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In cooperation with the Powells and Armstrong Creeks Watershed Association and the Dauphin County Conservation District

Surface-Water and Ground-Water Quality in the Powell Creek and Armstrong Creek Watersheds, Dauphin County, Pennsylvania, July-September 2001

Why Study Powell Creek and Armstrong Creek Watersheds?

Powell Creek and Armstrong Creek Watersheds are in Dauphin County, north of Harrisburg, Pa. The completion of the Dauphin Bypass Transportation Project in 2001 helped to alleviate traffic congestion from these watersheds to Harrisburg. However, increased development in Powell Creek and Armstrong Creek Watersheds is expected. The purpose of this study was to establish a baseline for future projects in the watersheds so that the effects of land-use changes on water quality can be documented. The Pennsylvania Department of Environmental Protection (PADEP) (2002) indicates that surface water generally is good in the 71 perennial stream miles in the watersheds. PADEP lists 11.1 stream miles within the Armstrong Creek and 3.2 stream miles within the Powell Creek Watersheds as impaired or not meeting water-quality standards (fig. 1). Siltation from agricultural sources and removal of vegetation along stream channels are cited by PADEP as likely factors causing this impairment.

What are the Characteristics of the Watersheds?

The drainage areas of the Powell Creek and Armstrong Creek Watersheds are 39.2 and 32.3 square miles (mi^2), respectively. The watersheds are in the Ridge and Valley Physiographic Province of Pennsylvania, where valleys are used primarily for agriculture, and the ridges generally are forested (fig. 1). Land-use data from the early 1990s show that the Armstrong Creek Watershed has a higher percentage of agricultural land (50 percent) than the Powell Creek Watershed (35 percent). The remaining land use is primarily forest for both watersheds; the only area of concentrated residential development is in the western part of the Powell Creek Watershed. According to the 2000 census, approximately 5,000 people live in the watersheds (Tri-County Regional Planning Commission, written commun., 2002).

The gray siltstone and sandstone of the Pocono and Spechty Kopf Formations form the ridges (fig. 2). The Catskill and Trimmers Rock Formations underlie the valleys and are similar to the formations on the ridges but contain some shale layers and generally are more grayish-red (Taylor and Werkheiser, 1984).

Soils in the watersheds vary with topography. Valley soils are deep to shallow, well-drained, and shaly silt-loam in subsoil. The lower to mid-slope soil series typically are similar to valley soils except the percentage of larger-grained particles is greater than in the valley soils. Soils on the ridges are typically well-drained and the subsoil is channery sandy loam to channery loam or rubble (Kunkle and others, 1972).

Armstrong Creek Valley

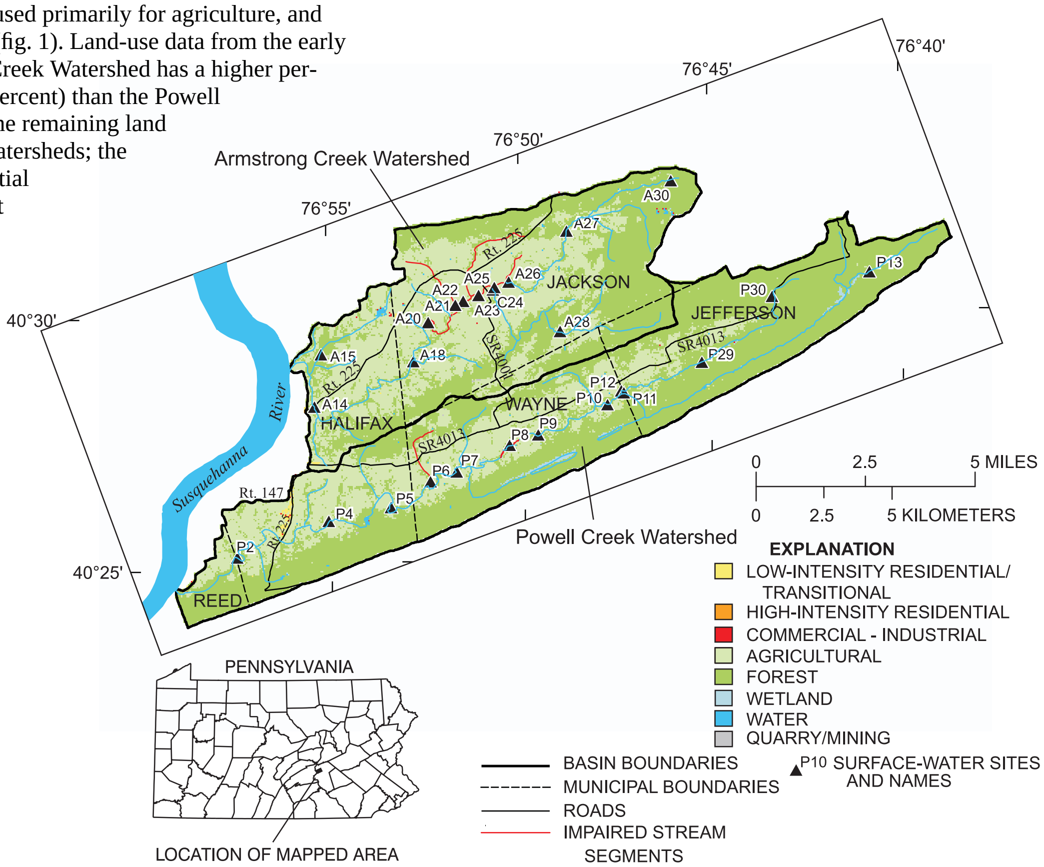

Figure 1. Powell Creek and Armstrong Creek Watersheds, major streams, land use and land cover, major roads, municipal boundaries, and surface-water sampling sites.

The climate of the watersheds is typical of the northeastern United States. The average amount of precipitation in the area is about 40-42 inches per year; the average annual temperature is about 50°F (Rossi, 1999). Terrain differences cause variations in rainfall and temperature in the watersheds.

Water use in the watersheds primarily is residential and agricultural. Most homeowners use private wells for water supply. The reported median domestic well yield is 12 gallons per minute (gal/min) (Taylor and Werkheiser, 1984). Surface water is used for recreational and agricultural purposes. Stream uses in both watersheds include cold-water and trout-stocked fisheries; one tributary to Armstrong Creek is designated as a high-quality cold-water fishery (Commonwealth of Pennsylvania, 2003).

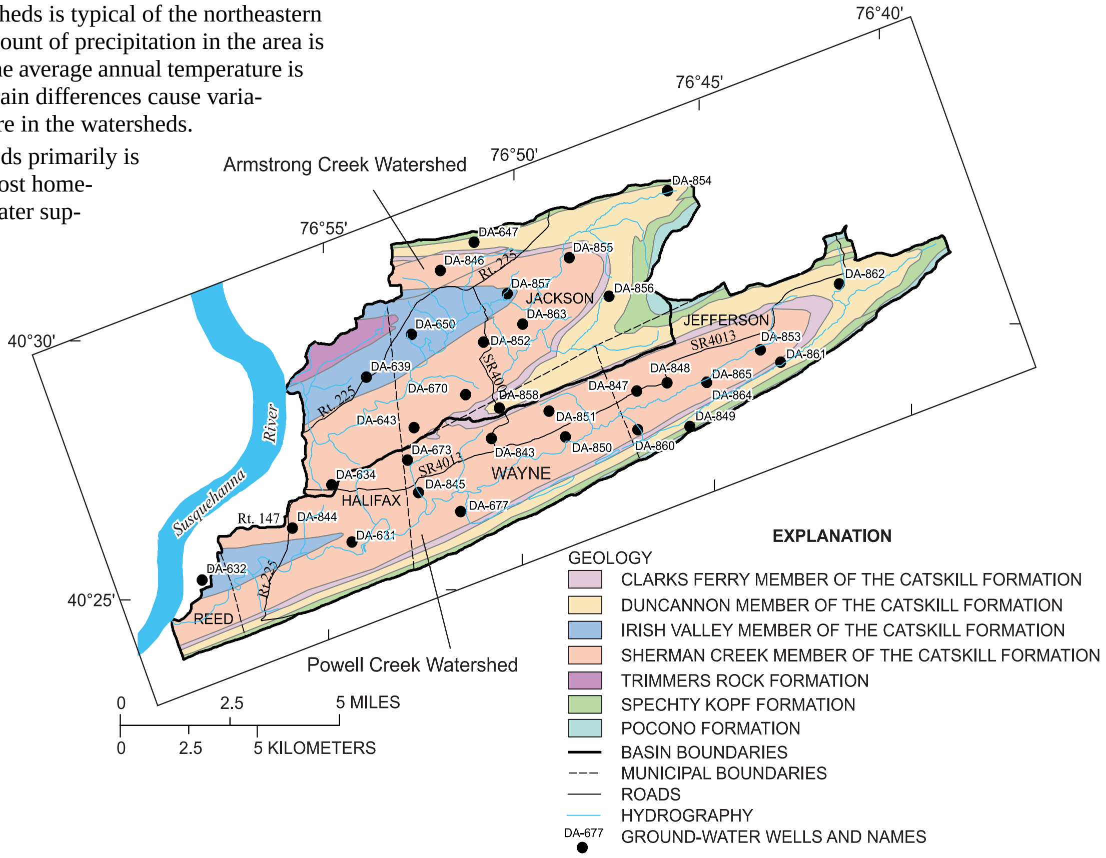

Figure 2. Powell Creek and Armstrong Creek Watersheds, geology, major streams, major roads, municipal boundaries, and ground-water sampling sites.

How was the Study Conducted?

The study was designed to characterize surface-water and ground-water quality in the Powell Creek and Armstrong Creek Watersheds during a period when precipitation was lower than average. When precipitation occurs, runoff to streams and recharge of the ground water affect surface- and ground-water chemistry and quantity. The surface-water sampling sites were selected using a sampling design generally based on tributary inflows to the main channel (Sanders and others, 1983). Using a grid approach, the ground-water sampling sites were distributed evenly throughout both watersheds. The U.S. Geological Survey (USGS) and the Powells and Armstrong Creeks Watershed Association (PACWA) met with landowners to obtain permission to access the sites, gather site information, and collect samples.

Water-quality sampling in the watersheds began in late July 2001 and ended in early September 2001. Only minor precipitation events occurred during this time period. The precipitation events did not strongly affect either the surface-water or ground-water systems. Thirteen surface-water sites in each watershed were sampled from September 4 to 10, 2001 (fig. 1). Thirty wells were sampled from July 27 through August 14, 2001; two additional wells were sampled on September 10, 2001 (fig. 2). On the basis of information from drillers for the wells sampled, the median well depth was 195 feet and the median well yield was 14 gal/min.

What were the Methods Used to Collect Data?

Location data, field data, and quality-assurance/quality-control (QA/QC) samples were collected for surface- and ground-water sites. Site-location data were determined through the use of global positioning system (GPS) units and topographical maps. The pH, dissolved oxygen (DO), specific conductance (SC), and water temperature were measured in the field using a four-parameter water-quality probe. USGS laboratories analyzed all water-quality samples. Laboratory analyses for chemical and suspended-sediment samples were performed according to techniques described in Fishman and Friedman (1989) and Guy (1969), respectively. Four QA/QC samples were collected during the study to ensure data quality. QA/QC sample results indicated that sampling techniques did not compromise the samples collected.

Surface Water

Surface-water data-collection methods followed standard USGS protocols (Wilde and others, 1998-99). Streamflow was measured using a pygmy current meter. The four-parameter water-quality probe was placed in the part of the stream where the flow was most concentrated (known as the thalweg). Grab samples submitted for chemical and suspended-sediment analyses also were collected from the thalweg. Unfiltered samples were analyzed for total phosphorus (P) and total ammonia plus organic nitrogen (N). Filtered (0.45 micron filter) samples were analyzed for dissolved nitrate plus nitrite, nitrite, ammonia, and P.

Ground Water

Ground-water samples were collected from domestic wells. A downhole electric measuring tape was used to measure the water level below land surface. To purge water from the well system and collect water-quality samples, an outlet or spigot was selected that bypassed water filters or other treatment systems. Water in the borehole or holding tank was considered “stale.” To determine when the stale water was adequately purged from the well system, water temperature and SC were monitored prior to sampling. Ground water was discharged to a 5-gallon bucket where the water-quality probe was positioned to monitor water temperature and SC. Field measurements were recorded once conditions were appropriate for sampling (stable temperature and SC) or there were indications that the well was starting to go dry. Samples were collected for the analysis of radon gas, dissolved iron, manganese, arsenic, and nitrate plus nitrite according to techniques described by Wilde and others (1998-99). Total coliform bacteria samples were collected according to methods described by the Hach Chemical Company (1998).

What are the Results/Findings?

The water-quality sampling program was designed to gather as much information in the shortest amount of time possible. This ensures that hydrologic conditions are relatively unchanged (precipitation inputs to either the ground-water or surface-water systems are minimal), hence permitting reliable comparisons between sites.

Surface Water

No water-quality problems were evident in the surface-water samples collected in the Powell Creek and Armstrong Creek Watersheds during the low-flow sampling period. Concentrations of nitrate-N were well below the U.S. Environmental Protection Agency (USEPA) maximum contaminant level (MCL) for drinking water of 10 milligrams per liter (mg/L) of nitrate-N (table 1). Virtually no ammonia N was detected in the low-flow samples. The median concentration of dissolved P was 0.02 mg/L. Although there is no drinking water standard for dissolved P, Correll (1998) indicated that concentrations of dissolved P equal to or exceeding 0.1 mg/L could cause eutrophication in most water bodies. DO concentrations were suitable for the support of aquatic life. Suspended-sediment concentrations were low.

Land use significantly affected SC, pH, and suspended-sediment concentrations of surface water (table 2). SC and pH were significantly lower in samples from surface-water sites dominated (>75 percent) by forest in comparison to samples from sites with less forest cover. Agricultural lands are predominantly in the valley, and hence streams in this area receive ground water that has traveled considerable distances compared to streams near ridge tops. This generally results in an increase in SC as a result of greater residence times and increased dissolution of rock material. Forest soils have a low pH and need to be amended with lime to grow crops, which increases soil pH; thus, lower pH values are expected in streams draining forest land. The higher concentrations of suspended sediment for areas draining agricultural land were expected because soil-erosion rates typically are greater for agricultural land than for forest.

Differences in SC measured during this low-flow period also were evident between Powell Creek and Armstrong Creek Watersheds (fig. 3). The median SC for samples collected in the Armstrong Creek Watershed was 99 microsiemens per centimeter (µS/cm); for Powell Creek Watershed, the median SC was 56 µS/cm. The mainstem sites on Powell Creek showed a significant relation between drainage area and SC during this sample period. The regression relation indicated that SC increased by 1.8 µS/cm for every square mile increase in drainage area. The mainstem of Powell Creek flows almost entirely


Measuring surface-water flow in the Armstrong Creek Watershed

***Table 1.** Summary statistics for surface-water samples collected in early September 2001 during low-flow conditions in the Powell Creek and Armstrong Creek Watersheds*

[Units are in milligrams per liter unless otherwise noted; ft^3/s, cubic foot per second; SC, specific conductance; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; <, less than]

Constituent	Number of sites	Minimum	Median	Maximum
Streamflow (ft^3/s)	26	0.01	0.36	1.4
Field SC (µS/cm)	26	18	80	140
Field pH (standard units)	26	5.5	6.7	7.3
Field temperature (°C)	26	14.1	17.1	21.6
Dissolved oxygen	26	6.7	8.0	9.7
Dissolved ammonia (as N)	26	<.04	<.04	.083
Total ammonia N plus organic N (as N)	26	.07	.26	.48
Dissolved nitrate plus nitrite (as N)	26	.092	.292	1.45
Dissolved nitrite (as N)	8	.003	<.006	.025
Dissolved P	26	.004	.020	.077
Total P	12	.019	.040	.113
Suspended sediment	26	1	6	18

MEDIAN—Data in this report are primarily summarized in tables using median values. The median is a summary statistic used in reporting water-quality data. Fifty percent of the values in a given data set fall above the median value and 50 percent of the values fall below the median.

NITRATE PLUS NITRITE—Laboratory analysis of nitrate typically involves determination of nitrate (NO_3^-) and nitrite (NO_2^-) together. Nitrite is then analyzed separately and nitrite concentrations are subtracted from the sum of nitrate plus nitrite to determine nitrate concentrations. For this study. virtually no nitrite was found; thus, it was assumed that nitrate plus nitrite concentrations were equal to nitrate concentrations.

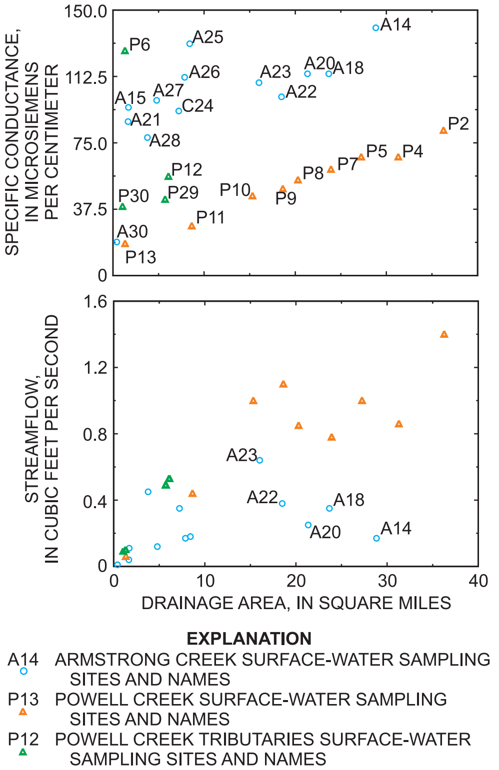

Figure 3 The relation between specific conductance and streamflow and drainage area for surface-water samples collected in the Powell Creek and Armstrong Creek Watersheds during low-flow conditions, September 2001.

***Table 2.** Median values of selected chemical and physical constituents for surface-water samples collected in the Powell Creek and Armstrong Creek Watersheds during low-flow conditions, September 2001*

[Q, streamflow; ft^3/s, cubic foot per second; SC, specific conductance; µS/cm, microsiemens per centimeter at 25 degrees Celsius; N, nitrogen; mg/L, milligrams per liter; P, phosphorus; Sed., suspended sediment]

Number of sites	Percent forested	Q (ft^3/s)	Field pH	Field SC (µS/cm)	Dissolved nitrate-N (mg/L)	Dissolved P (mg/L)	Sed. (mg/L)
10	76-100	0.47	6.40^{a}	47^{a}	0.26	0.021	$6^{a,b}$
10	51-75	.54	6.85^{b}	88^{b}	.34	.023	3^{a}
6	26-50	.14	6.85^{b}	114^{b}	.22	.018	11^{b}

^{a,b}Superscripts indicate statistically significant differences within each chemical measurement; values with different footnotes are significantly different from one another at an alpha level equal to 0.05. Data significantly different at an alpha level of 0.05 indicate that there is a 95-percent likelihood that the results of the statistical test are accurate. Tests for significant differences between more than two groups (such as when comparing between different land uses) required two different procedures, the Kruskal-Wallis and the Tukey multiple-comparison tests (Helsel and Hirsch, 1995).

through the Sherman Creek Member of the Catskill Formation, whereas Armstrong Creek flows through this unit and through the Irish Valley Member of the Catskill Formation. Possible factors influencing SC include lithology, topographic setting, and land use. For example, agricultural land use is more common in the Armstrong Creek Watershed than in the Powell Creek Watershed.

Differences in streamflow were measured between the watersheds and between sites along each mainstem. The loss of streamflow in Armstrong Creek became evident at site A22 near Fisherville (fig. 3). At A14, only 0.17 cubic foot per second of water was measured for a site draining 28.8 mi^2. Regression analysis indicated site A14 had about 20 percent of normal flow. This loss of water equals about 570,000 gallons per day. The loss of water from the stream may be the result of water withdrawals of unknown origin, loss of water through fractures or bedding planes, and (or) infiltration of water into unconsolidated materials beneath the stream channel.

Ground Water

Some water-quality problems were indicated in ground-water samples collected in the Powell Creek and Armstrong Creek Watersheds during July-September 2001. Water from some wells exceeded the USEPA MCL and secondary maximum contaminant level (SMCL) for total coliform bacteria, iron, manganese, and arsenic (table 3). Iron and manganese do not pose health problems; however, the usefulness of the water can be affected if concentrations of these constituents exceed SMCL levels, because materials coming in contact with the water can be stained (Hem, 1985, p. 77, 85). Although arsenic naturally occurs in rocks, other sources may include pressure-treated lumber (wood preservative) and pesticides. Long-term exposure to arsenic at or above the MCL of 10 micrograms per liter (µg/L) can cause different types of cancer; short-term exposure to arsenic levels exceeding the MCL also could cause health problems (U.S. Environmental Protection Agency, 2002). Concentrations of radon-222 exceeded 300 picocuries per liter (pCi/L) in 28 of the 30 wells sampled. Elevated concentrations of radon-222, however, are not uncommon. Lindsey and Ator (1996) found that 80 percent of wells sampled in the Susquehanna and Potomac River Basins contained radon-222 in concentrations greater than 300 pCi/L. The proposed MCL for radon-222 was 300 pCi/L; however, this MCL was withdrawn in 1997 (Senior, 1998). Nonetheless, Mose and others (1990) found that cancer occurrences increase as radon-222 concentrations increase in private water systems. Water releases radon gas into the atmosphere when agitated. For example, shower spray could release radon to the air. The presence of radon in domestic ground-water supplies would indicate a greater likelihood of elevated radon concentrations in unvented airspace within the home. Total coliform bacteria were detected in the water from 22 of the 30 wells sampled. Possible local sources of total coliform bacteria include septic systems, bacteria in the soil, or larger organisms (such as earwigs, spiders, warm-blooded animals) living in or near the well. Total coliform bacteria usually do not cause disease; however, their presence is correlated with that of other water-borne organisms that cause disease (Francy and others, 2000; Zimmerman and others, 2001).

***Table 3.** Summary of selected chemical constituents and properties in ground-water samples collected in the Powell Creek and Armstrong Creek Watersheds, July through September 2001*

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; <, less than; >, greater than; °C, degrees Celsius; µg/L, micrograms per liter; mg/L, milligrams per liter; pCi/L, picocuries per liter; col/100 mL, colonies per 100 milliliters; NA, not applicable]

Chemical constituent or property	Number of wells sampled	Maximum contaminant or action level[1]	Secondary maximum contaminant level[2]	Number of wells containing water that exceeds contaminant level	Minimum reported	Median	Maximum reported
Field specific conductance (µS/cm)	32	NA	NA	NA	22	144	390
Field pH (standard units)	32	NA	<6.5 >8.5	13	5.2	6.6	7.5
Field temperature (°C)	32	NA	NA	NA	11.1	12.8	14.8
Dissolved arsenic (µg/L)	17	10	NA	2	.1	1.9	19.9
Dissolved iron (µg/L)	32	NA	300	2	<10	<10	15,400
Dissolved manganese (µg/L)	32	NA	50	5	<.1	1.5	5,650
Dissolved nitrate (as N) (mg/L)	30	10	NA	0	.028	1.2	4.81
Dissolved oxygen (mg/L)	32	NA	NA	NA	.3	4.2	9.0
Radon-222 (pCi/L)	30	NA	NA	NA	83	1,925	4,600
Total coliform (col/100 mL)	30	0	NA	22	0	8	800

[1] U.S. Environmental Protection Agency, 2002.
[2] U.S. Environmental Protection Agency, 2000.

Land use likely affected concentrations of nitrate-N and field parameters in the ground-water samples. Ground water with concentrations of nitrate-N greater than 2 mg/L may indicate anthropogenic sources such as fertilizer or sewage from septic systems (Madison and Brunett, 1985). Only 1 of 13 wells in forested land contained water with concentrations of nitrate-N greater than 2 mg/L; 50 percent of all other wells had concentrations of nitrate-N greater than 2 mg/L (table 4). SC for ground water in forested land-use areas generally was lower than in areas dominated by agricultural, mixed, and residential land use (table 4). Elevated SC for other land uses probably was related to agricultural liming, the greater number of septic systems in valleys, and longer residence time of water in the soil-rock system. In general, the temperature of natural ground water is about 12°C (Williams and Eckhardt, 1987). However, with deforestation, agricultural expansion, and wetland destruction, subsurface temperatures will change and usually increase (Greenman and others, 1961, p. 84). Such a change may be evident in table 4 where land dominated by forest had a lower median ground-water temperature than the other land-use categories. Water temperatures also could be higher for non-forested sites because valley settings are topographically lower. Valley settings have a greater potential to mix shallow, warmer (samples were collected in summer) soil-rock water with deeper, cooler ground water. Lower pH for wells at forested sites likely was related to lime applications in farmed areas of the watersheds.

Lithology also affected water quality. Ground-water samples from wells completed in the Irish Valley Member had a median SC of 175 µS/cm; the median SC for wells completed in the Sherman Creek Member was 146 µS/cm.

Unlike surface-water samples, ground-water samples did not indicate any major differences between watersheds; however, SC and arsenic increased from ridge top toward valley bottoms. In general, wells near ridge tops intercept water with shallow flow paths and brief residence times. This is in contrast to wells in valley bottoms that intercept water with longer flow paths and greater residence times. Ground water with long flow paths and residence times typically is more enriched in dissolved constituents (Freeze and Cherry, 1979, p. 241).

What Do the Results of the Study Tell Us?

On the basis of the water-quality samples obtained from July through September 2001, surface water and ground water in the watersheds were acceptable for most water uses. Surface-water data collected during low-flow conditions indicated no water-quality problems in either watershed. Land use, however, significantly affected SC and pH. Surface-water samples from sites dominated by forest had lower SC and pH than sites with less forest cover. Sampling sites in both watersheds showed increasing SC with increasing drainage area but the relation was much stronger in the Powell Creek Watershed. The Armstrong Creek Watershed showed a significant loss of water from the surface-water system near the mouth of the watershed. Ground-water samples collected in the watersheds indicated some water-quality problems and land-use differences that affect water quality. Over 90 percent of the ground-water samples collected contained concentrations of radon gas that exceeded 300 pCi/L. Total coliform bacteria were found in about 75 percent of the wells sampled. Nitrate concentrations, SC, and pH were lowest in ground water from areas dominated by forest cover. Ground water from wells in or near valley bottoms generally had greater concentrations of dissolved constituents, including arsenic, than ground water in wells near ridge tops.

The comparison of surface- and ground-water quality data was limited to SC, pH, and nitrate-N. The ground-water samples had a higher median SC (by 64 µS/cm) than the surface-water samples. The median pH for the surface-water samples was slightly greater (0.16 standard units) than in the ground-water samples. The median concentration of nitrate-N in the surface-water samples was 0.91 mg/L lower than in the ground-water samples. Differences in SC may be related to a dominance of shallow and younger water in the streams than in ground water. Given that surface water may have a higher proportion of young water in relation to ground water, lower concentrations of nitrate-N in surface water compared to ground water may be the result of biological uptake of nitrate from soil water and stream channels during the growing season.

Where Do We Go From Here?

This study indicates that some additional investigations of streamflow and water quality would be beneficial in further assessment of land-use changes in the Powell Creek and Armstrong Creek Watersheds. The significant loss of stream water from Armstrong Creek beginning near Fisherville is not yet understood and may adversely affect aquatic life. The elevated concentrations of dissolved arsenic in ground water in valley bottoms may indicate a potential health concern. Although the concentration of radon gas in wells in the watersheds is not unusual, radon gas also constitutes a potential health hazard.

This study did not address stormflow-related issues. Given that recent PADEP assessments determined that siltation was impairing sections of both watersheds, further work to identify the source of the siltation and ways to reduce sediment loads to the streams during stormflow may be considered.

Table 4. *Median values of selected chemical constituents for ground-water samples collected in the Powell Creek and Armstrong Creek Watersheds, July through September 2001*

[Rn, radon-222; pCi/L, picocuries per liter; Mn, manganese; µg/L, micrograms per liter; Fe, iron; As, arsenic; TC, total coliform bacteria; col/100 mL, colonies per 100 milliliters; NO_3-N, nitrate nitrogen; mg/L, milligrams per liter; Temp., field temperature; °C, degrees Celsius; SC, field specific conductance; µS/cm, microsiemens per centimeter at 25 degrees Celsius; DO, dissolved oxygen; <, less than]

Number of wells	Land use	Rn (pCi/L)	Mn (µg/L)	Fe (µg/L)	As (µg/L)[1]	TC (col/100 mL)	NO_3-N (mg/L)	Temp. (°C)	SC (µS/cm)	Field pH (standard units)	DO (mg/L)
15	Forest[2]	1,780	2.5	<10	0.6	7	0.177	12.5	78	6.0	6.2
6	Agriculture	2,005	1.0	<10	7.6	1	1.80	13.1	161	6.6	2.8
5	Mix	1,870	.1	<10	1.4	40	2.33	12.8	152	6.6	4.1
6	Resident	1,845	3.2	<10	11.3	37	2.24	13.3	214	6.9	1.6

[1] Arsenic was analyzed in samples from nine wells in forested, three in agricultural, three in mixed, and two in residential land use.

[2] Thirteen wells in forested land use were analyzed for radon, total coliform, and nitrate.

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For Additional Information

Most data collected for this study were published in the USGS Annual Data Report for water year 2001 for the Susquehanna and Potomac River Basins (Durlin and Schaffstall, 2002). For copies of this report or other information concerning the USGS programs and activities in Pennsylvania, please visit the Web site of the Pennsylvania District office at ***http://pa.water.usgs.gov/*** or contact:

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This fact sheet can be accessed online at:

pa.water.usgs.gov/reports/fs052-03.pdf

A Coordinated Effort

This project was funded in part by PADEP through the Growing Greener Grant process. The overall project proposal was submitted by the Dauphin County Conservation District (DCCD) and PACWA. Upon acceptance by PADEP, the USGS provided matching funds through the Federal-State Cooperative Program. Members of PACWA helped USGS personnel conduct the investigation in both watersheds. Landowners permitted project personnel to conduct sampling on private land or allowed access to a designated surface-water sampling site. DCCD helped with the project design. Personnel from PACWA, DCCD, and USGS helped to review and improve this fact sheet.