Groundwater and Hydrogeology of Luzerne County, PA
Getting the Water Tested!

Llewellyn and Pottsville Formation Contact
Flowing Artesian Well (Well needs no pump)

Environmental Engineering and Earth Sciences Department

The EEES Department is within the School of Science and Engineering at Wilkes University. The EEES Department offers undergraduate degree programs and continuing education in environmental engineering and in earth and environmental sciences.

http://www.wilkes.edu

Information Compiled by:
- Dr. Dale Brans – Wilkes University
- Dr. Sid Halsor, PG – Wilkes University
- Mr. Brian Oram, PG – Wilkes University
- Dr. Brian Redmond, PG – Wilkes University
- LuzerneCounty. Org
- Carbon County Groundwater Guardians – Master Well Owner Program

Center for Environmental Quality

Non-profit/ equal opportunity employer, is operated and managed within the Department of Environmental Engineering and Earth Sciences at Wilkes University

Outreach Programs
- Environmental and Professional Education and Training
- Applied Research
- Community and Business Outreach Programs

Website: http://www.wilkes.edu/water

Geological Sequence

<table>
<thead>
<tr>
<th>Time</th>
<th>Period</th>
<th>Deposit or Rock Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1.8 million years</td>
<td>Quaternary – Glaciation</td>
<td>sand, silt, clay, and gravel</td>
</tr>
<tr>
<td>1.8 to 290 million years</td>
<td>Tertiary to Permian</td>
<td>Not present (eroded and weathered)</td>
</tr>
<tr>
<td>290 – 320 million years</td>
<td>Pennsylvania</td>
<td>Llewellyn (coal) and Pottsville (minor coal)</td>
</tr>
<tr>
<td>320 – 354 million years</td>
<td>Mississippian</td>
<td>Marcellus Shale</td>
</tr>
<tr>
<td>354 – 417 million years</td>
<td>Devonian</td>
<td>Catskill Formation</td>
</tr>
<tr>
<td>417 – 443 million years</td>
<td>Silurian</td>
<td>Delaware Formation</td>
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</tbody>
</table>
Ridge and Valley Province – Rt 309

Mahantango Formation

Marcellus Shale Photo

Geology of Columbia and Luzerne County

The Water Cycle Powered by the Sun: Solar Power

Primary Aquifers in PA
**Surfacewater & Groundwater**

**They Are Related and Connected!**

**Groundwater Moves - Slowly**

- Sea Level
- Saline/Brine Water
- Stagnant Water – no to little flow

**Why Test My Water?**

A USGS survey found that 70% of private wells were contaminated. This contamination could result in acute or chronic health concerns.

In general, there are no regulations related to well construction, placement, or required testing. It is up to you to determine the safety of your water.

EPA recommends, at minimum, an annual water test for private wells.

**Primary Standards (NPDWR)**

National Primary Drinking Water Regulations

Primary standards protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in water. They take the form of Maximum Contaminant Levels or Treatment Techniques.

There are over 100 chemical and biological primary drinking water standards, which include: trace metals, disinfection agents, disinfection by-products, radiological, microbiological agents, and organic chemicals.

**Examples:** Arsenic, Lead, MTBE, total coliform, Giardia, Trichloroethanes, Asbestos, Copper, Benzene, Trichloroethane, etc.

**Secondary Standards**

National Secondary Drinking Water Regulations

These standards were established more for cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor or color) in drinking water.

These are not regulated standards, but recommended limits.

The secondary standards include: aluminum, chloride, color, corrosivity, fluoride, foaming agents, iron, manganese, odor, pH, silver, sulfate, total dissolved solids, and zinc.
Groundwater Columbia and Luzerne County

Based on the geology of Columbia and Luzerne County, the common water quality problems are as follows:

- Corrosive Water
- Low pH
- Soft Water (low hardness) to Moderate Hardness
- Iron and Manganese
- Discolored Water – Reddish to Brown Tints
- Total Coliform Bacteria
- Sulfur Odors and Elevated Sulfates
- Methane – Fumes of Luzerne County

Air Quality Issues – Radon In Air!

An Ungrouted Residential Well

A Properly Grouted Well

Unsanitary Well Cap

- Insects, Larvae and Nests / Egg Masses
- Mouse Colonies
- Snakes
- Beehives
- Mud - when casing to close to ground

Types of Contamination - Bacteria, Pathogens, Sediment Subject to Vandalism, Salts, and Flooding

Less Common Problems

These water quality conditions are not common to groundwater in Columbia and Luzerne County:

- Elevated Nitrate – Nitrite Levels
- Radioactive Uranium, Molybdenum, and Radon in Air
- Arsenic (local counts)
- Organic Contamination Elevated Trace Metals (except corrosion by-products like Copper, Lead, Aluminum, Zinc)
- Salty or Brackish Water (very deep wells)
- Trihalomethanes
- Pathogenic Organisms

Radon (In Air) - PA

Luzerne County in the Red Zone – Suggests indoor air radon levels greater than 4 pCi/L

http://www.dep.state.pa.us/RadiationProtection_Apps/Radon/

Announcement:

Free Radon in Air Test Program

The American Lung Association of the Mid Atlantic has obtained a supply of radon test kits from a laboratory certified by the Pennsylvania Department of Environmental Protection.

A limited number of tests are available for each region of PA. To determine the availability of a kit go to

http://www.lunginfo.org/freeradonkit

Enter your zip-code

Please allow four to eight weeks for delivery.
**Corrosive Water**
- Chemical or Biochemical Reaction between the water and metal surfaces.
- The corrosion process is an oxidation/reduction reaction that returns refined or processed metal to their more stable ore state.
- Corrosion can also be accelerated by:
  1. low pH and high pH;
  2. high flow rate within the piping;
  3. high water temperature;
  4. chemistry of the water; and
  4. presence of suspended solids, such as sand.

*Image of corroded metal*

**Copper** – Typically Blue or Blue-Green Staining
May also have elevated levels of Lead and Zinc.

**pH**
- pH < 7 acidic
- pH > 7 basic
- Drink Water Standard 6.5 – 8.5

*Image of pH testing*

**Problems**
- Bitter or Sour Taste
- Corrosion
- Scale Formation
- Leaching Metals – Copper, Lead, Zinc, and Aluminum

**Coliform Bacteria**
- Coliform Bacteria
  - Absent or < 1 colony/100 ml
- Testing Purpose
  - Used as an Indicator of Sanitary Condition of Water Source
- Sources
  - Natural Soil Bacteria
  - Human and Animal Waste
  - Insect Waste

**Water Hardness, Iron, Manganese**
- The hardness of a water is a measure of the concentration of the multivalent cations (Ca²⁺, Mg²⁺, Fe²⁺, Mn²⁺, etc) associated with carbonates (HCO₃⁻).
- Hardness is typically reported as mg/L as CaCO₃ (calcium carbonate)
- Grains per gallon (gpg (US)) = 17.12 mg CaCO₃/L.
- Hardness Classification:
  - Soft: 0 to 17 mg CaCO₃/L
  - Slightly Hard: 17 to 60 mg/L
  - Moderately Hard: 60 to 120 mg/L
  - Hard: 120 to 180 mg/L
  - Very Hard: > 180 mg/L

*Image of water hardness test*

**Secondary Drinking Water Standard**
- Iron – 0.3 mg/L (red or black)
- Manganese – 0.05 mg/L (black)

**Sulfates in Water**
- Hydrogen sulfide gas also occurs naturally in some groundwater. The gas is formed from decomposition of organic compounds contained within the bedrock.
- Problems are typically found in aquifers that are shale, siltstone, peat related, or near surface sources of organic material.
- Sulfate-reducing bacteria are primary producers of large quantities of hydrogen sulfide.
- Drinking Water Standard is ≤ 250 mg/L. (Laxative Effect)

**Methane in Water**
- Methane has been a hidden issue in NEPA. The gas is colorless, tasteless, and odorless and there are no known health effects.
- Potential concerns relate to flammability/ explosiveness of gas.
- The Coal regions and northern portion of NEPA, and areas associated with the Mahantango / Marcellus Shale may have elevated levels of methane.
- No drinking water limit, but Office of Surface Mines recommends monitoring for concentrations from 10 to < 25 mg/L and immediate action for concentrations > 25 mg/L.
- Primary treatment options would include ventilation or aeration systems.
Methane Ventilation, process will also work for Radon and Hydrogen Sulfide.

Arsenic
- The drinking water MCL is 0.010 mg/L.
- Arsenic can result in the formation of malignant tumors on skin and lungs and may cause nervous system disorders.
- Observable symptoms of arsenic poisoning are: thickening and discoloration of the skin, stomach pain, nausea, vomiting, diarrhea, numbness in hands and feet, partial paralysis, and blindness.
- For this particular parameter within Northeastern Pennsylvania (NIEPA), it would be advisable to restrict the water for dissolved and total arsenic.
- In many cases, the arsenic has been linked from a colloidal or particle that could be more cost-effectively removed by standard filtration. It is also typically bound to iron oxide complexes.

Getting to The Natural Gas
- Fresh Water Well
- Sea Level
- Top of shale formation
- Possible saline brine/connate water
- Up to a few thousand feet

Marcellus Shale Drilling Site
- Pads can be 5+ acres—but one pad may support drilling multiple horizontal wells.
Concerns Related to Marcellus Shale

- Based on Location in Community Location – additional planning, education, and response plans are needed.
- In general, the issues are related to the following:
  - Erosion and Sedimentation
  - Volume of Water Used In Hydrofracturing- 2 to 9 million gallons per well.
  - Loss of Freshwater Aquifer or contamination by brine water and drilling fluids.
  - Drilling fluids may contain environmental contamination (metals and organics).
  - Impacts to Roadways, Tourism, and Ecology

Types of Fluids

- Top hole fluids – typically the water from the freshwater aquifer. This water from the first 600 to 800 feet.
- Bottom hole fluids – brine or connate water.
- Stimulation Fluids – fluid used to improve recovery (frac process)
- Production Fluids – water produced along the natural gas release – similar to bottom hole fluid.

Active Marcellus Production Site – Frac Fluid Chemistry

Typically Frac Water is comprised of clean water with a low probably for scale formation, but treated wastewater effluents and other sources being evaluated. The components include:

- Friction Reducer – anionic polymer high molecular weight (hold frac sand and other particles)
- Wetting Agent – nonionic surfactant – reduce surface tension and improve frac water flowback
- Biocides – control growth or regrowth of microorganisms.
- Scale Inhibitor – phosphate based chemicals to inhibit precipitate formation and scale formation.

Available Frac Water Chemistry

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Concentration</th>
<th>PWS</th>
<th>Multiple Above PWS Standard</th>
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<tbody>
<tr>
<td>Aluminum</td>
<td>mg/L</td>
<td>1.2</td>
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<td>6</td>
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<tr>
<td>Arsenic</td>
<td>mg/L</td>
<td>10.04</td>
<td>0.01</td>
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<tr>
<td>Barium</td>
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<td>418</td>
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<td>205</td>
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<tr>
<td>Iron</td>
<td>mg/L</td>
<td>17</td>
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<tr>
<td>Manganese</td>
<td>mg/L</td>
<td>0.94</td>
<td>0.06</td>
<td>17.6</td>
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<tr>
<td>Nickel</td>
<td>mg/L</td>
<td>17.2</td>
<td>5.01</td>
<td>3.2</td>
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<tr>
<td>Total Dissolved Solids</td>
<td>mg/L</td>
<td>313.24</td>
<td>500</td>
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<tr>
<td>Nitrite @ N</td>
<td>mg/L</td>
<td>90.1</td>
<td>46</td>
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<td>pH</td>
<td></td>
<td>6.71</td>
<td>6.5</td>
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<tr>
<td>Bromide</td>
<td>mg/L</td>
<td>0.1A</td>
<td>0.01</td>
<td>6180</td>
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<tr>
<td>Chloride</td>
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<td>27800</td>
<td>250</td>
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<tr>
<td>Gross Alpha</td>
<td>pCi/L</td>
<td>223</td>
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<td>pCi/L</td>
<td>98.02</td>
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<tr>
<td>Radium 226</td>
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<td>18.55</td>
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<td>4</td>
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<tr>
<td>Radium 228</td>
<td>pCi/L</td>
<td>60.64</td>
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Flowback Water Chemistry

Flowback water is generated from drilling and it is what gets produced from the first 5% of water returned after a well is started.

May contain elevated levels of trace metals, nitrogen, bromide, uranium, and hydrocarbons. Most of the dissolved solids includes chloride and sodium.

Production Water

Produced water is wasted water that accompanies oil extraction and is high in salinity. Typically, separated stored on site and then hauled to treatment/disposal facility.

May contain elevated levels of trace metals, nitrogen, bromide, uranium, and hydrocarbons. Most of the dissolved solids includes chloride and sodium.
Injection Wells – Class II

Class II wells inject fluids associated with oil and natural gas production. Most of the injected fluid is salt water (brine), which is brought to the surface in the process of producing (extracting) oil and gas.

Regulated by:
http://www.epa.gov/safewater/uic/wells_class2.html

Does the UIC Program regulate hydraulic fracturing?

Sometimes. The UIC Program regulates the following activities:

- Well injection of fluids into a formation to enhance oil and gas production (Class II wells).
- Fracturing used in connection with Class II and Class V injection wells to “stimulate” (open pore space in a formation).
- Hydraulic fracturing to produce methane from coal beds in Alabama.

Water Testing Recommendations

- Package # 1 – Based on Penn State University Recommendations and Workshops.
  - Parameters: total coliform, e. coli, chloride, barium, pH, and total dissolved solids, methane/ethane.
  - Estimated Cost w/o Chain-of-Custody and Collection – $1,200.00 to $1,250.00 plus sampling and travel
  - Very inadequate – If you are near a well site.

Water Testing Recommendation

Package # 2 – Based on the PADEP is Recommendations.

- Chloride, Total Coliform, T. Hardness, Magnesium, Strontium, Iron, Manganese, pH, Sodium, Conductivity, Calcium, Alkalinity, Arsenic, Nitrate, Total Dissolved Solids, Barium, Oil & Grease, VOC with MTBE, Bromide, MBAS, and Methane/ethane.

- Estimated Cost w/o Chain-of-Custody and Collection – $1,500.00 to $1,550.00 plus sampling and travel
- Missing Radiological and Trace Metals.

Water Testing Recommendations

Package # 3 – Based on a combination of what local gas company’s are doing as part of their background or baseline analysis, plus added total coliform and pH.

- Alkalinity, pH, Total Coliform, Arsenic, Barium, Calcium, Chloride, Conductivity, T. Hardness, Iron, Magnesium, Manganese, Oil/Grease, Potassium, Sodium, Sulfate, Total Dissolved Solids, MTBE/VOC’s (includes R1210, Sulfate, Nitrate, Ammonia, Strontium, Selenium, Bromide, MBAS (Surfactants), Methane/Ethane, and Total Suspended Solids.

- Estimated Range - $ 2,000.00 to $3,000.00, plus sampling and travel
- Problem – Does not include radiological and synthetic organic compounds.

Water Testing Recommendations

Package # 4 Based on Gas Company Background Testing and a review of the chemical analysis of used Frac Water.

- pH, standard plate count, total coliform, nitrate, nitrite, alkalinity, chloride, bromide, sulfate, color, odor, conductivity, corrosion index, alpha/beta ratio, T. Hardness, Mercury, Trace metals (BOC Metals: 13 metals),

- Strontium, potassium, regulated VOC’s & MTBE, Radium 226/228, ammonia, Total Dissolved Solids, secondary drinking water parameters, Uranium, Radon in Water, Total Kjeldahl Nitrogen, total suspended solids, MBAS, Methane/Ethane , Oil/ Grease, and Sulfates.

- Estimated Cost w/o Chain-of-Custody and Collection
  - $2,500.00 to $3,000.00, plus sampling and travel
- Missing Radiological and Trace Metals.

Background Testing and Baseline (Work as a Community !)

- Test wells within at least 1000 feet to 0.5 miles of proposed well location.
- Test wells along horizontal testing leg.
- Document static water levels, well production capacity, and spring flows
- Post Drilling Testing – within 6 months of completion and extend monitoring to 2 years
- Post Testing Area should be based on results of a detailed hydrological analysis and post-testing water quality should include parameters that would represent “frac chemicals” and daughters.
Project Sponsors

- Wilkes University
  http://www.wilkes.edu
- Pennsylvania Northeast Resource Conservation & Development Council
  http://www.pnrcd.org
- CSWPR Program - Consortium for Scientific Assistance to Watersheds Program
  http://pa.water.usgs.gov/cswpr/

Private Water Supply
A Pennsylvania Perspective
Luzerne County

Mr. Brian Oram, PG
Professional Geologist, PASEO, Licensed Well Driller
Lab Director, Center for Environmental Quality
Wilkes University
Environmental Engineering and Earth Sciences
Wilkes Barre, PA 18766
http://www.wilkes.edu/water

QUESTIONS – Answers are another story!

Groundwater and Hydrogeology of
Luzerne County, PA

Soils Evaluation
Hydrogeological Assessments

Columbia and Luzerne Counties were glaciated and they are within the Appalachian Plateau and the Ridge and Valley Provinces

What Does This Mean?

Source: LuzerneCounty.org
Appalachian Plateau Province
- Broad to Narrow Valleys
- Rounded Hills and Valleys Associated with Glaciation
- Valleys filled by glacial fluvial material

Unconsolidated Material (Un)

Ridge and Valley Province
- Bedrock has been folded into a series of anticline and synclinal structures.

Plunging Anticlines / Synclines

Hydrology Under Natural Conditions
Typical Annual Water Budget
- Evaporation-Transpiration 13.5%
- Surface Runoff 0.3%
- Groundwater 36.6%

Well Geology (Unconsolidated)
- Unconfined and confined groundwater conditions.
Problems with Sulfates

- Laxative Effect: MCL 250 mg/L
- Form Precipitates on Piping and Fixtures
- Rotten Egg Odors
- Sewage Gas Odors
- Corrosion
- Water Heater Failure/Odors

Sewage Gas Odors

- High Sodium
- Elevated Hardness or alkalinity
- Corrosion, Low pH, high metallic content (Cu, Fe, Mn, Pb, Al, Zn)

Taste Problems

- Salty or Brackish Taste
- Sour Taste
- High Sodium
- Elevated Hardness or alkalinity
- Metallic or Bitter Taste
- Corrosion, Low pH, high metallic content (Cu, Fe, Mn, Pb, Al, Zn)

Odors

- Rotten Egg / Musty Odor
- Oily
- Methane Like-Smell
- Chemical/ Solvent

- Sulfate, Sulfur, Nuisance Bacteria
- Gasoline, Oil Contamination or Nuisance Bacteria
- Organic Material or Gas Additives (mercaptanes) – this is not present in natural gas
- Industrial Chemicals

Note: Methane gas has no odor.

Sediments and Stains

- Milky or Cloudy
  Precipitation of carbonates / sulfates, excessive air, suspended solids, aquifer material
- Blackish Green – Green Precipitates
  Copper, hardness, aggressive water and corrosion by-products, nuisance bacteria
- Blackish Tint or Black Slimes
  Reactions with manganese and possibly iron, nuisance bacteria
- Yellowish or Reddish Tint or Slimes
  Organic material, dissolved or precipitated iron, nuisance bacteria
Ridge and Valley Province – Rt 309

Llewellyn

Pottsville