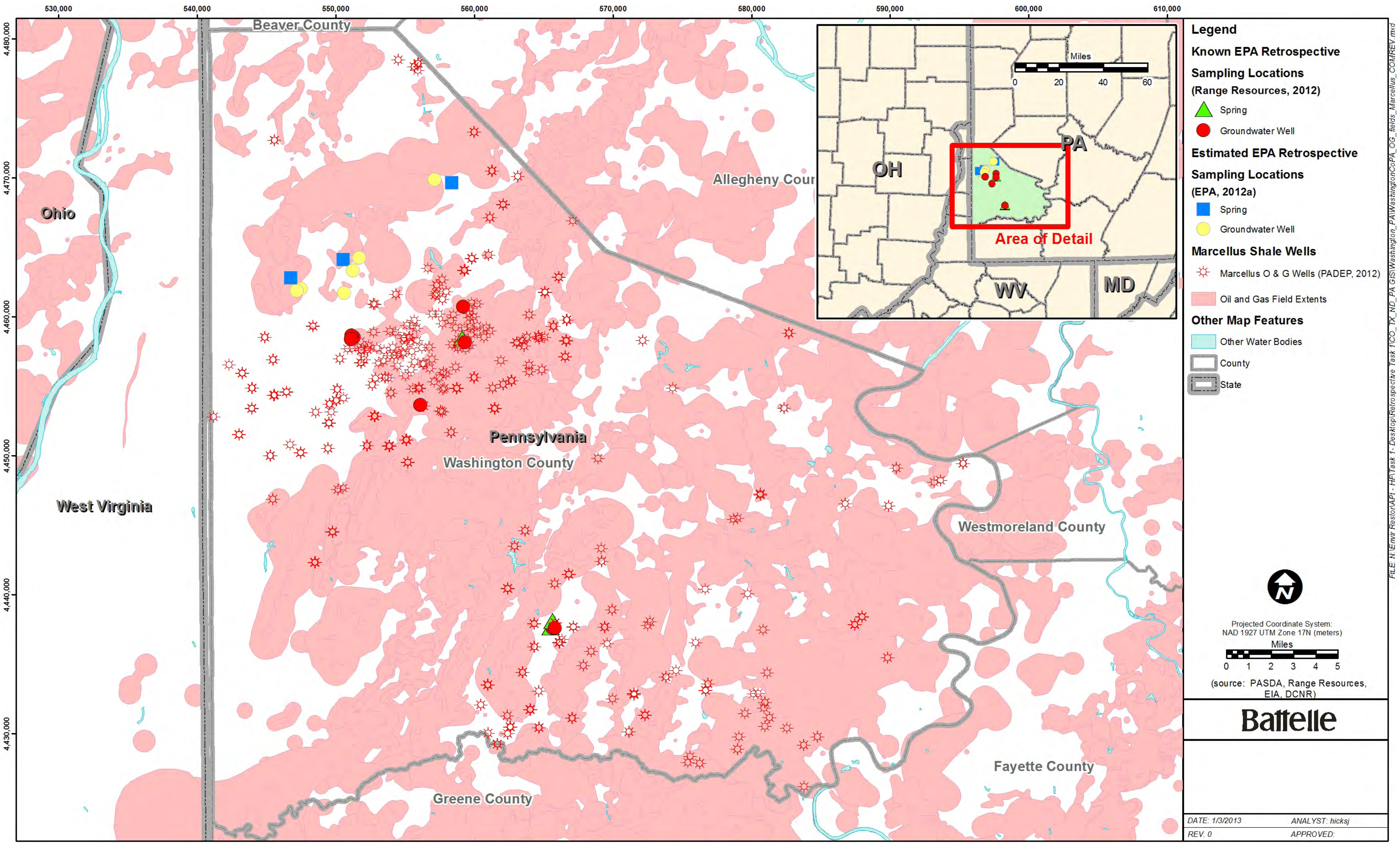

Figure 3-5. Unconventional Shale Gas Well Locations (Marcellus Only)

3.2 Groundwater Quality

This section summarizes the groundwater resources in Washington County, including the major groundwater-bearing units and available groundwater quality data in comparison to screening criteria.

3.2.1 Hydrogeology. Groundwater resources occur within shallow unconsolidated Quaternary alluvial deposits and consolidated Permian and Pennsylvanian age sedimentary rocks in Washington County (Table 3-2). These consolidated rocks dip gently toward the south. The depth to groundwater in Washington County is generally less than 100 feet, and is commonly at depths less than 40 feet. Due to the southerly dip, groundwater wells of similar depth in the northern part of the county are completed in older bedrock than those to the south. Salinity generally increases with depth within the sedimentary rocks with elevated levels of salts and TDS at depths greater than 300 feet. Drainage basins within Washington County tend to be small, and shallow groundwater flow is typically consistent with surface topography. Figure 3-6 depicts the shallow groundwater-bearing formations in Washington County.

Table 3-2. Shallow Permian and Pennsylvanian Hydrogeology in Washington County, PA

Group	Formation(s)	Thickness (ft bgs)	Lithology	Hydrogeology
Alluvium	Holocene Alluvium	0-63	Unconsolidated clay, silt, sand and gravel	Strong yields in high permeability deposits.
Dunkard	Greene Washington	100-550	Shales and fine-grained sandstone interbedded with coal and limestone	Moderate yield from sandstones.
Monongahela	Pittsburgh Redstone Sewickley Uniontown	50-400	Limestone beds, shale, discontinuous sandstone and coal beds	Moderate yields from limestone.
Conemaugh	Glenshaw Casselman Conemaugh Morgantown	50-440	Grey, green, and red shales with discontinuous sandstones; lesser amounts of limestones, and coal	Moderate yield from sandstone

Unconsolidated alluvial deposits in Washington County are the source of high-yielding wells, especially near major rivers and streams. Information regarding specific well yields is limited; however, PADEP (1999) states that yields of up to 500 gallons per minute (gpm) are not uncommon. These yields are highly variable over small distances because of the changes in sorting (Poth, 1973). Typically, water from the alluvium is hard and has high concentrations of iron, manganese, and TDS.

Groundwater yield in the consolidated rocks is defined by the density and interconnection of rock fractures. The Permian and Pennsylvanian aged water-bearing units yield, on average, nearly two orders of magnitude less water than the shallow alluvial deposits (PADEP, 1999). The yield in the consolidated rocks is, however, somewhat variable and is defined by the density and interconnection of rock fractures. The Dunkard Group is comprised of two major water-bearing formations, the Greene Formation and the Washington Formation. The Greene Formation is made up of sandstone (Fish Creek Sandstone Member), limestone (Donley Limestone Member), and coal beds. The sandstone is the major water-bearing unit of this group and typically has moderate yields of between 1 and 35 gpm with moderately hard water. The Washington Formation consists of interbedded shale, sandstone, and coal with some thin, discontinuous

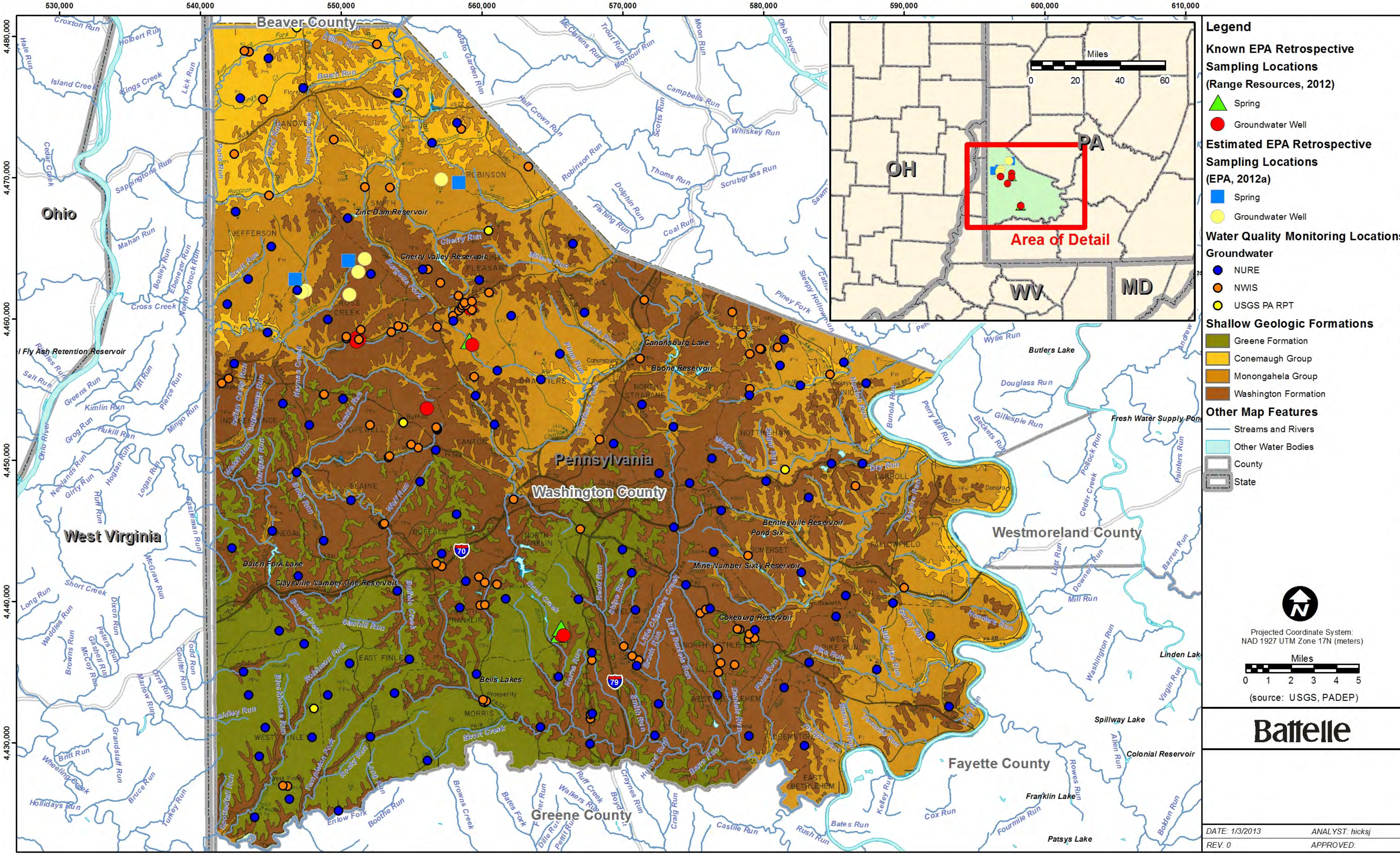

Figure 3-6. Shallow Groundwater-Bearing Formations and Groundwater Quality Monitoring Locations in Washington County, PA

limestones. The Washington Formation is generally a poor producer with well yields ranging from 1 to 70 gpm and a median of about 2 gpm. As noted above, coal seams are present in aquifers within the Dunkard Group, and could act as a natural source of methane gas.

The Monongahela Group is comprised of the Pittsburgh and Uniontown Formations, which are made up of limestone, shale, sandstone, and coal. Physical and chemical diagenesis has enlarged fractures in the limestones, resulting in the main water-bearing units of this group, augmented by some fractured shales. The Conemaugh Group consists of the Glenshaw and Casselman Formations, which are made up primarily of sandstone and shale with lesser amounts of limestone and coal. The water-bearing units in this group are the sandstones, which have variable yields depending on local permeability conditions. Water can also be obtained from fractures in the limestones, shales, and shallow coal beds in this unit. Yields range from small to moderate and are highly variable. Water contained in deeper Mississippian and Upper Devonian deposits is not used for drinking water because it is typically iron-rich and saline, with high amounts of TDS. Salinity and TDS in these rocks increase with depth, and ultimately the water is considered sodium chloride brine at depths greater than 1,000 ft. As noted above, coal seams present in Monongahela and Conemaugh Group aquifers could act as a natural source of methane gas.

The USGS completed several studies as part of its National Water-Quality Assessment (NAWQA) program that are important to the understanding of groundwater quality in Washington County. The major objectives of the program were to provide a consistent description of water quality conditions for the Nation's resources as well as identify long term trends and factors affecting water quality. One of the principle aquifers evaluated included the Allegheny-Monongahela River Basin which intersects Washington County. An early assessment (USGS, 1995) identified contamination (acidity, trace metals, sulfate, and dissolved solids) of surface and groundwater from AMD as the most significant source of water quality degradation. Degradation of water quality was also noted from oil and gas operations (brines, methane, trace metals and organic compounds), industry (organic compounds and trace elements), urban runoff (nutrients, bacteria, turbidity), pesticides and herbicides, and naturally occurring radiochemicals (especially radon).

Recent USGS studies (DeSimone, 2009; Ayotte et al., 2011) examined water quality in principal aquifers across the U.S. from data collected in the 1991-2004 timeframe. While not specific to Washington County, both studies demonstrate the importance of understanding factors that contribute to observed water quality and identify important considerations for making comparisons between data collected from different locations and times.

DeSimone (2009) assessed contamination in domestic wells, variation among and within aquifers, and the co-occurrence of contaminants. Compounds found most frequently at concentrations greater than human health benchmarks were naturally occurring (radon, fluoride, gross alpha- and beta-particle radioactivity, arsenic, iron, manganese, strontium, boron, and uranium), with the exception of nitrate and fecal indicator bacteria. Patterns of occurrence related to rock type, land use, and geochemical conditions were also noted.

Ayotte et al. (2011) provided a comprehensive analysis of trace elements occurrence in groundwater across the U.S. This study illustrates the importance of understanding how climate, well construction, geologic composition of aquifer and aquifer geochemistry affect trace elements detected in water quality. For example, aluminum, copper, iron, lead and manganese were detected in greater concentrations in humid regions (Washington County is characterized as humid region in the report) relative to dry regions due most likely to acidic and anoxic conditions. Concentrations of copper, lead, radon, and zinc were significantly greater in drinking water wells than in monitoring wells. Copper, lead, and zinc are found in pumps and pipes used in water well construction and may explain their elevated concentration in drinking water wells. Many trace elements (aluminum, antimony, barium, boron, chromium, cobalt, iron, manganese, molybdenum, nickel, selenium, strontium, and uranium) were all greater in monitoring wells than drinking water wells in humid regions. Land use (e.g., agricultural vs. urban), aquifer composition, and geochemistry were major factors affecting trace element concentrations in groundwater.

In Pennsylvania, over 3 million residents obtain their water from private groundwater wells. A majority of these private wells are completed in bedrock, and derive groundwater from local flow. Wells are commonly completed in consolidated bedrock or co-completed in both unconsolidated and consolidated formations, and are open hole completions with casing pounded to bedrock, often with no seal or grout. The state of Pennsylvania has established groundwater well installation regulations for public water supply wells. However, the state does not regulate the construction of private water wells, and currently there are no requirements regarding the location, construction materials, water quality or yield, of these wells. To operate in the state of Pennsylvania, groundwater well drilling companies are required to have a water well driller's license and valid rig permit. Upon well completion, drillers must provide a copy of the well completion report to the state and the home owner that describes the well location and construction method used (PA DCNR, 2010).

Poor groundwater well location and well construction are key factors resulting in water supply contamination. Several studies have been conducted in an attempt to evaluate whether groundwater quality can be compromised by poor well construction. As part of the National Water Quality Assessment Program, the USGS (Bickford et al., 1996) conducted a study of the Lower Susquehanna River basin and found that "nearly 70% of the [146] wells tested had total coliform present and thus were not suitable for drinking water without treatment." The majority of the wells sampled in this investigation were not sealed or grouted, and the USGS concluded that poor well construction can allow contaminated surface water or shallow groundwater to enter the well.

A statewide survey of 701 (450 wells in 2006; 251 wells in 2007) private wells conducted by the Pennsylvania Master Well Owner Network in 2009 showed that wells with poor construction had poor water quality and noted that statewide regulations requiring well construction components appeared to be warranted (Swistock et al., 2009). The wells in this study ranged in depth up to 1,000 feet with an average depth of 172 feet. All Pennsylvania counties were included in this study. The study found poor well construction was the most important factor for the elevated levels of coliform bacteria observed in 33% of the wells. Water quality was also found to be strongly tied to aquifer geology and associated with land use.

In response to growing concern regarding poor groundwater quality, several regulations have been proposed and a number of publications have been presented addressing the problem. The state of Pennsylvania has provided a fact sheet listing guidelines on siting and completion of private wells (PA DCNR, 2010). In 2009, Pennsylvania State University (PSU) released a guidance document (PSU, 2009) that was designed to assist homeowners on the proper construction, installation, and maintenance of private water systems. House Bill 1855 has been introduced in the Pennsylvania legislature to set statewide construction standards for residential wells; this bill was referred to Committee on Consumer Affairs in December 7, 2011 with hearings and testimony provided in January 2012 (Pennsylvania Groundwater Association [PGWA], 2012).

In 2010 and 2011, water quality data was collected near gas wells before and after hydraulic fracturing in 20 counties across Pennsylvania including several wells in Washington County (Boyer et al., 2011). Phase 1 included sampling of 42 wells within 2,500 feet of a gas well and 6 control wells. Phase 2 included 172 wells within 5,000 feet of a gas well and 13 control wells (>25,000 feet from nearest gas well). Phase 1 sampling included both pre and post hydraulic fracturing data; Phase 2 sampling consisted of only post hydraulic fracturing data. Note that for this study, pre and post hydraulic fracturing refer to sampling time relative to nearby gas wells. Findings from Boyer et al. (2011) include:

- 40% of water wells failed at least one Safe Drinking Water Act standard before gas drilling commenced with coliform bacteria, turbidity and manganese most common
- 20% of water wells had a detectable level of methane before gas drilling began
- Statistical analyses of pre- and post-drilling did not suggestion any major influences due to gas drilling; there was no significant correlation to distance from drilling, and no statistically significant increase for methane or constituents prominent in drilling waste fluids (e.g., TDS, chloride, sodium, sulfate, barium, and strontium);

Boyer et al. (2011) also noted that the results of their study should be used and interpreted with caution due to the short duration of the study. Additional research that include a larger number of study wells and control wells along with numerous pre and post drilling samples are needed to investigate potential for subtle water quality effects between pre and post drilling.

Groundwater Wells within Washington County

The PA DCNR stores well completion report data in a database known as the Pennsylvania Groundwater Information System (PA GWIS), which has collected data from drillers since 1969. Water quality data are not collected or stored in PA GWIS. For Battelle's groundwater well evaluation, only wells that were identified for domestic, commercial, industrial, public supply, or recreational water withdrawal were included. Also, not all groundwater well records within the PA GWIS database are complete. The PA GWIS database has 3,545 records for groundwater wells completed in Washington County, although only 1,965 wells include coordinates that allow for accurate location on a base map. The database confirms that groundwater is present and extracted from relatively shallow depths in Washington County, with a median well depth of 110 ft and a median depth to groundwater of 46 ft, well above proficient oil and gas production zones located at depths of 2,000 to 2,500 ft (although it should be noted that minor production from shallower zones has been documented). Groundwater wells in the PA GWIS database typically extract groundwater from unconsolidated deposits of Quaternary alluvium, consolidated deposits of the Permian age Dunkard Group, and the Pennsylvanian age Monongahela and Conemaugh Groups. As mentioned earlier, due to the south trending dip, groundwater wells of similar depth in the northern part of the county are completed in older bedrock than those to the south. Most residents of Washington County derive their drinking water from public supplies derived from the Monongahela River in Allegheny County.

3.2.2 Groundwater Data Summary. Groundwater quality data from sources identified in Table 2-2 (complete dataset) were compiled by Battelle into a database to characterize Washington County groundwater quality prior to unconventional oil and gas development (i.e., pre-2005). Summary tables were compiled as noted in Section 2.0 for the complete dataset (includes data potentially associated with environmental impacts) and for a reduced dataset that removed data potentially associated with environmental impacts. The data represent samples collected from 1926 to 2002 (no data are available from 2002-2005). Groundwater data were available from 207 wells. All but one well within this dataset contains results from a single groundwater sample; the remaining well contains two samples. Therefore, assessing time series water quality data at individual groundwater sampling locations is not possible with the current dataset. Figure 3-6 shows the groundwater sampling locations overlain on a map of shallow groundwater-bearing formations in Washington County. Known (eight wells and three springs) and estimated (six groundwater monitoring wells and three springs) EPA sampling locations for springs and groundwater for the Washington County retrospective case study also are included on Figure 3-6.

The available groundwater quality data consist primarily of general water quality parameters, major ions, metals, and nutrients. Only two samples included the analysis of VOCs for six analytes (m (and p)-xylene, benzene, ethylbenzene, methyl tert butyl ether [MTBE], o-xylene, and toluene) and only one sample was analyzed for both VOCs and semivolatile organic compounds (SVOCs). Many general water quality parameters, major and minor ions, metals, and nutrients have a limited number of results.

Table 3-3 (the complete dataset that includes data potentially associated with environmental impacts) provides a pre-2005 listing of parameters detected, number of samples, minimum, maximum, median, mean, standard deviation, date range for sample collection, and comparison against water quality standards and criteria, including the number of results above each screening criteria. For groundwater, the standards and criteria include the MCL, SMCL, Pennsylvania Act 2, EPA Region III carcinogenic and non-carcinogenic criteria. Section 2 provides an explanation of water quality screening criteria and how summary statistics were calculated. Table 3-3 also identifies those parameters monitored by EPA and includes a designation of whether the parameter is a critical analyte (CA) or a measured (M) parameter per the EPA QAPP (EPA, 2012b). Appendix B includes a listing of all groundwater data collected for Washington County.

Inorganic Summary. As indicated in Table 3-3, the observed concentration is above one or more of the screening criteria for three general water quality parameters: pH, TDS, and sulfide. For major ions (chloride, fluoride, sodium, and sulfate), the maximum observed concentration is above one or more screening criteria. Chloride, sodium, and sulfate are identified as EPA critcal analytes, whereas fluoride is identified as a EPA measured analyte. Chloride was higher than the SMCL of 250 mg/L in seven samples, with a maximum concentration of 1,200 mg/L and a mean concentration of 54 mg/L. Sodium was higher than the EPA Health Advisory level of 20 mg/L in 81 samples, with a maximum concentration of 900 mg/L and a mean concentration of 58 mg/L. The seven elevated chloride detections were compared against paired calcium and sodium data to attempt to determine the cause of the elevated detection (i.e., correlation of high chloride with high sodium would suggest a source such as road salt). In five of the six cases where chloride is higher than the SMCL, sodium concentrations are nearly an order of magnitude greater than the overall mean concentration of all sodium samples. Conversely, in all six cases where chloride is higher than the SMCL, calcium concentrations are lower than the overall mean concentration of all calcium samples. These data suggest the chloride values above SMCL are due to sodium chloride input and not related to oil and gas development. It should be noted that each of the six samples were collected between July and September when road salt is not applied; however, groundwater contamination from road salt application can occur over a period of months to years due to many factors impacting recharge of groundwater aquifers.

Sulfate was higher than the SMCL of 250 mg/L in four samples with a maximum detection of 1,800 mg/L and mean concentration of 85 mg/L. Sulfate is commonly associated with mining and high sulfate concentrations are indicative of AMD. Average sulfate concentrations in produced water associated with oil and gas development are typically less than 10 mg/L. Fluoride concentrations were detected above the MCL, SMCL, Pennsylvania Act 2, and the EPA Region III non-carcinogenic criteria.

The minimum, maximum, and/or mean observed concentration is higher than one or more of the screening criteria for several metals, including aluminum, arsenic, chromium(VI), iron, lead, manganese, and nickel. For both arsenic and chromium(VI), observed concentrations are above EPA Region 3 carcinogenic risk screening levels. Iron is above the SMCL and EPA Region III non-carcinogenic criteria, lead is above the MCL and Pennsylvania Act 2 criteria, manganese is above the Pennsylvania Act 2 criteria and EPA Region III non-carcinogenic criteria, and nickel is above the Pennsylvania Act 2 criteria. Of the metals noted here, all are EPA measured analytes with the exception of arsenic (CA) and chromium(VI) (not included on EPA's parameter list for Washington County [EPA 2012b]). One nitrate as N sample (16.9 mg/L) is above the MCL of 10 mg/L. Figure 3-7 shows the spatial distribution of inorganic parameters in groundwater detected above the screening criteria.

Table 3-3. Washington County Groundwater Summary Data (Includes Environmental Impact Data)

											Including NDs			Excluding NDs															
Class	Parameter	Field Results	Frac.	Units	EPA Class	No. Samples	No. Locations	No. ND	Min	Max	Median	Mean	SD	Median	Mean	SD	Begin Sample Date	End Sample Date	MCL	N Above MCL (no NDs)	SMCL	SMCL High	N Above SMCL (no NDs)	Act 2	N Above Act 2 (no NDs)	EPA Carc.	N Above EPA Carc. (no NDs)	EPA Non-Carc.	N Above EPA NonCarc. (no NDs)
Dissolved Gas	Carbon dioxide	No	Tot.	mg/l	M	88	87	0	0.6	224	19	26	28.4	19	26	28.4	Nov-67	Sep-97											
Gen WQ	Alkalinity as CaCO3	Yes	Tot.	mg/l	M	100	98	0	37	720	250	277	117	250	277	117	Sep-26	Sep-97											
Gen WQ	Hardness as CaCO3	No	Tot.	mg/l	-	100	98	0	6.18	1380	252	260	189	252	260	189	Sep-26	Sep-97											
Gen WQ	Hardness, non-carbonate as CaCO3	Yes	Tot.	mg/l	-	9	9	0	8	300	76	109	105	76	109	105	Sep-26	Sep-85											
Gen WQ	pH	No	Tot.	std units	M	81	81	0	5.9	8.7	7.4	7.49	0.42	7.4	7.49	0.42	Aug-83	Sep-97			6.5	8.5	2						
Gen WQ	pH	Yes	Tot.	std units	M	192	192	0	5.9	9.1	7.3	7.35	0.461	7.3	7.35	0.461	Nov-67	Jul-01			6.5	8.5	11						
Gen WQ	Specific conductance	No	Tot.	umho/cm	M	80	80	0	409	4430	694	931	706	694	931	706	Aug-83	Sep-97											
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	196	195	0	80	4400	640	769	528	640	769	528	Nov-67	Jul-01											
Gen WQ	Sulfide	No	Tot.	ug/l	M	61	61	59	250	600	250	260	54.6	550	550	70.7	Aug-83	Sep-84						5	2				
Gen WQ	Temperature, water	No	Tot.	deg C	M	98	96	0	10	23.5	16.7	16.7	3.32	16.7	16.7	3.32	Sep-26	Jul-01											
Gen WQ	Total dissolved solids	No	Dis.	mg/l	-	99	97	0	225	2860	419	558	429	419	558	429	Sep-26	Sep-97				500	33						
Inorganics, Major, Non-metals	Silica	No	Dis.	mg/l	-	96	94	0	6.8	26	11.8	12.1	3.56	11.8	12.1	3.56	Sep-26	Sep-97											
Major Anions	Bromide	No	Dis.	mg/l	M	38	38	0	0.011	1.867	0.0505	0.166	0.389	0.0505	0.166	0.389	Jul-78	Sep-97											
Major Anions	Chloride	No	Dis.	mg/l	CA	190	188	0	1.4	1200	16.6	52.7	133	16.6	52.7	133	Sep-26	Sep-97				250	7						
Major Anions	Fluoride	No	Dis.	mg/l	M	158	157	2	0.019	5.5	0.2	0.358	0.707	0.2	0.362	0.711	Jul-78	Sep-97	4	2		2	6	4	2			0.62	17
Major Anions	Sulfate	No	Dis.	mg/l	CA	100	98	0	0.6	1800	53.7	85.3	195	53.7	85.3	195	Sep-26	Sep-97				250	4						
Major Cations	Calcium	No	Dis.	mg/l	CA	98	96	0	1.5	400	73.5	73.8	51.1	73.5	73.8	51.1	Sep-26	Sep-97											
Major Cations	Magnesium	No	Dis.	mg/l	CA	184	182	0	0.59	130	11	14.9	15.8	11	14.9	15.8	Sep-26	Sep-97											
Major Cations	Potassium	No	Dis.	mg/l	CA	97	95	0	0.5	9.6	1.7	2.1	1.43	1.7	2.1	1.43	Sep-26	Sep-97											
Major Cations	Sodium	No	Dis.	mg/l	CA	191	189	0	1.85	900	15	57	121	15	57	121	Sep-26	Sep-97	20	81									
Metals	Aluminum	No	Dis.	ug/l	M	102	101	5	3.3	2500	21	83.8	291	21	86.6	296	Nov-67	Sep-97				200	5					16000	0
Metals	Arsenic	No	Dis.	ug/l	CA	10	10	2	0.5	4	3	2.4	1.24	3	2.88	0.835	Aug-83	Sep-97	10	0				10	0	0.045	8	4.7	0
Metals	Boron	No	Dis.	ug/l	CA	82	82	6	10	490	70	108	103	75	116	103	Aug-83	Sep-85						6000	0			3100	0
Metals	Cadmium	No	Dis.	ug/l	M	9	9	9	ND	ND	ND	ND	ND	ND	ND	ND	Aug-83	Sep-97	5	0				5	0			6.9	0
Metals	Chromium(VI)	No	Dis.	ug/l	-	9	9	7	0.5	1	0.5	0.611	0.22	1	1	0	Aug-83	Aug-85						100	0	0.031	2	31	0
Metals	Dysprosium	No	Dis.	ug/l	-	107	107	104	0.0005	0.04	0.0005	0.00142	0.0055	0.03	0.0333	0.00577	Jul-78	Jul-78											
Metals	Iron	No	Dis.	ug/l	M	66	65	4	1.5	87000	21	1830	10800	35	1920	11100	Sep-26	Sep-97				300	16					11000	1
Metals	Iron	No	Tot.	ug/l	M	86	86	0	20	130000	185	2390	14100	185	2390	14100	Aug-83	Oct-89				300	33					11000	2
Metals	Lead	No	Dis.	ug/l	M	8	8	6	0.5	200	0.5	25.5	70.5	101	101	141	Aug-83	Sep-97	15	1				5	1				
Metals	Manganese	No	Dis.	ug/l	M	105	104	3	0.5	2000	53	154	273	62	159	275	Nov-67	Sep-97				50	54	300	15			320	13
Metals	Manganese	No	Tot.	ug/l	M	85	85	11	5	1900	20	115	268	40	131	284	Aug-83	Sep-85				50	28	300	10			320	9
Metals	Mercury	No	Dis.	ug/l	M	9	9	7	0.05	0.2	0.05	0.0722	0.0507	0.15	0.15	0.0707	Aug-83	Aug-85	2	0				2	0			0.63	0
Metals	Nickel	No	Dis.	ug/l	M	9	9	6	0.5	200	0.5	23.3	66.3	5	68.8	114	Aug-83	Sep-97						100	1			300	0
Metals	Selenium	No	Dis.	ug/l	CA	10	10	9	0.5	1	0.5	0.55	0.158	1	1		Aug-83	Sep-97	50	0				50	0			78	0
Metals	Strontium	No	Dis.	ug/l	CA	8	8	0	310	6700	580	1340	2170	580	1340	2170	Aug-83	Aug-85										9300	0
Metals	Uranium	No	Dis.	ug/l	M	108	108	1	0.01	1.501	0.217	0.291	0.263	0.215	0.289	0.264	Jul-78	Sep-97	30	0									
Metals	Vanadium	No	Dis.	ug/l	M	107	107	101	0.05	3.1	0.05	0.114	0.376	0.55	1.18	1.24	Jul-78	Jul-78						260	0			78	0
Metals	Zinc	No	Dis.	ug/l	M	9	9	1	1.2	1100	30	147	358	30	164	378	Aug-83	Sep-97				5000	0	2000	0			4700	0
Nutrients	Nitrate as N	No	Dis.	mg/l	CA	13	13	2	0.01	16.9	0.15	2.13	5.08	0.18	2.51	5.46	Sep-26	Sep-97	10	1				10	1			25	0

M – measured, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
CA = Critical Analyte, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
A red highlight indicates the value is above a screening criteria.
MCL: EPA Maximum Contaminant Levels (National Primary Drinking Water Regulation)
SMCL: EPA Secondary MCL (Non-enforaceable guidance for drinking water)
Act 2: State of Pennsylvania Land Recycling Program (Voluntary Remediation Program) Screening Limits: Limits are for used, residential groundwater aquifer with TDS ≤ 2500 mg/L
EPA Carc./EPA Non-Carc.: The carcinogenic and non-carcinogenic screening limits established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level.

SD = standard deviation
ND = non detect

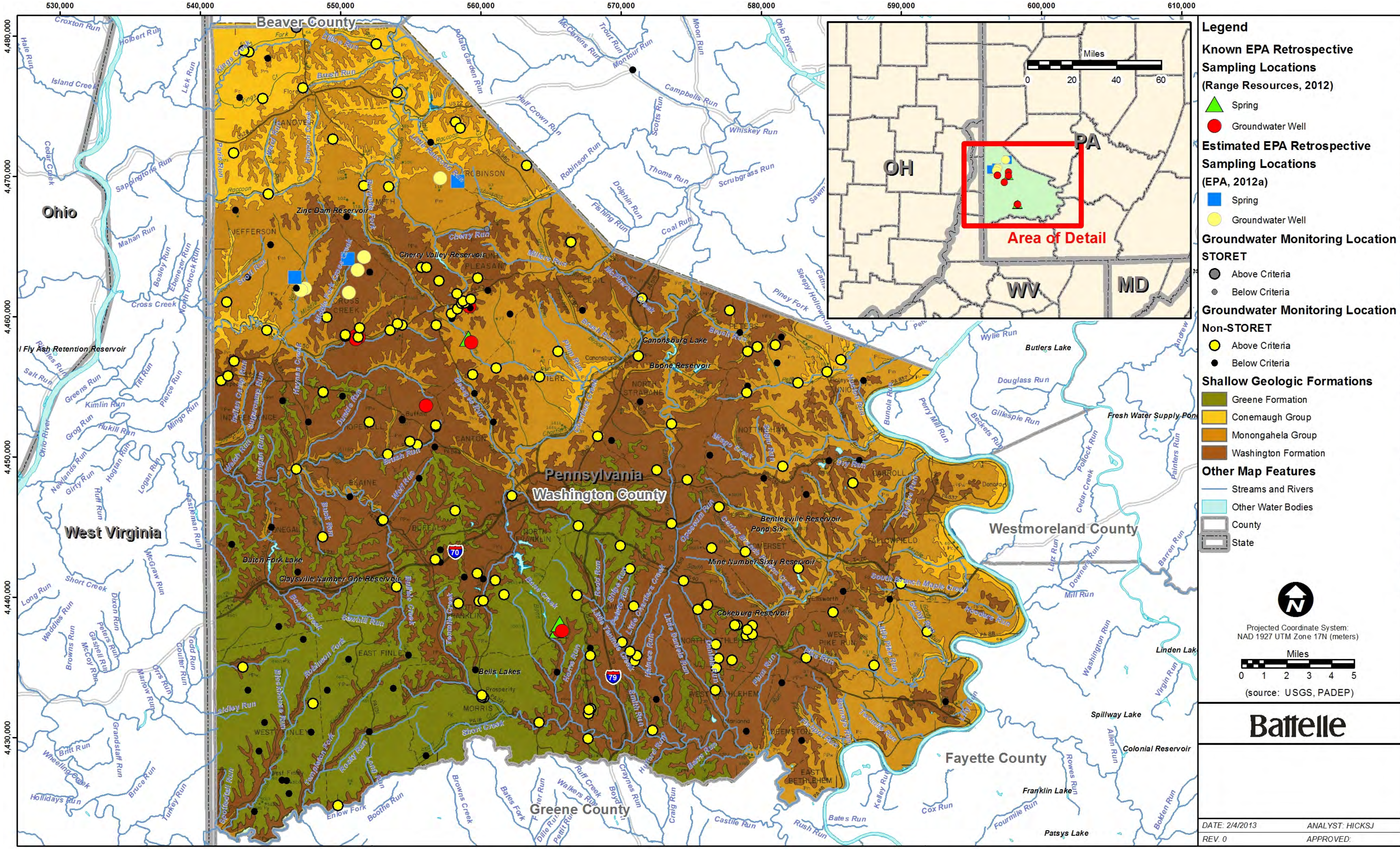

Figure 3-7. Groundwater Detections above Screening Criteria in Washington County, PA

Organic Summary. There are limited data for organic compounds, with only one or two sample results available. Therefore, none of the organic compounds have sufficient observations to characterize background groundwater quality for Washington County.

3.2.2.1 Comparison Against Reduced Data Table. Table 3-4 provides a summary of pre-2005 groundwater data in similar format to Table 3-3, with the exception of the five locations (three from NURE and two from USGS) that were removed based on the reasoning provided in Table 2-3. This summary data table was created for comparison against the complete background groundwater quality summary data table (Table 3-3) to determine whether the data identified as indicative of environmental impact monitoring or having location issues has a significant effect of background water quality values.

The parameters that are above screening criteria in the reduced summary data table (Table 3-4) are identical to those in the comprehensive data summary table, and include pH, TDS, sulfide, chloride, fluoride, sodium, and sulfate, aluminum, arsenic, chromium(VI), iron, lead, manganese, nickel, and nitrate as N. The maximum detected values for these parameters also are identical when comarping the two datasets, as are the respective screening criteria that are not met and the number of detections above these criteria (with the exception of one total iron value above the SMCL that was removed in the reduced dataset). Figure 3-7 shows the spatial distribution of parameters in groundwater in the complete and reduced data set detected above the screening criteria. For alkalinity, pH, chloride, sodium, sulfate, fluoride, arsenic, chromium(VI), lead, manganese, nickel, dissolved iron, and nitrate as N, there is minimal or no difference between the two datasets when comparing the summary statistics (mean, median, and standard deviation). For TDS, aluminum, and total iron the mean and median values are higher in the reduced dataset, suggesting the removed data had lower chemical concentrations. These results suggest that that the data in the two datasets are similar.

3.2.2.2 ANOVA Comparison. The available groundwater quality data span the period 1926-2002. Over this time, there have been changes in environmental policy and in analytical methods. To determine if older data can be comingled with more recent data, an analysis of variance (ANOVA) was completed using the complete dataset (including environmental impact monitoring data). Changes in environmental policy occurred in the early 1970s with the passage of the CWA (1972) and the SDWA (1974), and with these came increased awareness of water quality related issues and implementation of more standardized analytical methods. The year the CWA was implemented (1972) was selected for the comparison; data collected prior to 1972 were compared with data collected from 1972-2002 to determine if significant differences exist between the two datasets. Parameters analyzed included calcium, chloride, magnesium, sodium, and sulfate in the dissolved fractions. These parameters were selected because they are commonly detected in both time periods and are also expected to be present in any future groundwater quality data collected as part of the EPA case study or provided with data collected by operators. For the five parameters, the analyses indicated that there is not a significant difference between the pre-1972 and 1972-2005 data, suggesting the data from the two periods can be combined together as presented in Table 3-3. A more detailed explanation of the ANOVA are included in Appendix C.

3.2.2.3 Formation Comparison. Groundwater is derived from geologic formations as described in Section 3.2.1. Individual formations can have different water quality characteristics based upon the depositional environment. Water quality can also vary spatially within a formation. The groundwater quality data were reviewed to evaluate whether there is a difference between formations. The most likely differences are expected between groundwater derived from alluvial aquifers and groundwater derived from the bedrock aquifers. Less than half of the collected records (1,504 records out of 4,039 total records) have formation assignments indicating quantitative comparisons between formations are not viable until additional formation assignments are made. No attempt was made to assess spatial variability within the formations due to the limited number of formation assignments.

Table 3-4. Washington County Groundwater Summary Data (Reduced Dataset)

Class	Parameter	Field Results	Frac.	Units	EPA Class	No. Samples	No. Locations	No. ND	Min	Max	Including NDs Median	Including NDs Mean	Including NDs SD	Excluding NDs Median	Excluding NDs Mean	Excluding NDs SD	Begin Sample Date	End Sample Date	MCL	N Above MCL (no NDs)	SMCL	SMCL High	N Above SMCL (no NDs)	Act 2	N Above Act 2 (no NDs)	EPA Carc.	N Above EPA Carc. (no NDs)	EPA Non-Carc.	N Above EPA NonCarc. (no NDs)
Dissolved Gas	Carbon dioxide	No	Tot.	mg/l	M	88	87	0	0.6	224	19	26	28.4	19	26	28.4	Nov-67	Sep-97											
Gen WQ	Alkalinity as CaCO3	Yes	Tot.	mg/l	M	99	97	0	37	720	250	277	117	250	277	117	Sep-26	Sep-97											
Gen WQ	Hardness as CaCO3	No	Tot.	mg/l	-	98	96	0	6.18	1380	254	262	191	254	262	191	Sep-26	Sep-97											
Gen WQ	Hardness, non-carbonate as CaCO3	Yes	Tot.	mg/l	-	9	9	0	8	300	76	109	105	76	109	105	Sep-26	Sep-85											
Gen WQ	pH	No	Tot.	std units	M	79	79	0	5.9	8.7	7.4	7.49	0.424	7.4	7.49	0.424	Aug-83	Sep-97			6.5	8.5	2						
Gen WQ	pH	Yes	Tot.	std units	M	189	189	0	5.9	9.1	7.3	7.36	0.464	7.3	7.36	0.464	Nov-67	Jul-01			6.5	8.5	11						
Gen WQ	Specific conductance	No	Tot.	umho/cm	M	80	80	0	409	4430	694	931	706	694	931	706	Aug-83	Sep-97											
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	193	192	0	80	4400	640	770	532	640	770	532	Nov-67	Jul-01											
Gen WQ	Sulfide	No	Tot.	ug/l	M	61	61	59	250	600	250	260	54.6	550	550	70.7	Aug-83	Sep-84						5	2				
Gen WQ	Temperature, water	No	Tot.	deg C	M	98	96	0	10	23.5	16.7	16.7	3.32	16.7	16.7	3.32	Sep-26	Jul-01											
Gen WQ	Total dissolved solids	No	Dis.	mg/l	-	97	95	0	225	2860	431	564	432	431	564	432	Sep-26	Sep-97				500	33						
Inorganics, Major, Non-metals	Silica	No	Dis.	mg/l	-	96	94	0	6.8	26	11.8	12.1	3.56	11.8	12.1	3.56	Sep-26	Sep-97											
Major Anions	Bromide	No	Dis.	mg/l	M	37	37	0	0.011	1.867	0.049	0.168	0.394	0.049	0.168	0.394	Jul-78	Sep-97											
Major Anions	Chloride	No	Dis.	mg/l	CA	185	183	0	1.4	1200	17.2	53.5	135	17.2	53.5	135	Sep-26	Sep-97				250	7						
Major Anions	Fluoride	No	Dis.	mg/l	M	156	155	2	0.019	5.5	0.2	0.362	0.711	0.2	0.366	0.715	Jul-78	Sep-97	4	2		2	6	4	2			0.62	17
Major Anions	Sulfate	No	Dis.	mg/l	CA	98	96	0	0.6	1800	53.7	85.9	197	53.7	85.9	197	Sep-26	Sep-97				250	4						
Major Cations	Calcium	No	Dis.	mg/l	CA	98	96	0	1.5	400	73.5	73.8	51.1	73.5	73.8	51.1	Sep-26	Sep-97											
Major Cations	Magnesium	No	Dis.	mg/l	CA	181	179	0	0.59	130	11.2	15	15.9	11.2	15	15.9	Sep-26	Sep-97											
Major Cations	Potassium	No	Dis.	mg/l	CA	97	95	0	0.5	9.6	1.7	2.1	1.43	1.7	2.1	1.43	Sep-26	Sep-97											
Major Cations	Sodium	No	Dis.	mg/l	CA	188	186	0	1.85	900	15	57.8	121	15	57.8	121	Sep-26	Sep-97	20	81									
Metals	Aluminum	No	Dis.	ug/l	M	99	98	5	3.3	2500	21.5	85.9	295	23	88.9	301	Nov-67	Sep-97				200	5					16000	0
Metals	Arsenic	No	Dis.	ug/l	CA	10	10	2	0.5	4	3	2.4	1.24	3	2.88	0.835	Aug-83	Sep-97	10	0				10	0	0.045	8	4.7	0
Metals	Boron	No	Dis.	ug/l	CA	82	82	6	10	490	70	108	103	75	116	103	Aug-83	Sep-85						6000	0			3100	0
Metals	Cadmium	No	Dis.	ug/l	M	9	9	9	ND	ND	ND	ND	ND	ND	ND	ND	Aug-83	Sep-97	5	0				5	0			6.9	0
Metals	Chromium(VI)	No	Dis.	ug/l	-	9	9	7	0.5	1	0.5	0.611	0.22	1	1	0	Aug-83	Aug-85						100	0	0.031	2	31	0
Metals	Dysprosium	No	Dis.	ug/l	-	104	104	101	0.0005	0.04	0.0005	0.00145	0.00558	0.03	0.0333	0.00577	Jul-78	Jul-78											
Metals	Iron	No	Dis.	ug/l	M	66	65	4	1.5	87000	21	1830	10800	35	1920	11100	Sep-26	Sep-97				300	16					11000	1
Metals	Iron	No	Tot.	ug/l	M	84	84	0	20	130000	185	2430	14200	185	2430	14200	Aug-83	Sep-85				300	32					11000	2
Metals	Lead	No	Dis.	ug/l	M	8	8	6	0.5	200	0.5	25.5	70.5	101	101	141	Aug-83	Sep-97	15	1				5	1				
Metals	Manganese	No	Dis.	ug/l	M	105	104	3	0.5	2000	53	154	273	62	159	275	Nov-67	Sep-97				50	54	300	15			320	13
Metals	Manganese	No	Tot.	ug/l	M	85	85	11	5	1900	20	115	268	40	131	284	Aug-83	Sep-85				50	28	300	10			320	9
Metals	Mercury	No	Dis.	ug/l	M	9	9	7	0.05	0.2	0.05	0.0722	0.0507	0.15	0.15	0.0707	Aug-83	Aug-85	2	0				2	0			0.63	0
Metals	Nickel	No	Dis.	ug/l	M	9	9	6	0.5	200	0.5	23.3	66.3	5	68.8	114	Aug-83	Sep-97						100	1			300	0
Metals	Selenium	No	Dis.	ug/l	CA	10	10	9	0.5	1	0.5	0.55	0.158	1	1		Aug-83	Sep-97	50	0				50	0			78	0
Metals	Strontium	No	Dis.	ug/l	CA	8	8	0	310	6700	580	1340	2170	580	1340	2170	Aug-83	Aug-85										9300	0
Metals	Uranium	No	Dis.	ug/l	M	105	105	1	0.01	1.501	0.208	0.286	0.263	0.207	0.284	0.263	Jul-78	Sep-97	30	0									
Metals	Vanadium	No	Dis.	ug/l	M	104	104	98	0.05	3.1	0.05	0.115	0.381	0.55	1.18	1.24	Jul-78	Jul-78						260	0			78	0
Metals	Zinc	No	Dis.	ug/l	M	9	9	1	1.2	1100	30	147	358	30	164	378	Aug-83	Sep-97				5000	0	2000	0			4700	0
Nutrients	Nitrate as N	No	Dis.	mg/l	CA	11	11	1	0.01	16.9	0.18	2.5	5.47	0.215	2.75	5.7	Sep-26	Sep-97	10	1				10	1			25	0

M – measured, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
CA = Critical Analyte, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
A red highlight indicates the value is above a screening criteria.
MCL: EPA Maximum Contaminant Levels (National Primary Drinking Water Regulation)
SMCL: EPA Secondary MCL (Non-enforaceable guidance for drinking water)
Act 2: State of Pennsylvania Land Recycling Program (Voluntary Remediation Program) Screening Limits: Limits are for used, residential groundwater aquifer with TDS ≤ 2500 mg/L
EPA Carc./EPA Non-Carc.: The carcinogenic and non-carcinogenic screening limits established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level.

SD = standard deviation
ND = non detect

Available data for chloride further illustrate the limitations of the dataset in terms of making quantitative comparisons between formations. There are a total of 185 chloride (dissolved) results in the dataset. Forty-eight are assigned to formations, whereas 137 have no formation assignments. Chloride data were reviewed at the hydrogeologic group level (Table 3-2), representing the primary groundwater resources for Washington County. The results suggest that the Monongahela Group may contain higher chloride levels (poorer water quality) relative to the other formations and suggest a more detailed investigation into applicable formations for unassigned samples is warranted.

Group	N	Mean (mg/L)
Alluvium	1	12
Dunkard Group	7	18.6
Monongahela Group	29	62.5
Conemaugh Group	11	42.7
No Formation Assigned	137	54.9
All Results	185	53.8

3.2.2.4 ***Depth Comparison.*** Groundwater quality data for five dissolved constituents (calcium, chloride, magnesium, sodium, and sulfate) were plotted against the well depth and visually inspected for trends (Figure 3-8). These constituents were chosen primarily because they are commonly reported water quality parameters that can be indicative of many water quality impacts, including those associated with brines. These parameters are also expected to be present in any future groundwater quality data collected as part of the EPA case study or provided with data collected by operators. Well depths included in the database ranged from 0 to 301 feet. Most records (3,672 records of 4,039 total records) included information on the well depth; the majority of reported results for each of the five dissolved constituents also had well depths assigned. A plot of the concentration vs. depth showed no apparent trends for any of the five dissolved constituents.

Constituent	N	Samples with Depth Assigned	No Depth Assigned
Calcium	95	95	0
Chloride	185	156	29
Magnesium	181	154	27
Sodium	188	159	29
Sulfate	95	95	0

The plots indicate that higher concentration values are affected by variables other than depth. For example, the 1200 mg/L result for chloride from well depth of 48 feet suggests the potential for other impacts at this location, such as cross contamination from surface or near surface sources (e.g., road salt) due to poor well construction or impacts to shallow groundwater from surface releases. The actual source of the elevated chloride in this well cannot be determined without further investigation.

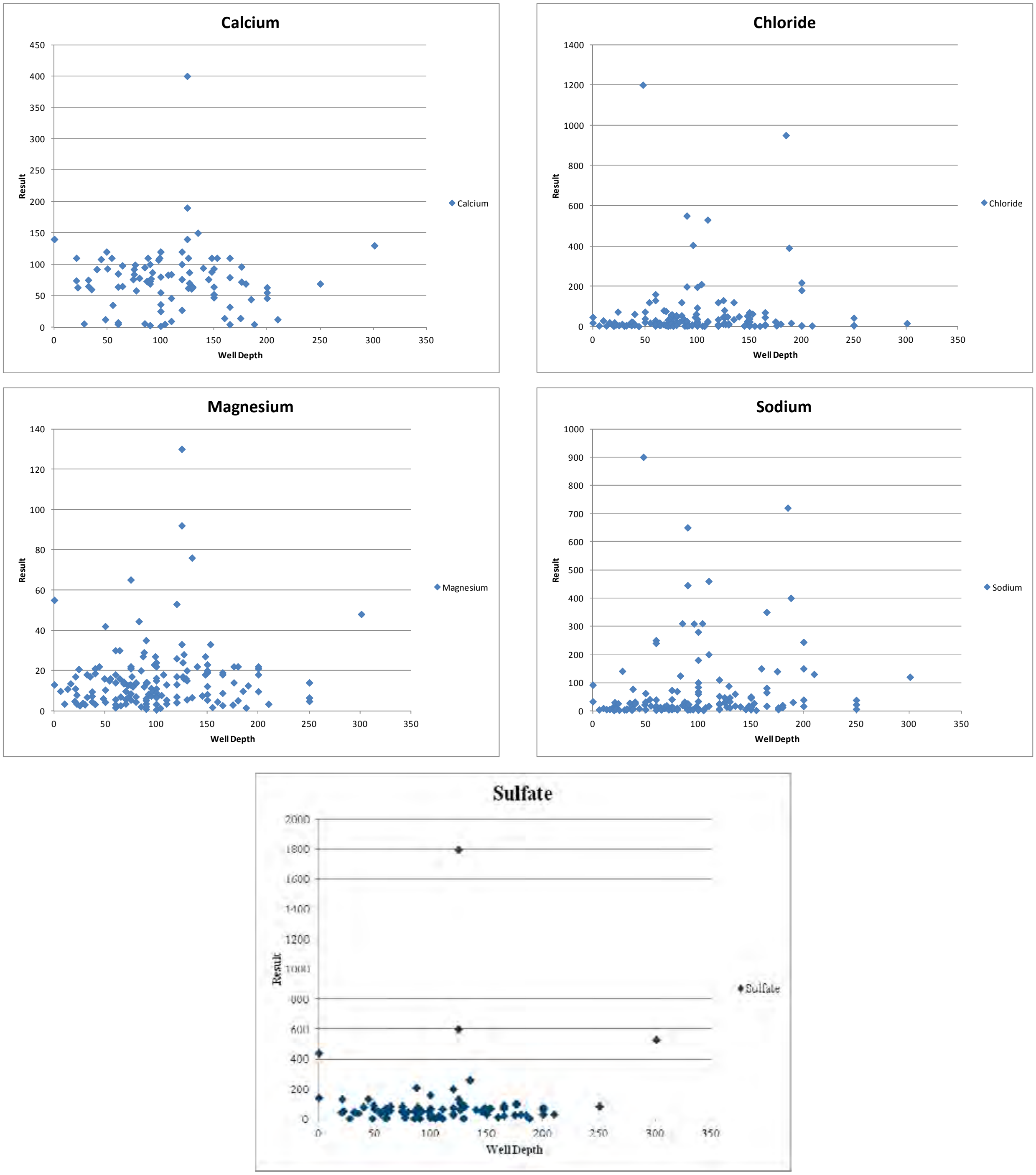

Figure 3-8. Data Plots Showing Dissolved Concentration (mg/L) vs. Depth for Selected Groundwater Quality Constituents

3.2.3 Coverage of EPA QAPP Analytes. Parameters identified by EPA for the Washington County Retrospective Case Study were identified in the QAPP for the study (EPA, 2012b). Of the parameters identified in the QAPP, 196 are designated as either CA (86) or M parameters (110). Table 3-3 summarizes the groundwater quality data for the EPA parameters (11 CA and 18 M parameters). Table 3-5 summarizes 116 EPA parameters for which no groundwater quality data are available (60 CA and 56 M) and 51 parameters (15 CA and 36 M) for which the number of sample locations was <8. Therefore, no water quality characterization is available for comparison should these parameters be detected in future sampling efforts.

3.3 Surface Water and Spring Water Quality

This section summarizes the characteristics of surface water resources and springs in the vicinity of Washington County. Separate analyses are also provided of available surface water and spring water quality data in comparison to screening criteria.

3.3.1 Watershed Characteristics. Washington County is located within the Ohio River Basin, which has a total drainage of 23,487 square miles. Figure 3-9 shows the location of named streams and rivers within Washington County. The streams and tributaries of northern Washington County drain directly to the Ohio River, while those in southern Washington County flow into the Monongahela River, which is a major tributary of the Ohio River. Table 3-6 summarizes the HUC 8 subbasins in Washington County, which are shown graphically in Figure 3-9. The northern portion of Washington County is located in the Upper Ohio HUC 8 Subbasin with a total size of 1,950 square miles. The southern portion of Washington County is located in the Lower Monongahela HUC 8 Subbasin with a total size of 1,450 square miles. The Upper Ohio-Wheeling HUC 8 Subbasin is located in the southwest portion of Washington County, with a total size of 1,490 square miles.

As part of its authority under the CWA, PADEP reviewed water quality conditions in order to characterize the nature and extent of water pollution across the state. The information gathered is reported in the *Draft 2012 Pennsylvania Integrated Water Quality Monitoring and Assessment Report* (PADEP, 2012a). Under the CWA, PADEP identifies streams that are impaired for their intended beneficial use and describes the nature of the impairment (e.g., the constituents of concern) and the potential causes of the impairment (e.g., the activities that led to the contaminant loading to the surface water). Figure 3-9 shows the location of streams and rivers within Washington County for which TMDLs have been established due to known surface water quality impairments. As shown in Figure 3-9, the majority of the impaired streams are located in the northeastern part of the county where historic surface and subsurface coal mining activities have taken place (as discussed in Section 3.1 under land use characteristics). Table 3-7 shows the constituents of concern that have caused these surface water impairments in Washington County including chlordane and pesticides, PCBs, metals, pH, siltation, suspended solids, nutrients, organic enrichment and low dissolved oxygen (DO), and turbidity. There are over 690 miles of impaired streams and rivers in Washington County, representing approximately 35% of the total stream length. It should be noted, however, that some streams have overlapping impairments on the same reach so the values in Table 3-7 should not be summed to a total value.

Table 3-5. List of EPA Parameters Not Present in Washington County Groundwater Quality Characterization Database

Parameter - Measured		Parameter - Critical Analyte	
NOT FOUND			
Acetylene	Gross alpha	2,4,5-Trichlorophenol	Diethyl phthalate
Butane	Gross beta	2,4,6-Trichlorophenol	Dimethyl phthalate
Ethane	Ra 226/228	2,4-Dichlorophenol	Di-n-octyl phthalate
Ethylene	1,2-dinitrobenzene	2,4-Dimethylphenol	Fluoranthene
Hydrogen	1,3-dimethyl adamantane	2,4-Dinitrotoluene	Fluorene
Methane	1,4-dinitrobenzene	2,6-Dinitrotoluene	Indeno[1,2,3-cd]pyrene
Propane	1-Methylnaphthalene	2-Chloronaphthalene	Isophorone
Inorganic carbon	2,3,4,6-Tetrachlorophenol	2-Methylnaphthalene	m-Cresol
Iron, ion (Fe2+)	2,4-Dinitrophenol	3,3'-Dichlorobenzidine	m-Nitroaniline
Redox Potential	2.3.5.6-Tetrachlorophenol	4,6-Dinitro-o-cresol	Nitrobenzene
Diethylene glycol monobutyl ether acetate	2-butoxyethanol	4-Methylphenol	N-Nitrosodi-n-propylamine
tetraethylene glycol	Adamantane	Acenaphthene	o-Chlorophenol
triethylene glycol	Aniline	Acenaphthylene	o-Cresol
Carbon-13/Carbon-12 ratio	Azobenzene	Anthracene	o-Nitroaniline
d2H	Benzoic acid	Benz[a]anthracene	o-Nitrophenol
d87/86Sr	bis(2-ethylhexyl) adipate	Benzo(b)fluoranthene	p-Bromophenyl phenyl ether
Oxygen-18/Oxygen-16 ratio	Cyclohexene, 1-methyl-4-(1-methylethenyl)-, (4R)-	Benzo[a]pyrene	p-Chloroaniline
Acetate	Diphenylamine	Benzo[ghi]perylene	p-Chloro-m-cresol
Butyric acid	Hexachlorobenzene	Benzo[k]fluoranthene	p-Chlorophenyl phenyl ether
Formate	Hexachlorocyclopentadiene	Benzyl alcohol	Pentachlorophenol
Isobutyrate	m-Dinitrobenzene	Bis(2-chloroethoxy)methane	Phenanthrene
Lactic acid	N-Nitrosodimethylamine	Bis(2-chloroethyl) ether	p-Nitroaniline
Propionic acid	Phenol	Bis(2-chloroisopropyl) ether	Pyrene
Cerium	p-Nitrophenol	Butyl benzyl phthalate	Diesel range organics
Silicon	Pyridine	Carbazole	Ethanol
Sulfur	Squalene	Chrysene	Gasoline range organics
Thallium	Terpineol	Di(2-ethylhexyl) phthalate	Isopropyl alcohol
Titanium	tri(2-butoxethyl)phosphate	Dibenz[a,h]anthracene	m-Xylene
		Dibenzofuran	p-Xylene
		Dibutyl phthalate	tert-Butanol
SAMPLE SIZE ≤ 8			
Organic carbon	1,2-Dichloroethane	Barium	p-Dichlorobenzene
Oxygen	1,3,5-Trimethylbenzene	Nitrite as N	Acrylonitrile
Turbidity	Acetone	1,2,4-Trichlorobenzene	Benzene
Antimony	Carbon disulfide	Hexachlorobutadiene	Ethylbenzene
Beryllium	Carbon tetrachloride	Hexachloroethane	o-Xylene
Chromium	Chlorobenzene	m-Dichlorobenzene	Toluene
Cobalt	Chloroform	Naphthalene	Xylene
Copper	*cis*-1,2-Dichloroethylene	o-Dichlorobenzene	
Molybdenum	Cumene		
Phosphorus	Ethyl tert-butyl ether		
Silver	Isopropyl ether		
Ammonia-nitrogen as N	Methyl tert-butyl ether		
1,1,1-Trichloroethane	Methylene chloride		
1,1,2-Trichloroethane	tert-Amyl methyl ether		
1,1-Dichloroethane	Tetrachloroethylene		
1,1-Dichloroethylene	*trans*-1,2-Dichloroethylene		
1,2,3-Trimethylbenzene	Trichloroethylene		
1,2,4-Trimethylbenzene	Vinyl chloride		

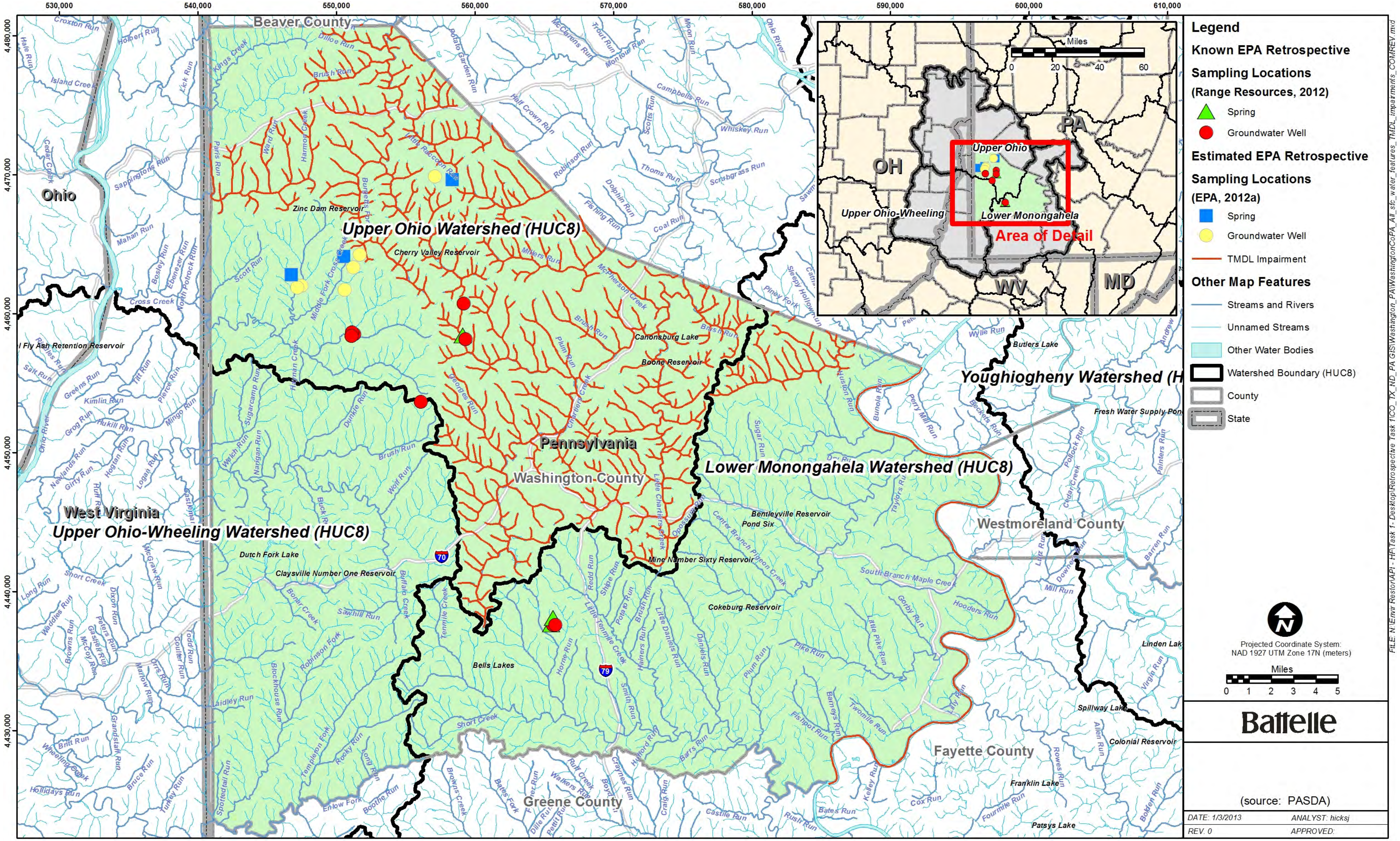

Figure 3-9. Surface Water Resources and Impairments in Washington County

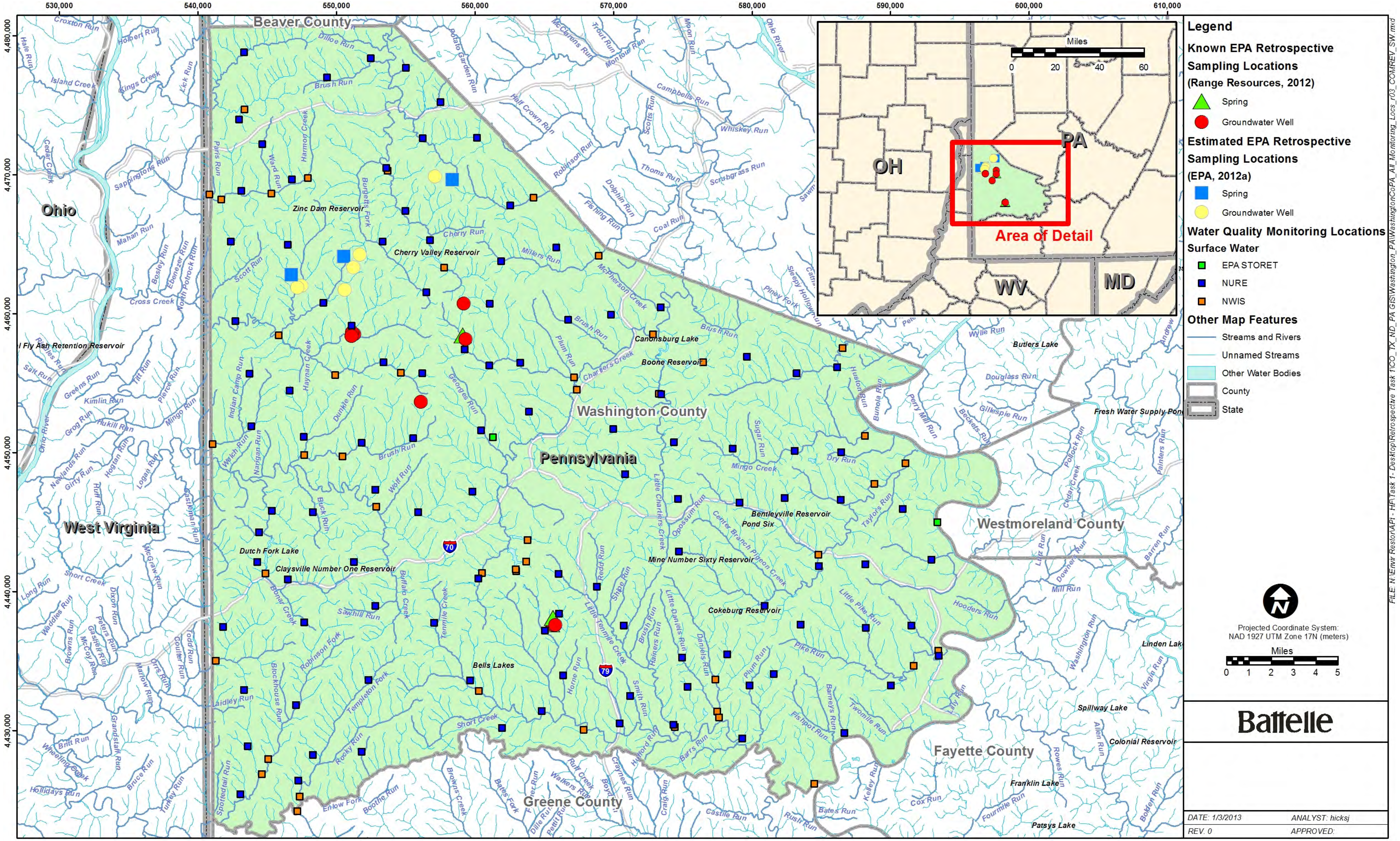

Figure 3-10. Surface Water Quality Monitoring Locations

Table 3-6. Definitions of HUC 8 Subbasins for Washington County, PA

HUC Code	Definition	Size, square miles	Location
05020005	Subbasin (HUC 8)	1,450	Lower Monongahela
05030101	Subbasin (HUC 8)	1,950	Upper Ohio
05030106	Subbasin (HUC 8)	1,490	Upper Ohio-Wheeling

Table 3-7. Sources of Impairment to Surface Water within Washington County

Source of Impairment	Miles of Impairment
Chlordane; PCB	41
Chlordane; PCB; Pesticides	340
Metals	34
Metals; pH; Siltation	2
Metals; pH; Siltation; Suspended Solids	187
Metals; pH; Suspended Solids	340
Nutrients; Organic Enrichment/Low DO; Siltation; Suspended Solids; Turbidity	22

Note: Some streams have overlapping impairments on the same reach so the values here should not be summed to a total value.

Table 3-8 shows the date that each TMDL was approved for the surface water bodies in Washington County. Five of the nine TMDLs listed were approved prior to 2005. The remaining four TMDLs approved from 2005 to 2009 were all associated with AMD impairments caused by historic coal mining activities from the late 1800s to mid 1900s. Table 3-9 shows the causes of these impairments for the three subbasins that cross Washington County, as determined by PADEP in 2006. This information was not available solely at the Washington County level, so is discussed here at the watershed (subbasin) level that extends beyond Washington County. There were also no dates associated with the individual causes of impairment, but the data compilation was prepared by PADEP in 2006 (EPA, 2012c). The top five major known sources of surface water impairment were as follows: (1) AMD and mining activities (30%), (2) agriculture (13%), (3) urban runoff and storm sewers (10%), (4) road runoff (7%), and (5) habitat modification (7%). These sources represent over 66% of the total impaired stream miles in the three watersheds that cross Washington County. Roughly 9% of the impairments are attributed to an unknown source.

3.3.2 Surface Water Data Summary. Surface water quality data (from the sources identified in Section 2.0) were compiled into a database to characterize the condition of surface water resources within Washington County. Summary tables were compiled as noted in Section 2.0 for the complete dataset (includes data potentially associated with environmental impacts) and for a reduced dataset that removed data potentially associated with environmental impacts. Figure 3-10 shows the location of the 156 surface water quality monitoring locations represented in the database (including locations potentially associated with environmental impacts). The dates of the sampling events (temporal boundary) range from 1964 to 2004. For the purpose of this evaluation, surface water data were evaluated for the pre-2005 timeframe prior to unconventional oil and gas development via hydraulic fracturing. The parameters monitored include general water quality parameters, major ions, metals, radionuclides, and organics including VOCs and SVOCs.

Table 3-8. Dates of Surface Water Impairments in Washington County

Surface Water Body	Date TMDL Approved	Category	Parameter	Notes
Ohio River	4/9/2001	Fish Consumption	Chlordane, PCB	Prior to 2005
Brush Run	4/9/2003	Non-Point Source	Nutrients, organic enrichment/ low D.O., turbidity, siltation, suspended solids	Prior to 2005
Chartiers Creek Watershed	4/9/2003	Unknown	Metals, pH	Prior to 2005
Plum Run	4/9/2003	Non-Point Source	Nutrients, organic enrichment/low D.O., turbidity, siltation, suspended solids	Prior to 2005
Canonsburg Lake Watershed	8/9/2003	Non-Point Source	Nutrients	Prior to 2005
Raccoon Creek	4/7/2005	AMD	Metals, pH, siltation, suspended solids	Coal mining 1880s to 1960s
Harmon Creek	4/4/2007	AMD	Metals, pH, siltation, suspended solids	Coal mining from 1900 to 1976
Peters Creek Watershed	4/7/2009	AMD	Metals	Coal mining since 1900s
Redstone Creek	4/9/2009	AMD	Metals, pH, siltation, suspended solids	Coal mining 1850s to 1950s

Table 3-9. Causes of Impairments in the Watersheds Crossing Washington County

	Length of Impairment (miles)			
Probable Cause	Lower Monongahela Subbasin	Upper Ohio Subbasin	Upper Ohio – Wheeling Subbasin	Total
Agriculture	200.6	212.2	10.4	423.2
AMD, Surface, and Subsurface Mining	528.8	394.6	23	946.4
Channelization	36.6	NA	NA	36.6
Combined Sewer Overflows	10.4	54.2	NA	64.6
Construction	15.4	32.7	NA	48.1
Erosion from Derelict Land (Barren Land)	49.1	22.8	NA	71.9
Golf Courses	6.4	3.5	NA	9.9
Habitat Modification (Other Than Hydromodification)	6.9	204.9	1.3	213.1
Highways, Roads, Bridges, Infrastructure (New Construction)	NA	2.6	NA	2.6
Hydromodification	NA	6	NA	6
Industrial Point Source Discharge	3.1	NA	NA	3.1
Land Development	NA	13	NA	13
Land Disposal	2.4	3.3	NA	5.7
Municipal Point Source Discharges	3.1	2.2	0.8	6.1
Natural Sources	37.3	7.5	NA	44.8
On-Site Wastewater	17	34.5	2.6	54.1
Removal Of Vegetation	32	64.5	5.9	102.4
Road Runoff	137	78.9	NA	215.9
Silviculture Activities	3.3	NA	NA	3.3
Small Residential Runoff	148	28.1	NA	176.1
Source Unknown or Other	132.8	162.1	9.1	304
Streambank Modifications/Destabilization	120.7	NA	1.6	122.3
Upstream Impoundments	13.6	1.4	NA	15
Urban Runoff/Storm Sewers	103.3	228	NA	331.3

NA – not applicable

Summary data tables are provided with a list of detected parameters, number of samples, minimum, maximum, median, mean, standard deviation, date range for sample collection and comparison against screening criteria. Table 3-10 provides a summary of water quality parameters in surface water prior to 2005. Surface water quality parameters were compared to EPA MCLs and SMCLs and Pennsylvania Surface Water Screening Limits for PWS and fish. The data were also compared to CWA freshwater surface water quality criteria (chronic).

Inorganic Summary. As indicated in Table 3-10, observed results are above one or more of the screening criteria for three general water quality parameters (TDS, alkalinity, and pH) and four major ions (sulfate, chloride, sodium, and fluoride). Sulfate, fluoride, and chloride detections were higher than the SMCL and the Pennsylvania Surface Water Screening Limits for PWS. Chloride also was higher than the CWA freshwater surface water quality criteria (chronic). Sodium was higher than the EPA Health Advisory level of 20 mg/L.

Observed concentrations are higher than one or more of the screening criteria for three metals: aluminum, iron, and manganese. Aluminum detections were higher than the SMCL and the Pennsylvania Surface Water Screening Limits for PWS and fish. Iron and manganese were higher than the SMCL and the Pennsylvania Surface Water Screening Limits for PWS. Iron also was higher than the CWA freshwater surface water quality criteria (chronic). Figure 3-11 shows the spatial distribution of inorganic parameters in surface water detected above the screening criteria.

Elevated TDS, sulfate, and iron concentrations are most likely related to AMD or mining impacted surface water locations. AMD can also come into contact with rock and soil resulting in the dissolution of other metals such as aluminum and manganese (NRC, 2005). It should be noted that several of the reported constituents in Table 3-10 have higher average dissolved than total concentration, which is likely an artifact of the different number of data points for the two sets of data.

Organic Summary. No organic constituents in surface water were detected in eight or more sample locations.

3.3.2.1 Comparison Against Reduced Data Table. Table 3-11 provides a summary of pre-2005 surface water data in similar format to Table 3-10, with the exception of three locations that were removed (two from STORET and one from NURE) that were removed based on the reasoning provided in Table 2-3. This summary data table was created for comparison against the complete background surface water quality summary data table (Table 3-10) to determine whether the data identified as indicative of environmental impact monitoring or having location issues has a significant effect on background water quality.

The parameters that are above screening criteria in the reduced summary data table (Table 3-11) are identical to those in the comprehensive data summary table, and include alkalinity, pH, TDS, chloride, fluoride, sodium, and sulfate, aluminum, iron, and manganese. The maximum detected values for these parameters also are identical when comparing the two datasets, as are the respective screening criteria that are not met. Figure 3-11 shows the spatial distribution of inorganic parameters in surface water in the reduced dataset detected above the screening criteria. For alkalinity, pH, chloride, and fluoride, there is minimal or no difference between the two datasets when comparing the summary statistics (mean, median, and standard deviation). For TDS, the mean and median values are higher in the reduced dataset, suggesting the removed data had lower chemical concentrations. For sulfate, aluminum, iron, and manganese, the mean value is lower and the median value is higher in the reduced dataset.

Table 3-10. Washington County Surface Water Summary Data (Includes Environmental Impact Data)

Class	Parameter	Field Results	Frac.	Units	EPA Class	No. Samples	No. Locations	No. ND	Min	Max	Including NDs Median	Including NDs Mean	Including NDs SD	Excluding NDs Median	Excluding NDs Mean	Excluding NDs SD	Begin Sample Date	End Sample Date	MCL	N Above MCL (no NDs)	SMCL	SMCL High	N Above SMCL (no NDs)	CWA Chronic	N Above CWA Chronic (no NDs)	PA SW Qual PWS	N Above SW Qual PWS (no NDs)	PA SW Qual Fish	N Above Qual Fish (no NDs)
Dissolved Gas	Carbon dioxide	No	Tot.	mg/l	M	324	46	1	0.1	121	4.36	6.4	7.3	4.36	6.25	6.58	May-64	Nov-04											
Gen WQ	Alkalinity as CaCO3	Yes	Tot.	mg/l	M	320	45	1	0.5	460	148	141	44.8	148	141	44.4	May-64	Aug-98						20	7				
Gen WQ	Carbonate (CO3)	Yes	Tot.	mg/l	-	30	22	0	1	22	7	8.09	4.51	7	8.09	4.51	Apr-80	Aug-85											
Gen WQ	Hardness as CaCO3	No	Tot.	mg/l	-	242	43	0	64	966	217	279	164	217	279	164	May-64	Nov-04											
Gen WQ	Hardness, non-carbonate as CaCO3	Yes	Tot.	mg/l	-	33	13	0	3	780	58	147	220	58	147	220	May-64	Aug-85											
Gen WQ	pH	No	Tot.	std units	M	238	39	0	3.7	8.7	7.88	7.67	0.668	7.88	7.67	0.668	Oct-80	Nov-04			6.5	8.5	15						
Gen WQ	pH	Yes	Tot.	std units	M	456	154	0	3.6	9.2	8	7.96	0.363	8	7.96	0.363	May-64	Nov-04			6.5	8.5	34						
Gen WQ	Specific conductance	No	Tot.	umho/cm	M	236	38	0	160	7350	476	850	829	476	850	829	Nov-80	Nov-04											
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	465	154	0	71	7000	541	768	612	541	768	612	May-64	Nov-04											
Gen WQ	Temperature, water	No	Tot.	deg C	M	316	45	0	0.5	26.5	16.5	16.3	2.57	16.5	16.3	2.57	Nov-65	Nov-04											
Gen WQ	Total dissolved solids	No	Dis.	mg/l	-	315	44	0	82	6050	313	609	649	313	609	649	May-64	Nov-04				500	86			750	57		
Inorganics, Major, Non-metals	Silica	No	Dis.	mg/l	-	166	37	0	0.00889	30	6.75	7.68	4.16	6.75	7.68	4.16	May-64	Aug-04											
Major Anions	Bromide	No	Dis.	mg/l	M	37	37	0	0.01	0.479	0.035	0.0604	0.083	0.035	0.0604	0.083	Aug-78	Aug-78											
Major Anions	Chloride	No	Dis.	mg/l	CA	346	150	0	2	910	9.4	23.4	48.7	9.4	23.4	48.7	May-64	Sep-98				250	8	230	9	250	8		
Major Anions	Fluoride	No	Dis.	mg/l	M	279	138	19	0.009	2.2	0.101	0.152	0.152	0.102	0.155	0.156	Aug-78	Nov-04	4	0		2	1			2	1		
Major Anions	Sulfate	No	Dis.	mg/l	CA	354	47	0	10	2600	70.8	274	348	70.8	274	348	May-64	Nov-04				250	82			250	82		
Major Cations	Calcium	No	Dis.	mg/l	CA	206	41	0	16	250	73	81	36.5	73	81	36.5	May-64	Sep-98											
Major Cations	Magnesium	No	Dis.	mg/l	CA	312	147	0	1.97	95	8.88	15.1	15.7	8.88	15.1	15.7	May-64	Sep-98											
Major Cations	Potassium	No	Dis.	mg/l	CA	165	36	0	0.2	19	3.03	3.29	1.56	3.03	3.29	1.56	May-64	Sep-98											
Major Cations	Sodium	No	Dis.	mg/l	CA	276	145	0	1.42	1700	10.2	32.8	104	10.2	32.8	104	May-64	Sep-98	20	98									
Metals	Aluminum	No	Dis.	ug/l	M	124	114	3	4	3426	106	166	322	108	170	326	Aug-78	Aug-98				200	23	87	70			750	1
Metals	Aluminum	No	Tot.	ug/l	M	46	11	2	40	7600	400	918	1370	600	952	1360	Jul-76	Nov-04				200	39	87	42			750	16
Metals	Boron	No	Dis.	ug/l	CA	158	35	2	10	1100	52.5	87.2	91.6	52.5	87.4	91.5	Dec-81	Aug-85								3100	0	8100	0
Metals	Dysprosium	No	Dis.	ug/l	-	107	107	102	0.0005	0.05	0.0005	0.00169	0.00646	0.02	0.026	0.0182	Aug-78	Aug-78											
Metals	Iron	No	Dis.	ug/l	M	253	36	13	1.5	29000	25.8	891	3690	26.6	892	3690	May-64	Sep-98				300	15	1000	14	300	15		
Metals	Iron	No	Tot.	ug/l	M	326	42	1	25	34000	675	1750	4080	675	1750	4080	Sep-75	Nov-04				300	235	1000	79	300	235		
Metals	Manganese	No	Dis.	ug/l	M	361	139	0	1	5400	140	364	695	140	364	695	Aug-78	Sep-98				50	219			1000	29		
Metals	Manganese	No	Tot.	ug/l	M	304	41	0	10	5400	137	342	771	137	342	771	Jul-76	Nov-04				50	206			1000	20		
Metals	Uranium	No	Dis.	ug/l	M	107	107	13	0.001	0.995	0.321	0.357	0.218	0.382	0.406	0.184	Aug-78	Aug-78	30	0									
Metals	Vanadium	No	Dis.	ug/l	M	107	107	74	0.05	2.1	0.05	0.275	0.444	0.6	0.779	0.524	Aug-78	Aug-78										510	0
Nutrients	Ammonia-nitrogen as N	No	Dis.	mg/l	M	61	10	20	0.01	2.5	0.0763	0.143	0.204	0.09	0.241	0.416	Oct-74	Nov-04											
Nutrients	Nitrate as N	No	Dis.	mg/l	CA	51	12	2	0.02	9.07	0.613	0.83	0.913	0.613	0.908	1.16	May-64	Nov-04	10	0						10	0		

M – measured, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
CA = Critical Analyte, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
A red highlight indicates the value is above a screening criteria.
MCL: EPA Maximum Contaminant Levels (National Primary Drinking Water Regulation)
SMCL: EPA Secondary MCL (Non-enforaceable guidance for drinking water)
Act 2: State of Pennsylvania Land Recycling Program (Voluntary Remediation Program) Screening Limits: Limits are for used, residential groundwater aquifer with TDS ≤ 2500 mg/L
EPA Carc./EPA Non-Carc.: The carcinogenic and non-carcinogenic screening limits established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level.
ND = non-detect
SD = standard deviation

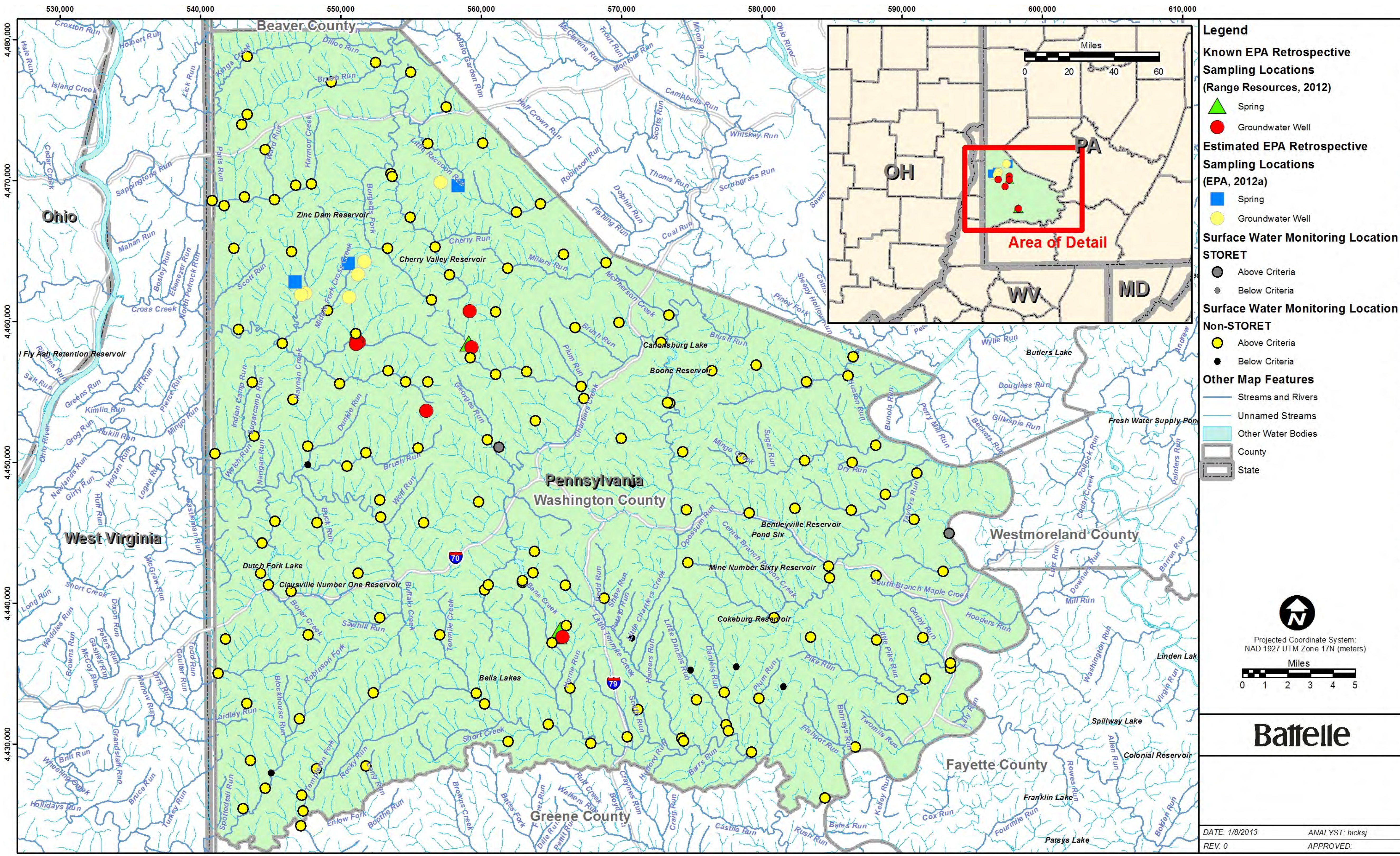

Figure 3-11. Surface Water Detections above Screening Criteria in Washington County, PA

Table 3-11. Washington County Surface Water Summary Data (Reduced Dataset)

Class	Parameter	Field Results	Frac.	Units	EPA Class	No. Samples	No. Locations	No. ND	Min	Max	Including NDs Median	Including NDs Mean	Including NDs SD	Excluding NDs Median	Excluding NDs Mean	Excluding NDs SD	Begin Sample Date	End Sample Date	MCL	N Above MCL (no NDs)	SMCL	SMCL High	N Above SMCL (no NDs)	CWA Chronic	N Above CWA Chronic (no NDs)	PA SW Qual PWS	N Above SW Qual PWS (no NDs)	PA SW Qual Fish	N Above Qual Fish (no NDs)
Dissolved Gas	Carbon dioxide	No	Tot.	mg/l	M	324	46	1	0.1	121	4.36	6.4	7.3	4.36	6.25	6.58	May-64	Nov-04											
Gen WQ	Alkalinity as CaCO3	Yes	Tot.	mg/l	M	320	45	1	0.5	460	148	141	44.8	148	141	44.4	May-64	Aug-98						20	7				
Gen WQ	Carbonate (CO3)	Yes	Tot.	mg/l	-	30	22	0	1	22	7	8.09	4.51	7	8.09	4.51	Apr-80	Aug-85											
Gen WQ	Hardness as CaCO3	No	Tot.	mg/l	-	225	42	0	64	966	217	284	164	217	284	164	May-64	Nov-04											
Gen WQ	Hardness, non-carbonate as CaCO3	Yes	Tot.	mg/l	-	33	13	0	3	780	58	147	220	58	147	220	May-64	Aug-85											
Gen WQ	pH	No	Tot.	std units	M	220	37	0	3.7	8.7	7.88	7.67	0.677	7.88	7.67	0.677	Oct-80	Nov-04			6.5	8.5	14						
Gen WQ	pH	Yes	Tot.	std units	M	438	152	0	3.6	9.2	8	7.96	0.36	8	7.96	0.36	May-64	Nov-04			6.5	8.5	33						
Gen WQ	Specific conductance	No	Tot.	umho/cm	M	219	37	0	160	7350	476	866	834	476	866	834	Nov-80	Nov-04											
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	448	152	0	71	7000	541	771	614	541	771	614	May-64	Nov-04											
Gen WQ	Temperature, water	No	Tot.	deg C	M	316	45	0	0.5	26.5	16.5	16.3	2.57	16.5	16.3	2.57	Nov-65	Nov-04											
Gen WQ	Total dissolved solids	No	Dis.	mg/l	-	298	43	0	82	6050	322	619	653	322	619	653	May-64	Nov-04				500	86			750	57		
Inorganics, Major, Non-metals	Silica	No	Dis.	mg/l	-	165	36	0	2.9	30	6.78	7.89	4.01	6.78	7.89	4.01	May-64	Sep-98											
Major Anions	Bromide	No	Dis.	mg/l	M	37	37	0	0.01	0.479	0.035	0.0604	0.083	0.035	0.0604	0.083	Aug-78	Aug-78											
Major Anions	Chloride	No	Dis.	mg/l	CA	345	149	0	2	910	9.4	23.2	48.8	9.4	23.2	48.8	May-64	Sep-98				250	8	230	9	250	8		
Major Anions	Fluoride	No	Dis.	mg/l	M	279	138	19	0.009	2.2	0.101	0.152	0.152	0.102	0.155	0.156	Aug-78	Nov-04	4	0		2	1			2	1		
Major Anions	Sulfate	No	Dis.	mg/l	CA	337	46	0	10	2600	70.5	278	350	70.5	278	350	May-64	Nov-04				250	82			250	82		
Major Cations	Calcium	No	Dis.	mg/l	CA	206	41	0	16	250	73	81	36.5	73	81	36.5	May-64	Sep-98											
Major Cations	Magnesium	No	Dis.	mg/l	CA	311	146	0	1.97	95	9.09	15.2	15.7	9.09	15.2	15.7	May-64	Sep-98											
Major Cations	Potassium	No	Dis.	mg/l	CA	165	36	0	0.2	19	3.03	3.29	1.56	3.03	3.29	1.56	May-64	Sep-98											
Major Cations	Sodium	No	Dis.	mg/l	CA	275	144	0	1.42	1700	10.2	32.9	105	10.2	32.9	105	May-64	Sep-98	20	97									
Metals	Aluminum	No	Dis.	ug/l	M	123	113	3	4	3426	105	166	324	107	170	327	Aug-78	Aug-98				200	23	87	69			750	1
Metals	Aluminum	No	Tot.	ug/l	M	30	10	2	40	7600	388	935	1450	500	973	1430	Jul-76	Nov-04				200	23	87	26			750	10
Metals	Boron	No	Dis.	ug/l	CA	158	35	2	10	1100	52.5	87.2	91.6	52.5	87.4	91.5	Dec-81	Aug-85								3100	0	8100	0
Metals	Dysprosium	No	Dis.	ug/l	-	106	106	101	0.0005	0.05	0.0005	0.0017	0.00649	0.02	0.026	0.0182	Aug-78	Aug-78											
Metals	Iron	No	Dis.	ug/l	M	253	36	13	1.5	29000	25.8	891	3690	26.6	892	3690	May-64	Sep-98				300	15	1000	14	300	15		
Metals	Iron	No	Tot.	ug/l	M	309	41	1	25	34000	665	1760	4130	665	1770	4130	Sep-75	Nov-04				300	219	1000	74	300	219		
Metals	Manganese	No	Dis.	ug/l	M	360	138	0	1	5400	140	365	697	140	365	697	Aug-78	Sep-98				50	218			1000	29		
Metals	Manganese	No	Tot.	ug/l	M	287	40	0	10	5400	136	347	780	136	347	780	Jul-76	Nov-04				50	189			1000	20		
Metals	Uranium	No	Dis.	ug/l	M	106	106	13	0.001	0.995	0.319	0.354	0.217	0.382	0.403	0.183	Aug-78	Aug-78	30	0									
Metals	Vanadium	No	Dis.	ug/l	M	106	106	73	0.05	2.1	0.05	0.277	0.446	0.6	0.779	0.524	Aug-78	Aug-78										510	0
Nutrients	Ammonia-nitrogen as N	No	Dis.	mg/l	M	46	9	20	0.01	2.5	0.09	0.152	0.215	0.095	0.264	0.439	Oct-74	Nov-04											
Nutrients	Nitrate as N	No	Dis.	mg/l	CA	49	11	2	0.02	9.07	0.646	0.858	0.952	0.646	0.943	1.21	May-64	Nov-04	10	0						10	0		

M – measured, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
CA = Critical Analyte, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
A red highlight indicates the value is above a screening criteria.
MCL: EPA Maximum Contaminant Levels (National Primary Drinking Water Regulation)
SMCL: EPA Secondary MCL (Non-enforaceable guidance for drinking water)
Act 2: State of Pennsylvania Land Recycling Program (Voluntary Remediation Program) Screening Limits: Limits are for used, residential groundwater aquifer with TDS ≤ 2500 mg/L
EPA Carc./EPA Non-Carc.: The carcinogenic and non-carcinogenic screening limits established by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level.
ND = non-detect
SD = standard deviation

3.3.2.2 Temporal Comparison. The data available to assess temporal trends are limited. Only two of the 207 monitoring locations had more than 30 results over time for commonly reported parameters. Temporal trends in surface water quality data were examined for five constituents (calcium, chloride, magnesium, sodium, and sulfate) and were plotted for the two surface water stations having the most results over time (Figures 3-12 and 3-13). These constituents were chosen primarily because they are commonly reported water quality parameters that can be indicative of many water quality impacts, including those associated with naturally-occurring brines generally found in rock layers below fresh groundwater aquifers in the region. These parameters are also expected to be present in any future groundwater quality data collected as part of the EPA case study or provided with data collected by operators.

The two USGS stations are located at the Monongahela River at North Charleroi, PA and at Enlow Fork near West Finley, PA. At the Monongahela River station, 70 samples were analyzed for calcium, magnesium, and sulfate, and 34 samples were analyzed for chloride and sodium. Elevated and highly variable sulfate levels in the Monongahela River are likely attributable to continuing AMD impacts and temporal variations in streamflow. At the Enlow Fork station, 11 samples were analyzed for calcium, sodium, and magnesium, 31 were analyzed for chloride, and 35 were analyzed for sulfate. Highly variable chloride and sulfate levels after 1983 suggest significant temporal variation in streamflow and possibly new AMD discharges associated with coal mining.

An additional comparison of select parameter results over time was completed to further characterize the surface water quality data. The data were grouped in the following periods for this evaluation (1964-1969, 1970-1979, 1980-1985, and 1998-2004) based upon the available data. The data were not evaluated for distribution within the years, for spatial variability between stations (due to limited temporal data available by station), between watersheds, or against seasonal conditions that may affect flow and water quality conditions.

Calcium, chloride, and sodium average concentrations over time are shown in Figure 3-14. As shown in the figure, limited data are available in the most recent time period (1998 to 2004) preceding development of the Marcellus Shale. The majority of the data are available prior to 1998, so review of the averages over time for these parameters should be considered in this light. There is no clear trend in the average concentrations over time; highest average values for calcium, chloride and sodium occur in the 1980-1985 timeframe. Further evaluation to assess the sources of the variability over time is beyond the current scope. What is apparent in Figure 3-14 is that the bulk of the surface water quality data collected prior to Marcellus Shale development were collected in the 1970 to 1985 timeframe. The data for calcium, chloride, and sodium suggest that water quality in the early to mid 1980s was different compared to the more recent 1998 to 2004 data, particularly for calcium. Figure 3-15 illustrates the change in frequency of detection (expressed as a percentage) that is above the SMCLs for sulfate, iron, and manganese. Sulfate exhibits a decreasing trend, whereas both iron and manganese have no apparent trend as depicted.

3.3.2.3 ANOVA Comparison. The surface water data (complete dataset) were assessed for differences between the HUC 8 watersheds within Washington County through ANOVA. The parameters assessed included calcium, chloride, magnesium, sodium, and sulfate in the dissolved fractions. The model was configured to include an indicator for each of the three HUC 8 watersheds, excluding an intercept from the model, so that the coefficients can be interpreted directly as the HUC 8 watershed average value of the chemical. The results indicate that there are highly significant differences between chemical levels in the dissolved fraction in surface water for each of the chemicals. These differences are likely due to the highly variable nature of stream flow (e.g., significant temporal effects from precipitation) and the resulting impact on the contribution of AMD (e.g., during periods of low stream flow, the percentage contribution of AMD increases). Because some of the locations had multiple observations over time, the analysis was repeated on data aggregated by location, using the location mean

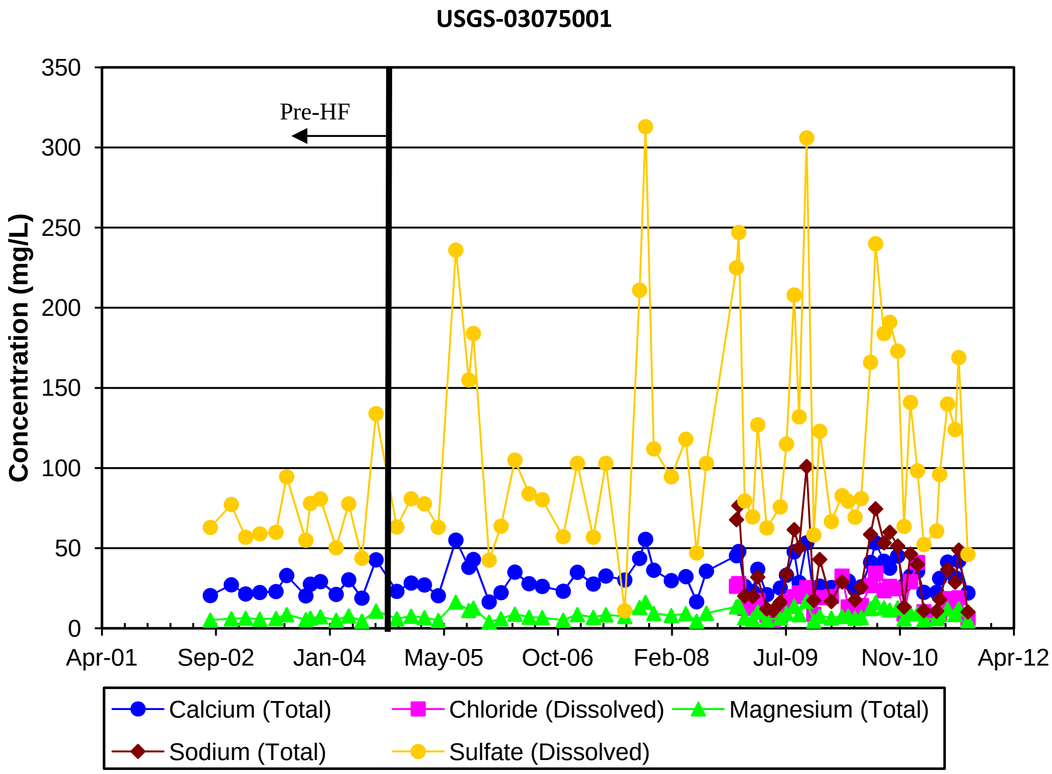

Figure 3-12. Water Quality vs. Time at Monongahela River (USGS Station)

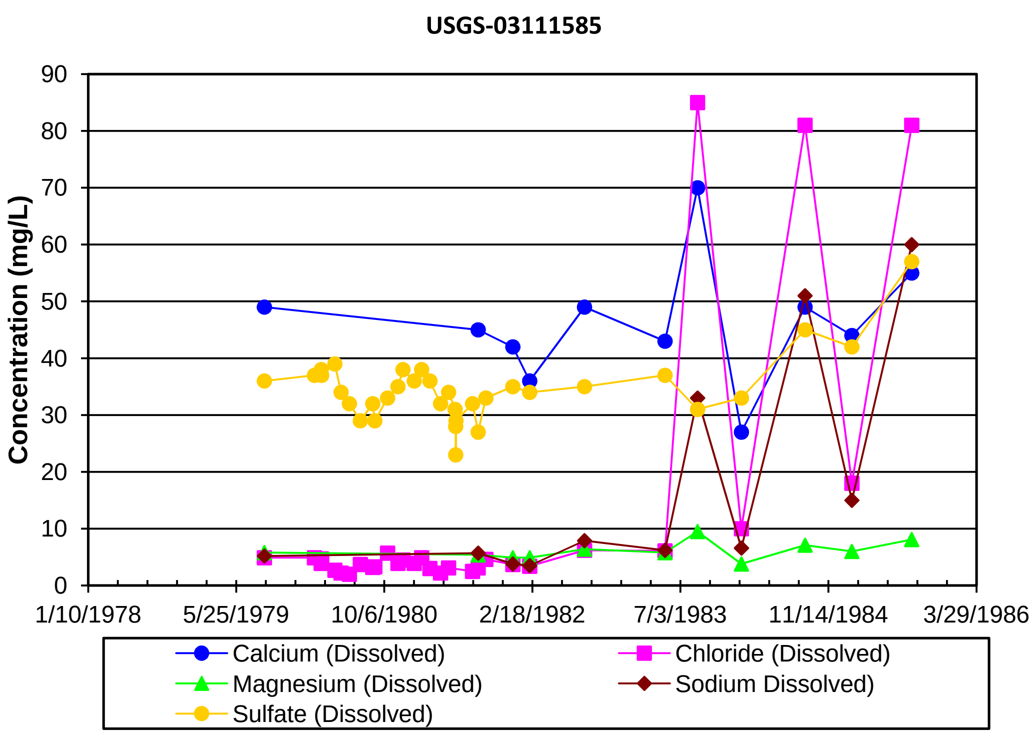

Figure 3-13. Water Quality vs. Time at Enlow Fork (USGS Station)

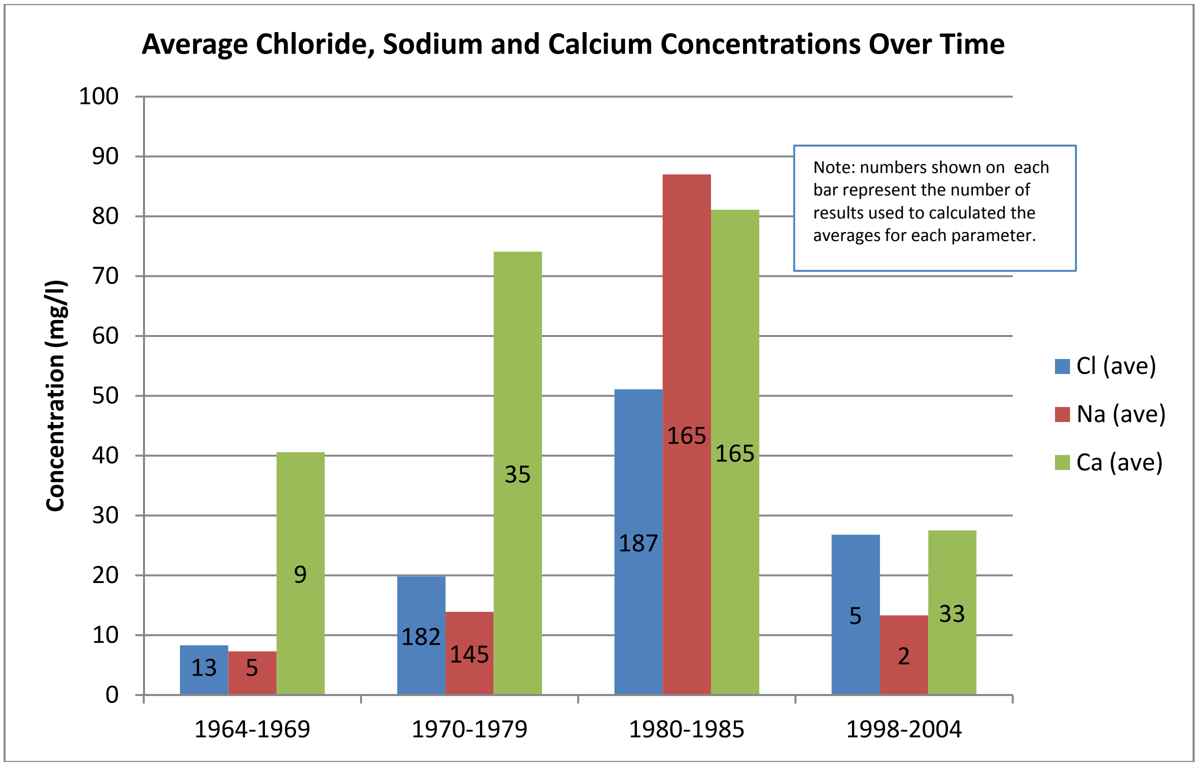

Figure 3-14. Average Chloride, Sodium, and Calcium Concentrations in Surface Water Over Time

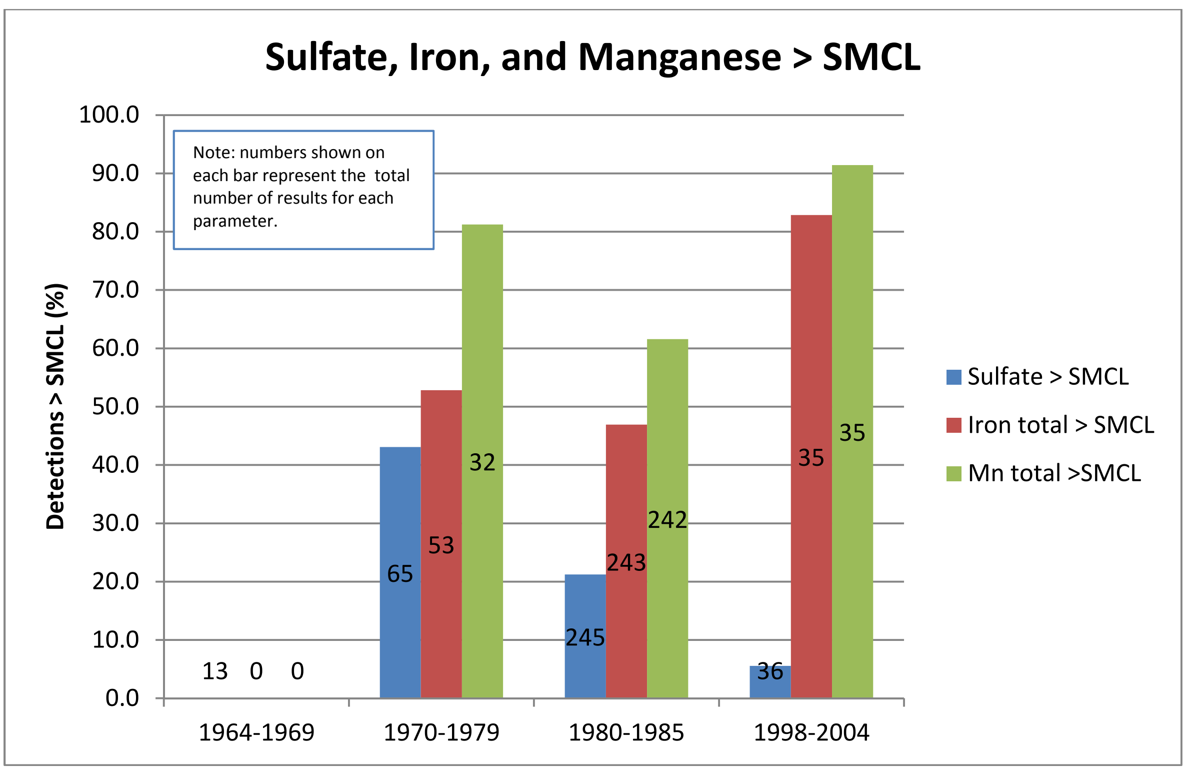

Figure 3-15. Sulfate, Iron and Manganese Frequency of Detections > SMCL

for each of the chemicals. The revised analysis still demonstrated significant differences between HUC 8 watersheds. In addition, boxplots of the chemical levels also indicated that the levels are skewed. Regression analyses were repeated on the log-transformed data. The conclusions are the same on the log and natural scales – there is significant difference in water quality data between the three HUC 8 watersheds. Appendix C includes data used in the surface water quality ANOVA.

3.3.3 Spring Water Data Summary. Spring water quality data (from the sources identified in Section 2.0) were compiled into a database to characterize the condition of springs within Washington County. Figure 3-16 shows the location of the 53 spring water quality monitoring locations represented in the database. The dates of the sampling events (temporal boundary) ranged from 1978 to 1985. The parameters monitored for include general water quality parameters, major ions, and metals.

Summary data tables are provided with a list of detected parameters, number of samples (total number and number of locations), minimum, maximum, median, mean, standard deviation, date range for sample collection, and comparison against screening criteria. Table 3-12 provides a summary of spring water quality parameters in surface water prior to 2005. Spring water quality parameters were compared to surface water screening criteria, including EPA MCLs and SMCLs and Pennsylvania Surface Water Screening Limits for PWS and fish. The data were also compared to CWA freshwater surface water quality criteria (chronic).

As indicated in Table 3-12, observed results are above one or more of the screening criteria for two major ions (chloride and sulfate). Chloride detections were higher than the CWA freshwater surface water quality criteria (chronic). Sodium was higher than the EPA Health Advisory level of 20 mg/L. In addition, observed concentrations are higher than one or more of the screening criteria for two metals: aluminum and manganese. Aluminum detections were higher than the CWA freshwater surface water quality criteria (chronic). Manganese detections were higher than the SMCL. No organic constituents in surface water were detected in eight or more sample locations. Figure 3-17 shows the spatial distribution of inorganic parameters in spring water detected above the screening criteria.

There were no spring water data identified as indicative of environmental impact monitoring or having location issues, so a reduced data summary table was not prepared.

3.3.4 Coverage of EPA QAPP Analytes. Tables 3-13 and 3-14 list whether or not the monitored parameters are part of the EPA QAPP for Washington County for surface water and springs, respectively. Of the parameters identified in the QAPP, 196 are designated as either critical analytes (86) or measured parameters (110). Upon review of the surface water data (Table 3-13), there are 161 parameters (76 CA and 85 M) listed in the EPA QAPP for the retrospective study that are not covered by the data gathered for Washington County, and an additional 14 (two CA and 12 M) for which there was not a sufficient sample size (≤8). Upon review of the spring data (Table 3-14), there are 176 parameters (79 CA and 97 M) listed in the EPA QAPP for the retrospective study that are not covered by the data gathered for Washington County, and an additional nine (four CA and five M) for which there was not a sufficient sample size (≤8). Therefore, no water quality characterization is available for comparison should these parameters be detected in future sampling efforts.

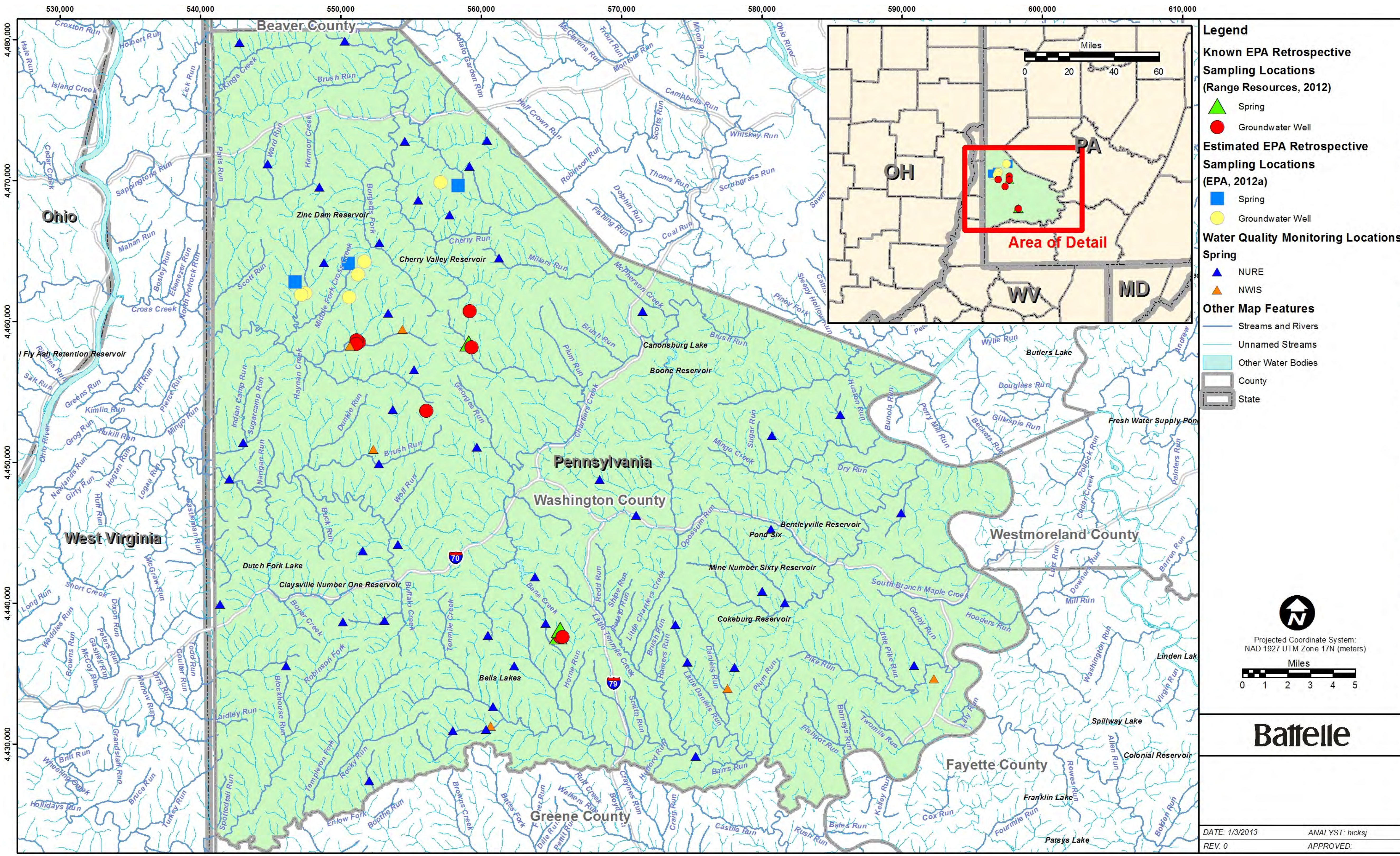

Figure 3-16. Spring Water Quality Monitoring Locations

Table 3-12. Washington County Spring Water Summary Data

Class	Parameter	Field Results	Frac.	Units	EPA Class	No. Samples	No. Locations	No. ND	Min	Max	Including NDs Median	Including NDs Mean	Including NDs SD	Excluding NDs Median	Excluding NDs Mean	Excluding NDs SD	Begin Sample Date	End Sample Date	MCL	N Above MCL (no NDs)	SMCL	SMCL High	N Above SMCL (no NDs)	CWA Chronic	N Above CWA Chronic (no NDs)	PA SW Qual PWS	N Above SW Qual PWS (no NDs)	PA SW Qual Fish	N Above Qual Fish (no NDs)
Gen WQ	pH	Yes	Tot.	std units	M	53	53	0	6.8	7.9	7.2	7.26	0.247	7.2	7.26	0.247	Jul-78	Sep-85			6.5	8.5	0						
Gen WQ	Specific conductance	Yes	Tot.	umho/cm	M	53	53	0	185	1500	500	533	234	500	533	234	Jul-78	Sep-85											
Major Anions	Bromide	No	Dis.	mg/l	M	11	11	0	0.007	0.323	0.041	0.0727	0.106	0.041	0.0727	0.106	Jul-78	Jul-78											
Major Anions	Chloride	No	Dis.	mg/l	CA	42	42	0	1.9	62.1	4.8	8.77	11.3	4.8	8.77	11.3	Jul-78	Sep-85				250	0	230	0	250	0		
Major Anions	Fluoride	No	Dis.	mg/l	M	36	36	0	0.013	0.4	0.064	0.108	0.102	0.064	0.108	0.102	Jul-78	Sep-85	4	0		2	0			2	0		
Major Cations	Magnesium	No	Dis.	mg/l	CA	43	43	0	1.02	55	7.58	9.27	8.98	7.58	9.27	8.98	Jul-78	Sep-85											
Major Cations	Sodium	No	Dis.	mg/l	CA	42	42	0	1.4	99.8	4.46	12	21.6	4.46	12	21.6	Jul-78	Sep-85	20	4									
Metals	Aluminum	No	Dis.	ug/l	M	35	35	0	3	161	26	34.2	31.8	26	34.2	31.8	Jul-78	Jul-78				200	0	87	3			750	0
Metals	Dysprosium	No	Dis.	ug/l	-	47	47	46	0.0005	0.01	0.0005	0.000702	0.00139	0.01	0.01		Jul-78	Jul-78											
Metals	Manganese	No	Dis.	ug/l	M	21	21	2	0.5	615	29	101	151	30	111	155	Jul-78	Sep-83				50	7			1000	0		
Metals	Uranium	No	Dis.	ug/l	M	47	47	0	0.042	1.709	0.292	0.362	0.268	0.292	0.362	0.268	Jul-78	Jul-78	30	0									
Metals	Vanadium	No	Dis.	ug/l	M	47	47	45	0.05	0.8	0.05	0.0755	0.126	0.65	0.65	0.212	Jul-78	Jul-78										510	0

M – measured, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
CA = Critical Analyte, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
A red highlight indicates the value is above a screening criteria.
MCL: EPA Maximum Contaminant Levels (National Primary Drinking Water Regulation)
SMCL: EPA Secondary MCL (Non-enforaceable guidance for drinking water)
CWA Chron.: National suggested aquatic life water quality criteria for chronic exposure as established by the Clean Water Act
PA PWS qual.: Pennsylvania human health standards for potable surface water sources as established by 25 PaC. §§ 93.7
PA PWS qual.: Pennsylvania aquatic life standards as established by 25 PaC. §§ 93.8
Note: Sodium does not have an MCL; the value listed in the MCL column represents the EPA Health Advisory Level.
ND = non-detect
SD = standard deviation

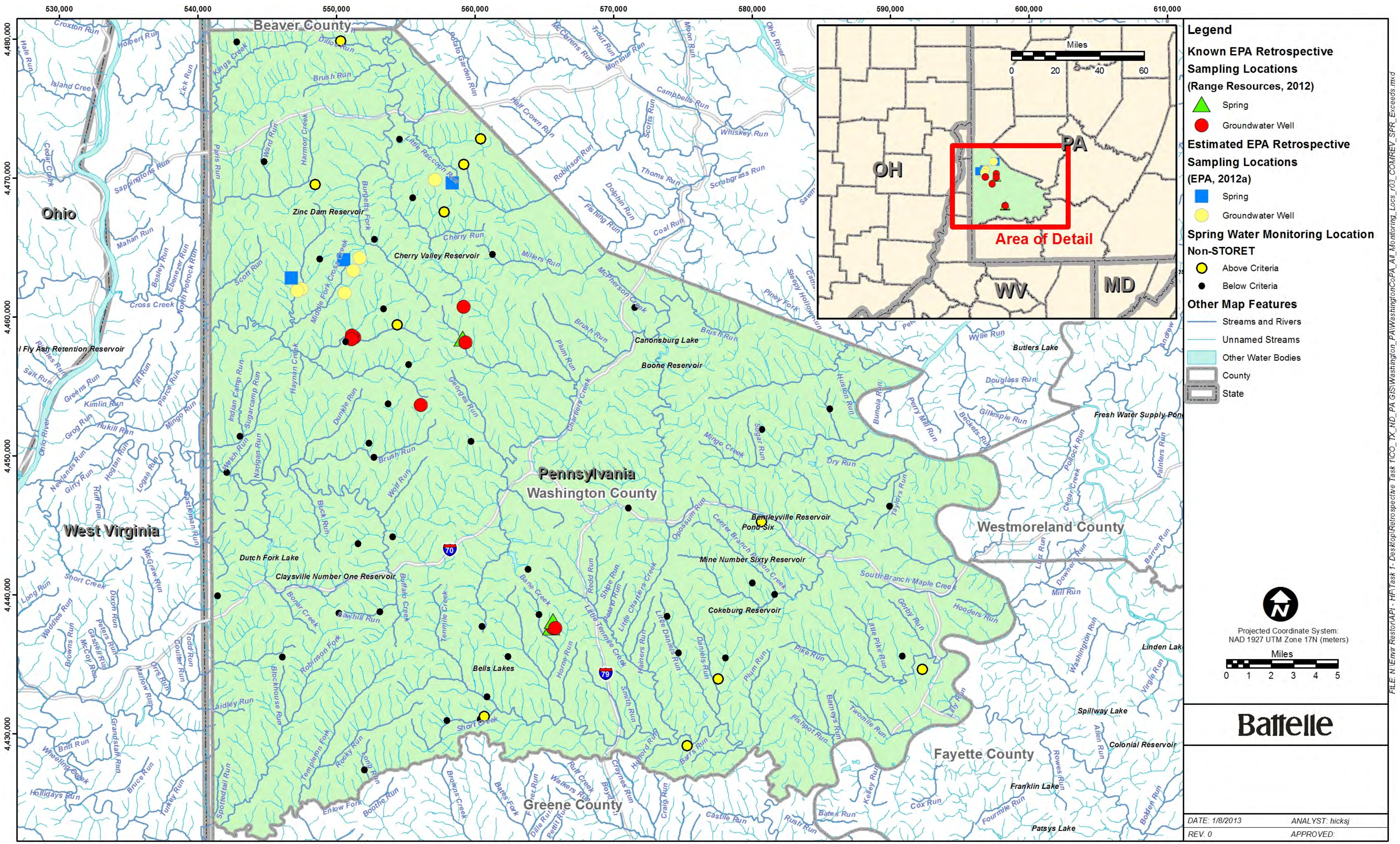

Figure 3-17. Spring Water Detections above Screening Criteria in Washington County, PA

Table 3-13. List of EPA Parameters Not Present in Washington County Surface Water Quality Characterization Database

Parameter - Measured		Parameter - Critical Analyte	
NOT FOUND			
Acetylene	2.3.5.6-Tetrachlorophenol	Barium	Fluorene
Butane	Adamantane	Selenium	Hexachlorobutadiene
Ethane	Aniline	Strontium	Hexachloroethane
Ethylene	Azobenzene	1,2,4-Trichlorobenzene	Indeno[1,2,3-cd]pyrene
Hydrogen	Benzoic acid	2,4,5-Trichlorophenol	Isophorone
Methane	bis(2-ethylhexyl) adipate	2,4,6-Trichlorophenol	m-Cresol
Propane	Cyclohexene, 1-methyl-4-(1-methylethenyl)-, (4R)-	2,4-Dichlorophenol	m-Dichlorobenzene
Inorganic carbon	Diphenylamine	2,4-Dimethylphenol	m-Nitroaniline
Iron, ion (Fe2+)	Hexachlorobenzene	2,4-Dinitrotoluene	N-Nitrosodi-n-propylamine
Redox Potential	Hexachlorocyclopentadiene	2,6-Dinitrotoluene	Naphthalene
Sulfide	m-Dinitrobenzene	2-Chloronaphthalene	Nitrobenzene
Diethylene glycol monobutyl ether acetate	N-Nitrosodimethylamine	2-Methylnapthalene	o-Chlorophenol
tetraethylene glycol	p-Nitrophenol	3,3'-Dichlorobenzidine	o-Cresol
triethylene glycol	Phenol	4,6-Dinitro-o-cresol	o-Dichlorobenzene
Carbon-13/Carbon-12 ratio	Pyridine	4-methylphenol	o-Nitroaniline
d2H	Squalene	Acenaphthene	o-Nitrophenol
d87/86Sr	Terpineol	Acenaphthylene	p-Bromophenyl phenyl ether
Oxygen-18/Oxygen-16 ratio	tri(2-butoxethyl)phosphate	Anthracene	p-Chloro-m-cresol
Acetate	1,1,1-Trichloroethane	Benz[a]anthracene	p-Chloroaniline
Butyric acid	1,1,2-Trichloroethane	Benzo(b)fluoranthene	p-Chlorophenyl phenyl ether
Formate	1,1-Dichloroethane	Benzo[a]pyrene	p-Dichlorobenzene
Isobutyrate	1,1-Dichloroethylene	Benzo[ghi]perylene	p-Nitroaniline
Lactic acid	1,2,3-Trimethylbenzene	Benzo[k]fluoranthene	Pentachlorophenol
Propionic acid	1,2,4-Trimethylbenzene	Benzyl alcohol	Phenanthrene
Antimony	1,2-Dichloroethane	Bis(2-chloroethoxy)methane	Pyrene
Beryllium	1,3,5-Trimethylbenzene	Bis(2-chloroethyl) ether	Acrylonitrile
Cerium	Acetone	Bis(2-chloroisopropyl) ether	Benzene
Cobalt	Carbon disulfide	Butyl benzyl phthalate	Diesel range organics
Silicon	Carbon tetrachloride	Carbazole	Ethanol
Silver	Chlorobenzene	Chrysene	Ethylbenzene
Sulfur	Chloroform	Di(2-ethylhexyl) phthalate	Gasoline range organics
Thallium	cis-1,2-Dichloroethylene	Di-n-octyl phthalate	isopropyl alcohol
Titanium	Cumene	Dibenz[a,h]anthracene	m-Xylene
Gross alpha	Ethyl tert-butyl ether	Dibenzofuran	o-Xylene
Gross beta	Isopropyl ether	Dibutyl phthalate	p-Xylene
Ra 226/228	Methyl tert-butyl ether	Diethyl phthalate	tert-Butanol
1,2-dinitrobenzene	Methylene chloride	Dimethyl phthalate	Toluene
1,3-dimethyl adamantane	tert-Amyl methyl ether	Fluoranthene	Xylene
1,4-dinitrobenzene	Tetrachloroethylene		
1-Methylnaphthalene	trans-1,2-Dichloroethylene		
2,3,4,6-Tetrachlorophenol	Trichloroethylene		
2,4-Dinitrophenol	Vinyl chloride		
2-butoxyethanol			
SAMPLE SIZE ≤ 8			
Organic Carbon	Lead	Arsenic	Nitrite as N
Oxygen	Mercury		
Turbidity	Molybdenum		
Cadmium	Nickel		
Chromium	Phosphorus		
Copper	Zinc		

Table 3-14. List of EPA Parameters Not Present in Washington County Spring Water Quality Characterization Database

Parameter - Measured		Parameter - Critical Analyte	
NOT FOUND			
Acetylene	1,3-dimethyl adamantane	Arsenic	Fluoranthene
Butane	1,4-dinitrobenzene	Barium	Fluorene
Ethane	1-Methylnaphthalene	Selenium	Hexachlorobutadiene
Ethylene	2,3,4,6-Tetrachlorophenol	Strontium	Hexachloroethane
Hydrogen	2,4-Dinitrophenol	Nitrate as N	Indeno[1,2,3-cd]pyrene
Methane	2-butoxyethanol	Nitrite as N	Isophorone
Propane	2.3.5.6-Tetrachlorophenol	1,2,4-Trichlorobenzene	m-Cresol
Inorganic carbon	adamantane	2,4,5-Trichlorophenol	m-Dichlorobenzene
Iron, ion (Fe2+)	Aniline	2,4,6-Trichlorophenol	m-Nitroaniline
Organic carbon	Azobenzene	2,4-Dichlorophenol	N-Nitrosodi-n-propylamine
Oxygen	Benzoic acid	2,4-Dimethylphenol	Naphthalene
Redox Potential	bis(2-ethylhexyl) adipate	2,4-Dinitrotoluene	Nitrobenzene
Turbidity	Cyclohexene, 1-methyl-4-(1-methylethenyl)-, (4R)-	2,6-Dinitrotoluene	o-Chlorophenol
Diethylene glycol monobutyl ether acetate	Diphenylamine	2-Chloronaphthalene	o-Cresol
Tetraethylene glycol	Hexachlorobenzene	2-Methylnaphthalene	o-Dichlorobenzene
Triethylene glycol	Hexachlorocyclopentadiene	3,3'-Dichlorobenzidine	o-Nitroaniline
Carbon-13/Carbon-12 ratio	m-Dinitrobenzene	4,6-Dinitro-o-cresol	o-Nitrophenol
d2H	N-Nitrosodimethylamine	4-methylphenol	p-Bromophenyl phenyl ether
d87/86Sr	p-Nitrophenol	Acenaphthene	p-Chloro-m-cresol
Oxygen-18/Oxygen-16 ratio	Phenol	Acenaphthylene	p-Chloroaniline
Acetate	Pyridine	Anthracene	p-Chlorophenyl phenyl ether
Butyric acid	Squalene	Benz[a]anthracene	p-Dichlorobenzene
Formate	Terpineol	Benzo(b)fluoranthene	p-Nitroaniline
Isobutyrate	Tri(2-butoxethyl)phosphate	Benzo[a]pyrene	Pentachlorophenol
Lactic acid	1,1,1-Trichloroethane	Benzo[ghi]perylene	Phenanthrene
Propionic acid	1,1,2-Trichloroethane	Benzo[k]fluoranthene	Pyrene
Antimony	1,1-Dichloroethane	Benzyl alcohol	Acrylonitrile
Beryllium	1,1-Dichloroethylene	Bis(2-chloroethoxy)methane	Benzene
Cadmium	1,2,3-Trimethylbenzene	Bis(2-chloroethyl) ether	Diesel range organics
Cerium	1,2,4-Trimethylbenzene	Bis(2-chloroisopropyl) ether	Ethanol
Chromium	1,2-Dichloroethane	Butyl benzyl phthalate	Ethylbenzene
Cobalt	1,3,5-Trimethylbenzene	Carbazole	Gasoline range organics
Copper	Acetone	Chrysene	Isopropyl alcohol
Lead	Carbon disulfide	Di(2-ethylhexyl) phthalate	m-Xylene
Mercury	Carbon tetrachloride	Di-n-octyl phthalate	o-Xylene
Molybdenum	Chlorobenzene	Dibenz[a,h]anthracene	p-Xylene
Nickel	Chloroform	Dibenzofuran	tert-Butanol
Phosphorus	cis-1,2-Dichloroethylene	Dibutyl phthalate	Toluene
Silicon	Cumene	Diethyl phthalate	Xylene
Silver	Ethyl tert-butyl ether	Dimethyl phthalate	
Sulfur	Isopropyl ether		
Thallium	Methyl tert-butyl ether		
Titanium	Methylene chloride		
Zinc	tert-Amyl methyl ether		
Ammonia-Nitrogen as N	Tetrachloroethylene		
Gross alpha	trans-1,2-Dichloroethylene		
Gross beta	Trichloroethylene		
Ra 226/228	Vinyl chloride		
1,2-dinitrobenzene			
SAMPLE SIZE ≤ 8			
Carbon Dioxide	Temperature, water	Sulfate	Potassium
Alkalinity as CaCO3	Iron	Calcium	Boron
Sulfide			

4.0: CONCLUSIONS AND KEY FINDINGS

EPA is conducting a retrospective case study in Washington County, PA as part of its evaluation of whether a relationship exists between hydraulic fracturing and drinking water. EPA selected this site "in response to complaints about appearance, odors and taste associated with water in domestic wells" (EPA, 2012b). To investigate these complaints, EPA is collecting groundwater and surface water quality data. The first completed and producing Marcellus Shale well in Washington County was recorded in late 2004, with additional substantial drilling and completions in the Marcellus Shale completed in 2005 to present. To assess potential water quality effects from post-hydraulic fracturing, sampling results in the appropriate context, pre-existing water quality conditions in the county must be first understood. To this end, this report provides an initial understanding and characterization of water quality conditions in Washington County based upon readily available data and information from the USGS, EPA, and state of Pennsylvania.

The primary objective of this report is to help understand and characterize groundwater and surface water conditions within the study area prior to unconventional oil and gas development, and identify parameters that may be present due to historic land use activities. This objective was satisfied by systematically conducting the steps outlined below.

- **Define the spatial boundaries and attributes of the Washington County study area.**

  EPA is currently collecting groundwater and surface water samples near Bulger in Smith Township, near Avella in Independence Township, near Hickory in Mt. Pleasant Township, near West Middleton in Hopewell Township, and near Amity in Amwell Township. The EPA study plan notes the areas investigated may expand or change within Washington County. Accordingly, the spatial boundary is defined as Washington County for this characterization report. Available information summarized in this report on land use, groundwater and surface water quality define the attributes of the study area. The study area of interest is vertically confined by near-surface geologic formations in Washington County that serve as drinking water resources. Where utilized for drinking water supply, these formations are generally within 300 feet of land surface, based upon groundwater well and groundwater quality data collected during this study. The depth to the Marcellus Shale formation ranges from roughly 5,000 to 7,500 ft bgs across the county.

- **Identify historical and current land use and water quality data that can be used to provide context for characterizing water resources in the defined study area, along with identifying associated parameters that could impact drinking water resources.**

  Both groundwater and surface water in Washington County have been significantly impaired by historical land uses that occurred long before shale gas drilling was introduced in 2005. These historical activities could provide sources for a large number of pollutants that may exist in groundwater and/or surface water in the study area. The most significant causes of water quality impairments in Washington County are AMD and agriculture. Other land uses that are known to impact water quality in the county include urban, residential, and road runoff; habitat modification; and municipal and industrial wastewater discharges. In addition, numerous recognized environmental sites were noted across the county and in close proximity to the EPA sampling locations, which could limit the ability to isolate impacts from one potential source and therefore require significant further investigation. Each of these activities has been in existence within Washington County prior to unconventional oil and gas development, and likely impacted water quality. Water quality parameters commonly associated with these land uses are summarized below:

- Coal mining and AMD: Constituents associated with coal mining activities include metal, ions, sulfate, and general water quality (i.e., TDS, pH). Approximately, 53% of the county has been mined using underground mining methods.
- Agricultural runoff: Chemical compounds associated with agricultural activities include insecticides, herbicides, fungicides, fertilizers (e.g., nitrogen and phosphorous), metals (e.g., arsenic), and other constituents (e.g., dissolved solids, bromide, selenium). In addition, algae blooms caused by agricultural runoff of nitrogen and phosphorous can be a source of organic carbon that promotes the formation of DBPs upon chlorination of surface water in water treatment plants (EPA, 2005). Agricultural and livestock activities can be a source of methane (King, 2012).
- Non-point sources, stormwater runoff, and industrial activities: Constituents associated with these sources include PAHs, PCBs, metals; salts, pH; siltation; suspended solids; and nutrients depending upon the types of activities in the area.
- Conventional oil and gas development: Constituents associated with these activities comprise petroleum hydrocarbons, including BTEX and methane. Over 11,600 oil and gas wells have been drilled over the past 130 years in Washington County, many of which were drilled prior to the existence of modern techniques or regulations. The Marcellus shale wells are typically deeper than these shallower conventional wells, being between 5,000 to 7,000 feet in depth.

TMDLs have been established due to known surface water quality impairments for over 690 miles of impaired streams and rivers in Washington County, representing approximately 35% of the total stream length. Most impaired streams are located in the northern part of the county where historic surface and subsurface coal mining activities have taken place. The entire length of the Monongahela River along the eastern boundary of the county is also listed as impaired. The chemicals that have caused these surface water impairments in Washington County including chlordane and pesticides, PCBs, metals, pH, siltation, suspended solids, nutrients, organic enrichment, low DO, and turbidity.

Numerous regulations and permitting requirements are in place to protect water resources from different land uses. Pennsylvania's oil and gas regulatory program is focused on the protection of water resources and is one of the most stringent programs of any oil and gas producing state. STRONGER, a multi-stakeholder organization requested by PADEP to review its oil and gas regulatory program, concluded in 2010 that the framework in place in Pennsylvania was well-managed, professional, and meeting its stated objectives (STRONGER, 2010).

- **Develop a comprehensive list of water quality parameters detected or monitored for in the study area, and compare to EPA QAPP requirements.**

  A comprehensive list of water quality parameters monitored for and detected in Washington County was established using information collected in the databases discussed in Section 2.2. One limitation of these databases is that the water quality data were focused on general water quality parameters; data on organic water quality parameters are limited. The data sources used are considered secondary data, and by definition were not originally collected for the specific purposes of this report. However, these data sources are commonly used to define background or baseline groundwater, surface water, and/or spring water quality. For this study, data collected prior to 2005 represent conditions prior to significant development of the Marcellus Shale through directional drilling and hydraulic fracturing in Washington County, and were considered to be representative of background conditions.

The majority of the parameters have insufficient data to adequately characterize background water quality. Of the 196 parameters listed as M or CA in the EPA QAPP, the evaluation identified 167 groundwater quality,175 surface water, and 185 spring water quality parameters that have no results or results from fewer than eight locations. This lack of historical water quality data in conjunction with historical land use and known impairments will make it challenging to determine whether recent hydraulic fracturing has impacted water quality without further investigation.

- **Conduct summary statistical analyses and comparing the water quality summary statistics to relevant state and federal screening criteria.**
  - Groundwater quality data summary
    - Groundwater quality data were compiled to characterize Washington County groundwater quality prior to unconventional oil and gas development (i.e., pre-2005). The data represent samples collected from 1926 to 2002 (no data are available from 2002-2005).
    - Groundwater data were available from 207 wells. All but one well within this dataset contains results from a single groundwater sample; the remaining well contains two samples. Therefore, assessing time series water quality data at individual groundwater sampling locations is not possible. Formation assignments were available for less than half of the available records; therefore, no quantitative assessments were completed between different groundwater-bearing units. No clear trends with depth are apparent over the range of available well depths (0-301 ft) reported in the collected data.
    - Data for organic compounds are extremely limited and are insufficient to characterize groundwater quality.
    - Parameters above one or more screening criteria and the number of results and percentage above each criteria are presented in Table 4-1
      - General water quality parameters (pH, TDS, and sulfide) are above one or more screening criteria. pH and sulfide are identified as EPA parameters.
      - Major ions chloride, fluoride, sodium, and sulfate are above one or more screening criteria; all are identified as EPA parameters.
      - Metals including aluminum, arsenic, chromium(VI), iron, lead, manganese, and nickel are abpve one or more screening criteria. All but chromium(VI) are identified as EPA parameters.
      - One nutrient, nitrate as N, is above two screening criteria and is identified as an EPA parameter.
    - Chemical data from five locations (two of which were potentially associated with impact monitoring) were removed from the complete dataset; summary statistics and the frequency of results above screening criteria are similar for both the complete and reduced data sets as shown in Table 4-1.
  - Surface water quality data summary
    - Elevated TDS, sulfate, and iron concentrations are most likely related to AMD or mining impacted surface water locations. AMD can also come into contact with

rock and soil resulting in the dissolution of other metals such as aluminum and manganese (NRC, 2005).

    - Surface water quality data were available at 156 locations. Temporal data at individual monitoring locations are extremely limited; as a result, characterizing changes in background surface water quality over time at individual locations over time is also extremely limited.
    - An AVOVA comparison revealed that significant surface water quality differences exist between the three HUC 8 watersheds present in Washington County.
    - Data for organic compounds are extremely limited and are insufficient to characterize surface water quality.
    - Parameters above one or more screening criteria and the number and percentage of results above each criteria are presented in Table 4-2
        - General water quality parameters alkalinity, pH and TDS are above one or more screening criteria. Alkalinity and pH are identified as EPA parameters.
        - Major ions, chloride, fluoride, sulfate, and sodium, are above one or more screening criteria; all are identified as EPA parameters.
        - Metals including aluminum, iron, and manganese are above one or more screening criteria; all are identified as EPA parameters.
    - Chemical data from three locations (two of which were potentially associated with impact monitoring) were removed from the complete dataset; summary statistics and the frequency of results above screening criteria are similar for both the complete and reduced data sets as shown in Table 4-2.
  - Spring water quality data summary
    - Spring water quality data were available at 53 locations; none of the locations had multiple samples.
    - Data for organic compounds are extremely limited and are insufficient to characterize spring water quality.
    - Parameters above one or more screening criteria and the number and percentage of results above each criteria are presented in Table 4-3
        - Major ions cloride and sulfate are above one or more screening criteria; both all are identified as EPA parameters.
        - Metals including aluminum and manganese are above one or more screening criteria; both are identified as EPA parameters.
- Determining a relationship between hydraulic fracturing and drinking water will be challenging given the lack of adequate data to characterize background water quality conditions. Water quality data presented to characterization conditions prior to hydraulic fracturing in this report should only be used in the context of providing an understanding of the observed range in parameter concentrations for the study area (e.g., Washington County). As noted by the USGS (DeSimone, 2009; Ayotte et al., 2011) and observed in the data presented here, natural variability, land use patterns and other factors affect observed water quality. These factors have to be understood at the local level or specific areas of interest before a good understanding of background water quality can be determined for those areas. Without adequate background water quality, impacts

observed as part of the EPA study will require a rigorous investigation before relating those impacts to hydraulic fracturing.

Table 4-1. Pre-2005 Groundwater Quality Summary of Parameters Above Screening Criteria

				Complete Dataset			Reduced Dataset		
Class	Parameter	Fraction	EPA	N	No. Above Screening Criteria	% Above Screening Criteria	N	No. Above Screening Criteria	% Above Screening Criteria
Gen WQ	pH	Total	M	81	2	2.5	79	2	2.5
Gen WQ	pH (field)	Total	M	192	11	5.7	189	11	5.8
Gen WQ	TDS	Dissolved	-	99	33	33	97	33	34
Gen WQ	Sulfide	Total	N	61	2	3.3	61	2	3.3
Major Anions	Chloride	Dissolved	CA	190	7	3.7	185	7	3.8
Major Anions	Fluoride	Dissolved	M	158	17	11	156	17	11
Major Anions	Sulfate	Dissolved	CA	100	4	4.0	98	4	4.1
Major Cations	Sodium	Dissolved	CA	191	81	42	188	81	43
Metals	Aluminum	Dissolved	M	102	5	4.9	99	5	5.1
Metals	Arsenic	Dissolved	CA	10	8	80	10	8	80
Metals	Chromium(VI)	Dissolved	-	9	2	22	9	2	22
Metals	Iron	Total	M	86	33	38	84	32	38
Metals	Iron	Dissolved	M	66	16	24	66	16	24
Metals	Lead	Dissolved	M	8	1	13	8	1	13
Metals	Manganese	Dissolved	M	105	54	51	105	54	51
Metals	Manganese	Total	M	85	28	33	85	28	33
Metals	Nickel	Dissolved	M	9	1	11	9	1	11
Nutrients	Nitrate as N	Dissolved	CA	13	1	7.7	11	1	9.1

M = measured, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
CA = critical analyte, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
N = number of samples

Table 4-2. Pre-2005 Surface Water Quality Summary of Parameters Above Screening Criteria

				Complete Dataset			Reduced Dataset		
Class	Parameter	Fraction	EPA	N	No. Above Screening Criteria	% Above Screening Criteria	N	No. Above Screening Criteria	% Above Screening Criteria
Gen WQ	Alkalinity as CaCO3	Total	M	320	7	2.2	320	7	2.2
Gen WQ	pH	Total	M	238	15	6.3	220	14	6.4
Gen WQ	pH (field)	Total	M	456	34	7.5	438	33	7.5
Gen WQ	TDS	Dissolved	-	315	86	27	298	86	29
Major Anions	Chloride	Dissolved	CA	346	9	2.6	35	9	2.6
Major Anions	Fluoride	Dissolved	M	279	1	0.4	279	1	0.4
Major Anions	Sulfate	Dissolved	CA	354	82	23	337	82	24
Major Cations	Sodium	Dissolved	CA	276	98	36	275	97	35
Metals	Aluminum	Total	M	46	42	91	30	26	87
Metals	Aluminum	Dissolved	M	124	70	56	123	69	56
Metals	Iron	Total	M	326	235	72	309	219	71
Metals	Iron	Dissolved	M	253	15	5.9	253	15	5.9
Metals	Manganese	Dissolved	M	361	219	61	360	218	61
Metals	Manganese	Total	M	304	206	68	287	189	66

M = measured, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
CA = critical analyte, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
N = number of samples

Table 4-3. Pre-2005 Spring Water Quality Summary of Parameters Above Screening Criteria

Class	Parameter	Fraction	EPA	N	No. Above Screening Criteria	% Above Screening Criteria
Major Cations	Sodium	Dissolved	CA	42	4	9.5
Metals	Aluminum	Dissolved	M	35	3	8.6
Metals	Manganese	Dissolved	M	21	7	33

M = measured, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
CA = critical analyte, as defined in EPA QAPP for Washington County Retrospective Case Study (EPA, 2012b).
N = number of samples

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Appendix A
QA/QC Review

WASHINGTON COUNTY DATA QUALITY ASSESSMENT

The site characterization data quality objectives (DQOs) were followed to assess the quality of the Washington County, Pennsylvania site characterization data and inform a general assessment of data quality. This assessment was performed on the full site database to assess the overall quality of available data. In general, it was determine that the available metadata and supporting information were not sufficient to make definitive statements about the quality of the data; therefore, no data were eliminated from the site characterization based on this data quality assessment. Table A-1 summarizes the review and the results of the data quality assessment. The assessment process is described below.

Table A-1. Summary of Data Quality Assessment

DQO Assessment Criteria[a]	Groundwater	Surface Water	Springs
Organizations contributing data	USGS (NWIS, NURE, PADEP[b])	USGS (NWIS, NURE), STORET	USGS (NWIS, NURE)
• Data were collected by an agency known to implement a rigorous quality system. • Data were collected under approved Quality Assurance Project Plan (QAPP)/Field Sampling Plan (FSP)	Yes	Yes	Yes
Data were collected by laboratories known to implement a rigorous quality system.	Unknown	Unknown	Unknown
The analysis methods were identified and appropriate	No	No	No
For non-detect values, the detection limits were defined and sensitive enough for the parameter.	Yes	Yes Except for Selenium	Yes
If quality control data were available, accuracy was demonstrated to be ≥80% and precision was demonstrated to be ±30%. Otherwise, is there evidence that quality-related qualifiers were applied to the data.	Unknown	Unknown	Unknown

[a] Assessment Criteria: **Yes** (DQO assessment criteria achieved for ≥90% of data in full dataset). **Variable** (DQO assessment criteria achieved for 50-90% of data in full dataset). **No** (DQO assessment criteria achieved for <50% of data in full dataset. **Unknown** (information was not provided ≥90% of data in full dataset).
[b] The PADEP report contains USGS data for five monitoring locations.

Organization and Quality Documentation

The existence and application of a quality system is a critical aspect of collecting high-quality data because it indicates that an organization has a documented, systematic approach to apply quality principles to data collection. A review of the website of each organization collecting data for the study was reviewed to for evidence that a quality system was in place. Evidence could include a reference or link to a quality management plan, quality assurance (QA) project plan, sampling and analysis plan, SOPs, a discussion of quality control, or other elements of a QA document.

- **Groundwater**. Groundwater data were gathered from three sources; these sources and the approximate percent of data contributed by each are as follows:
    - USGS NWIS (69%)
    - USGS NURE (28%)
    - USGS Pennsylvania (PA) Report (3%)

  Data collected by USGS are supported by a documented quality system. Field samples and measurement data are collected under the USGS National Field Manual for the Collection of Water-Quality Data and National Field Quality Assurance Program, respectively. The NURE database does not identify the organizations that contributed data posted on the website. None of the websites identified the laboratories performing analysis. Despite these unknowns, the quality of groundwater data is likely acceptable due to significant involvement of USGS as both the database source and organization reporting the data.

- **Surface Water**. Surface water data were gathered from three sources; these sources and the approximate percent of data contributed by each are as follows:
    - EPA STORET (10%)
        - EPA National Aquatic Resource Survey (0.13%)
        - PA Department of Environmental Protection (PADEP) (10%)
    - USGS NURE (10%)
    - USGS NWIS / USGS PA Water Science Center (80%)

  As noted above, data collected by USGS is supported by a quality system. Similarly, the PADEP appears to have a quality system for the collection of environmental samples. Although the laboratories performing analysis are not defined for most surface water data, the quality of these data is likely acceptable because it is supported by the quality systems of the collection organizations and, for NURE and NWIS, the requirements of the source databases. Data entered into the EPA STORET Data Warehouse are not collected by a single entity or organization but by a multitude of water resource management groups including states, tribes, watershed groups, other federal agencies, volunteer groups and universities. It was not possible to determine the specific collection organizations for the STORET data and therefore the existence of a quality system for these organizations is unknown. The assessment determined that the presence of a quality system could not be confirmed for STORET data used for this report.

- **Springs**. Spring water data were gathered from two sources; these sources and the approximate percent of data contributed by each are as follows:
    - USGS NURE (74%)
    - USGS NWIS / USGS PA Water Science Center (26%)

  As noted above, data collected by USGS is supported by a quality system. Although the laboratories performing analysis are not defined for any springs water data, the quality of these data is likely acceptable because it is supported by the quality systems of the collection organizations and, for NURE and NWIS, the requirements of the source databases.

Laboratories

The qualifications of analytical laboratories are critical in supporting the quality of data produced. Laboratory accreditation by an independent body such as the National Environmental Laboratory Accreditation Program (NELAP) indicates that the laboratory has a quality system in place.

- **Groundwater.** The analytical laboratories were not defined for any of the 4127 groundwater results and therefore the qualifications of the laboratory cannot be assessed.
- **Surface Water.** The analytical laboratories were not defined for any of the 658 stream results and therefore the qualifications of the laboratory cannot be assessed.
- **Springs.** The analytical laboratories were not defined for 12453 of the 12707 (98%) surface water results and therefore the qualifications of the laboratory cannot be assessed.

Methods

Many water quality parameters can be collected and measured using more than one method. For example, methods for collection and analysis of water samples for total organic carbon (TOC) analysis are described EPA SW846 method 9060, EPA waste water method 415.2 and Standard Methods 5310. Each method is appropriate for specific applications but may yield different results or have different detection limits. Therefore, it is important to know the sample collection and analytical methods used for analysis so that the appropriateness of the method for the current application can be determined.

- **Groundwater.** Analytical methods were reported for only 18% of the groundwater data. NWIS was the only organization reporting the methods associated with the analytical results. All of the methods reported were internal standard operating procedures (SOPs). However, the fact that internal SOPs exist for the analysis indicates that the methods are established and standardized. The groundwater data are considered variable for this assessment element.
- **Surface Water.** Analytical methods were reported for 31% of the surface water data. Most STORET results included the analytical method as did approximately 25% of the NWIS results. The methods cited are primarily organizational SOPs for which the analytical laboratory is not identified. As noted above, the fact that internal SOPs exist for the analysis indicates that the methods are established and standardized. The surface water data are considered variable for this assessment element.
- **Springs.** Analytical methods were reported for 6% of the spring water data. NWIS was the only organization reporting the methods associated with the analytical results. The one method cited is an organizational SOP for which the analytical laboratory is not identified. As noted above, the fact that internal SOPs exist for the analysis indicates that the methods are established and standardized. The spring water data are considered variable for this assessment element.

Detection Limits

Laboratory detection limits must be appropriate for the intended use of the data. While detection limits may be appropriate for the initial data collection purpose, they may not be appropriate for a secondary use, such as this report. Therefore, the detection limits of the dataset were reviewed vs. State and Federal screening criteria applicable to Washington County. The results are summarized in Table A-2.

- **Groundwater.** For groundwater, of the 1016 results for EPA chemicals of interest, results for 40 samples were below the laboratory detection limits (Table A-3). Laboratory detection limits were reported for all “U” values in the dataset. Laboratory detection limits for three parameters (acrylonitrile, arsenic, naphthalene) in four instances are above one or more screening criteria. Data quality based on laboratory detection limits is acceptable.

- **Surface Water.** For surface water, of the 2600 results for EPA chemicals of interest, 114 were measured below the laboratory detection limits (Table A-4). Laboratory detection limits were reported for all “U” values in the dataset with the exception of one selenium result reported in the EPA STORET database. All reported laboratory detection limits were lower than any applicable screening criteria with the exception of total selenium, total arsenic, and dissolved benzo[a]pyrene. All 11 total selenium results in the database were reported as less than the detection limit of 7 µg/l, which is higher than the CWA chronic screening threshold of 5 µg/l. Total arsenic and dissolved benzo[a]pyrene detection limits exceeded the state and regional screening thresholds in a single sample (see Table A-2). Data quality based on laboratory detection limits is acceptable with the exception of selenium.

- **Springs.** For groundwater, of the 151 results for EPA chemicals of interest, results for 2 samples were below the laboratory detection limits (Table A-5). Laboratory detection limits were reported for all “U” values in the dataset. All reported laboratory detection limits were lower than any applicable screening criteria.

Quality Control

Quality control samples collected in the field (field blanks and field duplicates) and in the laboratory (method blanks and spiked samples) are used to identify potential field or laboratory contamination and to quantify the bias, accuracy and precision of the entire measurement system. Neither the USGS data nor STORET data included quality control results. The STORET dataset included two field duplicates but the parent samples for these duplicates could not be identified. Therefore, the assessment of quality control results could not be used to inform the quality of data used for this report.

- **Groundwater.** For groundwater, no laboratory QC, field equipment blank, or field duplicate data were reported. Overall, there is insufficient QC data available to assess data quality, therefore on the basis of QC data, data quality is unknown.

- **Surface Water.** For surface water, no laboratory QC, field equipment blank, or field duplicate data were reported. Overall, there is insufficient QC data available to assess data quality, therefore on the basis of QC data, data quality is unknown.

- **Springs.** For springs, no laboratory QC, field equipment blank, or field duplicate data were reported. Overall, there is insufficient QC data available to assess data quality, therefore on the basis of QC data, data quality is unknown.

Data Qualifiers

Data qualifiers assigned by either a laboratory or independent validation provide information about the reported results. Of primary interest are qualifiers that indicate problems with sample collection, handling, analysis, or quality control samples that could influence the accuracy or precision of the reported results. For the datasets examined for this report, laboratory comments also provide valuable information about the data when no qualifiers are assigned. An exhaustive review of comment fields was conducted as part of this review. In some cases, the comments provided addition information about sample preservation or processing procedures, such as holding times or titration endpoints; other comments documented data quality issues. These comments were used to assign three qualifiers to the data: U (detected below reporting limits), S qualifier (suspect) and J (estimated value).

- U qualifiers were assigned if the comment indicated a value (a) was less than (<) another number, assumed to be the reporting limit; (b) was less than a practical quantitation limit or reporting limit, or (c) was between the reporting limit and method detection limit.
- J qualifiers were applied if the comment indicated problems with quality control sample results, blank contamination, holding time or temperature deviations, or if the values were estimated.
- S qualifier (suspect) was assigned if the data entry comment indicated that it was suspect; if the parameter was marked as a highly variable compound; if the method high range was exceeded; or if processing errors were noted.

If more than one qualifier applied to the same value the qualifiers were assigned according to the hierarchy: U > S>J.

For the Washington County dataset, dataset did not provide comments that could be used to assess data quality. Without data qualifiers or quality control data it is not possible to determine if the results of quality control samples analyzed with the field samples demonstrated that the analytical quantification system was in control. A summary of the qualifiers applied by the laboratories is presented below.

- **Groundwater**. Overall, 11% of the data were assigned qualifiers (Table A-3). Of the qualifiers assigned, the vast majority were "U" qualifiers, indicating that a compound was not detected above the reporting limit. One value (less than 0.1% of the data) was qualified with a data quality-related qualifier J (estimated).
- **Surface Water**. Overall, less than 10% of the data were assigned qualifiers (Table A-4). For surface water data, only the "U" qualifier was applied, indicating compounds not detected above the reporting limit. No "J" (estimated) qualifiers were assigned to the dataset.
- **Springs.** Overall, approximately 15% of the data were assigned qualifiers (Table A-5). For spring water data, only the "U" qualifier was applied, indicating compounds not detected above the reporting limit. No "J" (estimated qualifiers were assigned to the dataset.

Table A-2. Non-Detected Values with Detection Limits Equal to or Above Screening Criteria (All units are µg/L)

Data Source	EPA Chemical of Interest	Fraction	Lab Detection Limit (ug/l)	Non-Detected Values (U) >Screening Criteria	MCL	SMCL	PA PWS	PA Fish	PA Act2	CWA Chronic	Reg 3 Carc	Reg3 Non Carc
Groundwater												
USGS NWIS	Acrylonitrile	Total	1	1					**0.72**		**0.045**	4.1
USGS NWIS	Arsenic	Dissolved	1	2	10				10		**0.045**	4.7
USGS PA RPT	Arsenic	Total	4	1	10				10		**0.045**	4.7
USGS NWIS	Naphthalene	Total	0.2	1					100		**0.14**	6.1
Surface Water												
USGS NWIS	Arsenic	Total	20	1	**10**		**10**	340		150	**0.045**	
USGS NWIS	Benzo[a]pyrene	Dissolved	0.12	1	0.2		**0.0038**				**0.0029**	
USGS NWIS	Selenium	Total	7	11	50					**5**		

Bolded value indicates that detection limits are above or screening values.

Table A-3. Groundwater Data Qualifiers Based on Data Source and Chemicals Listed in the EPA QAPP

Source	J	U	No Qualifier Assigned	Total
EPA CHEMICALS OF INTEREST				
USGS NURE			273	273
USGS NWIS		35	660	695
USGS PA RPT		5	43	48
Total Qualifiers		**40**	**976**	**1016**
CHEMICALS MEASURED BY EPA BUT NOT CHEMICALS OF INTEREST				
USGS NURE		101	579	680
USGS NWIS	1	137	1066	1204
USGS PA RPT		15	42	57
Total Qualifiers	**1**	**253**	**1687**	**1941**
CHEMICALS NOT MEASURED BY EPA				
USGS NURE		104	110	214
USGS NWIS		65	868	933
USGS PA RPT		4	19	23
Total Qualifiers		173	997	1170
Grand Total	**1**	**466**	**3660**	**4127**

Table A-4. Surface Water Data Qualifiers Based on Data Source and Chemicals Listed in the EPA QAPP

Source	U	No Qualifier Assigned	Total
EPA CHEMICALS OF INTEREST			
EPA STORET	1	258	259
USGS NURE		319	319
USGS NWIS	113	1909	2022
Total Qualifiers	**114**	**2486**	**2600**
CHEMICALS MEASURED BY EPA BUT NOT CHEMICALS OF INTEREST			
EPA STORET		617	617
USGS NURE	87	690	777
USGS NWIS	411	4712	5123
Total Qualifiers	**498**	**6019**	**6517**
CHEMICALS NOT MEASURED BY EPA			
EPA STORET		399	399
USGS NURE	102	112	214
USGS NWIS	480	2497	2977
Total Qualifiers	582	3008	3590
Grand Total	**1194**	**11513**	**12707**

Table A-5. Springs Water Data Qualifiers Based on Data Source and Chemicals Listed in the EPA QAPP

Source	U	No Qualifier Assigned	Total
EPA CHEMICALS OF INTEREST			
USGS NURE		109	109
USGS NWIS	2	40	42
Total Qualifiers	**2**	**149**	**151**
CHEMICALS MEASURED BY EPA BUT NOT CHEMICALS OF INTEREST			
USGS NURE	45	236	281
USGS NWIS	6	72	78
Total Qualifiers	**51**	**308**	**359**
CHEMICALS NOT MEASURED BY EPA			
USGS NURE	46	48	94
USGS NWIS		54	54
Total Qualifiers	46	102	148
Grand Total	**99**	**559**	**658**

Conclusion for Groundwater
Based on the data quality assessment, the groundwater data should be used with care for the following reasons: the analytical laboratories and laboratory quality control data or quality-related qualifiers are not unknown; analytical methods were not reported for most data. Quality system elements that support the data include collection organizations with known quality systems and acceptable laboratory detection limits.

Conclusion for Surface Water
Based on the data quality assessment, the groundwater data should be used with care for the following reasons: the analytical laboratories and laboratory quality control data or quality-related qualifiers are not unknown; analytical methods were not reported for most data. Quality system elements that support the data include collection organizations with known quality systems and acceptable laboratory detection limits with the exception of Selenium, for which all reported detection limits were greater than the CWA Chronic value.

Conclusion for Springs
Based on the data quality assessment, the groundwater data should be used with care for the following reasons: the analytical laboratories and laboratory quality control data or quality-related qualifiers are not unknown; analytical methods were not reported for most data. Quality system elements that support the data include collection organizations with known quality systems and acceptable laboratory detection limits.

Appendix B
Washington County Water Quality Data

WASHINGTON COUNTY WATER QUALITY DATA

The groundwater, surface water and spring water quality data collected for this report were collected from several different databases. Often the parameter name for a compound was provided in a slightly different form or in different units. Where appropriate, the data were standardized to consistent units and parameter names prior to developing summary statistics for each parameter. Further screening of the parameters was performed prior to inclusion in the Section 3 summary data tables. For example, there had to be sufficient data for a parameter to be included in the summary tables. In this case, sufficient data were defined as having a result from at least eight distinct locations (note distinct locations were selected to reduce the influence of having multiple results from a single sampling location on the reported baseline data set). Prior to inclusion in Section 3 summary data tables, the collected data were aggregated by media (groundwater, surface water, spring water) initially, then screened for inclusion; data were removed from the summary tables if:

- There were less than eight distinct locations having at least one result (as noted above, this screen was included to minimize the influence of multiple results for a parameter from a single location).
- All results for a parameter are non-detect. Note for EPA parameters (M or CA), if the number of locations (N) with at least one result is eight or more, the parameter is identified as having sufficient baseline data for this effort and is included in the Section 3 summary data tables; if $N < 8$, the parameter is identified as having <8 results (insufficient baseline data for this effort).
- Results for a parameter are identified as redundant, meaning there are more than one reported result for the parameter for an individual sample (for example, TDS is reported both as a calculated and laboratory measured result by sample; the calculated values are identified as redundant and are not included in the summary data tables).

There were also several parameters for which result fractions were reported in a number of different ways depending upon the different data sources queried, even after the initial data standardization. In these cases, the result fraction with the greatest number of results is included in the Section 3 summary tables for EPA parameters (M or CA). Professional judgment was further used to reduce the number of non-EPA parameters included in Section 3 summary tables to exclude data that are of little or no concern to understanding baseline water quality conditions. Table B-1 summarizes data removed based upon the parameter name, result fraction, or reported units by media. This same screen was used for each characterization report; therefore, some of the parameters, result fractions, or units specified in Table B-1 may not be included within the raw data collected for this report.

All removed data are retained in this appendix for potential future use in electronic format. The electronic data are also provided by media. Four Excel files are included:

- Table B-2 Wash Removed 20121218.xls
- Table B-3 Washington GW Data Dump 20121218.xls
- Table B-4 Washington SW Data Dump 20121218.xls
- Table B-5 Washington SPR Data Dump 20121218.xls

Table B-2 contains three worksheets for data that were not included (data removed) from the Section 3 summary data tables, one each for the groundwater, surface water, and spring water quality data. Tables B-3, B-4, and B-5 contain the collected groundwater, surface water, and spring data for Washington County. This information represents all of the data used to characterize the water quality in Washington County, PA.

Table B-1. Data removed based on parameter, result fraction, or result units by media

All Media		
Result Fraction	Supernate	
Result Fraction	Suspended - as long as parameter name is not total suspended solids	
Result units	ueq/l, %, meq/l, none, or nu	
Surface and Spring Water		
Parameter Name	**Result Fraction**	**Result Units**
Acidity	Total	mg/l as H
Acidity	Total	mg/L $CaCO_3$
Ammonia and Ammonium	Dissolved	mg/l NH_4
Ammonia and Ammonium	Total	mg/l NH_4
Bicarbonate		
Hydrogen ion		
Gross alpha radioactivity	Dissolved	pCi/l
Thorium-230 ref std	Dissolved	pCi/l
Cesium-137 ref std	Dissolved	pCi/l
Inorganic nitrogen (nitrate and nitrite)	Total	
Inorganic nitrogen (nitrate and nitrite) as N	Total	
Inorganic nitrogen (nitrate and nitrite) as N	Dissolved	
Nitrate	Dissolved	mg/l
Nitrate-nitrite	Total	
Nitrogen, mixed forms (NH3), (NH4), organic, (NO2) and (NO3)	Total	mg/l NO_3
Phosphate	Dissolved	mg/l
Phosphate	Dissolved	mg/l as P
Phosphorous as PO4	Total	mg/l
Sodium adsorption ratio		
Sodium plus potassium		
Sodium, percent total cations		
Strontium	Dissolved	ug/l
Surfactants -- CWA304B		
Total Solids		
Turbidity	Total	FNU
Turbidity	Total	JTU
Groundwater		
Parameter Name	**Result Fraction**	**Result Units**
Acidity	Total	mg/l as H
Acidity	Total	mg/L $CaCO_3$
Carbonate (CO_3)		
Hydrogen ion		
Bicarbonate		
Sodium adsorption ratio		
Sodium plus potassium		
Sodium, percent total cations		
Nitrate	Dissolved	mg/l
Nitrate-Nitrite	Dissolved	mg/l
Nitrite	Dissolved	mg/l
Phosphate	Dissolved	mg/l

Table B-1. Data removed based on parameter, result fraction, or result units by media (Continued)

Phosphorous as PO_4	Total	mg/l
Orthophosphate as PO_4	Total	mg/l
Settleable solids	Total	mg/l
ammonia and ammonium	Dissolved	mg/l as NH_4
ammonia and ammonium	Total	mg/l as NH_4
d13C DIC		

Appendix C
Statistical Analyses

ANOVAs for Groundwater and Surface Water

Statistical Analysis of Ground Quality Data in Washington County, Pennsylvania

The data used in this analysis are included electronically in Tables C-1 Appendix C GW Dissolved Chem Pre 2004.csv.

Groundwater ANOVA

Groundwater quality data in Washington County, Pennsylvania were analyzed to evaluate whether older data could be summarized with more recently collected data. Five parameters were included in the analysis. Data were divided into two periods associated with changes in environmental policy and changes in drilling practices: Pre-1972 (year of Clean Water Act) and 1972-2002 (after CWA and before prevalent hydraulic fracturing practices). As noted in the report, the Clean Water Act was selected because it represent a change in environmental policy bringing more awareness to water quality problems and also represents a time when analytical methodology started to become more standardized. Data from the periods were available from various sources:

Periods	Sources
Pre-1972; 1972-2005	EPA STORET
Pre-1972; 1972-2005	NURE
Pre-1972; 1972-2005	NWIS
Pre-1972; 1972-2005	USGS PA RPT

Chemicals analyzed included calcium, chloride, magnesium, sodium and sulfate in the dissolved fractions. A visual inspection of the locations of the sources from the Pre-1972 and 1972-2002 periods indicated the spatial coverage of the two periods overlapped and were not clustered within Washington County.

The groundwater data were analyzed for significant differences between the periods by analysis of variance (ANOVA), treating the indicator for period (Pre 1972, 1972-2002) as the treatment covariate. An analysis was performed comparing the Pre 1972 and 1972-2002 data. In this analysis, the value of dissolved fraction is modeled as normally distributed around a mean related to the period, and with variance that is homogeneous for the two periods. Box plots of the groundwater chemical values vs. period indicate that some of the data are skewed, hence, the analyses were run both on the natural scale and on log-transformed data.

The statistical hypothesis is that the coefficients for period are not significantly different from zero; or equivalently that the F-statistic that tests whether a model with period included as an indicator is significantly different from an intercept model (without covariate indicators of period). For the groundwater analysis, Pre 1972 is the reference or intercept. In the analysis, for all the chemicals, the F-statistic indicates that there is not a significant difference between the pre 1972 and 1972-2002 data.

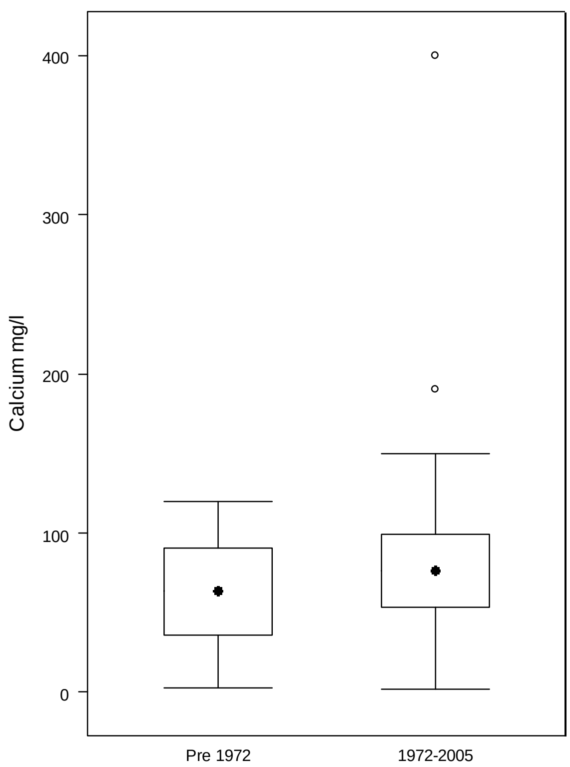
Surface Water ANOVA

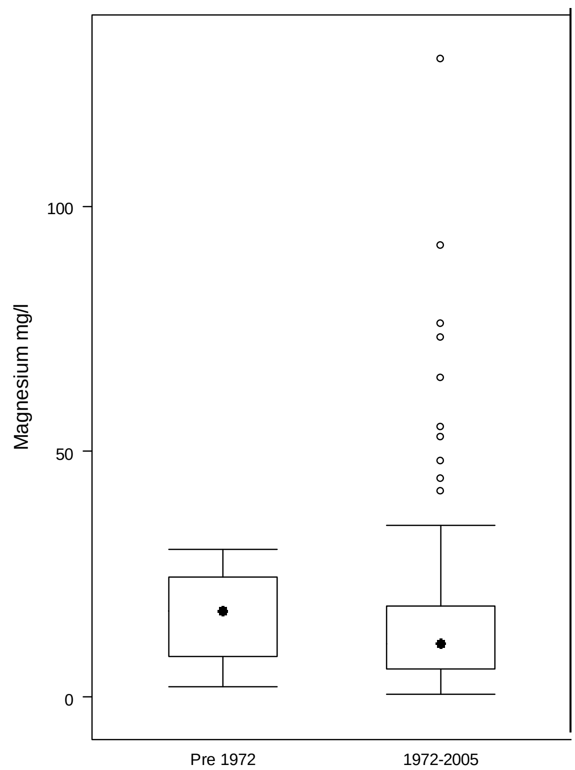
The surface water data (excluding springs) were analyzed for differences between the HUC 8 watersheds. The model was configured to include an indicator for each of the three HUC 8 watersheds, excluding an intercept from the model, so that the coefficients can be interpreted directly as the HUC 8 watershed average value of the chemical. The results indicate that there are highly significant differences between chemical levels in the surface water dissolved fraction for each of the chemicals. Because some of the locations had multiple observations over time, the analysis was repeated on data aggregated by location, using the location mean for each of the chemicals. The revised analysis does not change the conclusion that there are significant differences between HUC 8 watersheds. Also, boxplots of the chemical levels indicated that the levels are skewed. The regression analyses were repeated on the log-transformed data.

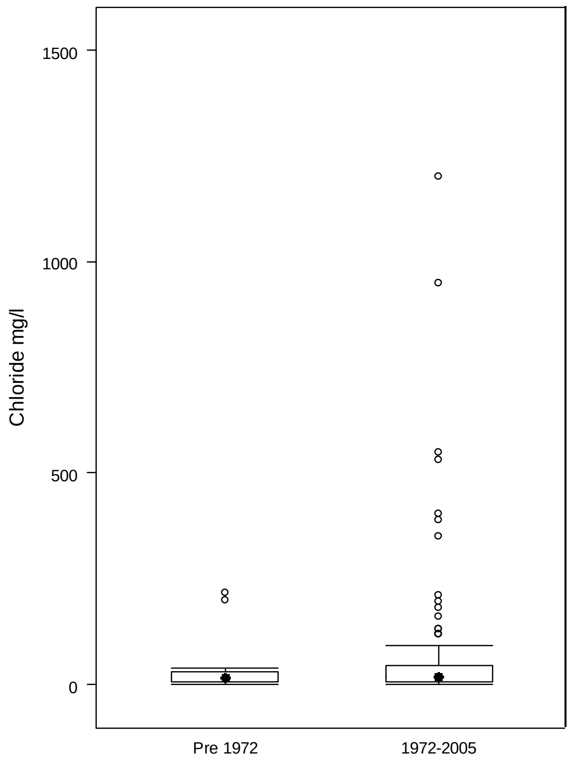
The conclusions are the same on the log and natural scales – there is significant difference between HUC 8 watersheds. For convenience of interpretation, the estimated coefficients of the HUC 8 watersheds (the HUC 8 watershed estimated average) are reported on the natural scale.

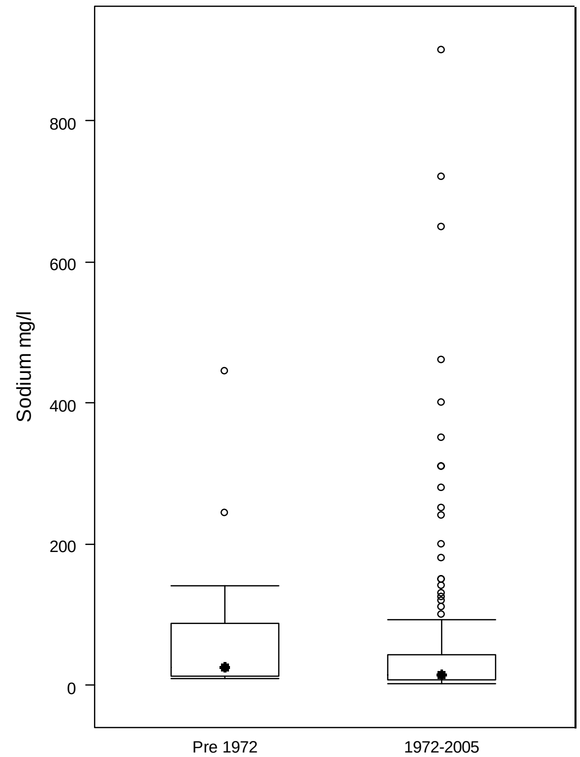
Box Plots
Box and whisker plots are included for both the groundwater analyses. Upper and lower ends of the rectangles indicate the 1st and 3rd quartile of the values. The solid dot represents the median. The whiskers extend to the observed value that is not more than 1.5 times the inter-quartile range beyond the 1st and 3rd quartiles. Circles beyond the whiskers represent any other observed values that may exist beyond the range of whiskers. Observations outside the whiskers are not necessarily outlier and can be thought of as indicating the tails of the distribution. However when one or two circles fall well beyond the rest, additional investigation is warranted to assess whether the observation is an outlier or if it is a recording or measurement error or somehow contaminated. No outliers were removed as part of this evaluation.

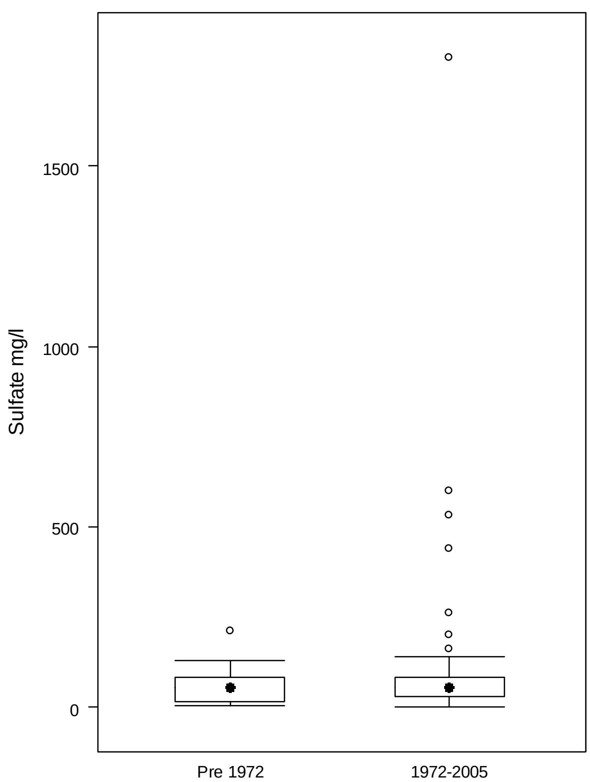
Groundwater Box Plots



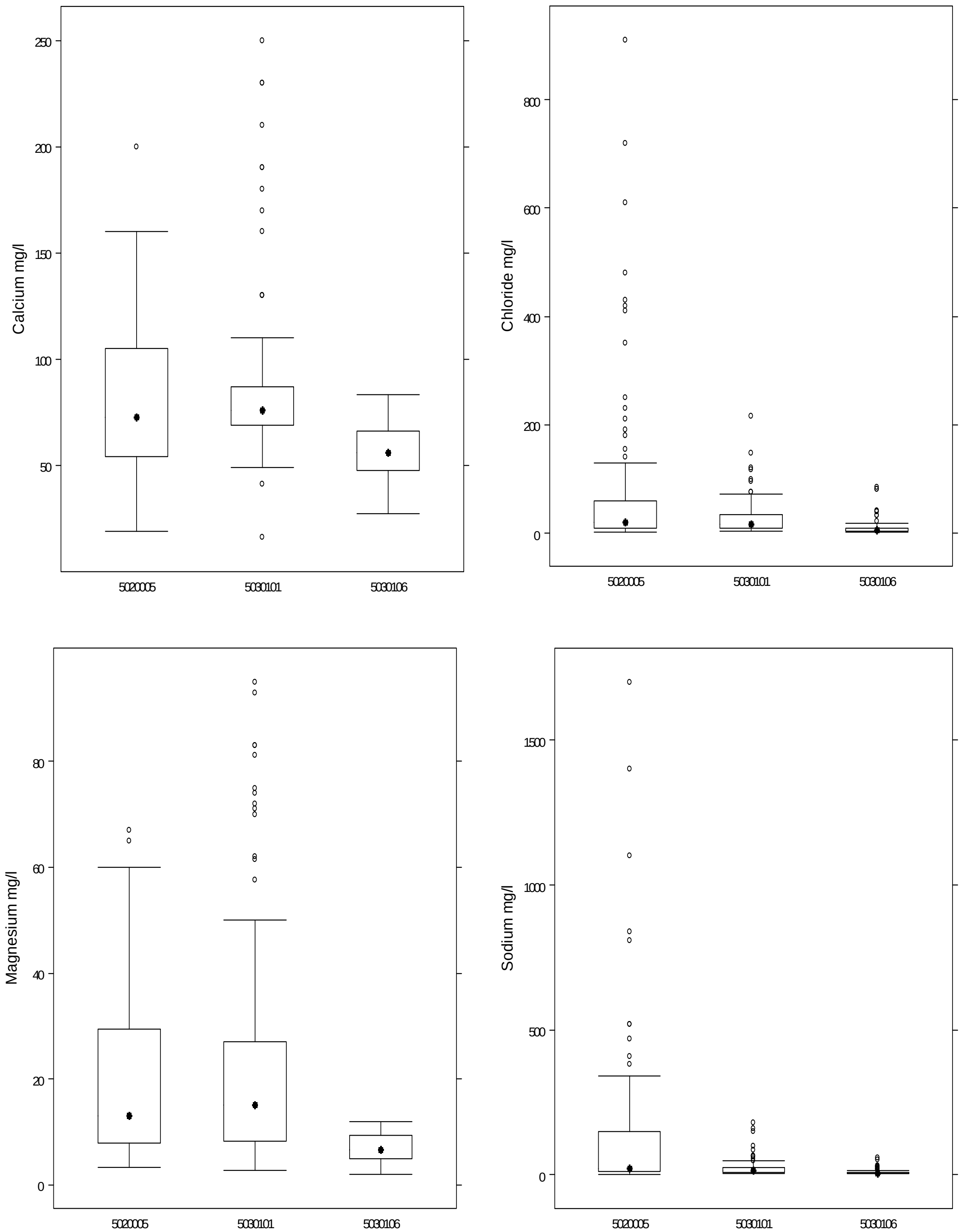


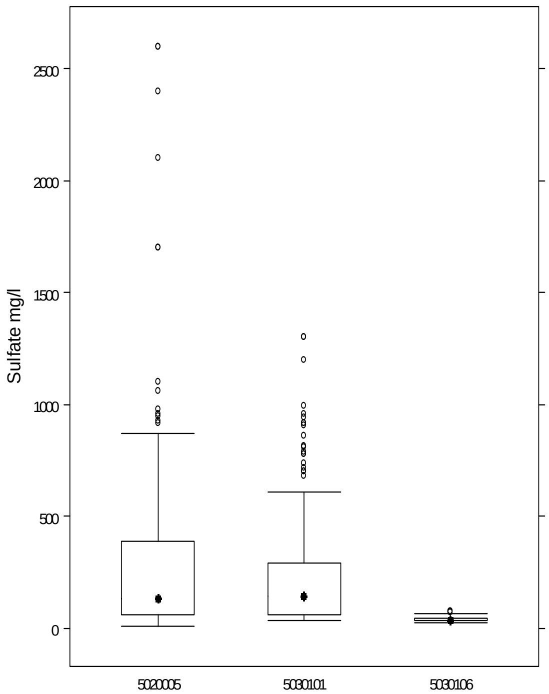

Chloride mg/l
1500
1000
500
0
Pre 1972
1972-2005


Sodium mg/l
800
600
400
200
0
Pre 1972
1972-2005


Sulfate mg/l
1500
1000
500
0
Pre 1972
1972-2005

Surface Water Box Plots





Sulfate mg/l
2500
2000
1500
1000
500
0
5020005
5030101
5030106