NEW JERSEY
GEOLOGICAL AND WATER SURVEY

Open-File Report 21-3

SPRINGS OF NEW JERSEY

New Jersey Department of Environmental Protection
Water Resource Management
New Jersey Geological and Water Survey

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For more information: contact:
New Jersey Department of Environmental Protection
Water Resource Management
New Jersey Geological and Water Survey
P.O. Box 420, mail stop 29-01
Trenton, NJ 08625-0420
Telephone (609) 292-1185
http:// www.state.nj.us/dep/njgs

Cover photo: Steer drinking spring water from Spring # 3 at Valley Crest Farm and Preserve, Clinton Township, Hunterdon County. Photo by Steve Domber, August 23, 2011.

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Open-File Report 21-3

Springs of New Jersey

By

Ted Pallis[1], Steven E. Domber [1], Raymond Bousenberry[1], Rachel Filo[1], Kathleen Strakosh Walz[2], Brian Henning[3], Yaritza Acosta Caraballo[4] Meiyin Wu[4]

1 NJDEP New Jersey Geological and Water Survey
2 NJDEP Office of Natural Lands Management
3 NJDEP Bureau of Freshwater and Biological Monitoring
4 New Jersey Center for Water Science and Technology, Montclair State University

New Jersey Department of Environmental Protection
Water Resources Management
New Jersey Geological & Water Survey
PO Box 420, mail stop 29-01
Trenton, NJ 08625-0420

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SPRINGS OF NEW JERSEY

ABSTRACT

New Jersey is home to many springs that provide drinking water, wildlife habitats, and recreational opportunities. Springs or areas of focused groundwater discharge are critically important headwater aquatic resources, sources of water to wetlands, and base flow in streams. They are an important part of the New Jersey landscape and help us understand the connection between groundwater and surface water and reflect the health of aquifers. They are also good indicators of shallow groundwater quality. Geologically, springs represent some of the most interesting locales available for study.

The New Jersey Geological and Water Survey (NJGWS) and the Natural Heritage Program (NHP), departments of the NJDEP developed a Spring Identification and Classification Study as part of a United States Environmental Protection Agency (USEPA) Region 2 Wetland Program Development Grant. The 2010 to 2016 grant funded by the USEPA includes 1) establishing a spring identification and classification system, 2) identifying/quantifying characteristics of springs in New Jersey, and 3) establishing monitoring at reference sites and conduct testing of spring water quality. Open-File Report, OFR 21-3 is a compilation of that research. The information collected about springs in this report will enable long-term trend analysis to help better define the States springs and to aid policy makers as they try to address land-use decisions to foster sustainable freshwater resources. Threatened by water use and climate change, it is important to understand these groundwater sources. This report provides data for scientists, planners, environmental managers, and the citizens of New Jersey.

Described in the report are the distinctive nature and features of selected springs with information that was collected and classified according to their 1) mean flow or discharge 2) geomorphology 3) geologic setting 4) mean temperature with analysis of spring water temperature 5) water quality 6) flora and fauna 7) macroinvertebrates, and 8) aquatic life. In addition, as part of this research a site-specific flow study was done at the Brau Kettle Spring. Also, a New Jersey springs database was created.

Until now very little information has been systematically collected on springs in New Jersey despite their historic, economic, geologic, and environmental importance. There have only been a few references about them scattered throughout the archives of the NJGWS and the New Jersey Department of Health and Senior Services. An internal NJDEP report, *Locations, Descriptions and Water Quality Data for miscellaneous "springs" located throughout the State where the public is known to collect water for private use* (Muzeni-Corino, Berchtold, 2010), analyzed spring water from selected springs where New Jersey residents gathered drinking water.

INTRODUCTION

Springs, or areas of concentrated groundwater discharge, are among New Jersey's most valuable natural resources as they provide unique sources of clean and plentiful water. Springs are known to have uncommon hydrologic, ecologic, geologic, and historical attributes. According to the Springs Stewardship Institute, a global springs initiative of the Museum of Northern Arizona, "Despite the relatively small area of springs within the landscape, these ecosystems support more than 20 percent of the endangered species in the United States, as well as a high number of rare groundwater-dependent species." Springs are coveted as local water sources for humans and animals alike. Unfortunately, springs all over the country face many common threats such as groundwater withdrawals, contamination, and climate change.

Unlike lakes, streams and wetlands, comprehensive assessments of springs have not typically been conducted. Many people know of a spring, but few people know much about the spring and its geologic and hydrologic qualities. Many springs are unremarkable and do not draw much attention as they emerge from the ground, sometimes hidden by plants.

Springs have hydro-ecological, socio-cultural, historical, agricultural and water supply importance. They can provide a relatively constant volume of water. They can also serve as ecological refuges for unique flora and fauna, macroinvertebrates, and aquatic life limited to a relatively small area. Wildlife is drawn to springs for water and food. Smaller, seasonal springs can provide breeding areas for amphibians such as salamanders. They are substantial sources of biological diversity. However, if springs dry up, their ecosystems may never be restored. Springs are also a barometer for the health of aquifers that people rely on for drinking water and crop irrigation and can tell us what our groundwater is like. If spring discharge declines, it could mean our groundwater could be running out. In New Jersey, approximately 50 percent of the public drinking water supply comes from groundwater. Continued water withdrawals from new development could have adverse impacts on the aquifer system in New Jersey.

Springs also contribute indirectly to the economy by sustaining the flow of streams. New Jersey has hundreds of clear spring-fed brooks which serve as focal points for a thriving recreation industry in many state, county, and local parks. They provide recreational opportunities such as hiking, fishing, and swimming and are generally places of unusual natural beauty.

To understand the significance of springs in New Jersey they must be located, comprehensively identified, classified, and characterized. The first goal of this project was to map the locations of New Jersey's springs (fig. 1). Spring location information was gathered from hydrogeologic surveys, literature reviews, newspaper articles, internet searches, field reconnaissance, and as discovered during unrelated field work. When a spring was identified, one of two methods was used to assign location coordinates. Where springs were accessible, they were mapped using a Global Positioning System (GPS) device. When a spring was inaccessible for various reasons, on screen computer digitizing was used to map the identified springs using Environmental Systems Research Institute (ESRI) ArcGIS software, a Geographic Information System (GIS) software. NJDEP Aerial photos, United States Geological Survey (USGS) 7.5 Minute quadrangle maps at a scale of 1:24,000, and U. S. Soil Conservation Service maps were also utilized to identify and locate numerous springs.

As part of this project a New Jersey statewide springs database was created with Microsoft Access software. It contains locations and attribute information on 512 springs. Though this represents a sizeable number of springs with most of the larger known springs in the state included in the database, there is no doubt many hundreds more springs exist and were not mapped. Most of them are small but together they are of great ecologic importance. This database is not considered a comprehensive list of New Jersey springs but an overview. The database is designed to be expanded as new springs are identified and as additional attribute information is collected in the future. It can also be expanded to include new attribute information not initially contained in the data structure. The spring's database was used to create an ESRI geodatabase file available for download from the New Jersey Geological and Water Survey web site (www.nj.gov/dep/njgs/)

After mapping and data collection were complete, the springs were classified. Springs can be classified in multiple ways; however, they are most often classified by the volume of water they discharge. At each visited spring, an estimate of the flow was recorded and input into the database. Along with classifying the discharge, for this report, springs were also classified by geomorphology, geology, temperature, water quality/chemistry, and ecology**.** As part of the ecologic classification, flora and fauna, macro-invertebrates, and aquatic life were analyzed at selected spring sites.

There were 14 springs selected for installation of temperature probes for long-term water temperature analysis along with quarterly monitoring of water-quality field parameters. Each of these sites were also sampled for a one-time water-chemistry analysis that was performed by two State of New Jersey certified laboratories. These 14 springs were selected from among New Jersey's four physiographic provinces in various geologic settings.

This report also provides a historical perspective on springs in New Jersey. In some cases, springs are compared from their current condition to historical data. Appendix A provides a summary by county of many of New Jersey's springs. The New Jersey Geological and Water Survey will continue to add information and update the New Jersey spring's database.

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THE SIGNIFICANCE OF SPRINGS IN NEW JERSEY, by Ted Pallis

Springs have been a focus of human settlement in New Jersey dating back to the Native Americans. Their village campsites, and hunting area locations were often near springs as they were attracted to good drinking water. They used springs for many purposes including irrigation, bathing, and drinking water. They also recognized the valuable curative properties of some springs, including the Schooley's Mountain chalybeate spring in Washington Township in Morris County. Tedyeesung, the renowned king of the Lenni Lenape, "is said to have always kept his camp fires burning within three miles of it in order that he might resort to it at any time" (Kobbe, 1890).

Later, as European settlers began to inhabit New Jersey, they were also drawn to springs, thus communities in New Jersey grew around them. One example is the Springtown section of

Pohatcong Township in Warren County, where the many springs that flow there attracted early settlers by the 1750s (Margulies, 2004). Springs also provided an important water source during the American Revolution. George Washington and his troops were known to have drunk from many New Jersey springs. On January 3, 1777, after the Battle of Princeton, Washington and his troops stopped to drink water from a spring, now called, "Washington's Spring." It is located not far from the intersection of Stockton Street (NJ Route 206) and Edgerstoune Road in Princeton. Today, there is a small monument at the intersection to commemorate the event. In 1780, the Continental Army was also reported to have utilized the waters at a spring in River Edge, Bergen County, during a September encampment. Today the spring is called "Washington Spring." A plaque near the spring in Van Saun Park commemorates this event.

Historically, springs have been important to rural, and urban lifestyles alike. For example, dairy farms required significant amounts of water, and many of their locations were chosen because a spring was nearby. Today, springs still provide water to supply livestock (cover image). In urban settings, industry also relied occasionally on spring water. This was evident in the paper industry in Millburn, Essex County, where the paper mills benefitted from local spring water. *The Industrial Directory of NJ, 1918,* stated, "An industry for the successful prosecution of which local conditions are most favorable is the manufacture of the finest grades of paper, because of the fact that spring water of a quality particularly suited to that purpose can be obtained here in abundance."

Additionally, in past years numerous municipal water supplies used springs as a source of water. During the early part of the twentieth century, Bordentown in Burlington County used both wells and springs as sources of their water supply while the Kanouse Spring supplied the Borough of Oakland, Bergen County with drinking water. Washington Township in Morris County was the last municipality in the state that derived a part of its water supply from a spring before the spring was decommissioned circa 2018.

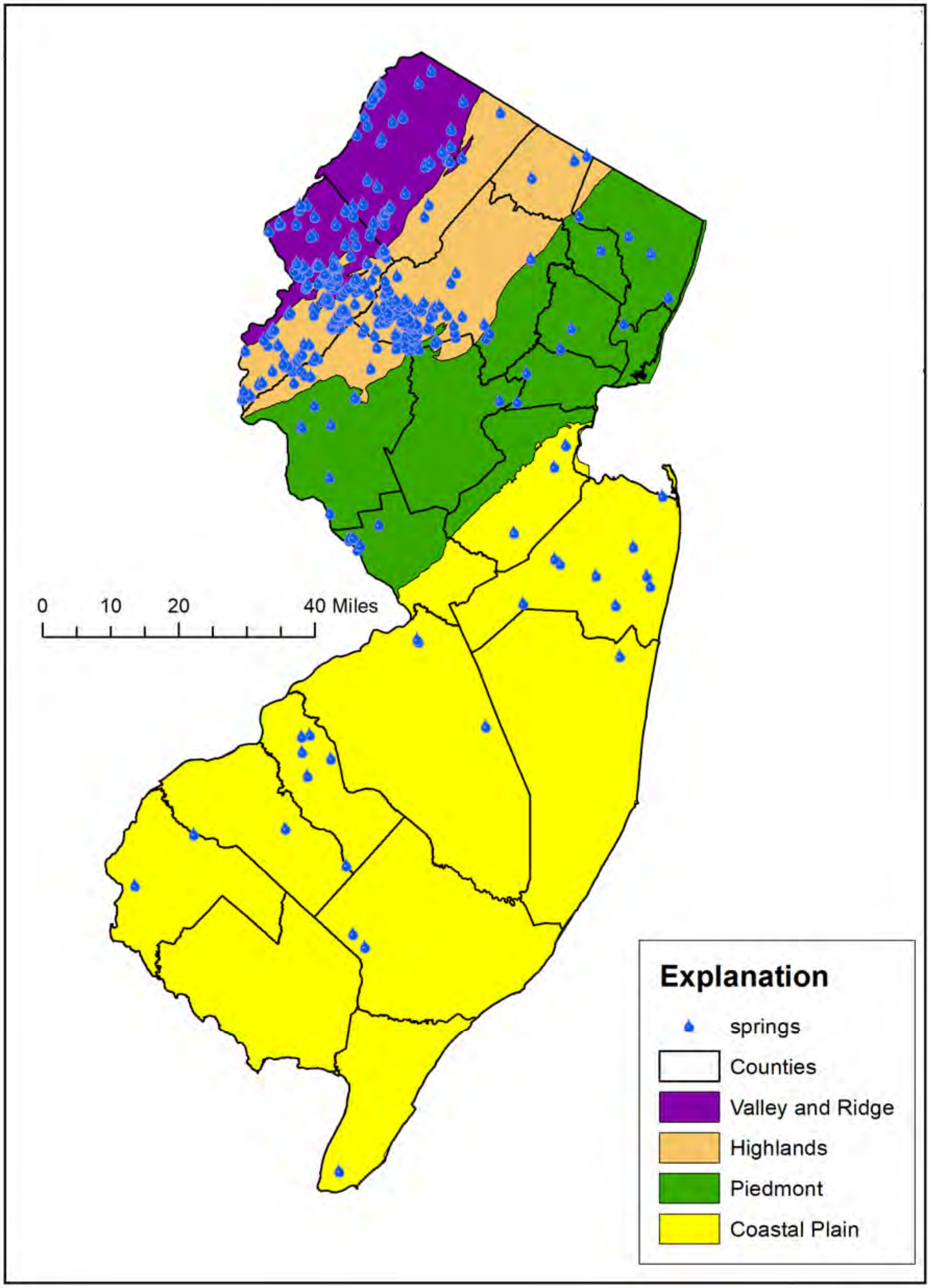


Figure 1. Map showing the location of all 512 springs mapped by the NJGWS in New Jersey and physiographic provinces.

HISTORY AND CURRENT USE OF SPRINGS, by Ted Pallis

Mineral Springs

If a spring has or is thought to have therapeutic value, they are often called medicinal or "mineral springs." The purported beneficial effects of mineral springs have been known since antiquity. In the ancient Greek world, temples were erected to Asclepius, a god of medicine and healing in ancient Greek religion (Raach, 1962). These temples were always associated with sacred springs whose waters it was said carried the healing powers of the Earth spirits (Williams, 1999). Because it was believed that Asclepius affected cures of the sick in dreams, those patients seeking the god's help first drank and bathed in the waters of his spring and then slept in the temple in an enclosure called an abaton. During dreams, Asclepius or his serpents would appear to the sick, giving them clues regarding their healing (Williams, 1999).

The Romans carried on the Greek tradition by erecting temples of their own which included springs, notably Bath in England and at Aix-la-Chapelle in Germany. During the eighteenth century throughout Europe and America, there was a resurgence of interest in the beneficial effects of mineral springs (Raach, 1962). In the United States from 1750 to 1900, hundreds of health centers were developed around mineral springs and many thousands visited these springs during this period (Raach, 1962). Mineral springs were believed to be especially beneficial for many ailments including, rheumatism, and certain phases of gout, hysteria, epilepsy, and colic.

Mineral springs in New Jersey have been important for their supposed curative benefits. There were numerous mineral springs and associated health resorts scattered throughout the state. Chalybeate springs were the dominant type of mineral springs in New Jersey. Drinking their "mineral-waters" was believed to be of great medicinal value. Chalybeate waters, also known as ferruginous waters, are mineral spring waters containing salts of iron. Sulphur springs were also found in a few various localities in the state but were less numerous. Some of New Jersey's sulphur springs were highly charged with hydrogen sulphide (Cook, 1868). There was also one saline spring known as the Warwick Spring in Newark (Peale, 1886). The location of this spring is not known today.

Different springs exhibit different water chemistry based mainly on the geologic setting of the spring. Mineral springs can be classified according to the chemical composition of the water. Mineral springs are those which yield water containing in solution unusual amounts of mineral matter, or some uncommon or especially noticeable mineral matter. They are distinguished from other springs which do not have mineral matter and are called "common springs." Groundwater takes up soluble substances from the rocks through which it flows. Small amounts of the material in solution are deposited at the spring (Bryan, 1919). One of the most elaborate spring classification systems is the one that was developed by Dr. Albert C. Peale, a geologist for the USGS from 1882-1898. He established his own scheme of classification for mineral springs, which were believed to have therapeutic properties. Under the Peale classification system, springs are categorized according to supposed mineral contents (Bryan, 1919). Some of the simpler and more generally used terms are self-explanatory. Saline springs contain common salt, sulphur springs contain compounds of sulphur, usually hydrogen sulfide, chalybeate springs contain iron, calcareous or lime springs contain calcium carbonate, gypsum "gyp" springs, gypsum, borax springs, borax, etc. (Bryan, 1919).

The most famous mineral spring in New Jersey was the Schooley's Mountain Spring. Schooley's Mountain Village is considered one of the oldest summer resorts in the United States because of the spring. The Schooley's Mountain chalybeate spring was well known to the Native Americans for its valuable curative properties. Although there were other mineral springs in New Jersey that were claimed to be water cures, Schooley's Mountain was the most celebrated (McCudden, 1988). The curative powers of the water were attributed to iron deposits in the nearby mountains. The local Lenni Lenape utilized the spring and Native American tribes from Pennsylvania sent for its waters. There is a legend that the spring became known to the European settlers only through chance. The Native Americans kept the spring's existence and location a profound secret. The Europeans first learned of it through a hunter, who coming upon it, quenched his thirst from the rill and, noticing the peculiar mineral taste, reported his discovery (Kobbe, 1890). After its discovery, the Schooley's Mountain Spring was first brought to the general public's attention by William Hamilton. The spring helped to create several summer resort hotels on Schooley's Mountain. The spring which flowed close to the summit of Schooley's Mountain eventually would have a springhouse which resembled a temple like structure built around it (fig. 2). The structure does not exist today (fig. 3). Prior to the era of boarding houses, visitors who wished to cure their ills at Schooley's Mountain spring lived in tents, and temporary shacks. As early as 1795, there was a hotel on Schooley's Mountain known as "The Alpha" (McCudden, 1988). The first advertisement of more substantial accommodations was placed in a Newark, New Jersey newspaper in 1801 by "Hager's Inn" or Tavern (The Hackettstown Gazette, 1946).

Figure 2. Postcard of Schooley's Mountain Spring, Washington Twp. Morris County. Courtesy of Washington Twp. Historical Society. Date unknown.

Figure 3. Schooley's Mountain Spring area, 2012, *Photo, S. Domber.*

About 1799, Judge Ephraim Marsh had begun to interest Joseph Heath in the springs at Schooley's Mountain and eventually Heath bought land for the erection of buildings (The Hackettstown Gazette, 1946). The Heath House was constructed about three quarters of a mile from the spring. In 1809, Joseph Heath built another building on the site capable of holding more guests (McCudden, 1988). Completion of the Morris Turnpike in about 1810, leading over Schooley's Mountain from Elizabethtown, New Jersey to Easton, Pennsylvania made Schooley's settlement more accessible and in a few years, attracted many visitors, some famous, including Joseph Bonaparte, brother of Napoleon Bonaparte (The Hackettstown Gazette, 1946). The elaborate and palatial hotel, Belmont Hall, later known as the Dorincourt, was built by Conover Browne in 1820 (fig. 4). The Dorincourt Hotel was one of two famous hotels (including the Heath House), that once accommodated visitors who traveled to the mountain. Both hotels attracted people from all over the country for over a century (New York Times, 1890). Newspaper advertisements were frequently taken out by the resorts to attract visitors to the area (figs. 5, 6). By 1830, the hotels on Schooley's Mountain rivaled those at spas at Sarasota and Ballston, New York (McCudden, 1988). People would travel long distances to drink and bathe in the spring water on Schooley's Mountain for more than 100 years.

According to the publication*, The Mineral Waters of The United States* by James K. Crook, published in 1899, said drinking Schooley's Mountain spring water was "recommended in cases of general debility, torpor of the liver, and in renal and bladder disorders." The book, *Mineral Springs of North America: How to Reach and How to Use Them* states, "The water of Schooley's Mountain Spring is well adapted to a variety of maladies marked chiefly by anemia, debility, and mucous discharges in which there is no inflammation of an organ present" (Moorman, 1873). In Morse's *The American Geography*, (1792), it is written that, "These waters have been used with considerable success, but perhaps the exercise necessary to get to them and the purity of the air in this lofty situation, aided by a lively imagination have a great efficacy in curing the patient, as the waters." Today on Schooley's Mountain, the hotels and the famous mineral spring are now gone. The Schooley's Mountain Spring which had a recorded flow of thirty gallons per hour in 1873 (Peale, 1886), became a victim of road widening construction in the 1930's and has since ceased to flow (fig. 3). Figure 7 gives the general location of the known mineral springs in New Jersey.

Figure 4. Postcard of the Dorincourt Hotel, Schooley's Mountain, New Jersey.

House and furniture new; electric lights throughout; within 100 yards of the ocean.

OCEAN GROVE.—THE PENNSYLVANIA, Main av., near the beach. Full ocean view, first-class table. Mrs. A. W. LYMAN, box 384.

SCHOOLEY'S MOUNTAIN SPRINGS, N. J.

HEATH HOUSE.

This beautiful mountain resort OPENS JUNE 10. Rates reduced; $12 to $16 per week. Diagrams, &c., at Evening Post Building, New York (room 88). Send for circular. J. WARREN COLEMAN.

BRIELLE INN,

BRIELLE, N. J.

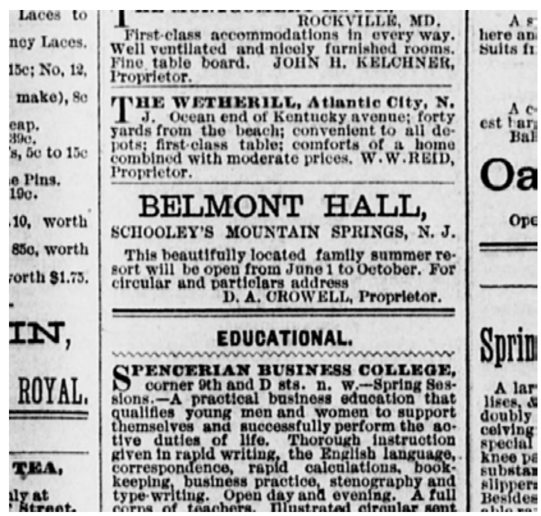
THIS FAVORITE AND CHARMING SEASIDE RESORT OPEN TILL OCTOBER

NOW OPEN FOR THE SEASON.

For particulars address

G. A. BRADY & CO.

Connecticut.



ROCKVILLE, MD.

First-class accommodations in every way. Well ventilated and nicely furnished rooms. Fine table board. JOHN H. KELCHNER, Proprietor.

THE WETHERILL, Atlantic City, N. J. Ocean end of Kentucky avenue; forty yards from the beach; convenient to all depots; first-class table; comforts of a home combined with moderate prices. W. W. REID, Proprietor.

BELMONT HALL,

SCHOOLEY'S MOUNTAIN SPRINGS, N. J.

This beautifully located family summer resort will be open from June 1 to October. For circular and particlars address

D. A. CROWELL, Proprietor.

EDUCATIONAL.

SPENCERIAN BUSINESS COLLEGE, corner 9th and D sts. n. w.—Spring Sessions.—A practical business education that qualifies young men and women to support themselves and successfully perform the active duties of life. Thorough instruction given in rapid writing, the English language, correspondence, rapid calculations, bookkeeping, business practice, stenography and type-writing. Open day and evening. A full corps of teachers. Illustrated circular sent

Figure 5. Left, Heath House Advertisement from the *New York Sun*, July 13, 1890.
Figure 6. Right, Advertisement for Belmont Hall in the *Washington Critic*, May 18, 1886.

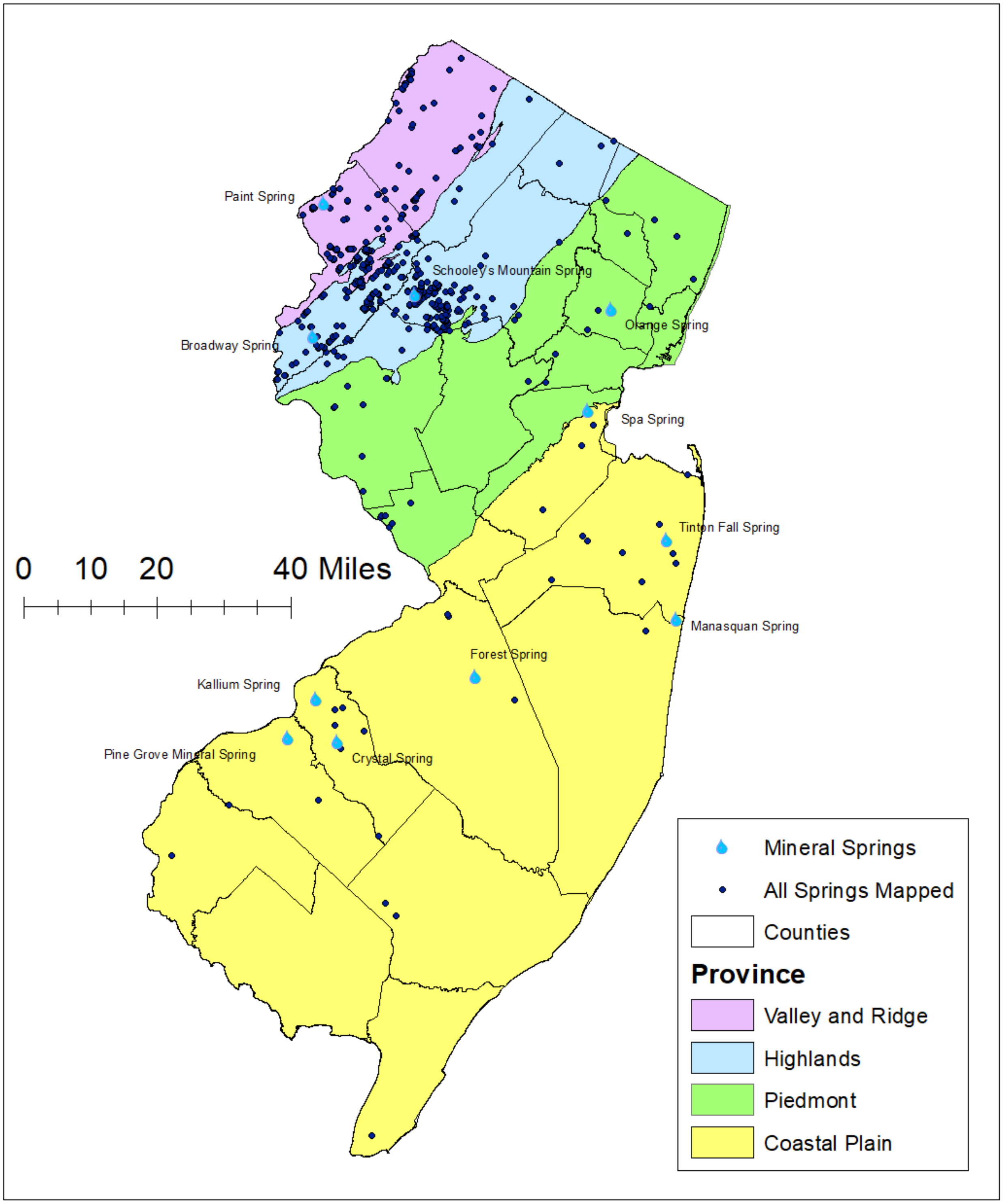


Figure 7. New Jersey springs with known mineral springs.

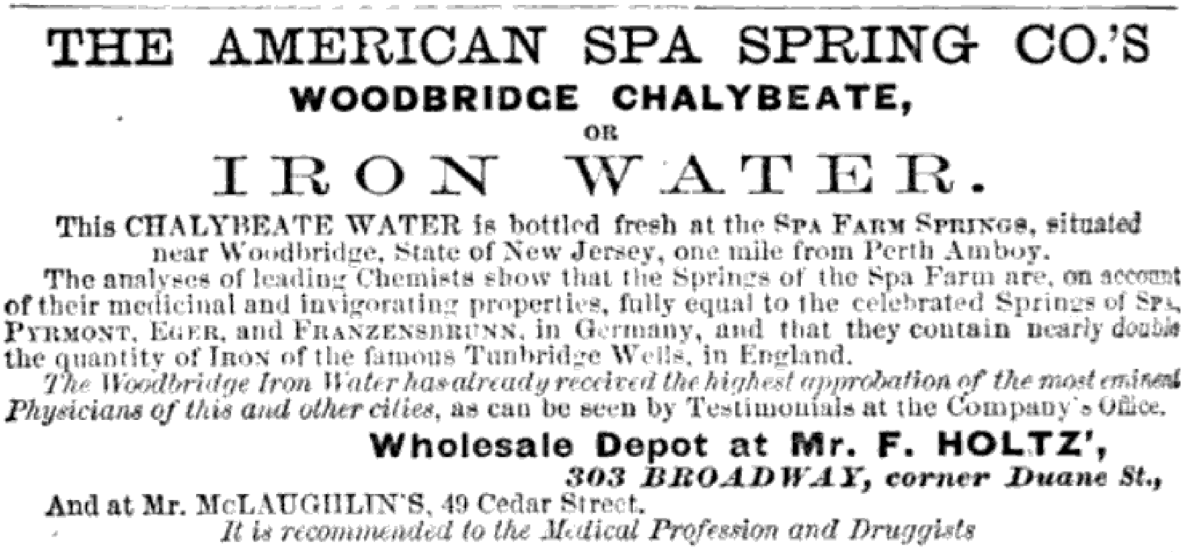
Bottled Spring Water and Public Water Supply, by Ted Pallis

There were many springs used for drinking water in New Jersey. Some were mineral and some were non-mineral springs (figs. 8 a - 8 f). Schooley's Mountain spring was the most well-known in New Jersey, however, there were numerous other mineral springs in the state. Some had hotels and spas nearby and some sold bottled mineral water to the public. Spa Spring, located near Woodbridge in Middlesex County was one of them (Cook, 1868). This chalybeate spring, though of less strength, was similar in character to the water of Schooley's Mountain Spring. It did not appear to have attracted any special attention at an early period and wasn't mentioned in any papers or documents prior to 1772. In the *New York Journal* of July 9th, in that same year, it was referred to in connection with the advertisement of a "new and convenient bath lately erected at Amboy" (Whitehead, 1856). The bath was said to be highly beneficial and had been of great efficacy in many disorders. The spa, as far as anyone could remember, had several times been fitted up with seats, a roof, and other appliances, but the waters have never had a great reputation to attract attention from people other than the local area (Whitehead, 1856). However, it was from Spa Spring that the first mineral water was bottled in New Jersey. On March 17, 1866, The American Spa Spring Company in Woodbridge was incorporated to manufacture and sell mineral water (Hood, 1870). The water at Spa Spring, known as "Woodbridge Iron Water," was bottled for sale locally and in New York City (fig. 9 a). Many of New Jersey's bottled water companies also advertised in local newspapers (figs. 9 b and 9 c.). Bottled mineral water in America predates the country's independence, with records of water bottled and sold from Jackson's Spa in Boston in 1767 (Hall, 2009).

The Tinton Falls chalybeate spring, located near the base of the Tinton Falls was frequented by those staying at local boarding houses and oceanfront hotels a few miles away on the Jersey shore (Gabrielson, 1999). In 1867, a group of businessmen formed the Tinton Falls Mineral Spring Company, the second company with authority to bottle, sell and ship their chalybeate water in the state. The water, however, when bottled would turn to the color of cider and precipitate solids after standing for several hours. It was ultimately deemed not suitable for bottling and shipping. Another well-known bottled water company was Indian Lady Hill (fig. 10). Also located in Monmouth County, records show it began bottling its spring water in the early 1900's and operated until the late 1960's or early 1970's.

Other notable mineral springs included one on Pohatcong Mountain near Broadway in Franklin Township, Warren County (Cook, 1868). This spring was once associated with an adjacent resort. Paint Spring was located on Kittatinny Mountain above the Delaware Water-Gap in Sussex County (Cook, 1868); the Orange Spring was a chalybeate mineral spring at Orange in Essex County that also had an associated hotel with it (Hoyt, 1860); the Manasquan Spring in Point Pleasant and the Forest Spring at Brown's Mills were associated with well-known hotels built near these once famous mineral springs (Raach, 1962). Other mineral springs in south Jersey included the Kallium Spring in Collingswood, Camden County and the Pine Grove Mineral Spring in Woodbury, Gloucester County (Crook, 1899).

(**Figure 8. a through f**). (a) Top left, Grotto of Crystal Spring. Laurel Springs, Camden County, *Photo, S. Domber*. (b) Top right, Spring house, Ballou Spring, Liberty Township, Warren County, *Photo, T. Pallis*. (c) Center left, Cistern for Schooley's Mountain municipal water spring, Washington Township, Morris County, *Photo, T. Pallis*. (d) Center right, Commercial drinking water, Belmar Spring Water Co. bottling plant, Glen Rock, Bergen County, *Photo, T. Pallis*. (e) Bottom left, Spring house, Indian Lady Hill spring bottled water source, Neptune Township, Monmouth County, *Photo, T. Pallis*. (f) Bottom right, Spring Hill, former publicly accessible spring water, Mine Hill, Morris County, *Photo, T. Pallis*.


THE AMERICAN SPA SPRING CO.'S
WOODBRIDGE CHALYBEATE,
OR
IRON WATER.
This CHALYBEATE WATER is bottled fresh at the SPA FARM SPRINGS, situated near Woodbridge, State of New Jersey, one mile from Perth Amboy.
The analyses of leading Chemists show that the Springs of the Spa Farm are, on account of their medicinal and invigorating properties, fully equal to the celebrated Springs of SPA, PYRMONT, EGER, and FRANZENSBRUNN, in Germany, and that they contain nearly double the quantity of IRON of the famous Tunbridge Wells, in England.
The Woodbridge Iron Water has already received the highest approbation of the most eminent Physicians of this and other cities, as can be seen by Testimonials at the Company's Office.
Wholesale Depot at Mr. F. HOLTZ',
303 BROADWAY, corner Duane St.,
And at Mr. McLAUGHLIN'S, 49 Cedar Street.
It is recommended to the Medical Profession and Druggists


PINE LAWN SPRING WATER.
THE PINE LAWN SPRING COMPANY is the only company which does both its bottle and siphon filling at the SPRING. This prevents any contamination either in transit or by being rehandled in city bottling works. All our NATURAL and CARBONATED water is shipped from the SPRING in the packages which are delivered to the consumer, thereby guaranteeing its purity.
25 Quart Bottles, original cases, (Lithiated).................. $3.00
Less than a case (Lithiated)..... 1.75 per doz.
50 Pint Bottles, original case, (Lithiated).................. 4.50
Less than a case (Lithiated)..... 1.35 per doz.
10 Siphons { Vichy / Seltzer / Carbonic } 28 oz. or 16 oz. — 7c. per siphon.
20 Siphons { Vichy / Seltzer / Carbonic } 16 oz. — 6c. per siphon.
DELIVERED FREE IN GREATER NEW YORK AND JERSEY CITY.
PINE LAWN SPRING WATER,
Hohokus, N. J., or 181 West Street.
The examination of this water shows: *a.* No evidence of pollution; *b.* The presence of only a small amount of mineral matter.
The water is therefore an exceptionally pure potable water, and is recommended for drinking.
FRASER & CO.


607
BOTTLED AT THE SPRING
Pilgrim Spring Water Co.
of
RIDGEFIELD PARK, N. J.
New York Office
54 Sixth Ave.
Tel. 917 Spring.

Figure 9 a. Top, the American Spa Spring Advertisement from, the *New York Medical Journal*, October 1868. p. 26.
Figure 9 b. Top left, Advertisement for the Pine Lawn Spring Water Co., Hohokus, NJ. From *The Tammany Times*, New York City, November 21, 1898.
Figure 9 c. Bottom right, Pilgrim Spring Water Company advertisement. Unknown newspaper and date.

As New Jersey's mineral spring resorts and spas were waning in popularity during the late 1800's, bottled spring water was in great demand. The bottled water industry took off at the turn of the twentieth century when there was a growing belief that the surface water many cities used for their water supplies was contaminated. Springs were considered a practically guaranteed source of safe-to-drink water (Day, 1905). New glass technologies at the time also made the cost of a bottle affordable and practical for mass production and consumption of water (Hall, 2009). Bottled spring water came in all shapes and sizes (fig. 10).

During this time the residents of New Jersey and New York City were looking for drinking water above suspicion of pollution. This caused the remarkable growth of the New Jersey bottled spring water trade in the early 1900's. In 1904, the nine New Jersey bottled water companies that reported sales for the year were; Alpha Spring in Springfield, Union County; Beacon Mountain Spring in Denville, Morris County; Hatwanna Spring in Budd Lake, Morris County; Indian Kalium Spring in Collingswood, Camden County; Oakland Vernam Spring, near Oakland, Bergen County; Red Rock Spring, Spring Valley Road, Bergen County; Washington Rock Spring in Warrenville, Somerset County; and Watchung Spring in Plainfield, Union County (Day, 1905).

By 1923, there were 13 active springs in New Jersey having their water bottled and sold at a total yearly total output of 507,680 gallons and valued at $50,261(Twitchell, 1925). There was an increase in 1923 of 216,872 gallons and $19,461 in profit as compared with the output for 1922 (Twitchell, 1925). Most of the water bottled by three of the operators, while for convenience in tabulation were classified as "mineral water," were non-medicinal in character. The water was bottled and sold because it was simply good, pure, potable water. The Mullins Spring Water Company of Perth Amboy, one of the 13 spring water bottlers in 1923, had also started using their spring water to produce five flavors of soft drinks in 1920.

The botted mineral and spring water business would slowly taper off after the 1920's as many towns and cities started to chlorinate their municipal water supplies. Jersey City, New Jersey was the first municipality in the United States to chlorinate their water supply. An adviser to the water company that served Jersey City at the turn of the century thought of the idea to chlorinate the city's water supply at the Boonton Reservoir, 23 miles west of Jersey City in Morris County which supplied the city with water. Disinfected water reached homes in Jersey City for the first time ever on Sept. 26, 1908. By the 1920s, chlorination was well-established as the primary means of disinfecting drinking water. This development kept the bottled spring water business in New Jersey small. A handful of New Jersey bottled spring water companies would continue to operate during most of the twentieth century, including the Belmar Spring Water Company, Bergen County, Indian Lady Hill, Monmouth County, Rock Spring Water Company, Essex County, Kepwel Spring Water Company, Monmouth County, and Great Bear Spring Water Company, Bergen County. By 1990, the bottled spring water business slowly started to grow again in the United States and New Jersey.

Figure 10. Water bottle from the Indian Lady Hill Water Company in Monmouth County. *Photo, Z, Allen Lafayette*.

New Jersey springs provide water to a thriving bottled spring water industry in the state. In 2021, eight springs located in New Jersey were the source for various bottled water companies. These springs, which were the source of New Jersey's bottled water industry were: Belmar Spring Water Company; Glen Rock, Bergen County; The Kepwel Spring Water Company, Ocean Township, Monmouth County; The Mountainwood Spring Water Company (Bonnie Brook) Blairstown, Warren County; Crystal Valley Springs, Asbury, Hunterdon County; Montana Mountain Spring Water, Phillipsburg, Warren County; The Rock Spring Water Company, West Orange, Essex County (fig. 11); Valley Crest Farm/Preserve in Clinton Twp.; Valley Crest Waters, Bloomsbury, Hunterdon County.

Bottled spring water is treated as a beverage and is regulated under the New Jersey food and beverage laws, maintained by the New Jersey Department of Health.

Figure 11. The original spring water collection outlet at the Rock Spring Water Company spring. West Orange, Essex County. *Photo, T. Pallis*.

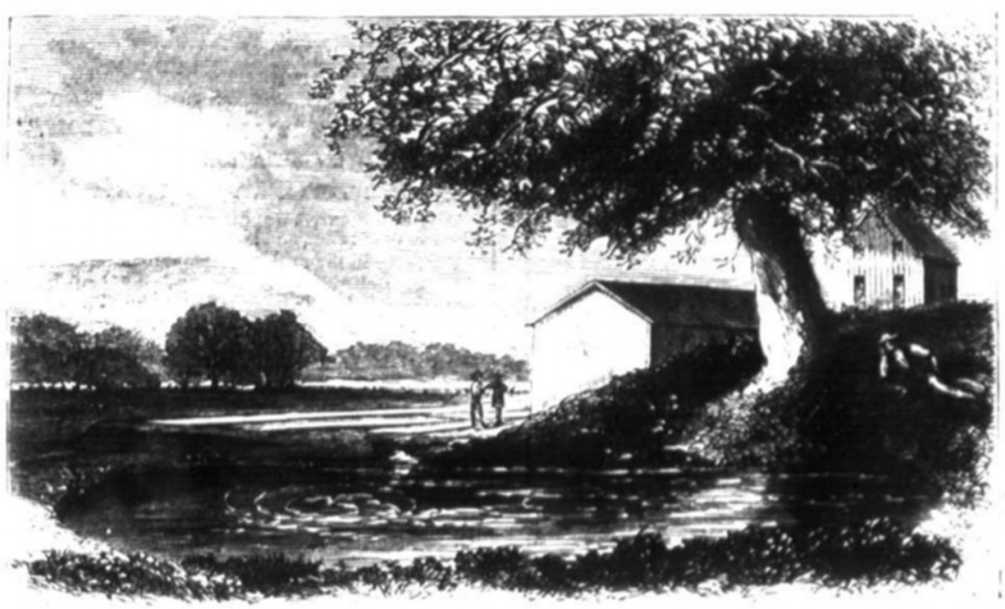
Fish Rearing, by Ted Pallis

Another industry that utilizes spring water is fish rearing. Several New Jersey fish hatcheries were located adjacent to some of the highest discharge springs in the state (Table 2). The location of the New Jersey State Fish Hatchery at Hackettstown, Warren County, also known as the Charles O. Hayford New Jersey State Fish Hatchery was picked in 1911 because of the pure, cool water flowing from multiple springs in Hackettstown. The New Jersey Board of Fish and Game Commissioners investigating the site at the time was thoroughly convinced the Hackettstown site could not be excelled anywhere in the state due to the quantity and quality of the springs found there. It was estimated in 1911, the multiple springs on the West or Main Hatchery property flowed at 125,000 gallons per hour and the water was a constant 52 degrees (Annual Report of the Board of Fish and Game Commissioners of NJ, 1912). One spring in particular at the West Hatchery flowed at an estimated 50,000 gallons per hour or about 833 gallons per minute (New York Sun, 1917). The Hackettsown hatchery had two separate units, the Main or West Hatchery and the East Hatchery. Both utilized springs to supply water to their fish pools. In the early 1950's when the New Jersey State Fish Hatchery at Hackettstown was the largest fish hatchery in the world, the East Hatchery was supplied with more than two million gallons of spring water daily while the West Hatchery used about three to four million gallons of water daily. About 85 percent of the water supplied to the West Hatchery came from springs, with the balance coming from streams (The Hackettstown Gazette, 1952).

In the mid 1950's, when the New Jersey State Fish Hatchery at Hackettstown was reaching capacity, a new location was investigated for a new fish hatchery. Under consideration was a site in White and Liberty Townships in Warren County which was owned at the time by the Federal Fish & Wildlife Service and was already being utilized as a small fish hatchery. In 1965, the New

Jersey Geological Survey, after an investigation decided there was not enough water at the site for a new hatchery. However, in about 1970, the site was investigated a second time for additional water by the New Jersey Geological Survey and this time it was found to have enough water for a new trout hatchery. The tract of land along the Pequest River in White and Liberty Townships was then chosen for a new State trout hatchery because of the large flowing springs discovered on the property. There were approximately seven springs on the plot of land where the Pequest State Trout Hatchery would be built. The two largest springs included the Shoemaker Spring which flowed at 1,347 gallons per minute (gpm) and the Hatchery Pool Spring which flowed at 1,122 gallons per minute.

The Musky Trout Hatchery is a private hatchery located in Asbury, Franklin Township in Warren County along the Musconetcong River. Established in 1958, it is the oldest private fish hatchery in New Jersey. It depends on spring water from the Stanley Spring to fill its fish pools. From the spring, the water is led by a raceway through the fishponds and the hatchery house. The spring water is a steady 51°F, which is ideal for spawning trout. The Stanley Spring has had its flow measured longer than any other spring in New Jersey beginning in 1868. Its flow has been variable over time. A flow of 1,200 gpm was reported by the owner of the hatchery in 2012. On June 1, 1948, its flow was measured by G. S. Hayes of the USGS, and it had a reported flow of 2,160 gallons per minute (Hayes, 1948). In July of 1947, the spring flow was measured by William Stanley and had a reported a flow of 650 gallons per minute (Herpers, Atlas Sheet 24.22.55, 1947). In 1868, Dr. J. H. Slack operated a trout hatchery at the same site using the spring to raise his trout. The spring was known then as the Troutdale Spring (fig. 12), had an estimated flow of 1,000 gallons per minute in 1868 (Harper's Weekly, 1868).



THE TROUTDALE SPRING.

Figure 12. Drawing of the Troutdale spring in Asbury, from, *A New Jersey Fish Farm*, Harpers Weekly from June 13, 1868.

BRAU KETTLE WEIR ANALYSIS, by Steve Domber and others

For this report, one spring was chosen to be monitored for a hydrogeologic investigation. An investigation of Brau Kettle (fig. 13), and its relationship to the Onondaga Limestone was conducted starting in 2008. This hydrogeologic investigation consisted of measured hourly water level data using the Automatic Data Recorder (ADR), In Situ Level TROLL 100 logger from the Brau Kettle and a nearby domestic well, precipitation data, and kettle discharge measurements were collected.

Figure 13. Brau Kettle filled with water January 14, 2016, outlet channel at the top of the photo. *Photo, T. Pallis*.

The volume of water passing through a point on a stream per unit of time is used to measure stream flow. A weir (a barrier across a river designed to alter and measure its flow characteristics and for measurement of flow) was also constructed in the outlet channel of Brau Kettle on October 23, 2013 (fig. 14). The rectangular weir was built in place when Brau Kettle was dry. The water flow characteristics over the weir and water level measurements of Brau Kettle were taken continuously from February 1, 2013, to July 1, 2014. The depth of the water passing over the weir was recorded on a regular basis (fig. 15). Two factors are required to determine volume (quantity) of water: cross sectional area, generally in square feet (ft^2) and flow velocity cubic feet per second (cfs) (Forero and Fulton 2013).

Flow through a rectangular weir can be expressed as:

$q = 3.33 (b – 0.2 h) h^{3/2}$
where
q = flow rate (ft^3/s)
h = head on the weir (ft)
b = width of the weir (ft)
Sometime referred to as the Frabcis Formula

(U.S. Department of the Interior, Bureau of Reclamation, 2001)

Figure 14. Weir being constructed when Brau Kettle was dry. *Photo, T. Pallis*.

Brau Kettle is a unique sink-hole-type karst feature located within the Milford, PA, USGS 7.5 Minute quadrangle. It lies along the western slope of the Walpack Ridge near the intersection of Jager Road and Old Mine Road in Sandyston Township, Sussex County. References to the kettle go back to the early French and Dutch settlers to New Jersey and the name likely derives from the Dutch name for a "brewing" or "boiling kettle" (Dalton, 1976). The kettle is an oval shaped structure approximately 8 feet deep with its lower point located in or possibly on top of the Onondaga Limestone and the larger upper end open at the ground surface with a diameter of around 20 feet. The sloping walls of the kettle are in till materials. Brau Kettle can be classified as an intermittent spring which varies from dry, to partially filled, to spilling, with highly variable fill and spill periods. It is hypothesized that the kettle was formed when a near-surface dissolution feature in the Onondaga Limestone enlarged to the point where it collapsed creating a sinkhole in the overlying unconsolidated materials. Over time the flowing groundwater removed most of the finer materials leaving the sinkhole feature we see today. Since this feature is about 90 feet above the Delaware River on the west slope of the Walpack Ridge, the ridge top is 230 feet above the kettle or 320 plus feet above the Delaware River, groundwater only rises to kettle elevations during wet recharge periods. Further down the slope, closer to the Delaware River is a series of perennial springs which discharge (in a boil-like fashion) through the presumably much thicker and younger fluvial deposits. The lower elevation springs can be thought of as the perennial "base-line" discharge point.

Figure 15. Weir at Brau Kettle with water flowing over it. *Photo, T. Pallis*.

The kettle can be thought of as the overflow or relief valve when groundwater levels are high, and a large volume of water is flowing through the local hydrogeologic system. Figure 16 shows selected water-level elevation data for the kettle and a nearby domestic well. The numbered descriptions below refer to the corresponding number on figure 17. 1) The dashed grey line is elevation of base of the kettle outlet channel; kettle elevations above this indicate that the kettle is discharging to the adjacent stream. When the green line is flat at approximately 434 feet, the kettle is dry. 2) Water levels in the well and kettle increase in response to precipitation/recharge on October 28th. 3) Water levels in the kettle and well recess. 4) Rate of water level recession increases in the kettle once the water level drops below the kettle outlet elevation 5) Kettle is dry while water level in well continues to decline. 6) Increase in well water levels due to small precipitation/recharge event, but not high enough to come above base of kettle. 7) Water levels in well increases and kettle temporarily fills in response to precipitation/recharge event. 8) Kettle fills and begins to discharge out of the outlet, water levels in well increase. 9) Note that water levels follow similar trends, however they are at different elevations since well water level represents a composite water level from multiple zones in the aquifer, whereas kettle represents only the upper-most zone in the aquifer. Figure 16 shows the period of time when the square notched weir was installed in the Brau Kettle outlet channel and used to measure discharge. Calibration of the manual and data recorder measurements was poor with an R-squared error of 0.79 and seepage around the edges of the weir was observed after several months of operation. The discharge estimates should be assumed approximate at best. The kettle and domestic well water level elevation can be seen rising and falling in response to recharge events as described in figure 17. Discharge is observed to have occurred in the wetter winter months when evapotranspiration is low and recharges rates and water levels are typically highest. Discharge also periodically occurs during the summer and fall for short durations when heavy rains cause substantial but temporary increases in water levels. Discharge rates hover in the 500 to 1000 gallons per minute range and peak as high as 3,500 gpm. This would make the kettle a third-order spring and large for what is typically observed in New Jersey. Also of interest is that the nearby stream channel (located approximately 100 feet to the north, and lower in elevation than the base of the kettle) is typically dry when the kettle is actively discharging. This is typical for the complex and site-specific hydrogeology of karst settings.

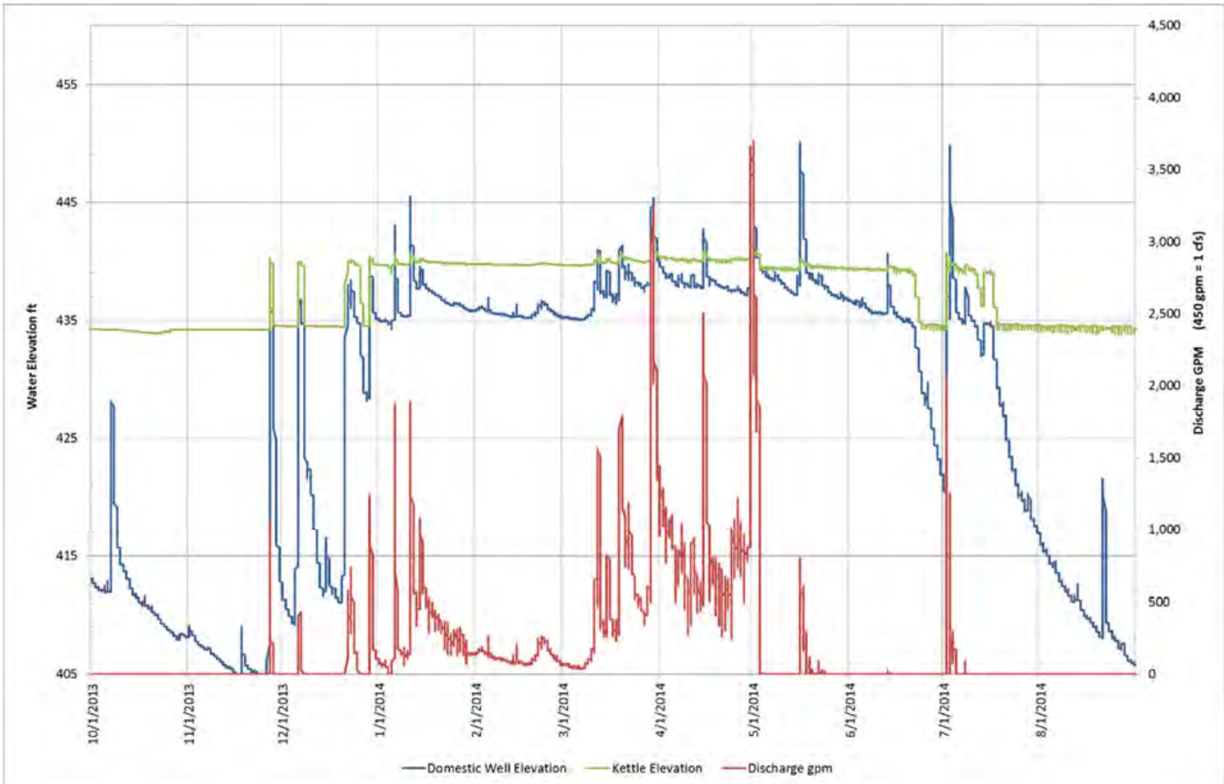


Figure 16. Water level elevation in Brau Kettle and in a nearby domestic well, Brau Kettle discharge as measured by a square-notched weir.

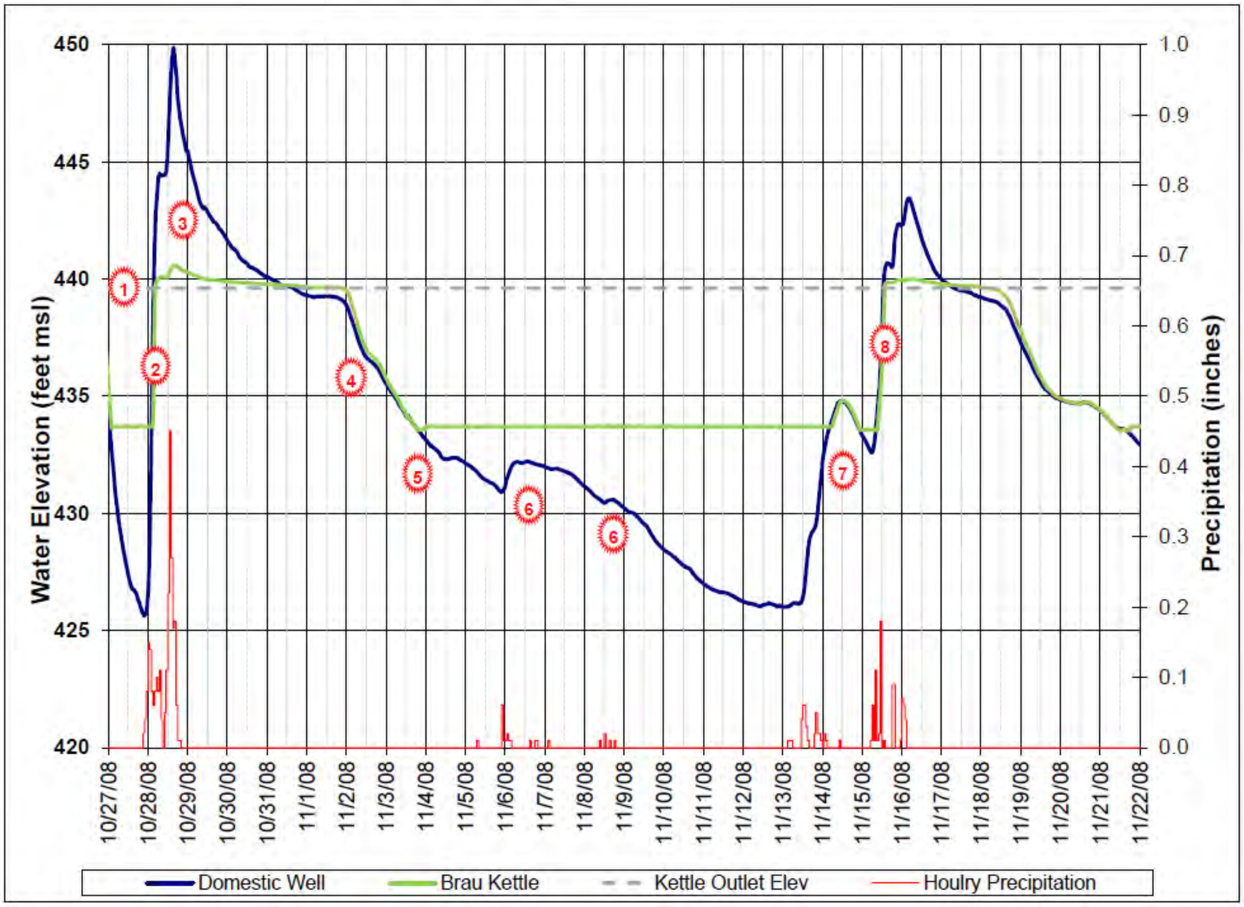


Figure 17. Annotated hydrologic data for Brau Kettle, October through November 2008. The red circled numbers refer to the description in the text for recharge events.

SPRINGS CHARACTERIZATION AND CLASSIFICATION

Springs may be classified or grouped in several ways according to their 1) mean flow or discharge rate 2) geomorphology 3) geologic setting 4) Mean temperature 5) chemistry of their water 6) flora and fauna 7) macroinvertebrates 8) aquatic life.

SPRINGS DISCHARGE, by Ted Pallis

The discharge of a spring can be determined with fair accuracy only by establishing a gaging station and obtaining continuous readings over a period of years (Meinzer, 1927). This has only been done periodically in New Jersey. There have been at least nine springs measured continuously over time. In eight cases, a weir was used to measure a spring's discharge rate over time. These include Big Springs/North Church, The Stanley/Troutdale Spring, Federal Springs, Shoemaker Spring, Bangma Spring, Hatchery Pool Spring, Swimming Pool Spring and Brau Kettle. In one other case, Schuster Pond Spring's discharge rate was measured with a stream-flow meter over time. For other springs in the past where a spring's discharge rate was not systematically measured with a weir or flow meter, the methods used are unknown and should be considered estimates. More recently, the springs with discharge rates observed were developed using area and velocity estimates by NJGWS staff experienced with flow gauging methods.

For classification purposes, springs are most often classified by the volume of the water they discharge. This is the most common way of classifying the size of a spring. Oscar E. Meinzer, the American hydrologist (1876-1948), proposed a classification of springs in terms of magnitude and discharge rate in his report, *Water Supply Paper 557, Large Springs in the United States* in 1927, while working for the USGS. Meinzer, often called "the father of modern groundwater hydrology," described the distribution and character of large springs and their classification with respect to quantity of water they discharge (Meinzer, 1927). For this report, the NJGWS employed the Meinzer Classification Method to describe springs discharge rates. The categories suggested by Meinzer (1927), are found in Table 1. According to Meinzer, springs are classified by magnitude (from one to eight) based on their volume of flow, or discharge of water.

Table 1. Meinzer spring discharge magnitude classification. Note: cfs = cubic feet per second. Modified from Meinzer (1927).

Magnitude	Discharge Rate
1st magnitude	>100 cfs
2nd magnitude	<100 to >10cfs
3rd magnitude	<10 to >1 cfs or
4th magnitude	<1 cfs to >100 gal/min
5th magnitude	<100 to >10 gal/min
6th Magnitude	<10 to >1 gal/min
7th magnitude	<1 gal/min to >1 pint/min
8th magnitude	<1 pint/min

Some springs can fluctuate greatly in their rate of discharge, while others are nearly constant. Springs have dynamic flows dependent on climate and hydrogeology. A spring classified as being a certain magnitude at one time may not continue to flow at that rate at other times (Meinzer, 1927). According to Meinzer, the largest springs are rated as first-magnitude, which is defined as springs that discharge water at a rate of at least 2,800 liters or 100 cubic feet (2.8 m^3) of water per second or 44,883 gpm. Seventy-two springs statewide were classified and mapped by discharge rate for this report (fig. 18), with discharge information gathered from historical reports or site visits and one spring being continuously monitored (Brau Kettle). There are no first magnitude springs (the largest in the Meinzer classification system), and only one second magnitude spring in New Jersey. On May 22, 1967, Bonnie Brook Spring (fig. 19) in Stillwater, Sussex County had the highest recorded discharge rate ever recorded in New Jersey with a flow of 11.1 cfs or 5,000 gpm (Herpers et. al, 1967). The 17 largest springs by discharge rate, where at least one discharge rate observation has been made are shown in Table 2. There is one second magnitude spring (Bonnie Brook) and 16 third-magnitude springs. All are in Sussex and Warren counties in the northwest part of the state with one exception, the Kanouse Spring in Oakland, Bergen County. The large springs found in the northwest parts of the state emerge mostly from karst geology. Karst is a distinctive type of geology that commonly occurs where limestones and dolomites are at the surface. Karst springs form when groundwater discharges to the surface through a karst opening and differ from other springs because they normally have a much higher production as they are usually at the end of a water filled cave system. The Kanouse Spring in Oakland is not located in karst geology.

Table 2. Meinzer discharge rate classification for 17 of the largest springs in New Jersey.

Rank	Spring	Magnitude	Details	County	Notes
1	Bonnie Brook Spring	2n^{d} <100 to >10cfs	900 gpm in 1947 and 5,000 gpm in 1967 per USGS.	Sussex	Estimate
2	Schuster Pond/Mountainwood Spring Water Co.	3rd 1 to 10 cfs	4,000 gpm in 1934. 3.7 cfs (1,630 gpm) 1966.	Warren	Reported in 1934. Measured with Stream-flow meter in 1966.
3	Stanley Spring/Troutdale Spring, Muskey Trout Hatchery	3rd 1 to 10 cfs	2,160 gpm in 1948 per USGS. 1,200 gpm per owner, 2012.	Warren	Weir measurement 1948.
4	Shoemaker Spring, Pequest Fish Hatchery	3rd 1 to 10 cfs	1,347 gpm, June 16, 1973.	Warren	Weir measurement.
5	Hatchery Pool Spring, Pequest Fish Hatchery	3rd 1 to 10 cfs	1,222 gpm, June 16, 1973.	Warren	Weir measurement.
6	Shurts Road Spring	3rd 1 to 10 cfs	1,000 gpm, with 35 gpm from adjacent spring house.	Warren	Verified during visit.
7	State Fish Hatchery at Hackettsown Spring	3rd 1 to 10 cfs	833 gpm. NY Sun, 1917.	Warren	Verified during visit.
8	Brau Kettle Spring	3rd 1 to 10 cfs	500-100 gpm. With a peak of 3,500 gpm.	Sussex	Weir measurement.
9	Kennedy Mill-Stewartsville Spring	3rd 1 to 10 cfs	2.23 cfs. At least 4 discrete springs at base of cliff.	Warren	Verified during visit.
10	Marble Mountain Spring	3rd 1 to 10 cfs	1,000 gpm, June 29, 1948.	Warren	Verified during visit.

Rank	Spring	Magnitude	Details	County	Notes
11	Carpentersville Spring	3rd 1 to 10 cfs	700 gpm.	Warren	Verified during visit.
12	Swimming Pool Spring	3rd 1 to 10 cfs	275-300 gpm in 1947. 1.5 cfs or about 700 gpm in 8/17/2011.	Sussex	Weir measurement.
13	Federal Springs	3rd 1 to 10 cfs	600 gpm in 1947.	Warren	Weir measurement
14	Bevan's Spring	3rd 1 to 10 cfs	500 gpm.	Sussex	Verified during visit
15	Big Springs North Church	3rd 1 to 10 cfs	350-500 gpm. 1947	Sussex	Weir measurement
16	Kanouse Spring	3rd 1 to 10 cfs	448 gpm in 1936.	Bergen	Verified during visit
17	Dingman's Ferry Spring	3rd 1 to 10 cfs	Good discharge.	Sussex	Verified during visit

Figure 18. Bonnie Brook Spring springhouse. Stillwater Twp., Sussex County. *Photo. Z. Allen Lafayette*.

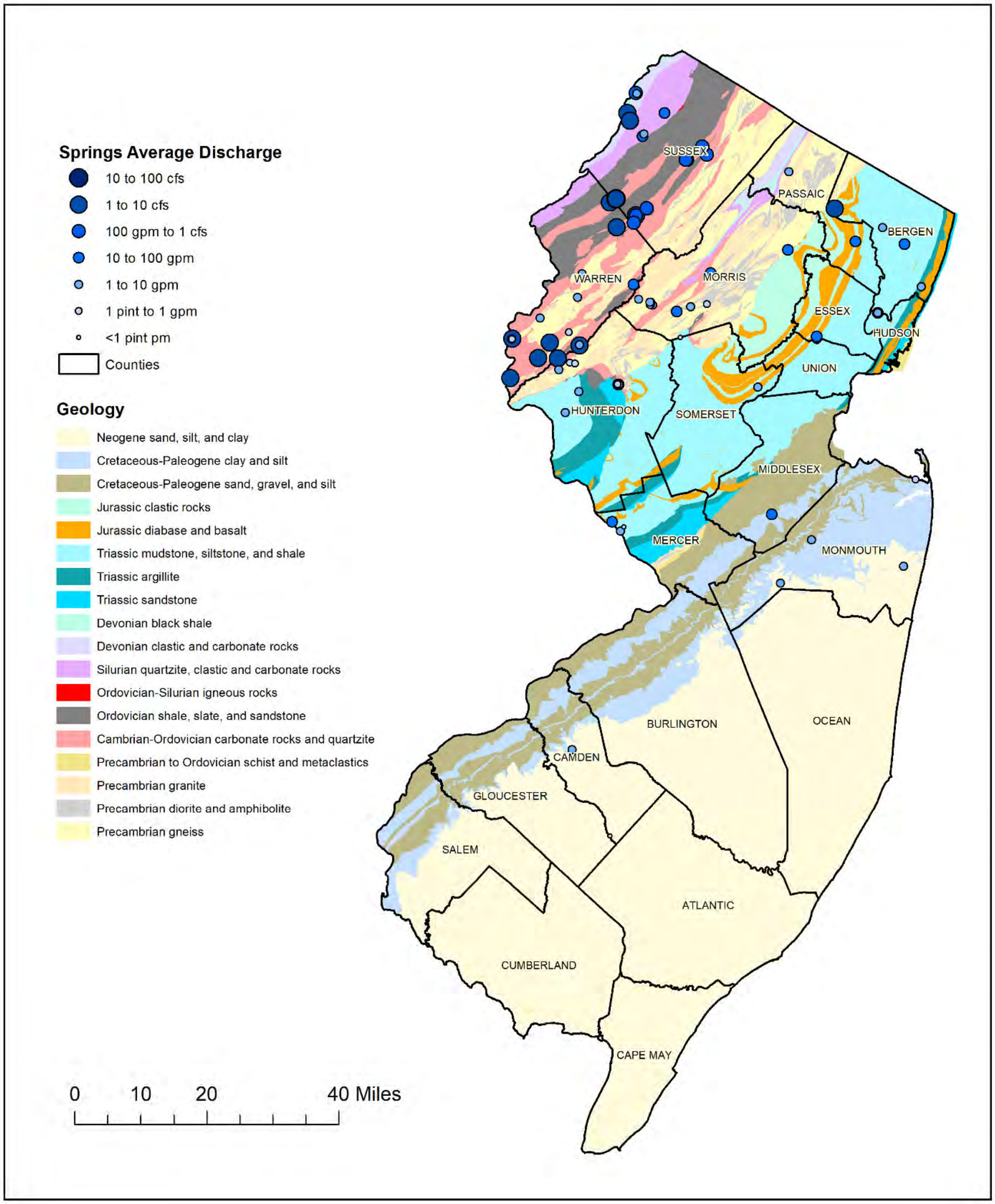


Figure 19. Map of springs by average discharge rate for 72 selected springs in New Jersey where a discharge rate has been recorded.

SPRINGS GEOMORPHOLOGY, by Ted Pallis

Springs can also be classified by geomorphology (fig. 27), which is the study of the physical features of the surface of the earth. For this report, spring types classified by geomorphology include springs that emerge in caves, contact/hanging garden springs, gushette springs, helocrene springs, hillslope springs, limnocrene springs, and rheocrene springs. The NJGWS visited 50 random springs and categorized/classified them by geomorphology (Table 3). The results showed hillslope with (30), were the most common springs geomorphology in New Jersey followed by limnocrene (8) (Table 4). To determine a spring's geomorphology for classification purposes, the first point of emergence was used. A larger spring complex often has multiple geomorphologies such as when a stream is formed. Groundwater could be considered discharging to multiple geomorphologies.

Cave springs are common in karst terrain. Karst provides the geologic settings for cave springs to develop (fig. 20). Cave springs can contain ecosystems with species including troglobites (such as millipedes), and troglophile species, such as cave snails, salamanders, fish, beetles, and crayfish (Elliot, 2007).

Figure 20. Cave spring, Dingman's Ferry Spring, Sandyston Township, Sussex County. *Photo, R. Witte*.

Contact/hanging garden springs (fig. 21), emerge along contacts and seep, drip, or pour down onto underlying walls. Hanging gardens are spring-fed colonies of plants clinging to the vertical wall of a cliff and feed off the moisture from the spring.

Figure 21. Contact/hanging garden spring with moss growing at the contact. Alexandria Township, Hunterdon County. *Photo, G. Herman*.

Gushette springs pour from cliff faces (fig. 22). They typically emerge from perched or unconfined aquifers, often with dissolution enhancement along fractures. Gushettes typically support madicolous habitat, which consists of thin sheets of water flowing over rock faces (Springer and Stevens, 2008). They have very diverse ecosystems. Although they occur prominently in areas with steeply dissected topography, they can also occur in regions with more modest topography, if there is sufficient topographic relief to allow for free falling-flow (Springer and Stevens, 2008).

Figure 22. Gushette spring, Henry Hudson Spring, Atlantic Highlands, Monmouth County. *Photo, S. Domber*.

Helocrene springs usually emerge in a diffuse fashion in marshy, wet meadow, or bog settings (fig. 23). Wetlands in New Jersey have been formed through various processes. Groundwater discharge, which can be in the form of a spring, flows into depressional wetlands that are connected to the water table. Helocrene springs are usually found in wetlands areas, and may be situated in a mixture of sand, clay, and silt. Wetlands might also be fed by limnocrene springs, in which discharge from aquifers form lentic pools. These pools can sustain pond and aquatic species. Groundwater-dependent ecosystems are a vital yet poorly understood component of the natural environment and are vulnerable to environmental change.

Figure 23. Helocrene spring, Paint Island Spring, Millstone Township, Monmouth County. *Photo, S. Domber*.

Hillslope springs emerge from confined or unconfined aquifers on non-vertical hillslopes at 30-to 60-degree slopes and usually have indistinct or multiple sources (Springer and Stevens, 2008). The Kanouse Spring is one of many hillslope springs in New Jersey (fig. 24).

Figure 24. Hillslope spring, Kanouse Spring, Oakland, Bergen County. *Photo, T. Pallis*.

Rheocrene Springs are springs that flow from a defined opening to a confined channel (fig. 25). The term rheocrene describes springs where discharge emerges as flowing streams (Springer and Stevens, 2008). Spring-fed streams are also referred to as spring brooks or spring runs. Some rheocrene spring could also be classified as hillslope springs as they are usually located in areas of relief causing the stream to flow away from the spring. The Kanouse Spring, (fig. 24), among others could also be classified as rheocrene since it has a defined channel flowing away from the spring.

Figure 25. Rheocrene spring run, George Washington Spring, Paramus, Bergen County. *Photo, T. Pallis*.

Limnocrene springs are springs which originate from large, deep pools of water (fig. 26). Due to their relatively uniform temperature and chemistry, the sources of these springs may support aquatic species that are different from surrounding habitat influenced by surface water.

Figure 26. Limnocrene spring, Blue Hole-Inskeep, Winslow Township, Gloucester County. *Photo, S. Domber*.

Table 3. 50 Selected Springs Visited by the NJGWS Categorized by Geomorphology.

Number	Spring Name	Geomorphology
1	Brau Kettle Spring	Limnocrene
2	Ballou's Spring	Gushette
3	Belmar Spring Glen Rock	Limnocrene
4	Big Spring Whittingham	Limnocrene
5	Blue Hole-Inskeep	Limnocrene
6	Bonnie Brook Spring	Limnocrene
7	Broadway Spring	Hillslope
8	Capstick Spring	Hillslope
9	Carpentersville – Snyders Rd. Spring	Hillslope
10	Carpentersville Spring	Hillslope
11	Cold Spring	Helocrene
12	Cramers Creek Spring	Hillslope
13	Crystal Spring	Hillslope
14	Dark Moon Fen Spring	Hillslope
15	Dingman's Ferry Spring	Cave
16	Federal Springs	Limnocrene
17	George Washington Spring, Van Saun Park	Rheocrene
18	Great Bear/Trinity Spring	Hillslope
19	Henry Hudson Spring	Gushette
20	Highlands Ridge Park Spring	Hillslope
21	Huff Spring	Hillslope
22	Indian Lady Hill	Hillslope
23	Kanouse Spring	Hillslope
24	Kennedy Mill – Stewartsville Spring	Rheocrene
25	Lake Kittatinny Woods Rd. Spring	Hillslope
26	Locust Grove Spring	Hillslope
27	Maple Springs Road Spring	Contact/Hanging Garden

Number	Spring Name	Geomorphology
28	Marble Mountain Spring	Rheocrene
29	Molly Pitcher Spring	Hillslope
30	National Spring Water Company Spring	Hillslope
31	North Arlington Spring	Limnocrene
32	Paint Island Spring	Helocrene
33	Perrine Hill Spring	Hillslope
34	Rae Spring – Schooley's Mountain	Hillslope
35	Schooley's Mountain Park Spring 1	Hillslope
35	Schooley's Mountain Park Spring 2	Hillslope
37	Schooley's Mountain Park Spring 3	Hillslope
38	Schooley's Mountain Park Spring 4	Hillslope
39	Schooley's Mountain Road Spring	Hillslope
40	Shurts Road Spring	Rheocrene
41	Stanley Spring, Musky Trout Hatchery	Limnocrene
42	Swimming Pool Spring	Cave
43	Thompson Park Spring	Hillslope
44	Tinton Falls Spring	Helocrene
45	Valley Crest Spring 1	Hillslope
46	Valley Crest Spring 2	Hillslope
47	Valley Crest Spring 3	Hillslope
48	Honeyman Spring	Hillslope
49	Washington Crossing State Park Spring 2	Hillslope
50	Washington Rock Spring	Hillslope

Table 4. Totals of 50 Selected Springs Categorized by Geomorphic Occurrences.

Geomorphology	Occurrences
Cave	2
Contact/Hanging Garden	1
Gushette	2
Helocrene	3
Hillslope	30
Limnocrene	8
Rheocrene	4

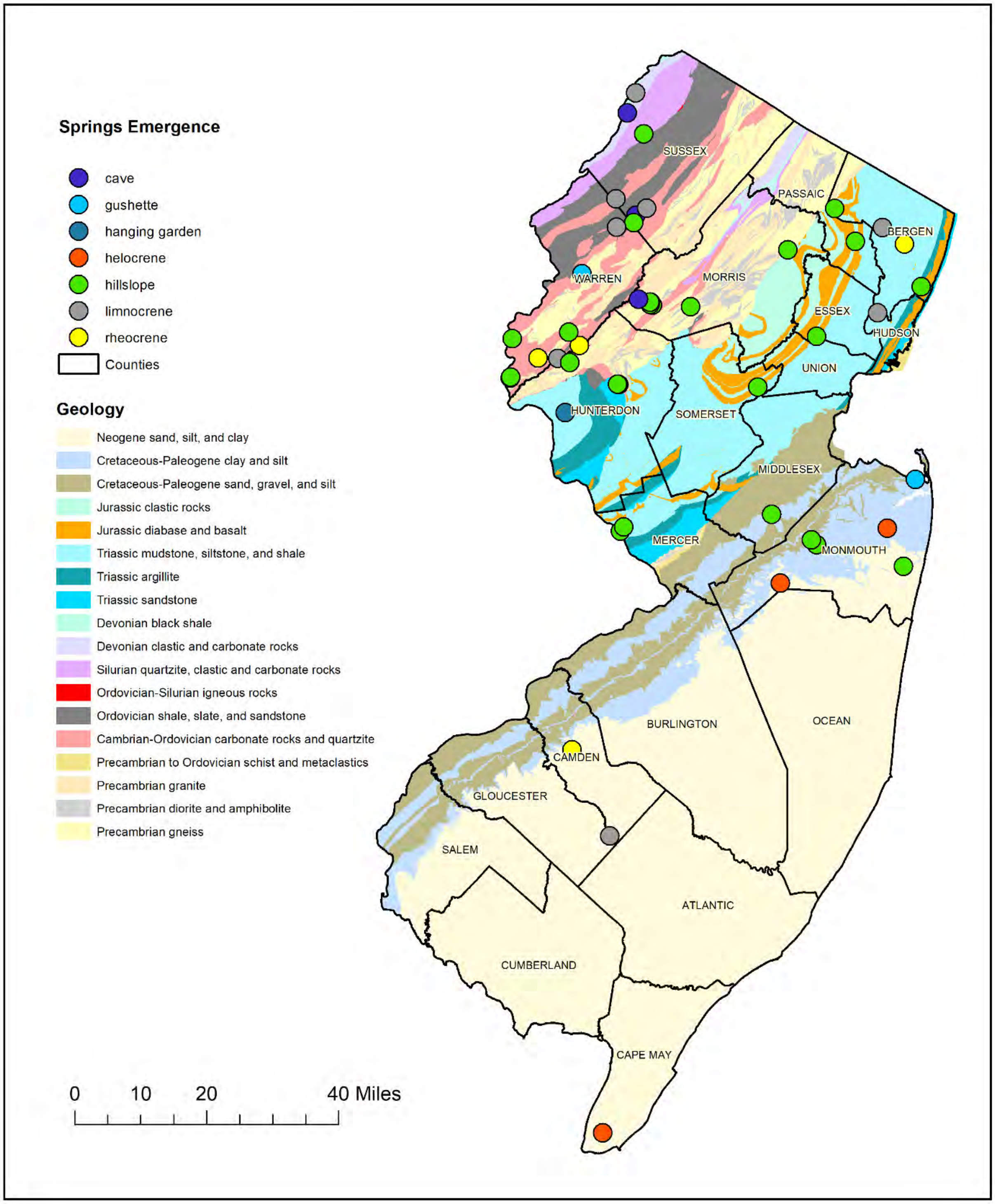


Figure 27. Map of 50 Selected Springs by Geomorphology.

THE GEOLOGY OF SPRINGS, by Ted Pallis, Steve Domber, Rachel filo

General Hydrogeological Overview

A spring is any natural discharge of water from rock or soil onto the surface of the land. Specifically, springs are places where subsurface water comes to the surface and flows or where it lies in pools that are continually replenished from below. The water source for a spring can vary. Some springs are fed by shallow groundwater seepage out of the soil, while others are fed by deep aquifer water discharged under artesian pressure. These differences influence the hydrology and the water chemistry of springs. They can range in size from intermittent seeps, which flow only after a great deal of rain, to huge spring pools with tens of thousands of gallons flowing daily. Cave systems can have streams which discharge to the surface at different locations. Perched ground water can discharge as seeps or intermittent springs.

Springs may be permanent (perennial) and flow throughout the year or ephemeral (intermittent or temporary) and flow only during or after rain. During the warm season when evapotranspiration is high, the flow of springs can decrease or cease.

The amount of water that flows from springs depends on many factors including: the size of the voids (or porosity) within the rocks; the head in the water bearing unit; the size of the spring basin and the amount of rainfall. Human activities can also influence the volume of water that discharges from a spring. Ground-water withdrawals in a nearby area can reduce the water-table, causing water levels to drop and ultimately decrease the flow from the spring. In some cases, springs have completely disappeared over time due to increases in groundwater withdrawal due to development. New Jersey has many examples of springs which once flowed strong but do not exist anymore.

NEW JERSEY GEOLOGY AND SPRINGS

Springs can be classified by geology. The NJGWS classified each of the 512 springs in its springs database by intersecting their locations with the bedrock geology layer in a GIS system (Table 5). In New Jersey, larger springs are generally found in higher porosity geologic units such as carbonates, jointed or fractured rock, unconsolidated sediments, and glacial sediments. New Jersey springs occur in all rock types but those in insoluble rocks are generally small, discharging only a few gallons per minute (gpm). Some springs that occur in sand and gravel may be very large with flows exceeding 1,000 (gpm). Springs in carbonate rock areas range in size from very small to very large and they commonly vary more widely in flow than those in sand and gravel. For instance, the estimated flow of Bonnie Brook Spring in Stillwater Township in Sussex County on September 10, 1947, was about 900 (gpm), and on May 22, 1967, the flow of about 5,000 (gpm) was recorded by the USGS when the NJGWS requested a flow measurement.

Table 5. 512 New Jersey Mapped Springs and the Bedrock Geology they occur in.

Geology	Occurrences
Allentown Dolomite	21

Geology	Occurrences
Amphibolite	5
Biotite-Quartz-Feldspar Gneiss	24
Bloomsburg Red Beds	12
Bushkill Member of Martinsburg Formation	16
Buttermilk Falls Limestone	16
Cohansey Formation	6
Diorite	19
Englishtown Formation	3
Feltville Formation	2
Franklin Marble	6
Hardyston Quartzite	2
Hornblende Granite	74
Hornblende Syenite	3
Hornerstown Formation	1
Hypersthene-Quartz-Oligoclase Gneiss	16
Jacksonburg Limestone	4
Jacksonburg Limestone and Sequence at Wantage undivided	1
Jurassic Diabase	2
Kalkberg Limestone Coeymans Limestone Manlius Limestone	1
Leithsville Formation	14
Lockatong Formation	2
Lower Member Kirkwood Formation	7
Lower Part of Beekmantown Group	15
Martinsburg Formation	1
Merchantville Formation	1
Microantiperthite Alaskite	1
Microcline Gneiss	4
Microperthite Alaskite	13
Migmatite	3
Monazite Gneiss	3
Mt. Laurel Formation	2
Orange Mountain Basalt	3
Passaic Formation	7
Passaic Formation Conglomerate and Sandstone facies	1
Passaic Formation Mudstone facies	1
Passaic Formation Quartzite-clast Conglomerate facies	2
Passaic Formation Sandstone and Siltstone facies	2
Potassic Feldspar Gneiss	20
Preakness Basalt	2
Pyroxene Alaskite	2
Pyroxene Gneiss	23
Pyroxene Granite	30
Pyroxene Syenite	6
Pyroxene-Epidote Gneiss	4
Quartz-Oligoclase Gneiss	39
Ramseyburg Member	16
Raritan Formation	2

Geology	Occurrences
Red Bank Formation Sandy Hook Member	1
Schoharie Formation	2
Shawangunk Formation	7
Red Bank Formation Shrewsbury Member	2
Stockton Formation	1
Tinton Formation	1
Towaco Formation	2
Cape May Formation Unit 3	1
Upper Part of Beekmantown Group	6
Vincentown Formation	1
Woodbury Formation	1

Bedrock Springs

Joint/Fracture/Slope Break/Springs

These types of springs occur due to the existence of jointed or permeable fracture zones in low permeability rocks. Movement of groundwater is mainly through fractures that may tap shallow as well as deep water-bearing zones. Springs are formed where these fractures intersect the land surface and water has followed a natural course of voids or weaknesses in the bedrock (fig. 28). Springs are most common in any type of consolidated rock occurring in fractured bedrock of northern New Jersey.

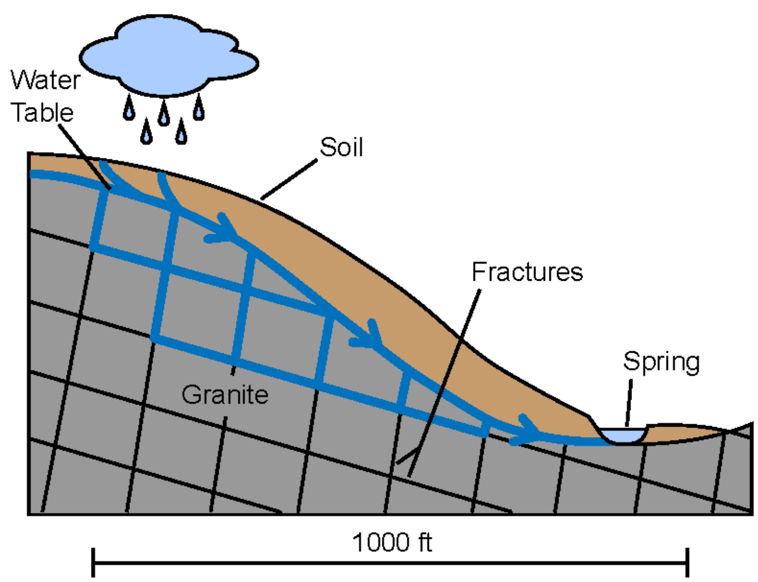


Figure 28. Bedrock spring diagram. *C. Kosar*.

Contact Springs

Contact springs are formed where relatively permeable rocks overlie rocks of low permeability (fig. 29). A lithological contact is usually marked by a line of springs. Such springs are usually associated with perched water tables in mountains.

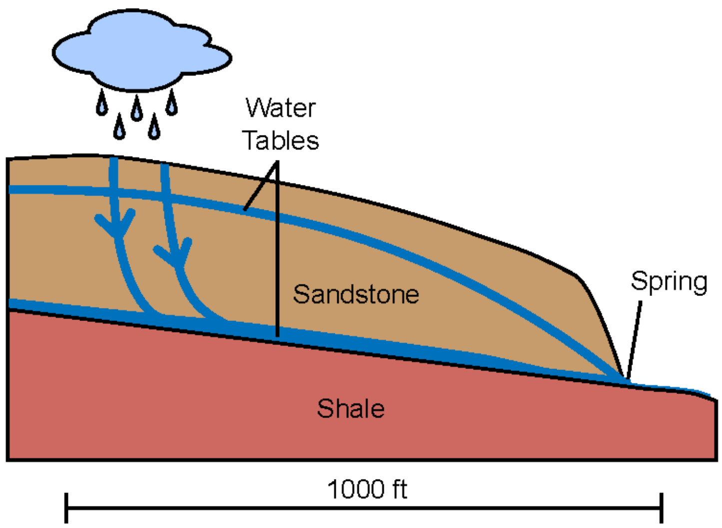


Figure 29. Contact spring diagram. *C. Kosar*.

Karst/Carbonates

Karst Springs Geologic Setting

The largest springs in New Jersey are formed in karst limestone and dolomite formations. Rainfall, made slightly acidic by the carbon dioxide that it picks up from the atmosphere, enters the aquifer and slowly dissolves fractures, channels and caves in the limestone and the dolomite, forming complex underground flow systems. Water moving through small pore spaces travels slowly (on a scale of years). Water that travels through channels and caves can move rapidly (on a scale of days to weeks). Where the water creates large cavities, the overlying sediments may collapse, forming a sinkhole or a spring.

"Karst geology is characterized by diffuse recharge through weathered joints and strata, by concentrated recharge by way of sinkholes, disappearing streams, box canyons, underground streams, and springs" (Canace and others, 1996). All New Jersey limestone, including dolomite and marble units, is not porous except for the Vincentown Formation. Groundwater movement is secondary porosity through fractures. "Carbonate rocks crop out in the northwestern part of New Jersey along the regional, northeast-southwest Appalachian structural trend. The Wisconsinan Terminal Moraine bisects the outcrop belt into a northern glaciated sector and a southern unglaciated sector. The rocks range in age from Middle Proterozoic to Middle Paleozoic" (Monteverde and Dalton, 2002).

Springs near carbonate ridges are mostly recharged by mountain runoff that enters through sinkholes. These types of springs typically have waters with wide variation in water quality and are low in solutes (Jacobson and Langmuir, 1974). Karst springs can form in mid-valley areas are recharged by water that seeps in through soils or from a circulating groundwater system (fig. 30).

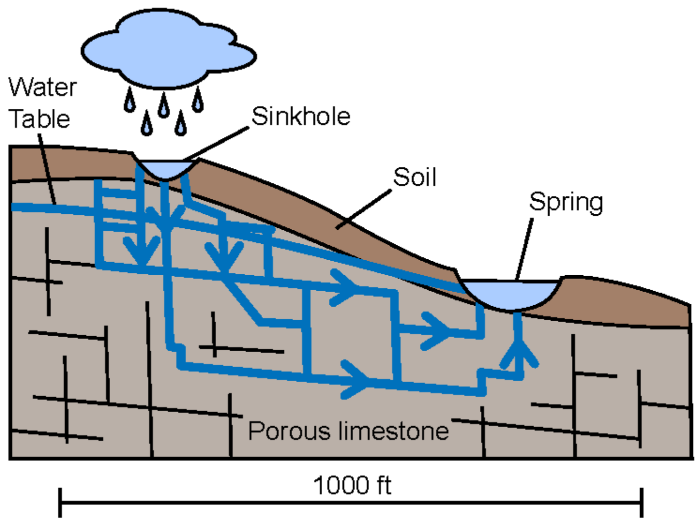


Figure 30. Karst spring diagram. *C. Kosar*.

Mid valley springs, typically have waters with a higher percentage of total dissolved solids, and less variability in solute amounts and discharge (Jacobson and Langmuir, 1974). Carbonate bedrock springs commonly show a faster and greater response to rainfall because they are discharge points for large networks of underground solution channels. In karst areas, rainfall runs off into sinkholes and sinking streams and is directed downward into open channels in the underlying carbonate bedrock aquifer.

A karst aquifer may consist of many individual drainage basins that discharge to a large spring or series of springs (fig. 31). The karst aquifer is extremely susceptible to contamination as there is little to no filtration of the subsurface water and any contamination can spread rapidly in the aquifer. In karst areas much rainfall runs off into sinkholes and sinking streams and is directed downward into open channels in the underlying carbonate bedrock aquifer. There is little or no filtration of any contaminant picked up by the rainfall because there usually is little soil between the surface and the aquifer, where water flow is in open channels. (Dalton, 2014).

Figure 31. Karst spring outlet, Federal Springs, Frelinghuysen Twp., Warren County. *Photo, S. Domber*.

One of the largest documented karst drainage systems in New Jersey discharges at Bonnie Brook Spring in Stillwater Township, Sussex County. As part of a 1968 New Jersey Department of Health investigation to identify the source of bacterial contamination in the spring, the New Jersey Geological Survey recommended placing dye in the swallow-hole (Closed depressions receiving a stream) -outlet of Schuster Pond, located more than 4,000 feet away from the spring along the strike of the local bedrock. The dye appeared in the spring in less than two hours. The 1968 Schuster Pond dye test showed a connection between the Schuster Pond and the spring. “The Schuster Pond area exhibits disappearing streams, springs and ground-water flow characteristics typical of a karst conduit-influenced flow system” (Canace and others, 1996).

“Allogenic recharge may contribute considerable water to Schuster Spring and other springs in the area, including “Tucker Spring” and Bonnie Brook Spring” (Canace and others, 1996). “For the allogenic stream to reach Schuster Spring, ground-water to flow across the strike of bedding and dominant joints would need to occur” (Canace and others, 1996). “The discharge of Schuster Spring was measured on August 6, 1996, by the NJGS. Spring flow was measured using a stream-flow meter (Teledyne Gurley model 645) to measure discharge through the rectangular, concrete outlet channel for the spring. An instantaneous discharge of 3.7 cfs (1,630 gpm) was measured using the flow meter. This corresponds to a daily discharge of 2.345 million gallons” (Canace and others, 1996). The record of spring discharge as measured by the owner of the spring shows significant variation over the course of a year, including changes exceeding an order of magnitude within time spans of one month. The record resembles a stream hydrograph, which would experience rapid and substantial changes in discharge correlative to precipitation events. Such extreme variations in discharge from a major spring is an indication that the spring at Schuster Pond is fed by a conduit system. The regular changes in spring discharge further support the idea that the system is being fed by a surface-water source (Canace and others 1996).

As stated earlier, one of the most interesting New Jersey karst features is the Brau Kettle (fig. 13), located west of the intersection of Old Mine Road with Hainesville Road, four miles northeast of the Dingman’s Ferry bridge in Sandyston Township, Sussex County. This is a sinkhole approximately twenty feet in diameter and eight feet deep, with small rocks up to a half-foot in size at the bottom. After a heavy rain, Brau Kettle fills with water which rises-up through these rocks, sometimes within a half an hour. The water can be seen bubbling up from the bottom, from which the name Brau Kettle (brewing or boiling kettle) is derived. A stream passes within a few feet of this sink, but fluorescent dye tests in the spring of 1963 revealed no connection between the two. It is likely that water flows to Brau Kettle under pressure through underground crevices in the Onondaga Limestone from the higher land in the southeast (Dalton, 1976).

Coastal Plain/Unconsolidated

Vincentown Formation

"Soluble rocks such as limestone, dolomite, and marble and limestone-clast conglomerate cover about 350 square miles in the Valley and Ridge, Highlands, and Piedmont Provinces. In the Coastal Plain Province, the Vincentown Formation underlies about 100 square miles, and consists locally of soluble lime sand and thin limestone layers. The limestone layers are more common from western Monmouth County southwestward to the Delaware River. Also, a few thin, cemented shell beds occur locally in other Coastal Plain formations" (Dalton, 2014). The loosely cemented limestone and calcareous sands in some cases contain some small shallow depressions which may be small sinkholes. One example of a spring from the Coastal Plain Province limestone layers is Crystal Spring in Laurel Springs, Camden County.

Kirkwood and Cohansey Formations

The more steeply sloped, higher –permeability sands of the Cohansey formation are on top (fig. 32). These are basically "contact" springs in unconsolidated deposits. This could occur in the outcrop of any Coastal Plain Formation.

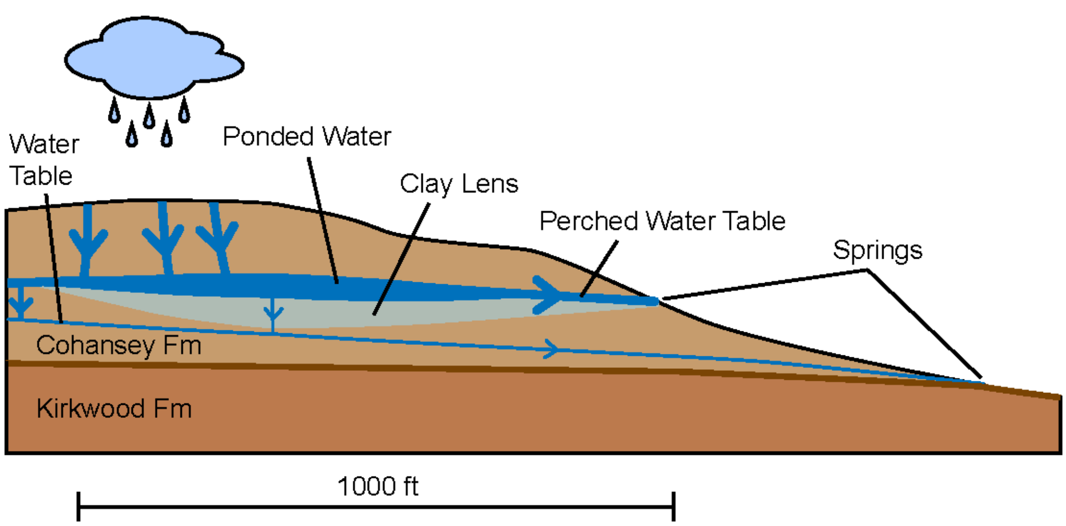


Figure 32. Diagram, a vertical gradient break in confining unit, Kirkwood Cohansey Formation. *C. Kosar*.

Surficial Geology

Surficial deposits are sediments laid down by rivers, glaciers, ocean currents, waves, wind, and movement of soil and rocks on hillslopes. They overlie bedrock and unconsolidated Coastal Plain formations and are the parent material for agronomic soils. In New Jersey they are as much as 400 feet thick but are typically less than 25 feet thick. New Jersey is a coastal state at the southern limit of continental glaciation and so it has a variety of surficial deposits formed during its rich geologic history of glaciation, changing sea level, and evolving river systems (NJGWS, 2016).

Glacial

The Pleistocene Age

The distribution of glacial deposits in northern New Jersey and wide differences in the extent of their weathering and preservation, show that continental ice sheets expanded to and retreated from New Jersey at least three times during the Pleistocene Epoch. In the early Pleistocene, sometime between 2.5 million and 800 ka (thousand years ago), a glacier entered New Jersey and advanced as far south as the Somerville area. This advance, known as the pre-Illinoian glaciation, deposited till (mixed sediment laid down directly from glacial ice) and a few sand and gravel deposits laid down by glacial meltwater. A second glaciation advanced into New Jersey in the Middle Pleistocene, most likely during the Illinoian stage at 150 ka. Deposits of this glaciation are exposed in a belt in Morris and Warren counties and lie buried beneath younger glacial deposits east and north of the outcrop belt. The most recent glacier advanced to its terminus at 25 ka, during the Wisconsinan stage of the late Pleistocene (125 to 11 ka). Its terminal position and some retreat positions are marked by moraines (ridges of till laid down along the glacier margin). During their maximum extent, the ice sheets may have been 2,000 feet thick above High Point in Sussex County. Sea level dropped as glaciers grew, then rose as the glaciers melted (Witte 1998).

Ice Delta/Outwash

In general, because outwash is more permeable than the underlying bedrock (especially in the Highlands, Watchung Mountains, Palisades, and Kittatinny Mountain), groundwater tends to pond and flow laterally in the till on top of the rock surface and discharge in springs and seeps along the base or lower parts of hillslopes (fig. 33).

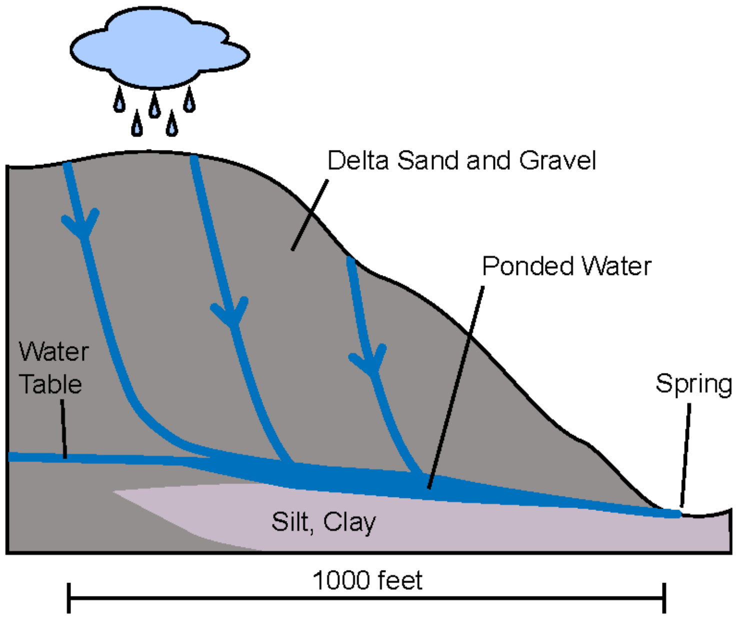


Figure 33. Diagram of a Glacial Ice Delta/Outwash spring. *C. Kosar*.

Springs are seen in many glacial deposits in New Jersey (fig. 34). The map shows springs (blue dots) north of the terminal moraine overlaying the glacial sediments layer from, NJGWS, *Glacial Sediments of New Jersey*, Digital Geodata Series (DGS 96-1), an ESRI GIS shapefile. As the map shows, springs on glacial sediments are common in New Jersey. In the eastern half of northern New Jersey, almost all mapped springs occur in the glacial sediments. The glacial deposits act primarily as a conduit through which water from the more extensive bedrock part of the aquifer is discharged to the surface. Deposits of sand, silt and gravel commonly occur in glacial sediment, many at disconformities between different age sediment sheets. Sand and gravel that originated as outwash plains may be several tens of feet thick. Kanouse Spring in Oakland, Bergen County is an example of a hillslope glacial outwash spring.

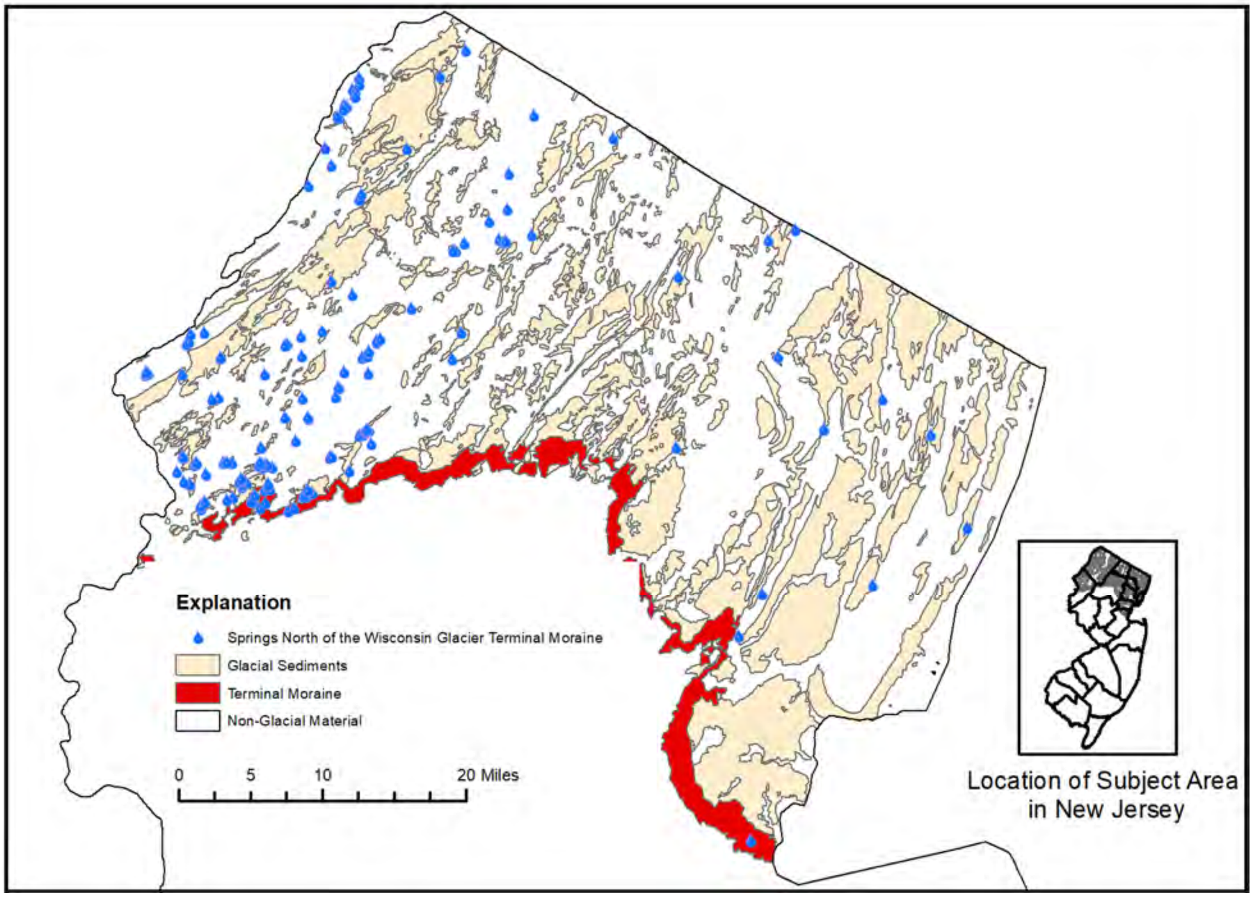


Figure 34. Mapped springs over glacial formations in north Jersey showing numerous springs occurring in glacial material.

SPRING WATER TEMPERATURE, by Steve Domber, Ted Pallis

As part of this report, in 2012, the NJGWS began recording continuous long-term water temperature in 14 selected springs. In order to improve our understanding and quantify processes that affect spring water temperature, continuous water temperature monitoring devices were installed in each of the 14 springs closest to where the spring water emerges from the earth.

In each of the 14 springs, one Onset TidbiT v2 water temperature data logger was installed to collect hourly temperature data. Data were periodically downloaded from the Onset TidbiT devices with a handheld Onset HOBO Optic USB base station. The water temperature study was conducted from January 2012 through September 2013. Continuous temperature readings were collected over periods that ranged from one to 20 months depending on location.

Continuous temperature data collected for each spring are provided in figures 35-49. Springs that show a fairly constant discharge temperature include those that show seasonal or delayed seasonal variations, and springs that showed short-term responses to precipitation events exhibited something in between. Temperature variability or the lack thereof often is a function of the hydrogeologic setting of an individual spring. Springs which show little, or no variation likely discharge water that has longer residence time in the aquifer.

The water temperature of these springs usually represents the average annual air temperature; approximately 50 to 55 degrees Fahrenheit in New Jersey. Karst springs in New Jersey, such as Brau Kettle show signs of both steady discharge temperatures periodically influenced by the temperature of large intense precipitation events. Under high rainfall events, warmer or colder than average groundwater influences the deeper flow paths and warms or cools the water for a short period. Shortly after the precipitation event ends and the recently recharged water is discharged, spring water temperature returns to its “normal” baseline condition.

The spring water temperature graph in figure 35 shows a comparison of long-term temperature variability from three springs. Marble Mountain Spring in Lopatcong Township, Warren County shows fairly constant temperatures. Valley Crest Spring in Clinton Township, Hunterdon County shows seasonally variable temperatures influenced by periodic precipitation events. Dingman’s Ferry Spring in Sandyston Township, Sussex County shows a presumed combination of multiple influences. Figures 36 through 49 show temperature data from individual springs.

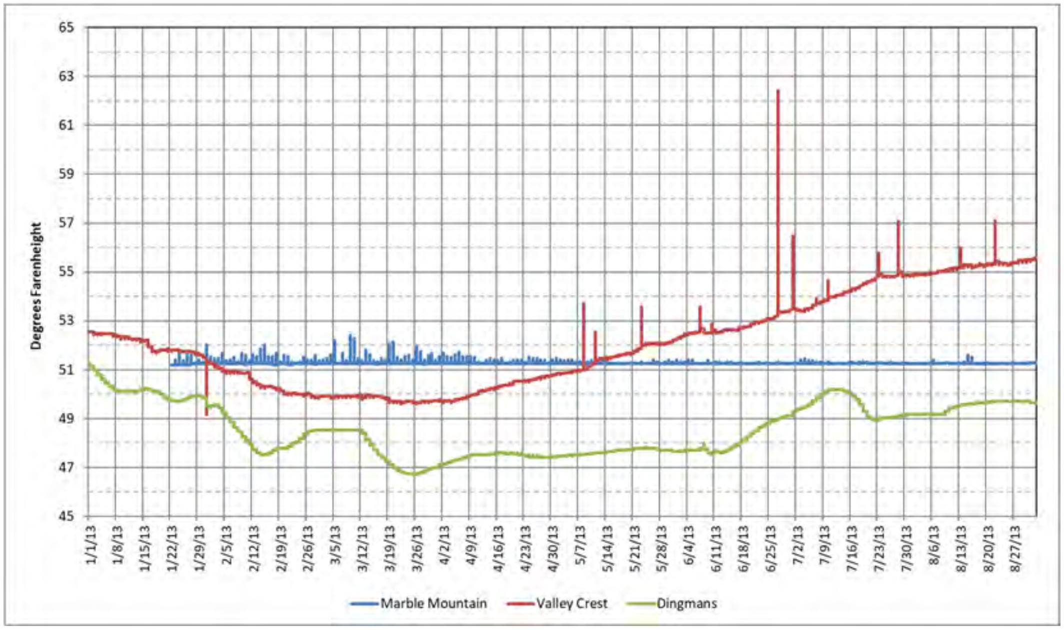


Figure 35. Combined Water Temperature Chart, Marble Mountain, Valley Crest and Dingman's Ferry springs.

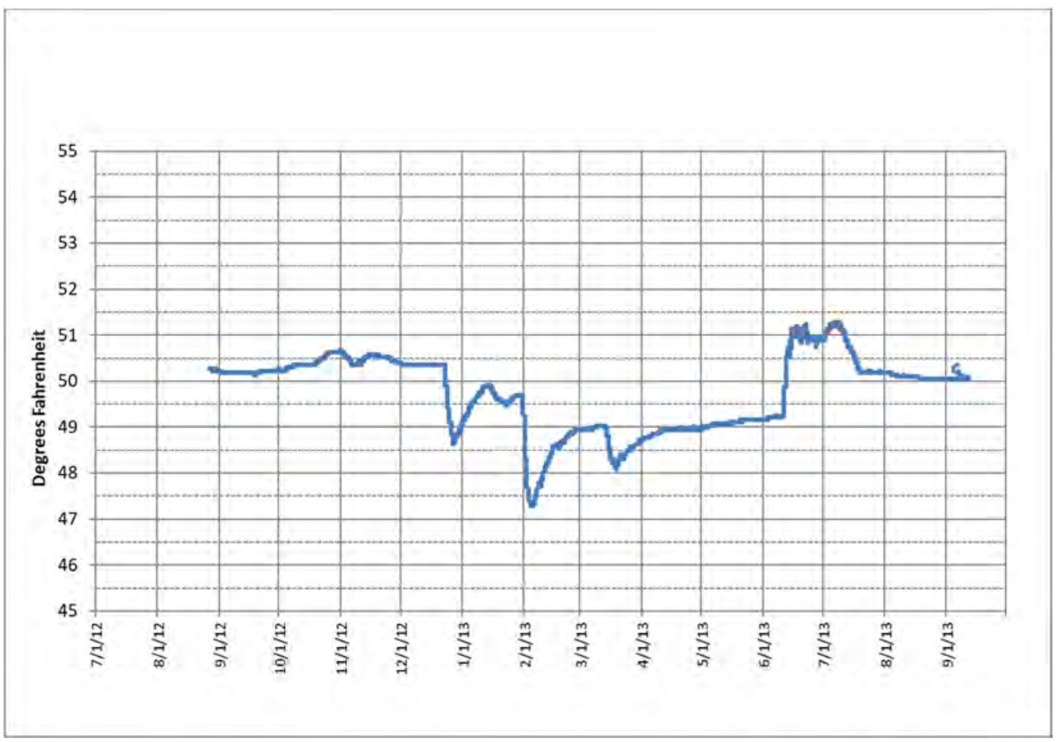


Figure 36. Big Spring, Water Temperature Chart.

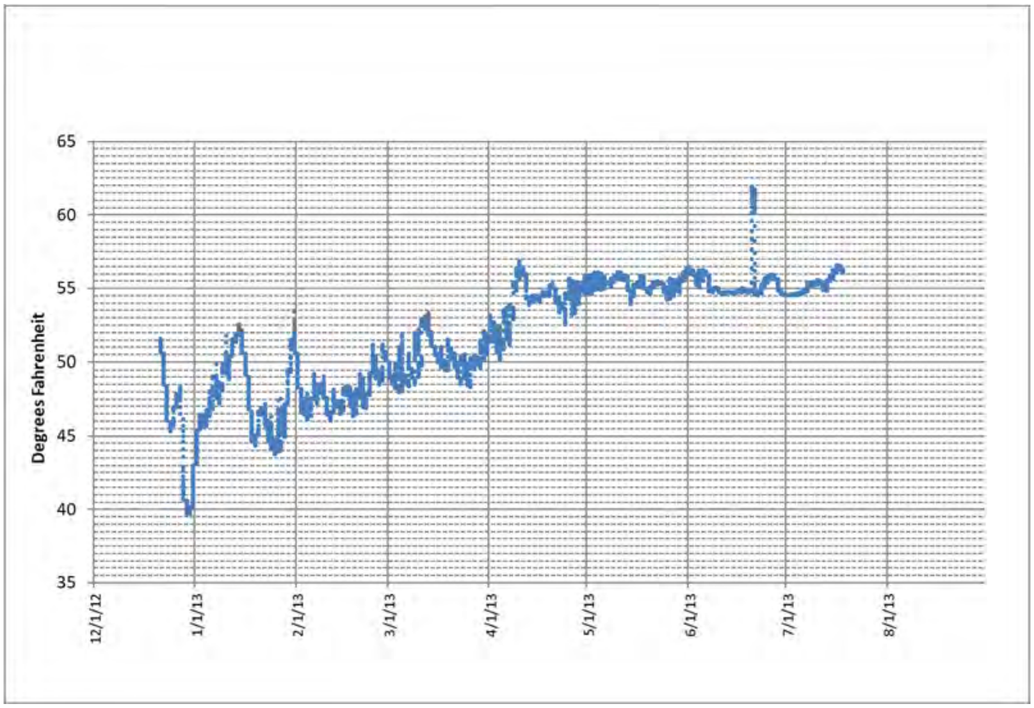


Figure 37. Blue Hole-Inskeep, Water Temperature Chart.

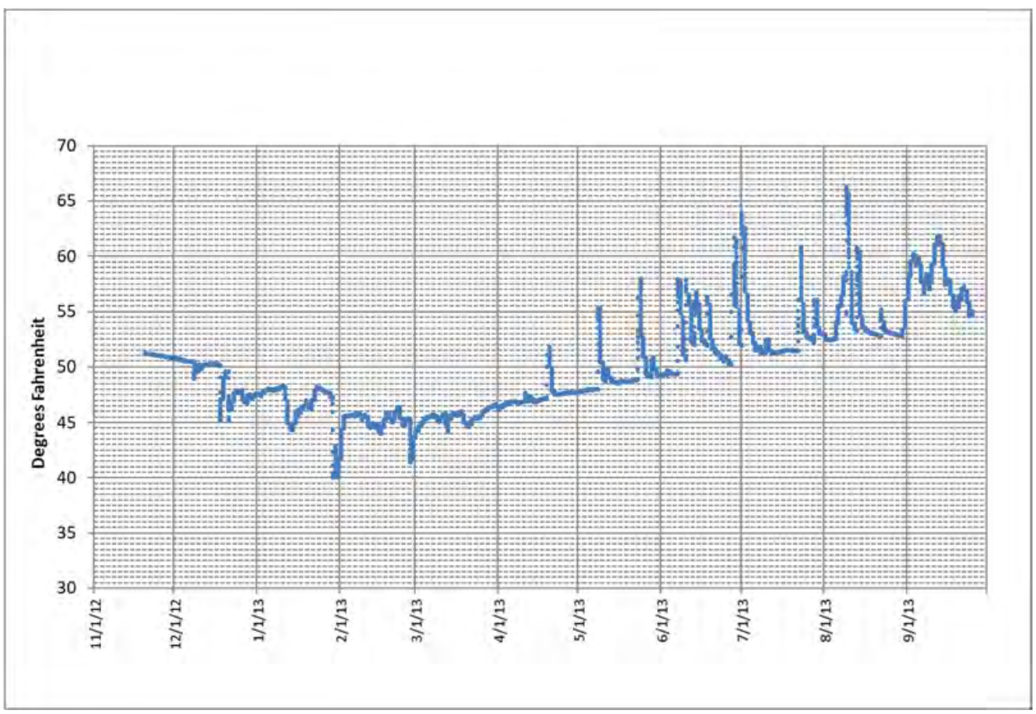


Figure 38. Brau Kettle, Water Temperature Chart.

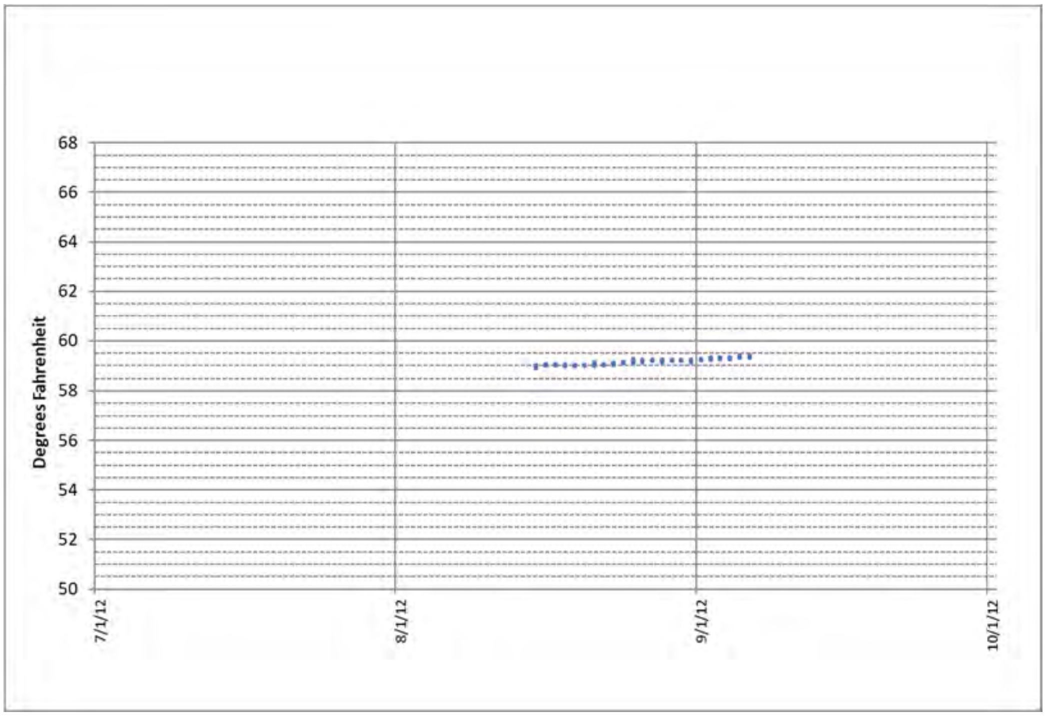


Figure 39. Crystal Spring, Water Temperature Chart.

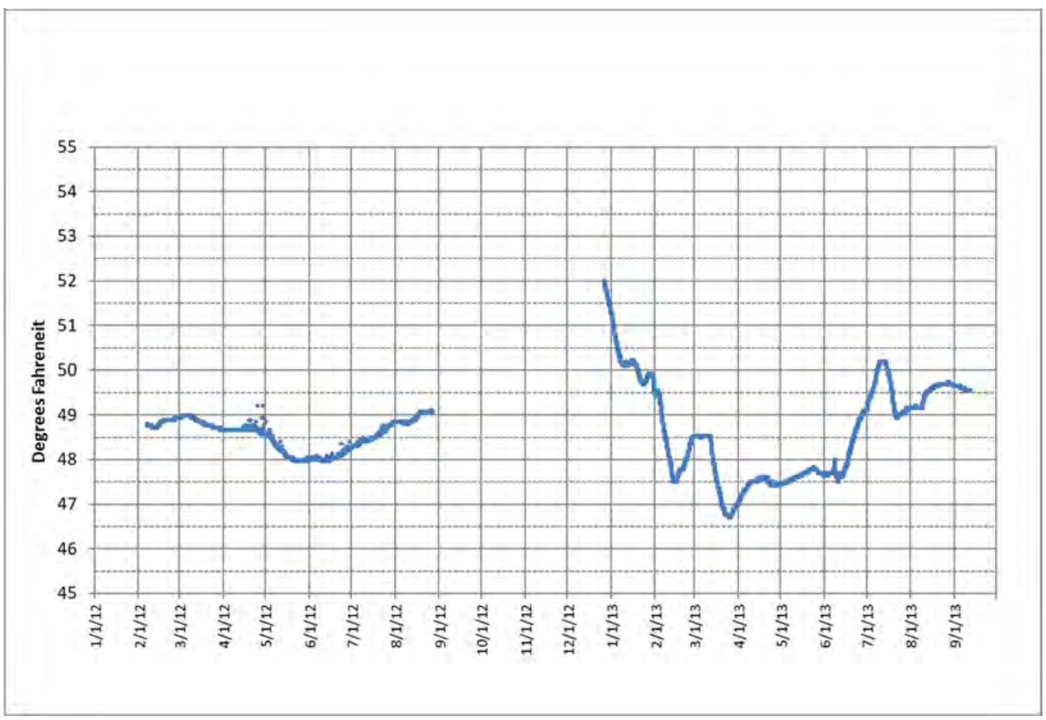


Figure 40. Dingman's Ferry Spring, Water Temperature Chart.

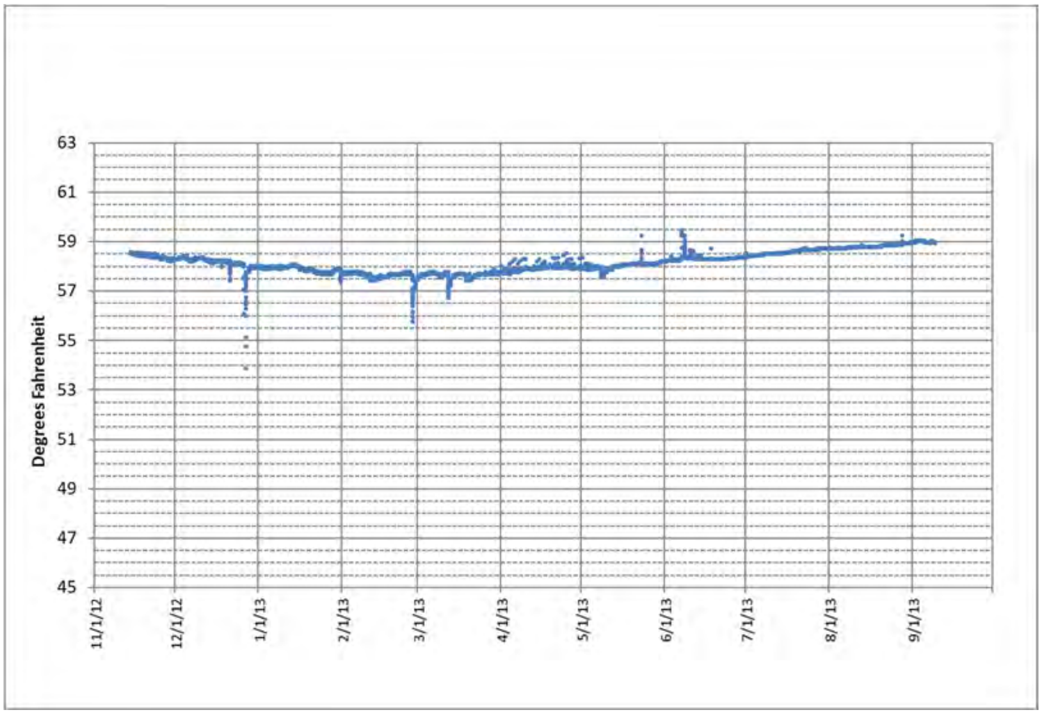


Figure 41. Great Bear/Trinity Spring, Water Temperature Chart.

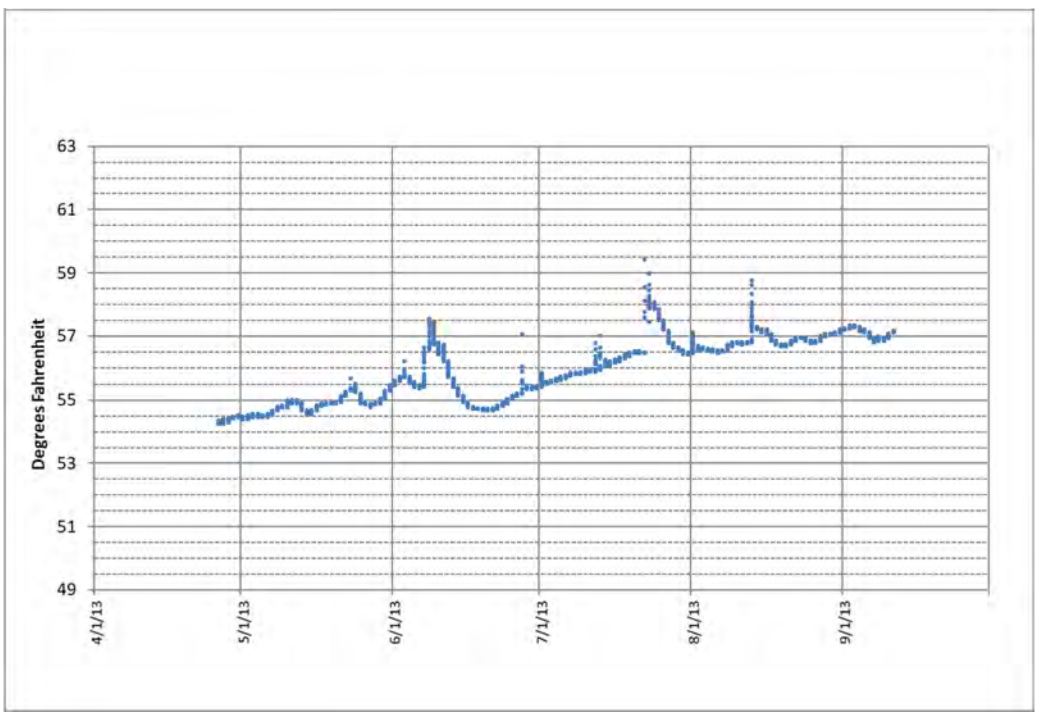


Figure 42. Honeyman Spring, Water Temperature Chart.

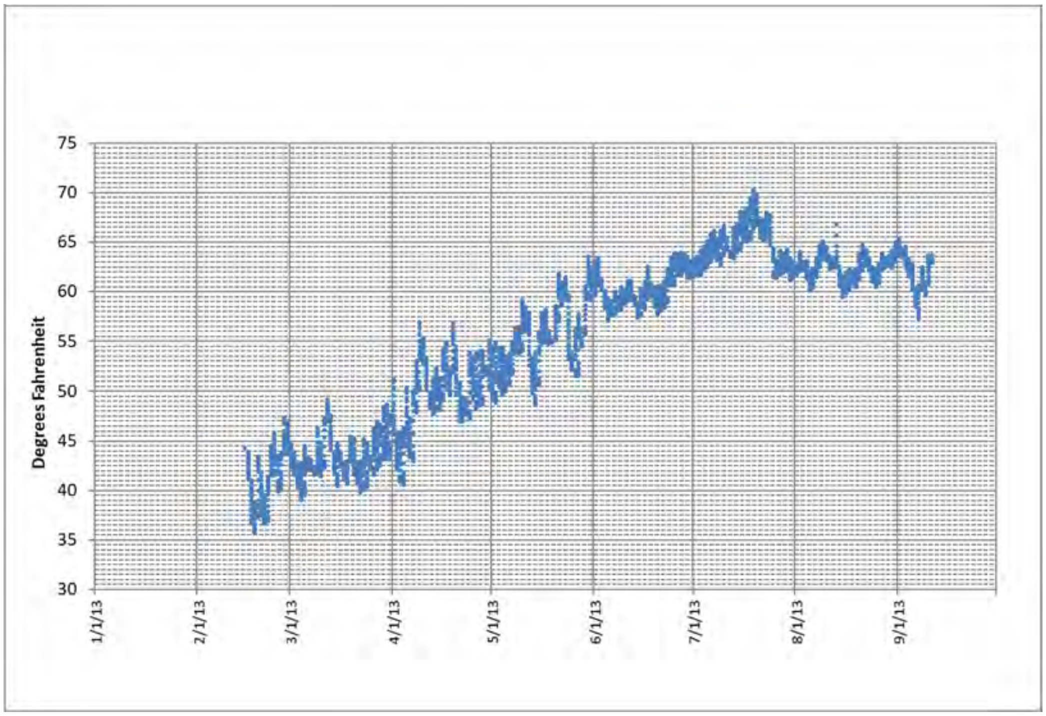


Figure 43. Indian Lady Hill Spring, Water Temperature Chart.

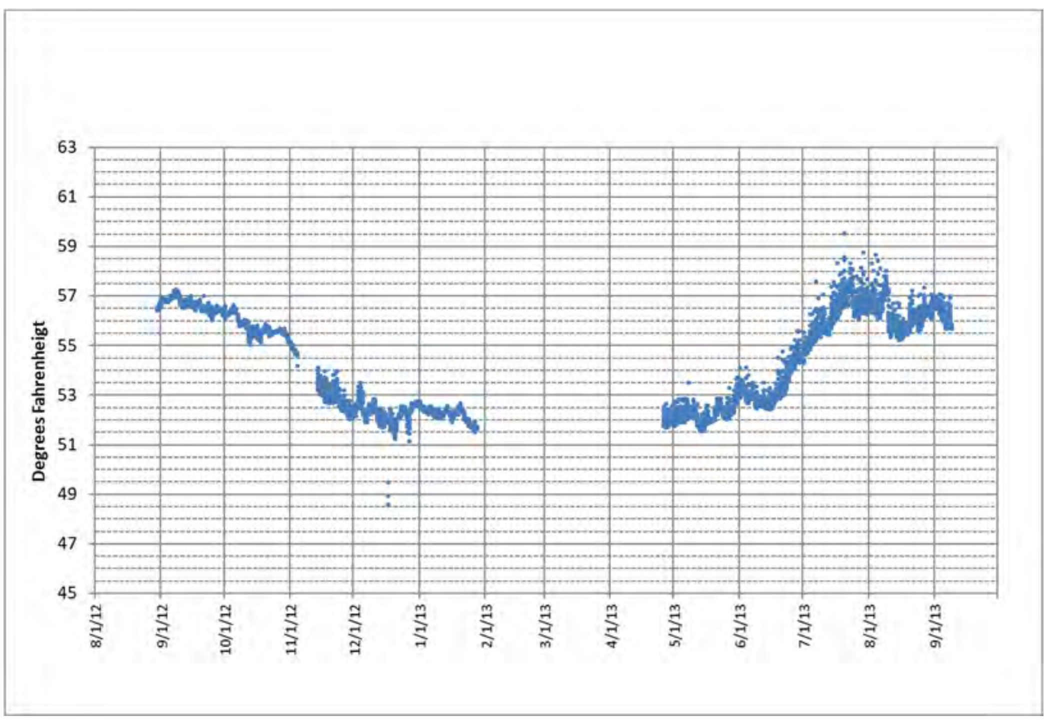


Figure 44. Locust Grove Spring, Water Temperature Chart.

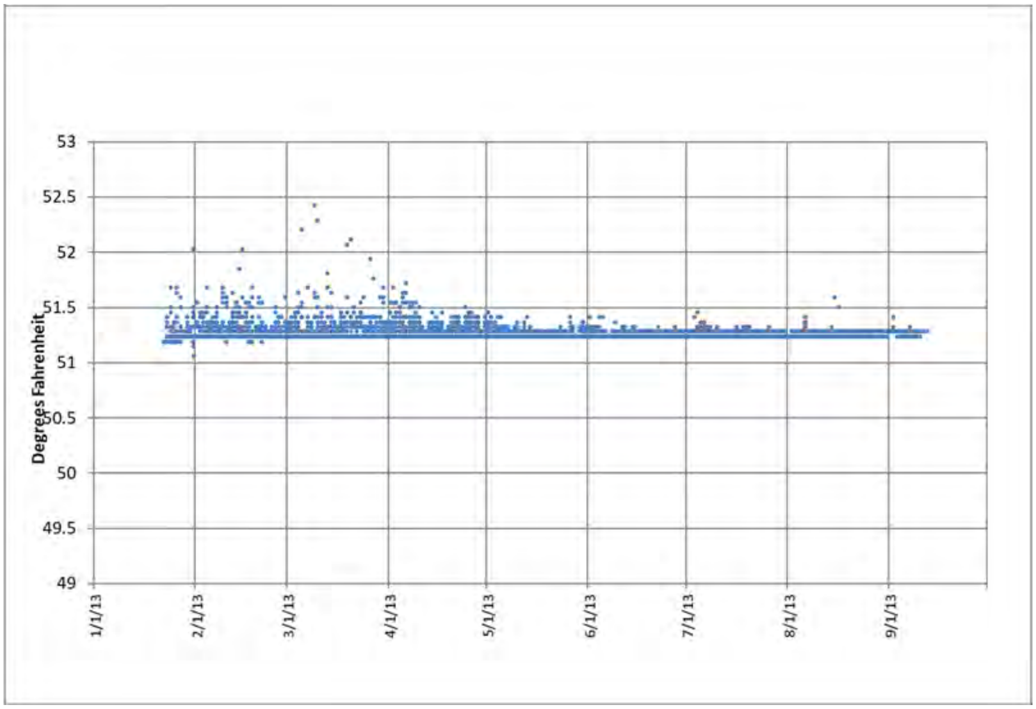


Figure 45. Marble Mountain Spring, Water Temperature Chart.

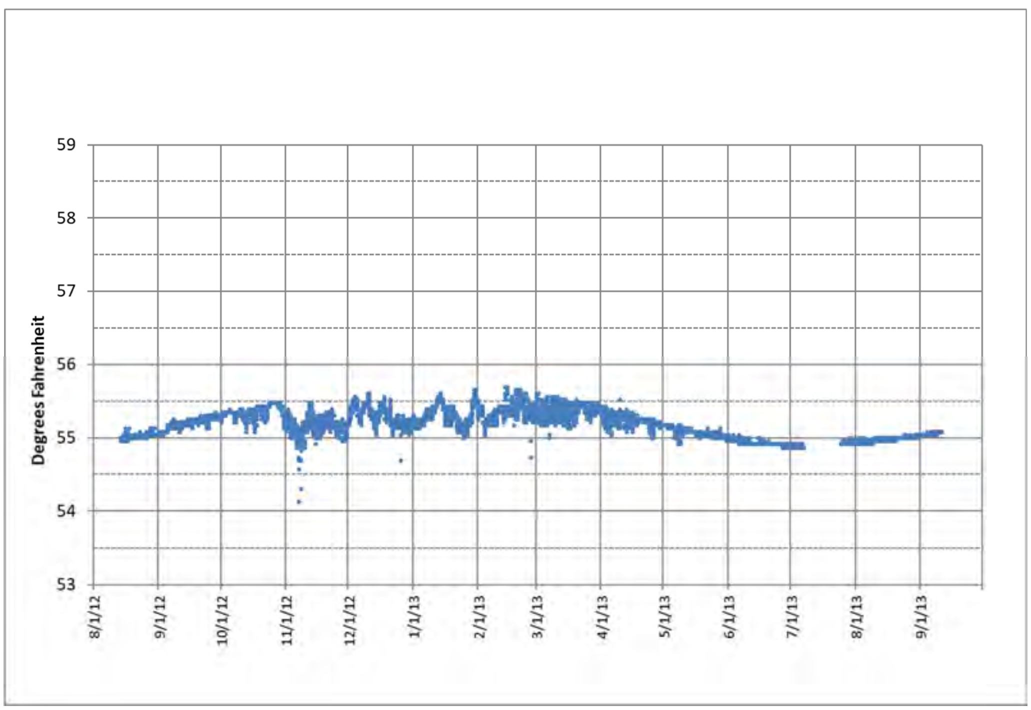


Figure 46. Paint Island Spring, Water Temperature Chart.

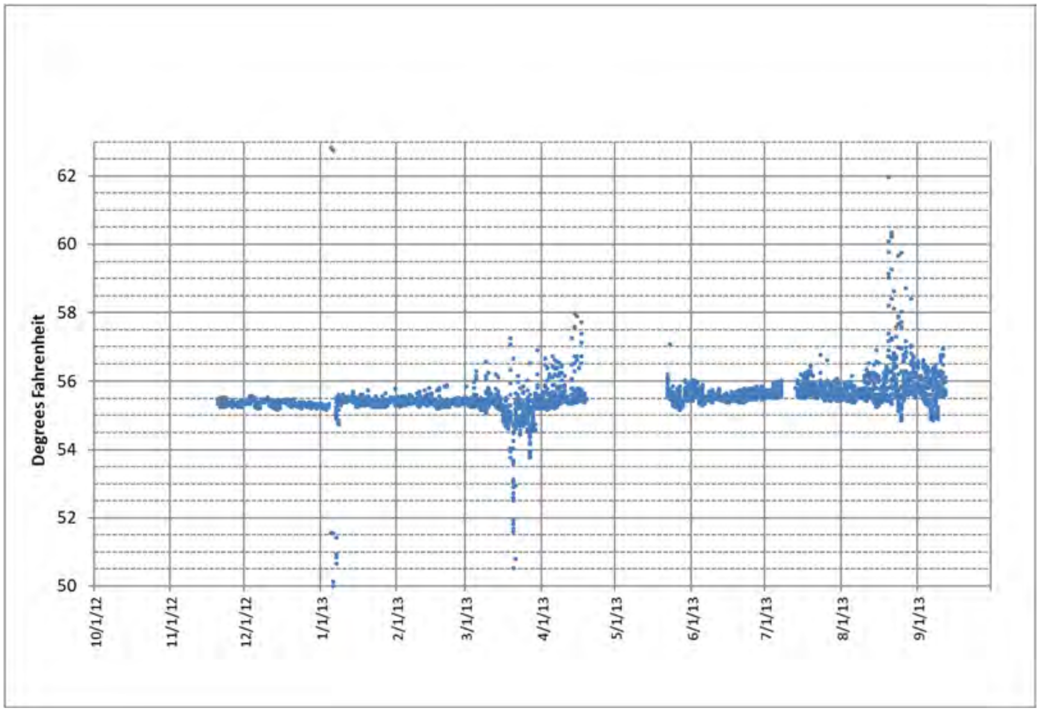


Figure 47. Shurts Road Spring, Water Temperature Chart.

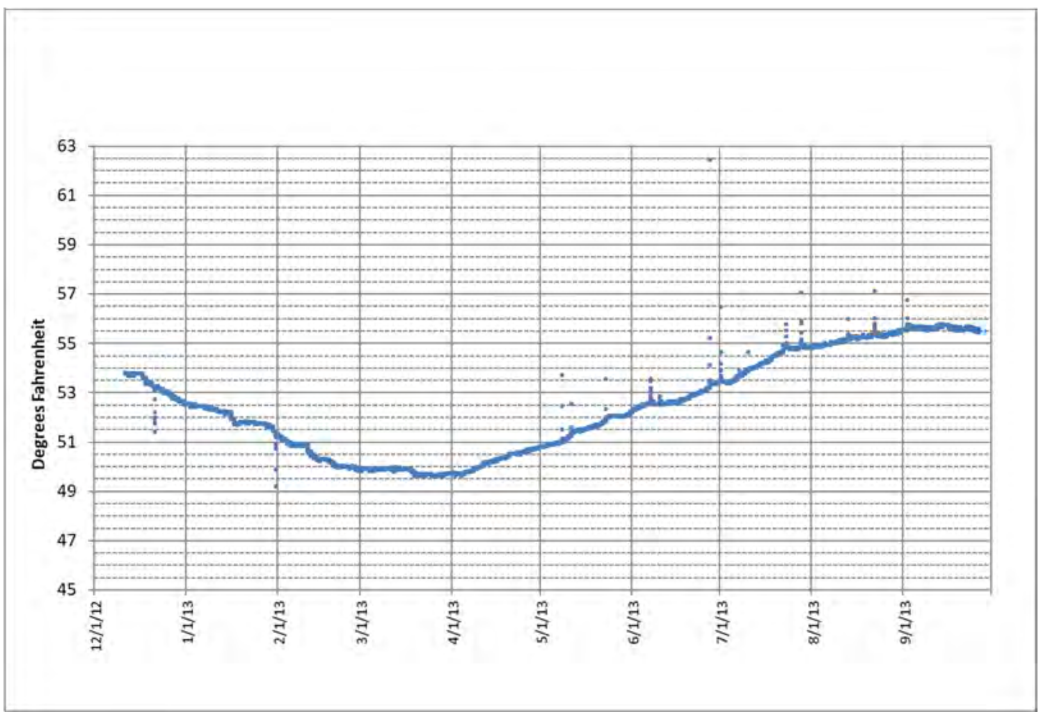


Figure 48. Valley Crest Spring, Water Temperature Chart.

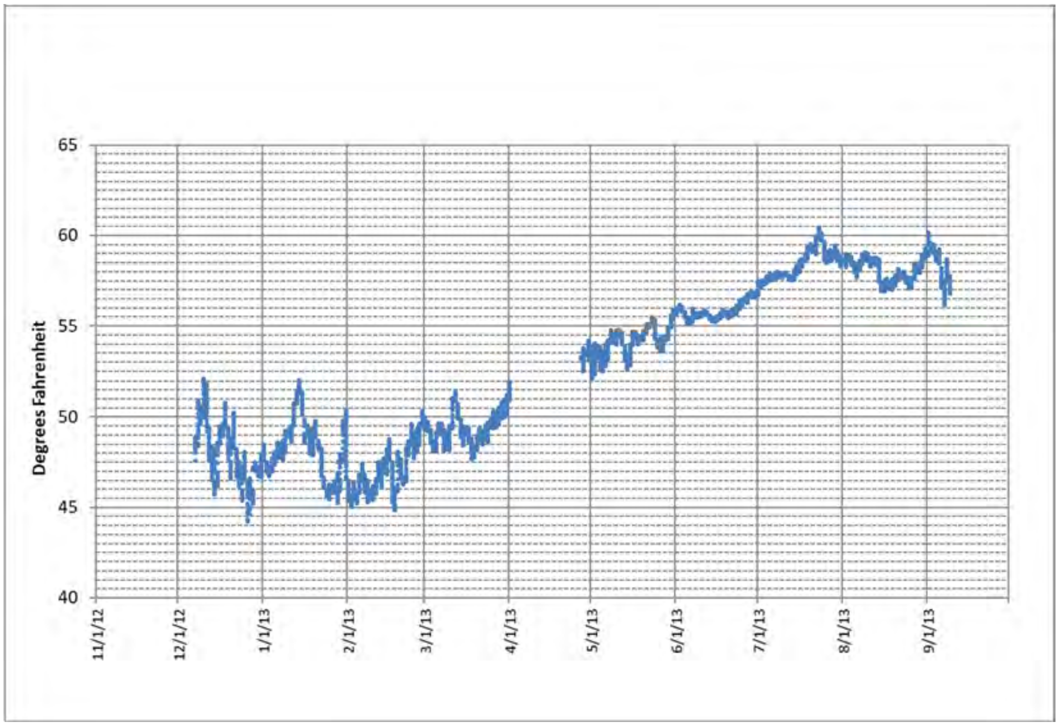


Figure 49. Washington Spring, Van Saun Park, Water Temperature Chart.

SPRING WATER CHEMISTRY, by Ted Pallis

Spring Water Monitoring and Sampling

Spring water can be classified by its water chemistry and includes the chemical, physical, biological, and radiological characteristics. The earliest quantitative chemical analysis of spring water in the United States was most likely made during 1807 when there were several water analyses performed from various mineral springs in and near the towns of Ballston and Saratoga Springs, New York (Davis and Davis, 1997). Historically in New Jersey, independent analysis of a few selected springs was done in the late 19th century including Schooley's Mountain Chalybeate Spring, analyzed by C. McIntyre Jr. analytical chemist. The Heath House Spring, also on Schooley's Mountain was analyzed by Professor George Cook, State Geologist at the New Jersey Geological Survey. Both results were published in *The Mineral Waters of the United States and Their Therapeutic Uses* (Crook, 1899). Though no exact date was given the analysis of both springs most likely were conducted in the 1880's. The Pine Lawn Spring in Hohokus, Bergen County was analyzed in 1897. The New Jersey State Board of Health began sampling various springs throughout the state when springs were used as bottled water sources during the early 1900's.

Assessing water quality generally involves comparing measured chemical concentrations with natural, background, or baseline concentrations and with guidelines established to protect human health or ecological communities. Spring water discharge can provide a means of determining the quality of water in the aquifer as well as the degree of human impact in the springshed. Numerous factors influence ground-water chemistry. These include the precipitation chemistry, surface conditions at the site of recharge, soil type in the recharge area, mineralogy and composition of the aquifer system, nature of the aquifer system, porosity and structure, flow path in the aquifer, residence time of the water in the aquifer, mixing of other waters in the aquifer system, and aquifer microbiology (Scott and others, 2001).

To better understand the water quality of New Jersey's springs, water was sampled and analyzed at select New Jersey's springs. Along with a one-time water sample taken an analyzed in a lab, for one-year, quarterly field parameters including pH, specific conductance, total dissolved solids, dissolved oxygen, and turbidity were measured in 14 selected springs. Additionally, in three of the 14 springs, nitrates and chloride were also measured. The results of the field parameter sampling can be found in (Appendix B). Comparing the similar quarterly field parameter data can yield information about how water quality changes over time and what may be causing these changes. The analytical field parameter data and lab analyzed water chemistry sample provides a snapshot of water quality at a point in time. A detailed one-time laboratory analysis of spring water chemistry was conducted by the NJGWS with water samples being collected from the same 14 selected springs across the state (Appendix C).

Indicators of Water Quality Problems

Spring water, when it is in an aquifer, is considered groundwater. However, once spring water exits from the spring vent onto the earth's surface, it is considered surface water. Because of this distinction, the question arises whether scientists and regulators should apply groundwater or surface-water quality standards to the water in New Jersey.

The State has authority over drinking water and wells in the state. The NJ Department of Health set the water quality for drinking water. Since the 1950's, spring and well construction for drinking water, were regulated first under "Chapter, 199, P. L. 1954 and Standards for the Construction of Water Supply Systems for Realty Improvements." "The Water Supply Code of New Jersey (1959)" and, "Individual and Semipublic Water Supply Code of New Jersey (1960)," were the first laws to regulate drinking water including springs. According to the New Jersey Safe Drinking Water Act from 1996, as defined by "Chapter 10, of the New Jersey Safe Drinking Water Act 1996," authority is given by the State of New Jersey to the local governing health department over springs used as domestic water sources. Under the New Jersey Safe Drinking Water Act, "An administrative authority shall approve the use of a spring only when construction of a well is not practicable, and provided the water derived from the spring is disinfected in accordance with New Jersey Administrative Code (N.J.A.C.) 7:10-12.32 if construction of a well is not possible due to the local terrain and/or geology, provided the water derived from the spring or springs is disinfected pursuant to N.J.A.C. 7:10-12.32." In New Jersey, some local governing authorities permit springs to be used as drinking water sources while others do not.

Contaminant criteria thresholds may exist for an analyte while the water is considered groundwater, but not for surface water. Nitrate (NO3 + NO2 as N) is a good example. Based on drinking water criteria, nitrate has a groundwater threshold value of 10 milligrams per liter (mg/L). During 1962, the U.S. Public Health Service recommended a permissible level equal to 10 parts per million (ppm) or 10 milligrams of nitrate-nitrogen in 1 liter of drinking water (mg/L) which is the federal drinking water standard (Bowers, 2019). In surface water, for Nitrate-Nitrogen a level of 2 mg/L shall be maintained (N. J. A. C. 7:9B Surface Water Quality Standards).

Field Parameter Sampling Methodology and Water Quality Sampling

From October 2012 through July 2013, NJGWS staff recorded quarterly field parameter readings at 14 selected springs in New Jersey. Additionally, at these springs a water sample was also taken during the late summer of 2014 and analyzed in a lab (Table 6). The springs chosen for the field parameter and sampling were selected statewide spanning the four different physiographic provinces found in the state and in different geologic settings (fig. 50). These are the same 14 springs that were selected for long-term continuous temperature monitoring as discussed previously. Standard, NJDEP sampling protocols were followed for each field parameter and water quality sampling event. The resulting field parameter and water quality data collected provides baseline information for the future and helps identify trends or changes in water quality and aids investigations into problems such as nonpoint-source pollution and nutrient enrichment.

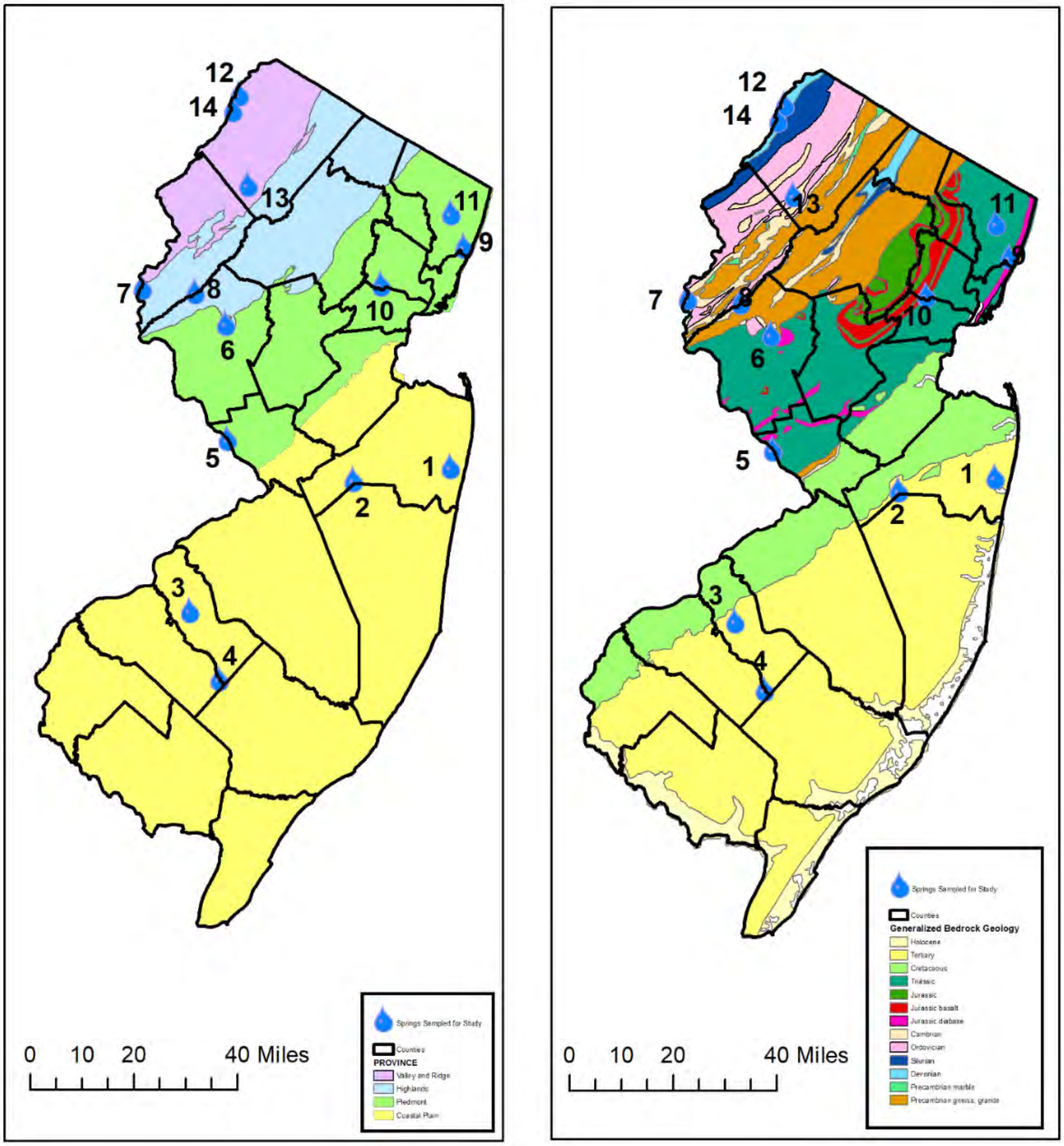


Figure 50. The 14 selected springs sampled for the study in relation to Physiographic Provinces left, and Generalized Geology, right with Spring ID numbers from Table 6.

Field Parameters

Two different techniques, instrument and non-instrument (wet chemistry) were used for recording the field parameters. Field parameter readings were collected quarterly over a one-year period at the 14 selected spring monitoring sites using Hanna handheld multi-parameter probes, a LaMotte (water quality) test kit, and a Winkler Titration kit. The Winkler Titration test kit was used to obtain dissolved oxygen results. The four quarterly field parameter measurements were taken during the months of October 2012, January 2013, April 2013, and July 2013 (Appendix B).

The quarterly field parameters obtained were pH, specific conductivity, total dissolved solids (TDS), dissolved oxygen, water temperature, and turbity. Additionally, for three specific springs, nitrates and chloride were also measured. At 11 springs, samples were taken with a Hanna multi-parameter probe and data logger while the non-instrument LaMotte (water quality) test kit and Winkler Titration test kit were used at three springs. Nitrates and chloride tests were only performed at the three springs where the non-instrument LaMotte (water quality) test kit and Winkler Titration test kit were used. Consistency was maintained using the same methods for each spring. The Hanna multi parameter probe and data logger was used for the following springs as listed in table 6; 1) Indian Lady Hill Spring, 2) Paint Island Spring, 3) Crystal Spring, 4) Blue Hole-Inskeep, 7) Marble Mountain Spring, 9) Great Bear/Trinity Spring, 10) Locust Grove Spring, 11) George Washington Spring – Van Saun Park, 12) Brau Kettle 2 Spring, 13) Big Spring – Whittingham, 14) Dingman's Ferry Spring. The LaMotte (water quality) test kit and Winkler Titration test kit were used at the; 5) Honeyman Spring, 6) Valley Crest Spring, and 8) Shurts Road Spring. A table with the results of the four quarterly field sampling results can be found in Appendix B.

On Site Analysis Methods

The Hanna multi-parameter probe and data logger were calibrated before each sampling session. The calibration procedure was to insert clean water into the flow chamber where water was pumped through with a constant-flow rate. No purge was required because springs are considered already purged. When in use at a spring, the field-parameter values were recorded after the field meter displayed a stable reading (approximately 10 min.). Its conductivity cell and temperature sensor were checked against potassium chloride (KCl) standard solutions and a certified thermometer. The conductivity measurements were temperature compensated. The dissolved oxygen probe was checked regularly against a commercial Winkler Titration test kit (LaMotte (water quality) test kit model 5860, lot 329814. The test kit performance was checked against a potassium iodide primary standard LaMotte (water quality) test kit catalog number (6809). The turbidity determinations were performed using an Orbeco model TB200 meter. The Orebco meter was calibrated before use with the manufacturer's prepared calibration standards of 1000 Nephelometric Turbidity Units (NTU), 10.0 NTU, and 0.02 NTU. A model IQ150 pH meter was used for the pH determinations performed in the field. The meter was calibrated either at pH 7 and 4, or pH 7 and 10 depending on the water condition. The performance of the meter was checked against an intermediate buffer at either pH 6 or 9 depending on the calibration range. The meter was recalibrated if the intermediate buffer's pH differed by more than 0.2 pH units from the manufacturer's published value.

Other field parameters noted during data collection in most but not all cases were discharge rate, adjacent land use, discharge point, current weather and watercolor, and odor. The aquatic vegetation conditions were noted along with the occurrence of watercress. The field parameter information collected was recorded on field sheets (Appendix B).

Springs One Time Water Quality Sampling for Laboratory Analysis

A single water sample was taken from each of 14 selected springs when each of the spring sites was visited during August of 2014 (Table 6). Unlike the field sampling which was done four times within a one-year period, water sample laboratory analysis was done only once. The summer season was selected because it provided the most reliable base water chemistry that was not influenced by fall and winter precipitation or spring snowmelt and rains. All samples were collected as grab samples as close as possible to the point where the springs discharged from the ground. This was typically in a pool formed at the spring's emergence. Since the discharge rate and shape and size of the discharge pool varied, it is likely that the pool residence time and hence exposure to the atmosphere varied between each spring. All efforts were made to collect the water samples from as close as possible to the actual discharge point to minimize exposure to the atmosphere and minimize any changes to the water chemistry that might occur. It is important to note that the residence time and exposure to the atmosphere likely varied from seconds, to at least a few hours. Once collected, the samples were placed in coolers at 4° C. The radionuclide samples were taken to the lab the same day and the remaining samples were taken to the lab within 24 hours.

Table 6. One Time Water Quality Spring Sampling Locations and Dates.

Spring ID	Name	Sampling Date	Alternate Date
1	Indian Lady Hill Spring	8/14/2014	
2	Paint Island Spring	8/14/2014	
3	Crystal Spring	8/18/2014	
4	Blue Hole (Inskeep)	8/18/2014	
5	Honeyman Spring	8/19/2014	
6	Valley Crest Spring	8/21/2014	
7	Marble Mountain Spring	8/21/2014	
8	Shurts Road Spring	8/21/2014	
9	Great Bear/Trinity Spring	8/25/2014	
10	Locust Grove Spring	8/25/2014	8/28/2014, Radionuclides only
11	George Washington Spring, Van Saun Park	8/25/2014	
12	Brau Kettle Spring 2	8/26/2014	
13	Big Spring (Wittingham)	8/26/2014	
14	Dingman's Ferry Spring	8/26/2014	

Results and Observations, by Raymond Bousenberry

The complete results for analytes at each spring sampled are shown in Appendix C. Laboratory Sample Analysis Results from one-time sampling at the 14 selected springs.

Table 7. Combined summary of results which includes only those parameters which had at least one value above the detection limit.

Analyte Category	Analyte
General Chemistry	Alkalinity
General Chemistry	Ammonia as N
General Chemistry	Chloride
General Chemistry	Conductivity
General Chemistry	Fluoride
General Chemistry	Nitrate
General Chemistry	Nitrite
General Chemistry	Ph
General Chemistry	Sulfate
General Chemistry	Total Dissolved Solids
General Chemistry	Total Kjeldahl Nitrogen
Metals	Aluminum
Metals	Arsenic
Metals	Barium
Metals	Boron
Metals	Calcium
Metals	Chromium
Metals	Copper
Metals	Iron
Metals	Lead
Metals	Magnesium
Metals	Manganese
Metals	Nickel
Metals	Potassium
Metals	Selenium
Metals	Silica
Metals	Sodium
Metals	Uranium
Microbiological	E. Coli
Microbiological	Total Coliform
Pesticides	alpha-Chlordane
Pesticides	Dieldrin
Pesticides	Hexachlorobenzene
Radon	Gross Alpha Final

Analyte Category	Analyte
Radon	Radon Average
Volatile Organic Compounds	Carbon disulfide
Volatile Organic Compounds	Chloroform
Volatile Organic Compounds	Methyl tert-Butyl Ether (MTBE)
Volatile Organic Compounds	Toluene

One-time water quality-analysis samples were collected by the New Jersey Geological and Water Survey. The results were analyzed by New Jersey Analytical Labs in West Trenton, New Jersey and RAdata, Inc. in Flanders, New Jersey. For a description of analytes see (AppendixC).

While it is difficult to draw scientifically defensible conclusions from this initial, one-time round of sampling, it is possible to make some general observations from the available data.

1) In general, it appears as if spring water chemistry resembles that of groundwater rather than of surface water. This observation was based upon the iron, aluminum and manganese concentrations observed in coastal plain springs and upon the neutral to basic pH and higher alkalinity with those springs associated with carbonate geology, which are consistent with groundwater quality observations from the New Jersey Ambient Groundwater Quality Network. The general lack of testing and existing data makes this baseline observation relevant. Ideally, however, shallow groundwater samples adjacent to the spring would be collected simultaneously to provide a true groundwater, spring water comparison. Additional surface water and true groundwater sample comparisons still need to be made.

2) There appears to be a general correlation between land use and spring water chemistry. This observation is supported by higher chloride levels in many of the more urban/suburban area springs and those springs near roads. Similarly, methyl tert-butyl ether (MTBE) a gasoline additive, was higher in springs located downwind of major urban areas, such as in the coastal plain downwind of Philadelphia. In general, there were more anthropogenic compounds found in springs in the older, more developed regions of New Jersey and more pesticides found in agricultural areas. More frequent sampling over multiple years as well as during the year including additional sites would be needed to confirm this observation.

3) From the data collected on this project and from the related ambient groundwater sampling experience, NJGWS recommends the same parameters sampled in the New Jersey Ambient Ground Water Quality Monitoring Network (AGWQMN) be tested in any future rounds of spring sampling. If this is not possible then trace elements such as metals, major ions, and field parameters are the top priority to characterize the spring waters. To assess the anthropogenic impacts to the spring water quality, limited but selective nutrient, pesticide, and volatile organic compounds will be selected. Bacteria (*E. coli)* has been detected at all the springs, except one, but can be excluded from future sampling unless there is a willingness to track the source of the bacteria (as human or non-human).

Springs Specific Observations

The following paragraphs briefly describe observations for each spring based upon the water quality results for that spring and any other spring specific data collected as part of this or the related studies.

1) Indian Lady Hill Spring

The spring water had a pH of 5.75, and if this spring was fed by young groundwater, you would typically expect pH below 5.00, based on the observed pH of the young groundwater from the AGWQMN undeveloped land use monitoring wells located in the Coastal Plain. This could be indicative that the spring water is 'older' than recent recharge. It also included detections of lead, dieldrin, and chloroform which indicates the water from this spring is impacted by anthropogenic activities.

2) Paint Island Spring

In 1966 the U.S. banned the use of hexachlorobenzene as a fungicide used widely on wheat. Since this area is no longer agricultural (now suburban), the detection of this compound in the sample could indicate that the water is in fact groundwater and from the deeper portions of the Kirkwood Cohansey aquifer and thus older water.

3) Crystal Spring

Uranium was detected in this spring water sample. Radium is the predominate radionuclide detected in the Coastal Plain Physiographic Province.

4) Blue Hole-Inskeep

Two volatile organic compounds most commonly associated with gasoline were detected in this spring water; MTBE and toluene, though there could be multiple sources. This spring is located downwind of Philadelphia and urban areas in the southwestern portion of the State. The detections could be from atmospheric deposition or more likely a nearby groundwater contamination.

5) Honeyman Spring

The highest uranium concentration, (below the drinking water standard of 30 Micrograms per Liter (µg/L) and arsenic concentration (below the drinking water standard, but above the groundwater standard) was obtained from this spring. Uranium and Arsenic are naturally occurring in groundwater and are observed in similar geologic settings in New Jersey.

6) Valley Crest Spring 1

Nitrate concentration in this spring was the second highest of all the samples and was one of three springs that had a detection for chloroform. Chloroform can be from anthropogenic or natural sources. The low-level concentration and the forest setting tentatively indicates natural sources for the chloroform detected.

7) Marble Mountain Spring

The water quality results show nothing unusual having concentrations similar to those found in shallow ground water.

8) Shurts Road Spring

Hexachlorobenzene was also detected in this spring water sample. The spring is also in an agricultural setting, like Paint Island Spring, indicating that the hexachlorobenzene is a result of the past agricultural activities. That the pesticide was banned in the 1960s could also indicate that the water is 'older' than recent recharge or in the soil and being moved by redistribution into the water.

9) Great Bear/Trinity Spring

This spring had the highest gross alpha activity and radon concentration. This could be due to radium mobilization from anthropogenic activities, which is supported by the potassium, chloride, sodium, nitrate, and other analyte concentrations in the water sample taken from this spring. Limited pesticides were detected in this initial study, however, two separate pesticide compounds (which have been prohibited or have limited use) were detected in this spring water sample. This is also the only spring with a detection of ammonia.

10) Locust Grove Spring

The water quality results show nothing unusual having concentrations similar to those found in nearby shallow ground water.

11) George Washington Spring-Van Saun Park

Sodium, chloride, and calcium concentrations are indicative of possible road salt impact to the spring water quality, when compared to known concentrations from the AGWQMN.

12) Brau Kettle Spring 2

Copper, manganese, nickel, magnesium, and silica were detected in the spring's water. The local geology is carbonate rock with overlying till. There is also the report of aeolian sands near the site. The spring also has detection for carbon disulfide which can be associated with marsh ecologies or with fungicides.

13) Big Spring (Whittingham)

Sodium and chloride concentrations at this spring are elevated when compared to those found in the background (undeveloped land use) monitoring wells in the AGWQMN. This could indicate possible anthropogenic influence; particularly, road salt. As Big Spring is located several thousand feet from the nearest road, this suggests that the recharge area may be distant from the spring itself.

14) Dingman's Ferry Spring

Water quality data from this spring strongly mimics background (undeveloped land use) ground-water quality from the AGWQMN. This spring also has the presence of carbon disulfide similar to the nearby Brau Kettle Spring 2.

Springs Water Quality Summary, by Raymond Bousenberry

To characterize and to put the spring water quality in perspective the water quality data from all selected springs was compared to data from the third sampling cycle (2009-2013) of the New Jersey Ambient Groundwater Quality Monitoring Network (AGWQMN). The AGWQMN is composed of 150 wells and assesses, monitors, and provides information about land-use-related non-point-source contaminant effects on shallow-groundwater quality in the State.

The geological setting in which the springs and groundwater are located will impact the waters' characteristics. As such, when appropriate the groundwater and spring samples were grouped by geological setting for comparison. AGWQMN groundwater samples and spring samples collected the unconsolidated sandy, clayey sediments from the southern part of the State in the Coastal Plain Physiographic Province are herein referred to as Coastal Plain. The samples collected from glacial sediments, weathered soil and regolith, and/or consolidated bedrock in the three northern Physiographic Provinces (Piedmont, Highlands and Valley and Ridge), are herein referred to as Bedrock Provinces or bedrock regions.

Conductivity, TDS, and pH are considered general water-chemistry parameters. These parameters can be helpful as indicator parameters to assess if water has been affected by anthropogenic sources. The median values for these parameters from the springs water are above the median AGWQMN concentrations in undeveloped land use (undisturbed/background) areas in the Coastal Plain and bedrock geological setting. The springs' median values are more comparable to the median values found in the AGWQMN agricultural land use monitoring wells, in the both the Coastal Plain and bedrock geological settings, but more prominently in the bedrock region of the State.

The concentrations of major ions (magnesium, silica, calcium, sodium, potassium, chloride, fluoride, and sulfate) found in the spring water can be naturally occurring or elevated due to anthropogenic sources. For the Coastal Plain springs, the median values for these parameters are above those found in groundwater samples in the undeveloped land use areas, and yet are generally below the median values of the agricultural monitoring wells in the Coastal Plain. Interestingly, calcium and fluoride were not detected in any of the Coastal Plain springs, while both are detected in low concentrations in AGWQMN undeveloped land use monitoring wells. For springs in the bedrock region of the State major ion concentrations are very similar to those found in the AGWQMN agricultural monitoring wells located in the same geological units. Elevated sodium and chloride levels in the AGWQMN have a positive linear correlation with frequent road salting events/seasons, and since these concentrations in springs are similar to those in the AGWQMN, temporal sampling of the springs may exhibit the same correlation.

The only trace element to be detected in 100 percent of the springs was boron, having a median concentration of 10.95 µg/L. Boron does not have a Drinking Water or Groundwater Standard. A higher frequency of detection of manganese, aluminum, and iron was observed in springs in the Coastal Plain than those in the Bedrock Provinces. The median concentrations for these parameters were also higher in the Coastal Plain springs than those observed in the Bedrock Provinces. These metals are commonly mobilized in reducing groundwater. Arsenic was detected in 43 percent of the springs, and none of the springs had a concentration greater than the Drinking Water Standard of 5 µg/L. However, two springs did exceed the Groundwater Standard of 3 µg/L: one in the outer Coastal Plain, the other in the Piedmont Physiographic Province, an area with well-documented naturally-occurring arsenic in the groundwater (Serfes, 2004).

All but two of the springs had detections of nitrates, and out of those springs ten had nitrate concentrations greater than 1 mg/L. This nitrate concentration is an indicator of surface contamination from anthropogenic sources, such as lawn and agricultural practices and subsurface septic systems, to groundwater. The median nitrate concentration of 1.63 mg/L in the springs samples is comparable to the nitrite plus nitrate median values in groundwater samples from urban monitoring wells in the AGWQMN (1.54 and 1.67 mg/L in the Coastal Plain and bedrock regions respectively). A study by Panno and others, (2006), observes that total Nitrogen (TKN plus Nitrate) over 10 mg/L may indicate water quality impairment from animal waste, septic effluent, landfill leachate, and/or field tiles (artificial soil drainage, generally in agricultural fields). None of the water samples from the springs had total nitrogen concentrations greater than 10 mg/L.

Five of the 14 springs had a combined total of six pesticide detections, with three of those springs in the Coastal Plain and two north of the fall line. Only three pesticide compounds were detected: hexachlorobenzene (in three springs), dieldrin, and alpha-chlordane (in 2 springs each). The total sum concentration of all the pesticide compounds detected is 0.223 mg/L. All three compounds are bioaccumulative and persistent in the environment and their use has been banned in the United States, with hexachlorobenzene being banned as far back as 1966 in the United States. While the concentration is low, the presence of these compounds may indicate that the spring water is not newly recharged water but is older in age. Age dating the water would help understand the water cycle of the springs, and the possible impacts to the water quality.

Volatile organic compounds (VOCs) were detected in six springs, two in the Coastal Plain and 4 in bedrock geology for a total of seven detections. Four individual volatile organic compounds were detected. Chloroform (24 percent of the springs) and carbon disulfide (14 percent of the springs) were the two most frequently detected compounds, and both can have anthropogenic and naturally occurring sources. Chloroform can enter the groundwater system through treated water and septic systems but can also be produced by termites and some soil funguses. Road salting runoff may enhance the chloroform formation process by these funguses in nearby soils. Carbon disulfide is associated with fungicides (anthropogenic) and marsh ecologies (natural). The springs that had the detections for carbon disulfide were in the northeastern part of the State, in forested areas, and did not have any pesticide detections. This may indicate the carbon disulfide detected could be naturally occurring. The only two gasoline/petroleum compounds detected were MTBE and toluene. Both were detected in the Blue Hole-Inskeep spring located in the Coastal Plain. This spring is in an area where the predominate wind pattern is from the more industrialized and residential areas to the west, possibly depositing these petroleum type compounds through atmospheric deposition. The detections of these compounds could also be from run-off or a local petroleum spill.

Radium is directly correlated with gross alpha, particularly in the Coastal Plain. Acidic water and agrochemicals are known to mobilize radium in groundwater. The median gross alpha value 2.2 pCi/L (picouries per liter) in the spring water samples is comparable to the state wide median gross alpha concentration of 2.7 pCi/L in the AGWQMN. Two springs had a concentration over the Drinking Water Standard of 15 pCi/L. The radium in the groundwater will decay into radon, and the radon values were much higher than the gross alpha in this study, with 11 of the 14 springs having radon concentrations above the USEPA proposed limit of 300 pCi/L.

Radium is a byproduct of the uranium decay process, and uranium was detected in 36 percent of the springs, with one spring located in the Coastal Plain and the remaining four in the bedrock region of the State. Uranium mobilization is linked to oxic/mixed redox conditions and generally under high (basic) pH. It is not unheard of, for uranium to be present in reducing conditions. Crystal Spring had an elevated pH (neutral 7.11 su) and TDS (410 mg/L) than is commonly observed in the Coastal Plain. The more basic pH and the fact that uranium has a direct correlation with TDS which is elevated in this sample, could possibly explain the mobilization and detection of uranium in this spring water sample. All uranium concentrations were below 1 µg/L except for Washington Crossing State Park Spring that had a concentration of 8.2 µg/L. Uranium, besides with TDS, has a correlation with other oxyanions and ion-complex forming trace elements, such as arsenic, and sulfate. Washington Crossing State Park Spring also had the highest arsenic concentration and the highest uranium concentration.

Total coliform was detected in 100 percent of the springs sampled. Eighty five percent of the springs tested positive for *Escherichia coli* (*E. coli*). *E. coli* is from the lower intestine of warm-blooded organisms and has a limited life-span outside of the host organism's body and is considered an indicator organism for fecal contamination. Out of the two springs without an *E. coli* detection, one was Brau Kettle located in the forested northwestern part of the State, and the other was Paint Island Spring where the surrounding land use around Paint Island Spring is classified as urban. Although *E. coli* is an indicator of fecal contamination it cannot be stated if it is human, livestock, or wildlife contamination in these water samples without further testing using microbial source tracking techniques.

Overall, the spring water quality closely resembles that of shallow groundwater which is impacted by anthropogenic and natural sources. While the springs' water quality is comparable to shallow (newly recharged) groundwater, the samples from the springs do not appear to be as newly recharged as the groundwater in the AGWQMN. The detection of the banned pesticides, and concentrations resembling groundwater found in agricultural and urban land use areas in the AGWQMN, could be explained by the water being older than the groundwater sampled in the AGWQMN. The water may have traveled through more than one land use and possibly more than one geological setting with each land use and geological feature leaving an impression on the water quality. More temporal and spatial water quality data from springs is needed to properly characterize and assess the geological and anthropogenic influences on the water quality.

SPRINGS ECOLOGY

Ecology is the scientific analysis and study of interactions among organisms and their environment, and the interactions organisms have with each other. Springs ecosystems are among the most structurally complicated, ecologically, and biologically diverse, productive, evolutionarily provocative, and threatened ecosystems on earth (Stevens, and Meretsky, 2008).

Biologically, springs ecosystems exert a vastly disproportionate impact on regional ecology in relation to their size. Springs may provide long-term stable habitats that support unique species and evolutionary processes (Stevens, and Meretsky, 2008). The NJGWS along with assistance from the NJDEP Office of Natural Lands Management, (ONLM), and Montclair State University, (Montclair, New Jersey), and the NJDEP Bureau of Freshwater and Biological Monitoring (BFBM), undertook an ecological classification of some of the 14 springs identified for sampling for this study. All of the selected 14 springs were not useable for the ecological study due to various constraints depending on the study conducted.

ECOLOGICAL INTEGRITY ASSESSMENT OF HEADWATER WETLANDS ASSOCIATED WITH SPRING MONITRING SITES,

by Kathleen Strakosh Walz

An ecological integrity assessment of headwater wetlands and associated spring water monitoring sites was undertaken by the Office of Natural Lands Management ONLM, within the NJDEP. The work was completed as part of a larger project titled *Developing a Wetland Condition Monitoring Network for New Jersey: Application of New Assessment Methods* and was funded in part by United States Environmental Protection Agency, State Wetlands Protection Development Grant, Section 104(B)(3); CFDA No. 66.461, CD97225809. An outline of the work is included below: Each study area was as close as possible to the spring, but the actual vegetation plots had to be in wetlands. Some spring sites did not have wetlands large enough to sample so those were dropped from the headwater wetland study.

Introduction

Springs most often occur in upper reaches of watersheds in the landscape and serve as key sources of fresh water for streams, rivers, lakes, ponds, and associated wetlands. In some cases, the springs are quite small or too narrow to support wetland vegetation. Springs that have a large volume of groundwater, or that emerge from a linear geological formation, can support larger wetland systems. Only seven sites of the 14 selected in the spring characterization and classification study described above had wetlands that were extensive enough to establish vegetation sampling plots (0.1 hectare) and assessment areas (0.5 hectare). (One hectare contains about 2.47 acres). Ecological Integrity Assessment protocols (Faber-Langendoen and others, 2016) were used to collect data from wetlands at all seven spring monitoring sites. Figure

51 shows the location of the seven sites in this wetland study. Table 8 lists spring characterization information for the seven sites with associated headwater wetlands, and Table 9 lists the associated abiotic and biotic data collected by site.

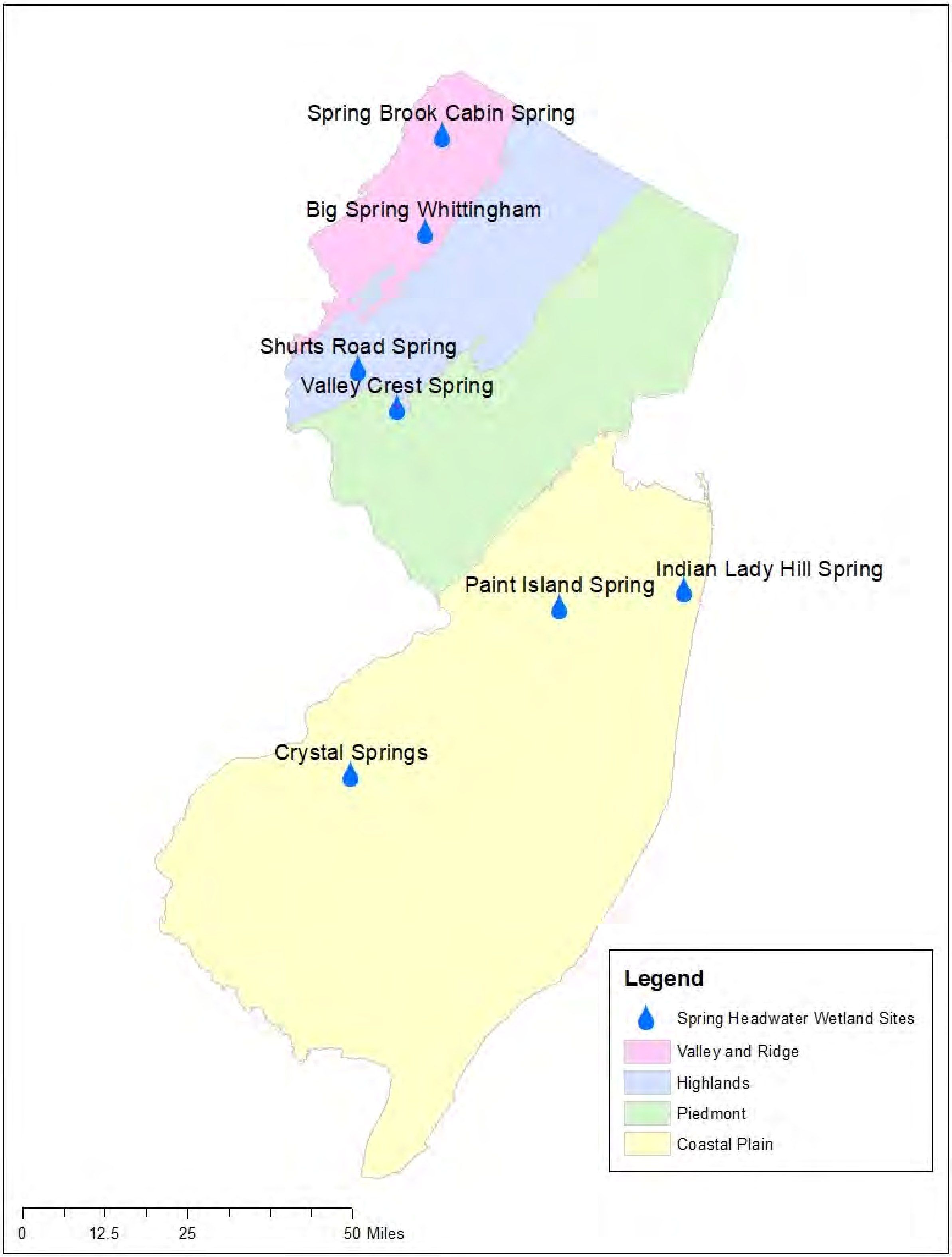


Figure 51. Map Showing Location of Spring Monitoring Sites, Headwater Wetlands Study.

Table 8. Spring Classification and Characterization for Seven Headwater Wetland Study Sites in New Jersey.

#	Spring Site Name	Township	County	Associated River	Bedrock Geology	Surficial Geology	Groundwater Emergence
1	Big Spring - Whittingham	Fredon Twp.	Sussex	Pequest River	Allentown Dolomite	Late Wisconsinan Glacial Delta Deposits	Limnocrene
2	Crystal Spring	Laurel Springs	Camden	North Branch Big Timber Creek	Vincentown Formation (Glauconite)	Weathered Coastal Plain Formations	Limnocrene
3	Indian Lady Hill Spring	Neptune	Monmouth	Hollow Brook	Cohansey Formation	Weathered Coastal Plain Formations	Hillslope
4	Paint Island Spring	Millstone Twp.	Monmouth	Toms River	Lower Member Kirkwood Formation	Alluvium	Helocrene
5	Shurts Road Spring	Franklin Twp.	Warren	Musconetcong River	Allentown Dolomite	Weathered Carbonate Rock	Rheocrene
6	Spring Brook Cabin Spring	Sandyston Twp.	Sussex	Big Flat Brook	Bloomsburg Red Beds	Late Wisconsinan Recessional Moraine Deposits, Kittatinny Mountain Till	Hillslope
7	Valley Crest Spring	Clinton Twp.	Hunterdon	South Branch Raritan River	Leithsville Formation	Alluvium	Hillslope

Table 9. Spring Abiotic and Biotic Study sites. x = data collected

		Abiotic Study	Biotic Studies			
#	Spring Site Name	Water Quality		Fish & Amphibians	Macro-Invertebrates	Ecological Integrity Assessment
1	Big Spring-Whittingham	x				x
2	Crystal Spring	x			x	x
3	Indian Lady Hill Spring	x			x	x
4	Paint Island Spring	x			x	x
5	Shurts Road Spring	x		x	x	x

		Abiotic Study		Biotic Studies		
6	Spring Brook Cabin Spring			x		x
7	Valley Crest Spring	x		x	x	x

Methods

Ecological Integrity

This study of the ecological integrity of headwater wetlands associated with spring monitoring sites was conducted as part of a larger statewide wetland condition assessment funded by a Wetland Program Development Grant from the United States Environmental Protection Agency Region 2. The methods used in the spring study were developed and used in that multi-year research project; “New Jersey’s Wetland Condition Assessment Intensification Study: A Multi-Tiered Assessment of Wetlands and Watersheds” (Walz and Faber-Langendoen, 2017). The assessment of ecological integrity can be defined as “an assessment of the structure, composition, function, and connectivity of an ecosystem as compared to reference ecosystems operating within the bounds of natural or historical disturbance regimes.” The Ecological Integrity Assessment (EIA) protocol (Faber-Langendoen and others, 2016) is a 3-tiered assessment method used to evaluate the condition of a wetland. Level 1 is a landscape scale evaluation utilizing GIS data, Level 2 is a rapid on-the-ground field assessment, and Level 3 is an intensive plot-based quantitative evaluation. The EIA method is largely a Level 2 rapid assessment method, but also includes Level 3 quantitative vegetation plot data and Level 1 land use data. Ecological attributes of landscape context and condition (vegetation, soils, hydrology) were assessed, and a separate stressor evaluation was conducted. Table 10 lists the Level 2 EIA metrics used in the spring wetland study. EIA Assessment Areas (AA) are 0.5 hectares in size (5000m^2) with a 100-meter buffer and 500-meter landscape envelope, covering a total site area of 20 ha. Quantitative vegetation plots were established within the 0.5ha AA 0.1ha (1000m^2) and established in either 18-meter radius circles or rectangular plots 20 meters by 50 meters. Vegetation, soils, and hydrology data were collected within the AA. Human Stressor Index data were collected in the AA and Buffer. A Trimble GeoXT Global Positioning System with TerraSync and ArcPad were used to establish a centrum, locate the vegetation plot boundaries, and navigate transects through the buffer. ArcGIS was used to assess the Landscape Context metrics.

Table 10. Ecological integrity metrics for wetland rapid assessment (Level 2). Some metrics have variants based on either wetland type in the U.S. National Vegetation Classification (USNVC) (e.g., bog & fen, marsh, floodplain & swamp forests, mangrove) or on hydrogeomorphic (HGM) class (e.g., tidal, nontidal, riverine, depression, lacustrine, slope). Two optional metrics are only applicable to forested wetlands. See Faber-Langendoen and others, (2016) for details on metric protocols (Size metrics are not shown).

Primary Rank Factor (RF)	Major Ecological Factor (MEF)	EIA Metric Name	Metric Variant	Metric Variant Type
LANDSCAPE CONTEXT	LANDSCAPE	**LAN1**. Contiguous Natural Land Cover		
		LAN2. Land Use Index		
	BUFFER	**BUF1**. Perimeter with Natural Buffer		
		BUF2. Width of Natural Buffer		
		BUF3. Condition of Natural Buffer		
CONDITION	VEGETATION	**VEG1**. Native Plant Species Cover		
		VEG2. Invasive Nonnative Plant Species Cover		
		VEG3. Native Plant Species Composition	Yes	USNVC
		VEG4. Vegetation Structure	Yes	USNVC
		VEG5. Woody Regeneration [opt.]		
		VEG6. Coarse Woody Debris [opt.]	Yes	USNVC
	HYDROLOGY	**HYD1.** Water Source	Yes	HGM
		HYD2. Hydroperiod	Yes	HGM
		HYD3. Hydrologic Connectivity	Yes	HGM
	SOIL	**SOI1.** Soil Condition	Yes	USNVC

The headwater wetlands in this spring study include many different types of wetlands. Three sites are forested wetland (swamp), three are herbaceous wetlands (marsh), and one is a shrub swamp. Table 11 shows a list of wetland types by site as classified by U.S. National Vegetation Classification (USNVC) (FGDC 2008, Faber-Langendoen and others, 2016, Jennings and others, 2009), National Wetlands Inventory (NWI) (Cowardin and others, 1979) and hydrogeomorphic (HGM) classification (Smith and others, 1995). All seven sites are classified as "slope" wetlands in the hydrogeomorphic (HGM) classification: "Slope wetlands normally are found where there is a discharge of groundwater to the land surface. They normally occur on sloping land; elevation gradients may range from steep hillsides to slight slopes." (Smith and others, 1995). All of the spring wetland sites support vegetation characteristic of groundwater seepage.

Table 11. Classification of Wetland Types at Seven Spring Study Sites.

#	Spring Site Name	USNVC Ecological Community (Association) Scientific Name	Cowardin Wetland Type	HGM Type
1	Big Spring - Whittingham	*Acer rubrum - Fraxinus nigra - (Larix laricina) / Rhamnus alnifolia* Swamp Forest	Palustrine Forested Wetland (PFO)	Slope
2	Crystal Spring	*Symplocarpus foetidus - Impatiens capensis* Seepage Meadow	Palustrine Emergent Marsh (PEM)	Slope
#	**Spring Site Name**	**USNVC Ecological Community (Association) Scientific Name**	**Cowardin Wetland Type**	**HGM Type**
3	Indian Lady Hill Spring	*Pinus rigida - Nyssa sylvatica - Clethra alnifolia - Leucothoe racemosa* Forest	Palustrine Forested Wetland (PFO)	Slope
4	Paint Island Spring	*Acer rubrum - Nyssa sylvatica - Magnolia virginiana / Viburnum nudum var. nudum / Osmunda cinnamomea* Swamp Forest	Palustrine Forested Wetland (PFO)	Slope
5	Shurts Road Spring	*Cornus (amomum, sericea) - Viburnum dentatum - Rosa multiflora* Ruderal Shrub Swamp	Palustrine Scrub-Shrub (PSS)	Slope
6	Spring Brook Cabin Spring	*Carex stricta - Carex vesicaria* Wet Meadow	Palustrine Emergent Marsh (PEM)	Slope
7	Valley Crest Spring	*Carex stricta - Carex vesicaria* Wet Meadow	Palustrine Emergent Marsh (PEM)	Slope

Floristic Quality

"The composition and abundance of plant species at a site reflects and influences other ecological processes related to hydrology, water chemistry, and soil properties. Plants integrate different wetland processes, and they respond to physical, chemical, and biological disturbances, making them a particularly valuable attribute to track (USEPA, 2016). Our primary method for level 3 vegetation data analysis was based on the Floristic Quality Assessment (FQA). The FQA approach to assessing ecological communities is based on the concept of species conservatism. The core of the FQA method is the use of "coefficients of conservatism" (C-values), which are assigned to all native species in a flora following the methods described by (Swink and Wilhelm 1979), and Taft and others (1997), as applied by Bried and others, (2013) and Kutcher and Forrester (2018) in the Northeast. C-values range from 0 to 10 and represent an estimated probability that a plant is likely to occur in a landscape relatively unaltered from pre-European settlement conditions. High C-values are assigned to species which are obligate to high-quality natural areas and cannot tolerate habitat degradation, while low C-values are assigned to species with a wide tolerance to human disturbance. Generally, C-values of 0 are reserved for nonnative species.

Complete plant species lists with percent cover of species were compiled for each site in the 0.1 hectare plot and 0.5 hectare assessment area. Floristic Quality Index scores were calculated using the New Jersey Floristic Quality Assessment developed as part of the larger

USEPA grant (Walz and others, 2018); the list of New Jersey vascular and moss taxa is posted on the website tool Universal FQA (Freyman and others, 2016). The FQA scores are highly correlated to EIA scores and provide a meaningful way to evaluate the condition of sites. The EIA scorecard includes several FQA metrics including Mean C, Cover-weighted Mean C, and Floristic Quality Index.

Stressor Checklist and Human Stressor Index (HSI)

In the context of ecological condition stressors are direct threats to a wetland ecosystem; "the proximate (human) activities or processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of biodiversity and natural processes" or altered disturbance regime (e.g. flooding, fire, or browse). Stressor categories include development, recreation, vegetation (e.g. invasive species, resource extraction), natural disturbance, soils, and hydrology; a total of 36 stressors were evaluated for each site. Scope and severity of each stressor was assessed for the AA (Vegetation, Soils/Substrate), and the buffer in the field. Stressor impact was calculated from stressor scope and severity scores, and the sum of impact scores used to calculate the Human Stressor Index (HSI) rating for each site. The EIA protocol (Faber-Langendoen and others, 2016) provides more details on the HSI protocol and analysis. HSI scores are included on the EIA scorecards for each site.

Database and EIA Scorecards

All vegetation, soils, hydrology and stressors data were entered into the New Jersey module of NatureServe's EcoObs (ecological observation) database. EIA scores are weighted by metrics, major ecological factors, and rank factors; which are then used to calculate an overall ecological integrity score. The data is summarized in an EIA scorecard and exported from the EcoObs database in pdf format by site.

Results

The study of headwater wetlands associated with springs across the physiographic provinces of New Jersey using NatureServe's Ecological Integrity Assessment protocols to evaluate condition provides the first set of baseline condition data for selected springs in New Jersey. Wetland condition data was collected in coordination with the hydrogeological, water quality, and macroinvertebrate sampling in hopes that some correlation could be found between the abiotic and biotic results. Table 12 provides an overview of the geologic and hydrologic setting in which the seven spring wetland assessment sites were sampled. The sites are ordered from best to worst condition based on the final EIA condition score (A=excellent, B=good, C=fair, D=poor). The headwater wetlands associated with springs in the best condition occur in well-buffered landscape settings on protected land. The fair to poor condition spring wetland sites occur in fragmented landscapes with either intensive agriculture or development.

Table 12. Summary of Spring Site Location, Geology, Hydrology, and Final EIA Score.

Spring Site Name	Township	County	Bedrock Geology	Headwater to River	Groundwater Emergence	EIA Score
Big Spring Whittingham	Fredon Twp.	Sussex	Allentown Dolomite	Pequest River	limnocrene	A-
Spring Brook Cabin Spring	Sandyston Twp.	Sussex	Moraine Deposits	Big Flat Brook	rheocrene	B+
Indian lady Hill Spring	Neptune Twp.	Monmouth	Cohansey Formation	Hollow Brook	hillslope	**B+**
Paint Island Spring	Millstone Twp.	Monmouth	Lower Member Kirkwood Formation, Alluvium	Toms River	helocrene	**C+**
Spring Site Name	**Township**	**County**	**Bedrock Geology**	**Headwater to River**	**Groundwater Emergence**	**EIA Score**
Shurts Road Spring	Franklin Twp.	Warren	Allentown Dolomite	Musconetcong River	rheocrene	**C+**
Valley Crest Spring	Clinton Twp.	Hunterdon	Leithsville Formation, Alluvium	South Branch Raritan River	hillslope	**C+**
Crystal Spring	Laurel Springs	Camden	Vincentown Formation (Glauconite)	North Branch Big Timber Creek	limnocrene	**C-**

A summary of abiotic and biotic data by spring site is presented in Table 13. High quality wetland sites had higher dissolved oxygen levels in the summer, higher macroinvertebrate HBI scores (Caraballo, 2016), high EIA and good land use index (LUI) scores, and low HSI stressor scores. The best condition wetlands associated with springs in this study were in 1) Big Spring at Whittingham Wildlife Management Area and 2) Spring Brook Cabin Spring in Stokes State Forest and 3) Indian Lady Hill Spring. The lower quality spring sites with anthropogenic impacts had lower dissolved oxygen, low EIA and LUI scores, and high HSI stressor scores. The wetlands in worst condition were found at Crystal Spring (surrounded by residential development) and Valley Crest Spring (surrounded by agriculture). While Shurts Road Spring had a low EIA score and a very high HSI stressor score, the water quality was good. This site had good water quality in the spring and extensive toe of slope seepage, good macroinvertebrate diversity, but only a fair EIA score due to the abundance of invasive plant species and high stressor rating due to surrounding land use (farming, roads).

Table 13. Spring Abiotic and Biotic Summary Results.

Spring Site Information				Abiotic Study	Biotic Studies			
Wetland ID#	**NJGS ID #**	**Biotic Study Spring Symbol**	**Spring Site Name**	**Water Quality Summer minimum DO mg/l**	**HBI[1] Macro-Invertebrate Score**	**EIA[2] Ecological Integrity Assessment Score**	**HSI[3] Human Stressor Index Score**	**LUI[4] Land Use Index Score**
NJWET-S7-BS	56	BS	Big Spring Whittingham	6.7		3.76 (A-)	1.5 (Low)	A-
NJWET-S5-CS	24	CS	Crystal Spring	1.2	6.1 ± 0.2	1.78 (C-)	17.8 (Very High)	D
NJWET-S4-IL	422	IL	Indian Lady Hill Spring	5.2	5.9 ± 0.1	3.40 (B+)	4.3 (Medium)	B-
NJWET-S6-PI	715	PI	Paint Island Spring	1.5	5.9 ± 0.6	2.46 (C+)	13.6 (Very High)	C+
NJWET-S3-SR	33	SR	Shurts Road Spring	6.2	5.2 ± 0.3	2.28 (C+)	10.5 (Very High)	C-
NJWET-S2-SB	436	SB	Spring Brook Cabin Spring	8.0		3.49 (B+)	3.9 (Low)	A-
NJWET-S1-VC	685	VC	Valley Crest Spring	5.6	5.4 ± 0.7	2.48 (C+)	7.9 (High)	D

[1]HBI=Hilsenhoff Biotic Index for Macroinvertebrates - tolerance score where 0 is pristine and 10 is impacted (Caraballo, 2016)
[2]EIA = Ecological Integrity Assessment Rating based on Landscape Context and Condition (Vegetation, Hydrology, Soils) where a score of 4 is Excellent and 0 is Poor Condition
[3]HSI = Human Stressor Index based on field onsite 0.1-0.5ha Assessment Area and surrounding100m Buffer, evaluation of both Biotic and Abiotic Stressors. HSI Site Score and Rating range from 0-10+ where 0 is Stressors Absent and 10+ is Very High Stressors present.
[4]LUI = Land Use Index (used in EIA protocol) for assessing Landscape Condition in a 500m envelope surrounding the buffered wetland sites using GIS attribute weighted NJDEP LULC12 land use cover types. Scoring A-D where A is Excellent, B is Good, C is Fair and D is Poor.

Floristic Diversity

Plant species diversity tends to be high in groundwater seepage wetlands with vegetation adapted to perennial cold, running water with a wide range of site pH values. A total of 273 taxa were documented during the study, ranging from 40 to 89 species per site. Of the 273 taxa, 235 are native (19 of which are sedges) and 38 are non-native. Two of the native species, *Carex leptalea* (Bristly-stalked sedge) and *Juncus dudleyi* (Dudley's rush), are considered rare, ranked S3 (20-50 populations statewide) by the New Jersey Natural Heritage Program (https://www.state.nj.us/dep/parksandforests/natural/heritage/njplantlist.pdf). While some of the springs were pristine or near pristine, more than half of the sites had invasive species including Japanese barberry, Autumn Olive, Japanese honeysuckle, Stiltgrass, and Multiflora rose. A list of the flora by site can be found in Appendix D.

Floristic diversity and abundance of native plant species was correlated to wetland condition as shown in the EIA scores. Sites with higher percentage of native taxa (Native N), higher Mean C and Cover-weighed Mean C and FQI scores had better EIA scores. Three spring sites had the best floristic scores: 1) Big Spring at Whittingham, 2) Indian Lady Hill Spring, and 3) Spring Brook Cabin. The sites with highest number of species (Paint Island Spring and Shurts Road Spring) also had 14-18% non-native taxa in abundance. Table 14 shows a summary of the floristic quality results with green shading highlighting the sites with the best EIA scores.

Table 14. Spring Headwater Wetland Floristic Diversity Results.

Spring Site Information		**Ecological Integrity Assessment**	**Floristic Quality Index (FQI) Data and Scores**					
Wetland ID#	**Spring Site Name**	**EIA Site Ecological Integrity Assessment Score**	**Total N (# of plant taxa)**	**Native N (# taxa)**	**Non-native N (# taxa)**	**Mean C**	**Cover-Weighted Mean C**	**FQI**
NJWET-S7-BS	Big Spring Whittingham	3.76 (A-)	71	67 (92%)	4 (6%)	4.76	4.30	40.11
NJWET-S5-CS	Crystal Spring	1.78 (C-)	40	31 (78%)	9 (23%)	3.20	2.28	20.24
NJWET-S4-IL	Indian Lady Hill Spring	3.40 (B+)	52	51 (98%)	1 (2%)	5.77	5.59	41.60
NJWET-S6-PI	Paint Island Spring	2.46 (C+)	80	69 (86%)	11 (14%)	3.81	2.83	34.10
NJWET-S3-SR	Shurts Road Spring	2.28 (C+)	89	73 (82%)	16 (18%)	3.35	2.93	31.59
NJWET-S2-SB	Spring Brook Cabin Spring	3.49 (B+)	75	69 (92%)	6 (8%)	4.65	4.83	39.49
NJWET-S1-VC	Valley Crest Spring	2.48 (C+)	57	40 (70%)	17 (30%)	2.47	2.40	18.68

Ecological Integrity Assessment (EIA) Site Scorecards

Ecological Integrity Assessment Scorecards provide a good summary of the EIA metrics and ratings used to score the condition of spring sites. Scorecards with the overall EIA site rating as well as for Landscape Context (Landscape, Buffer) and Condition (Vegetation, Hydrology, Soils) for all seven springs in this study are presented below. For each site there is a map of the EIA Assessment Area and Buffer, the EIA Scorecard, and photographs of key features in the wetlands at each site. NJWET = New Jersey Wetland Condition Assessment Site code (# or Symbols identify which site)

Big Spring Whittingham

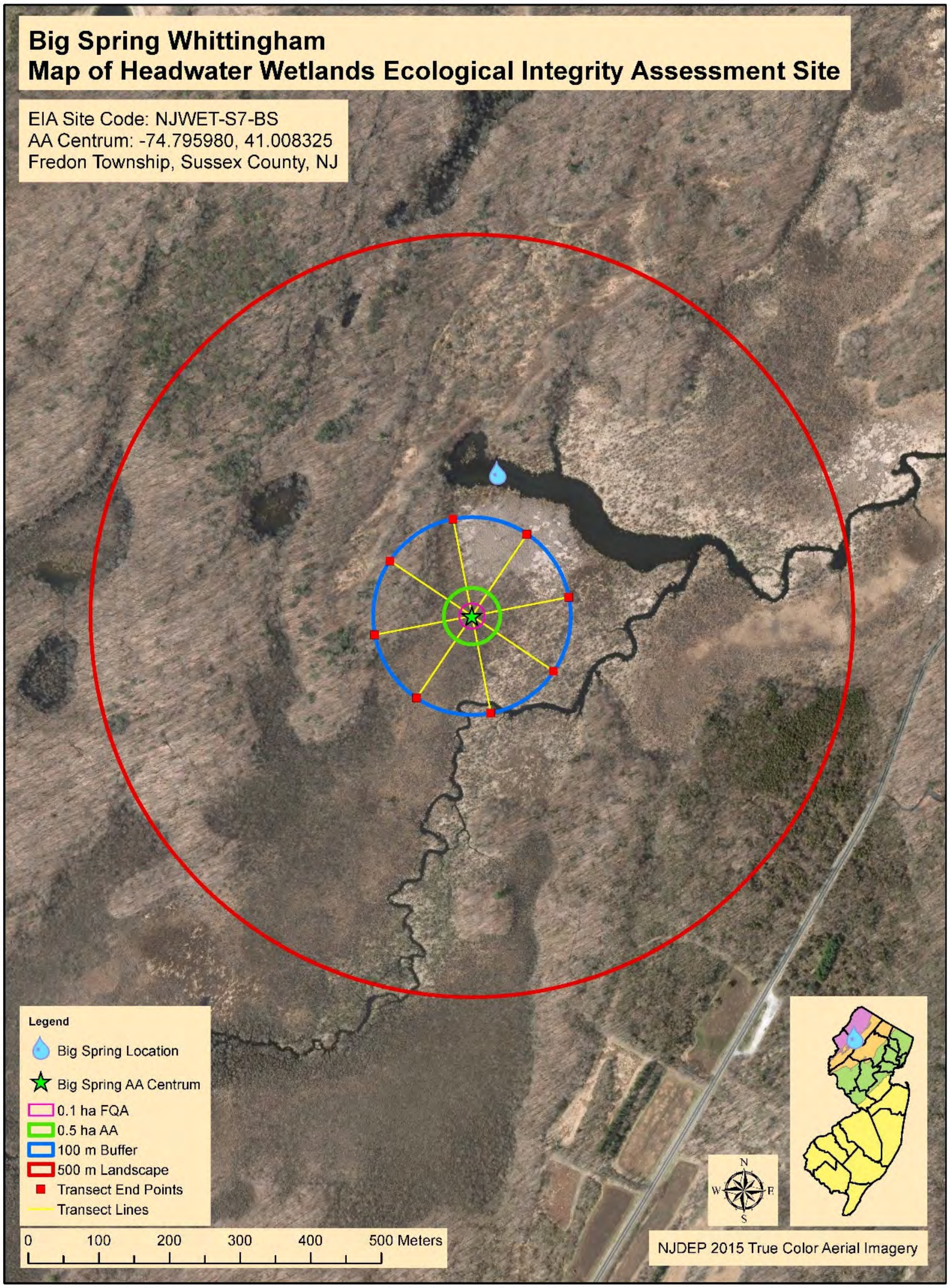


Figure 52. Big Spring Whittingham, Map of Headwater Wetlands Ecological Integrity Assessment Site (NJWET-S7-BS).

State/Prov: NJ **Site:** Springdale **ObsArea Code:** NJWET-S7-BS
ObsArea Name: Big Spring Whittingham **ObsDate:** 2015/09/15
Project: NJ Springs **County:** NJ - Sussex **Analysis Obs Code:** 046NS7BSD
Observers: Kathleen Walz, Gemma Milly

Macrogroup: M504 Laurentian-Acadian-North Atlantic Coastal Flooded & Swamp Forest
Association: CEGL006009 Acer rubrum - Fraxinus nigra - (Larix laricina) / Rhamnus alnifolia Swamp Forest
General Type:
HGM: Slope
Cowardin: Palustrine (Forested Wetland)

Human Stressors Index (HSI) Scores: *Total:* 1.5 (Low) *Abiotic:* 1.6 (Low) *Onsite:* 0.4 (Absent)
by Major Ecological Factor (MEF): *Buffer:* 4 (Medium) *Veg:* 1 (Low) *Soil:* 0 (Absent) *Hydro:* 0 (Absent)

Floristic Quality Index (FQI) Scores:
N: 71 *MeanC:* 4.76 *CWMeanC:* 4.3 *FQI:* 40.11

Protocol: NatureServe Wetland 2015	Wt	Field Rating	Field Pts	Calc Pts	Calc Rating
ECOLOGICAL INTEGRITY				3.76	A-
ECOLOGICAL INTEGRITY + SIZE (EO Rank)					
Rank Factor: LANDSCAPE CONTEXT	0.3			3.64	A-
MEF: LANDSCAPE	0.33			4.00	A+
LAN1. Contiguous Natural Land Cover	1	A	4		
LAN2. Land Use Index	1	A	4		
MEF: BUFFER	0.66			3.46	B+
BUF1. Perimeter with Natural Buffer	n/a	A	4		
BUF2. Width of Natural Buffer	n/a	A	4		
BUF3. Condition of Natural Buffer	n/a	B	3		
BUF4. Contiguous Natural Buffer Cover	n/a				
Rank Factor: CONDITION	0.7			3.82	A+
MEF: VEGETATION	0.55			3.67	A-
VEG1. Native Plant Species Cover	1	B	3		
VEG2. Invasive Nonnative Plant Species Cover	1	B	3		
VEG3. Native Plant Species Composition	1	A	4		
VEG4. Overall Vegetation Structure	1	A	4		
VEG5. Woody Regeneration	1	A	4		
VEG6. Coarse Woody Debris	1	A	4		
MEF: HYDROLOGY	0.35			4.00	A+
HYD1. Water Source	1	A	4		
HYD2. Hydroperiod	1	A	4		
HYD3. Hydrologic Connectivity	1	A	4		
MEF: SOIL	0.1			4.00	A+
SOI1. Soil Condition	1	A	4		
SOI2. Water Quality / Surface Water Turbidity / Pollutants	0.5				
SOI3. Water Quality / Algal Growth	0.5				
Rank Factor: SIZE	n/a				

Figure 53. Ecological Integrity Assessment Scorecard for Big Spring Whittingham.

Photographs of Big Spring Whittingham Wetlands

Figure 54 a. Big Spring at source showing high flow and marl deposits. *Photo, K. Strakosh Walz*.

Figure 54 b. Big Spring forested calcareous seepage swamp in EIA Assessment Area and **Figure 54 c**. Pequest River headwater in buffer (south transect). *Photos, K. Strakosh Walz*.

Crystal Spring

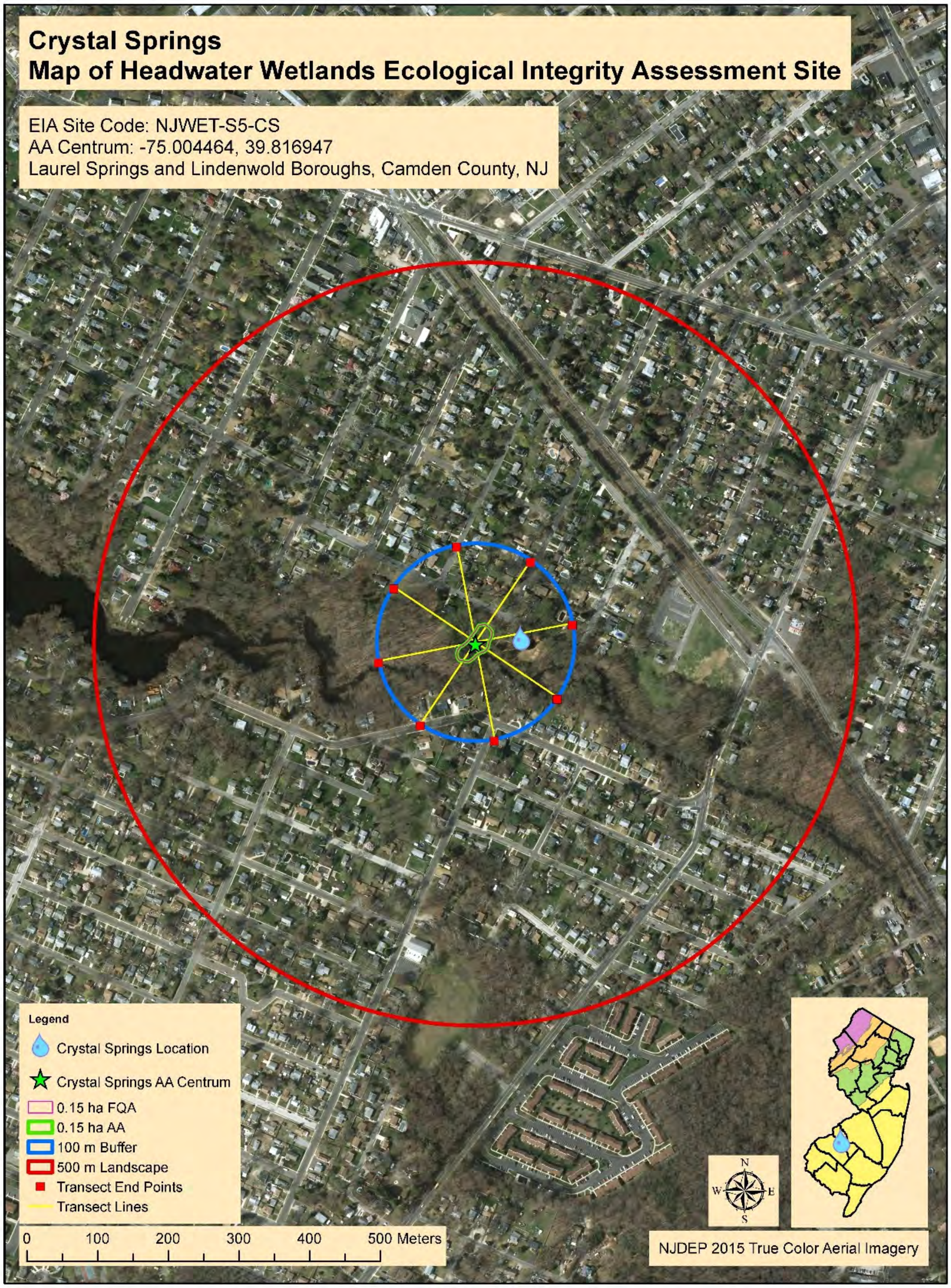


Figure 55. Crystal Spring, Map of Headwater Wetlands Ecological Integrity Assessment (NJWET-S5-CS).

State/Prov: NJ **Site:** North Branch Big Timber Creek at Laurel Springs **ObsArea Code:** NJWET-S5-CS
ObsArea Name: Crystal Springs at Laurel Springs **ObsDate:** 2015/07/09
Project: NJ Springs **County:** NJ - Camden **Analysis Obs Code:** 189NS5CSL
Observers: Kathleen Walz, Gemma Milly, Jason Beury

Macrogroup: M061 Eastern North American Cool Temperate Seep
Association: CEGL006567 Symplocarpus foetidus - Impatiens capensis Seepage Meadow
General Type:
HGM: Slope
Cowardin: Palustrine (Emergent Wetland)

Human Stressors Index (HSI) Scores: *Total:* 17.8 (Very High *Abiotic:* 15.4 (Very High *Onsite:* 8.6 (High)
by Major Ecological Factor (MEF): *Buffer:* 38 (Very High *Veg:* 21 (Very High *Soil:* 1 (Low) *Hydro:* 0 (Absent)

Floristic Quality Index (FQI) Scores:
N: 40 *MeanC:* 3.2 *CWMeanC:* 2.28 *FQI:* 20.24

Protocol: NatureServe Wetland 2015

	Wt	Field Rating	Field Pts	Calc Pts	Calc Rating
ECOLOGICAL INTEGRITY				1.78	C-
ECOLOGICAL INTEGRITY + SIZE (EO Rank)					
Rank Factor: LANDSCAPE CONTEXT	0.3			1.45	D
MEF: LANDSCAPE	0.33			1.00	D
LAN1. Contiguous Natural Land Cover	1	D	1		
LAN2. Land Use Index	1	D	1		
MEF: BUFFER	0.66			1.68	C-
BUF1. Perimeter with Natural Buffer	n/a	A	4		
BUF2. Width of Natural Buffer	n/a	C	2		
BUF3. Condition of Natural Buffer	n/a	D	1		
BUF4. Contiguous Natural Buffer Cover	n/a				
Rank Factor: CONDITION	0.7			1.92	C-
MEF: VEGETATION	0.55			1.25	D
VEG1. Native Plant Species Cover	1	D	1		
VEG2. Invasive Nonnative Plant Species Cover	1	D	1		
VEG3. Native Plant Species Composition	1	C	2		
VEG4. Overall Vegetation Structure	1	D	1		
VEG5. Woody Regeneration	1				
VEG6. Coarse Woody Debris	1				
MEF: HYDROLOGY	0.35			2.67	B-
HYD1. Water Source	1	C	2		
HYD2. Hydroperiod	1	B	3		
HYD3. Hydrologic Connectivity	1	B	3		
MEF: SOIL	0.1			3.00	B+
SOI1. Soil Condition	1	B	3		
SOI2. Water Quality / Surface Water Turbidity / Pollutants	0.5				
SOI3. Water Quality / Algal Growth	0.5				
Rank Factor: SIZE	n/a				

Figure 56. Ecological Integrity Assessment Scorecard for Crystal Spring.

Photographs of Crystal Spring Wetlands

Figure 57 a. and **Figure 57 b**. Crystal Spring Photographs 1 and 2: Spring seep at base of slope (west of Crystal Spring proper) showing dominance of *Symplocarpus foetidus* and *Impatiens capensis*. Seepage stream flows south through the assessment area into the North Branch of Big Timber Creek. *Photos, K. Strakosh Walz*.

Figure 57 c. Figure 57 d. Crystal Spring Photographs 3 and 4: Buffer invaded by non-native Kudzu (*Pueraria montana*) vine. Photos, *K. Strakosh Walz*.

Indian Lady Hill Spring

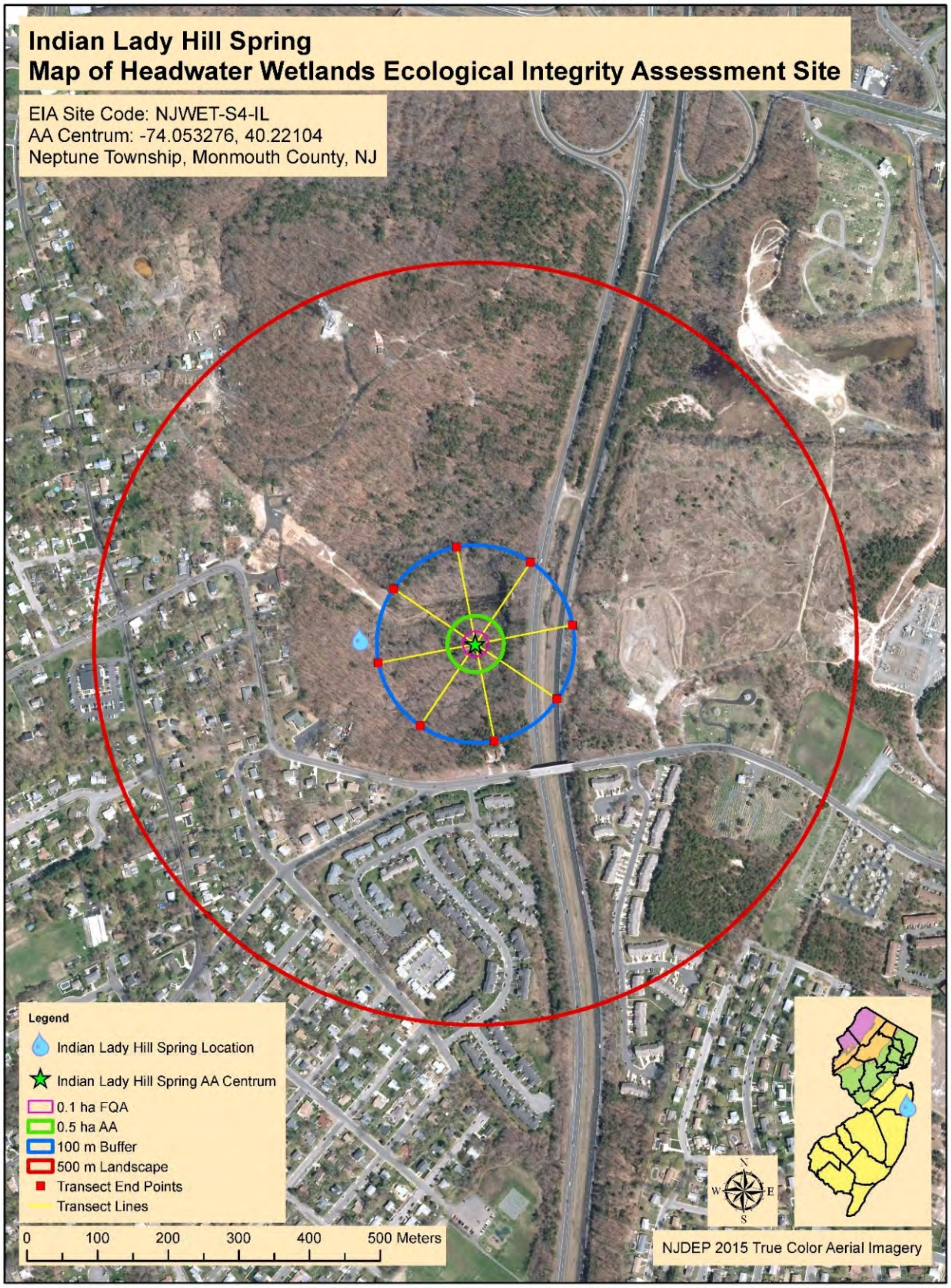


Figure 58. Indian Lady Hill Spring, Map of Headwater Wetlands Ecological Integrity Assessment Area (NJWET-S4-IL)

State/Prov: NJ **Site:** Hollow Brook Headwater Neptune
ObsArea Code: NJWET-S4-IL
ObsArea Name: Indian Lady Hill Spring
ObsDate: 2015/07/02
Project: NJ Springs **County:** NJ - Monmouth
Analysis Obs Code: 039NS4ILM
Observers: Kathleen Walz, Gemma Milly, Jason Beury

Macrogroup: M504 Laurentian-Acadian-North Atlantic Coastal Flooded & Swamp Forest
Association: CEGL006926 Pinus rigida - Nyssa sylvatica / Clethra alnifolia - Leucothoe racemosa Forest
General Type:
HGM: Slope
Cowardin: Palustrine (Forested Wetland)

Human Stressors Index (HSI) Scores: *Total:* 4.3 (Medium) *Abiotic:* 5.8 (Medium) *Onsite:* 0.2 (Absent)
by Major Ecological Factor (MEF): *Buffer:* 14 (Very High *Veg:* 0 (Absent) *Soil:* 1 (Low) *Hydro:* 0 (Absent)

Floristic Quality Index (FQI) Scores:
N: 52 *MeanC:* 5.77 *CWMeanC:* 5.59 *FQI:* 41.6

Protocol: NatureServe Wetland 2015	Wt	Field Rating	Field Pts	Calc Pts	Calc Rating
ECOLOGICAL INTEGRITY				3.40	B+
ECOLOGICAL INTEGRITY + SIZE (EO Rank)					
Rank Factor: LANDSCAPE CONTEXT	0.3			2.82	B-
MEF: LANDSCAPE	0.33			2.00	C+
LAN1. Contiguous Natural Land Cover	1	C	2		
LAN2. Land Use Index	1	C	2		
MEF: BUFFER	0.66			3.22	B+
BUF1. Perimeter with Natural Buffer	n/a	A	4		
BUF2. Width of Natural Buffer	n/a	B	3		
BUF3. Condition of Natural Buffer	n/a	B	3		
BUF4. Contiguous Natural Buffer Cover	n/a				
Rank Factor: CONDITION	0.7			3.65	A-
MEF: VEGETATION	0.55			3.58	A-
VEG1. Native Plant Species Cover	1	A	4		
VEG2. Invasive Nonnative Plant Species Cover	1	A	4		
VEG3. Native Plant Species Composition	1	A	4		
VEG4. Overall Vegetation Structure	1	B	3		
VEG5. Woody Regeneration	1	B	3		
VEG6. Coarse Woody Debris	1	A&B	3.5		
MEF: HYDROLOGY	0.35			3.67	A-
HYD1. Water Source	1	A	4		
HYD2. Hydroperiod	1	A	4		
HYD3. Hydrologic Connectivity	1	B	3		
MEF: SOIL	0.1			4.00	A+
SOI1. Soil Condition	1	A	4		
SOI2. Water Quality / Surface Water Turbidity / Pollutants	0.5				
SOI3. Water Quality / Algal Growth	0.5				
Rank Factor: SIZE	n/a				

Figure 59. Ecological Integrity Assessment Scorecard for Indian Lady Hill Spring

Photographs of Indian Lady Hill Spring Wetlands


Figure 60 a. and **Figure 60 b**. Indian Lady Hill Spring Photograph 1: Spring seep upslope and Photograph 2: Seepage stream at base of slope. *Photos, K. Strakosh Walz*.


Figure 60 c. and **Figure 60 d**. Indian Lady Hill Spring Photograph 3 and 4: Forested wetland with seepage channels and strong coastal plain Pine Barrens flora influence. *Photos, K. Strakosh Walz*.

Paint Island Spring

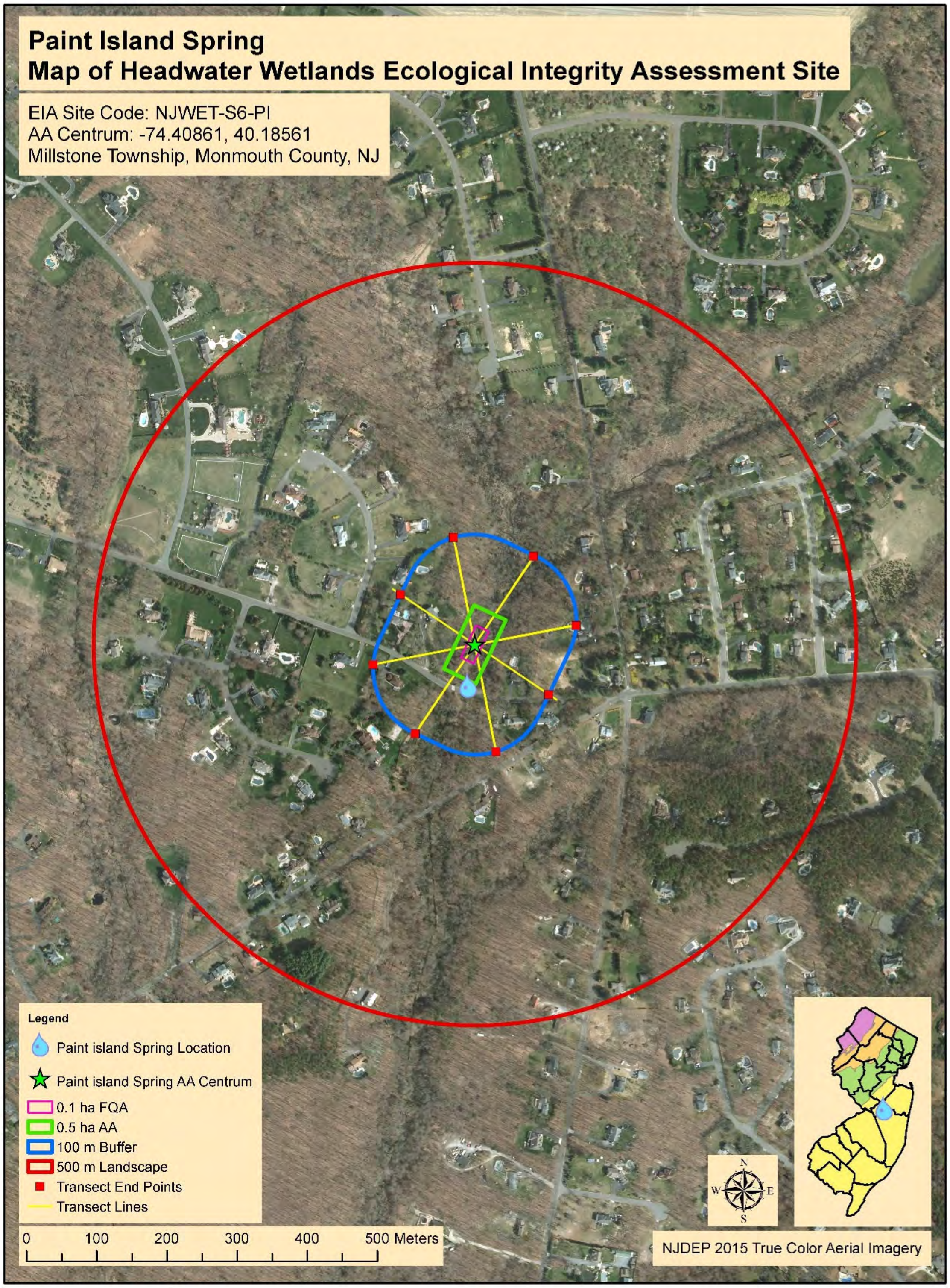


Figure 61. Paint Island Spring, Map of Headwater Wetlands Ecological Integrity Assessment Site (NJWET-S6-PI).

State/Prov: NJ **Site:** Paint Island North of Carrs Tavern
ObsArea Name: Paint Island Spring
Project: NJ Springs **County:** NJ - Monmouth
Observers: Kathleen Walz, Gemma Milly, Jason Beury

ObsArea Code: NJWET-S6-PI
ObsDate: 2015/08/06
Analysis Obs Code: 045NS6PIM

Macrogroup: M504 Laurentian-Acadian-North Atlantic Coastal Flooded & Swamp Forest
Association: CEGL006238 Acer rubrum - Nyssa sylvatica - Magnolia virginiana / Viburnum nudum var. nudum / Osmunda cinnamomea Swamp Forest
General Type:
HGM: Slope
Cowardin: Palustrine (Forested Wetland)

Human Stressors Index (HSI) Scores: *Total:* 13.6 (Very High *Abiotic:* 12.6 (Very High *Onsite:* 5.8 (Medium)
by Major Ecological Factor (MEF): *Buffer:* 31 (Very High *Veg:* 14 (Very High *Soil:* 1 (Low) *Hydro:* 0 (Absent)

Floristic Quality Index (FQI) Scores:
N: 80 *MeanC:* 3.81 *CWMeanC:* 2.83 *FQI:* 34.1

Protocol: NatureServe Wetland 2015

	Wt	Field Rating	Field Pts	Calc Pts	Calc Rating
ECOLOGICAL INTEGRITY				2.46	C+
ECOLOGICAL INTEGRITY + SIZE (EO Rank)					
Rank Factor: LANDSCAPE CONTEXT	0.3			2.09	C+
MEF: LANDSCAPE	0.33			1.50	C-
LAN1. Contiguous Natural Land Cover	1	D	1		
LAN2. Land Use Index	1	C	2		
MEF: BUFFER	0.66			2.38	C+
BUF1. Perimeter with Natural Buffer	n/a	A	4		
BUF2. Width of Natural Buffer	n/a	C	2		
BUF3. Condition of Natural Buffer	n/a	C	2		
BUF4. Contiguous Natural Buffer Cover	n/a				
Rank Factor: CONDITION	0.7			2.62	B-
MEF: VEGETATION	0.55			2.13	C+
VEG1. Native Plant Species Cover	1	C-	1.75		
VEG2. Invasive Nonnative Plant Species Cover	1	D	1		
VEG3. Native Plant Species Composition	1	B	3		
VEG4. Overall Vegetation Structure	1	B	3		
VEG5. Woody Regeneration	1	C	2		
VEG6. Coarse Woody Debris	1	C	2		
MEF: HYDROLOGY	0.35			3.00	B+
HYD1. Water Source	1	B	3		
HYD2. Hydroperiod	1	B	3		
HYD3. Hydrologic Connectivity	1	B	3		
MEF: SOIL	0.1			4.00	A+
SOI1. Soil Condition	1	A	4		
SOI2. Water Quality / Surface Water Turbidity / Pollutants	0.5	A	4		
SOI3. Water Quality / Algal Growth	0.5				
Rank Factor: SIZE	n/a				

Figure 62. Ecological Integrity Assessment Scorecard for Paint Island Spring.

Photographs of Paint Island Spring Wetlands

Figure 63 a. **Figure 63 b**. and **Figure 63 c**. Paint Island Spring Photograph 1: Iron-rich water and muck from source at historic Paint Island Spring on edge of assessment area; Photograph 2: spring fed clear seepage stream swiftly moving over coastal plain quartzite sand bottom; through middle of assessment area; Photograph 3: Vernal water-starwort (*Callitriche vernalis*) in spring seeps. *Photos, K. Strakosh Walz*.

Figure 63 d. Paint Island Spring Photograph 4: Seepage swamp forested wetland with openings in canopy that support a high diversity of herbaceous plants. *Photo, K. Strakosh Walz*.

Shurts Road Spring

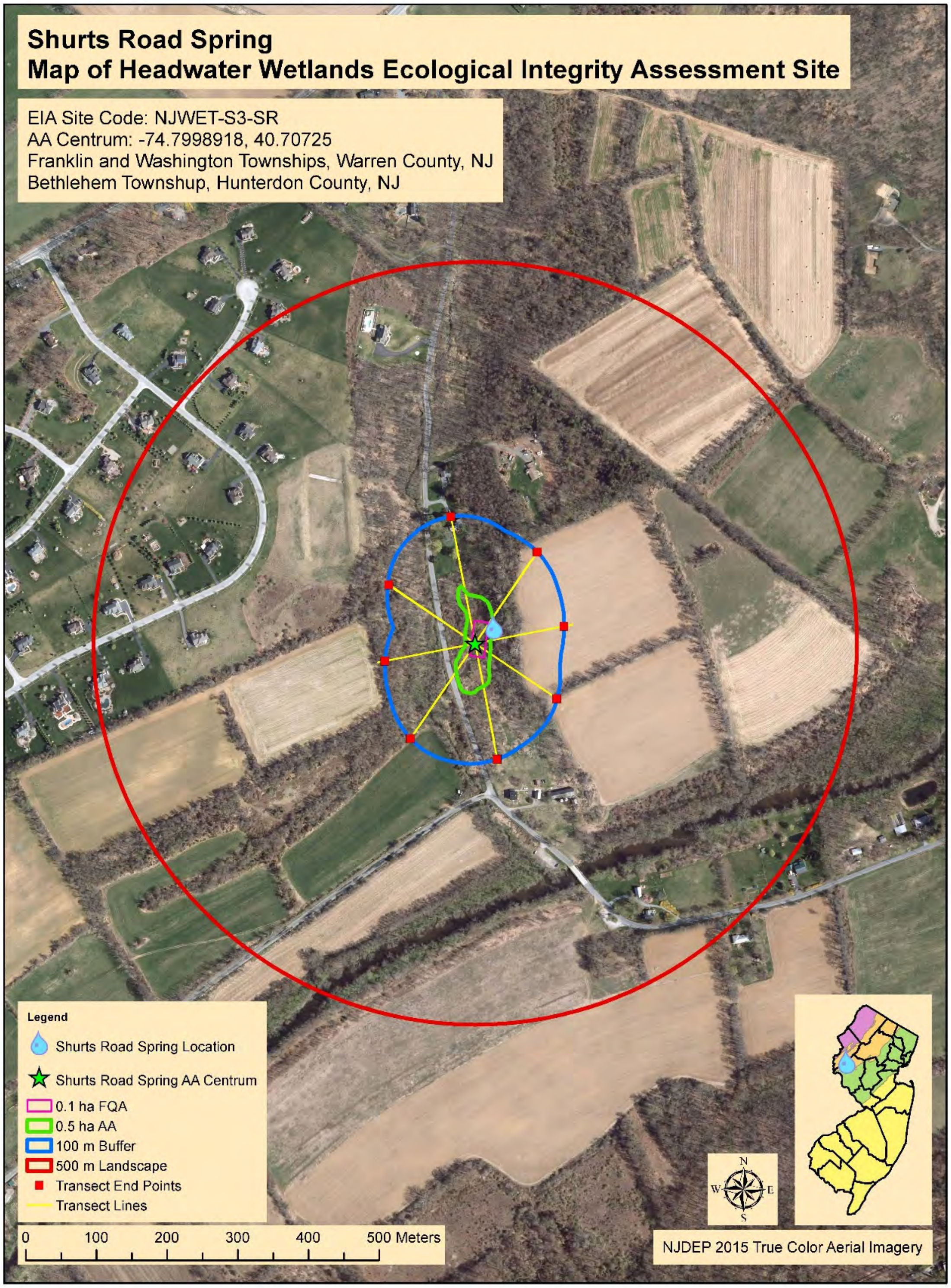


Figure 64. Shurts Road Spring, Map of Headwater Wetlands Ecological Integrity Assessment Site (NJWET-S3-SR).

State/Prov: NJ **Site:** Musconetcong Headwaters at Hampton
ObsArea Code: NJWET-S3-SR
ObsArea Name: Shurts Road Spring
ObsDate: 2015/06/25
Project: NJ Springs **County:** NJ - Warren
Analysis Obs Code: 167NS3SRD
Observers: Kathleen Walz, Gemma Milly, Jason Beury

Macrogroup: M069 Eastern North American Marsh, Wet Meadow & Shrubland
Association: CEGL006576 Cornus (amomum, sericea) - Viburnum dentatum - Rosa multiflora Ruderal Shrub Swamp
General Type:
HGM: Slope
Cowardin: Palustrine (Scrub-Shrub Wetland)

Human Stressors Index (HSI) Scores: *Total:* 10.5 (Very High *Abiotic:* 10 (Very High) *Onsite:* 4 (Medium)
by Major Ecological Factor (MEF): *Buffer:* 25 (Very High *Veg:* 10 (Very High *Soil:* 0 (Absent) *Hydro:* 0 (Absent)

Floristic Quality Index (FQI) Scores:
N: 89 *MeanC:* 3.35 *CWMeanC:* 2.93 *FQI:* 31.59

Protocol: NatureServe Wetland 2015

	Wt	Field Rating	Field Pts	Calc Pts	Calc Rating
ECOLOGICAL INTEGRITY				2.28	C+
ECOLOGICAL INTEGRITY + SIZE (EO Rank)					
Rank Factor: LANDSCAPE CONTEXT	0.3			1.98	C-
MEF: LANDSCAPE	0.33			1.50	C-
LAN1. Contiguous Natural Land Cover	1	D	1		
LAN2. Land Use Index	1	C	2		
MEF: BUFFER	0.66			2.21	C+
BUF1. Perimeter with Natural Buffer	n/a	B	3		
BUF2. Width of Natural Buffer	n/a	C	2		
BUF3. Condition of Natural Buffer	n/a	C	2		
BUF4. Contiguous Natural Buffer Cover	n/a				
Rank Factor: CONDITION	0.7			2.41	C+
MEF: VEGETATION	0.55			1.75	C-
VEG1. Native Plant Species Cover	1	C-	1.75		
VEG2. Invasive Nonnative Plant Species Cover	1	D	1		
VEG3. Native Plant Species Composition	1	C	2		
VEG4. Overall Vegetation Structure	1	D	1		
VEG5. Woody Regeneration	1				
VEG6. Coarse Woody Debris	1	B	3		
MEF: HYDROLOGY	0.35			3.00	B+
HYD1. Water Source	1	B	3		
HYD2. Hydroperiod	1	B	3		
HYD3. Hydrologic Connectivity	1	B	3		
MEF: SOIL	0.1			4.00	A+
SOI1. Soil Condition	1	A	4		
SOI2. Water Quality / Surface Water Turbidity / Pollutants	0.5				
SOI3. Water Quality / Algal Growth	0.5				
Rank Factor: SIZE	n/a				

Figure 65. Ecological Integrity Assessment Scorecard for Shurts Road Spring.

Photographs of Shurts Road Spring Wetlands

Figure 66 a. Shurts Road Spring, spring seepage channel formed by a series of springs that discharge along base of a dolomite cliff and drain to small creek that flows to Musconetcong River. View facing north along east side of EIA Assessment Area. *Photo, K. Strakosh Walz*.

Figure 66 b. and **Figure 66 c**. Shurts Road Spring, dense shrub swamp dominated by non-native invasive shrubs including *Rosa multiflora, Lonicera morrowii, Elaeagnus umbellata*. *Photos, K. Strakosh Walz*.

Spring Brook Cabin Spring

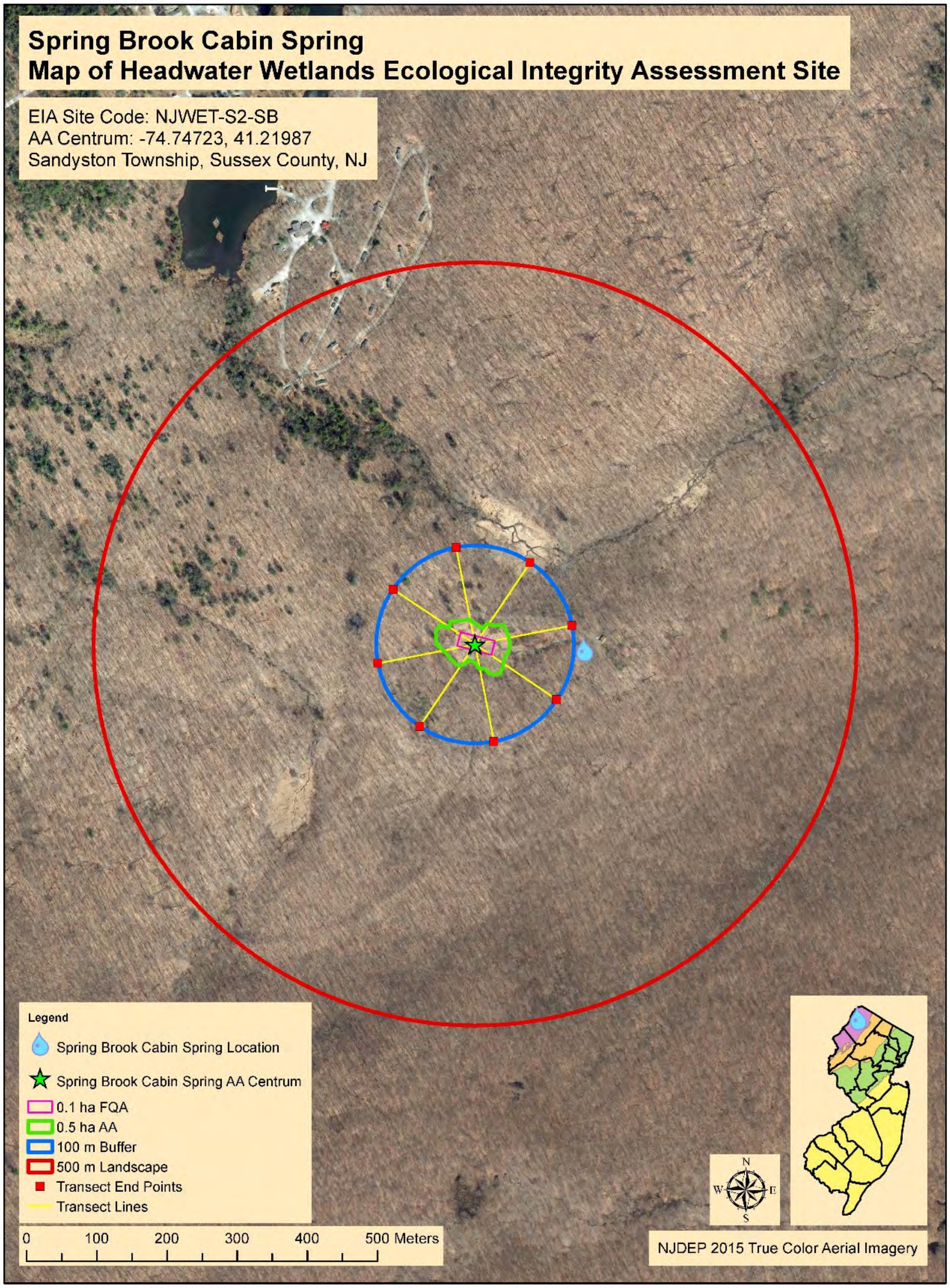


Figure 67. Spring Brook Cabin Spring (Stokes SF), Map of Headwater Wetlands Ecological Integrity Assessment (NJWET-S2-SB).

State/Prov: NJ **Site:** Stokes Spring Cabin **ObsArea Code:** NJWET-S2-SB
ObsArea Name: Spring Brook at Stokes SF **ObsDate:** 2015/06/17
Project: NJ Springs **County:** NJ - Sussex **Analysis Obs Code:** 771NS2SBD
Observers: Kathleen Walz

Macrogroup:	M069 Eastern North American Marsh, Wet Meadow & Shrubland
Association:	CEGL006412 Carex stricta - Carex vesicaria Wet Meadow
General Type:	
HGM:	Slope
Cowardin:	Palustrine (Emergent Wetland)

Human Stressors Index (HSI) Scores: *Total:* 3.9 (Low) *Abiotic:* 4.4 (Medium) *Onsite:* 0.8 (Absent)
by Major Ecological Factor (MEF): *Buffer:* 11 (Very High *Veg:* 2 (Low) *Soil:* 0 (Absent) *Hydro:* 0 (Absent)

Floristic Quality Index (FQI) Scores:
N: 75 *MeanC:* 4.56 *CWMeanC:* 4.83 *FQI:* 39.49

Protocol: NatureServe Wetland 2015	**Wt**	**Field Rating**	**Field Pts**	**Calc Pts**	**Calc Rating**
ECOLOGICAL INTEGRITY				3.49	B+
ECOLOGICAL INTEGRITY + SIZE (EO Rank)					
Rank Factor: LANDSCAPE CONTEXT	0.3			3.64	A-
MEF: LANDSCAPE	0.33			4.00	A+
LAN1. Contiguous Natural Land Cover	1	A	4		
LAN2. Land Use Index	1	A	4		
MEF: BUFFER	0.66			3.46	B+
BUF1. Perimeter with Natural Buffer	n/a	A	4		
BUF2. Width of Natural Buffer	n/a	A	4		
BUF3. Condition of Natural Buffer	n/a	B	3		
BUF4. Contiguous Natural Buffer Cover	n/a				
Rank Factor: CONDITION	0.7			3.42	B+
MEF: VEGETATION	0.55			2.95	B-
VEG1. Native Plant Species Cover	1	C-	1.75		
VEG2. Invasive Nonnative Plant Species Cover	1	D	1		
VEG3. Native Plant Species Composition	1	A	4		
VEG4. Overall Vegetation Structure	1	A	4		
VEG5. Woody Regeneration	1	A	4		
VEG6. Coarse Woody Debris	1				
MEF: HYDROLOGY	0.35			4.00	A+
HYD1. Water Source	1	A	4		
HYD2. Hydroperiod	1	A	4		
HYD3. Hydrologic Connectivity	1	A	4		
MEF: SOIL	0.1			4.00	A+
SOI1. Soil Condition	1	A	4		
SOI2. Water Quality / Surface Water Turbidity / Pollutants	0.5	A	4		
SOI3. Water Quality / Algal Growth	0.5	A	4		
Rank Factor: SIZE	n/a				

Figure 68. Ecological Integrity Assessment Scorecard for Spring Brook Cabin Spring.

Photographs of Spring Brook Cabin Spring Wetlands

Figure 69 a. Spring Brook Cabin Spring at its source, with abundant native vernal water-starwort (*Callitriche vernalis)* and non-native watercress (*Nasturtium officinale*) located just east and outside the EIA Buffer. *Photo, K. Strakosh Walz*.

Figure 69 b. Spring Brook Cabin Spring seep stream in EIA with high diversity of herbaceous species particularly sedges. Evidence of prior beaver activity. *Photo, K. Strakosh Walz*.

Valley Crest Spring

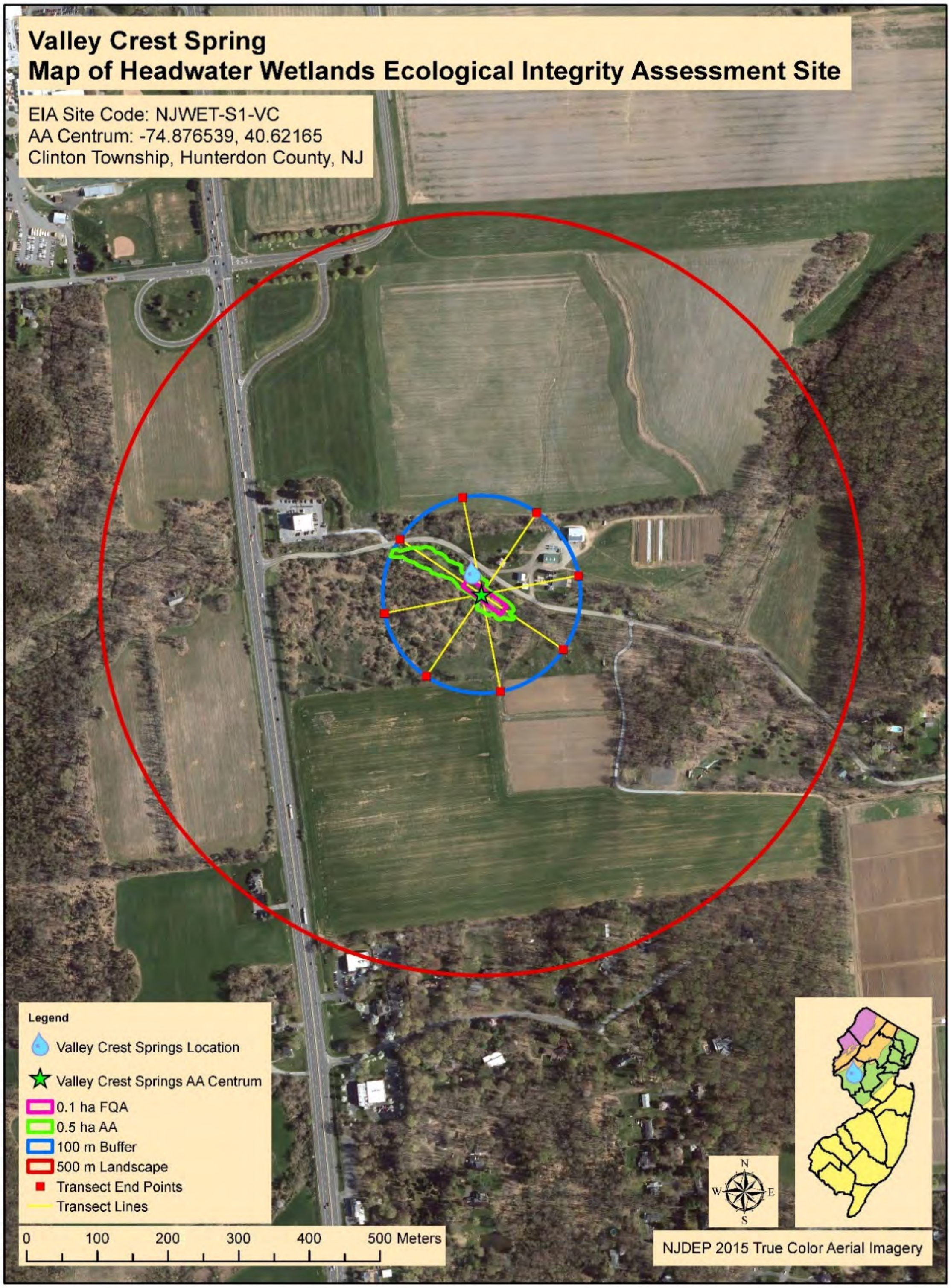


Figure 70. Valley Crest Spring, Map of Headwater Wetlands Ecological Integrity Assessment (NJWET-S1-VC)

State/Prov: NJ **Site:** Cramers Creek Clinton
ObsArea Name: Valley Crest Spring
Project: NJ Springs **County:** NJ - Hunterdon
Observers: Kathleen Walz, Gemma Milly

ObsArea Code: NJWET-S1-VC
ObsDate: 2015/06/10
Analysis Obs Code: 771NS1VCR

Macrogroup: M069 Eastern North American Marsh, Wet Meadow & Shrubland
Association: CEGL006412 Carex stricta - Carex vesicaria Wet Meadow
General Type:
HGM: Slope - Topographic
Cowardin: Palustrine (Emergent Wetland)

Human Stressors Index (HSI) Scores: *Total:* 7.9 (High) *Abiotic:* 8.6 (High) *Onsite:* 2.6 (Low)
by Major Ecological Factor (MEF): *Buffer:* 20 (Very High *Veg:* 5 (Medium) *Soil:* 1 (Low) *Hydro:* 1 (Low)

Floristic Quality Index (FQI) Scores:
N: 57 *MeanC:* 2.47 *CWMeanC:* 2.4 *FQI:* 18.68

Protocol: NatureServe Wetland 2015

	Wt	Field Rating	Field Pts	Calc Pts	Calc Rating
ECOLOGICAL INTEGRITY				2.48	C+
ECOLOGICAL INTEGRITY + SIZE (EO Rank)					
Rank Factor: LANDSCAPE CONTEXT	0.3			1.28	D
MEF: LANDSCAPE	0.33			1.00	D
LAN1. Contiguous Natural Land Cover	1	D	1		
LAN2. Land Use Index	1	D	1		
MEF: BUFFER	0.66			1.41	D
BUF1. Perimeter with Natural Buffer	n/a	C	2		
BUF2. Width of Natural Buffer	n/a	C	2		
BUF3. Condition of Natural Buffer	n/a	D	1		
BUF4. Contiguous Natural Buffer Cover	n/a				
Rank Factor: CONDITION	0.7			2.99	B-
MEF: VEGETATION	0.55			2.80	B-
VEG1. Native Plant Species Cover	1	C+	2.25		
VEG2. Invasive Nonnative Plant Species Cover	1	C-	1.75		
VEG3. Native Plant Species Composition	1	C	2		
VEG4. Overall Vegetation Structure	1	A	4		
VEG5. Woody Regeneration	1				
VEG6. Coarse Woody Debris	1	A	4		
MEF: HYDROLOGY	0.35			3.00	B+
HYD1. Water Source	1	B	3		
HYD2. Hydroperiod	1	B	3		
HYD3. Hydrologic Connectivity	1	B	3		
MEF: SOIL	0.1			4.00	A+
SOI1. Soil Condition	1	A	4		
SOI2. Water Quality / Surface Water Turbidity / Pollutants	0.5	A	4		
SOI3. Water Quality / Algal Growth	0.5	A	4		
Rank Factor: SIZE	n/a				

Figure 71. Ecological Integrity Assessment Scorecard for Valley Crest Spring.

Photographs of Valley Crest Spring Wetlands

Figure 72 a. Valley Crest Spring open herbaceous wet meadow with groundwater seepage flowing from spring's upslope as well as from both sides of meadow. *Photo, K. Strakosh Walz*.

Figure 72 b. and **Figure 72 c**. Valley Crest Spring seepage channel on south side of site flowing west towards spring house on northwest end of EIA Assessment Area. *Photos, K. Strakosh Walz*.

MACROINVERTEBRATE ASSEMBLAGES IN SELECTED NEW JERSEY SPRINGS,

by Yaritza Acosta Caraballo and Meiyin Wu

Introduction

Springs are often very diverse aquatic systems that have important ecological functions and host a variety of biota (Hoffsten and Malmqvist, 2000). They create important terrestrial and aquatic ecotones, which increase the regional biodiversity of freshwater systems (Boulton, 2005). Among all aquatic taxa, macroinvertebrates are important in aquatic ecosystems via affecting food webs, nutrient cycling, decomposition, and primary productivity (Wallace and Webster 1996). They serve as bioindicators in aquatic systems due to some species being sensitive to pollution (Ilmonen and Paasivirta, 2005). Spring aquatic macroinvertebrate communities are unlikely to adapt to quickly changing environments due to the constant habitat conditions present in springs (Ilmonen and Paasivirta, 2005). Unfortunately, the recent trend of increasing urbanization and habitat degradation has led to decreasing spring biodiversity around the world (Ilmonen and Paasivirta, 2005). There is no published study on macroinvertebrates in springs of New Jersey. Documenting macroinvertebrate composition and biodiversity in New Jersey springs serves as a baseline for future monitoring of spring waters. The objective of this study is to examine macroinvertebrate assemblages of New Jersey springs.

Methods

Macroinvertebrate assemblages of seven springs in New Jersey were studied from August 2014 to March 2015 (fig. 73). Depending on the environment of each site, samples were collected with a Hess sampler (lotic; Wildco; 33.02 centimeter diameter; 243 micromeer mesh size) or an Ekman dredge (lentic) based on the USEPA protocol: Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, Benthic Macroinvertebrates and Fish (Barbour and others, 1999). In springbrook environments, macroinvertebrates were collected from six transects which were distributed evenly along the total sample length. The total sample length was calculated by measuring the spring depth and multiplying the depth by 40 times. Macroinvertebrate samples were collected by alternating to the left, right and center of the springbrook. Infaunal organisms were sampled by manually disturbing the substrates and sediments. All six samples, one per transect, within a spring site were composited into one sample. Large predators were separated on site before preservation. The composite samples were immediately preserved with 95 percent ethanol and then transported back to Montclair State University laboratories for further processing and identification.

Aquatic macroinvertebrate specimens were identified to the lowest taxonomic level possible using identification keys including Merritt & Cummins (1996) and Holsinger (1972). Some taxa, such as Oligochaeta, Chironomidae, and Asellidae, were only identified to the taxonomic rank of family. Empty snail shells, exuviae, insect pupae, terrestrial invertebrates, caddisfly cases, aerial adult insects, and body fragments were excluded from macroinvertebrate counts.

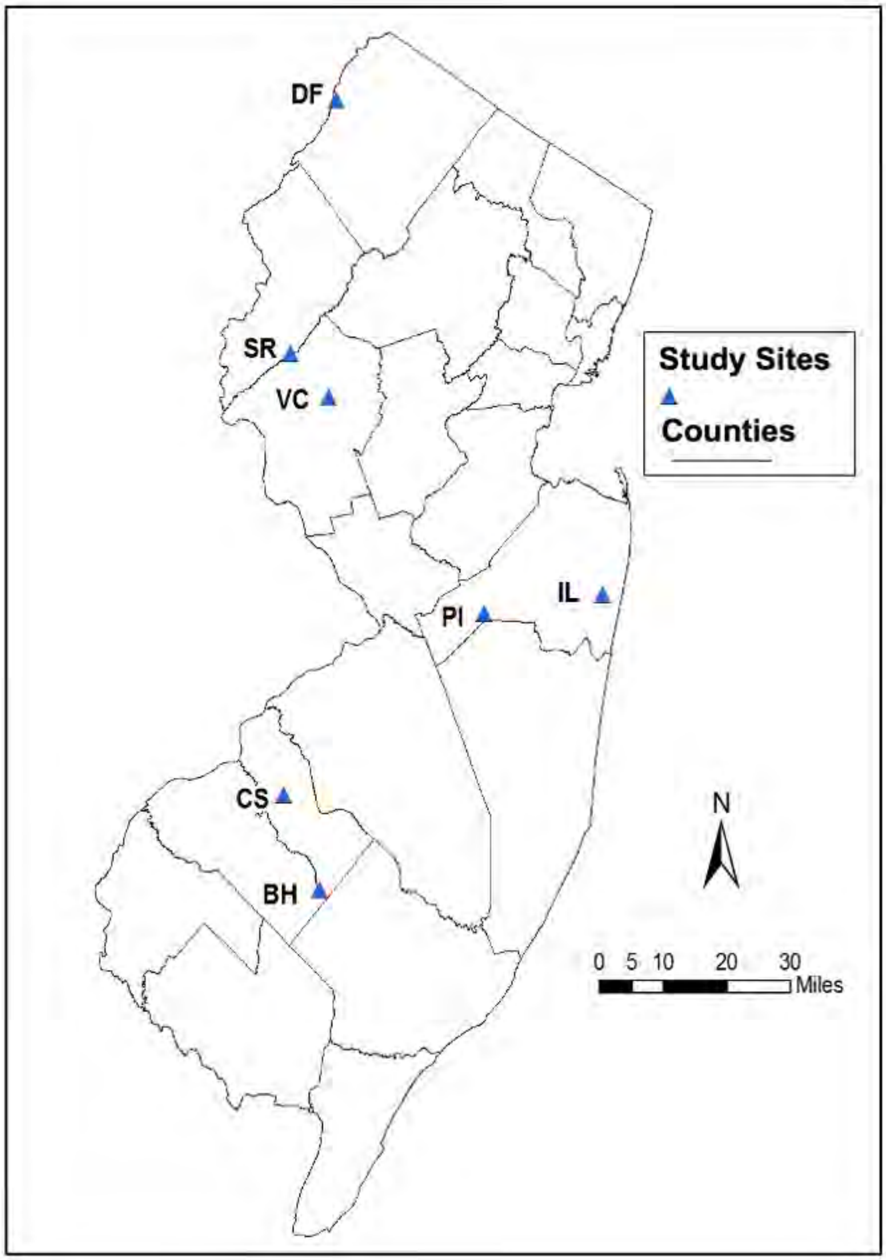


Figure 73. Map of the location of the seven New Jersey springs sites. Dingman's Ferry (DF), Shurts Road (SR), Valley Crest (VC), Indian Lady Hill (IL), Paint Island (PI), Crystal Spring (CS), and Blue Hole-Inskeep (BH).

Functional feeding groups (FFG) and Pollution tolerance values (PTV) were assigned for taxa according to the NJDEP "Master Bug List" (NJDEP, 2020), and the New York State Department of Environmental Conservation (NYSDEC) "Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State" (NJDEP Bureau of Freshwater and Biological

Monitoring; NYSDEC, 2012). The NJDEP staff in the Bureau of Freshwater and Biological Monitoring verified all samples.

For this study, a total of nine metrics were analyzed for each spring site in order to evaluate spring macroinvertebrate assemblages as well as water quality conditions including taxa richness, Mean Pollution Tolerance Values (MPTV), Ephemeroptera, Plecoptera and Tricoptera (EPT) richness, percent EPT, percent non-insect, percent Chironomidae, composition of functional feeding groups, Shannon Wiener Index of Biodiversity (SWIB), and Hielsenhoff Biotic Index (HBI). SWIB values are used to compare species diversity between communities in multiple locations. The HBI was calculated to quantify the tolerance of benthic macroinvertebrate assemblages to nutrient enrichment (Hilsenhoff 1982). HBI values can range from 0 to 10; values close to 0 indicate low organic pollution present while values close to 10 indicate high organic pollution.

Hilsenhoff Biotic Index Calculations

HBI scores were calculated using the total number of individuals per taxa multiplied by their tolerance value. Then each taxa product is summed and divided by a number of organisms in a sample. A score is produced based on the overall tolerance of the community in the sample (Hilsenhoff, 1982).

$$HBI = \text{sum} \frac{(n)(a)}{N}$$

Where: n= number of individuals in each taxon
a= tolerance value of taxon
N= total number of organisms in a sample

Results

Aquatic macroinvertebrates were collected in summer and fall 2014, and spring, summer, and fall 2015 from all seven spring sites, which encompassed 105 taxa in 17 different orders (Appendix E). Most aquatic macroinvertebrates collected were juveniles (80%). In contrast, a lesser percentage of aquatic macroinvertebrates were adults (20%), comprised mainly of arthropods such as amphipods, coleopterans, and isopods. No single genus or species was found at all seven sites. Only one family, the non-biting midges (Chironomidae), and one class, the aquatic worms (Oligochaeta), were found in all spring sites. The highest number of individuals found was Diptera (975; 40.9%), followed by Amphipoda (484; 20.3%) and Coleoptera (372; 15.61%). Bivalvia, Collembolla, Tricladia, Decapoda, Plecoptera, Ephemeroptera, Platyhelmynthes, Gastropoda, Hemiptera, Odonata, Isopoda, and Megaloptera were least abundant and each occupied less than two percent of the community. *Gammarus fasciatus* (PTV6) and *Caecidotea* sp. (PTV8) were the most commonly observed taxa found in three out of the seven sites. *Gammarus fasciatus* inhabits cold, well-oxygenated areas and in some sites made up 50% of the taxa present (NJDEP, 2012). The *Caecidotea* spp., which are a part of the Asellidae family, are known to live in springs and can survive in polluted systems with low oxygen conditions (NJDEP, 2012).

Two taxa were observed that were not keyed in the NJDEP reference list: Neoplasta sp. and Cecidomyiidae. The Neoplasta sp. was found in Dingman's Ferry (DF) spring during the summer 2014. This species forms a part of the family Empididae, also known as the dagger flies, and has not previously been documented in New Jersey. It is, however, present in the state of New York and has been documented in the New York State Department of Environmental Conservation (NYSDEC) reference list (NYSDEC, 2012). The Cecidomyiidae taxon was present in Paint Island (PI) spring during summer 2014. This family of gall midges has been found on the east coast of the United States in both New Jersey and New York but is not currently on either the NJDEP or NYSDEC reference list (Gagné, 2010). There is very limited information available on the gall midges. Ephemeroptera was rarely seen in all spring sites, which may be attributed to its observed poor adaptation to spring habitats (Erman, 1998). Lastly, it is important to note that the family Crangonyctidae found in Dingman's Ferry Spring represents epigean amphipods that have no observable eyes. This characteristic can be attributed to the emergence of the spring from a small cave.

Biotic Index Results

HBI mean values among all sites ranged from 3.7 to 7.3 (Table 15). The lowest mean value for MPTV was 3.8 and the highest mean value was 6.9. SWIB results showed mean ranges from 1.3 to 2.0. %Chironomidae mean values ranged from 3.6 to 48.8. The lowest mean value for %Non-Insect was 5.6 and the highest mean value was 62.6. %EPT results showed mean ranges from 0.0 to 41.6. EPT Richness mean values ranged from 0.0 to 14.5. The lowest mean value for taxa richness was 6.3 and the highest mean value was 18.5.

Shurts Road Spring. The dominant orders in Shurts Road (SR) spring were Amphipoda (47.4%) and Coleoptera (24.1%). The most abundant species was freshwater shrimp (43.1%), which prefers cold, well-oxygenated areas. Three taxa with a PTV of 1 were found in SR, the little brown sedge caddisfly, *Lepisostoma* spp., the green sedges *Rhyacophila* spp., and mayfly genus *Ephemerella*. SR exhibits the third highest total number of taxa among all seven spring sites (fig. 74). SR was found to house low percent of Chironomidae (1.0%) and has the second lowest HBI result (4.82).

Table 15. Results of metrics calculated for each spring site in summer 2014 (S1), fall 2014 (F1), spring 2015 (P1), summer 2015 (S2), and fall 2015 (F2) including mean values and standard deviation (SD). Data is not available for Valley Crest Spring in fall 2014 (F) since it was dry. Data is not available for Blue Hole-Inskeep Spring in summer 2015 (S2) and fall 2015 (F2). SR=Shurts Road Spring, CA=Crystal Spring, VC=Valley Crest Spring, DF=Dingmans Ferry Spring, IL=Indian Lady Hill Spring, PI= Paint Island Spring, BH=Blue Hole-Inskeep.

		HBI	MPTV	SWIB	%Chir.	%Non-Ins	%EPT	EPT Rich.	Taxa Rich
	S1	5.2	5.8	1.5	1.0	47.9	9.3	2.0	12.0
	F1	5.1	5.1	1.8	4.9	51.9	20.5	4.0	12.0
	P1	4.8	4.5	1.7	1.9	49.5	21.7	4.0	12.0
	S2	5.6	5.5	1.7	9.0	54.0	13.0	3.0	12.0
	P2	5.3	4.1	1.3	1.0	61.0	16.0	4.0	9.0
SR	Mean± SD	5.2 ± 0.3	5.0 ± 0.7	1.6 ± 0.2	3.6 ± 3.4	52.9 ± 5.1	16.1 ± 5.2	3.4 ± 0.9	11.4 ± 1.3
	S1	6.4	6.6	1.6	11.0	81.0	0.0	0.0	12.0
	F1	6.1	6.2	1.2	46.0	24.5	0.0	0.0	5.0
	P1	6.0	5.8	1.0	57.0	35.0	0.0	0.0	5.0
	S2	6.0	6.7	1.2	11.0	85.0	0.0	0.0	7.0
	P2	6.2	5.3	1.3	55.2	26.0	2.1	2.0	8.0
CS	Mean± SD	6.1 ± 0.2	6.1 ± 0.6	1.3 ± 0.2	36.1 ±23.3	50.3 ±30.1	0.4 ± 0.9	0.4± 0.9	7.4 ± 2.9
	S1	5.9	5.7	2.2	43.0	19.3	10.7	3.0	23.0
	F1	4.8	4.2	1.8	50.0	7.0	24.0	5.0	14.0
VC	Mean± SD	5.4 ± 0.7	4.9 ± 1.0	2.0 ± 0.3	13.2 ± 8.7	46.5 ± 4.9	17.4 ± 9.4	14.5 ± 13.4	18.5 ± 6.4
	S1	5.1	4.1	1.4	67.7	8.6	13.9	6.0	16.0
	F1	4.6	3.7	1.4	55.5	23.2	19.1	4.0	10.0
	P1	3.8	3.8	1.9	34.3	21.8	40.6	6.0	14.0
	S2	2.2	3.3	2.0	18.0	9.0	62.0	7.0	12.0
	P2	2.7	3.9	1.7	13.0	12.0	72.0	7.0	13.0
DF	Mean± SD	3.7 ± 1.3	3.8 ± 0.3	1.7 ± 0.3	37.7 ± 23.6	14.9 ± 7.1	41.6 ± 25.5	6.0 ± 1.2	13.0 ± 2.2
	S1	5.7	3.8	1.3	53.0	12.0	2.0	2.0	9.0
	F1	5.9	6.0	1.4	62.0	3.0	4.0	2.0	11.0
	P1	5.9	6.0	1.5	50.5	14.1	7.0	2.0	9.0
	S2	6.1	4.6	1.3	45.7	4.4	7.6	2.0	8.0
	P2	5.8	4.7	1.4	33.0	1.0	6.0	2.0	9.0
IL	Mean± SD	5.9 ± 0.1	5.0 ± 1.0	1.4 ± 0.1	48.8 ± 10.7	6.9 ± 5.8	5.3 ± 2.3	2.0 ± 0.0	9.2 ± 1.1
	S1	5.9	5.6	2.0	25.5	9.3	0.0	0.0	10.0
	F1	4.9	5.1	1.9	1.9	1.9	0.0	0.0	11.0
	P1	6.7	6.0	1.3	4.5	9.0	0.0	0.0	7.0
	S2	5.8	5.3	1.9	7.5	7.5	0.0	0.0	9.0
	P2	5.9	5.3	1.7	8.9	0.0	0.0	0.0	8.0
PI	Mean± SD	5.9 ± 0.6	5.5 ± 0.3	1.8 ± 0.1	9.7 ± 9.3	5.6 ± 4.3	0.0 ± 0.0	0.0 ± 0.0	9.0 ± 1.1
	S1	7.40	7.33	10.4	20.69	79.31	0.00	0.0 ± 0.0	3.00
	F1	7.48	6.86	1.57	24.39	53.66	2.44	0.00	7.00
	P1	7.12	6.44	1.30	31.51	54.79	5.48	1.00	9.00
BH	Mean± SD	7.3± 0.2	6.9± 0.4	1.3± 0.3	25.5± 5.5	62.6± 14.5	2.6± 2.7	1.0± 1.0	6.3±3.1

Crystal Spring (CS). Amphipoda (38.0%) and Diptera (48.8%) dominated macroinvertebrate assemblages in CS. CS had low EPT species present (20.8%) and a high percent Non-Insect value of 85.0% (fig. 75 and 77). Shannon Wiener Index of Biodiversity results showed that this site had the lowest value at 1.02. The HBI value for CS was the second highest site at 6.41 and MPTV value was 6.71 (out of 10).

Figure 74. Total number of taxa results for seven spring sites in August 2014 (S1), October 2014 (F1), April 2015 (P1), August 2015 (S2), and October 2015 (F2). Valley Crest (VC) was dry in October 2014 (F1). Data is not available for Blue Hole-Inskeep (BH) in summer 2015 (S2) and fall 2015 (F2).

Valley Crest (VC). Diptera (56.9%) and Coleoptera (11.4%) dominated macroinvertebrate assemblages in VC. Good water quality indicator species were present in VC including the combmouth minnow mayfly (*Ameletus* sp.), which has a pollution tolerance value (PTV) of 0. Two other taxa found in VC, *Stylogomphus* spp. (Gomphidae) and *Rhyacophila* spp. (Trichoptera), have a PTV of 1. The highest number of taxa per site was observed in VC (fig. 74) with a total of 23. The percentage of EPT was the second highest at VC (fig. 76), and the percentage of Chironomidae was the third highest at VC. VC also had the third lowest value of percent non-insect at 7%. The above results were based on the data collection of three seasons only. Samples were not collected during Fall 2014, and Summer and Fall 2015 due to low water quantity.

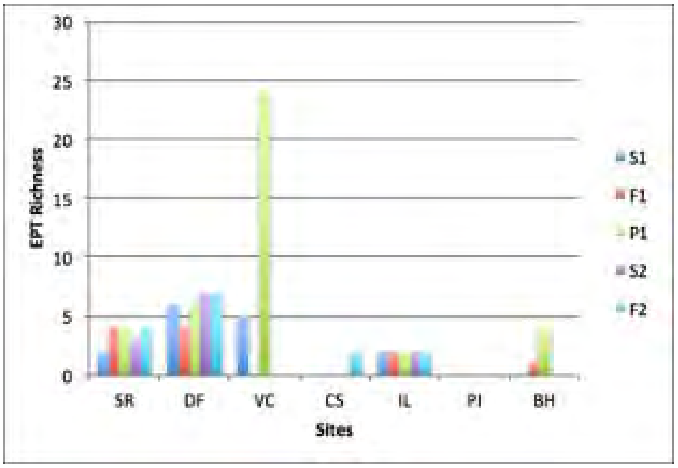


Figure 75. EPT Richness results for seven spring sites in August 2014 (S1), October 2014 (F1), April 2015 (P1), August 2015 (S2), and October 2015 (F2). VC was dry in October 2014 (F1). Data is not available for BH in summer 2015 (S2) and fall 2015 (F2).

Dingman's Ferry (DF). Diptera (42%) and Trichoptera (23.6%) were the dominant orders in DF. Three water pollution sensitive taxa (PTV of 0) were observed in DF: the cassifly genus *Parapsyche*, the needleflies, genus *Lecutra*, and the free-living caddisfly family Rhyacophilidae. DF had the second highest taxa richness of 16. The taxa richness of EPT species were also the highest at DF (7). SWIB results showed that DF had the highest biodiversity index value among study sites at 1.99 (fig. 81). HBI results were the lowest of all sites at DF at 2.15. MPTV values were the lowest in DF at 3.33.

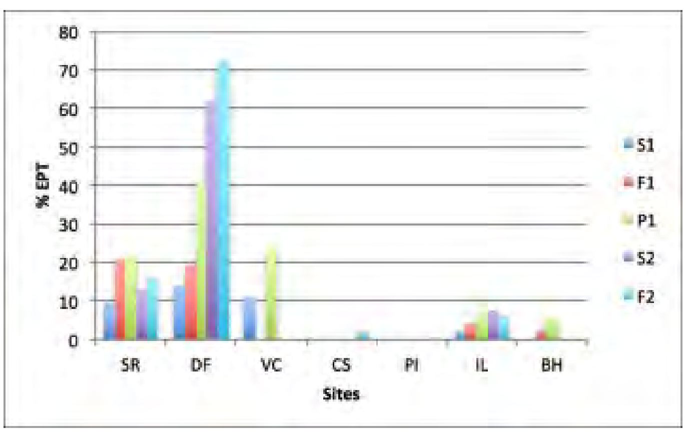


Figure 76. Percent EPT results for seven spring sites in August 2014 (S1), October 2014 (F1), April 2015 (P1), August 2015 (S2), and October 2015 (F2). VC was dry in October 2014 (F1). Data is not available for BH in summer 2015 (S2) and fall 2015 (F2).

Indian Lady Hill (IL). The most abundant macroinvertebrate orders in IL were Diptera (57.1%) and Coleoptera (29.7%). A large number of species favoring habitats with slow moving water and abundance of detritus were present in IL, such as deer fly larvae (*Chrysops* spp.), fishflies (Chauliodes), dragonfly nymph (*Somatochlora* spp.), and predaceous diving beetles (Dysticidae). Individuals from the isopod genus *Caecidotea* were observed to be brooding in summer 2014 and spring 2015. IL was found to exhibit a low taxa richness of 8 and a low EPT richness of 2. Percent Chironomidae average values were the greatest in ILH at 62% (fig. 78).

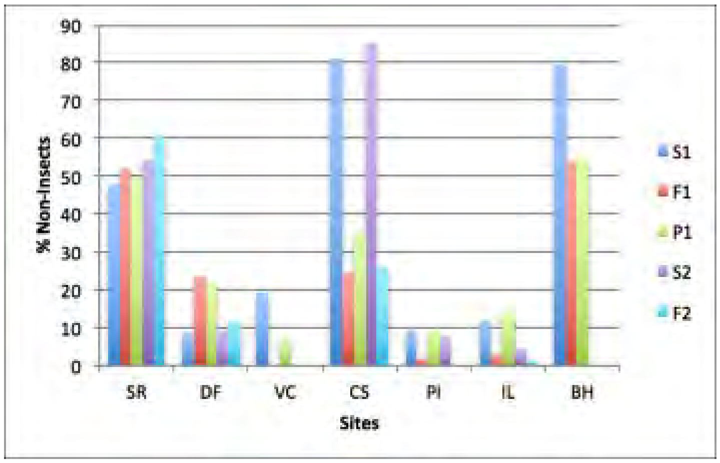


Figure 77. Percent non-insects results for seven spring sites in August 2014 (S1), October 2014 (F1), April 2015 (P1), August 2015 (S2), and October 2015 (F2). VC was dry in October 2014 (F1). Data is not available for BH in summer 2015 (S2) and fall 2015 (F2).

Paint Island (PI). The dominant orders in PI spring were Diptera (47.6%) and Coleoptera (37%). Most of the macroinvertebrates that inhabit PI spring were wetland species that live in stagnant water, such as phantom crane flies (*Bittacomorpha* spp.) and marsh beetles (Scirtidae). Others include fishflies (*Chauliodes* spp.) that live in habitats where decaying logs are present (Arnold and Drew 1987). PI had the second lowest taxa richness of 7 and with no EPT species present. Percent Chironomidae (2%) and percent non-insect (0.0%) values were the lowest at this site. The highest HBI score was observed in PI at 6.73.

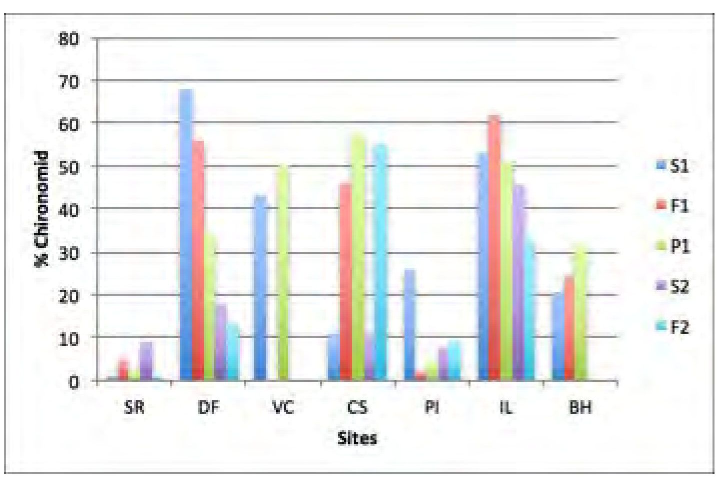


Figure 78. Percent Chironomidae results for seven spring sites in August 2014 (S1), October 2014 (F1), April 2015 (P1), August 2015 (S2), and October 2015 (F2). VC was dry in October 2014 (F1). Data is not available for BH in summer 2015 (S2) and fall 2015 (F2).

Blue Hole-Inskeep (BH). Isopoda and Chironomidae dominated Blue Hole-Inskeep (BH) spring. There was also numerous water boatman (Corixidae) present that are common in lentic environments. BH and had low taxa richness at 6.33. Low taxa richness indicates that this site was greatly disturbed. There were no EPT species present at BH while percent Non-Insect (62.59%) and MPTV (6.88) values were high at BH (fig. 80). HBI results was 7.40, which indicate that the degree of organic pollution is probably very high (fig. 81).

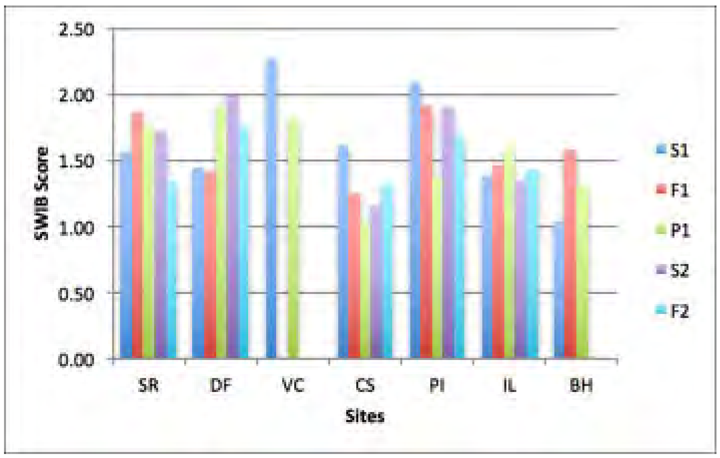


Figure 79. Shannon Wiener Index of Biodiversity results for seven spring sites in August 2014 (S1), October 2014 (F1), April 2015 (P1), August 2015 (S2), and October 2015 (F2). VC was dry in October 2014 (F1). Data is not available for BH in summer 2015 (S2) and fall 2015 (F2).

Index Results

Results showed that CS, IL BH, and PI, had lower EPT Richness, percent EPT, and taxa richness than SR and DF. Similarly, CS, IL, BH, and PI showed lower taxa richness than VC. IL and PI have similar biotic metrics results with low taxa richness, low EPT, and high HBI values. Functional Feeding Groups (FFG) results showed that CS had the lowest number of FFGs present, which suggests poor water quality since the system is not able to support a diverse community. Collector gatherers were most abundant at CS (84.7%) and the least abundant at ILH (4.5%). The dominance of collector gatherers suggests high presence of Fine Particulate Organic Matter (FPOM), which is characteristic of low discharge systems (Vannote and others, 1980). Low percentage of shredders observed in CS and PI could be related to the low availability of Coarse Particulate Organic Matter (CPOM), associated with their low discharge (Bisson and Bilby 1998).

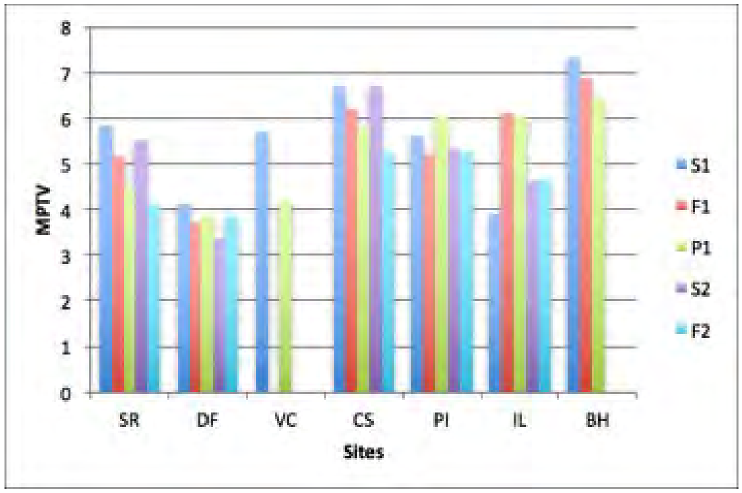


Figure 80. Mean pollution tolerance value results for seven spring sites in August 2014 (S1), October 2014 (F1), April 2015 (P1), August 2015 (S2), and October 2015 (F2). VC was dry in October 2014 (F1). Data is not available for BH in summer 2015 (S2) and fall 2015 (F2).

SR and DF were found to have high pollution sensitive species and taxa richness. Additionally, SR and DF had lower MPTV, HBI than CS, IL, and PI. FFG results showed that SR, DF, and VC had all six FFGs present in all seasons (fig. 82- 86). The presence of multiple FFGs suggests good water quality since the system can support a diverse community. Shredders were most abundant at DF (43.0%) and SR (10.7%) while CS and PI had no shredders present (fig. 82-86). High presence of shredders indicated the availability of CPOM, which is characteristic of high discharge forested systems and 3rd discharge magnitude springs (Vannote and others, 1980).

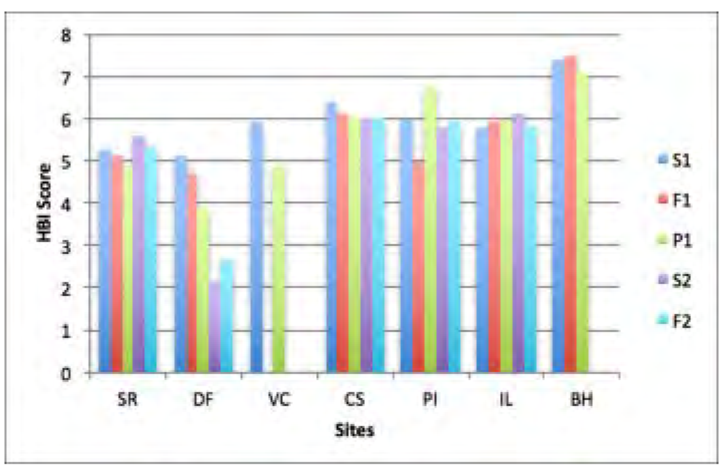


Figure 81. Hilsenhoff biotic index results for seven spring sites in August 2014 (S1), October 2014 (F1), April 2015 (P1), August 2015 (S2), and October 2015 (F2). VC was dry in October 2014 (F1). Data is not available for BH in summer 2015 (S2) and fall 2015 (F2).

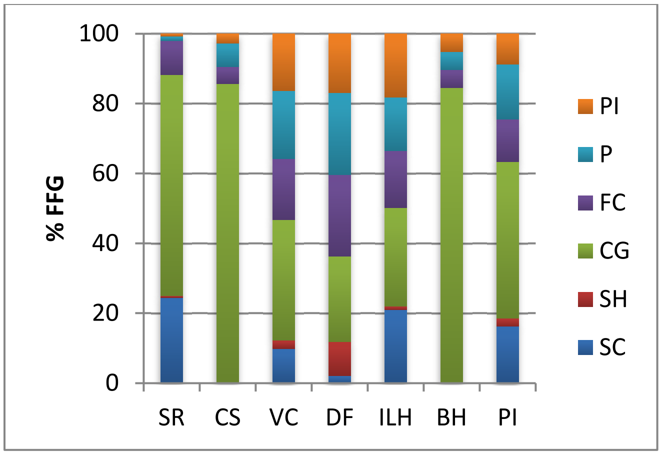


Figure 82. Functional feeding group (FFG) composition for spring sites in summer 2014 (GC= gatherer/collector; FC= filter/collector; SC= scraper; SH= shredder; PI= piercer; P= predator).

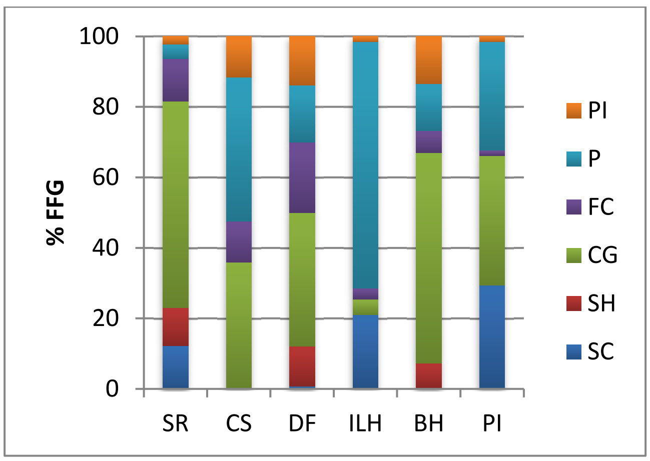


Figure 83. Functional feeding group (FFG) composition for spring sites in fall 2014 (GC= gatherer/collector; FC= filter/collector; SC= scraper; SH= shredder; PI= piercer; P= predator). VC was dry in October 2014 (F1).

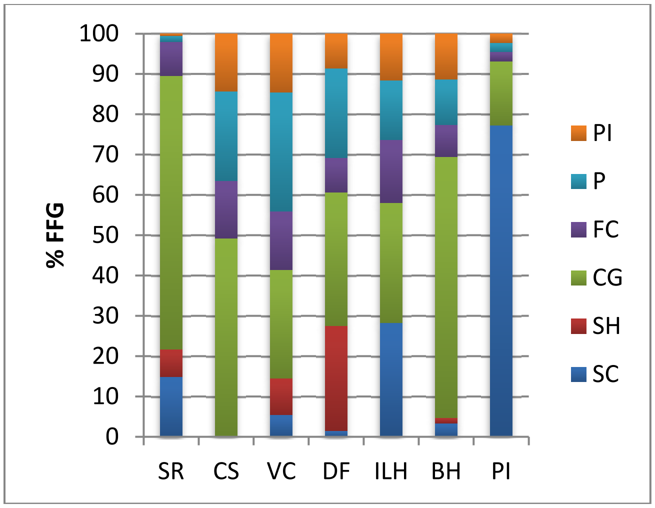


Figure 84. Functional feeding group (FFG) composition for spring sites in spring 2015 (GC= gatherer/collector; FC= filter/collector; SC= scraper; SH= shredder; PI= piercer; P= predator).

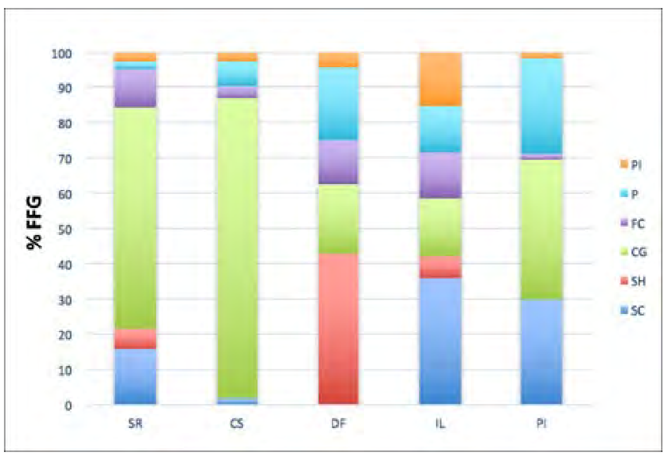


Figure 85. Functional feeding group (FFG) composition for spring sites in summer 2015 (GC= gatherer/collector; FC= filter/collector; SC= scraper; SH= shredder; PI= piercer; P= predator). Data is not available for BH.

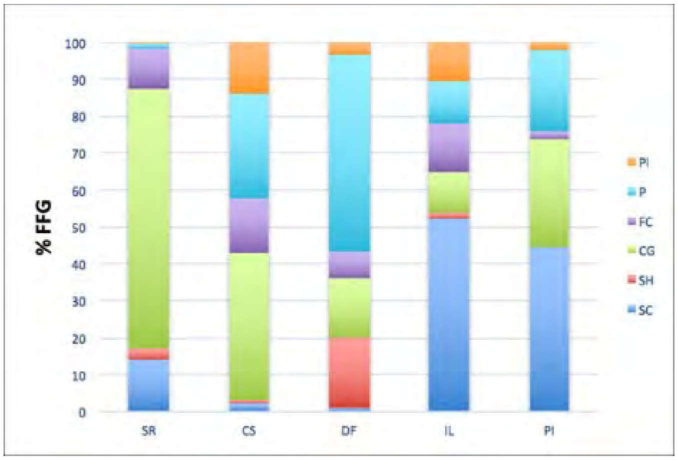


Figure 86. Functional feeding group (FFG) composition for spring sites in fall 2015 (GC= gatherer/collector; FC= filter/collector; SC= scraper; SH= shredder; PI= piercer; P= predator). Data is not available for BH.

Discussion

Results showed that DF, SR, and VC show the best habitat quality for aquatic macroinvertebrates, with the highest biodiversity index number, good water quality indicators (Appendix B), presence of all six functional feeding groups (106– 110) and abundance of pollution-sensitive species. The biotic metric indexes of these sites suggested good water quality, such as high taxa richness, low percent Chironomidae, low HBI, low percent non-insect, and low MPTV. In contrast, springs with low discharge such as IL, CS, BH, and PI had poor habitat quality with low biodiversity values, poor water quality, absence of some functional feeding groups and with little to no pollution sensitive species present. In general, these sites had biotic metric results indicating poor water quality, such as low taxa richness, high percent Chironomidae, high HBI, high percent non-insect, and high MPTV.

Two unique taxa were present in DF and PI, the genus *Neoplasta* and family Crangonyctidae. The genus *Neoplasta* had not been documented in New Jersey before but have been documented in the neighboring state of New York (Smith and other, 2012). *Neoplasta* spp. are predators and tolerant to pollution (PTV 6). The family Crangonyctidae found in DF spring were epigean amphipods that have no observable eyes. This characteristic can be attributed to the emergence of the spring from a small cave. Crangonyctidae are collector-gatherers and sensitive to pollution (PTV 4) requiring good water quality in order to survive.

Springs SR and DF are dominated by collector gatherers and have presence of shredders, which suggests allochthonous systems and presence of coarse particulate organic matter. The high discharge velocity of these sites indicated high flow velocity, which increases erosion and sediment transport of fine particulate organic matter and provides food sources for collector gatherers. VC and BH had less abundance of collector gatherers, scrapers, and shredders. Low discharge velocity increases sediment deposition of fine particulate organic matter. CS was dominated by collector gatherers and predators, which suggests presence of fine particulate organic matter. PI, and IL have less collector gatherers and more scrapers and no shredders present suggesting autochthonous system.

This study documented diverse macroinvertebrate communities in New Jersey springs. Increasing urbanization in New Jersey is leading to the degradation of spring habitats. Thus, management practices should be put in place to protect these unique and valuable systems. Continuation of future monitoring in springs should be implemented to better understand the communities and to monitor any changes caused by both anthropogenic and natural disturbances.

AQUATIC VERTEBRATE ASSEMBLAGES IN SELECTED NEW JERSEY SPRINGS,

by *Brian Henning*

Introduction

Springs are unique habitats that harbor a plethora of biodiversity. The aquatic fauna of a spring may be influenced by the flow regime, temperature, and water quality (van der Kamp, 1995). Additionally, the relatively small size of springs coupled with their many uses in human society make them highly vulnerable to perturbation (Barquin and Scarsbrook, 2008). Human practices such as farming, irrigation, drinking, mining and animal husbandry in and along spring water habitats and aquifers threaten biodiversity and water quality (Howell and others, 1995, Myers and Resh, 2002). The aquatic vertebrates in New Jersey's springs are not well documented and warrant further investigation to identify their ecological importance. The objective of this study is to characterize the aquatic vertebrate assemblage of fish, salamanders, and frogs in selected spring water locations in New Jersey.

Methods

Site selection - A total of eight springs were selected for the aquatic vertebrate study. All springs selected were in northern New Jersey, within the Piedmont, Highlands, and Valley and Ridge physiographic provinces. Site selection was focused in this region of the state because methods used in this study were adopted and modified from the NJDEP Bureau of Freshwater and Biological Monitoring's Headwaters Index of Biotic Integrity (HIBI) Monitoring Program which was developed for high gradient wadeable streams of northern New Jersey. The HIBI utilizes fish, crayfish, salamanders, and frogs to characterize the stream quality in small headwater streams. Due to the similar size, connectivity, and presence of similar species between springs and headwater streams, the HIBI methods were used in this study to collect and describe the aquatic fauna of these springs. All springs selected were generally characterized as rheocrene (the spring's discharge forms a flowing stream channel), to standardize the sampling protocol and reduce variation that may occur between sampling different habitat types.

Electrofishing - The spring biological sampling occurred between June 10, and August 18, 2015. All springs sampled contained water the day of sampling and was conducted during daylight hours between 0900 and 1600. A reach of 50 m of spring run was sampled using one backpack electrofishing unit with a crew of two to three individuals. Electrofishing was conducted in an upstream manner in which the operator systematically sampled all available habitats. All stunned fish, frogs and salamanders were collected by the crew using dip nets and placed into live wells for later identification. All biota sampled by electrofishing were identified to species and enumerated. Any fish or amphibian not readily identified in the field (except for New Jersey listed threatened or endangered species) were preserved in 10% formalin for later identification in the laboratory.

Area Constrained Surveys – An area of 60 m^2 (2 transects, one measuring 15 x 1 m area in the water and one measuring 15 x 1 m area along the wetted edge of the spring) was sampled by area constrained survey (ACS) by a crew of two individuals. All available cover (rocks, logs, debris) within the 60m^2 area greater than 15 square inches were turned over by hand and all salamanders and frogs were captured with the aid of dip nets. All objects turned in the survey were returned to their original position to reduce habitat disturbance. The two transects of the ACS were conducted one on each bank, targeting the best available and diverse habitats. If the 60m^2 search area along the wetted edge of the spring contained insufficient moveable cover, then the search area was moved onto the adjacent floodplain. Taxa observed that escaped catchment were recorded and identified to the lowest taxonomic level based on observed characters. All biota sampled by ACS were identified to species and enumerated. The life stage (larval or adult) of each amphibian sampled was recorded. Larval specimens not readily identified in the field were preserved in 10% formalin for later identification in the laboratory using taxonomic keys (Petranka, 1998; Stranko and others, 2010). Captured specimens were released closely to the object or habitat from where it was captured (e.g. rock, log, debris) so that the animal may return to the underside of an object on its own.

Field measures- In situ water quality measures were recorded using a Hydrolab MS5 Water Quality Monitoring System at each site prior to faunal sampling for dissolved oxygen (DO), pH, water temperature, and specific conductivity. These physical/chemical parameters were taken in situ, mid-depth, in a free-flowing area of the stream near the upstream source of the spring.

Data Analysis - To assess aquatic vertebrate assemblage patterns and environmental gradients, a multivariate analysis, canonical corresponding analysis (CCA) was performed on data from the eight selected springs. The CCA is a direct gradient analysis on the species within the assemblage and environmental variables (Ter Braak, 1986). To perform the CCA, the aquatic vertebrate assemblage data was transformed into binary (presence absence) data to reduce the effect of rare species on the ordination. The environmental variables used were dissolved oxygen in mg/L, pH, water temperature, and specific conductivity.

Results

A combined total of 14 vertebrates species (7 fish, 4 salamanders, and 3 frogs) were collected from the eight springs during the study. Fish represented 68.8 % of the relative abundance in selected springs; whereas salamanders accounted for 28.6 % and frogs 2.6%. Total species richness ranged from 1 to 7 species, with the average being 3 species (fig. 89). Spring Brook Cabin Spring had the highest species richness (7 species) and Dingman's Ferry had the lowest (1 species). One of the springs (Dingman's Ferry) was fishless and four springs contained no frogs (fig. 90). The slimy sculpin (fig. 87) was found in three of the eight springs and was the most abundant species accounting for 62% of the individuals captured in the study (Table 16).

Three salamander species were also dominant in the selected springs; northern two-lined salamander (13.3%), northern red salamander (7.3%), and the northern dusky salamander 7.3%, (fig. 88). A total of 77% of the individual aquatic vertebrates collected from the eight springs were deemed "intolerant," an ecological designation given to species that are more sensitive to environmental perturbation (Table 16). The percentage of intolerant individuals in springs averaged 62% and ranged from 0-100% (fig. 91).

Figure 87. Two slimy sculpins pictured along the bottom of Ennis Spring. *Photo, B. Henning*.

Figure 88. Northern dusky salamander found under rock guarding a clutch of eggs at Dingman's Ferry Spring. *Photo, B. Henning*.

Table 16. List of species collected in spring study and their associated ecological designations.

Species name		Origin	Temperature	Tolerance	% relative abundance
Fish					
American eel	*Anguilla rostrata*	N	W	T	1.2
Blacknose dace	*Rhinichthys atratulus*	N	C-W	M	3.8
Brook trout	*Salvelinus fontinalis*	N	C	I	1.0
Creek chub	*Semotilus atromaculatus*	N	C-W	M	0.6
Largemouth bass	*Micropterus salmoides*	A	W	M	0.4
Redfin pickerel	*Esox americanus*	N	W	M	0.2
Slimy sculpin	*Cottus cognatus*	N	C	I	61.7
Amphibians					
Bullfrog	*Lithobates catesbeianus*	N		T	0.2
Green Frog	*Lithobates clamitans*	N		T	2.0
Northern Dusky Salamander	*Desmognathus fuscus*	N		I	7.3
Northern Red Salamander	*Pseudotriton ruber*	N		I	7.3
Northern Two-lined Salamander	*Eurycea bislineata*	N		T	13.3
Pickerel Frog	*Lithobates palustris*	N		M	0.4
Red-spotted Newt	*Notophthalmus viridescens*	N		M	0.6

Origin: A = non-native, N = native; Temperature: C = coldwater, C-W=coolwater, W= warmwater; Tolerance: T=tolerant, I= intolerant, M=moderate.

Table 17. Water chemistry measures from eight selected springs taken on the day of vertebrate sampling.

Site	Dissolved oxygen (mg/L)	Dissolved oxygen (% saturation)	Temperature (°C)	pH	Specific Conductivity (µmhos/cm)
Brau Kettle	10.56	96.6	10.74	7.54	282
Dingman's Ferry	10.73	94.5	8.84	7.05	442
Ennis	10.33	96.3	11.01	7.75	393
Kanouse	7.29	70.9	13.65	6.49	628
Marble Mountain	9.69	87.2	10.74	7.23	328
Shurts Road	7.29	70.5	13.5	7.88	368
Spring Brook Cabin	10.48	106.9	15.59	6.61	61
Valley Crest	9.04	85.3	12.62	7.34	356

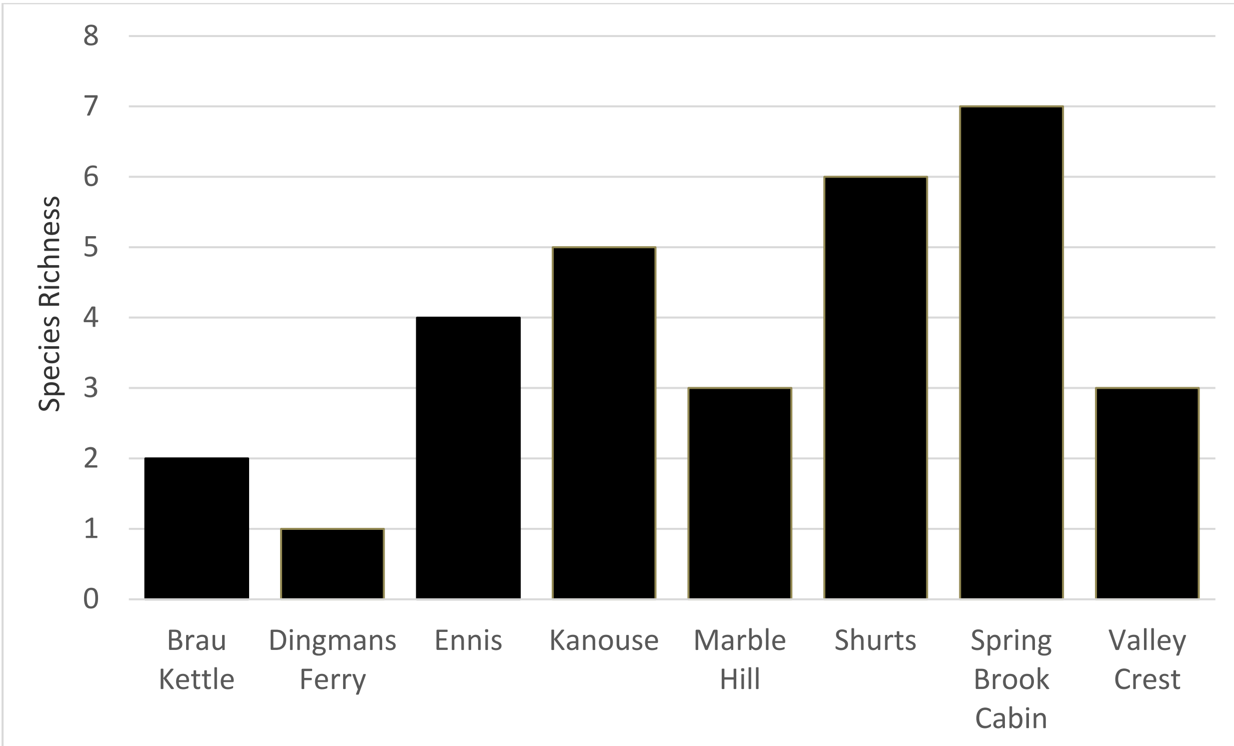


Figure 89. Total vertebrate species richness from each of eight springs.

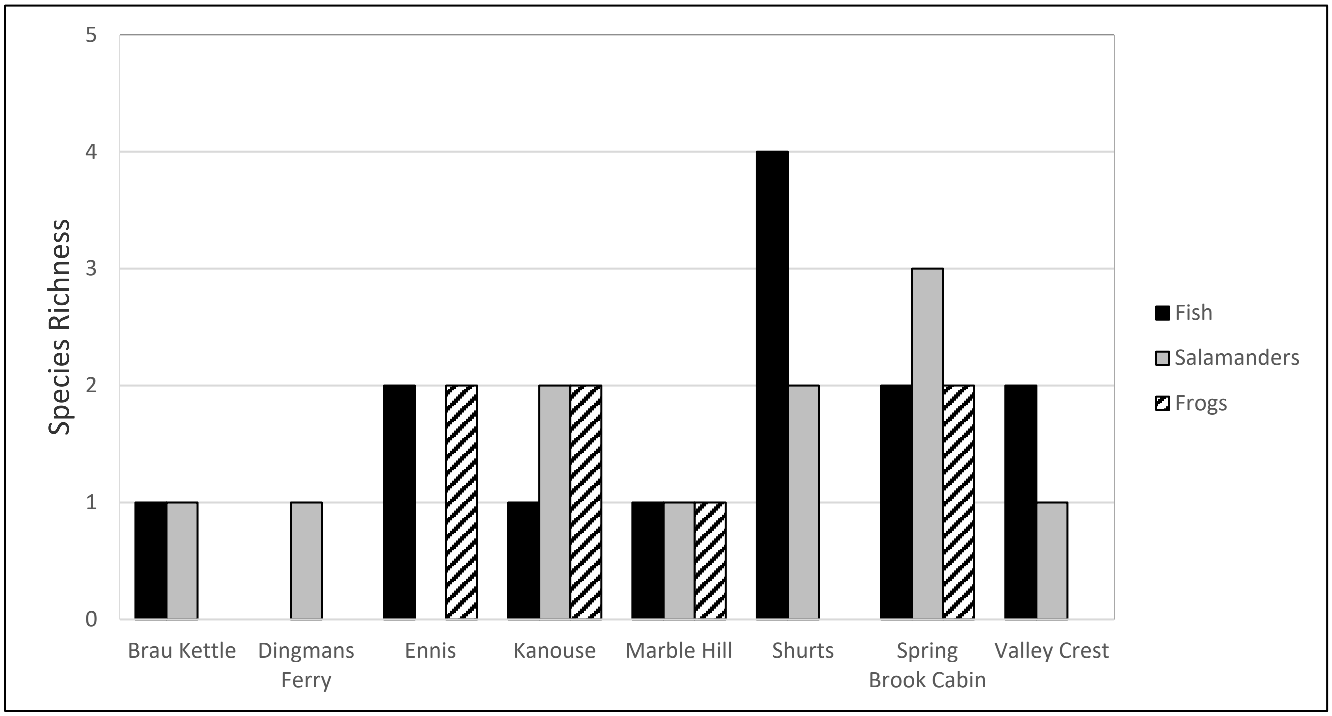


Figure 90. Species richness by taxonomic group from each of eight springs.

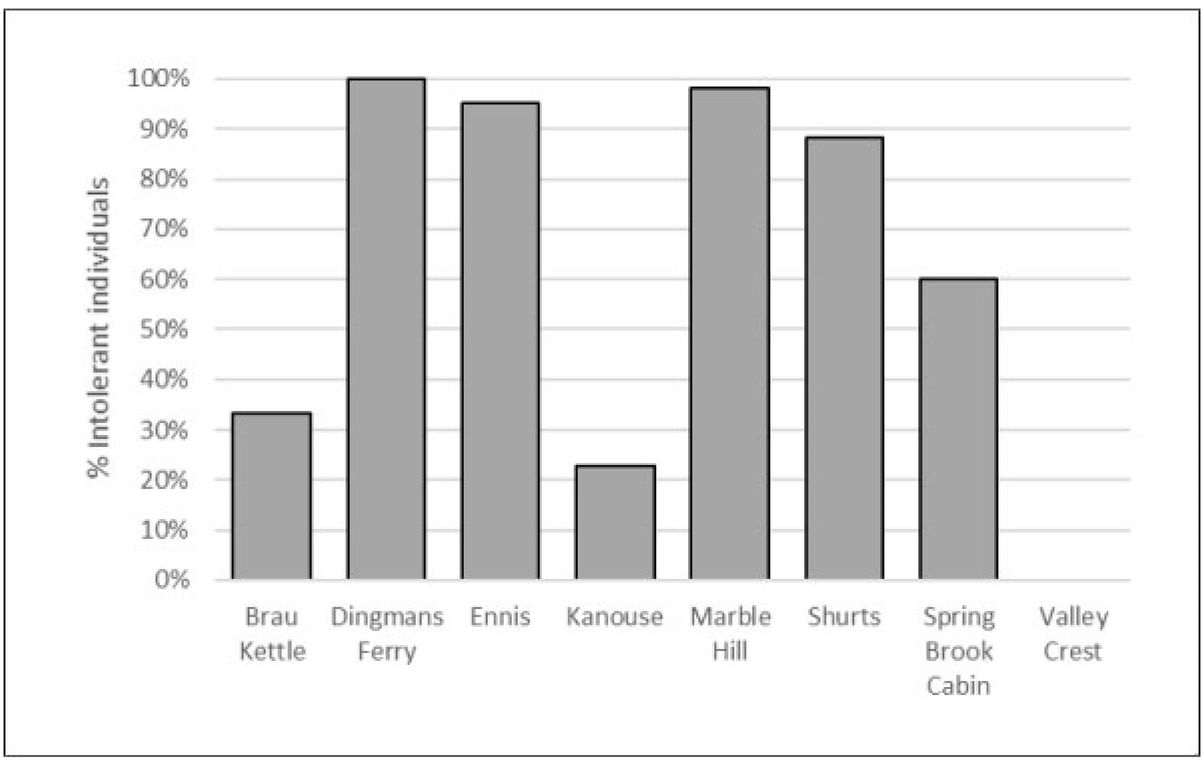


Figure 91. The percent of intolerant individuals from each of eight springs.

The canonical correspondence analysis (CCA) indicated that temperature was the most influential variable in structuring aquatic vertebrate assemblages in eight selected springs (fig. 92). Axis 1 explained 16.3% and Axis 2 explained 13.5% of the variation in the springs' vertebrate fauna-environmental variable relations. The CCA revealed that northern dusky salamander, slimy sculpin, and brook trout had an affinity for springs with lower water temperatures. Largemouth bass, bullfrog, northern red salamander, red-spotted newt, and redfin pickerel had a higher affinity for warmer springs. Largemouth bass, bullfrog, and northern red salamander also were associated with higher specific conductivity. Northern dusky salamander, slimy sculpin, and brook trout had an affinity for springs with high dissolved oxygen concentrations. Largemouth bass, bullfrog, northern red salamander, and green frog were associated with lower pH; whereas, brook trout, slimy sculpin, pickerel frog, American eel, red-spotted newt, and redfin pickerel were associated with higher pH.

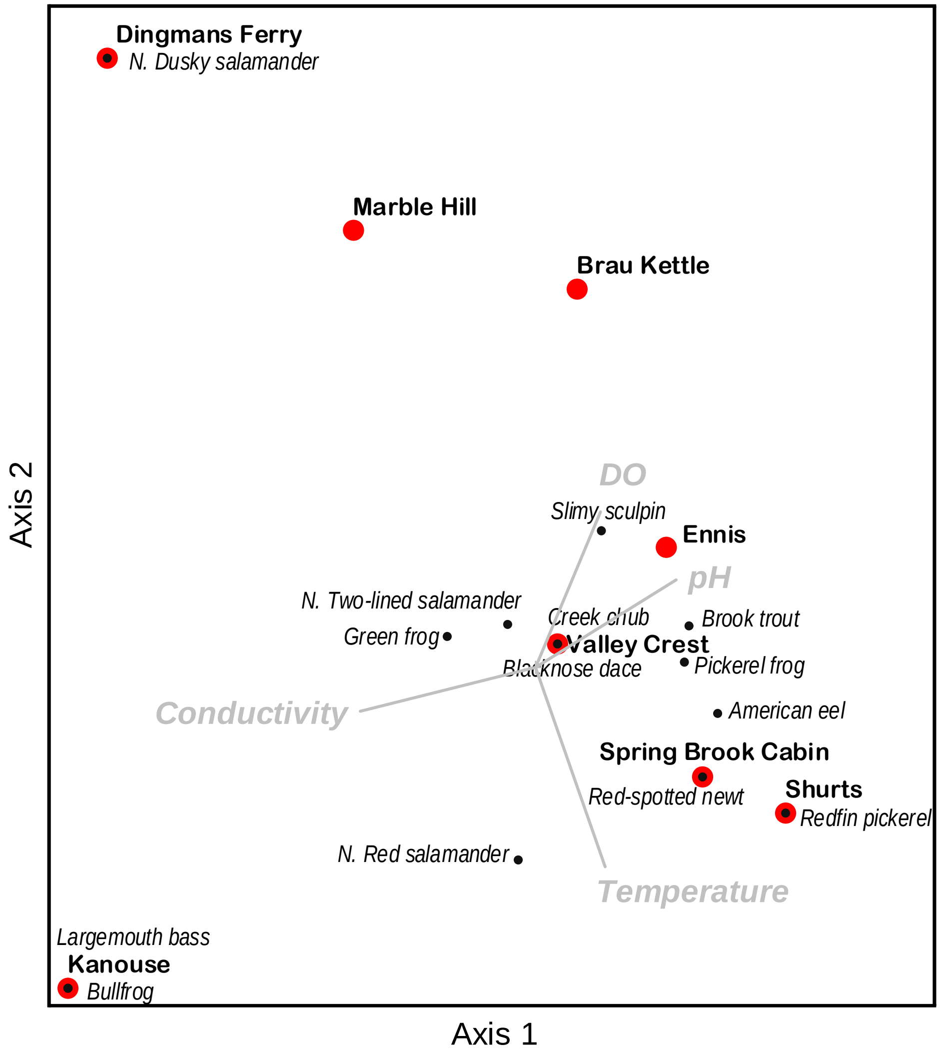


Figure 92. Biplot of canonical correspondence analysis for aquatic vertebrate assemblages at eight spring locations using presence/absence data. The length of gray line indicates the importance of a particular variable. The longer the gray line, the more important the variable is in structuring the assemblage. Environmental variables are dissolved oxygen (DO), pH, water temperature (Temperature), and specific conductivity (Conductivity). Red circles represent spring sites and species centroids are denoted by black circles. The proximity of a species centroid to an environmental variable indicates its association with the variable (positively associated if in the same direction as the line).

Discussion

The spring water habitats sampled in the eight selected New Jersey springs were found to be ecologically significant. The selected springs sampled contained sensitive aquatic vertebrate species that are intolerant of anthropogenic stressors. Although springs are not as diverse as larger order streams and rivers, a large percent of the individuals found in springs were of intolerant species. In particular, the slimy sculpin, a cold water stenotherm which is intolerant of degraded water quality, was highly abundant when present in a spring. Slimy sculpins prefer small headwater streams with suitable substrate and temperature (Scott and Crossman, 1973). In the locations where we found slimy sculpins, the stream substrate was often not high quality and rather highly embedded with fine sediment and silt. It has been documented that stream temperature was often the best predictor of slimy sculpin abundance (Edwards and Cunjak, 2007; Lessard and Hayes, 2003). Slimy sculpins prefer waters between 11 and 16°C (Lyons, 1990) with increases in temperature becoming increasingly stressful and becoming lethal at temperatures exceeding 22 °C (Otto and Rice, 1977). Slimy sculpins were present in three out of the eight springs, with water temperatures at the time of collection ranging from 10.74°C to 13.50°C. In a recent "Species Status Review of Freshwater Fishes" by the New Jersey Division of Fish and Wildlife Endangered and Nongame Species Program, the slimy sculpin, which accounts for 62% of the individuals in this study, was given the status of threatened (New Jersey Division of Fish and Wildlife, 2016). Additionally, brook trout were also found in this study at low abundances in three locations and were recently designated as a species of special concern. Due to the abundance of threatened species and species of concern in the selected springs studied, further protection of springs may be warranted.

Springs and groundwater seeps are also ecologically important habitats for stream dwelling salamanders that are sensitive to water quality degradation (Petranka, 1998). The selected springs sampled were dominated by northern two-lined salamander, northern red salamander and the northern dusky salamander; all of which have aquatic larval stages ranging from 9 months (northern dusky salamander) to 3.5 years (northern red salamander; Petranka, 1998). Often, salamanders are the top predator in many fishless springs and seeps (Southerland and other, 2004) and salamanders with multiyear larvae are highly vulnerable to the quality and quantity of water in a stream (Petranka, 1998). As adults, streamside salamanders are good ecological indicators because they have stable populations with limited home ranges, are ubiquitous and relatively long lived, are lungless and breathe cutaneously through their skin making them vulnerable to toxins, contaminants and desiccation (Southerland and others, 2004). The spring water habitats sampled in this study provided several abiotic and biotic conditions that are favorable to streamside salamanders. The stable temperature and discharge of water may provide optimal conditions for larval salamander growth and survival, especially during winter (Ashton and Ashton, 1978). Several springs sampled contained watercress *Nasturtium officinale* which was found to be commonly occupied by northern red salamander larvae. Only one spring sampled (Ennis Road Spring) was devoid of salamanders; however, the reach sampled was in a meadow that lacked favorable cobble substrate along the streambank.

The spring habitats sampled for the eight selected springs were all generally rheocrene springs, thus all springs eventually discharged into a channel; however, some springs were impounded at the source. Although the selected eight springs were all broadly rheocrene springs there were still variations in habitat, slope of spring channel(gradient), connectivity to adjacent streams and waterbodies, rate of discharge and underlying geology. Seasonal variation in aquatic vertebrate assemblages were not investigated in this study. However, during summer low flows and increasing stream temperatures springs, seeps and upwelling areas may provide thermal refugia for may stenothermic species such as trout and sculpin. Additionally, stable temperatures of springs in the winter prevent freezing and ice development which may increase overall condition and survival for fish, frogs and larval salamanders (Lamoureux and Madison, 1999;

Cunjak, 1996). Salmonids have been documented to move several kilometers to reach wintering areas (Clapp and others, 1990), which may provide ideal spawning conditions for salmonids due to their stable water temperatures, substrate, and oxygen supply during the fish egg incubation period (Power and others, 1999). Further investigations into the seasonal variation of aquatic vertebrate assemblages may further document the ecological significance of springs.

Differences observed between aquatic vertebrate communities in the eight selected springs may have been influenced largely by their degree of connectivity to adjacent waterbodies and their available species pools. Springs are often isolated sections of a river network, and the species present are often the result of the connecting watershed. Several factors can influence the movement of fishes within an aquatic system: dams (man-made and beaver), barriers (waterfalls), channel slope or stream gradient, and flow permanence (Jackson and others, 2001). Obstructions limiting connectivity were observed on several springs in this study. For example, a small dam was found on Ennis Road Spring downstream of our sampling location disconnecting this crucial habitat from the rest of the watershed. At Marble Mountain Spring, a culvert obstructed with debris under a railroad was observed to prevent wild brown trout from reaching the spring's emergence. Natural impediments to fish movement were observed at Dingman's Ferry Spring which had a high channel slope and as a result was fishless. Human movement of fish or incidental stocking may explain the presence of largemouth bass in Kanouse Spring, an isolated spring surrounded by a suburban neighborhood where a person may have placed the fish in the grotto of the spring to serve as a fishing hole. Connectivity to spring habitats is vital for providing cold-water stenotherms access to summer and winter refugia. Since New Jersey has a limited amount of cold-water habitat, efforts made to increase connectivity to upstream spring habitats where access may be limited may be beneficial to cold-water fish.

SPRINGS AND CLIMATE CHANGE

by *Rachel Filo*

Global climate change, brought on by increases of atmospheric CO_2 and other gases, could have a significant impact on springs. The effects of climate change vary for different springs depending on their locations and conditions, though there are some consistencies. Generally, a rise in temperature would alter the timing of the annual groundwater recharge cycle, affecting the flow rates of springs. An increase in humidity means more precipitation and water body depth, which could lead to an increase in spring flow. An annual increase in winter temperatures would mean less snowfall, therefore reducing the spring snowmelt peak. This would also cause the average monthly recharge rate for the summer to be significantly reduced (Eckhardt and Ulbrich, 2003).

Studies have also shown that a temperature increase, even a small one, could reduce precipitation in an area over time and cause spring flow reduction, especially in carbonate aquifers. Models and studies of the Delaware River Basin show that winter warming would cause more precipitation to fall as rain instead of snow, increasing winter runoff and decreasing summer groundwater discharge. In an area of temperate climate, such as New Jersey, a 2°C- 4°C warming could decrease runoff by up to 25% if there is no increase in precipitation (McCabe and Ayers, 2007). A decrease in rainfall and groundwater recharge would shrink areas feeding springs, and so would impact the springs themselves.

Climate change would also affect the contamination of springs, especially karst springs, which are more vulnerable to surface water because they are contained within porous rock. Overall, altered temperature and precipitation patterns due to climate change would greatly affect the flow and the water quality of springs.

NJGWS SPRINGS DATABASE SCHEMA

A New Jersey statewide spring's relational database was created with Microsoft Access software (fig. 93). The database contains data and information collected on New Jersey Springs by the NJGWS. The database is designed to be updated as new springs are identified and as additional information is collected. It can also be expanded to include new attribute information not initially contained in the data structure.

This database is a collection of information that is related to springs in New Jersey. The organization of the database includes tables to store the data. The main table contains pertinent attributes including Spring ID, Spring name, Short description, Description, Street address, Coordinates, Elevation, and Location method. The database also contains accessory tables. These tables include discharge rates, chemistry, cultural characteristics, discharge characteristics, ecology, geology, and geomorphology. Subsequently, a subset of the spring's database containing the spring locations and attributes was used to create an ESRI GIS geodatabase containing the feature class and accessory tables. The spring's accessory tables can be joined together with the springs feature class based on a unique ID number in the geodatabase.

A copy of the unpopulated database is available upon request to the New Jersey Geological and Water Survey.

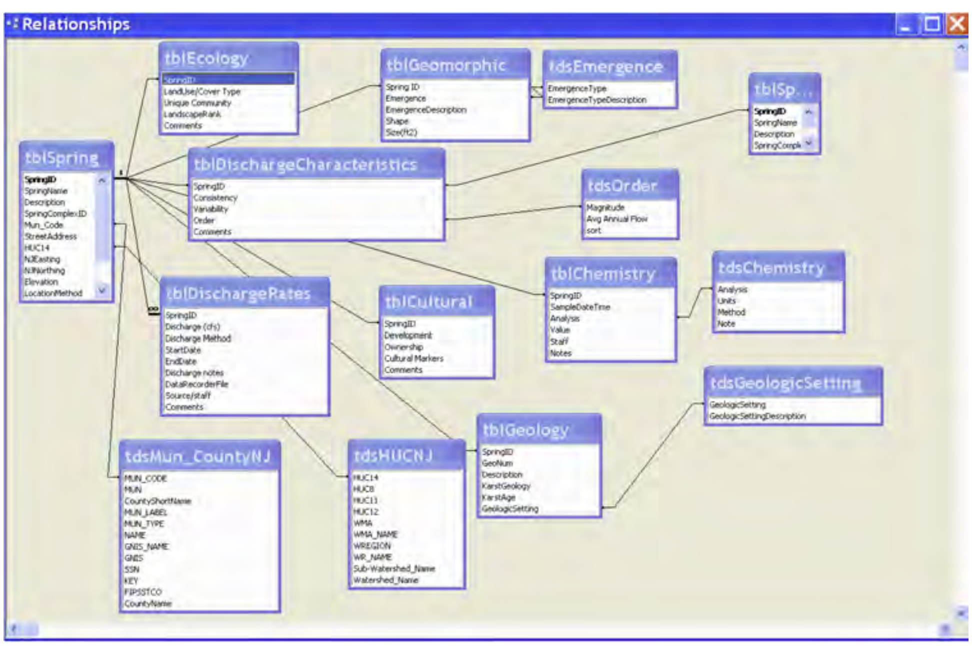


Figure 93. Schematic of Springs Characterization.

CONCLUSION

Included in this report is information on the identification, classification and characterization of springs. After springs were identified, they were classified or grouped in several ways according to their; 1) mean flow or discharge 2) geomorphology 3) geologic setting (rock type or formation name) 4) long-term temperature analysis of spring water at 14 selected springs 5) water chemistry including a comprehensive water quality analysis at 14 selected springs along with quarterly chemical parameter monitoring 6) fauna 7) macroinvertebrates and 8) aquatic life. A site-specific study of flow characteristics at Brau Kettle spring was completed and a spring's database was also created.

Despite their obvious significance as indicators of groundwater conditions, ecosystem ecology, conservation biology, and cultural and economic well-being, springs have been broadly ignored as research subjects. The lack of scientific attention of springs has contributed to inadequate management and education about these important ecosystems and increases the likelihood of their neglect and degradation across New Jersey. This research on the distinctive nature and features of springs in New Jersey with the information collected, classified, and characterized in this report provides a more complete understanding of the springs in the state. This information also provides a baseline for new research projects in the future.

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APPENDICES

Appendix A.

Springs Summary by County

This section provides information on springs that were visited by the NJGWS, and a few historical springs not visited; they were grouped by county. The table for each spring includes basic information about each including spring name; spring ID number, which correlates to the springs GIS database created by the NJGWS as part of this study; notes about the spring; the municipality where the spring is located; the county where the spring is located; the coordinates of the spring in New Jersey State Plane easting and northing format. The discharge rate for the spring with the units is included. Springs can be classified by geomorphology. Geomorphic features for springs in New Jersey are numerous and include springs that emerge in caves, contact/hanging garden springs, gushette springs, helocrene springs, hillslope springs, limnocrene springs, and rheocrene springs; the geology is based on the New Jersey Geological and Water Survey 1:100,000 scale geologic maps.

Atlantic County

No springs mapped.

Bergen County

Belmar Spring Water Company Spring	
ID: 675	
Notes: Spring water from this spring is used for bottled water supply.	
Town: Glen Rock	Discharge: 70 gpm
County: Bergen	Emergence: Hillslope
East/North: 396889.879, 863283.395	Geology: Passaic Formation

Located at 410 Grove Street in Glen Rock, the water from the spring of the Belmar Spring Water Company (fig. A-2) is one of springs used for bottled water in New Jersey. The Belmar spring is located beneath protected land. The water is collected and bottled at the site of the spring (fig. A-2). The family began bottling Belmar Spring Water in 1924 and three generations later are still bottling water every day from the same spring.


Figure A-1. Left. Belmar Spring original spring house. *Photo, T. Pallis*.
Figure A-2. Right. Belmar Spring outflow. *Photo, T. Pallis*.

Kanouse Spring	
ID: 40	
Notes:	
Town: Oakland	**Discharge: 1 CFS, measured in 1936.**
County: Bergen	**Emergence: Hillslope**
East/North: 561157.0, 792844.0	**Geology: Glacial till**

The Kanouse Spring, also known as the Vernum Spring or Indian Spring is located on the side of Kanouse Mountain in Oakland. It was once a source of water for the town of Oakland. In the early part of the 20th century, it was also a source of water for the Kanouse Mountain Water Company that formed in 1905. The company bottled and sold spring water at local grocery stores in New York City, Jersey City, and Hoboken. In 1909, the spring had a flow estimated to be about 17 gallons per minute when 800 cases of water were bottled per day. To collect the water from the spring a 7,300-foot-long pipe was constructed. It carried water by gravity down Kanouse Mountain to a bottling plant in the town of Oakland. After the spring ceased to be used as a source of water for the town or bottled water, water cress was grown in the pool where the spring emerged (fig. A-3), and sold in local stores. Watercress was still seen growing in December of 2011 when the spring was visited by the NJGWS. In 1936, the water was also used as a water supply for a trout pond.

Figure A-3. Pool at the source of the Kanouse Spring. *Photo, S. Domber*.

North Arlington Spring	
ID: 423	
Notes:	
Town: North Arlington	**Discharge: 5 gpm**
County: Bergen	**Emergence: Hillslope**
East/North: 595666.34, 709063.65	**Geology: Passaic Formation**

This spring emerges just below the ridge out of a parking lot (fig. A-4). It is said by the locals the spring has been flowing continuously from as long as anyone can remember from the late 1800s until today. It is also said the water never freezes no matter how cold it is.

Figure A-4. North Arlington Spring. *Photo, T. Pallis*.

Great Bear/Trinity Spring	
ID: 65	
Notes: Springs are fenced off.	
Town: Ridgefield Park	**Discharge: 10 gpm**
County: Bergen	**Emergence: Hillslope**
East/North: 630472.201, 730064.868	**Geology: Lockatong Formation**

The Great Bear/Trinity Spring is located inside the Ridgefield Nature Center. The Ridgefield Nature Center is located at the corner of Shaler Boulevard at Ray Avenue in Ridgefield Park. The site of Great bear/Trinity Spring was the source of spring water for the now defunct Great Bear Spring Water Company for many years. It was originally called Trinity Spring because there were three springs surfacing close to each other. The springs still flow and all three are now channeled into an underground tank (fig. A-5), and then water is piped to nearby Wolf Creek (fig. A-6). In 1920, Great Bear purchased the property and used these three springs for distributing spring water throughout the New York metropolitan area. These springs were eventually abandoned by Great Bear because of a decrease in flow. In 1975, Great Bear sold the property to the Borough of Ridgefield.

 

Figure A-5. Left. Surface view of source area of the Great Bear/Trinity Spring cement basin. *Photo, T. Pallis*.
Figure A-6. Right. Inside of underground tank for the Great Bear/Trinity Spring with piping used to collect the spring water. *Photo, S. Domber*.

Washington Spring, Van Saun Park	
ID: 64	
Notes: Located in Van Saun County Park.	
Town: River Edge	**Discharge: 5 gpm**
County: Bergen	**Emergence: Rheocrene**
East/North: 617150.57, 764250.46	**Geology: Passaic Formation**

Washington Spring is located within Van Saun County Park in a garden setting (fig. A-7). The spring and park are in River Edge, Bergen County. A plaque at this spring says the Continental Army is reported to have utilized the spring during the September 1780 encampment west of the Hackensack River. Reports indicated that General Washington visited here and drank from the spring, giving rise to the name Washington Spring.

Figure A-7. Washington Spring. *Photo, T. Pallis*.

Burlington County

Blue Hole, Mt. Misery	
ID: NA	
Notes: Location is confidential.	
Town: Pemberton Township	Discharge: NA
County: Burlington	Emergence: Helocrene
East/North: NA	Geology: Cohansey Formation

Blue Hole, Mt. Misery is a blue hole (figs. A-8, A-9). Blue holes are simply strong riverine springs that issued from deep, circular cavities or holes occupying the bottom of relict and modern streambeds. Blue holes, found in parts of South Jersey originate from the Ice Age. In Pine Barrens folklore, each hole was as sinister as the next. All were reputed to be bottomless, and all possessed dangerous 'whirlpools.' Like spungs, blue holes often had precontact trails that were contiguous with their shores since freshwater sites were important places. Upwellings that flowed with great force over a century ago (e.g., Inskeeps, Mt. Misery, Danger Hole, Dog Heaven) are now a rarity in the Pine Barrens landscape. Their absence from the modern landscape is attributed to over-withdrawal of ground water (Demitroff, 2007).

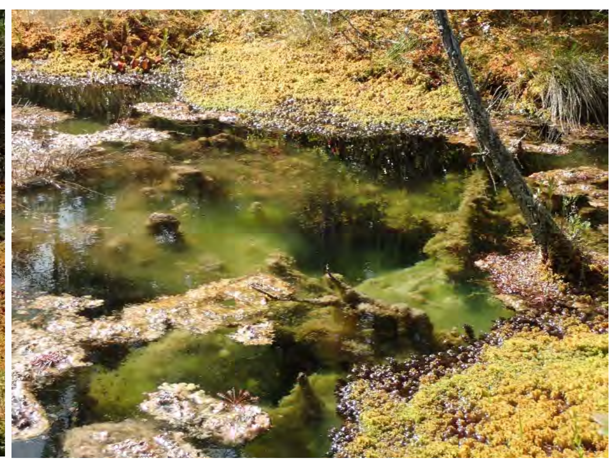

Figure A-8. Left. Blue Hole, Mt. Misery wide angle. *Photo, K. Strakosh Walz*.
Figure A-9. Right. Blue Hole, Mt. Misery close in. *Photo, K. Strakosh Walz*.

Clear Spring	
ID: NA	
Notes: Historical spring location unknown.	
Town: Pemberton Township	Discharge: NA
County: Burlington	Emergence: NA
East/North: NA	Geology: NA

Not much is known about this spring other than the vintage postcard (fig. A-10). There is no known location for this spring, and it was not visited as part of this study.

Figure A-10. Postcard of Clear Spring in Browns Mills. c. 1905 *by M.W. Hargrove*.

Camden County

Crystal Spring	
ID: 24	
Notes:	
Town: Laurel Springs Borough	**Discharge: 5 gpm**
County: Camden	**Emergence: Hillslope**
East/North: 350643.0, 358669.0	**Geology: Lower Member Kirkwood Formation**

Crystal Spring is in Crystal Spring Park in Laurel Springs Borough, Camden County (figs. A-11 – A-14). Crystal Springs has long been celebrated for its medicinal qualities and purity. In the past it had been credited with curing numerous cases of long-standing kidney and liver diseases. The spring was also acknowledged to be a sure cure of other disorders of the stomach and bowels, dyspepsia, indigestion, diabetes, rheumatism, cystitis, etc. as well. Crystal Spring Park was the favorite location of poet Walt Whitman during his summer stays in the area. Between 1876 and 1884, Whitman spent summers in his later life nearby at a friend's farmhouse a few blocks from Laurel Lake. Much of Whitman's work for "Specimen Days" and part of "Leaves of Grass" were written here. In the late nineteenth century, realtors touted the medicinal qualities of Crystal Spring in their promotional literature to entice prospective homeowners to relocate to Laurel Springs because of the spring water found there. Crystal Spring is located at the bottom of a hill in a beautiful, wooded area at the edge of Laurel Lake. The main spring is in an alcove; pooling at the base, and then it flows in a very small channel to the lake. It is said Whitman would sit by the spring, drink the water, and take mud baths near the spring to help his recovery after a partial stroke. Water from Crystal Spring was also bottled and sold in Philadelphia for 15 cents a gallon during the late1800s.




Figure A-11. Top left. Crystal Spring with spring run. *Photo, S. Domber*.
Figure A-12. Top right. Crystal Spring grotto. *Photo, S. Domber*.
Figure A-13. Bottom left. Close up view of Crystal Spring grotto. *Photo, S. Domber*.
Figure A-14. Bottom right. Vintage postcard of Crystal Spring Grotto. Date and photographer unknown.

Cape May County

Cold Spring	
ID: 724	
Notes:	

Town: Lower Township	**Discharge: > 1 gpm**
County: Cape May	**Emergence: Helocrene**
East/North: 375205.0, 51559.0	**Geology: Unnamed Formation at Cape May**

Cold Spring is in Lower Township, Cape May County (fig. A-15). It lies a few miles north of Cape May City. Its name is derived from an excellent spring of cold water flowing up from the salt marsh which overflowed at every tide. Today, this spring does not flow as it once did.

Figure A-15. Cold Spring. *Photo, S. Johnson*.

Cumberland County

No springs mapped.

Essex County

Locust Grove Spring	
ID: 83	
Notes:	
Town: Milburn Township	**Discharge: 15 gpm**
County: Essex	**Emergence: Hillslope**
East/North: 546666.587, 690204.623	**Geology: Basalt**

Locust Grove Spring is located at the very southern end of the South Mountain Reservation in Millburn Township near Glen Avenue and Lackawanna Place. This spring has bubbled out of the ground longer than anyone can remember. There is a constant stream of water, although it is fenced in and marked “not safe for human consumption” (fig’s. A-16, A-17). The NJDEP considers the bacteria levels too high for drinking (fig. A-18). The NJDEP conducted laboratory analysis from water sample from this spring in 2009, (Muzeni-Corino, Berchtold, 2010). The results can be seen below.

Coliform Results:		
12/14/2009	Coliform, Total	TNTC w/+
	Coliform, Fecal	Positive
12/22/2009	Coliform, Total	All positive
(10 samples)	Coliform, E. Coli and/or Fecal	Positive (7 out of 10)
Inorganic Results:		
	Antimony	ND
12/2009	Arsenic	ND
	Barium	6.85 µg/L
	Beryllium	~ 0.086 µg/L
	Cadmium	~ 0.265 µg/L
	Chromium	~ 1.57 µg/L
	Copper	ND
	Cyanide	ND
	Fluoride	ND
	Lead	ND
	Mercury	ND
	Nickel	~ 0.499 µg/L
	Nitrate+Nitrite (As N)	1.68 mg/L
	Nitrite (As N)	~ 0.00159 mg/L
	Selenium	ND
	Silver	ND
	Thallium	ND
Radionuclide Results:		
	Gross Alpha, Including Ra & U, Excluding Rn	1.5 pCi/L
	Radium-228	.02 pCi/L
	Radon 222	451 pCi/L
General Chemical and Secondary Characteristics:		
	Alkalinity, Total	65 mg/L
	Aluminum	117 µg/L
	Chloride	16.8 mg/L
	Color	ND
	Hardness, Total (As Caco3)	84.7 mg/L
	Iron	109 µg/L
	Manganese	~ 1.24 µg/L
	MBAS - Foaming Agents (Surfactants)	ND

Odor	1.15 T.O.N.
pH	~ 6.9 pH Units
Sodium	5.69 mg/L
Solids, Total Dissolved (TDS)	122 mg/L
Sulfate	16 mg/L
Turbidity	2.85 NTU
Zinc	ND
Volatile Organic Compounds: All ND	

Figure A-16. Top left. Fenced in Locust Grove Spring. *Photo, S. Domber*.
Figure A-17. Bottom left. Close up view of Locust Grove spring outlet. *Photo, S. Domber*.
Figure A-18. Bottom right. Not safe for human consumption sign. *Photo, S. Domber*.

Rock Spring	
ID: 427	
Notes:	
Town: West Orange	**Discharge: NA**
County: Essex	**Emergence: Hillslope**
East/North: 555190.62, 705760.21	**Geology: Basalt**

In 1820, a mineral spring discovered near Northfield Avenue launched suburban and recreational development in West Orange's Watchung Mountains. Believed to contain minerals that would cure sickness and disease, city dwellers in Newark and New York City came westward to spend their summers near the mineral spring. The Rock Spring Water Company dates as far back as 1893 when local businessman Gordon Brewer, founded the company and erected the stone structure that stands today along Northfield Avenue (fig. A-19). The water was collected more recently from behind the stone wall. At one time water was collected at the stone structure along Northfield Ave. itself. The Rock Spring Water Company was located near the South Mountain Reservation at 479 Northfield Avenue (fig. A-20). Established in 1893, it was operated continuously until it was shut down after being sold in 2011, then reopening a few years later. In the past, water from the Rock Spring Water Company was sold as bottled water (fig. A-21) and used to make soda.

Figure A-19. Top left. Rock Spring Water Company original outlet. *Photo, T. Pallis*.
Figure A-20. Right. Rock Spring Water Company bottling plant. *Photo, S. Johnson*.
Figure A-21. Bottom. Vintage five-gallon Rock Spring Water Company bottle, c. 1960's. *Photo, T. Pallis*.

Gloucester County

The Blue Hole-Inskeep	
ID: 12	
Notes:	
Town: Winslow Township	**Discharge: > 1 pt. per minute**
County: Gloucester	**Emergence: Limnocrene**
East/North: 380778.0, 289163.2	**Geology: Cohansey Formation**

The Blue Hole-Inskeep, possibly a spring, is located in the Winslow Watershed Management Area in the Pinelands off of Piney Hollow Road (fig. A-22). This is the most well-known of the multiple Blue Holes of the Pine Barrens. The color of the water in this spring is unusually clear; most lakes and ponds in the area are brownish due to large deposits of bog iron and the presence of tannins in the water. The Blue Hole is circular and about 70 feet (21 m) across. In the 1930's it was a popular party and swimming spot. The Blue Hole can only be reached on foot from trail in the Winslow Watershed Management Area. Several popular legends exist about the Blue Hole. One is that the Blue Hole is bottomless with powerful currents. Another is that a meteor hitting the earth created the Blue Hole. Other legends proclaim that the water is freezing cold year-round. Another legend says some years ago, a group of engineers and scientists brought a large crane to the site and dropped a large weight on steel cable, which never hit the bottom of the hole, even when they ran out of cable. Legend says the Blue Hole is the home of the Jersey Devil and a passageway directly to hell. It was said at night you could hear his hoof beats through the pines as he raced to his hideaway. If someone dared swim to the middle of the Blue Hole, the Jersey Devil would reach up and grasp their leg and drag them to their death. Another legend says it is where the Jersey Devil drinks water for refreshment, swims, and uses it as a bathtub on a regular basis. Parents warned their children never to swim in the hole because if they did, the Jersey Devil would pull them to the bottom. The Blue Hole is also known by another name, the Bottomless Pit of Beelzebub. Most likely, these legends were invented to keep people away and children away from the blue hole. The Blue Hole was once probably spring fed from cold underground springs. Swimmers' muscles would cramp, and it would feel like they were being pulled to the bottom. The water temperature of the Blue Hole is said to be in the range of 50 to 60 degrees Fahrenheit, even in the hottest part of the summer. The Blue Hole is not bottomless, however. It is reported that the sandy bottom is similar in texture to quicksand. Today, it is not known if the springs are flowing and from the water chemistry the water resembles surface water more than spring water.

Figure A-22. The Blue Hole-Inskeep, Winslow. *Photo, S. Domber*.

Hudson County

No springs mapped.

Hunterdon County

Dietz Spring	
ID: 721	
Notes:	
Town: Bethlehem Township	**Discharge: > 5 gpm**
County: Hunterdon	**Emergence: Hillslope**
East/North: 339953.325, 663548.641	**Geology: Migmatite**

Dietz Spring is used as a household water supply. It is in the box underneath cover in (fig. A-23). It discharges into a brook.

Figure A-23. Dietz Spring. *Photo, M. Godfrey*.

Crystal Spring	
ID: 25	
Notes: A grouping of multiple springs.	
Town: Lebanon Township	**Discharge: > 1 gpm, visible spring**
County: Hunterdon	**Emergence: Limnocrene**
East/North: 392917.0, 702867.0	**Geology: Pyroxene Granite**

Crystal Spring Preserve in Lebanon Township in Hunterdon County contains an important source of water for New Jersey. The preserve contains seven springs. One can be seen in (fig. A-24). The ponds in the preserve are fed by these natural springs (hence the park name) and form the headwaters of Spruce Run Creek, and one of three waterways that flow into Spruce Run Reservoir.

Figure A-24. Left. Brush overgrowth surrounds a cement basin box, where one of the seven springs in the Crystal Spring Preserve bubbles up. *Photo, S. Domber*.
Figure A-25. Bottom. Crystal Spring Preserve, spring fed pond. *Photo, T. Pallis*.

Tower Hill Reserve Spring	
ID: 742	
Notes:	
Town: Bethlehem Township	**Discharge: 1 gpm**
County: Hunterdon	**Emergence: Helocrene**
East/North: 352971.0, 668454.0	**Geology: Quartz-Oligoclase Gneiss**

Tower Hill Reserve Spring is located at 944 Mountain View Road in Bethlehem Township (fig. A-25). Conrad Wene (1798-1881) purchased his farm and the spring on the property in 1841. Shortly after, he built a one-room frame house and outbuildings, including a unique two-story springhouse, (fig. A-26) now called the Tower Hill springhouse. The farm was eventually sold by his descendants to Hunterdon County in 1983 and is now part of the Tower Hill Reserve. The springhouse held some water when it was visited on February 17, 2017 (fig. A-27). There was a wet spot adjacent to the spring house, but no flow was detected.

Figure A-26. Tower Hill Reserve springhouse view from the south. *Photo, T. Pallis*.
Figure A-27. Tower Hill Reserve springhouse view looking west. *Photo, T. Pallis*.

Valley Crest Farms Springs 1, 2, 3	
ID: 685, 686, 687	
Notes: Three distinct springs.	
Town: Clinton Township	**Discharge: 5 gpm, 1 gpm, 5 gpm**
County: Hunterdon	**Emergence: Hillslope**
East/North: 387563.0, 651695.0	**Geology: Allentown Dolomite, Leithsville**

There are three springs Valley Crest Farm and Preserve. Valley Crest Spring 1 (fig. A-28), Valley Crest Spring 2 (fig. A-29), and Valley Crest Spring 3 (fig. A-30). Valley Crest Spring 1 emerges from a springhouse. The three springs are near each other and were part of a farm water supply for the Valley Crest Farm and Preserve. Spring water from the area is now collected in large amounts and sold as commercial bottled water.

Figure A-28. Top left. Valley Crest Farms Spring # 1. *Photo. T. Pallis*.
Figure A-29. Top right. Valley Crest Spring Farms Spring # 2. *Photo. T. Pallis*.
Figure A-30. Bottom left. Valley Crest Spring Farms Spring # 3. *Photo. T. Pallis*.

Homestead Farm Spring	
ID: 761	
Notes: Holcombe House Spring	
Town: Lambertville City	**Discharge: NA**
County: Hunterdon	**Emergence: Hillslope**
East/North: 368188.235, 562091.944	**Geology: Passaic Formation**

Homestead Farm Spring is a small spring in a springhouse located just east of Rt. 29 on Homestead Farm in Lambertville, Hunterdon County (fig. A-31). The spring is associated with a historic Holcombe house which dates back to the 1700's. Historical records indicate George Washington and his generals' devised plans for the Battle of Monmouth during the Revolutionary War here and perhaps drank water from the spring. After hearing of the British evacuation of Philadelphia, Washington made the decision to leave Valley Forge, Pennsylvania. On June 20, 1777, he arrived at the Pennsylvania side of the Delaware at Coryell's Ferry. The following day, General Washington crossed over into the New Jersey side (what is now Lambertville) and made his headquarters at the Holcombe house. On the 22nd, the main body of the troops also crossed over into New Jersey. Early the next morning, the army then began their march in pursuit of the British troops. On June 28, they would encounter the British forces at Monmouth Courthouse and fight the Battle of Monmouth, the longest continuous battle of the war.

Figure A-31**.** Homestead Farm Spring springhouse with the Holcombe House to the left**.** *Photo. Courtesy of Sotheby's.*

Mercer County

Kuser Mountain Spring	
ID: 77	
Notes: Located in a park.	
Town: Hopewell Township	Discharge: 20 gpm on 7/19/2007
County: Mercer	Emergence: Hillslope
East/North: 382736.0, 541560.0	Geology: Passaic Formation

On the side of Kuser Mountain, also known as Baldpate Mountain, there is a springhouse with a collapsed roof in the woods along the service road (fig. A-32). The spring still flows strong.

Figure A-32. The remains of a collapsed roof of the Kuser Mountain Spring springhouse. The cinderblock catch basin is still visible. *Photo, W. Marzulli*.

Honeyman Spring	
ID: 629	
Notes: In Washington Crossing State Park.	
Town: Hopewell Township	Discharge: 5 gpm
County: Mercer	Emergence: Hillslope
East/North: 389347.23, 533988.624	Geology: Passaic Formation

The Honeyman Spring contains a springhouse with an underground pipe that leads to a grotto approximately 50 feet away (fig. A-33). The springhouse is located just west of Route 29 south, (River Rd.) in Washington Crossing State Park across Route 29 from the Johnson Ferry House in Hopewell Township (fig. A-34). The spring was flowing about 5 (gpm) on July 18, 2011. The springs outlets into the Delaware and Raritan Canal (fig. A-35). The grotto (fig. A-36). Before 1931 they don't have a name for the spring listed anywhere; since then, the park calls it Honeyman Spring, after John Honeyman (a spy). The springhouse is called the John Honeyman Spring House, but the spring is just called Honeyman Spring. It is located where Washington's army landed for its march on Trenton in 1776. It is named after John Honeyman, a spy who provided valuable information on the British for General Washington. He once served with the British but was sympathetic to the Patriot's cause and wanted to help them. Washington's army pretended to capture Honeyman when he came to advise Washington and then "released" him so he could return to Trenton and, ultimately, carry inaccurate information about the Continental Army's plans back to the Hessians. Along with the stormy weather during the crossing on Christmas night and the 9-mile march south to Trenton, this trick might have played an important role in Washington's victorious December 26, 1776, attack on the Hessian soldiers at Trenton. At the spring stands a stone memorial fountain with a bronze plaque on it. It was erected by the Patriotic Order Sons of America, and high officials of the state of New Jersey attended the dedication on December 26, 1930. It reads:

"Dedicated in memory of John Honeyman who served Washington and the Continental Army as a spy, drink of the fount ofF liberty let posterity inherit freedom."

Figure A-33. Top left, John Honeyman Spring springhouse and spring outlet. *Photo, T. Pallis*.
Figure A-34. Top right, John Honeyman Spring springhouse. *Photo, T. Pallis*.
Figure A-35. Bottom left, John Honeyman Spring springhouse, grotto and the Delaware and Raritan Canal. *Photo, T. Pallis*.
Figure A-36. Lower right, Honeyman Spring grotto. *Photo, T. Pallis*.

Honeyman Spring was field sampled in 2006. Below are the results from that sampling.

Sample date, 10/27/2006

pH	7
Dissolved Oxygen	5.8
Nitrate	1.2
Orthophosphate	<0.2
Specific Conductivity	200
Spring Temperature	12.5
Air Temperature	9.5 C

Honeyman Spring has been included in the more comprehensive analyte sampling. See Appendix C.

Washington Crossing Park Farm Spring	
ID: 727	
Notes: In Washington Crossing State Park.	
Town: Hopewell Township	**Discharge: > 1 gpm**
County: Mercer	**Emergence: Hillslope**
East/North: 574105.975, 514071.388	**Geology: Passaic Formation**

This spring house is the only remaining structure of a farm that stood nearby (fig. 37). This springhouse was used for storing milk. The cold spring water running over the milk containers kept it cool as a refrigerator does today. Earth was usually sprinkled on the roof to encourage the growth of moss. This served as insulation to keep the inside of the building cool.

Figure A-37. Farm springhouse in Washington Crossing State Park. *Photo, T. Pallis*.

Washington's Spring	
ID: NA	
Notes: Small monument along Route 206.	
Town: Princeton	**Discharge: N/A**
County: Mercer	**Emergence: N/A**
East/North: NA	**Geology: Passaic Formation**

This is a historic spring. The location is unknown. During the Revolutionary War, it had historical significance. There is a small monument that stands at the corner of Route 206 and Edgerstoune Road in Princeton (fig. A-38). The monument states that on January 3, 1777, after the Battle of Princeton, George Washington and his troops stopped to drink water from a nearby spring.

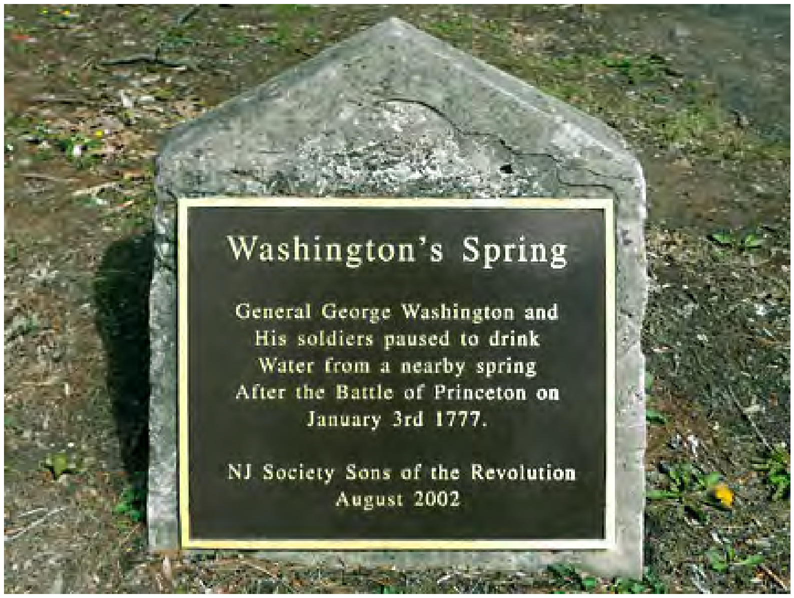

Figure A-38. Washington's Spring monument. *Photo credit unknown.*

Middlesex County

Roosevelt Spring	
ID: 773	
Notes:	
Town: Edison	**Discharge: N/A**
County: Middlesex	**Emergence: N/A**
East/North: 536,227.93, 624,877.49	**Geology: Passaic Formation**

The spring is in Roosevelt Park near the intersection of Route1 and Grand View Avenue along Elm Drive down in a hollow (fig. A-39). This is one of two mapped springs in Middlesex County, both of which have the same three signs posted by Middlesex County warning that the source and quality of the "spring" water is questionable at best. Despite the warnings this is a very popular watering hole.

When water chemistry was done on this spring in 2009 by the DEP, (Muzeni-Corino, Berchtold, 2010). (See below). Initial Total Coliform results were "Too Numerous to Count" without positives. Resampling was conducted several months later, and these results were "Too Numerous to Count" with positives. Middlesex County conducts regular coliform testing and maintains the postings as well as periodic cleanings of the outfall pipe.

Nitrate was not detected. The only metal detected above the reporting level was Barium (270 ppb). Sodium was detected at moderate levels (40.4 ppm) and general water quality characteristics showed it to be hard water (299) with a neutral pH (6.82 – 7.1) and a high amount of total dissolved solids (540). Radiological results showed it to potentially have gross alpha levels exceeding the MCL (14.5 pCi/l) and a Radon level of 1089.

Figure A-39. Roosevelt Park Spring. *Photo, A. Muzeni-Corino, J. Berchtold*.

Coliform Results:		
5/18/2009	Coliform, Total	TNTC w/o+
10/15/2009	Coliform, Fecal	Negative
	Coliform, Total	TNTC w/+
Inorganic Results:		
May 18, 2009	Antimony	ND
	Arsenic	~ 0.13 µg/L
	Barium	270 µg/L
	Beryllium	~ 0.16 µg/L
	Cadmium	ND
	Chromium	ND
	Copper	~ 1.78 µg/L
	Cyanide	ND
	Fluoride	~ 0.063 mg/L
	Lead	ND
	Mercury	ND
	Nickel	ND
	Nitrate (as N)	~ 3.47 mg/L
	Nitrite (as N)	ND
	Selenium	ND
	Silver	ND
	Thallium	ND
Radionuclide Results:		
	Gross alpha, including Ra & U, excluding Rn	14.5 pCi/L

	Radium-226	0.04 pCi/L
	Radium-228	0.41 pCi/L
	Radon 222	1089 pCi/L
General Chemical and Secondary Characteristics:		
	Alkalinity, Total	101 mg/L
	Aluminum	ND
	Chloride	108 mg/L
	Color	ND
	Hardness, Total (as CaCO3)	299 mg/L
	Iron	ND
	Manganese	ND
	MBAS - foaming agents (surfactants)	ND
	Odor	1 T.O.N.
	PH	7.1 pH units
	Sodium	40.4 mg/L
	Solids, Total dissolved (TDS)	540 mg/L
	Sulfate	31.7 mg/L
	Turbidity	0.73 NTU
		ND
	Zinc	
Volatile Organic Compounds:		
	Chloroform	0.77 µg/L

Thompson Park Spring	
ID: 730	
Notes: Used as a public drinking water source.	
Town: Jamesburg	**Discharge: 10 gpm**
County: Middlesex	**Emergence: Hillslope**
East/North: 510604.2, 547550.3	**Geology: Merchantville Formation**

There is a spring located in a park setting in Thompson Park in Jamesburg, Monmouth County (fig. A-40). This spring is posted with signs as drink at your own risk (fig. A-41). It is used as a public drinking water source where people can bring empty bottles to fill up. It has an improved outlet with steps and handrail making the spring water accessible (figs. A-42, A-43, A-44). There is an eight bottle per person limit.

Figure A-40. Top left. Thompson Park and spring location near parking area. *Photo, T. Pallis*.
Figure A-41. Top right. Drink at your own risk signs posted at the spring. *Photo, T. Pallis*.
Figure A-42. Middle left. Wide angle view of spring discharge area. *Photo, T. Pallis*.
Figure A-43. Middle right. Thompson Park Spring discharge pit. *Photo, T. Pallis*.
Figure A-44. Bottom. Close up view of spring water. *Photo, T. Pallis*.

Thompson Park Spring was sampled during 2009 as part of a NJDEP study to test the water at certain springs where people use the water to drink. (Muzeni-Corino, Berchtold, 2010)

The results are as follows:

Thompson Park Spring, PWSID: 1213337 (Inactive)
Middlesex County, Monroe Township
Jurisdiction: Middlesex County Public Health Department
Address: Off Perrineville Rd. near the intersection with School House Road
Source: Spring
Sampled: October 29, 2009 & November 19, 2009 (Coliform resample)

This site is the other Middlesex County "spring" that has water quality problems. The County maintains this site with the same signage as the Roosevelt Park Spring. This site is generally in the center of the 700-acre park along a dirt maintenance road down in a hollow. According to the Middlesex County Public Health Department, the attempts to block off this location with fences have been unsuccessful.

This system was deactivated as a drinking water system because it originates from an "unknown source" and is unprotected.

Initial Total Coliform results were "Too Numerous to Count" without positives. Resampling was conducted and these results were negative. Middlesex County conducts regular coliform testing and maintains the postings as well as periodic cleanings of the outfall pipe.

Nitrate was detected at low levels (4.4 ppm). Metals detected above the reporting level were Aluminum (49.1 ppb), Barium (63.2 ppb), Chromium (1.20 ppb), Manganese (202 ppb), and Nickel (3.74 ppb). Sodium was detected at low levels (29.4 ppm) and general water quality characteristics showed it to have a slightly acidic pH (4.81 – 5.0). Radiological results showed it to have very low gross alpha levels (2.87 pCi/l) and a Radon level of 1052.

Coliform Results:		
10/29/2009	Coliform, Fecal	Negative
	Coliform, Total	TNTC w/o+ 99
11/19/2009	Coliform, Total	Negative
Inorganic Results:		
October 29, 2009	Antimony	~ 0.271 µg/L
	Arsenic	ND
	Barium	63.2 µg/L
	Beryllium	~ 0.111 µg/L
	Cadmium	~ 0.078 µg/L
	Chromium	1.2 µg/L
	Copper	~ 0.375 µg/L
	Cyanide	~ 0.003 mg/L
	Fluoride	ND

	Lead	ND
	Mercury	~ 0.025 µg/L
	Nickel	3.74 µg/L
	Nitrate+Nitrite (as N)	4.4 mg/L
	Nitrite (as N)	ND
	Selenium	~ 0.241 µg/L
	Silver	ND
	Thallium	~ 0.02 µg/L
Radionuclide Results:		
	Gross alpha, including Ra & U, excluding Rn	2.87 pCi/L
	Radium-228	0.75 pCi/L
	Radon 222	1152 pCi/L
General Chemical and Secondary Characteristics:		
	Alkalinity, Total	1 mg/L
	Aluminum	49.1 µg/L
	Chloride	46.2 mg/L
	Color	ND
	Hardness, Total (as CaCO3)	27.4 mg/L
	Iron	~ 3.72 µg/L
	Manganese	202 µg/L
	MBAS - foaming agents (surfactants)	ND
	Odor	1 T.O.N.
	PH	5 pH units
	Sodium	29.4 mg/L
	Solids, Total dissolved (TDS)	112 mg/L
	Sulfate	2.28 mg/L
	Turbidity	0.214 NTU
	Zinc	~ 3.34 µg/L
Volatile Organic Compounds:		
	Chloroform	0.124 µg/L

Monmouth County

Henry Hudson Springs	
ID: 74	
Notes: Henry Hudson's crew drank from this spring in 1609.	
Town: Atlantic Highlands	**Discharge: 1 gpm**
County: Monmouth	**Emergence: Gushette**
East/North: 626019.25, 575553.37	**Geology: Shrewsbury Member**

In early September of 1609, Henry Hudson, an Englishman sailing for the Dutch, entered

Sandy Hook Bay during his exploration of the east coast of the United States. He stopped near a small freshwater spring in along the bay to collect water for his ship the Half Moon before sailing up the Hudson River (Asbury Park Press, 2017). The spring, now known as Henry Hudson Springs, is located on a steep wooded hillside on Bayside Drive in Atlantic Highlands, Monmouth County.

Before the arrival of European explorers, the Lenni Lenape Native Americans had obtained water from this spring. Later, packet ships (a regular scheduled service, carrying freight and passengers) continued to use the spring into the 1800s (The Historical Marker Database, 2020). The spring has since been modified: a stone wall was built at the face of the spring and pipes convey the water from behind it.

Interesting folklore is associated with the Henry Hudson Springs including, "The Curse of Henry Hudson Springs." Henry Hudson's visit to New Jersey spawned this local legend about the ill-fated captain and his wandering apparition (Moran, Sceurman 2006). When Hudson and his crew came ashore in New Jersey to collect spring water for his journey, they climbed over sacred Native American burial grounds to reach the spring. The Lenape also thought this spring had medicinal properties and used it as a source of healing (Moran, Sceurman 2006).

At the time of their visit, Hudson's crew gave little thought on trampling over the Lenni Lenape burial sites to reach the spring. But once the sacred land had been violated. The evil unleashed by the ancient forces was the beginning of the Half Moon's untimely demise. Members of the crew were mysteriously taken ill, sails tore, masts snapped, and moorings sprang loose. One crew member, John Coleman, was killed by the Native Americans when an arrow was shot through his neck. Their explorations became an aquatic nightmare on the high seas. The superstitious crew recalled how Hudson forced them to go through sacred lands to reach the spring and laid the blame on Hudson's shoulders (Moran and Sceurman 2006). On Hudson's final voyage from England in April 1610 to find a northwest passage through the North American continent, he found a large body of water that he thought was the Pacific Ocean. However, it was only a large bay, later to be named Hudson Bay in Canada. Hudson continued to sail down the coast until he hit the southern point of Hudson Bay at James Bay and found there was no western passage. The ship was stranded in James Bay over the winter by harsh weather. Tensions ran high and some of the crew members grew hostile.

When the ice melted in the spring of 1611, Hudson planned to continue to explore for the Northwest Passage to Asia. However, most of his crew desired to return home. On June 22, 1611, the crew mutinied. The mutineers set Hudson, his teenage son John, and seven crewmen loyal to Hudson adrift from a small open rowboat, marooning them in Hudson Bay. They were never to be seen again. No one knows what happened to them. It is assumed that they died soon after. This was until various reported sightings over the past few centuries along the coast of New Jersey.

Stories tell of seeing Hudson's apparition calling "Ahoy!" from the ocean as he searches the shoreline of Atlantic Highlands for a safe landing spot. The ancients still protect the area from unwanted intruders, and his relentless spirit is not permitted to set foot on the same lands he violated in 1609. The captain of the Half Moon is forever doomed to roam the rock-strewn shores of Atlantic Highlands. It is said that moonlit nights are the best to look for him (Moran, Sceurman 2006).

Today the spring is a moss-covered fieldstone retaining wall with several rusty pipes protruding from it (figs. A-45, A-46, A-47). The spring continues to spew cool water (fig A-48), though the town health department has posted signs warning not to drink the water (fig. A-49).

Figure A-45. Top left. View of the wall. *Photo, S. Domber*.
Figure A-46. Top right. Close up view of wall. *Photo, S. Domber*.
Figure A-47. Middle left, close-up picture of the outlet pipes. *Photo, S. Domber*.
Figure A-48. Middle right, Warning sign warns to not drink the spring water. *Photo, S. Domber*.
Figure A-49. Bottom. View of Sandy Hook Bay looking out from near the Henry Hudson Spring. *Photo, T. Pallis*.

Indian Lady Hill Spring	
ID: 422	
Notes: Springhouse in disrepair. Spring was once used as a bottled water source.	
Town: Neptune Township	**Discharge: 1 gpm**
County: Monmouth	**Emergence: Hillslope**
East/North: 616329.45, 505771.79	**Geology: Cohansey Formation**

This spring was once a source of water for the Indian Lady Hill Spring Water Company. Today the spring is abandoned (fig. A-50), and in disrepair but still flowing (fig. A-51).

Figure A-50. Left, Indian Lady Hill Spring springhouse. *Photo, T. Pallis*,
Figure A-51. Right, Inside Indian Lady Hill Spring springhouse. *Photo, S. Domber*.

Kepwel Spring	
ID: 76	
Notes: Used as bottled water source.	
Town: Ocean Township	**Discharge: NA**
County: Monmouth	**Emergence: Limnocrene**
East/North: 613862.0, 513547.0	**Geology: Lower Member Kirkwood Formation**

Kepwel Spring is located at the corner of Bowne Road and Cold Indian Spring Road in the Wayside section of Ocean Township, Monmouth County. The Lenni Lenape Native Americans camped in the area of the spring. As legend has it, the Lenape would come to the spring every summer and camp on the banks of the spring-fed pond. They were thought to have picked the area of the spring because of the legendary healing powers of the water. In one account the Lenape King Ockanickon was carried to the spring from a great distance on his death bed to be revived by the healing powers of the free-flowing spring water. The area surrounding the spring became known as the "Cold Indian Springs," now also known as Wayside. In the Mid 1700s, Benjamin Woolley became the first European owner of the property after purchasing the Cold Indian Spring parcel from the Lenape for one barrel of whiskey. Next "Quaker Billy" Layton purchased the land and built a house on it. Around 1872, descendants of Quaker Billy began bottling and selling the spring water, then called Cold Indian Springs, in small and large glass bottles. Later, William Morrell bought the property and spring water business including the spring source (fig. A-52). In the late 1930s, the name of the bottling company, Kepwel Spring Water was first used. Today, Kepwel Spring Water is delivered by truck (fig. A-53).

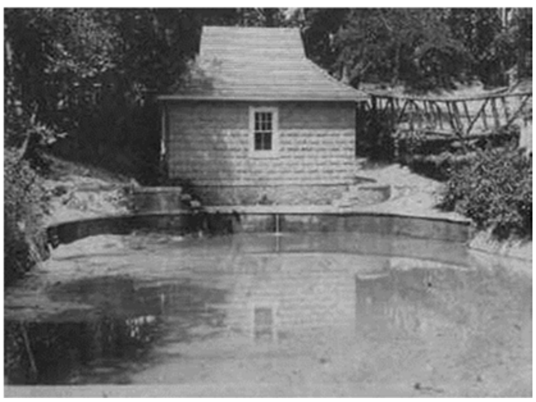

Figure A-52. Left. Vintage picture of the Kepwel spring water source as it comes up from the ground into a protected spring house, c. 1920. *Photo courtesy of Kepwel Spring.*
Figure A-53. Right. A Kepwel Spring Water delivery truck. *Photo, S. Domber.*

Information and photographs courtesy of Kepwel Natural Spring Water Company.

Perrine Hill Spring	
ID: 720	
Notes:	
Town: Manalapan Township	**Discharge: 1 gpm**
County: Monmouth	**Emergence: Hillslope**
East/North: 542390.169, 526985.57	**Geology: Navesink Formation**

During the American Revolution at the Battle of Monmouth in Freehold and Manalapan Townships on June 28, 1778, Molly Pitcher (Mary Hays McCauley), (Carino, 2014), carried water from a spring to thirsty troops on a 97-degree day. The next day she was thought to have taken over the firing of a cannon after her husband was wounded. This is according to legend and is possible but unverified (Carino, 2014). Today the spring is known as the Perrine Hill Spring and is located inside Monmouth Battlefield State Park in Manalapan Township. The park's walking tour No. 2 will get you to the site. To get to the spring hike 10 minutes north of Route 522 and veer left past Perrine Hill and head toward the tree line. There is a narrow path into the woods that ends at a wooden deck overlooking a ravine. After careful examination of the battle lines and written accounts, this location is where it is thought Molly Pitcher got her water for the troops (Carino, 2014). There is a plaque commemorating the event (fig. A-54), overlooking the site (fig. A-55).

Figure A-55. Left. Overlook at Perrine Hill Spring. *Photo, T. Pallis*.
Figure A-55. Right. The source of the Perrine Hill Spring. *Photo, T. Pallis*.

Molly Pitcher Spring	
ID: 669	
Notes: Location of stone monument.	
Town: Manalapan Township	**Discharge: <1 gpm**
County: Monmouth	**Emergence: Hillslope**
East/North: 546580.605, 523135.065	**Geology: Navesink Formation**

Another spring, honoring Molly Pitcher but not thought to be where Molly Pitcher got her water during the American Revolution at the Battle of Monmouth is located nearby in another area of Monmouth Battlefield State Park. The spring location is near Freehold Road in Manalapan. There is a small seep coming from hillside a few yards away near a ditch in some briar bushes (fig. A-56). The Molly Pitcher Spring monument is nearby (fig. A-57).

 

Figure A-56. Molly Pitcher Spring, Monmouth Battlefield State Park Monmouth County. *Photo, T. Pallis*.
Figure A-57. Molly Pitcher Spring stone historical marker at Monmouth Battlefield State Park Monmouth County. *Photo, T. Pallis*.

Tinton Falls Spring	
ID: 681	
Notes: Spring is fenced off.	
Town: Tinton Falls	**Discharge: >1 gpm**
County: Monmouth	**Emergence: Hillslope**
East/North: 603408.81, 536279.82	**Geology: Tinton Formation**

Long ago, the local Lenni Lenape Native Americans revered the Tinton Falls Springs therapeutic chalybeate waters (fig. A-58). A historical marker stands next to the spring explaining its history (fig. A-59). In 1883, the "Mineral Springs Hotel" was built across the street from the spring, providing lodging for tourists who would come to benefit from the spring's medicinal properties. Also, in the 1800s, water from the spring was bottled and sold by the "Tinton Falls Mineral Spring Company." It was prescribed as a cure for everything from colic to killing flatworms in the stomach, though the only real benefit was likely alleviating anemia or iron-poor blood. The water, however, would turn to the color of cider and precipitate solids after standing for several hours. This made it unsuitable for bottling and shipping (www.tintonfalls.com).

Figure A-58. Left. Tinton Falls Spring. *Photo, N. Malerba*.
Figure A-59. Right. Historical marker in front of the Tinton Falls Spring. *Photo, N. Malerba*.

Paint Spring Island	
ID: 715	
Notes:	
Town: Millstone Township	**Discharge: >1 gpm**
County: Monmouth	**Emergence: Helocrene**
East/North: 517625.66, 492347.66	**Geology: Lower Member Kirkwood Formation**

Paint Island Spring is in Millstone Township, Monmouth County and is a large chalybeate spring situated along the side of Paint Island Road. The spring at one time was used by the Native Americans for the attractive colors it produced. Later, doctors prescribed its waters for medicinal purposes. Some local residents recalled a Dr. Thomas and a Dr. Woodward, who used to send patients down to Paint Island Spring to drink the water (Beck, 1963). It was once so visited that it became a park for all to enjoy (www.millstonenj.gov/history.com). The spring has the appearance of a small volcano. The water at the top of its crater-like formation has an oily hue (fig. A-60). The surrounding marsh is tinctured with rich ochre (fig A-61). Oxides in the water created the hues desirable for paint (Beck, 1963). It is said the soils of the area were dug up and possibly brought to Imlaystown where there was a paint factory (Beck, 1963). The outlet is subterranean and flows free and clear from a small hole beside the stream closer to the bridge along Paint Island Road. The spring area is scattered with bricks and there was once a small wall around the spring. The name Paint Island Spring came about because the spring itself was in the middle of a marsh and the spring was truly an island.

Figure A-60. Left. Paint Island Spring volcano like structure, oily hued water. *Photo, S. Domber*.
Figure A-61. Right. The surrounding marsh is tinctured with rich ochre. *Photo, S. Domber*.

Morris County

Capstick Spring	
ID: 37	
Notes: Spring emerges from pipe.	
Town: Montville	**Discharge: 1 gpm**
County: Morris	**Emergence: Hillslope**
East/North: 523691.0, 759541.0	**Geology: Quartz-Oligoclase Gneiss**

This spring is also referred to as the Montville Spring. Its place of origin has been buried by road construction which has covered over the historic location of the spring. This spring now discharges from a pipe on the side of a hill, 100 feet north of the railroad tracks on the east side of Taylortown Road (fig. A-62). A Belgium block channel at side of road carries water from the spring almost year-round (fig. A-63). Numerous other seeps along the same slope have been observed nearby.

Figure A-62. Left, Capstick spring water as it emerges from a pipe. *Photo, S. Domber*.
Figure A-63. Right, water running downhill from the Capstick Spring outlet as it flows down the drainage area. *Photo, S. Domber*.

Buttermilk Falls Springs	
ID: 743, 744, 745.	
Notes: 3 distinct springs in close proximity.	**Coordinates are for spring 1**
Town: Mendham Township	**Discharge: 1 gpm, 1 gpm, 5 gpm**
County: Morris	**Emergence: Hillslope**
East/North: 458465.794, 716196.432	**Geology: Diorite**

Three springs, Buttermilk Falls Spring # 1 (fig. A-64), Buttermilk Falls Spring # 2 (fig. A-65), and Buttermilk Falls Spring # 3 (fig. A-66), emerge from steep slopes surrounding the pool around Buttermilk Falls along India Brook in Mendham Township. All are within approximately 50 feet from each other.



Figure A-64. Top left. Buttermilk Falls Spring # 1, east side of India Brook. *Photo, T. Pallis*.
Figure A-65. Top right. Buttermilk Falls Spring # 2, east side of India Brook. *Photo, T. Pallis*.
Figure A-66. Bottom. Buttermilk Falls Spring # 3, west side of India Brook. *Photo, T. Pallis*.

Highlands Ridge Park Spring	
ID: 690	
Notes: Community garden water supply.	
Town: Chester Township	**Discharge: 5 gpm**
County: Morris	**Emergence: Hillslope**
East/North: 445521.574, 714141.214	**Geology: Diorite**

This spring emerges in a springhouse in a hillside forest in Highlands Ridge Park, Chester Township (fig. A-67). It is the water supply for the Chester community garden.

Figure A-67. Springhouse at Highlands Ridge Park. *Photo, T. Pallis*.

Hedges Mine Spring	
ID: 73	
Notes: Discharges into a channel.	
Town: Chester Borough	**Discharge: 20 gpm**
County: Morris	**Emergence: Rheocrene**
East/North: 434476.86, 710025.74	**Geology: Diorite**

This spring has a steady flow of 20 gpm most of the year and has an orange color (fig. A-68). Being an iron-rich spring, water oxidizes on contact with air to form thick orange deposits. This spring is located adjacent to the Hedges iron mine, formerly an active iron mine during the 1800s. The spring discharges into a channel (fig. A-69).

Figure A-68. Left, Hedges Mine Spring source. *Photo, T. Pallis*.
Figure A-69. Right, spring run, right. *Photo, T. Pallis*.

This spring was field sampled by the NJGWS on July 29, 2010.

Results:

pH: 6.5
Specific Conductivity: 290
Spring temperature: 14.5 C, 58.1°F
Air temperature: 21 C, 69.8°F

Schooley's Mountain Spring, (Inactive), Historical	
ID: 433	
Notes: Spring does not flow anymore.	
Town: Washington Township	**Discharge: NA**
County: Morris	**Emergence: Hillslope**
East/North: 403930.0, 721313.0	**Geology: Quartz-Oligoclase Gneiss**

The Schooley's Mountain Spring was at one time housed under a pavilion like springhouse (fig. A-70). At is non-extant but was included in this report due to its historic significance (fig. A-71). The spring was a victim of road widening construction in the 1930s and has since ceased to flow. The road was widened by blasting and it is thought the water changed its course because of this disturbance.

The spring was analyzed late in the nineteenth century by distinguished chemists, who also testified that it was the purest chalybeate water in the United States (Kobbe, 1890). The following is the analysis by Dr. T. M. Coan as reported in 1890 (Kobbe, 1890).

Solids	**Grains per gallon**
Sodium bicarb	0.58
Magnesium carb	1.60
Iron carb	0.58
Calcium carb	1,42
Solids	**Grains per gallon**
Calcium sulphate	1.68
Alumina	0.14
Silicic acid	0.74
Sodium chloride	0.43
Total	**7.17**

With a trace of Manganese Carbonate and of Ammonia (Kobbe, 1890).

Figure A-70. Left. Schooley's Mountain Spring springhouse. Date and photographer unknown.
Figure A-71. Right. Schooley's Mountain Spring historical marker. Schooley's Mountain Rd. Washington Twp., Morris County. *Photo, S. Domber*.

Schooley's Mountain Road Spring	
ID: 684	
Notes: Along Schooley's Mtn. Road.	
Town: Washington Township	**Discharge: 1 gpm**
County: Morris	**Emergence: Hillslope**
East/North: 403957.0, 719983.0	**Geology: Biotite-Quartz-Feldspar Gneiss**

This spring lies alongside Schooley's Mountain Road near the former famous Schooley's Mountain Chalybeate spring location. This spring emerges from a stone grotto (fig. A-72). A close-up view of the spring shows water present in the grotto (fig. A-73). Not much is known about the history of this spring.

Figure A-72. Left. Schooley's Mountain Road Spring. *Photo, S. Domber*.
Figure A-73. Right. Stone grotto of Schooley's Mountain Road Spring. *Photo, S. Domber*.

Schooley's Mountain Water Supply Spring, Washington Township MUA	
ID: 223	
Notes: Washington Twp. MUA Spring.	
Town: Washington Township	**Discharge: NA**
County: Morris	**Emergence: Hillslope**
East/North: 413407.982, 713829.566	**Geology: Pyroxene Granite**

The Washington Township Municipal Utilities Authority water system in Washington Township, Morris County was the last municipal water system in the state that captured water from a spring to use as part of its water supply (fig. A-74). The township ceased the use of spring water from this spring in about 2018.

Figure A-74. Washington Township Municipal Utilities Authority water system, Schooley's Mountain water supply springhouse. *Photo, T. Pallis*.

Spring Hill, Canfield Spring	
ID: 437	
Notes: Closed to the public.	
Town: Mine Hill Township	**Discharge: 5 gpm**
County: Morris	**Emergence: Hillslope**
East/North: 461640.72, 740976.2	**Geology: Biotite-Quartz-Oligoclase Gneiss**

Known locally as Spring Hill at Canfield or Spring Hill, this site is privately owned. Until November of 2015, this spring was open to the public. The spring was closed on November 2, 2015, due to the high cost of water testing (fig. A-75). Before shutting down, this was the only spring in New Jersey where potable spring water was available to the public with regular water quality testing done. Spring Hill is located on Canfield Avenue between State Highways 10 and 46 in Mine Hill Township, Morris County.

Figure A-75. Spring Hill, Canfield Spring. *Photo, T. Pallis*.

This spring was sampled by the NJDEP on January 13, 2010, for a separate project (Muzeni-Corino, Berchtold, 2010). The water sample results showed no violations. The results are below. Total Coliform results were negative, and Nitrate was detected at low levels (2.3 ppm). The only metals detected above the reporting level were Aluminum (33.7 ppb), Barium (359 ppb) Copper (2.13 ppb), Manganese (74.3 ppb), and Nickel (1.08 ppb). Sodium was detected at high levels (125 ppm) and general water quality characteristics showed it to have a slightly acidic pH (5.29 – 5.3) and a high amount of total dissolved solids (517). Radiological results showed it to have low Gross Alpha levels (4.28 pCi/l) and a Radon level of 3009 pCi/l.

Coliform Results:		
	Coliform, Total	Negative
Inorganic Results:		
	Antimony	~ 0.245 µg/L
	Arsenic	~ 0.213 µg/L
	Barium	359 µg/L
	Beryllium	~ 0.606 µg/L
	Cadmium	~ 0.388 µg/L
	Chromium	ND
	Copper	2.13 µg/L
	Cyanide	ND
	Fluoride	~ 0.048 mg/L
	Lead	~ 0.035 µg/L
	Mercury	ND
	Nickel	1.08 µg/L
	Nitrate+Nitrite (as N)	2.3 mg/L
	Nitrite (as N)	ND

	Selenium	ND
	Silver	ND
	Thallium	~ 0.018 µg/L
Radionuclide Results:		
	Gross alpha, including Ra & U, excluding Rn	4.28 pCi/L
	Radium-228	0.69 pCi/L
	Radon 222	3009 pCi/L
General Chemical and Secondary Characteristics:		
	Alkalinity, Total	3 mg/L
	Aluminum	33.7 µg/L
	Chloride	246 mg/L
	Color	ND
	Hardness, Total (as $CaCO_3$)	114 mg/L
	Iron	~ 6.83 µg/L
	Manganese	74.3 µg/L
	MBAS - foaming agents (surfactants)	ND
	Odor	1.15 T.O.N.
	PH	5.3 pH units
	Sodium	125 mg/L
	Solids, Total dissolved (TDS)	517 mg/L
	Sulfate	8.26 mg/L
	Turbidity	0.348 NTU
	Zinc	ND
Volatile Organic Compounds:		
	Methyl tert-butyl ether (MTBE)	~ 0.201 µg/L

Willowwood Arboretum Spring	
ID: 632	
Notes:	
Town: Chester Township	**Discharge: > 1 gpm**
County: Morris	**Emergence: Helocrene**
East/North: 437264.012, 689476.710	**Geology: Passaic Formation**

There is a small spring located at Willowood Arboretum in Chester Township, Morris County. It is in a cement box with a cover over it (fig. A-76). The flow is minimal.

Figure A-76. Willowood Arboretum Spring. *Photo, T. Pallis*.

Burnham Park Spring	
ID: 769	
Notes:	
Town: Morristown	**Discharge: 8 gpm**
County: Morris	**Emergence: Hillslope**
East/North: 493232.38, 715606.575	**Geology: Quartz-Oligoclase Gneiss**

Burnham Park Spring is located on a hillslope at the bottom of Spring View Drive (fig. A-77), in Morristown Morris County. It can be viewed from the road (fig A-78). There are three emergences of this spring in close proximity One is visible in (fig. A-79). The long spring run eventually drains into a storm drain (fig. A-80), and then is piped into Burnham Pond.

Figure A-77. Left. Spring Hill Drive, Street sign. *Photo, T. Pallis*.
Figure A-78. Right. Spring looking down from Spring Hill Drive. *Photo, T. Pallis*.

 

Figure A-79. Left. Emergence of spring. *Photo, T. Pallis*.
Figure A-80. Right. View from the bottom of the spring run outlined by the green grass surrounded by the snow in the middle of January. *Photo, T. Pallis*.

Great Spring	
ID: 772	
Notes:	
Town: Roxbury Township	**Discharge: NA**
County: Morris	**Emergence: Helocrene**
East/North: 453933.599, 745654.078	**Geology: Dolomite, Dolomitic Sandstone, Siltstone and Shale**

This spring flows from a small wetland along a streambed of glacial sand. Not shown on any modern maps, the springs existence, however, was well known to Leni Lenape families who lived in the adjacent forests for perhaps thousands of years. They called this now forgotten place "great spring." They called the stream "gentle flowing." The Great Spring and its waters were also well known to the first European settlers in the Succasunna Valley. According to written accounts from the 1700s, folks marveled at the constant flow even during dry spells. The water was described as always cool and delicious. In what may have been a translation error back then, the early settlers called this stream flowing from the spring the Black River. *Munsell's 1882 History of Morris County mentions* the water that flowed from the spring near McCainsville as being cool, clear, and remarkable for its quantity and purity. The actual Lenape name for this gentle flowing stream was "Alamatong" from which we get its modern name, the Lamington. While most everyone knows of the Black River or the Lamington River, the spring itself has faded from memory and disappeared from maps. The Native Americans knew that the Great Spring is literally the fountainhead of the North Branch of the Raritan River. (fig. A-81). For over 150 years the spring has been located on 1,000 acres of privately owned industrial land where TNT and other explosives were manufactured. This environmentally important spring is at the southernmost edge of the former Hercules Powder property along U.S. Route 46 in Kenvil, New Jersey. The spring's wetlands have remained off-limits to the public and its ecology and geology have never been properly studied." From, *The Great Spring*, Data-Driven Viewpoints: The Great Spring. by Brian T. Lynch, (aseyeseesit.blogspot.com) March 22, 2022, Accessed June 20. 2022.

Figure A-81. The Black River as it flows from the Great Spring. Photo, *Brian T. Lynch.*

Ocean County

No springs mapped.

Passaic County

National Spring Water Company Spring	
ID: 228	
Notes:	
Town: Haledon	**Discharge: Unknown**
County: Passaic	**Emergence: Hillslope**
East/North: 577812.41, 766364.17	**Geology: Preakness Basalt**

The National Spring Water Company continuously served northern New Jersey with bottled water from this spring since the company was established in 1939 until it shut down in 2016. The spring is located inside the bottling plant building and it emerged inside the middle of a hole in the floor of the building where the water is collected (fig. A-82). The building is located at 419 Southside Avenue in Haledon (fig. A-83).

Figure A-82. Left, Spring inside the building which is the source of National Spring Water. *Photo, T. Pallis*.
Figure A-83. Right, National Spring Water delivery truck in front of the building, January 2012. *Photo, T. Pallis*.

Borough of Haledon Tilt Spring	
ID: NA	
Notes: Spring is not flowing. Historical.	
Town: Haledon Borough	**Discharge: 0 gpm**
County: Passaic	**Emergence: Hillslope**
East/North: 578050.35, 766204.67	**Geology: Preakness Basalt**

This municipal spring at Southside Avenue and Tilt Street in Haledon, (fig A-84) was such a beloved attraction in the past for the community, a centennial book of the borough's history referred to it as the "fountain of youth" (Rolondo, 2016). This spring is not operational anymore due to lack of flow. It ceased to flow around 2005 and the Borough of Haledon has discontinued upkeep of the spring. The spring will remain decommissioned for the foreseeable future due to the lack of flow. The Tilt Street spring obtained water from the same source as the National Spring Water Company just a few hundred feet uphill. The reason for the spring drying up has not been determined. According to an article in the Bergen Record, "engineers looked at it. They tried to do all kinds of things to get it going again. The people wanted it" (Rolondo, 2016). Before the current spring house was built in the late 1930s, Perlino Giardino, who owned a hardware store in Paterson, had an outlet for the spring built across the street. Giardino's friend Ernest Roffino, a Haledon mason/contractor, built a horseshoe-shaped masonry structure with steps leading to a clay pipe, from which "the water flowed constantly," according to the centennial book of Haledon (Rolondo, 2016).

Years later the Borough of Haledon bought the spring and relocated the outlet to Southside and Tilt Streets. People came from all over day and night to get the water. This caused disturbances with some neighbors until the borough established specific hours to draw water from the spring. Special keys were issued to Haledon residents and to Haledon water utility customers in order to open the specialized taps (Rolondo, 2016). Because of the popularity of the spring, issues arose. Residents reported brawls associated with the lines for water. People were blocking driveways. Some people went in with five or six gallons to fill, and others did not want to wait their turn in line. Fines were issued and a four gallon per person limit was instituted to "control the indiscriminate and excessive use of said spring" (Rolondo, 2016). According to the ordinance adopted by the Haledon Borough council in 1981, those taking the water by illegal means could be fined $25 to $250 for each offense, while those who exceeded the four gallons per visit limit could be fined $10 per jug (Rolondo, 2016). At the time, the Borough Council decided the "uncontrolled removal and taking of water from the municipal spring had resulted in creating increased cost and had caused deterioration in the service to citizens (Rolondo, 2016). One day, a sign at the spring pronounced a "temporary closing"; temporary became permanent and even today residents wonder what could have caused the spring's demise (Rolondo, 2016).

Figure A-84. Two-spigot outlet of Tilt Street Spring. *Photo, T. Pallis*.

Bubbling Springs	
ID: 18	
Notes:	
Town: West Milford Twp.	**Discharge: 10 gpm**
County: Passaic	**Emergence: Hillslope**
East/North: 524397.1, 822272.4	**Geology: Hornblende Granite**

Bubbling Springs is in Bubbling Springs Recreation Area on Macopin Road, West Milford, Passaic County (fig. A-85). When the spring was visited in November of 2015, there was water bubbling out of the ground into a bed of sand inside a spring house (fig. A-86). The flow was approximately ten gallons per minute during moderate drought conditions. There was no history about the spring in the literature. However, 1930s aerial photos show farmland adjacent to the spring. Most likely the spring was associated with the farm. The spring is located inside a springhouse (fig. A-87). The water flows to the outside of the springhouse into a wet area on the east side of the springhouse (fig. A-88).



Figure A-85. Top left, entrance sign to Bubbling Springs Recreation Area. *Photo, T. Pallis*.
Figure A-86. Top Right, inside the springhouse in the where the spring water rises. *Photo, T. Pallis*.
Figure A-87. Bottom left, springhouse. *Photo, T. Pallis*.
Figure A-88. Bottom right, springhouse from a distance with outlet pond. *Photo, T. Pallis*.

Salem County

No springs mapped.

Somerset County

Washington Rock Spring	
ID: 630	
Notes: Spring does not flow.	
Town: Green Brook Township	**Discharge: >1 gpm**
County: Somerset	**Emergence: Limnocrene**
East/North: 499587.89, 649635.63	**Geology: Orange Mountain Basalt**

Washington Rock Spring is spring is located in Washington Rock State Park in Green Brook Township, Somerset County (fig. A-89). Washington Rock Spring had no flow on the date visited by the NJGS and was at one time a source for bottled water (fig. A-90). A spring water bottling company, the Washington Rock Spring Water Company opened in 1903 using the water from this spring. It would shut down operations in 1921. Eventually, because of development, its two springs in the area dried up. Only one pit was located. The land is now owned by the State of New Jersey and is part of Washington Rock State Park.

Figure A-89. Left, spring well pit # 1 at Washington Rock Spring. *Photo, T. Pallis*.
Figure A-90. Right, water bottle from Washington Rock Spring Water Company. *Photo, T. Pallis*.

SUSSEX COUNTY

Bevans Spring, Peters Valley	
ID: 702	
Notes:	
Town: Sandyston Township	**Discharge: 500 gpm**
County: Sussex	**Emergence: Rheocrene**
East/North: 396889.879, 863283.395	**Geology: Kalkberg Limestone**

The Bevans Spring emerges from the hillside. There are some improvements associated with this spring including a cement grotto (fig. A-91). The water flowing from the spring does not freeze in winter and is warm enough to promote the growth of water cress in the winter even when the ground is snow covered (fig. A-92).

Figure A-91. Left, Bevan's Spring grotto wall with spring outlet under the fallen tree. *Photo, T. Pallis*.
Figure A-92. Right, spring run flowing away from Bevan's spring. *Photo, T. Pallis*.

Big Springs (North Church)	
ID: 7	
Notes:	
Town: Hardyston Township	**Discharge: 350-500 gpm, July/1947**
County: Sussex	**Emergence: Helocrene**
East/North: 458539.9, 836037.4	**Geology: Allentown Dolomite**

Big Spring's North Church is located at the intersection of Route 94 and Big Springs Road in Hardyston Township, approximately five miles south of Hamburg (fig. A-93). There is a small pond where the spring emerges (fig. A-94). When the flow was measured in 1947 by Mr. William Stanley of Roselle after a rain with a weir, the discharge was 350-500 gpm, the pH was 7.4, and the temperature was 57.4 °F (NJGS Permanent Notes, 9/10/1947).

Figure A-93. Left, Big Springs (North Church) along Route 94. *Photo, T. Pallis*.
Figure A-94. Right Big Springs (North Church) with pond. *Photo, T. Pallis*.

Big Spring, Whittingham	
ID: 56	
Notes: Visited during drought conditions.	
Town: Fredon Township	**Discharge: >10 gpm**
County: Sussex	**Emergence: Hillslope**

East/North: 410303.532, 793055.844	Geology: Allentown Dolomite

This spring is located in the Whittingham Wildlife Management Area. The flow varies throughout the year depending on rainfall and is sometimes dry. It was visited by the NJGWS during drought conditions and was not flowing (fig. A-95). The spring drains into an old marl quarry. The outlet area for the spring was mined at one time for marl which created a large pond (fig. A-96).

Figure A-95. Left, Big Spring Whittingham source after a long dry spell. *Photo, T. Pallis*.
Figure A-96. Right, Big Spring Whittingham drainage area into pond. *Photo, S. Domber*.

Brau Kettle	
ID: 17	
Notes:	
Town: Sandyston Township	Discharge: 500 gpm
County: Sussex	Emergence: Limnocrene
East/North: 401669.4, 885417.0	Geology: Buttermilk Falls Limestone

The Brau Kettle is a geological feature located along the Walpack Ridge in the Delaware Water Gap National Recreation Area (fig. A-97). Its name derives from the Dutch for "brewing" or "boiling kettle," which describes how water suddenly bubbles up from the ground. This site is referenced in early French Jesuit and Dutch colonial manuscripts as a landmark near which colonial traders exchanged goods with the Munsee and other local Native American Indian tribes. The feature looks like a sinkhole in dry times during the year (Usually in late summer and early fall). It is known to flow at random, after periods of precipitation, and is thought to be fed by a sinking stream that vanishes in the forest roughly 1,800 feet away. It has never been seen iced over even after nights with temperatures below well zero (fig. A-98).

Figure A-97. Left, Brau Kettle in springtime, full of water. *Photo R. Witte*,
Figure A-98. Right, Brau Kettle in winter, full of water and no ice on a cold day. *Photo, S. Domber*.

Brau Kettle Spring 2	
ID: 646	
Notes:	
Town: Sandyston Township	**Discharge: 5 gpm**
County: Sussex	**Emergence: Hillslope**
East/North: 402275.5, 884911.7	**Geology: Buttermilk Falls Limestone**

This spring is approximately a quarter mile uphill from Brau Kettle along the south side of Jager Road (fig. A-99). It contains some improvements such as a cement grotto to collect water indicating that the spring might have been used for domestic water supplies at one time.

Figure A-99. Brau Kettle Spring # 2. *Photo, T. Pallis*.

Crystal Spring Sink/Herkimer Diamond Spring	
ID: 23	
Notes:	
Town: Stillwater Township	**Discharge: > 10 gpm**
County: Sussex	**Emergence: Helocrene**
East/North: 396876.1, 820674.6	**Geology: Upper Part of Beekmantown Group**

Crystal Spring Sink/Herkimer Diamond Spring emerges in a wooded area in Stillwater Township, Sussex County (fig. A-100). Its flow is steady (fig. A-101).

Figure A-100. Left, Crystal Spring Sink/ Herkimer Diamond Spring. *Photo, K. Strakosh Walz.* **Figure A-101**. Right, Crystal Spring Sink/ Herkimer Diamond Spring, close up view. *Photo, K. Strakosh Walz*.

Dingman's Ferry Spring	
ID: 52	
Notes:	
Town: Sandyston Township	**Discharge: 100 gpm**
County: Sussex	**Emergence: Cave Spring**
East/North: 394754.7, 869553.3	**Geology: Buttermilk Falls Limestone**

Dingman's Ferry Spring is a large-flow spring on the side of Walpack Ridge. It discharges from a hillside through a one-meter-wide hole (fig. A-102). This subterranean stream flows through a large open joint before appearing on the surface. During periods of high flow, discharge can be greater than 100 gallons per minute (fig. A-103).

 

Figure A-102. Left, Dingman's Ferry Spring discharges from a hillside through a one-meter-wide hole. *Photo, T. Pallis*.
Figure A-103. Right, Dingman's Ferry Spring during a period of high flow. *Photo, S. Domber*.

Sperry Spring	
ID: NA	
Notes: Historical spring, location unknown.	
Town: Hopatcong Borough	**Discharge: NA**
County: Sussex	**Emergence: Unknown**
East/North: NA	**Geology: Unknown**

Sperry Spring was once located on the south side of Byram Bay in Hopatcong Borough not far from Lake Hopatcong is a historical spring where the locals would obtain drinking water years ago (fig. A-104). The current location of this spring is unknown though there is a section of Hopatcong Borough known as Sperry Springs. Sperry Spring was the most celebrated spring on Lake Hopatcong at the turn of the twentieth century. It was described as a rill of clear, icy water in the *Suburbanite* magazine article, *Hopatcong: The Lake Among the Hills,* by Gustave Koebbe in April 1906. This spring was considered to have the freshest drinking water from any spring found around Lake Hopatcong. Families from the Byram Bay and Bear Pond areas were known to fill up their water pails here for picnics or hiking excursions (fig. A-105).

Figure A-104. Sperry Spring, Hopatcong Borough, Lake Hopatcong, Sussex County. Date/photographer unknown. *Courtesy, Lake Hopatcong Historical Society*.

Figure A-105. Sperry Spring, Hopatcong Borough, Lake Hopatcong, Sussex County. Date/photographer unknown. *Courtesy, Lake Hopatcong Historical Society*.

Spring Brook Cabin Spring	
ID: 436	
Notes: Located in Stokes State Park.	
Town: Sandyston Township	**Discharge: Unknown**
County: Sussex	**Emergence: Helocrene**
East/North: 424625.1, 869373.7	**Geology: Bloomsburg Red Beds**

The Spring Brook Cabin Spring is associated with some glacial material that formed at the base/break in the slope coming off the mountain (fig. A-106). It has a strong flow (fig. A-107). This spring is located at the headwaters of a small wetland and stream about 150 feet from a cabin, (fig. A-108) (hence the Spring Brook Cabin name!). There is plentiful wildlife near this spring including salamanders (fig. A-109).

Figure A-106. Left, Glacial material at spring source. *Photo, B. Henning*.
Figure A-107. Right, Wetland and stream. *Photo, B. Henning*.

 

Figure A-108. Left, Turtle and Cabin near Spring Brook Cabin Spring. *Photo, B. Henning*.
Figure A-109. Right, Salamander near the spring. *Photo, B. Henning*.

Swimming Pool Spring	
ID: 39	
Notes:	
Town: Green Twp.	**Discharge: 275-300 gpm**
County: Sussex	**Emergence: Cave Spring**
East/North: 401755.9, 787277.4	**Geology: Allentown Dolomite**

Swimming Pool Spring discharges from Swimming Pool Cave at the base of a cliff and is a spring of large capacity near Huntsberg, Green Township, Sussex County (fig. A-110). An artificial pond is directly below the entrance pools the spring discharge (fig. A-111).

Mr. William Stanley of Roselle measured the capacity of this spring in July of 1947 and supplied the following data to the NJGS.

Yield: 275-300 gpm (weir measurement)
pH: 7.5
Temperature: 49 degrees F

(Herpers, 9/10/1947)

 

Figure A-110. Left, Water discharge from base of cliff. *Photo, S. Domber*.
Figure A-111. Right, Manmade "Swimming pool" below the spring. *Photo, S. Domber*.

Union County

Watchung Reservation Spring	
ID: 740	
Notes:	
Town: Mountainside	**Discharge: 1 gpm**
County: Union	**Emergence: Hillslope**
East/North: 520854.5, 671266.2	**Geology: Feltville Formation**

This small hillside spring is stop # 8 on the Ruth Canstein Yablonsky self-guided geology trail at the Watchung Reservations Trailside Nature Center in Mountainside (fig. A-112). It's a muddy spot where water from a hillside spring emerges at the surface and flows down the trail. There is a great supply of water stored below the surface of the Watching Reservation. Native Americans were known to have used this spring. At the time when the picture below was taken on November 2, 2016, New Jersey was in a drought and there was almost no flow from this spring.

Figure A-112. The spring emerges in front of the sign under the leaves. *Photo, T. Pallis*.

Warren County

Ballou's Spring	
ID: 689	
Notes: On private property.	
Town: Liberty Township	**Discharge: 5 gpm**
County: Warren	**Emergence: Hillslope**
East/North: 358610.8, 740531.6	**Geology: Hornblende Granite**

This spring is in the Mountain Lake Section of Liberty Township on the edge of Jenny Jump State Park (fig. A-113). It emerges from the rock into a stone springhouse across the street from Mountain Lake at the corner of Lakeside Drive West and Lakeside Drive. This site is known locally as Ballou's Spring and is within two miles of Route 46. This site is privately owned.

Figure A-113. Ballou's Spring and spring house. *Photo T. Pallis*.

The NJDEP sampled the spring on April 24, 2009, for another study (Muzeni-Corino, Berchtold, 2010).

Total Coliform results were negative, and Nitrate was detected at very low levels (0.194 ppm). The only metals detected above the reporting level were Aluminum (11.2 ppb) and Barium (4.33 ppb). Sodium was detected at low levels (14.6 ppm) and general water quality characteristics showed it to have a slightly acidic pH (6.25 – 6.43). Radiological results showed it to have negligible gross alpha activity (0.97 pCi/l) and a Radon level of 3029 pCi/L.

Coliform Results:		
	Coliform, Fecal	Negative
	Coliform, Total	Negative
Inorganic Results:		
	Antimony	ND
	Arsenic	ND
	Barium	4.33 µg/L
	Beryllium	~ 0.1 µg/L
	Cadmium	ND
	Chromium	ND
	Copper	~ 1.7 µg/L
	Cyanide	ND
	Fluoride	~ 0.088 mg/L
	Lead	ND
	Mercury	ND
	Nickel	ND
	Nitrate (as N)	0.194 mg/L
	Nitrite (as N)	ND

Selenium	ND
Silver	ND
Thallium	ND
Radionuclide Results:	
Gross alpha, including Ra & U, excluding Rn	0.97 pCi/L
Radium-228	Less Than 1 pCi/L
Radon 222	3029 pCi/L
General Chemical and Secondary Characteristics:	
Alkalinity, Total	35 mg/L
Aluminum	11.2 µg/L
Chloride	1.44 mg/L
Color	ND
Hardness, Total (as $CaCO_3$)	41.1 mg/L
Iron	~ 5.65 µg/L
Manganese	~ 0.25 µg/L
MBAS - foaming agents (surfactants)	ND
pH	6.43 pH units
Sodium	14.6 mg/L
Solids, Total dissolved (TDS)	60 mg/L
Sulfate	12.3 mg/L
Turbidity	0.4 NTU
Zinc	ND
Volatile Organic Compounds: All ND	

Broadway Spring	
ID: 731	
Notes:	
Town: Franklin Township	**Discharge: > 1 gpm**
County: Warren	**Emergence: Hillslope**
East/North: 347930.7, 693457.4	**Geology: Migmatite**

This mineral spring, a chalybeate spring, is located on Pohatcong Mountain near the village of Broadway in Franklin Township (fig. A-114). It was once the site of a health resort which utilized these chalybeate waters.

Figure A-114. Notice the orange tinted chalybeate water as the Broadway Spring flows from the ground. *Photo, M. Godfrey*.

New Jersey State Fish Hatchery at Hackettstown, West Hatchery, Springs # 1	
ID: 66	
Notes: Located at the West (main) Hatchery.	**Coordinate is for spring # 1**
Town: Hackettstown	**Discharge: Various**
County: Warren	**Emergence: Helocrene**
East/North: 398267.3, 732224.9	**Geology: Allentown Dolomite**

The hatchery encompasses 240 acres, with 65 freshwater ponds and features a state-of-the-art intensive fish culture facility. The site was chosen as a fish hatchery in 1911 because of its ample supply of pure cool spring water. There is a large volume of spring water available to fill the ponds for breeding trout and other species of fish. The water from the multiple springs on the hatchery grounds is collected and piped to the raceways and ponds. At one point there were at least five springs supplying water. Figure A-115 shows a large spring contained in a wooden springhouse at the hatchery. Flow was measured there at an estimated 50,000 gallons per hour or about 833 gallons per minute in 1917 (NY Sun, 1917). Figure A-116 shows some overflow water flowing out of the springhouse. Figure A-117 shows the opposite side view of the springhouse. Figure A-118 shows the modern intensive fish culture building.

Figure A-115. Top left. NJ State Fish Hatchery, West Hatchery Spring # 1 springhouse. *Photo, G. Steidl*.
Figure A-116. Top Right, springhouse with overflow of water flowing out of the springhouse. *Photo, G. Steidl*.
Figure A-117. Bottom Left, opposite side view of spring # 1springhouse. *Photo, G. Steidl*.
Figure A-118. Bottom Right, The intensive fish culture building. *Photo, G. Steidl*.

New Jersey State Fish Hatchery at Hackettstown, West Hatchery Spring 5	
ID: 70	
Notes: Located at the West (main) Hatchery	
Town: Hackettstown	**Discharge: NA**
County: Warren	**Emergence: Helocrene**
East/North: 399781.7, 732014.7	**Geology: Upper Part of Beekmantown group**

The second spring surveyed at the New Jersey State Fish Hatchery in Hackettsown was the West Hatchery Spring # 5 (fig. A-119). Today the spring flow is just a trickle (fig. A-120) and (fig. A-121). When the hatchery was built it was one of the main springs at the hatchery and it had a large and impressive spring house over it (fig. A-122).




Figure A-119. Top left, Springhouse foundation, with fishpond behind it. *Photo, G. Steidl*.
Figure A-120. Top right. View inside of springhouse foundation. *Photo, G. Steidl*.
Figure A-121. Bottom left. View of the inside of the springhouse foundation. *Photo, G. Steidl*.
Figure A-122. Main entrance to the New Jersey State Fish Hatchery at Hackettstown along Reese Ave., circa 1912 showing the springhouse. *Photo, courtesy of the New Jersey State Fish Hatchery at Hackettstown*.

Leyburn Spring	
ID: 711	
Notes:	
Town: Franklin Township	**Discharge: 1 gpm**
County: Warren	**Emergence: Hillslope**
East/North: 354832.4, 680885.7	**Geology: Allentown Dolomite**

This springhouse and spring are located on a farm in Warren County (fig. A-123).

Figure A-123. Springhouse on a Warren County farm. *Photo, T. Pallis*.

Federal Springs	
ID: 60	
Notes:	
Town: Frelinghuysen Township	**Discharge: Unknown.**
County: Warren	**Emergence: Hillslope**
East/North: 386221.0, 777758.0	**Geology: Lower Part of Beekmantown Group**

Federal Springs is a spring of large capacity near Johnsonburg (fig. A-124). It flows from a hillside and outlets into a small pond (fig. A-125). US President Franklin Delano Roosevelt is known to have made a few trips to the area near the spring to visit relatives or a possible mistress. There was a rail siding constructed in the area for his train to park during his visits to the area. There is also the Roosevelt Room in the nearby Rutherford mansion in Allamuchy (Sweetman, 2012). This all could have led to the name "Federal Springs."

Mr. William Stanley of Roselle, NJ measured the capacity of this spring with a weir in July 1947. The data from his measurement is as follows.

Yield: 600 gpm.
pH: 7.2.
Temp: 49.2°F
10 ppm of Oxygen, (84% saturation)

Herpers, September 10, 1947, Atlas Sheet 21.44.138.

 

Figure A-124. Left. Emergence of Federal Springs from Hillslope. *Photo, S. Domber*.
Figure A-125. Right. Pond formed by outflow water from Federal Springs. *Photo, S. Domber*.

Huff Spring	
ID: 732	
Notes:	
Town: Bethlehem Township	**Discharge: > 1 gpm**
County: Warren	**Emergence: Hillslope**
East/North: 348678.018, 669272.401	**Geology: Quartz-Oligoclase Gneiss**

The Huff Spring is a small spring located near the Huff iron mine in Warren County (fig. A-126).

Figure A-126. Huff Spring. *Photo, M. Godfrey*.

Marble Mountain Spring	
ID: 36	
Notes: Privately owned.	**Also known as Heitzman Spring.**
Town: Lopatcong Township	**Discharge: 1,000 gpm in 1947, 1 to 2 CFS in 2012. 600 gpm in the 1870's.**
County: Warren	**Emergence: Hillslope**
East/North: 302479.269, 688295.242	**Geology: Franklin Marble**

This is a large spring about one mile north of Phillipsburg and 1/8 mile south of the old Lizzie Clay Quarry. It is located between River Road and the Delaware River, 20 feet below the Marble Hill and River Roads intersection (fig. A-127). It was known as Heitzman Spring in the 1870's when its flow was measured at 600 gpm. At that time this spring supplied water to a fish hatchery just below the spring in the spring run (fig. A-128), (Report of the Commissioner of Fisheries, 1874). For a short time, this spring was used as a supply for bottled water. The flow of this spring is variable. Its flow was measured at 1,000 gallons per minute in 1947 (Johnson, 1948).

Figure A-127. Left, Marble Mountain Spring springhouse outlet pipe. *Photo, T. Pallis*.
Figure A-128. Right, Marble Mountain Spring, spring run. *Photo, T. Pallis*.

Marble Mountain Spring 2	
ID: 737	
Notes:	
Town: Lopatcong Township	Discharge: 5 gpm
County: Warren	Emergence: Hillslope
East/North: 302184.701, 688149.581	Geology: Amphibolite

This is a small spring between Marble Mountain Spring and the Delaware River (fig. A-129). It is west of the railroad tracks and closer to the Delaware River than Marble Mountain Spring. It flows into the same spring run as Marble Mountain Spring which drains into the Delaware River. The spring run contained small native trout when visited by the NJGWS.

Figure A-129. Marble Mountain Spring 2. *Photo, T. Pallis*.

Marble Mountain Spring 3	
ID: 737	
Notes:	
Town: Lopatcong Township	Discharge: 5 gpm
County: Warren	Emergence: Hillslope
East/North: 302206.055, 688116.768	Geology: Amphibolite

This is another small spring west of the railroad tracks and close to the Delaware River near Marble Mountain Spring 2 (fig. A-130). It drains into the Delaware River by the same spring run as Marble Mountain Spring and Marble Mountain Spring 2.

Figure A-130. Marble Mountain Spring 2. *Photo T. Pallis*.

Mountainwood Spring/Schuster Pond Spring	
ID: 218	
Notes: Bottled water source.	
Town: Blairstown Township	**Discharge: 4,000 gpm.**
County: Warren	**Emergence: Hillslope**
East/North: 380778, 797609	**Geology: Allentown Dolomite**

Located in the foothills of the Kittatinny Mountains, Mountainwood Spring is located on 75 acres of protected, untouched land. Mountainwood Spring, the source of bottled water for the Mountainwood Spring Water Company is the second most prolific spring in the Valley and Ridge region of New Jersey and flows at an average of about five million gallons per day directly from the limestone. It also supplies the Paulinskill with high quality groundwater that sustains the river quality.

No photos available.

Stanley Spring, Musky Trout Hatchery	
ID: 441	
Notes: Flow measured July 1947.	
Town: Bloomsbury Township	**Discharge: 650 gpm.**
County: Warren	**Emergence: Hillslope**
East/North: 339075.053, 672499.121	**Geology: Bushkill Member**

The Stanley Spring was known as the Troutdale Spring when a trout hatchery was opened at this location in 1868. Today, the Stanley Spring feeds water to the Musky Trout Hatchery, which was established in 1958 (fig. A-131). The spring flows out of the ground at a temperature of 51 °F, which is ideal for spawning trout. The hatchery uses a system of raceways and circular tanks using water supplied from the onsite spring (figs. A-132, A-133, A-134).

Figure A-131. Top left. Source of spring, Musky Trout Hatchery. *Photo, T. Pallis*.
Figure A-132. Top right. Spring fed fish holding tanks, Musky Trout Hatchery. *Photo, T. Pallis*.
Figure A-133. Bottom right. Holding tanks filled with golden trout. *Photo, T. Pallis*.
Figure A-134. Bottom right. Close up of holding tanks filled with golden trout. *Photo, T. Pallis*.

Bonnie Brook Spring	
ID: 16	
Notes: Largest flowing spring in NJ.	
Town: Hardwick Township	**Discharge: 5,000 gpm.**
County: Warren	**Emergence: Rheocrene**
East/North: 385682.622, 800507.169	**Geology: Allentown Dolomite**

Bonnie Brook is a large flowing spring, having the largest spring flow ever measured in the state. The spring is dammed to form a large pool with two outlets (figs. A-135, A-136). This spring flow is variable. On September 10, 1947, flow from Bonnie Brook Spring was estimated to be plus or minus 900 gpm by Mr. William Stanley of Roselle (Herpers, 1947). The flow at Bonnie Brook Spring was measured by the US Geological Survey on 5/22 at 5,000 gpm (Kasabach et. al, 1967).

 

Figure A-135. Bonnie Brook Spring springhouse and pond in summer. *Photo, T. Pallis*.
Figure A-136. Bonnie Brook Spring springhouse and pond in fall. *NJGWS Photo*.

Kennedy Mills/Stewartsville Spring	
ID: 32	
Notes:	
Town: Pohatcong Township	**Discharge: NA**
County: Warren	**Emergence: Hillslope**
East/North: 323360.305, 672824.682	**Geology: Jacksonburg Limestone**

The Kennedy Mills/Stewartsville Spring emerges into a cement grotto next to Pohatcong Creek (fig. A-137). It then drains into a large spring run and merges into Pohatcong Creek (fig. A-138).

 

Figure A-137. Left, Kennedy Mills/Stewartsville Spring outlet and grotto. *Photo, T. Pallis*. **Figure A-138**. Right, Kennedy Mills/Stewartsville Spring drainage area leading to Pohatcong Creek. *Photo, T. Pallis*.

Shurts Road Spring	
ID: 33	
Notes:	
Town: Washington Township	**Discharge: 400-500 gpm in 1948**
County: Warren	**Emergence: Hillslope**
East/North: 356607.107, 682994.144	**Geology: Allentown Dolomite**

The Shurts Road Spring has a high rate of discharge. This spring emerges from the side of a hill adjacent to a farm field (fig. A-139). It drains into a spring run (fig. A-140).


Figure A-139. Left. Emergence of Shurts Road Spring. *Photo, T. Pallis*.
Figure A-140. Right. Shurts Road Spring, spring run. *Photo, T. Pallis*.

Shurts Road Farm House Spring	
ID: 723	
Notes:	
Town: Washington Township	**Discharge: 20 gpm**
County: Warren	**Emergence: Hillslope**
East/North: 365505.132, 683455,458	**Geology: Allentown Dolomite**

This spring is located on private property. It emerges from a wooded area and is channeled into a springhouse (fig. A-141). This spring outlets to a pond (fig. A-142).


Figure A-141. Left. Shurts Road Farmhouse Spring springhouse. *Photo, T. Pallis*.
Figure A-142. Right. Shurts Road Farmhouse Spring Springhouse and outlet pond. *Photo, T. Pallis*.

Carpentersville Spring	
ID: 20	
Notes: Inactive fish hatchery site.	
Town: Pohatcong Township	**Discharge: 700 gpm**
County: Warren	**Emergence: Hillslope**
East/North: 301090.765, 656830.181	**Geology: Upper Part Beekmantown Group**

The Carpentersville Spring emerges into a fish hatchery and supplied large amounts of spring water to the hatchery when it was in use in March of 2012 (fig. A-143). As of October 2020, the hatchery was not in use (fig. A-144).


Figure A-143. Left. Operational fish hatchery, 2012. *Photo, T. Pallis*.
Figure A-144. Right. Dormant fish hatchery is still being supplied by spring water in 2020. *Photo, T. Pallis*.

Carpentersville/Snyders Road Spring	
ID: 713	
Notes: Just off Snyders Road.	
Town: Pohatcong Township	**Discharge: 1 to 10 gpm**
County: Warren	**Emergence: Hillslope**
East/North: 301260.014, 657481.813	**Geology: Jacksonburg Limestone**

There is a small spring in a meadow just off Snyders Road in Carpentersville (fig. A-145).

Figure A-145. Area of the Carpentersville/Snyders Road Spring. *Photo, T. Pallis*.

Appendix B. Quarterly Field Parameter Results from 14 Sampled Springs

Parameters tested during field sampling.

pH - pH measures the acidity or alkalinity of water. It is defined as the negative log of the activity of the hydrogen ion in a solution. Values range between 0 and 14. A low pH (below 7) represents acidic conditions, and a high pH (above 7) represents alkaline conditions. A pH of 7 indicates the water is near neutral conditions. As raindrops form, they incorporate dissolved carbon dioxide, forming weak carbonic acid. The resulting rain has a low pH. When acidic water enters a limestone aquifer, the acids react with calcium carbonate in the limestone and dissolution occurs. Generally, most spring water falls within a pH range of 7 to 8. During heavy rain events, spring water can drop in pH as tannic acids from nearby surface waters are flushed into the spring system.

Specific Conductance - Specific conductance is a measure of the ability of a substance, in this case spring water, to conduct electricity. The conductance is a function of the amount and type of ions in the water. The variability of the specific conductance of spring water can be quite high when the spring is discharging saline water or when the spring is discharging into the marine environment.

Total Dissolved Solids -Refers to any minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amounts of organic matter that are dissolved in water.

Dissolved Oxygen - Oxygen readily dissolves in water. The source of oxygen can be atmospheric or biological. Typically, springs that discharge water from a deep aquifer source has a low dissolved oxygen content. On the other hand, the dissolved oxygen content in river water is high relative to springs. This is due to a greater exposure to the atmosphere and an increase in biological activity

Water Temperature - Geologic material is characteristically a good insulator. Rocks and sediments tend to buffer changes in the temperature of spring water. Thus, spring water temperature does not vary much and tends to reflect the average annual air temperature in the vicinity of the spring. In New Jersey, this temperature can range from (13° C to 20° C). Temperature plays a role in chemical and biological activity within the aquifer and can help in determining residence time of the water in the aquifer.

Nitrates -Nitrate is a polyatomic ion. It is made up of one nitrogen and three oxygen atoms. It is a part of many important molecules. Potassium nitrate is a common nitrate, used in fertilizers because plants need nitrates to live and grow.

Chloride - An electrolyte. It is a negatively charged ion that works with other electrolytes, such as potassium, sodium, and bicarbonate, to help regulate the amount of fluid in the body and maintain the acid-base (pH) balance.

Results from Parameter Field Sampling.

Locust Grove Spring, Millburn, Essex County

	Sampling 1	**Sampling 2**	**Sampling 3**	**Sampling 4**
Date	11/14/12 9:45	1/28/13 13:45	4/25/13 8:30	7/30/13 10:00
Weather	clear	cloudy	clear	sunny
Wind	light breeze	light breeze	calm	
Water Color	no color	no color	no color	No color
Water Clarity	clear	clear	clear	clear
Water odor	no	no	no	no
Water odor desc.				
Air Temp °C	7	0.6	--	24
Water Temp°C	11	10.4	10.6	15.6
pH Stand. Units	7	6.9	6.7	6.3
SC µS·cm-1	346	252	191	378
TDS ppm	190	125	95	184
DO mg/L	6.8	11.1*	8.8	5.7
NO3- ppm				
PO4++ ppm				
Chloride ppm				
Method(s)	Hanna/Probes	Hanna/Probes	Hanna/Probes	Hanna/Probes

Great Bear/Trinity Spring, Ridgefield Park, Bergen County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	11/14/2012 11:30	1/28/2013 11:25	4/25/2013 10:00	7/31/2013 11:00
Weather	clear	cloudy	clear	partly cloudy
Wind	light breeze	light breeze	calm	
Water Color	no color	no color	no color	No color
Water Clarity	clear	clear	clear	clear
Water odor	no	no	no	no
Water odor desc.				
Air Temp °C	10.5	9.6	11.5	26
Water Temp°C	14.5	14.8	14.7	16.2
pH Stand. Units	6.8	6.66	6.48	6.3
SC μS·cm-1	818	826	799	773
TDS ppm	409	411	390	384
DO mg/L	6.7	9.8	8.4	7.8
NO3- ppm				
PO4++ ppm				
Chloride ppm				
Method(s)	Hanna/Probes	Hanna/Probes	Hanna/Probes	Hanna/Probes

Washington Spring, Van Saun Park, Bergen County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	11/14/2012 12:45	1/28/2013 12:35	4/25/2013 10:45	7/31/2013 14:00
Weather	clear	cloudy	clear	
Wind	light breeze	calm	calm	
Water Color	no color	no color	no color	No color
Water Clarity	clear	clear	clear	clear
Water odor	yes	no	no	no
Water odor desc.	sulphur/rotting veg.			
Air Temp °C	9.5	5.5	13.3	22
Water Temp°C	11	8.2	12.5	13.6
pH Stand. Units	7.2	7	7	6.8
SC µS·cm-1	600	709	611	513
TDS ppm	301	350	306	256
DO mg/L	4.5	7.6	3.9	3.6
NO3- ppm				
PO4++ ppm				
Chloride ppm				
Method(s)	Hanna/Probes	Hanna/Probes	Hanna/Probes	Hanna/Probes

Brau Kettle Spring # 2, Sandyston Twp., Sussex County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	10/18/2012 10:00	1/22/2013 11:00	4/10/2013 12:30	7/26/2013 12:10
Weather	cloudy	clear	partly cloudy	clear
Wind	light breeze	light breeze	light breeze	calm
Water Color	blue	grey	green	grey
Water Clarity	clear	clear	clear	clear
Water odor	no	no	no	no
Water odor desc.				
Air Temp °C	11	-10		16
Water Temp°C	11.7	8.6	10.5	12
pH Stand. Units	7.5	7.45	7.46	6.97
SC µS·cm-1	400	472	266	310
TDS ppm	202	212	139	157
DO mg/L	8.8	10.3	11.3	8.3
NO3- ppm				
PO4++ ppm				
Chloride ppm				
Method(s)	Hanna/Probes	Hanna/Probes	Hanna/Probes	Hanna/Probes

Dingman's Ferry Spring, Sandyston Twp., Sussex County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	10/18/2012 10:45	1/9/2013 11:30	4/10/2013 11:45	7/26/2013 11:30
Weather	partly cloudy	cloudy	partly cloudy	clear
Wind	light breeze	light breeze	light breeze	calm
Water Color	brown	grey	brown	brown
Water Clarity	clear	clear	clear	turbid
Water odor	no	no	no	no
Water odor desc.				
Air Temp °C	11.8	-2	24.8	19
Water Temp°C	11.6	10.3	9.9	10.8
pH Stand. Units	7.42	7.25	7.3	7.25
SC µS·cm-1	358	351	326	326
TDS ppm	179	175	161	163
DO mg/L	8.3	12.5	9.4	7.3
NO3- ppm				
PO4++ ppm				
Chloride ppm				
Method(s)	Hanna/Probes	Hanna/Probes	Hanna/Probes	Hanna/Probes

Big Spring, Whittingham WMA, Fredon Twp., Sussex County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	10/18/12 12:10	1/21/13 10:05	4/23/13 12:15	7/16/13 12:00
Weather		cloudy	cloudy	clear
Wind	gusty	light breeze	gusty	calm
Water Color	green	green		grey
Water Clarity	clear	clear	clear	clear
Water odor	no	no	no	no
Water odor desc.				
Air Temp °C	13.8	13.3	11.4	25
Water Temp°C	11	10.8	10.5	11.5
pH Stand. Units	7.4	7.22	7.17	6.95
SC µS·cm-1	419	366	350	360
TDS ppm	209	183	175	180
DO mg/L	7	12.2	8.6	6.7
NO3- ppm				
PO4++ ppm				
Chloride ppm				
Method(s)	Hanna/Probes	Hanna/Probes	Hanna/Probes	Hanna/Probes

Marble Mountain Spring, Lopatcong Twp., Warren County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	10/18/2012 14:30	1/22/2013 13:00	4/23/2013 10:40	7/15/2013 15:00
Weather		partly cloudy	cloudy	clear
Wind	gusty	light breeze	gusty	calm
Water Color	no color	green	no color	no color
Water Clarity	clear	clear	clear	clear
Water odor	no	no	no	no
Water odor desc.				
Air Temp °C	18.4	-9	8	22
Water Temp°C	11.7	10.8	10.5	11.5
pH Stand. Units	7.79	7.57	7.47	7.13
SC µS·cm-1	257	264	275	256
TDS ppm	128	132	137	128
DO mg/L	9.8	na	9.2	8.3
NO3- ppm				
PO4++ ppm				
Chloride ppm				
Method(s)	Hanna/Probes	Hanna/Probes	Hanna/Probes	Hanna/Probes

Honeyman Spring, Hopewell Twp., Mercer County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	10/23/2012 10:00	1/19/2013 9:15	4/16/2013 9:30	7/16/2013 10:00
Weather	cloudy			
Wind	calm			
Water Color	no color			
Water Clarity	clear			
Water odor	no			
Water odor desc.				
Air Temp °C	11	-3.5	16	29
Water Temp°C	13	12	12	14
pH Stand. Units	7	7	7.5	7.5
SC µS·cm-1	252	174	225	245
TDS ppm				
DO mg/L	9.9	6.9	8	6.5
NO3- ppm	1	0.5	0.8	1
PO4++ ppm	0.1	0.1	0.1	0.2
Chloride ppm	28	16	30	na
Method(s)	Lamont Kits	Lamont Kits	Lamont Kits	Lamont Kits

Valley Crest Spring, Clinton Twp., Hunterdon County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	10/23/2012 12:00	1/19/2013 11:40	4/16/2013 11:40	7/16/2013 12:00
Weather	cloudy			
Wind	calm			
Water Color	no color	no color	no color	no color
Water Clarity	clear	clear	clear	clear
Water odor	no	no	no	no
Water odor desc.				
Air Temp °C	15	-2.5	18	30
Water Temp°C	12	10	11.5	12
pH Stand. Units	7	7	7.25	7
SC µS·cm-1	280	290	290	260
TDS ppm				
DO mg/L	7.1	7.75	6	5.6
NO3- ppm	1.6	0.8	1	3.2
PO4++ ppm	0.1	0.1	0.1	0.2
Chloride ppm	24	24	28	24
Method(s)	Lamont Kits	Lamont Kits	Lamont Kits	Lamont Kits

Shurts Road Spring, Franklin Twp., Warren County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	10/23/2012 15:00	1/19/2013 14:00	4/16/2013 13:30	7/16/2013 14:15
Weather	cloudy			
Wind	calm			
Water Color	No color	No color	No color	No color
Water Clarity	clear	clear	clear	clear
Water odor	no	no	no	no
Water odor desc.				
Air Temp °C	15	-2	20	32
Water Temp°C	13	11	13	15
pH Stand. Units	7.5	8	8	8
SC µS·cm-1	250	275	225	240
TDS ppm				
DO mg/L	8.2	7.7	7.1	6.15
NO3- ppm	1	0.6	0.5	1.6
PO4++ ppm	0.1	0.1	0.1	0.1
Chloride ppm	31	32	28	32
Method(s)	Lamont Kits	Lamont Kits	Lamont Kits	Lamont Kits

Paint Island Spring, Millstone Twp., Monmouth County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	10/18/12 08:45	2/13/2013 12:15	5/30/2013 12:20	7/24/2013 10:45
Weather	clear	partly cloudy	clear	clear
Wind	calm	calm	calm	calm
Water Color	Light brown/red	orange	brown/orange	brown/orange
Water Clarity	clear	clear	turbid	clear
Water odor	no	yes	yes	yes
Water odor desc.		rotting plant	sulphur	sulphur
Air Temp °C	14.5	7.5	29.7	24.2
Water Temp°C	13.7	13	15.1	13.2
pH Stand. Units	7.24	6.9	6	6.5
SC µS·cm-1	278	202	140	143
TDS ppm	151.25	95	70	72
DO mg/L	1.2	0.9	1.5	1.4
NO3- ppm				
PO4++ ppm				
Chloride ppm				
Method(s)	Hanna/Probes	Hanna/Probes	Hanna/Probes	Hanna/Probes

Indian Lady Hill Spring, Neptune Twp., Monmouth County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	10/18/2012 10:15	2/13/2013 10:30	5/30/2013 11:00	7/24/2013 9:45
Weather	clear	partly cloudy	clear	clear
Wind	calm	calm	calm	calm
Water Color	brown	brown	brown	brown
Water Clarity	turbid	clear	turbid	clear
Water odor	no	no	no	yes
Water odor desc.				decaying organic material
Air Temp °C	16.1	14	26.6	24.7
Water Temp°C	13.7	6.5	16.5	18.25
pH Stand. Units	6.4	6.3	5.1	5.9
SC µS·cm-1	304	297	185	261
TDS ppm	152	148	92	130
DO mg/L	5.2	8.6	7.9	5.2
NO3- ppm				
PO4++ ppm				
Chloride ppm				
Method(s)	Hanna/Probes	Hanna/Probes	Hanna/Probes	Hanna/Probes

Crystal Spring, Laurel Springs, Camden County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	10/11/2012 12:10	2/7/2013 12:15	4/15/2013 9:30	7/22/2013 12:00
Weather	clear	cloudy	clear	partly cloudy
Wind	light breeze	calm	light breeze	calm
Water Color	no color	no color	blue	no color
Water Clarity	clear	clear	clear	clear
Water odor	no	no	no	no
Water odor desc.				
Air Temp °C	17.9	1	14.9	26.7
Water Temp°C	15.7	13.5	14.9	15.1
pH Stand. Units	7.6	7	7.25	6.96
SC µS·cm-1	729	646	507	548
TDS ppm	365	320	253	274
DO mg/L	2.5	2.9	2.3	1.2
NO3- ppm				
PO4++ ppm				
Chloride ppm				
Method(s)	Hanna/Probes	Hanna/Probes	Hanna/Probes	Hanna/Probes

Blue Hole-Inskeep, Gloucester County

	Sampling 1	Sampling 2	Sampling 3	Sampling 4
Date	10/11/2012 10:50	2/7/2013 10:50	4/16/2013 10:50	7/22/2013 11:00
Weather	clear	cloudy	clear	cloudy
Wind	light breeze	calm	calm	calm
Water Color	no color	brown	no color	brown
Water Clarity	clear	clear	clear	muddy
Water odor		no	no	yes
Water odor desc.				sewage
Air Temp °C	18.1	0	25.2	24.8
Water Temp°C	13.4	6.45	14.3	14.3
pH Stand. Units	5.5	4.2	4.8	5.4
SC µS·cm-1	70	92	85	54.5
TDS ppm	29	46	43	28
DO mg/L	2.2	5.6	2.7	1.5
NO3- ppm				
PO4++ ppm				
Chloride ppm				
Method(s)	Hanna/Probes	Hanna/Probes	Hanna/Probes	Hanna/Probes

Appendix C: One Time Lab Sample Analysis Results from 14 Selected Springs with Description of Analytes

One time Lab sample Analysis Results from 14 Selected Springs with Description of Analytes

Description of the chemical indicators used to describe and assess water quality.

Laboratory Analytes

Metals:
Aluminum (Al)
Antimony (Sb)
Arsenic (As)
Barium (Ba)
Beryllium (Be)
Boron (B)
Cadmium (Cd)
Chromium (Cr)
Copper (Cu)
Iron (Fe)
Lead (Pb)
Manganese (Mn)
Nickel (Ni)
Selenium (Se)
Silver (Ag)
Thallium (Tl)
Zinc (Zn)
Uranium (U)

Cations:
Calcium Dissolved (Ca)
Magnesium Dissolved (Mg)
Sodium Dissolved (NA)
Potassium Dissolved (K)

Anions:
Sulfate Dissolved (SO_4)
Chloride Dissolved (CL)
Fluoride Dissolved (F)
Ortho phosphate (OPO_4)
Nitrite plus Nitrate (NO_2, NO_3)

Pesticides:

USEPA 508.1 Pesticides

Volatile Organic Compounds (VOC's):
USEPA 524.2 VOC's

Other:
Ammonia
Colilert- Coliform
Hardness Total T
Alkalinity
Total Kjeldahl Nitrogen
Dissolved Solids sum
Specific Conductance
pH – Laboratory analysis
Acid Neutrality (alkalinity)

Gross Alpha	NJDEP ELLS-R-GA rapid
Radon in water	Method 7500RN (NJDEP)

Common Ions

Alkalinity - The alkalinity of spring water is affected primarily by the presence of bicarbonate, hydroxide and carbon dioxide. Highly alkaline waters are usually associated with high pH, dissolved solids and hardness which, when combined, may be detrimental to the aquatic environment.

Potassium (K) – The weathering of mica, feldspar and clay minerals can contribute potassium to spring water. In addition, because potassium is an essential nutrient, it is a component of fertilizers.

Sodium (Na) - In New Jersey, Ph is the most likely source of sodium coming from road salt. The weathering of sodium-bearing minerals like feldspars and clays are also sources.

Total Dissolved Solids (often abbreviated TDS) is a measure of the combined content of all inorganic and organic substances contained in a liquid in: molecular, ionized or micro-granular (colloidal sol) suspended form.

Chloride (Cl) - Chloride is the most abundant constituent in seawater. Chloride is chemically conservative and reacts very little with spring water.

Sulfate (SO_4) - Sulfate is commonly found in aquifer waters in New Jersey and has several sources. Sulfate is often used as a soil amendment to acidify soils, and thus is associated with agricultural activities. Finally, disposal and industrial waste activities release sulfate to groundwater. Sulfate-rich spring water can potentially be toxic to plants. In higher concentrations it affects the taste of drinking water.

Nutrients

Orthophosphate (PO4) - Phosphate is an essential nutrient and occurs in spring water in New Jersey. Unfortunately, an excess of phosphate can cause run-away plant growth and the eutrophication of surface waters. Other sources include organic and inorganic fertilizers, animal waste, human waste effluent and industrial waste.

Ammonial plus organic nitrogen

Total Nitrogen - The amount of nitrate, nitrite, ammonia, and organic nitrogen, when summed, gives the total nitrogen content of spring water.

Nitrogen - a colorless tasteless odorless element that as a diatomic gas is relatively inert and constitutes 78 percent of the atmosphere and that is a constituent of organic compounds found in all living tissues

Nitrate + Nitrite (NO_3 + NO_2) as N - Nitrate and nitrite are both found in spring water in New Jersey. Nitrate found in spring water originates from fertilizers, septic tanks and animal waste that enter the aquifer in the spring recharge area. Nitrate, being a nutrient, encourages algal and aquatic plant growth in spring water, which may lead to eutrophication of the spring and the associated water body. Nitrite, which is much less of a problem, can originate from sewage and other organic waste products.

Gross Alpha

Radium 226 & 228 (Ra226 & Ra228) - Radium is a naturally occurring radioactive element that is produced when uranium and thorium minerals decay ("break down") in the environment. Radium itself decays into other elements, and eventually to lead (Pb), but exists in the environment long enough to be of concern in groundwater. Radium is of similar size and nature to phosphorus and often substitutes for it. Consumption of radium isotopes can lead to the incorporation of radium into bone and other body systems. Radium is a known carcinogen. Uranium-bearing minerals, the natural source of radium, are found in all of New Jersey's aquifer systems in varying, usually minor, amounts.

Radon in water - Radon is a gas that has no color, odor, or taste and comes from the natural radioactive breakdown of uranium in the ground. You can be exposed to radon by two main sources:

Radon in the air in your home (frequently called "radon in indoor air") and Radon in drinking water.

Uranium

USEPA Pesticides 508.1
USEPA VOCs 524.2

One Time Lab Sample Analysis Results

Name	Analyte	Results	RDL	Units
Big Spring (Whittingham)	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/26/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	ND	<0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	ND	<0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	0.5	0.5	µg/L
	Lead	ND	<0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	ND	<0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	0.8	0.5	µg/L
	Arsenic	ND	<0.5	µg/L
	Chromium	ND	<0.5	µg/L
	Nickel	1.2	0.5	µg/L
	Boron	10.1	5	µg/L
	Beryllium	ND	<0.5	µg/L
	Aluminum	ND	<10	µg/L
	Barium	1.34	0.500	µg/L

Name	Analyte	Results	RDL	Units
	Cadmium	ND	<0.5	µg/L
	Uranium	ND	<0.50	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	14500		µg/L
	Silica	9870		µg/L
	Iron	ND	<0.050	mg/L
	Calcium	ND	<50	mg/L
	Sodium	32	1.5	mg/L
	Potassium	1.2	1	mg/L
	Total Dissolved Solids	340	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	17	5.0	mg/L
	Alkalinity	210	2.5	mg/L
	Total Kjeldahl Nitrogen	0.37	0.200	mg/L
	Orthophosphate	ND	<0.5	mg/L
	Chloride	54	5.0	mg/L
	Nitrate	1.69	0.500	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	460	10	umhos/cm
	pH	7.52		pH units
	Ammonia as N	ND	<0.1	mg/L
	E. Coli	Presence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0580	µg/L
	4,4'-DDE	ND	<0.0580	µg/L
	4,4'-DDT	ND	<0.0580	µg/L
	Aldrin	ND	<0.0580	µg/L
	alpha-BHC	ND	<0.0580	µg/L
	alpha-Chlordane	ND	<0.0580	µg/L
	beta-BHC	ND	<0.0580	µg/L
	Chlordane	ND	<1.15	µg/L
	delta-BHC	ND	<0.0580	µg/L
	Dieldrin	ND	<0.0580	µg/L
	Endosulfan I	ND	<0.0580	µg/L
	Endolsulfan II	ND	<0.0580	µg/L
	Endolsulfan sulfate	ND	<0.0580	µg/L
	Endrin	ND	<0.0580	µg/L
	Endrin Aldehyde	ND	<0.0580	µg/L
	Endrin ketone	ND	<0.0580	µg/L
	gamma-BHC (Lindane)	ND	<0.0580	µg/L
	gamma-Chlordane	ND	<0.0580	µg/L
	Heptachlor	ND	<0.0580	µg/L
	Heptachlor epoxide	ND	<0.0580	µg/L
	Hexachlorobenzene	ND	<0.0580	µg/L
	Hexachlorocyclopentadiene	ND	<0.0580	µg/L
	Methoxychlor	ND	<0.0580	µg/L
	Propachlor	ND	<0.0580	µg/L
	Toxaphene	ND	3.87	µg/L
	Trifluralin	ND	<0.0580	µg/L
	Gross Alpha Init	0.57	0	(pCi/L)

Name	Analyte	Results	RDL	Units
	Gross Alpha Final	0	0	(pCi/L)
	Radon	235	0	(pCi/L)
	Radon	228.8	0	(pCi/L) Dup
	Radon Average	228.9	0	(pCi/L)
Blue Hole-Inskeep	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/18/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	ND	<0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	ND	<0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	0.78	0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	1.77	0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	0.6	0.5	µg/L
	Lead	1.4	0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	8.1	0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	ND	<0.5	µg/L
	Arsenic	ND	<0.5	µg/L
	Chromium	ND	<0.5	µg/L
	Nickel	0.9	0.5	µg/L
	Boron	4.3	5	µg/L
	Beryllium	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Aluminum	137	10	µg/L
	Barium	12.7	0.500	µg/L
	Cadmium	ND	<0.50	µg/L
	Uranium	ND	<0.5	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	403		µg/L
	Silica	11600		µg/L
	Iron	1.3	0.5	mg/L
	Calcium	ND	<15	mg/L
	Sodium	1.7	0.50	mg/L
	Potassium	ND	<1	mg/L
	Total Dissolved Solids	38	10	mg/L
	Nitrite	7.7	5	mg/L
	Sulfate	ND	<0.5	mg/L
	Alkalinity	3.5	2.5	mg/L
	Total Kjeldahl Nitrogen	1.2	0.20	mg/L
	Orthophosphate	ND	<0.50	mg/L
	Chloride	5.6	5.0	mg/L
	Nitrate	2.45	0.500	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	36	10	umhos/cm
	pH	4.68		pH units
	Ammonia as N	ND	<0.10	mg/L
	E. Coli	Presence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0580	µg/L
	4,4'-DDE	ND	<0.0580	µg/L
	4,4'-DDT	ND	<0.0580	µg/L
	Aldrin	ND	<0.0580	µg/L
	alpha-BHC	ND	<0.0580	µg/L
	alpha-Chlordane	ND	<0.0580	µg/L
	beta-BHC	ND	<0.0580	µg/L
	Chlordane	ND	1.15	µg/L
	delta-BHC	ND	<0.0580	µg/L
	Dieldrin	ND	<0.0580	µg/L
	Endosulfan I	ND	<0.0580	µg/L
	Endolsulfan II	ND	<0.0580	µg/L
	Endolsulfan sulfate	ND	<0.0580	µg/L
	Endrin	ND	<0.0580	µg/L
	Endrin Aldehyde	ND	<0.0580	µg/L
	Endrin ketone	ND	<0.0580	µg/L
	gamma-BHC (Lindane)	ND	<0.0580	µg/L
	gamma-Chlordane	ND	<0.0580	µg/L
	Heptachlor	ND	<0.0580	µg/L
	Heptachlor epoxide	ND	<0.0580	µg/L
	Hexachlorobenzene	0.068	<0.0580	µg/L
	Hexachlorocyclopentadiene	ND	<0.0580	µg/L
	Methoxychlor	ND	<0.0580	µg/L
	Propachlor	ND	<0.0580	µg/L
	Toxaphene	ND	2.87	µg/L

Name	Analyte	Results	RDL	Units
	Trifluralin	ND	<0.0580	µg/L
	Gross Alpha Init	4.08	0	(pCi/L)
	Gross Alpha Final	0	0	(pCi/L)
	Radon	158.8	0	(pCi/L)
	Radon	162.4	0	(pCi/L) Dup
	Radon Average	160.6	0	(pCi/L)
Brau Kettle Spring # 2	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/26/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	1.46	0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	0.5	0.5	µg/L
	Lead	ND	<0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	3.7	0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	ND	<0.5	µg/L
	Arsenic	ND	<0.5	µg/L
	Chromium	ND	<0.5	µg/L
	Nickel	1.5	0.5	µg/L

Name	Analyte	Results	RDL	Units
	Boron	8.5	5	µg/L
	Beryllium	ND	<0.5	µg/L
	Aluminum	ND	<10	µg/L
	Barium	ND	<0.5	µg/L
	Cadmium	ND	<0.5	µg/L
	Uranium	ND	<0.5	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	3020		µg/L
	Silica	8540		µg/L
	Iron	ND	<0.050	mg/L
	Calcium	52.7	30	mg/L
	Sodium	6.5	0.50	mg/L
	Potassium	ND	<1	mg/L
	Total Dissolved Solids	200	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	13	0.5	mg/L
	Alkalinity	140	2.5	mg/L
	Total Kjeldahl Nitrogen	0.439	0.200	mg/L
	Orthophosphate	ND	<0.50	mg/L
	Chloride	11	2.5	mg/L
	Nitrate	0.990	0.500	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	530	10	umhos/cm
	pH	7.48		pH units
	Ammonia as N	ND	<0.10	mg/L
	E. Coli	Absence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0680	µg/L
	4,4'-DDE	ND	<0.0580	µg/L
	4,4'-DDT	ND	<0.0580	µg/L
	Aldrin	ND	<0.0580	µg/L
	alpha-BHC	ND	<0.0580	µg/L
	alpha-Chlordane	ND	<0.0580	µg/L
	beta-BHC	ND	<0.0580	µg/L
	Chlordane	ND	<1.15	µg/L
	delta-BHC	ND	<0.0580	µg/L
	Dieldrin	ND	<0.0580	µg/L
	Endosulfan I	ND	<0.0580	µg/L
	Endolsulfan II	ND	<0.0580	µg/L
	Endolsulfan sulfate	ND	<0.0580	µg/L
	Endrin	ND	<0.0580	µg/L
	Endrin Aldehyde	ND	<0.0580	µg/L
	Endrin ketone	ND	<0.0580	µg/L
	gamma-BHC (Lindane)	ND	<0.0580	µg/L
	gamma-Chlordane	ND	<0.0580	µg/L
	Heptachlor	ND	<0.0580	µg/L
	Heptachlor epoxide	ND	<0.0580	µg/L
	Hexachlorobenzene	ND	<0.0580	µg/L
	Hexachlorocyclopentadiene	ND	<0.0580	µg/L
	Methoxychlor	ND	<0.0580	µg/L

Name	Analyte	Results	RDL	Units
	Propachlor	ND	<0.0580	µg/L
	Toxaphene	ND	<3.87	µg/L
	Trifluralin	ND	<0.0580	µg/L
	Gross Alpha Init	0.64	0	(pCi/L)
	Gross Alpha Final	0	0	(pCi/L)
	Radon	781.1	0	(pCi/L)
	Radon	726.4	0	(pCi/L) Dup
	Radon Average	753.7	0	(pCi/L)
Crystal Spring	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/18/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	ND	<0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Chloroethane	ND	<0.5	µg/L
	Chloroform	ND	<0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	0.7	0.5	µg/L
	Lead	ND	<0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	3	0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	1.6	0.5	µg/L
	Arsenic	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Chromium	0.7	0.5	µg/L
	Nickel	2.9	0.5	µg/L
	Boron	52.2	5	µg/L
	Beryllium	ND	<0.5	µg/L
	Aluminum	34.3	10	µg/L
	Barium	81.5	0.500	µg/L
	Cadmium	ND	<0.5	µg/L
	Uranium	0.65	0.5	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	5750		µg/L
	Silica	9390		µg/L
	Iron	ND	<0.050	mg/L
	Calcium	ND	<150	mg/L
	Sodium	21	1.5	mg/L
	Potassium	2.5	1	mg/L
	Total Dissolved Solids	410	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	5.1	0.5	mg/L
	Alkalinity	230	2.5	mg/L
	Total Kjeldahl Nitrogen	0.55	0.20	mg/L
	Orthophosphate	ND	<0.5	mg/L
	Chloride	2.6	2.5	mg/L
	Nitrate	ND	<0.500	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	640	10	umhos/cm
	pH	7.11	0	pH units
	Ammonia as N	ND	<0.10	mg/L
	E. Coli	Presence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0590	µg/L
	4,4'-DDE	ND	<0.0590	µg/L
	4,4'-DDT	ND	<0.0590	µg/L
	Aldrin	ND	<0.0590	µg/L
	alpha-BHC	ND	<0.0590	µg/L
	alpha-Chlordane	ND	<0.0590	µg/L
	beta-BHC	ND	<0.0590	µg/L
	Chlordane	ND	<1.18	µg/L
	delta-BHC	ND	<0.0590	µg/L
	Dieldrin	ND	<0.0590	µg/L
	Endosulfan I	ND	<0.0590	µg/L
	Endolsulfan II	ND	<0.0590	µg/L
	Endolsulfan sulfate	ND	<0.0590	µg/L
	Endrin	ND	<0.0590	µg/L
	Endrin Aldehyde	ND	<0.0590	µg/L
	Endrin ketone	ND	<0.0590	µg/L
	gamma-BHC (Lindane)	ND	<0.0590	µg/L
	gamma-Chlordane	ND	<0.0590	µg/L
	Heptachlor	ND	<0.0590	µg/L
	Heptachlor epoxide	ND	<0.0580	µg/L
	Hexachlorobenzene	ND	<0.0590	µg/L

Name	Analyte	Results	RDL	Units
	Hexachlorocyclopentadiene	ND	<0.0590	µg/L
	Methoxychlor	ND	<0.0590	µg/L
	Propachlor	ND	<0.0590	µg/L
	Toxaphene	ND	<2.94	µg/L
	Trifluralin	ND	<0.0590	µg/L
	Gross Alpha Init	6.31	0	(pCi/L)
	Gross Alpha Final	2.41	0	(pCi/L)
	Radon	644.6	0	(pCi/L)
	Radon	688	0	(pCi/L) Dup
	Radon Average	666.3	0	(pCi/L)
Dingman's Ferry Spring	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/26/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	1.70	0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	ND	<0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	0.9	0.5	µg/L
	Lead	ND	<0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	ND	<0.5	µg/L
	Silver	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Selenium	0.7	0.5	µg/L
	Arsenic	ND	<0.5	µg/L
	Chromium	ND	<0.5	µg/L
	Nickel	1.8	0.5	µg/L
	Boron	3.8	5	µg/L
	Beryllium	ND	<0.5	µg/L
	Aluminum	ND	<10	µg/L
	Barium	1.13	0.500	µg/L
	Cadmium	ND	<0.5	µg/L
	Uranium	ND	<0.50	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	3340		µg/L
	Silica	8040		µg/L
	Iron	ND	<0.050	mg/L
	Calcium	ND	<100	mg/L
	Sodium	8.4	0.50	mg/L
	Potassium	ND	<1	mg/L
	Total Dissolved Solids	300	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	7.4	0.5	mg/L
	Alkalinity	190	2.5	mg/L
	Total Kjeldahl Nitrogen	1.70	0.200	mg/L
	Orthophosphate	ND	<0.5	mg/L
	Chloride	8.4	2.5	mg/L
	Nitrate	2.29	0.500	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	460	10	umhos/cm
	pH	7.54		pH units
	Ammonia as N	ND	<0.10	mg/L
	E. Coli	Presence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0650	µg/L
	4,4'-DDE	ND	<0.0650	µg/L
	4,4'-DDT	ND	<0.0650	µg/L
	Aldrin	ND	<0.0650	µg/L
	alpha-BHC	ND	<0.0650	µg/L
	alpha-Chlordane	ND	<0.0650	µg/L
	beta-BHC	ND	<0.0650	µg/L
	Chlordane	ND	<1.30	µg/L
	delta-BHC	ND	<0.0650	µg/L
	Dieldrin	ND	<0.0650	µg/L
	Endosulfan I	ND	<0.0650	µg/L
	Endolsulfan II	ND	<0.0650	µg/L
	Endolsulfan sulfate	ND	<0.0650	µg/L
	Endrin	ND	<0.0650	µg/L
	Endrin Aldehyde	ND	<0.0650	µg/L
	Endrin ketone	ND	<0.0650	µg/L
	gamma-BHC (Lindane)	ND	<0.0650	µg/L
	gamma-Chlordane	ND	<0.0650	µg/L
	Heptachlor	ND	<0.0650	µg/L

Name	Analyte	Results	RDL	Units
	Heptachlor epoxide	ND	<0.0650	µg/L
	Hexachlorobenzene	ND	<0.0650	µg/L
	Hexachlorocyclopentadiene	ND	<0.0650	µg/L
	Methoxychlor	ND	<0.0650	µg/L
	Propachlor	ND	<0.0650	µg/L
	Toxaphene	ND	3.25	µg/L
	Trifluralin	ND	<0.0650	µg/L
	Gross Alpha Init	0.22	0	(pCi/L)
	Gross Alpha Final	0	0	(pCi/L)
	Radon	617.5	0	(pCi/L)
	Radon	657.7	0	(pCi/L) Dup
	Radon Average	637.6	0	(pCi/L)
George Washington Spring- Van Saun Park	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/25/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	ND	<0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	ND	<0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	0.6	0.5	µg/L
	Lead	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Thallium	ND	<0.5	µg/L
	Manganese	3	0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	0.6	0.5	µg/L
	Arsenic	ND	<0.5	µg/L
	Chromium	1	0.5	µg/L
	Nickel	1.8	0.5	µg/L
	Boron	23.7	5	µg/L
	Beryllium	ND	<0.5	µg/L
	Aluminum	ND	<10	µg/L
	Barium	283	0.500	µg/L
	Cadmium	ND	<0.5	µg/L
	Uranium	0.63	0.50	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	11700		µg/L
	Silica	24600		µg/L
	Iron	ND	<0.050	mg/L
	Calcium	164	100	mg/L
	Sodium	29	1.5	mg/L
	Potassium	1.2	1	mg/L
	Total Dissolved Solids	630	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	32	5.0	mg/L
	Alkalinity	170	2.5	mg/L
	Total Kjeldahl Nitrogen	2.22	0.200	mg/L
	Orthophosphate	ND	<0.50	mg/L
	Chloride	120	5.0	mg/L
	Nitrate	1.71	0.500	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	690	10	µmhos/cm
	pH	7.81	0	pH units
	Ammonia as N	ND	<0.1	mg/L
	E. Coli	Presence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0600	µg/L
	4,4'-DDE	ND	<0.0600	µg/L
	4,4'-DDT	ND	<0.0600	µg/L
	Aldrin	ND	<0.0600	µg/L
	alpha-BHC	ND	<0.0600	µg/L
	alpha-Chlordane	ND	<0.0600	µg/L
	beta-BHC	ND	<0.0600	µg/L
	Chlordane	ND	<1.20	µg/L
	delta-BHC	ND	<0.0600	µg/L
	Dieldrin	ND	<0.0600	µg/L
	Endosulfan I	ND	<0.0600	µg/L
	Endolsulfan II	ND	<0.0600	µg/L
	Endolsulfan sulfate	ND	<0.0600	µg/L
	Endrin	ND	<0.0600	µg/L
	Endrin Aldehyde	ND	<0.0600	µg/L
	Endrin ketone	ND	<0.0600	µg/L

Name	Analyte	Results	RDL	Units
	gamma-BHC (Lindane)	ND	<0.0600	µg/L
	gamma-Chlordane	ND	<0.0600	µg/L
	Heptachlor	ND	<0.0600	µg/L
	Heptachlor epoxide	ND	<0.0600	µg/L
	Hexachlorobenzene	ND	<0.0600	µg/L
	Hexachlorocyclopentadiene	ND	<0.0600	µg/L
	Methoxychlor	ND	<0.0600	µg/L
	Propachlor	ND	<0.0600	µg/L
	Toxaphene	ND	<3.01	µg/L
	Trifluralin	ND	<0.0600	µg/L
	Gross Alpha Init	5.5	0	(pCi/L)
	Gross Alpha Final	2.14	0	(pCi/L)
	Radon	459.3	0	(pCi/L)
	Radon	538.6	0	(pCi/L) Dup
	Radon Average	499	0	(pCi/L)
Great Bear/Trinity Spring	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/25/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	ND	<0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	0.87	0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L

Name	Analyte	Results	RDL	Units
	Copper	1.1	0.5	µg/L
	Lead	ND	<0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	7.5	0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	2.5	0.5	µg/L
	Arsenic	0.6	0.5	µg/L
	Chromium	0.9	0.5	µg/L
	Nickel	3.6	0.5	µg/L
	Boron	437	5	µg/L
	Beryllium	ND	<0.5	µg/L
	Aluminum	ND	<10	µg/L
	Barium	177	0.500	µg/L
	Cadmium	ND	<0.5	µg/L
	Uranium	0.87	0.50	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	20700		µg/L
	Silica	28700		µg/L
	Iron	ND	<0.050	mg/L
	Calcium	102	100	mg/L
	Sodium	70	2.5	mg/L
	Potassium	2.6	1	mg/L
	Total Dissolved Solids	1100	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	54	25	mg/L
	Alkalinity	85	2.5	mg/L
	Total Kjeldahl Nitrogen	1.36	0.200	mg/L
	Orthophosphate	ND	<0.50	mg/L
	Chloride	250	2.5	mg/L
	Nitrate	3.99	0.500	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	1000	10	umhos/cm
	pH	6.59		pH units
	Ammonia as N	0.12	0.10	mg/L
	E. Coli	Presence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0630	µg/L
	4,4'-DDE	ND	<0.0630	µg/L
	4,4'-DDT	ND	<0.0630	µg/L
	Aldrin	ND	<0.0630	µg/L
	alpha-BHC	ND	<0.0630	µg/L
	alpha-Chlordane	0.0190 J	<0.0630	µg/L
	beta-BHC	ND	<0.0630	µg/L
	Chlordane	ND	<1.25	µg/L
	delta-BHC	ND	<0.0630	µg/L
	Dieldrin	0.0560 J	0.0630	µg/L
	Endosulfan I	ND	<0.0630	µg/L
	Endolsulfan II	ND	<0.0630	µg/L
	Endolsulfan sulfate	ND	<0.0630	µg/L
	Endrin	ND	<0.0630	µg/L

Name	Analyte	Results	RDL	Units
	Endrin Aldehyde	ND	<0.0630	µg/L
	Endrin ketone	ND	<0.0630	µg/L
	gamma-BHC (Lindane)	ND	<0.0630	µg/L
	gamma-Chlordane	ND	<0.0630	µg/L
	Heptachlor	ND	<0.0630	µg/L
	Heptachlor epoxide	ND	<0.0630	µg/L
	Hexachlorobenzene	ND	<0.0630	µg/L
	Hexachlorocyclopentadiene	ND	<0.0630	µg/L
	Methoxychlor	ND	<0.0630	µg/L
	Propachlor	ND	<0.0630	µg/L
	Toxaphene	ND	<3.12	µg/L
	Trifluralin	ND	<0.0630	µg/L
	Gross Alpha Init	26.6	0	(pCi/L)
	Gross Alpha Final	25.6	0	(pCi/L)
	Radon	3618.4	0	(pCi/L)
	Radon	3671.3	0	(pCi/L) Dup
	Radon Average	3644.9	0	(pCi/L)
Indian Lady Hill Spring	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/14/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	ND	<0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	0.940	0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L

Name	Analyte	Results	RDL	Units
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	1.4	0.5	µg/L
	Lead	1.4	0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	28	0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	0.6	0.5	µg/L
	Arsenic	3.4	0.5	µg/L
	Chromium	0.9	0.5	µg/L
	Nickel	2.1	0.5	µg/L
	Boron	12.5	5	µg/L
	Beryllium	ND	0.5	µg/L
	Aluminum	325	10	µg/L
	Barium	16.9	0.500	µg/L
	Cadmium	ND	<0.5	µg/L
	Uranium	ND	<0.50	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	1260		µg/L
	Silica	4730		µg/L
	Iron	ND	<0.050	mg/L
	Calcium	ND	<15	mg/L
	Sodium	27	1.5	mg/L
	Potassium	ND	<1	mg/L
	Total Dissolved Solids	100	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	14	0.5	mg/L
	Alkalinity	3.5	2.5	mg/L
	Total Kjeldahl Nitrogen	1.47	0.200	mg/L
	Orthophosphate	ND	<0.50	mg/L
	Chloride	46	2.5	mg/L
	Nitrate	0.940	0.500	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	190	10	umhos/cm
	pH	5.75		pH units
	Ammonia as N	ND	<0.1	mg/L
	E. Coli	Presence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0630	µg/L
	4,4'-DDE	ND	<0.0630	µg/L
	4,4'-DDT	ND	<0.0630	µg/L
	Aldrin	ND	<0.0630	µg/L
	alpha-BHC	ND	<0.0630	µg/L
	alpha-Chlordane	ND	<0.0630	µg/L
	beta-BHC	ND	<0.0630	µg/L
	Chlordane	ND	<1.27	µg/L
	delta-BHC	ND	<0.0630	µg/L
	Dieldrin	0.0310J	0.0630	µg/L
	Endosulfan I	ND	<0.0630	µg/L
	Endolsulfan II	ND	<0.0630	µg/L

Name	Analyte	Results	RDL	Units
	Endolsulfan sulfate	ND	<0.0630	µg/L
	Endrin	ND	<0.0630	µg/L
	Endrin Aldehyde	ND	<0.0630	µg/L
	Endrin ketone	ND	<0.0630	µg/L
	gamma-BHC (Lindane)	ND	<0.0630	µg/L
	gamma-Chlordane	ND	<0.0630	µg/L
	Heptachlor	ND	<0.0630	µg/L
	Heptachlor epoxide	ND	<0.0630	µg/L
	Hexachlorobenzene	ND	<0.0630	µg/L
	Hexachlorocyclopentadiene	ND	<0.0630	µg/L
	Methoxychlor	ND	<0.0630	µg/L
	Propachlor	ND	<0.0630	µg/L
	Toxaphene	ND	<3.16	µg/L
	Trifluralin	ND	<0.0630	µg/L
	Gross Alpha Init	8.99	0	(pCi/L)
	Gross Alpha Final	11.2	0	(pCi/L)
	Radon	122.6	0	(pCi/L)
	Radon	129.2	0	(pCi/L) Dup
	Radon Average	125.9	0	(pCi/L)
Locust Grove Spring	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/25/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
8/28/2014, Radionuclides only	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L

Name	Analyte	Results	RDL	Units
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	ND	<0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	ND	<0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	ND	<0.5	µg/L
	Lead	ND	<0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	ND	<0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	ND	<0.5	µg/L
	Arsenic	ND	<0.5	µg/L
	Chromium	0.7	0.5	µg/L
	Nickel	1	0.5	µg/L
	Boron	21.1	5	µg/L
	Beryllium	ND	<0.5	µg/L
	Aluminum	ND	<10	µg/L
	Barium	2.97	0.500	µg/L
	Cadmium	ND	<0.5	µg/L
	Uranium	ND	<0.50	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	13500		µg/L
	Silica	35600		µg/L
	Iron	ND	<0.050	mg/L
	Calcium	35.2	10	mg/L
	Sodium	7	0.50	mg/L
	Potassium	ND	<1	mg/L
	Total Dissolved Solids	320	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	18	5.0	mg/L
	Alkalinity	72	2.5	mg/L
	Total Kjeldahl Nitrogen	2.90	0.200	mg/L
	Orthophosphate	ND	<0.5	mg/L
	Chloride	46	5.0	mg/L
	Nitrate	1.69	0.5	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	330	10	umhos/cm
	pH	7.05		pH units
	Ammonia as N	ND	<0.10	mg/L
	E. Coli	Presence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0630	µg/L
	4,4'-DDE	ND	<0.0630	µg/L
	4,4'-DDT	ND	<0.0630	µg/L
	Aldrin	ND	<0.0630	µg/L
	alpha-BHC	ND	<0.0630	µg/L
	alpha-Chlordane	ND	<0.0630	µg/L
	beta-BHC	ND	<0.0630	µg/L
	Chlordane	ND	<1.27	µg/L
	delta-BHC	ND	<0.0630	µg/L

Name	Analyte	Results	RDL	Units
	Dieldrin	ND	<0.0630	µg/L
	Endosulfan I	ND	<0.0630	µg/L
	Endolsulfan II	ND	<0.0630	µg/L
	Endolsulfan sulfate	ND	<0.0630	µg/L
	Endrin	ND	<0.0630	µg/L
	Endrin Aldehyde	ND	<0.0630	µg/L
	Endrin ketone	ND	<0.0630	µg/L
	gamma-BHC (Lindane)	ND	<0.0630	µg/L
	gamma-Chlordane	ND	<0.0630	µg/L
	Heptachlor	ND	<0.0630	µg/L
	Heptachlor epoxide	ND	<0.0630	µg/L
	Hexachlorobenzene	ND	<0.0630	µg/L
	Hexachlorocyclopentadiene	ND	<0.0630	µg/L
	Methoxychlor	ND	<0.0630	µg/L
	Propachlor	ND	<0.0630	µg/L
	Toxaphene	ND	<3.16	µg/L
	Trifluralin	ND	<0.0630	µg/L
	Gross Alpha Init	1.1	0	(pCi/L)
	Gross Alpha Final	0	0	(pCi/L)
	Radon	743.3	0	(pCi/L)
	Radon	730.1	0	(pCi/L) Dup
	Radon Average	736.2	0	(pCi/L)
Marble Mountain Spring	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/21/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	ND	<0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	ND	<0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	0.7	0.5	µg/L
	Lead	ND	<0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	1.6	0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	0.9	0.5	µg/L
	Arsenic	ND	<0.5	µg/L
	Chromium	1.1	0.5	µg/L
	Nickel	0.8	0.5	µg/L
	Boron	6.4	5	µg/L
	Beryllium	ND	<0.5	µg/L
	Aluminum	27.7	10	µg/L
	Barium	61.3	0.500	µg/L
	Cadmium	ND	<0.5	µg/L
	Uranium	ND	<0.5	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	17500		µg/L
	Silica	15200		µg/L
	Iron	ND	<0.050	mg/L
	Calcium	35.9	10	mg/L
	Sodium	5.1	0.50	mg/L
	Potassium	1.3	1	mg/L
	Total Dissolved Solids	220	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	8.3	1.0	mg/L
	Alkalinity	130	2.5	mg/L
	Total Kjeldahl Nitrogen	2.6	0.20	mg/L
	Orthophosphate	ND	<0.50	mg/L
	Chloride	11	0.5	mg/L
	Nitrate	3.53	0.500	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	350	10	umhos/cm
	pH	7.49		pH units
	Ammonia as N	ND	<0.1	mg/L
	E. Coli	Presence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0630	µg/L
	4,4'-DDE	ND	<0.0630	µg/L
	4,4'-DDT	ND	<0.0630	µg/L
	Aldrin	ND	<0.0630	µg/L
	alpha-BHC	ND	<0.0630	µg/L
	alpha-Chlordane	ND	<0.0630	µg/L
	beta-BHC	ND	<0.0630	µg/L

Name	Analyte	Results	RDL	Units
	Chlordane	ND	<1.25	µg/L
	delta-BHC	ND	<0.0630	µg/L
	Dieldrin	ND	<0.0630	µg/L
	Endosulfan I	ND	<0.0630	µg/L
	Endolsulfan II	ND	<0.0630	µg/L
	Endolsulfan sulfate	ND	<0.0630	µg/L
	Endrin	ND	<0.0630	µg/L
	Endrin Aldehyde	ND	<0.0630	µg/L
	Endrin ketone	ND	<0.0630	µg/L
	gamma-BHC (Lindane)	ND	<0.0630	µg/L
	gamma-Chlordane	ND	<0.0630	µg/L
	Heptachlor	ND	<0.0630	µg/L
	Heptachlor epoxide	ND	<0.0630	µg/L
	Hexachlorobenzene	ND	<0.0630	µg/L
	Hexachlorocyclopentadiene	ND	<0.0630	µg/L
	Methoxychlor	ND	<0.0630	µg/L
	Propachlor	ND	<0.0630	µg/L
	Toxaphene	ND	<3.12	µg/L
	Trifluralin	ND	<0.0630	µg/L
	Gross Alpha Init	1.71	0	(pCi/L)
	Gross Alpha Final	0	0	(pCi/L)
	Radon	795.7	0	(pCi/L)
	Radon	740.6	0	(pCi/L) Dup
	Radon Average	768.1	0	(pCi/L)
Paint Island Spring	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/14/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane2	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L

Name	Analyte	Results	RDL	Units
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	ND	<0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	ND	<0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	ND	<0.5	µg/L
	Lead	ND	<0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	81.2	0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	ND	<0.5	µg/L
	Arsenic	1.2	0.5	µg/L
	Chromium	ND	<0.5	µg/L
	Nickel	ND	<0.5	µg/L
	Boron	10.7	5	µg/L
	Beryllium	ND	<0.5	µg/L
	Aluminum	ND	<10	µg/L
	Barium	22.7	0.500	µg/L
	Cadmium	ND	<0.5	µg/L
	Uranium	ND	<0.5	µg/L
	Antimony	ND	<0.50	µg/L
	Magnesium	2010		µg/L
	Silica	23400		µg/L
	Iron	27	1.0	mg/L
	Calcium	ND	<15	mg/L
	Sodium	2.6	0.50	mg/L
	Potassium	2.1	1.0	mg/L
	Total Dissolved Solids	110	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	13	0.5	mg/L
	Alkalinity	ND	<2.5	mg/L
	Total Kjeldahl Nitrogen	0.919	0.200	mg/L
	Orthophosphate	ND	<0.50	mg/L
	Chloride	18	2.5	mg/L
	Nitrate	ND	<0.5	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	120	10	umhos/cm
	pH	4.11		pH units
	Ammonia as N	ND	<0.10	mg/L
	E. Coli	Abscence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0580	µg/L
	4,4'-DDE	ND	<0.0580	µg/L
	4,4'-DDT	ND	<0.0580	µg/L
	Aldrin	ND	<0.0580	µg/L
	alpha-BHC	ND	<0.0580	µg/L

Name	Analyte	Results	RDL	Units
	alpha-Chlordane	ND	<0.0580	µg/L
	beta-BHC	ND	<0.0580	µg/L
	Chlordane	ND	<1.16	µg/L
	delta-BHC	ND	<0.0580	µg/L
	Dieldrin	ND	<0.0580	µg/L
	Endosulfan I	ND	<0.0580	µg/L
	Endolsulfan II	ND	<0.0580	µg/L
	Endolsulfan sulfate	ND	<0.0580	µg/L
	Endrin	ND	<0.0580	µg/L
	Endrin Aldehyde	ND	<0.0580	µg/L
	Endrin ketone	ND	<0.0580	µg/L
	gamma-BHC (Lindane)	ND	<0.0580	µg/L
	gamma-Chlordane	ND	<0.0580	µg/L
	Heptachlor	ND	<0.0580	µg/L
	Heptachlor epoxide	ND	<0.0580	µg/L
	Hexachlorobenzene	0.0310 J	<0.0580	µg/L
	Hexachlorocyclopentadiene	ND	<0.0580	µg/L
	Methoxychlor	ND	<0.0580	µg/L
	Propachlor	ND	<0.0580	µg/L
	Toxaphene	ND	<2.91	µg/L
	Trifluralin	ND	<0.0580	µg/L
	Gross Alpha Init	2.21	0	(pCi/L)
	Gross Alpha Final	0	0	(pCi/L)
	Radon	1294.8	0	(pCi/L)
	Radon	1177.7	0	(pCi/L) Dup
	Radon Average	1236.3	0	(pCi/L)
Shurts Road Spring	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/21/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane2	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	ND	<0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	ND	<0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	ND	<0.5	µg/L
	Lead	ND	<0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	ND	<0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	ND	<0.5	µg/L
	Arsenic	0.7	0.5	µg/L
	Chromium	ND	<0.5	µg/L
	Nickel	1.1	0.5	µg/L
	Boron	2.5	5	µg/L
	Beryllium	ND	<0.5	µg/L
	Aluminum	ND	<10	µg/L
	Barium	14.9	0.500	µg/L
	Cadmium	ND	<0.5	µg/L
	Uranium	ND	<0.50	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	19000		µg/L
	Silica	12700		µg/L
	Iron	ND	<0.050	mg/L
	Calcium	37.8	10	mg/L
	Sodium	10	0.50	mg/L
	Potassium	1.1	1	mg/L
	Total Dissolved Solids	250	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	14	0.5	mg/L
	Alkalinity	130	2.5	mg/L
	Total Kjeldahl Nitrogen	3.2	0.20	mg/L
	Orthophosphate	ND	<0.50	mg/L
	Chloride	ND	<2.5	mg/L
	Nitrate	3.08	0.500	mg/L
	Fluoride	0.5	0.5	mg/L
	Conductivity	410	10	umhos/cm
	pH	7.65		pH units
	Ammonia as N	ND	<0.015	mg/L
	E. Coli	Presence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0630	µg/L
	4,4'-DDE	ND	<0.0630	µg/L
	4,4'-DDT	ND	<0.0630	µg/L

Name	Analyte	Results	RDL	Units
	Aldrin	ND	<0.0630	µg/L
	alpha-BHC	ND	<0.0630	µg/L
	alpha-Chlordane	ND	<0.0630	µg/L
	beta-BHC	ND	<0.0630	µg/L
	Chlordane	ND	<1.25	µg/L
	delta-BHC	ND	<0.0630	µg/L
	Dieldrin	ND	<0.0630	µg/L
	Endosulfan I	ND	<0.0630	µg/L
	Endolsulfan II	ND	<0.0630	µg/L
	Endolsulfan sulfate	ND	<0.0630	µg/L
	Endrin	ND	<0.0630	µg/L
	Endrin Aldehyde	ND	<0.0630	µg/L
	Endrin ketone	ND	<0.0630	µg/L
	gamma-BHC (Lindane)	ND	<0.0630	µg/L
	gamma-Chlordane	ND	<0.0630	µg/L
	Heptachlor	ND	<0.0630	µg/L
	Heptachlor epoxide	ND	<0.0630	µg/L
	Hexachlorobenzene	0.0180 J	0.0630	µg/L
	Hexachlorocyclopentadiene	ND	<0.0630	µg/L
	Methoxychlor	ND	<0.0630	µg/L
	Propachlor	ND	<0.0630	µg/L
	Toxaphene	ND	<3.12	µg/L
	Trifluralin	ND	<0.0630	µg/L
	Gross Alpha Init	3.1	0	(pCi/L)
	Gross Alpha Final	0	0	(pCi/L)
	Radon	309.5	0	(pCi/L)
	Radon	321.9	0	(pCi/L) Dup
	Radon Average	315.7	0	(pCi/L)
Valley Crest Spring 1	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/21/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<0.1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane2	ND	<0.5	µg/L
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	ND	<0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	1.2	0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	1.7	0.5	µg/L
	Lead	ND	<0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	4.2	0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	0.6	0.5	µg/L
	Arsenic	0.5	0.5	µg/L
	Chromium	1.7	0.5	µg/L
	Nickel	1.3	0.5	µg/L
	Boron	11.2	5	µg/L
	Beryllium	ND	<0.5	µg/L
	Aluminum	58.6	10	µg/L
	Barium	43.1	0.5	µg/L
	Cadmium	ND	<0.5	µg/L
	Uranium	0.5	0.5	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	1280	0	µg/L
	Silica	5120	0	µg/L
	Iron	ND	<0.5	mg/L
	Calcium	ND	<15	mg/L
	Sodium	10	1.5	mg/L
	Potassium	1.3	1	mg/L
	Total Dissolved Solids	510	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	15	0.5	mg/L
	Alkalinity	170	2.5	mg/L
	Total Kjeldahl Nitrogen	3.4	0.2	mg/L
	Orthophosphate	ND	<0.5	mg/L
	Chloride	21	2.5	mg/L
	Nitrate	3.84	0.5	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	460	10	umhos/cm
	pH	7.24	0	pH units
	Ammonia as N	ND	<0.1	mg/L
	E. Coli	Presence	1	CFU/100 ml
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0630	µg/L

Name	Analyte	Results	RDL	Units
	4,4'-DDE	ND	<0.0630	µg/L
	4,4'-DDT	ND	<0.0630	µg/L
	Aldrin	ND	<0.0630	µg/L
	alpha-BHC	ND	<0.0630	µg/L
	alpha-Chlordane	ND	<0.0630	µg/L
	beta-BHC	ND	<0.0630	µg/L
	Chlordane	ND	<1.25	µg/L
	delta-BHC	ND	<0.0630	µg/L
	Dieldrin	ND	<0.0630	µg/L
	Endosulfan I	ND	<0.0630	µg/L
	Endolsulfan II	ND	<0.0630	µg/L
	Endolsulfan sulfate	ND	<0.0630	µg/L
	Endrin	ND	<0.0630	µg/L
	Endrin Aldehyde	ND	<0.0630	µg/L
	Endrin ketone	ND	<0.0630	µg/L
	gamma-BHC (Lindane)	ND	<0.0630	µg/L
	gamma-Chlordane	ND	<0.0630	µg/L
	Heptachlor	ND	<0.0630	µg/L
	Heptachlor epoxide	ND	<0.0630	µg/L
	Hexachlorobenzene	ND	<0.0630	µg/L
	Hexachlorocyclopentadiene	ND	<0.0630	µg/L
	Methoxychlor	ND	<0.0630	µg/L
	Propachlor	ND	<0.0630	µg/L
	Toxaphene	ND	<3.12	µg/L
	Trifluralin	ND	<0.0630	µg/L
	Gross Alpha Init	2.24	0	(pCi/L)
	Gross Alpha Final	0	0	(pCi/L)
	Radon	1055	0	(pCi/L)
	Radon	880.6	0	(pCi/L) Dup
	Radon Average	967.8	0	(pCi/L)
Honeyman Spring	1,1,1,2- Tetrachloroethane	ND	<0.5	µg/L
Sample Date: 8/19/2014	1,1,1-Trichloroethane	ND	<0.5	µg/L
	1,1,2,2-Tetrachloroethane	ND	<0.5	µg/L
	1,1,2-Trichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethane	ND	<0.5	µg/L
	1,1-Dichloroethene	ND	<0.5	µg/L
	1,1-Dichloropropanone	ND	<1	µg/L
	1,1-Dichloropropene	ND	<0.5	µg/L
	1,2,3-Trichlorobenzene	ND	<0.5	µg/L
	1,2,3-Trichloropropane	ND	<0.1	µg/L
	1,2,4-Trichlorobenzene	ND	<0.5	µg/L
	1,2,4-Trimethylbenzene	ND	<0.5	µg/L
	1,2-Dibromo-3-chloropropane	ND	<0.5	µg/L
	1,2-Dibromoethane	ND	<0.5	µg/L
	1,2-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloroethane	ND	<0.5	µg/L
	1,2-Dichloropropane	ND	<0.5	µg/L
	1,2,3-Trimethylbenzene	ND	<0.5	µg/L
	1,3-Dichlorobenzene	ND	<0.5	µg/L
	1,2-Dichloropropane2	ND	<0.5	µg/L

Name	Analyte	Results	RDL	Units
	1,4-Dichlorobenzene	ND	<0.5	µg/L
	1-Chlorobutane	ND	<0.5	µg/L
	2,2-Dichloropropane	ND	<0.5	µg/L
	2-Chlorotoluene	ND	<0.5	µg/L
	2-Hexanone	ND	<1	µg/L
	2-Nitropropane	ND	<1	µg/L
	3-Chloro-1-propene	ND	<0.5	µg/L
	4-Chlorotoluene	ND	<0.5	µg/L
	4-Isopropyltoluene	ND	<0.5	µg/L
	4-Methyl-2-pentanone	ND	<2	µg/L
	Acetone	ND	<2	µg/L
	Acrylonitrile	ND	<0.5	µg/L
	Benzene	ND	<0.5	µg/L
	Bromobenzene	ND	<0.5	µg/L
	Bromochloromethane	ND	<0.5	µg/L
	Bromodichloromethane	ND	<0.5	µg/L
	Bromoform	ND	<0.5	µg/L
	Bromomethane	ND	<0.5	µg/L
	Carbon disulfide	ND	<0.5	µg/L
	Carbon Tetrachloride	ND	<0.5	µg/L
	Chloroacetonitrile	ND	<0.5	µg/L
	Chlorobenzene	ND	<0.5	µg/L
	Chloroethane	ND	<0.5	µg/L
	Chloroform	ND	<0.5	µg/L
	Chloromethane	ND	<0.5	µg/L
	cis-1,2-Dichloroethane	ND	<0.5	µg/L
	cis-1,3-Dichloropropene	ND	<0.5	µg/L
	Dibromochloromethane	ND	<0.5	µg/L
	Dibromomethane	ND	<0.5	µg/L
	Dichlorodifluoromethane	ND	<0.5	µg/L
	Diethyl ether	ND	<0.5	µg/L
	Ethyl Methacrylate	ND	<0.5	µg/L
	Ethylbenzene	ND	<0.5	µg/L
	Hexachlorobutadiene	ND	<0.5	µg/L
	Hexachloloethane	ND	<0.5	µg/L
	Isopropylbenzene	ND	<0.5	µg/L
	Methacrylonitrile	ND	<1	µg/L
	Methyl Ethyl Ketone	ND	<0.5	µg/L
	Methyl Iodide	ND	<0.5	µg/L
	Methyl tert-Butyl Ether (MTBE)	ND	<0.5	µg/L
	Methylacrylate	ND	<0.5	µg/L
	Methylene Chloride	ND	<0.5	µg/L
	Methylmethacrylate	ND	<1	µg/L
	Napthalene	ND	<0.5	µg/L
	n-Butylbenzene	ND	<0.5	µg/L
	Nitrobenzene	ND	<2	µg/L
	n-Propylbenzene	ND	<0.5	µg/L
	o-Xylene	ND	<0.5	µg/L
	Pentachloroethane	ND	<0.5	µg/L
	Propiontirile	ND	<1	µg/L

Name	Analyte	Results	RDL	Units
	sec-Butylbenzene	ND	<0.5	µg/L
	Styrene	ND	<0.5	µg/L
	tert-Butylbenzene	ND	<0.5	µg/L
	Tetrachloroethane	ND	<0.5	µg/L
	Tetrahydrofuran	ND	<1	µg/L
	Toluene	ND	<0.5	µg/L
	trans-1,2-Dichloroethane	ND	<0.5	µg/L
	trans-1,3-Dichloropropene	ND	<0.5	µg/L
	trans-1,4-Dichloro-2-butene	ND	<0.5	µg/L
	Trichloroethene	ND	<0.5	µg/L
	Trichloroflouromethane	ND	<0.5	µg/L
	Vinyl chloride	ND	<0.5	µg/L
	t-Butyl alcohol	ND	<1	µg/L
	m,p-Xylene	ND	<2	µg/L
	Xylene	ND	<1	µg/L
	Copper	1.3	0.5	µg/L
	Lead	ND	<0.5	µg/L
	Thallium	ND	<0.5	µg/L
	Manganese	0.7	0.5	µg/L
	Silver	ND	<0.5	µg/L
	Selenium	0.9	0.5	µg/L
	Arsenic	4.1	0.5	µg/L
	Chromium	ND	<0.5	µg/L
	Nickel	1	0.5	µg/L
	Boron	81.1	5	µg/L
	Beryllium	ND	<0.5	µg/L
	Aluminum	ND	<10	µg/L
	Barium	199	0.5	µg/L
	Cadmium	ND	<0.5	µg/L
	Uranium	8.2	0.5	µg/L
	Antimony	ND	<0.5	µg/L
	Magnesium	15800	0	µg/L
	Silica	18400	0	µg/L
	Iron	ND	<0.05	mg/L
	Calcium	ND	<50	mg/L
	Sodium	12	.50	mg/L
	Potassium	ND	<1	mg/L
	Total Dissolved Solids	260	10	mg/L
	Nitrite	ND	<0.5	mg/L
	Sulfate	38	2.5	mg/L
	Alkalinity	130	2.5	mg/L
	Total Kjeldahl Nitrogen	2.2	0.2	mg/L
	Orthophosphate	ND	<0.5	mg/L
	Chloride	38	2.5	mg/L
	Nitrate	1.63	0.5	mg/L
	Fluoride	ND	<0.5	mg/L
	Conductivity	410	10	µmhos/cm
	pH	7.7	0	pH units
	Ammonia as N	ND	<0.1	mg/L
	E. Coli	Presence	1	CFU/100 ml

Name	Analyte	Results	RDL	Units
	Total Coliform	Presence	1	CFU/100 ml
	4,4'-DDD	ND	<0.0590	µg/L
	4,4'-DDE	ND	<0.0590	µg/L
	4,4'-DDT	ND	<0.0590	µg/L
	Aldrin	ND	<0.0590	µg/L
	alpha-BHC	ND	<0.0590	µg/L
	alpha-Chlordane	ND	<0.0590	µg/L
	beta-BHC	ND	<0.0590	µg/L
	Chlordane	ND	<1.18	µg/L
	delta-BHC	ND	<0.0590	µg/L
	Dieldrin	ND	<0.0590	µg/L
	Endosulfan I	ND	<0.0590	µg/L
	Endolsulfan II	ND	<0.0590	µg/L
	Endolsulfan sulfate	ND	<0.0590	µg/L
	Endrin	ND	<0.0590	µg/L
	Endrin Aldehyde	ND	<0.0590	µg/L
	Endrin ketone	ND	<0.0590	µg/L
	gamma-BHC (Lindane)	ND	<0.0590	µg/L
	gamma-Chlordane	ND	<0.0590	µg/L
	Heptachlor	ND	<0.0590	µg/L
	Heptachlor epoxide	ND	<0.0590	µg/L
	Hexachlorobenzene	ND	<0.0590	µg/L
	Hexachlorocyclopentadiene	ND	<0.0590	µg/L
	Methoxychlor	ND	<0.0590	µg/L
	Propachlor	ND	<0.0590	µg/L
	Toxaphene	ND	<2.93	µg/L
	Trifluralin	ND	<0.0590	µg/L
	Gross Alpha Init	17.8	0	(pCi/L)
	Gross Alpha Final	14.1	0	(pCi/L)
	Radon	898.3	0	(pCi/L)
	Radon	862.3	0	(pCi/L) Dup
	Radon Average	880.3	0	(pCi/L)

Appendix D: List of Plant Taxa (with percent cover) Documented in Headwater Wetlands at Seven Spring Sites in New Jersey.

CoC value (Walz et al, 2018); N=Native, I=Non-native; NJWET-Spring site code key: BS=Big Spring, IL=Indian Lady Hill Spring, PI=Paint Island Spring, SR=Shurts Road Spring, SB=Spring Brook Cabin Spring, VC=Valley Crest Spring

				Taxa per spring site						
Scientific Name	**Common Name**	**FQA CoC value**	**Native (N) vs Non-native (I)**	**BS**	**CS**	**IL**	**PI**	**SR**	**SB**	**VC**
Acer negundo	Box-elder	2	N		3					
Acer rubrum	Red maple	3	N	30	3	3	30		0.5	
Agrimonia parviflora	Harvestlice	3	N					0.5		
Alisma subcordatum	American water-plantain	5	N	0.5						
Alliaria petiolata	Garlic-mustard	0	I				0.5	0.5		0.5
Allium vineale	Field garlic	0	I					0.5		0.5
Alnus incana	Speckled alder	6	N						0.5	
Alnus serrulata	Smooth alder	4	N	10			0.5			
Amelanchier arborea	Common service-berry	6	N			0.5			0.5	
Amelanchier sp.	Serviceberry	7	N	0.5			0.5			
Amphicarpaea bracteata	Hog peanut	4	N					0.5		0.5
Anthoxanthum odoratum	Sweet vernalgrass	0	I					0.5		
Apios americana	Ground-nut	5	N	0.5	0.5		0.5			
Apocynum sp.	Dogbane	3	N						0.5	0.5
Arisaema triphyllum	Jack-in-the-pulpit	5	N		0.5		0.5			
Aronia sp.	Chokeberry	6	N	0.5						
Arthraxon hispidus	Small carpgrass	0	I							0.5
Asclepias incarnata	Swamp milkweed	5	N	0.5						
Asclepias syriaca	Common milkweed	1	N					0.5		0.5
Aster sp.	Aster	7	N	0.5	0.5					
Bartonia paniculata	Screwstem	8	N			0.5				
Bartonia virginica	Bartonia	6	N			0.5				
Berberis thunbergii	Japanese barberry	0	I	0.5			0.5	0.5	0.5	0.5
Betula alleghaniensis	Yellow birch	8	N						0.5	
Betula populifolia	Gray birch	3	N			0.5				
Bidens connata	Purple-stemmed beggar -ticks	5	N				0.5	0.5		

Scientific Name	**Common Name**	**FQA CoC value**	**Native (N) vs Non-native (I)**	**BS**	**CS**	**IL**	**PI**	**SR**	**SB**	**VC**
Bidens frondosa	Beggar-ticks	2	N		0.5		0.5			0.5
Bidens sp.	Beggarticks	5	N	0.5	0.5					
Boehmeria cylindrica	False nettle	4	N	0.5	0.5				0.5	
Bromus inermis	Smooth brome	0	I							0.5
Callitriche sp.	Water-Starwort	5	N				0.5			
Campanula sp.	Bellflower	6	N	0.5						
Cardamine pensylvanica	Pennsylvania bittercress	4	N					0.5		
Carex atlantica subsp. atlantica	Prickly bog sedge	7	N			0.5			40	
Carex bromoides	Brome-like sedge	7	N						0.5	
Carex canescens subsp. disjuncta	Silvery sedge	7	N						0.5	
Carex collinsii	Collins' sedge	9	N			0.5				
Carex crinita	Fringed sedge	5	N		0.5		0.5			0.5
Carex echinata	Star sedge	10	N						30	
Carex folliculata	Long sedge	5	N			0.5				
Carex hystericina	Porcupine sedge	8	N					0.5		3
Carex intumescens	Bladder sedge	5	N				0.5		0.5	
Carex laevivaginata	Smooth-sheathed sedge	7	N					0.5	3	
Carex leptalea	Bristlystalked sedge	9	N					0.5		
Carex lupulina	Hop sedge	6	N						0.5	
Carex lurida	Sallow sedge	4	N		0.5		0.5	0.5	0.5	10
Carex scoparia	Broom sedge	3	N					0.5	10	
Carex sp.	Sedge	7	N	0.5			0.5			
Carex stipata	Awl-fruited sedge	2	N							3
Carex stricta	Tussock sedge	5	N	30			0.5		3	
Carex swanii	Swan's sedge	5	N				0.5			
Carex vulpinoidea	Fox sedge	3	N					0.5		10
Carya sp.	Hickory	6	N	0.5			0.5			
Celastrus orbiculatus	Oriental bittersweet	0	I					0.5		
Cephalanthus occidentalis	Buttonbush	6	N	3			0.5			
Chelone glabra	Turtlehead	6	N	0.5				0.5		
Cicuta sp.	Water Hemlock	7	N	0.5						
Cinna arundinacea	Wood reedgrass	5	N	0.5			0.5			
Cirsium arvense	Canada thistle	0	I						0.5	

Scientific Name	Common Name	FQA CoC value	Native (N) vs Non-native (I)	BS	CS	IL	PI	SR	SB	VC
Cirsium vulgare	Bull-thistle	0	I							0.5
Clematis terniflora	Sweet autumn virginsbower	0	I				0.5			
Clethra alnifolia	Sweet pepperbush	5	N	0.5		3	0.5			
Commelina communis	Asiatic dayflower	0	I				0.5			
Conium maculatum	Poison-hemlock	0	I					0.5		0.5
Cornus amomum	Silky dogwood	5	N		10			0.5		
Cornus racemosa	Grey dogwood	5	N	0.5				20		
Cornus sp.	Dogwood	7	N	0.5						
Cuscuta gronovii	Common dodder	3	N		0.5		0.5			
Cuscuta sp.	Dodder	5	N							0.5
Cypripedium sp.	Lady's slipper	10	N			0.5				
Dasiphora fruticosa subsp. floribunda	Shrubby Cinquefoil	9	N	0.5						
Dichanthelium clandestinum	Deertongue	2	N				0.5		0.5	0.5
Dichanthelium dichotomum var. ensifolium	Cypress panicgrass	7	N			0.5				
Dioscorea villosa	Wild yam	5	N				0.5			
Drosera intermedia	Spatulate-leaved sundew	6	N			0.5				
Drosera rotundifolia	Round-leaved sundew	6	N			0.5				
Dryopteris carthusiana	Spinulose wood fern	5	N					0.5		
Dryopteris cristata	Crested shield fern	8	N				0.5			
Duchesnea indica	Indian strawberry	0	I		0.5					
Echinocystis lobata	Prickly cucumber	2	N					0.5		
Elaeagnus umbellata	Autumn-olive	0	I	3			0.5	3		0.5
Eleocharis intermedia	Matted spike-rush	10	N						0.5	
Eleocharis obtusa	Blunt spike-rush	4	N					0.5	0.5	
Eleocharis ovata	Ovate Spike-rush	5	N					0.5		
Eleocharis sp.	Spikerush	8	N			0.5	0.5	0.5		
Eleocharis tenuis	Slender spike-rush	3	N							0.5
Elymus repens	Quackgrass	0	I					0.5		
Epilobium coloratum	Purple-leaved willow-herb	2	N		0.5			0.5	0.5	0.5
Epilobium sp.	Willowherb	5	N	0.5						
Equisetum fluviatile	Water horsetail	8	N					0.5		

Scientific Name	**Common Name**	**FQA CoC value**	**Native (N) vs Non-native (I)**	**BS**	**CS**	**IL**	**PI**	**SR**	**SB**	**VC**
Equisetum sp.	Horsetail	8	N	0.5						
Erechtites hieraciifolius	American burnweed	2	N				0.5			
Erigeron annuus	Daisy fleabane	1	N					0.5		
Eriophorum virginicum	Tawny cotton-grass	7	N			0.5				
Eubotrys racemosus	Fetter-bush	6	N				0.5			
Eupatorium perfoliatum	Boneset	4	N					0.5		0.5
Eupatorium serotinum	Late eupatorium	1	N					0.5		
Eupatorium sp.	Thoroughwort	4	N	0.5						
Euphorbia sp.	Spurge	0	I							0.5
Euthamia graminifolia	Flat-top goldentop	2	N					0.5	0.5	0.5
Eutrochium fistulosum	Trumpetweed	5	N					3		
Fragaria sp.	Strawberry	3	N	0.5						
Fraxinus pennsylvanica	Green ash	5	N					10		
Fraxinus sp.	Ash	5	N	0.5						
Galium tinctorium	Stiff marsh bedstraw	4	N	0.5			0.5		0.5	
Galium triflorum	Fragrant bedstraw	5	N					0.5		
Gaultheria procumbens	Teaberry	5	N			0.5				
Gaylussacia frondosa	Dangleberry	6	N			20				
Geum canadense	White avens	5	N		0.5			0.5		
Glechoma hederacea	Gill-over-the-ground	0	I		10					
Glyceria canadensis	Rattlesnake manna grass	6	N		0.5					
Glyceria obtusa	Blunt manna grass	6	N						0.5	
Glyceria striata	Fowl manna grass	4	N				0.5	0.5		30
Hackelia virginiana	Virginia stickseed	3	N					0.5		0.5
Hedera helix	English ivy	0	I		0.5					
Hydrocotyle americana	Marsh pennywort	5	N					0.5	0.5	
Hypericum canadense	Canadian St. John's-wort	4	N			0.5				
Hypericum punctatum	Spotted St. John's-wort	1	N					0.5		
Hypericum sp.	St. Johnswort	6	N					0.5		
Ilex glabra	Inkberry	6	N			0.5				
Ilex opaca	American holly	4	N			0.5				
Ilex verticillata	Winterberry	7	N	10		0.5	10	0.5		
Impatiens capensis	Jewelweed	3	N	0.5	3		0.5	0.5	0.5	3
Iris pseudacorus	Water flag	0	I				0.5			

Scientific Name	Common Name	FQA CoC value	Native (N) vs Non-native (I)	BS	CS	IL	PI	SR	SB	VC
Iris versicolor	Northern blue flag	5	N	0.5					0.5	
Juglans nigra	Black walnut	3	N					3		
Juncus dudleyi	Dudley's rush	8	N					0.5		
Juncus effusus	Common rush	2	N				0.5	0.5		0.5
Juncus effusus var. pylaei	Common rush	2	N						0.5	
Juncus pylaei	Common rush	2	N				0.5			
Juncus sp.	Rush	6	N			0.5				
Juncus tenuis	Poverty rush	1	N							0.5
Juniperus virginiana	Eastern red-cedar	2	N	0.5						
Kalmia latifolia	Mountain laurel	6	N						0.5	
Leersia oryzoides	Rice cutgrass	3	N	0.5	0.5		3	0.5	3	10
Lemna minor	Duckweed	3	N				0.5	0.5	0.5	0.5
Ligustrum vulgare	Common privet	0	I		3					
Lindera benzoin	Spicebush	5	N	0.5	3			3	0.5	
Liquidambar styraciflua	Sweetgum	3	N				3			
Liriodendron tulipifera	Tuliptree	5	N	0.5			3	0.5	0.5	
Lobelia cardinalis	Cardinal-flower	5	N	0.5	0.5					
Lonicera japonica	Japanese honeysuckle	0	I		0.5		3	3		0.5
Lonicera morrowii	Morrow's honeysuckle	0	I					3		
Ludwigia palustris	Marsh-purslane	2	N	0.5			0.5	0.5		
Lycopodiella appressa	Southern bog clubmoss	6	N			0.5				
Lycopus sp.	Water-horehound	4	N	0.5						
Lycopus uniflorus	Northern bugleweed	4	N						0.5	
Lycopus virginicus	Virginia water horehound	4	N		0.5		0.5			0.5
Lyonia ligustrina	Maleberry	6	N						0.5	
Lyonia sp.	Staggerbush	6	N	0.5						
Lysimachia quadrifolia	Whorled loosestrife	5	N						0.5	
Lysimachia sp.	Yellow Loosestrife	5	N	0.5						
Lythrum salicaria	Purple loosestrife	0	I	0.5	0.5					
Magnolia virginiana	Sweet-bay magnolia	7	N			30	0.5			
Malus sp.	Apple	0	I				0.5			
Medeola virginiana	Indian cucumber-root	6	N			0.5				
Mentha arvensis	Wild mint	2	N					0.5		

Scientific Name	Common Name	FQA CoC value	Native (N) vs Non-native (I)	BS	CS	IL	PI	SR	SB	VC
Mentha spicata	Spearmint	0	I					0.5		0.5
Microstegium vimineum	Stiltgrass	0	I				60	0.5	50	10
Mikania scandens	Climbing hempweed	3	N		0.5		0.5			
Mimulus ringens	Allegheny monkeyflower	5	N					0.5	0.5	0.5
Mitchella repens	Partridge-berry	5	N			0.5				
Monarda fistulosa	Wild bergamot	4	N		0.5					
Morella sp.	Bayberry	7	N	0.5						
Moss (non-Sphagnum)	Moss (non-Sphagnum)	6	N							0.5
Myosotis laxa	Wild forget-me-not	4	N						0.5	
Nasturtium officinale	Watercress	0	I					0.5	0.5	
Nyssa sylvatica	Sourgum	4	N			10	3			
Onoclea sensibilis	Sensitive fern	3	N	0.5			0.5	10	0.5	0.5
Osmunda cinnamomea	Cinnamon fern	5	N			30	0.5		0.5	
Osmunda claytoniana	Interrupted fern	6	N						0.5	
Osmunda regalis	Royal fern	7	N	10					0.5	
Oxalis dillenii	Southern yellow wood-sorrel	1	N				0.5			
Oxalis sp.	Woodsorrel	1	N						0.5	
Packera aurea	Golden ragwort	5	N					0.5		
Parthenocissus quinquefolia	Virginia-creeper	2	N		0.5	0.5	3	3	0.5	0.5
Pastinaca sativa	Wild parsnip	0	I					0.5		
Peltandra virginica	Arrow-arum	4	N	0.5						
Phalaris arundinacea	Reed canary-grass	1	N	0.5				3		3
Philonotis fontana var. fontana	Philonotis moss	6	N						10	
Phragmites australis	Common reed	0	I		0.5	0.5			0.5	
Pilea pumila	Clearweed	3	N		3		3	0.5		
Pilea sp.	Clearweed	5	N	0.5						
Pinus rigida	Pitch pine	6	N			20				
Platanthera clavellata	Clubspur orchid	8	N	0.5						
Platanthera sp.	Fringed Orchid	10	N			0.5				
Poa pratensis	Kentucky bluegrass	0	I							0.5
Poa sp. (Native in natural habitats)	Bluegrass	8	N						0.5	
Poa trivialis	Rough bluegrass	0	I							40
Polygonatum sp.	Solomon'S Seal	6	N				0.5			

Scientific Name	Common Name	FQA CoC value	Native (N) vs Non-native (I)	BS	CS	IL	PI	SR	SB	VC
Polygonum arifolium	Halberd-leaf tearthumb	5	N	0.5			20			0.5
Polygonum cespitosum	Oriental lady's thumb	0	I				0.5			
Polygonum punctatum	Dotted smartweed	5	N	0.5	0.5		3	0.5	0.5	3
Polygonum sagittatum	Arrow-leaved tearthumb	3	N				0.5	0.5	0.5	20
Polygonum scandens	Climbing false buckwheat	2	N							0.5
Polygonum sp. (upright)	Knotweed	3	N	0.5						
Prunus serotina	Wild black cherry	2	N				0.5			
Pteridium aquilinum	Bracken fern	4	N			0.5				
Pueraria montana	Kudzu	0	I		40					
Quercus palustris	Pin oak	4	N					0.5		
Quercus sp.	Oak	6	N			0.5				
Ranunculus sp. (terrestrial only)	Crowfoot	4	N				0.5			
Rhexia sp.	Meadowbeauty	9	N			0.5				
Rhododendron viscosum	Swamp azalea	6	N	0.5		3			0.5	
Rhynchospora alba	White beak-rush	6	N			0.5				
Rhynchospora fusca	Brown beaked-rush	8	N			0.5				
Ribes sp. (Native, swamps)	Gooseberry	10	N	0.5						
Rosa multiflora	Multiflora rose	0	I	0.5			0.5	40	0.5	3
Rosa palustris	Swamp rose	6	N	3						
Rubus allegheniensis	Allegheny blackberry	3	N						0.5	
Rubus hispidus	Bristly dewberry	5	N			0.5	0.5		0.5	
Rubus occidentalis	Black-cap raspberry	3	N						0.5	
Rubus sp. (natives only)	Blackberry	3	N					0.5		
Rumex sp.	Dock	0	I		0.5					
Sagittaria latifolia	Wapato	4	N		0.5		0.5			
Salix sp. (Natives only)	Willow	8	N						0.5	
Sambucus nigra subsp. canadensis	American black elderberry	4	N				0.5		0.5	
Sassafras albidum	Sassafras	2	N			0.5				
Schizachyrium scoparium	Little bluestem	3	N			0.5				
Schoenoplectus fluviatilis	River bulrush	7	N							0.5
Schoenoplectus tabernaemontani	Great bulrush; softstem bulrush	5	N						3	
Scirpus atrovirens	Black bulrush	4	N		0.5			0.5	0.5	10

Scientific Name	**Common Name**	**FQA CoC value**	**Native (N) vs Non-native (I)**	**BS**	**CS**	**IL**	**PI**	**SR**	**SB**	**VC**
Scirpus cyperinus	Wool-grass	3	N	40						
Scirpus pendulus	Reddish Bulrush	7	N					0.5		
Scutellaria lateriflora	Mad-dog skullcap	4	N	0.5			0.5			
Sisyrinchium angustifolium	Blue-eyed-grass	5	N					0.5		
Sium suave	Water-parsnip	7	N		0.5					
Smilax rotundifolia	Roundleaf greenbrier	2	N				3			
Solanum carolinense	Horse-nettle	0	I					0.5		
Solanum dulcamara	Bittersweet nightshade	0	I					0.5		0.5
Solidago altissima	Canada goldenrod	2	N					0.5		
Solidago juncea	Early goldenrod	2	N					3		
Solidago rugosa	Wrinkle-leaf goldenrod	3	N				0.5	0.5	0.5	
Solidago sp.	Goldenrod	6	N	0.5					0.5	0.5
Sparganium androcladum	Branching bur-reed	8	N				0.5			
Sparganium eurycarpum	Giant bur-reed	7	N						3	
Sparganium sp.	Bur-Reed	8	N			0.5				
Sphagnum affine	Sphagnum	6	N						10	
Sphagnum magellanicum	Sphagnum	7	N			0.5				
Sphagnum palustre	Sphagnum	5	N			0.5				
Sphagnum recurvum	Sphagnum	6	N			0.5				
Spiraea sp.	Spirea	5	N	0.5						
Spiraea tomentosa	Steeplebush	5	N						0.5	
Stellaria graminea	Lesser stitchwort	0	I							0.5
Symphyotrichum puniceum var. puniceum	Purple-stemmed aster	4	N					0.5		3
Symphyotrichum sp.	Aster	7	N				0.5			
Symplocarpus foetidus	Skunk cabbage	5	N		10		3	0.5	0.5	0.5
Thalictrum dioicum	Early meadow-rue	7	N	0.5						
Thelypteris palustris	Eastern marsh fern	4	N	3			0.5		3	
Tilia americana	American basswood	7	N	0.5						
Toxicodendron radicans	Poison ivy	1	N	0.5	0.5	0.5	3	3		
Toxicodendron vernix	Poison sumac	7	N	0.5		0.5				
Triadenum virginicum	Marsh St. John's-wort	7	N						0.5	
Trientalis borealis	Star-flower	5	N			0.5				
Typha latifolia	Broadleaf cattail	3	N	0.5			0.5	0.5	0.5	0.5

Scientific Name	**Common Name**	**FQA CoC value**	**Native (N) vs Non-native (I)**	**BS**	**CS**	**IL**	**PI**	**SR**	**SB**	**VC**
Ulmus americana	American elm	6	N		10					
Utricularia sp.	Bladderwort	9	N			0.5				
Vaccinium corymbosum	Highbush blueberry	5	N	3		20	0.5		0.5	
Verbena urticifolia	White vervain	2	N					0.5		0.5
Vernonia noveboracensis	New York ironweed	4	N					3		
Veronica anagallis-aquatica	Water speedwell	7	N					0.5		0.5
Veronica scutellata	Marsh speedwell	7	N						0.5	
Viburnum dentatum	Southern arrowwood	5	N	0.5						
Viburnum prunifolium	Black-haw	5	N					0.5		
Viburnum recognitum	Northern arrow-wood	7	N				3	10	0.5	
Viola cucullata	Blue marsh violet	6	N						0.5	
Viola sp.	Violet	6	N	0.5		0.5	0.5			
Vitis labrusca	Fox grape	5	N				10			
Vitis riparia	Riverbank grape	8	N					3		
Vitis sp.	Grape	5	N						0.5	0.5
Vitis vulpina	Frost grape	4	N					3		
Woodwardia areolata	Netted chain fern	7	N				0.5			
Xyris torta	Twisted yellow-eyed grass	7	N			0.5				
	Total # Taxa per Spring Site			**70**	**40**	**52**	**79**	**89**	**75**	**58**

Appendix E: Benthic Macroinvertebrate community assemblages for seven spring sites for Summer 2014 (S), Fall 2014 (F) and Spring 2015 (P). Pollution Tolerance Values (PTV) and Functional Feeding Groups (FFG) are also provided for each taxon.
Seven spring sites, (SR) Shurts Road Spring (DF) Dingman's Ferry Spring (VC) Valley Crest Spring (IL) Indian Lady Hill Spring (PI) Paint Island Spring (BH) Blue Hole-Inskeep (CS) Crystal Spring.

		SR			DF			VC			ILH			PI			BH			CS			PTV	FFG
		S	F	P	S	F	P	S	F	P	S	F	P	S	F	P	S	F	P	S	F	P		
Order/Family	**Identification**																							
Amphipoda																								
Crangonyctidae	*Crangonyctidae*				5	18	11																4	CG
Gammaridae	*Gamarrus fasciatus*	38	45	46				3		2										53	17	32	6	CG
Gammaridae	*Gamarrus* spp.	1																					6	CG,SH
Hyalellidae	*Hyalella azteca*							1															8	CG
Bivalvia																								
Pisidiidae	Pisidiidae				1															2			8	FC
Sphaeriidae	*Musculium* spp.							2			2												5	FC
Coleoptera																								
Dytiscidae	*Agabus* spp.		3	1		1				12													5	P
Dytiscidae	*Chantus* spp.											3											5	P
Dytiscidae	*Hydroporus* spp.							1															5	P, PI
Dytiscidae	*Potamonectes* spp.									1									1				5	PI
Elmidae	*Optioservus* spp.	35	17	21		1		6		1													4	CG, SC
Elmidae	*Stenelmis* spp.	1		1	2						21	18	24										5	SC
Haliplidae	*Peltodytes* spp.																	1	1				5	SH
Hydrophilidae	*Hydrophilidae* spp.														1								5	P
Psephenidae	*Psephenus* spp.							1															4	SC
Scirtidae	*Cyphon* spp.															9							7	SC
Scirtidae	*Prionocyphon* spp.													7	15	8							5	SC
Collembola																								
Entomobryidae	Entomobryidae				1																		10	CG
Entomobryidae	*Salina* spp.					1	1																5	CG

		SR			DF			VC			ILH			PI			BH			CS			PTV	FFG
		S	F	P	S	F	P	S	F	P	S	F	P	S	F	P	S	F	P	S	F	P		
Order/Family	**Identification**																							
Isotomidae	Isotomidae																			3			10	CG
Decapoda																								
Cambaridae	Cambaridae																				1		5	CG
Diptera																								
Ceratopogonidae	*Ceratopogon* spp.														1								6	P
Ceratopogonidae	Ceratopogonidae																			2	30	7	6	P
Chironomidae	*Bezzia* spp.											3	4										6	SC
Chironomidae	Chironomidae	1	5	2	63	55	33	40		50	53	59	46	11	1	1	6	10	23	11	47	57	6	-
Culicidae	*Aedes* spp.											2		3									8	CG, FC
Cecidomyiidae	Cecidomyiidae													4									6	CG, FC, P, PI
Diptera	Diptera							1							2	1							6	-
Dolichopodidae	Dolichopodidae																			2			4	P
Empididae	*Clinocera stagnalis*							1															6	P
Empididae	Empididae				1																		6	P
Empididae	Hemerodromia							1															6	P
Empididae	*Neoplasta* spp.				1																		6	P
Ephydridae	Ephydridae							2															6	PI
Muscidae	*Muscidae* spp.	1																					6	P
Psychodidae	Psychodidae																			1			10	CG
Ptychopteridae	*Bittacomorpha* spp.												2	6	8								8	CG
Simuliidae	*Cnephia* spp.	2																					4	FC
Simuliidae	*Prosimulium* spp.									2													2	FC
Simuliidae	*Simulium* spp.							4															6	FC
Stratiomyidae	Stratiomyidae																			2			10	CG
Tabanidae	*Chrysops* spp.	1								2	10	2											6	CG, PI
Tabanidae	Tabanidae		1																				6	PI
Tabanidae	*Tabanus* spp.							3															5	P, PI
Tipulidae	*Antocha* spp.			4																			3	CG
Tipulidae	*Dicranota* spp.	2		2																			3	P
Tipulidae	*Limnophila* spp.																					1	3	P
Tipulidae	*Molophilus* spp.																				1		3	CG
Tipulidae	*Ormosia* spp.													4	9	1							3	CG
Tipulidae	*Pilaria* spp.											4											7	P
Tipulidae	*Pseudolimnophila* spp.												2		1								2	CG
Tipulidae	*Tipula* spp.		2					1		1				1	2								4	SH
Tipulidae	Tipulidae				3		1	1															3	SH
Tipulidae	*Pedicia* spp.							1											3				6	P
Ephemeroptera																								
Baetidae	Baetidae																						4	CG, SC
Baetidae	*Baetis* spp.	2	1					4															6	CG
Ephemerellidae	*Ephemerella* spp.			7			1																1	CG, SC

		SR			DF			VC			ILH			PI			BH			CS			PTV	FFG
		S	F	P	S	F	P	S	F	P	S	F	P	S	F	P	S	F	P	S	F	P		
Order/Family	**Identification**																							
Ephemerellidae	*Eurylophella* spp.																		1				4	SC
Siphlonuridae	*Ameletus* spp.									6													0	CG
Gastropoda																								
Physidae	*Physella* spp.	5						1															9.1	SC
Physidae	Physidae		4																				7	SC
Hemiptera																								
Corixidae	Corixidae																	6	3				9	P, PI
Gerridae	*Trepobates* spp.							1															8	PI
Isopoda																								
Asellidae	Asellidae																14	5					8	CG
Asellidae	*Caecidotea* spp.	2	4	3							10	3	6						38				8	CG
Lepidoptera																								
Lepidoptera	Lepidoptera																	1					5	SH
Megaloptera																								
Corydalidae	*Chauliodes* spp.										1			1									4	P
Sialidae	*Sialis* spp.													2	10								4	P
Odonata																								
Aeshnidae	*Aeshna* spp.											2											5	P
Coenagrionidae	*Ischnura* spp.																		1				9	P
Corduliidae	*Somatochlora* spp.										1												1	P
Gomphidae	*Stylogomorphus* spp.							1															1	P
Oligochaeta																								
Enchytraeidae	Enchytraeidae						5																10	CG
Lumbricidae	*Eiseniella tetraedra*																			2			5	CG
Lumbricidae	Lumbricidae							1															10	CG
Lumbriculidae	Lumbriculidae																					3	8	CG
Oligochaeta	Oligochaeta			1	1	4		10		5			8	4	1	2	9	7	2	16	7		8	CG
Tubificidae	*Limnodrilus* spp.						3																10	CG
Platyhelminthes																								
Platyhelminthes	Platyhelminthes						1																6	CG
Plecoptera																								
Leuctridae	*Leuctra* spp.				1		1				1												0	SH
Nemouridae	*Amphinemura* spp.				2					8													3	SH
Nemouridae	Nemouridae				2																		2	SH
Nemouridae	*Soyedina* spp.						2																2	CG
Perlidae	*Perlinella* spp.							2															2	P
Perlodidae	*Isoperla* spp.					1																	2	P
Plecoptera	Plecoptera					1																	2	-
Trichoptera																								
Brachycentridae	*Lepidostoma* spp.		9			11																	1	SH

		SR			DF			VC			ILH			PI			BH			CS			PTV	FFG
		S	F	P	S	F	P	S	F	P	S	F	P	S	F	P	S	F	P	S	F	P		
Order/Family	**Identification**																							
Hydropsychidae	*Cheumatopsyche* spp.		7	8								1	1										5	FC
Hydropsychidae	*Diplectrona* spp.										1												0	FC
Hydropsychidae	*Hydropsyche* spp.		1																				4	FC
Hydropsychidae	Hydropsychidae	7																					4	FC
Hydropsychidae	*Parapsyche* spp.				5	6																	0	FC
Lepidostomatidae	*Lepidostoma* spp.			4	1		23																1	SH
Limnephilidae	*Pycnopsyche* spp.			3																			4	SH
Molannidae	*Molanna* spp.							4		1													6	SC
Phrygaenida	*Agrypnia* spp.																	1					7	SH
Polycentropodidae	*Polycentropus* spp.											1	6										8	FC, P
Rhyacophilidae	*Rhyacophila* spp.				2					5													1	P
Rhyacophilidae	Rhyacophilidae						11																0	P
Uenoidae	*Neophylax* spp.			1						4													3	SC
Tricladida																								
Planariidae	Planariidae																			5			4	CG

Appendix F. List of Acronyms and Abbreviations.

(AA) Assessment Areas
(ACS) Area Constrained Survey
(ADR) Automatic Data Recorder
(AGWQMN) Ambient Groundwater Quality Monitoring Network
(BFBM) Bureau of Freshwater and Biological Monitoring
(BH) Blue Hole
(CCA) Canonical Correspondence Analysis
(CFDA) Catalog of Federal Domestic Assistance
(cfs) Cubic Feet Per Second
(CPOM) Coarse Particulate Organic Matter
(CS) Crystal Spring
(DO) Dissolved Oxygen
(DF) Dingman's Ferry
(EcoObs) (ecological observation) database
(EIA) Ecological Integrity Assessment
(ESRI) Environmental Systems Research Institute
(FFG) Functional Feeding Groups
(EPT) Ephemeroptera, Plecoptera and Tricoptera
(FQA) Floristic Quality Assessment
(GIS) Geographic Information System
(gpm) Gallons Per Minute
(GPS) Global Positioning System
(HBI) Hielsenhoff Biotic Index
(HGM) Hydrogeomorphic Classification
(HIBI) Headwaters Index of Biotic Integrity
(HSI) Human Stressor Index
(IL) Indian Lady Hill
(KCl) Potassium Chloride
(LUI) Land Use Index
(MPTV) Mean Pollution Tolerance Values
(MTBE) Methyl tert-butyl ether
(ND) Non-Detect
(NTU) Nephelometric Turbidity Units
(N.J.A.C.) New Jersey Administrative Code
(NJDEP) New Jersey Department of Environmental Protection
(NJWET) = New Jersey Wetland Condition Assessment Site code (# or Symbols identify which site)
(NJGWS) The New Jersey Geological & Water Survey
(NYSDEC) New York State Department of Environmental Conservation
(NWI) National Wetlands Inventory
(ONLM) Office of Natural Lands Management
(PI) Paint Island

(PPM) Parts Per Million
(PTV) Pollution Tolerance Values
(SR) Shurts Road
(SWIB) Shannon Wiener Index of Biodiversity
(TDS) Total Dissolved Solids
(USB) Universal Serial Bus
(USEPA) United States Environmental Protection Agency
(USNVC) U.S. National Vegetation Classification
(VC) Valley Crest
(VOCs) Volatile Organic Compounds
(mg/L) Milligrams per Liter
(µg/L) Micrograms per Liter