HOPEWELL FURNACE NATIONAL HISTORIC SITE WATER QUALITY SURVEY

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and

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Introduction

Hopewell Furnace National Historic Site (NHS) is located in a valley in southeastern Pennsylvania, near the headwaters of French Creek. The pastoral environment of the reconstructed iron furnace belies its past, as Hopewell Furnace was, from its construction in 1771 to its demise in 1883, a highly productive source of cast-iron goods and unrefined "pig" iron. Located at the border of Berks and Chester counties, about fifty miles northwest of Philadelphia, Hopewell Furnace NHS lies in the heart of a region that is steeped in early American history.

The U.S. Government acquired the land surrounding Hopewell Furnace in 1935, and Hopewell Furnace NHS was created there on August 3, 1938. The locale was selected for restoration and preservation because it serves as an excellent representative of "iron plantations" which dotted the Pennsylvanian landscape during the eighteenth and nineteenth centuries. Regional availability of resources was a crucial consideration when choosing furnace locations during that era. Important resources included extensive stands of hardwoods for charcoal production, mineable outcrops of iron-rich rock, and substantial flowing water in the furnace's vicinity. Water was diverted from a stream channel or lake to the furnace's waterwheel, which powered "blast machinery" that fanned the flames within the furnace.

Supplies of water were not always adequate to power the waterwheel at Hopewell Furnace NHS. Two headraces were used to divert water from three streams on the plantation grounds. The East Headrace captured water from Spout and Baptism Creeks, and the West Headrace drained water from the furnace pond, now overlain by Hopewell Lake. Water supplies were also utilized for domestic needs, livestock consumption, irrigation, and refrigeration, since a population of ironworkers and their families inhabited the plantation. Perennial springs located

on a hillside near the furnace likely furnished cool drinking water that was a necessity in the sweltering confines of the ironworks.

Production at Hopewell Furnace NHS was also facilitated by the presence of raw materials. Extensive shallow deposits of magnetite-rich rock were located nearby, providing easily accessed iron ore for the smelting process. The forestland in the area held large stands of chestnut and black oak trees used in the production of charcoal. A constant quantity of charcoal was required to maintain sufficiently high furnace temperatures. The availability of these materials permitted the remarkable output of Hopewell Furnace NHS during the height of its productivity.

Anthropogenic stresses have begun to tax the quality of the natural resources of Hopewell Furnace NHS. Water resources at Hopewell Furnace NHS have been disturbed or threatened by a variety of activities such as upstream development, turbidity during high flows and contamination from leaky septic systems. This report has been developed as a continuation of a previous management plan that identified these activities and estimated the stresses inflicted upon Hopewell Furnace NHS's water resources. Water quality parameters reported in Sharpe and Neff (1993) will be compared to similar data from the year 2002.

Study Objectives

The purpose of this investigation was to sample the sites previously sampled in the Hopewell Furnace NHS Water Resources Plan (Sharpe and Neff 1993) for the same water quality parameters to allow for comparisons in assessments of water quality changes through time. This was accomplished with the following objectives:

1) water quality samples were collected at six sites twice throughout 2002 (once at low flow and once at high flow conditions and handled and analyzed according to USEPA and Standard Methods,
2) water quality inventory data were organized and reported in spreadsheet format,
3) water quality parameters and analyses were defined and recorded,
4) water sampling locations were described and documented,
5) project background information, including project goals and objectives and contact information for those involved with the project were recorded, and
6) a report was prepared containing a description of site history, sampling efforts, goals, objectives, a map of sampled sites, tables depicting results of the analyses and a comparison of results to past results and water quality standards to highlight any specific problems.

Land Use and Planning Relationships

Hopewell Furnace NHS has an area of 848.06 contiguous acres, with no inholdings (Figure 1). It is divided between two townships, Union and Warwick, which lie within Berks and Chester counties, Pennsylvania, respectively. Approximately two-thirds of Hopewell Furnace NHS is bordered by French Creek State Park, a park of primarily recreational value, which receives substantial summer tourism. Agricultural lands and low-density residential development border the remaining one-third.

The privately owned lands adjacent to Hopewell Furnace NHS are situated entirely within Warwick Township. In the late 1970's, Warwick residents assumed an anticipatory stance regarding developmental pressures creeping into the township along its major byways. Consultation with a land use planning specialist resulted in a set of long-range goals for growth control in the township. These goals included preservation of historic character, conservation of agricultural lands, protection of environmentally sensitive areas, and provision of orderly development. Although the lands south of Hopewell Furnace NHS are still at risk of piecemeal, high-density development, citizen activism has reduced the risk to a minimum.

French Creek State Park contains nearly all the French Creek Basin upstream of Hopewell Furnace NHS, and therefore is the source of much of the streamwater found in French Creek within NPS boundaries. Because of this relationship, the land use activities in the state park warrant as much attention as those occurring in Hopewell Furnace NHS itself. Since Hopewell Lake, the source of French Creek, is located in French Creek State Park, all activities which affect the lake's water quality or quantity will also impact French Creek. These conditions emphasize the need for cooperative management of water resources by Hopewell

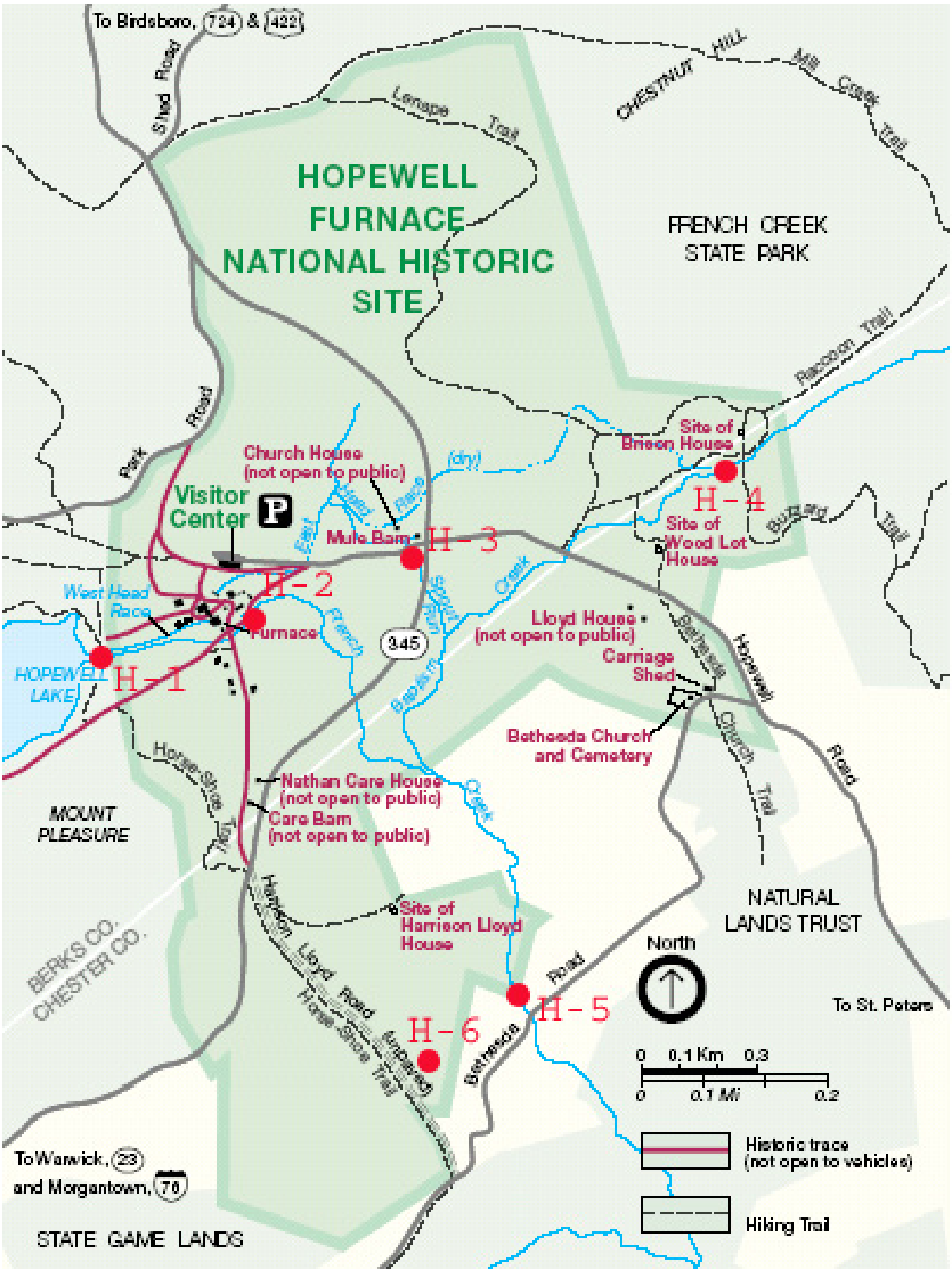

Figure 1. Hopewell Furnace National Historic Site (general map)

Furnace NHS and French Creek State Park in the uppermost portion of the French Creek Basin (Figure 2).

A housing development upstream of Hopewell Furnace NHS is a potential threat to the quality of the park's water resources. Problems with erosion, sedimentation, and bacterial contamination can develop rapidly from poorly managed construction sites and septic systems. Impacts have been documented in communities near Hopewell Furnace NHS ("Housing plan worries park leaders," Pottstown Mercury, May 31, 1989).

Sedimentation is not the greatest hazard to Hopewell Furnace NHS, as there are two impoundments along Scott's Run and French Creek between NPS parklands and the development site. These lakes act as settling ponds, removing suspended sediments from the stream before it passes into Hopewell Furnace NHS. However, excessive turbidity, especially during high flows, could still be a problem.

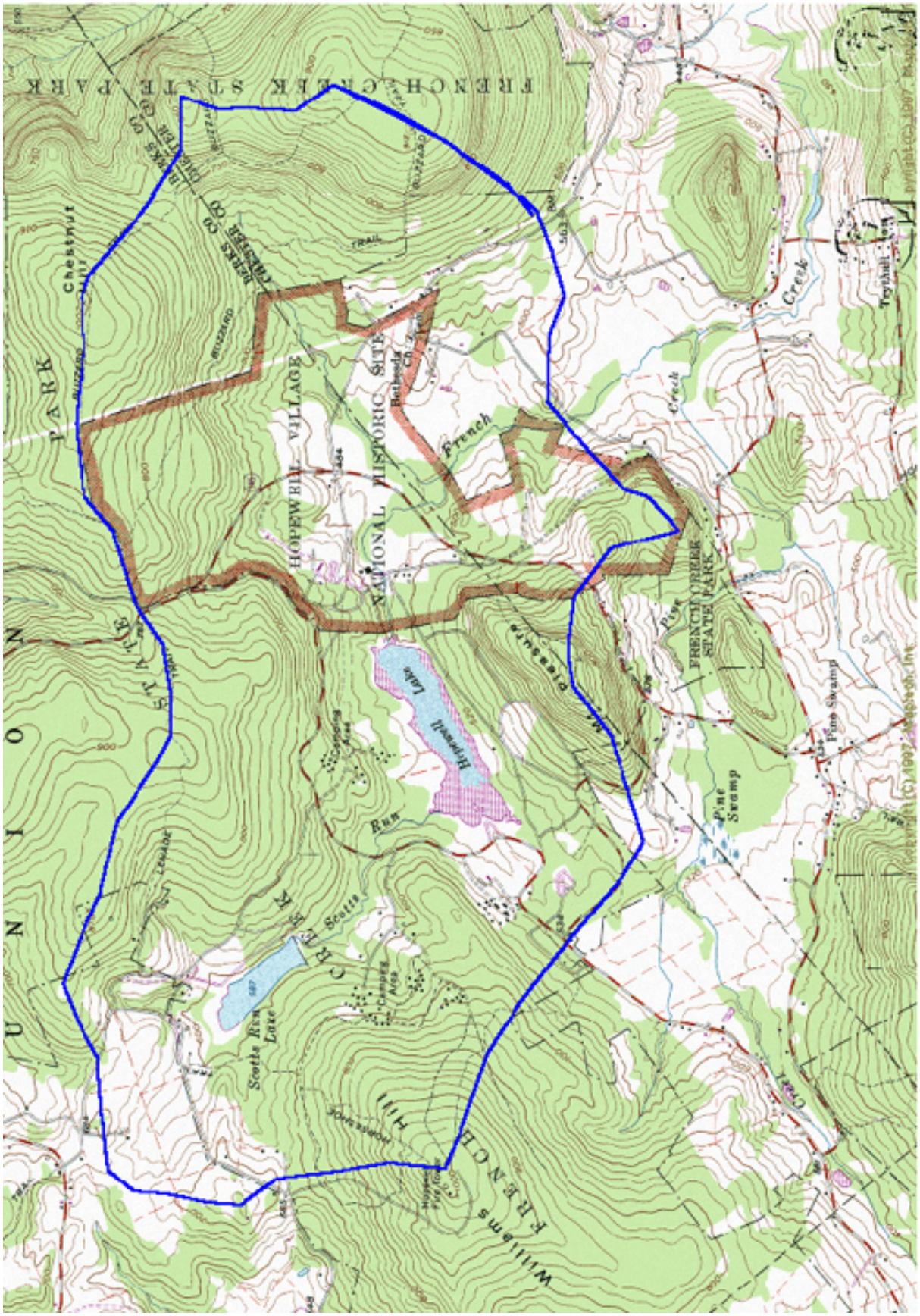

Figure 2. Hydrologic boundaries for the Upper French Creek Watershed.

Site Description

Management of the 848 acres of land at Hopewell Furnace NHS is explicitly described in the historic site's Resource Management Guide (USNPS Hopewell Furnace Resource Management Objectives 2003). The parkland is divided into three zones, which are differentiated by their designated uses:

1) Eastern deciduous forest – 635 acres of the park area, managed for conservation of woodlands, recreation and scientific study.
2) Agricultural uses in twelve fields – 135 acres of the park area.
3) Historic and developed areas – 78 acres of the park area.

Forested lands are much more extensive presently than during the period of industrial activity, when most of the land surrounding the furnace proper was logged and cultivated.

Two issues concerning pre-existing land use conditions at Hopewell Furnace NHS can be raised as well. Cattle and sheep, which graze on Hopewell Furnace NHS lands, have access to French Creek, and runoff from the stockyard drains into the waterwheel tailrace, which in turn empties into French Creek. Previous water analysis found high concentrations of fecal streptococcus and coliform bacteria in French Creek (Sharpe and Neff 1993). Risks involving dissolved oxygen depletion, increased eutrophication, and excessive turbidity also remain. However, these problems are not serious enough to warrant compromising the historical integrity of Hopewell Furnace NHS by corrective action.

The NPS and the Civilian Conservation Corps created at least one landfill of unknown content near the southern boundary of Hopewell Furnace NHS. Its approximate location is known (H-6 in Figure 1), and levels of NO_3-N and SO_4 were found to be relatively elevated when it was sampled in 1992 (Sharpe and Neff 1993).

Presently, the West Headrace, waterwheel, East Headrace and tailrace are the only man-made hydrologic structures within Hopewell Furnace NHS. Water is carried to the waterwheel from Hopewell Lake in normal conditions by the West Headrace. If the water level of the lake drops substantially, the headrace is cut off, and water must be channeled from other sources to keep the wheel turning. This has been a significant issue during past drawdowns of Hopewell Lake.

Reconstruction of Hopewell Furnace's East Headrace to increase the historical accuracy of Hopewell Furnace NHS's appearance was considered a few years back, but renovation of the canal to operational capacity has not been completed.

The headwaters of the French Creek watershed flow from springs in the Piedmont hills of southeastern Pennsylvania. Prominent topographic highs in the Hopewell Furnace NHS vicinity include Williams Hill, Brush Hill, Chestnut Hill, and Mt. Pleasure. These hills rise approximately 800-1000 feet above mean sea level, and 400 feet above French Creek as it flows through the core historic district (Figure 2).

French Creek State Park surrounds Hopewell Furnace NHS on three sides with forestland, and to the south, Hopewell Furnace NHS is bounded by small-scale agriculture, low-density residential development, and state game lands. The two parks located at the head of the French Creek watershed allow much of the basin to remain forested, in contrast to lands outside the parks which are developed for agricultural, residential and commercial uses.

French Creek Basin has a climate typical of Mid-Atlantic lowlands, with warm humid summers and winters that are usually wet and mild. Mean summer temperature is 79°F, while mean winter temperature is about 32°F. Mean annual precipitation is 42-44 inches, with

approximately 25 inches falling during the frost-free season, a time period which averages about 188 days per year (PaDER 1984).

Most of Hopewell Furnace NHS is situated on the border of extensive Triassic Basin "redbeds," which are composed of sandstones and conglomerates (Figure 3). These rocks were deposited during a long period of erosional activity, when large quantities of sediments were produced, transported into lowland basins, and lithified. The resultant sedimentary rocks, known as the Hammer Creek and Stockton Formations, contain significant volumes of stored water, and are considered to be sources of high quality groundwater in southeastern Pennsylvania. The Stockton Formation underlies and is recharged through the valley floor in the upper reaches of French Creek Basin. Bedding dips north-northwest in the Hopewell Furnace NHS region at angles of 5 to 25 degrees. The middle member of the Stockton, a moderately-sorted, poorly cemented, arkosic sandstone, typically has the best hydrologic qualities for well production. The water supply wells presently in use at Hopewell Furnace NHS were drilled in the Stockton Formation, and probably pump mainly from the middle member. Lateral changes in the texture and porosity of the sandstones and conglomerates cause site-specific variations in well yields.

The Stockton Formation is conformably overlain by the Hammer Creek Formation, which is locally represented by a lobate fanglomerate. This quartz-pebble conglomerate is very resistant to erosion, and forms the hills north and east of the park's historic zone. The formation has good storage capacity and yields groundwater, which generally exceeds potability requirements. The dip of the Hammer Creek Formation precludes its utilization within Hopewell Furnace NHS park boundaries, since wells need to be placed downdip, or north, of recharging outcrops, and the Hammer Creek outcrops in the northernmost portion of the park (Wood 1980). Diabase rocks in the Hopewell Furnace NHS vicinity were emplaced prior to and during

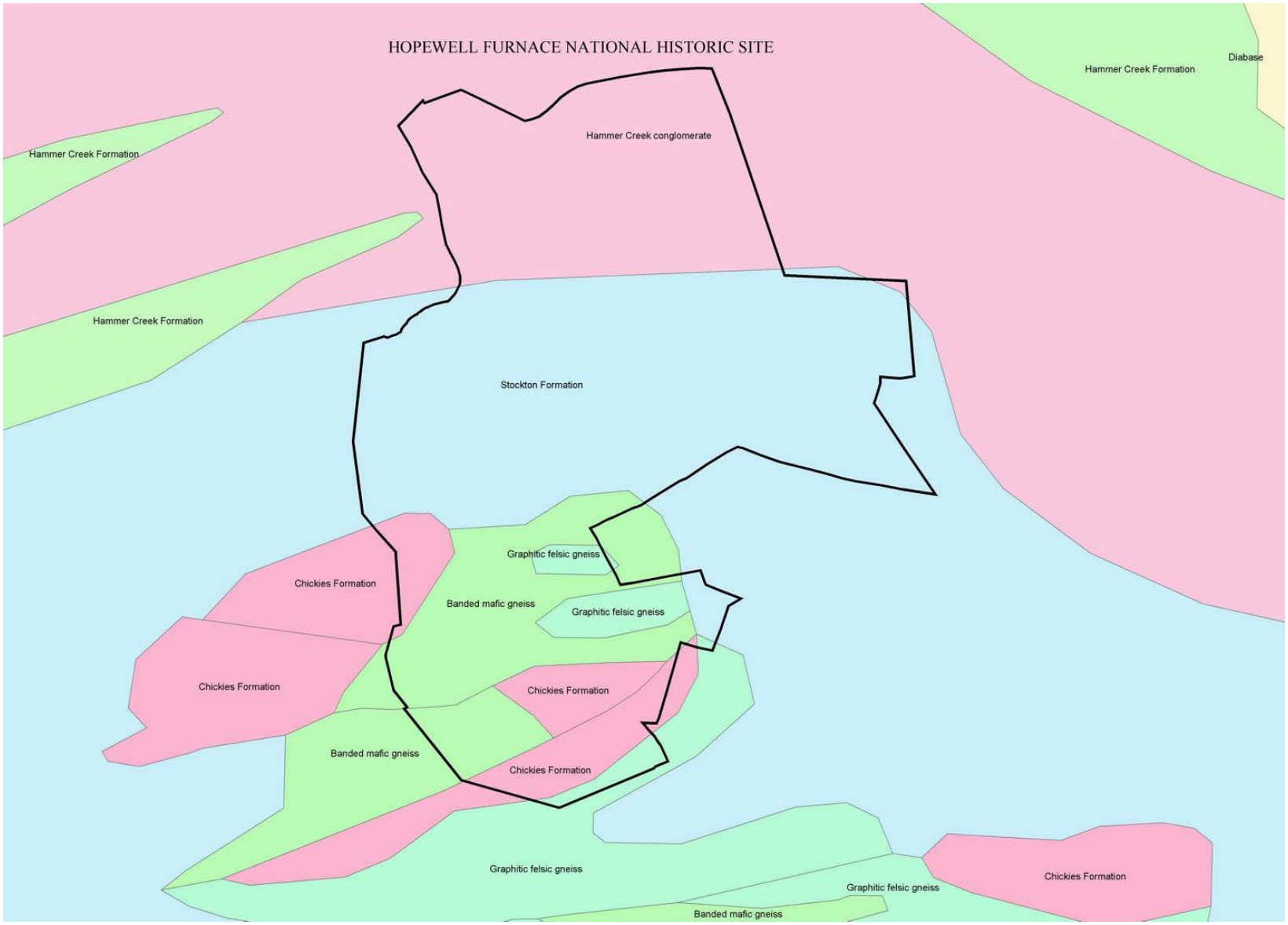

Figure 3. Geologic map of Hopewell Furnace NHS area

deposition of the Triassic sediments. These rocks are associated with the Morgantown Pluton, a large body of molten rock that was emplaced and cooled at a depth of several thousand feet. Subsequent periods of intense erosion have dissolved overlying rocks and sediments, exposing the igneous rock and related metamorphics. Magnetite-rich rocks deposited in association with the pluton provided iron ore for the operation of Hopewell Furnace. These dikes and sills of impermeable igneous rock act as groundwater flow boundaries. Such boundaries impede groundwater flow, increasing residence time and concurrent mineralization.

A tentative but interesting correlation can be discerned when surface water concentrations of sulfate, chloride, and silica are compared over time at the USGS monitoring station at Trythall. Temporal plots of these solutes indicated large fluctuations in concentrations between 1975-1977 and 1981-1982 (USGS 1992). The increased dissolved silica concentrations suggest a volumetric increase in groundwater baseflow as a fraction of total streamflow during these time periods. The fact that dissolved sulfate and chloride variations correlate with fluctuations in dissolved silica concentrations suggest two conditions. First, like most stream systems, French Creek stream chemistry is substantially altered when baseflow dominates total streamflow. Second, impermeable diabase formations in the area create stagnant groundwater zones in which sulfate and chloride concentrations are intensified.

The water table in the Hopewell Furnace NHS region is generally considered to be a subdued replica of surface topography (Rima et al. 1962). Springs are usually small, emitting from the lower flanks of hills. Water levels vary seasonally, with a decline beginning in March or April, and continuing until late autumn, when increased precipitation replenishes subsurface water storage.

At least seventeen different soil types have been identified with the Hopewell Furnace NHS boundaries (U.S.D.A. Soil Conservation Service 1967). All the soils are listed in order of prevalence, and the most common types are briefly described.

Lewisberry Series – Deep, well drained, very stony, sandy loam; typical in forested areas.

Bowmansville Series – Poorly drained silt loam formed in alluvial sediments; often utilized for pasture.

Klinesville Series – Shallow, well-drained, shaly silt loam; erosional hazard limits farm use.

Croton Series – Deep, poorly drained silt loams; found in nearly level areas, depressions, and drainageways.

Penn Series – Moderately deep, well-drained, shaly silt loam; moderate erosion hazard.

Lamington Series – Deep, poorly drained, reddish silt loam; commonly located on stream channel terraces, fragipan subsoil.

Others – Readington Series, Glenville Series, Chester Series, Edgemont and DeKalb Series, Glenville Series, and “made” (excavated or disturbed) lands.

French Creek, the primary flowing surface water in Hopewell Furnace NHS, is a tributary of the Schulykill River. It reaches 21.9 miles southeast from headwaters to mouth, and drains a surface area of 70.2 square miles. In the proximity of Hopewell Furnace NHS, French Creek has relatively shallow banks, and is enclosed by moderately steep hillsides. Channel slope averages 20.7 ft./mile, and the stream maintains an irregular, dendritic drainage pattern in its upper reaches. French Creek shows little seasonal deviation in its hydrologic response to storm events, which is typical of rural watersheds. The degree of response is determined by the size of the precipitate event and the level of groundwater storage in the watershed prior to precipitation (PA DER 1984).

French Creek receives significant quantities of flow from two creeks within Hopewell Furnace NHS (Figure 1). Spout Creek, a spring-fed stream three-quarters of a mile in length, flows southeast from hills above the Hopewell Furnace NHS historic zone. Stream channel width increases from two feet to four feet along its reach, and the entire stream is densely shaded. Water flows at a moderate velocity over a rocky streambed, where small pools and shelters are common. Flows in Spout Creek are moderately affected by dry weather periods. Baptism Creek is a tributary of French Creek, and is approximately two and a half miles in length. It is fed by springs, and also by Spout Creek at a confluence just southeast of the intersection of Hopewell Road and Route 345. The stream is characteristically similar to Spout Creek, with a slightly wider and deeper stream channel, and a marginally greater flow. Baptism Creek flows into Hopewell Furnace NHS from an east-northeasterly direction, crosses the eastern half of the park, and empties into French Creek near the Chester County line in the southern portion of Hopewell Furnace NHS. Areas of poorly drained, seepy land along the banks of French Creek to the southeast of the historic zone constitute wetlands within Hopewell Furnace NHS. Several small, unnamed, spring-fed streams drain these wetlands and enter French Creek in the woodlands near the southern boundary of the park.

Two impoundments are positioned between the upper limits of French Creek watershed and the upstream boundary of Hopewell Furnace NHS, both resulting from constructed earthen dams. The smaller of the two is Scott's Run Lake; the larger is Hopewell Lake (Figure 2). Both of these dams are within French Creek State Park and are under regulation of the Federal Dam Safety Act. Scott's Run Lake rests high in the watershed, and is replenished by small streams which are entirely spring-fed.

Hopewell Lake is the primary source of water for French Creek within Hopewell Furnace NHS, hence it deserves attention when evaluating surface water resources within the park. The lake is located wholly within French Creek State Park, although its outflow is less than 100 feet from the western border of Hopewell Furnace NHS. Water is also diverted from Hopewell Lake through a headrace, which flows over a waterwheel in the central furnace works. Surface area draining into Hopewell Lake is 2.7 square miles in extent, and the outflow of Scott's Run Lake, known as Scott's Run, is the primary feeder stream, flowing several hundred yards downgradient from the northwest. Diffuse overland flow also occurs from Pine Swamp, located to the west. Hopewell Lake at normal level has a surface area of 68 acres, a volume of 537 acre-feet, a shoreline length of 2.1 miles, and an altitude of 505 feet (above MSL). Its mean depth is 7.9 feet, maximum depth is 18 feet, and mean flow-through time is 89 days at 3 cubic feet/second (PaDER 1978).

Very little documentation exists for water quantity in the uppermost section of the French Creek Basin. Three measurements of flow at Hopewell Dam during the late summer of 1951 averaged about one cubic foot/second (PaDER 1984). This is the only data available for the quantity of French Creek water at its source. Flow measurements were obtained for this report at five sites throughout Hopewell Furnace NHS (H-1, H-2, H-3, H-4 and H-5) on March 26, 2002 and November 6, 2002 (Figure 1). These measurements are discussed in the results section.

Various activities in French Creek State Park pertaining to Hopewell Lake have led to five major drawdown events since the lake has been under state supervision. The effects of the drawdowns on the discharge from Hopewell Lake remain undocumented, although a lake water level drop of six feet or more will cut off water supply to the West Headrace, which feeds water to the waterwheel on the reconstructed furnaceworks. Reconstruction of the Hopewell Dam

spillway by the Pennsylvania Department of Environmental Protection required a large lake level drawdown in 1992-93. The West Headrace was consequently cut off and Hopewell Furnace NHS was forced to pump water to supply the headrace.

Physical data obtained from field measurements indicates that Hopewell Lake has good water quality and is thermally and chemically stratified for much of the year (PaDER 1978). A thermocline was well developed during July of 1973 and August of 1984, suggesting that such conditions are normal for Hopewell Lake. Both temperature and dissolved oxygen levels drop significantly beneath the upper thermocline (PaDER 1978). Dissolved oxygen is totally depleted below a depth of 13 feet (PaDER 1978). The lake water also becomes more acidic and increasingly laden with metallic constituents at depth (PaDER 1978). High trace concentrations of iron (100 micrograms/liter) can be attributed to the bedrock in the lakebed (PaDER). Under normal conditions, water chemistry at the outflow of Hopewell Lake retains the characteristics of near-surface lakewater. Since Hopewell Lake is stratified for much of the year, this water will have an eplimnionic chemistry, which is low in dissolved solids and high in dissolved oxygen (PA Fish and Boat Commission 1977). However, during drawdown conditions, periods of low flow, or drought, water is drawn from near the bottom of the lake. Discharge into French Creek will have hypolimnionic chemistry of the deeper lake water, with higher acidity, higher dissolved solids, and less dissolved oxygen. This condition is qualitatively poor for the maintenance of aquatic biota in French Creek.

Detailed water quality data for French Creek in the vicinity of Hopewell Furnace NHS is limited. On August 14, 1986, samples of French Creek water at Hopewell Furnace NHS were collected and analyzed for fecal streptococcus and fecal coliform bacteria (UPRPS 1987). One sample, from Spout Creek, contained high bacterial concentrations. Again in 1992 and 1993,

water samples were analyzed for total coliform, fecal coliform and fecal streptococcus (Sharpe and Neff 1993). Elevated levels were noted at sites H-1 (downstream of Hopewell Lake) and H-2 (downstream of tailrace and French Creek confluence) on November 13, 1992 and H-5 (intersection of downstream Hopewell Furnace NHS boundary and French Creek) on March 23, 1993 (Figure 1). Some isolated chemical data from water samples taken at a French Creek sampling station about one mile downstream from Hopewell Furnace NHS (USGS 1992) were observed to determine any trends in water quality. Tributaries entering French Creek between its outflow from Hopewell Furnace NHS and the aforementioned downstream sampling station probably contributed chemical components to the tested streamwater as well. These conditions make substantive interpretations of the data impossible.

Iron staining found in 1992-93 on rocks at the outflow of Hopewell Dam suggests that dissolved and suspended iron was being transported downstream into French Creek from Hopewell Lake. Excessive turbidity and an orange discoloration was found in the water of Hopewell Lake and French Creek below the dam outflow, and some discoloration was apparent in the stream channel passing through the Hopewell Furnace NHS historic zone. This was a visual degradation of French Creek water, and probably stressed the aquatic ecosystem as well. Extensive iron oxidation may result from the drawdown of lake water levels, and the consequential exposure of iron-rich sandstone bedrock to oxidizing conditions. Since these rocks are normally submerged in deep lakewater with lower dissolved oxygen concentrations, exposure to oxygen-rich waters near the surface, or to atmospheric conditions, many cause an increase in the oxidation of iron minerals. Concentrations of dissolved and suspended iron in French Creek stream water are presently unknown. However, the visual characteristics of water flowing through Hopewell Furnace NHS have suggested at times that the effects of Hopewell

Lake drawdowns are significant, and there have already been five major drawdowns. The effects of repeated drawdowns of Hopewell Lake water level need to be examined, since ecological stresses of this sort can be very damaging to the aquatic biota.

Acidic precipitation has been recorded at sites near Hopewell Furnace NHS (Lynch et al. 1990). The mean annual pH of wet deposition in this area was about 4.2 (Lynch et al. 1990), but has since improved slightly (Lynch et al. 2000). It is most likely that this acidity was a result of anthropogenic influences on the atmosphere, in the form of industrial and automotive emissions. All agencies responsible for the management of natural resources in southeastern PA should be aware of the deleterious ecological effects of acidified precipitation, and should be attentive to any indication that such conditions exist.

French Creek supports a diverse aquatic ecosystem, indicating relatively high water quality. Scotts Run Lake, which connects to Hopewell Lake and eventually drains into the French Creek is stocked with rainbow and brown trout (*Oncorhynchus mykiss* and *Salmo trutta*, respectively) by the Pennsylvania Fish and Boat Commission. Two creeks at Hopewell Furnace NHS, which flow into French Creek, were stocked with brook trout (*Salvelinus fontinalis*): Baptism Creek, once a year from 1949-1951 and Spout Creek, once a year from 1950-1951.

Many other varieties of fish have been recorded to thrive in the waters of Hopewell Furnace NHS. These include minnows, dace, pickerel, sunfish, shiners, darters, eel and catfish (Sharpe and Keener 2003). Creek chub (*Semotilus atromaculatus*), white suckers (*Catostomus commersoni*), and fallfish (*Semotilus corporalis*) are also found in Hopewell Furnace NHS stream water, as well as brook trout and largemouth bass (*Micropterus salmoides*) (Table 1) (Sharpe and Keener 2003).

Table 1. Number of fish by species in 90-meter fish survey sections, Hopewell Furnace NHS August 21, 2002 (Sharpe and Keener 2003).

Common Name	Scientific Name	Spout Creek	Baptism Creek	French Creek
American eel	*Anguilla rostrata*			1
White sucker	*Catostomus commersoni*			12
Rosyside dace	*Clinostomus funduloides*		42	
Chain pickerel	*Esox niger*			3
Tesselated darter	*Etheostoma olmstedi*			8
Cutlips minnow	*Exoglossum maxillingua*			10
Yellow gullhead	*Ictalurus natalis*			8
Bluegill	*Lepomis macrochirus*			6
Largemouth bass	*Micropterus salmoides*			1
Margined madtom	*Noturus insignis*			10
Blacknose dace	*Rhinichthys atratulus*	105	104	26
Blacknose dace	*Rhinichthys atratulus* YOY*	17	10	
Brook trout	*Salvelinus fontinalis*	2	5	
Creek chub	*Semotilus atromaculatus*		74	11
Creek chub	*Semotilus atromaculatus* YOY		5	
Fallfish	*Semotilus corporalis*			62
	Total	124	240	158

* YOY is an abbreviation for young of year

A large variety of aquatic invertebrates provide a prey base for the numerous vertebrates in French Creek. These include the larvae of several types of flies, including mayflies (*Ephemeroptera*), caddisflies (*Trichoptera*), stoneflies (*Plecoptera*) and dragonflies (*Odonata*). There are an abundance of beetles from the Dryopidae, Dytiscidae, Elmidae, Gyrinidae, and Psephenidae families. Other types of organisms found in the waters of French Creek at Hopewell Furnace NHS are water striders (*Hemiptera*), planaria (Planariidae), gastropods (*Gastropoda*), freshwater clams (*Pelecypoda*), aquatic worms (*Annelida)* and freshwater nymphs (*Polymictarcidae*) (USGS 2003; PA Fish and Boat Commission 1977). No federal or state

threatened or endangered biota are known to exist in the aquatic ecosystem at Hopewell Furnace NHS.

Legislative and Planning Relationships

The following state and federal statutes have regulatory significance regarding Hopewell Furnace NHS water resources. A description of the primary tenets of each statute is provided.

Water Quality Act (1965)

The original legislation was amended significantly by the Water Quality Control Act Amendments of 1972, the Clean Water Act of 1977, and again in 1987. This legislation's anti-degradation provisions provide a statutory cornerstone for the protection of water quality throughout the NPS system. At the same time, the 1965 Act and subsequent amendments require that NPS managers comply with state implementing statutes for effluent limitations, federal development projects, wetland provisions (Sec. 404), and state established water quality criteria. Any NPS facility that discharges pollutants is subject to state effluent permit requirements (NPDES). The NPS facility is treated under law in the same manner as any private entity, and is subject to the same sanctions provided in the law to any entity. All federal development projects, which would include construction projects in the NPS system, must be reviewed to insure compliance with state nonpoint pollution guidelines.

Section 404 of the Water Quality Control Act Amendments of 1972 covers the dredging and filling of wetlands. Again, state laws apply and NPS managers must conform to the permitting requirements of the state. On the other hand, NPS managers may comment on the issuance of 404 permits that could have potential adverse impacts on the park. This could lead to significant permit modifications of benefit to the water resources of the park.

State water quality criteria have been established for waters falling within a particular state's jurisdiction. These criteria and associated water uses are to be protected from

degradation. All activities leading to either point or nonpoint pollution are regulated to maintain or enhance these criteria. Specific criteria for French Creek and its tributaries, portions of which flow through Hopewell Furnace NHS, are given in Table 2.

Safe Drinking Water Act (1974)

This Act protects the quality of water resources used for human consumption. Water supplies for public consumption and private use at Hopewell Furnace NHS are protected according to standards required by the Safe Drinking Water Act as delineated in NPS-83: Public Health Management Guidelines (West 1991).

Fish and Wildlife Coordination Act (1934)

This Act stipulates that "whenever the waters of any stream or other body of water are proposed or authorized to be impounded, diverted, or otherwise controlled," the acting government body must consult first with the U.S. Fish and Wildlife Service, the Department of Interior, and the State agency responsible for overseeing management of wildlife which may be impacted.

Pennsylvania Clean Streams Law

In response to the Federal Clean Water Act, the Commonwealth adopted a system of water quality standards specified in Title 25 Ch. 93 of the Pennsylvania Clean Streams Laws. This system is organized in the manner preferred by the Environmental Protection Agency, the federal agency with authority to approve state water quality standards. The "use-specific" nature of the system provides standards for a specific reach of a stream according to the pre-existing water quality and uses found in that reach. The highest designated use for French Creek is a cold water fishery. Standards listed for the stretch of French Creek between its source (Hopewell Lake) and the mouth of the South Branch, including all tributaries, are itemized in the Clean Streams Water

Quality Criteria (Table 2). The Pennsylvania Department of Environmental Protection enforces water quality standards with authorization from the Environmental Quality Board.

Table 2. Specific state water quality criteria and standards for French Creek and its tributaries (Environment Reporter 1993).

Specific Water Quality Criteria	Standards
Aluminum (Al)	Maximum 0.1 of the 96-hour LC50 for representative important species.
Alkalinity (Alk)	Minimum 20 mg/l as CaCO3, except where natural conditions are less. Where discharges are to waters with 20 mg/l or less alkalinity, the discharge should not further reduce the alkalinity of the receiving waters.
Ammonia Nitrogen (Am)	The maximum shall not exceed the numerical value given by: un-ionized ammonia nitrogen (NH3-N) x (log-1 [pKt-pH] + 1). The average over any 30 consecutive days shall be less than or equal to the numerical value given by: un-ionized ammonia nitrogen (NH3-N) x (log-1 [pKt-pH] + 1).
Bacteria (Bac 1)	During the swimming season (May 1-Sept. 30) the max. fecal coliform level shall be a geometric mean of 200 per 100 ml based on five consecutive samples each sample collected on different days; for the remainder of the year the maximum shall be a geometric mean of 2000 per 100 ml based on five consecutive samples on different days.
Bacteria (Total Coliform)	The maximum shall not exceed 5000 per 100 ml as an average. There can be no more than this number in more than 20 samples during the month nor more than 20,000 per 100 ml in more than 5% of samples.
Fluoride (F1 and F2)	Daily average 2.0 mg/l. Four-day average 0.01 of the 96 hour LC50; one-hour average 0.05 of the 96 hour LC50 for representative important species.
Iron (Fe)	Daily average 1.5 mg/l as total iron; maximum 0.3 mg/l as dissolved iron.
Manganese (Mn)	Maximum 1.0 mg/l.
Nitrite + Nitrate (N)	Maximum 10 mg/l as nitrogen.
Osmotic Pressure (OP)	Maximum 50 milliosmoles per Kg.
pH (pH1)	From 6.0 to 9.0 inclusive.
Phenolics (Phen1 or Phen3)	Maximum 0.0005 mg/l, or four-day average 0.02 mg/l; 1-hour average 0.1 mg/l.
Total Dissolved Solids (TDS1)	500 mg/l as a month average value; maximum 750 mg/l.

Water Resource Management Objectives

With mandate from the Historic Sites Act of 1935, an Executive Order (3FR 2039) was given, which transferred several hundred acres of land in Berks and Chester counties to the Federal Government, thereby establishing the heart of what is now Hopewell Furnace NHS. The intention of this order was "to preserve for public use historic sites, buildings and objects of national significance for the inspiration and benefit of the people of the United States." The Statement for Management (Hopewell Furnace Resource Management Objectives, 2003) for Hopewell Furnace NHS includes the following objectives:

1. To preserve and protect artifacts, documents, historic objects, man-made structures and the landscape features significant to the ironmaking operation and the Hopewell Furnace NHS Community.
2. Preserve the rural landscape around the park to reflect the historic setting of the furnace community.
3. Preserve the rural approach to the park to place the Hopewell Furnace NHS story in a rural context for the visitor.
4. Preserve and protect significant resources related to the ironmaking community.
5. Present a more complete representation of Hopewell Furnace NHS's rural-industrial landscape of the 19th century through interpretation and resource management.
6. To manage natural resources to support cultural values while protecting and preserving natural resources in accordance with legislation and policy; and to provide leadership in the conservation of natural resources contributing to park values.

These objectives are all similar in that they require the preservation of the historic site in keeping with conditions present during peak historical activity.

In order to provide the highest quality experience for visitors at Hopewell Furnace NHS, a balance must be sought with regard to historical and ecological preservation. Present conditions of the Hopewell Furnace NHS parklands are quite different from those prevalent in the mid-nineteenth century. Impact caused by the colonial inhabitants and rudimentary industrial processes were undoubtedly significant. In the twenty-first century, a new set of environmental stresses has evolved. Effort must be made to promote a park experience which is historically accurate, but water quality standards must also be maintained. Restoration of the ironwork's water supply system has progressed since the park's inception, and more reconstruction is expected in the future. Restoration fulfills one of the most important objectives of this historic site. Nevertheless, proposed restoration activities must be consistent with current water quality standards.

Specific water resource management objectives for the Hopewell Furnace NHS are (Hopewell Furnace 2004):

- To protect the natural processes of the water cycle from disturbance and thus preserve the diverse ecological systems dependent on natural water levels, flows and quality.
- To maintain or restore the quality of water resources of Hopewell Furnace NHS and an understanding of current and potential human impacts upon these resources.
- To contribute to the scientific base for water resources management and perform and/or coordinate water resources research.
- To promote public awareness of the water resources of Hopewell Furnace NHS and an understanding of current and potential human impacts upon these resources.

- To promote water conservation through direct NPS action and through cooperation with local communities and regional, state and federal agencies.
- To provide for visitor safety by evaluating the quality of water resources at Hopewell Furnace NHS and insuring that appropriate health based standards are met.

Water Resource Issues

The issues listed below are prioritized in accordance with NPS management objectives (USNPS 1992). It is important to note that other significant issues may exist, and could be substantiated by a consistent water-monitoring program. However, the content of this survey provides a continuation point for water resource evaluation in the park, and outlines the hydrologic relationships, which are critical to the future of all components of the hydrologic system in Hopewell Furnace NHS. More than one of these issues may be encompassed in a project statement.

1) **Sufficient water levels to maintain flow in the historic headraces and waterwheel.** Consistent water supplies must be available for operation of historical furnace structures.
2) **Stream contamination caused by upbasin development.** French Creek Wood development may threaten water quality at Hopewell Furnace NHS.
3) **High suspended iron concentrations in French Creek.** Suspended iron is probably being produced by the drawdown of Hopewell Lake, and may chemically and visually compromise water quality.
4) **Decreased infiltration and surface water contamination caused by deforestation.** Alterations in land use could result in permanent changes in the hydrologic processes and water chemistry at Hopewell Furnace NHS.
5) **Best management practices for livestock.** High bacteria concentrations measured in French Creek and Spout Creek suggest livestock-related water quality impacts.
6) **Potential degradation related to acid precipitation.** Mobilization of metal ions and depressed pH are two documented surface water quality effects of acidified rain and snowfall.

7) **Exportation of water from French Creek Basin.** Increased French Creek State Park spray field operations could cause quantitative problems at Hopewell Furnace NHS.

8) **Infiltrative loss of streamwater resulting from excessive municipal or private groundwater utilization.** Several watersheds in southeastern PA have already been impacted by deepening water tables.

9) **Seepage from landfill with Hopewell Furnace NHS.** Substances leached from landfill debris may contaminate surface water or groundwater.

10) **Wellhead protection.** All groundwater wells located within Hopewell Furnace NHS must be adequately grouted or sealed to prevent aquifer contamination.

11) **Wetlands survey and classification.** All wetlands areas within Hopewell Furnace NHS should be delineated and properly protected.

12) **East Headrace Water Division.** The flow reductions in Spout and Baptism Creeks attendant to reconstruction of the East Headrace should be evaluated.

Current Water Quality Study

Methods

Similar to samples obtained in 1992-1993 (Shaarpe and Neff 1993), water quality grab samples were obtained from six sites within the Hopewell Furnace NHS boundaries for high and low flow conditions on March 26, 2002 and November 6, 2002. These sites included: H-1 – 25 meters downstream of the old spillway at Hopewell Lake and Hopewell Furnace NHS boundary, H-2- 20 meters downstream of the tailrace and French Creek confluence, H-3 – Spout Run at the crossing point of the East Headrace, H-4 – Baptism Creek at the intersection point with the East Headrace, H-5 – the intersection of the downstream Hopewell Furnace NHS boundary and French Creek and H-6 – an intermittent stream directly below the old CCC dump site (Figure 1). Each of these samples was analyzed for pH, conductivity, nitrogen species, turbidity, sulfates, chlorine, lead, nickel, cadmium, iron, aluminum and bacterial concentrations. Organic water parameters were analyzed for site H-6. Inorganic analyses were performed at The Pennsylvania State University, Environmental Resources Consortium. Organic and bacterial analyses were performed in the lab of Todd Giddings and Associates, Inc., State College, PA 16801, and organic analyses were also conducted by Fairway Labs of Altoona, PA using EPA methods. Fewer organic analyses were determined in the March 2002 sampling because of insufficient sample volume at the H-6 location. These parameters were compared between the 1992-1993 season and the 2002 season using a Mann-Whitney non-parametric test. During 2002, dissolved oxygen concentrations (Yellow Springs Instrument Co., Model 58) and temperature (field thermometer) were measured at all sites, and stream discharge (Marsh-McBirney FloMate Current Meter) was determined at all sites but H-6 because a sufficient amount of running water was not available to sample this site on both sampling dates.

Results

Dissolved oxygen concentrations, temperature and discharge measurements for March 26, 2002 and November 6, 2002 are found in Appendix A. In the spring of 2002, water temperatures ranged from 5.3º C at site H-4 to 7º C at site H-2. In the fall of the same year, temperatures were much higher, ranging from 8.4º C at site H-3 to 9.7º C at site H-6. Dissolved oxygen levels in the spring ranged from 4 mg/l at site H-3 to 12 mg/l at site H-4. In the fall, dissolved oxygen levels represented a much closer range with the lowest being 10.5 mg/l at sites H-2 and H-5 and the highest being 11.5 mg/l at sites H-3 and H-4. A variety of discharge measurements were obtained between seasons. Discharge in the spring of 2002 ranged from 0.23 cfs at site H-3 to 2.69 cfs at site H- 5. In the fall, discharge ranged from 0.21 cfs at site H-4 to 4.97 cfs at site H-5. Discharge measurements among sites were similar for both seasons with site H-5 consistently having the greatest flow, followed by H-1 and H-2. H-3 and H-4 were anomalies in this regard; however, the differences between the measurements at these sites were minimal.

The results from the evaluation of organic compounds for 2002 are listed in Appendices B and C. For comparison, the results from evaluation of the same compounds from 1992-1993 are listed in Appendices D and E. No organic compound concentration exceeded its detection limit for either the March 26, 2002 sample or the November 6, 2002 sample.

Inorganic and biological water quality results for 2002 are listed in Appendices F and G. Most meet state water quality standards; however, there are a few parameters that exceed these standards. For comparison, the results from evaluation of the same parameters from1992-1993 are listed in Appendices H and I. It is important to note, however, that when samples are combined to determine a mean (Appendices J and K), none of the standards are exceeded. As most standards are based on several samples over a period of time, these results are more

significant than the single day samples. As discussed in Table 1, the state standard for pH is between 6 and 9. For March 27, 2002, pH at site H-1 was 5.89 and on November 6, 2002, pH at site H-4 was 5.7. On November 6, 2002, fecal coliform bacteria at site H-5 was 280/100ml. This does not exceed the state standard for when it was sampled, but does during the swimming season, when the standard is 200/100ml. Also, on November 6, 2002, again at site H-5, total coliform bacteria was 5600/100ml, exceeding the state standard of 5000/100ml.

Discussion

Temperature, dissolved oxygen and discharge were not measured in the 1992-1993 samples, so no long-term comparison of these data could be made. When comparing between seasons, it can be noted that, on average, temperature and dissolved oxygen were greater for the November 2002 samples than for the ones obtained in March 2002. This is probably due to the overall higher water levels and discharge that were observed in November as opposed to those in March. The first half of 2002 was particularly dry and at some points experienced drought. Discharge fluctuations varied by site, but were fairly consistent with regard to which sites had the highest and lowest values.

No changes in organic compound concentrations were observed between 1992-1993 and 2002. The higher concentration of 2-Chloroethylvinyl ether during 2002 was an artifact of the higher detection limit for this compound in 2002. Notably, none of the observed organic compounds from either period of study (1992-1993 and 2002) exceeded their detectable limits.

There were no significant differences for inorganic and biological analyses between 1992-1993 and 2002 (Appendices F, G, H and I). There were however, some notable differences in some analyses between the two sampling periods (Appendices J and K). Conductivity, turbidity, chlorine and total coliform concentrations were all consistently greater during 2002

compared to 1992-1993, although none of these were high enough to cause concern. It is difficult to make any conclusions about these values due to the low number of samples. However, stream flows were quite low on both 2002 sampling dates and this may have resulted in increased concentrations of some compounds. Continued monitoring of this situation would appear to be warranted.

Also, as the results portray, certain parameters at certain sites (pH at H-1 and H-4 and total and fecal coliform at H-5) during the 2002 sampling season exceeded their standards on at least one sampling occasion. These events are not significant unto themselves, but continued monitoring of these sites may be necessary to determine if a problem exists, especially since the data from the 1992-1993 sampling season reveals that no standard was exceeded.

Water resources in Hopewell Furnace NHS are at risk of being severely degraded if up-basin housing developments are constructed with laissez-faire attitudes toward erosion and sewage management. Although Berks County has designated the private lands of Union Township to be a low-density development area into the twenty-first century, several of the most highly urbanized townships in Berks County share borders with Union Township. The upper reach of the French Creek watershed is in the path of urban growth extending south from central Berks County, so it is inevitable that developmental pressures in environmentally sensitive areas near Hopewell Furnace NHS will increase for the foreseeable future. Importantly, both Berks and Chester counties contain in their comprehensive plans suggestions for the prevention of sprawl and piecemeal development.

While the overall water quality in Hopewell Furnace NHS is good with regard to the parameters measured in this study, it is evident that certain conditions such as pH and bacteria concentrations need to be monitored closely. These are not alarming changes, but important to

note. With pressures from development, agriculture and household consumption and disposal of wastes both within Hopewell Furnace NHS and French Creek and its tributaries, water quality is at risk of degradation. The information from this report is useful in helping to manage water quality in this area and helping to note where problems may exist. It is recommended that in the future, monitoring for bacteria be increased to ensure the maintenance and protection of water quality in Hopewell Furnace NHS and all those who benefit from it.

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Appendix A. Temperature, Dissolved Oxygen (DO) and Discharge for 3/26/2002 and 11/6/2002, Hopewell Furnace NHS.

Site*	H-1	H-2	H-3	H-4	H-5	H-6
			3/26/2002 Sampling Date			
Temperature (°C)	6.9	7.0	5.4	5.3	6.2	5.8
DO (mg/l)	6.7	8.0	4.0	12.0	7.1	10.4
Flow (cfs)	1.55	0.95	0.23	0.27	2.69	-
			11/6/2002 Sampling Date			
Temperature (°C)	8.6	9.4	8.4	8.4	9.0	9.7
DO (mg/l)	10.7	10.5	11.5	11.5	10.5	10.6
Flow (cfs)	2.47	0.59	0.28	0.21	4.97	-

* H-1 - 25 meters downstream of the olf spillway at Hopewell Lake and Hopewell Furnace NHS boundary (41.65451N, 76.84936W)
H-2 - 20 meters downstream of the tailrace and French Creek confluence (40.20424N, 75.77702W)
H-3 - Spout Run at the crossing point of the East Headrace (40.20747N, 75.76917W)
H-4 - Baptism Creek at the intersection point with the East Headrace (40.20594N, 75.77252W)
H-5 - the intersection of the downstream Hopewell Furnance NHS boundary and French Creek (40.20483N, 75.76919W)
H-6 - an intermittent stream directly below the old CCC dump site (40.19695N, 75.76792)

Appendix B. Organic Water Quality Data Summary for Location H-6 on 3/26/2002, Hopewell Furnace NHS.

Parameter	Concentration (ug/l)	Detection Limit (ug/l)
Benzene	<1	1
Bromodichloromethane	<1	1
Bromoform	<1	1
Bromomethane	<1	1
Carbon tetrachloride	<1	1
Chlorobenzene	<1	1
Chloroethane	<1	1
2- Chloroethylvinyl ether	<50.0	50
Chloroform	<1	1
Chloromethane	<1	1
Dibromochloromethane	<1	1
1,2- Dichlorobenzene	<1	1
1,3- Dichlorobenzene	<1	1
1,4- Dichlorobenzene	<1	1
1,1- Dichloroethane	<1	1
1,2- Dichloroethane	<1	1
1,1- Dichloroethane	<1	1
trans-1,2- Dichloroethane	<1	1
1,2- Dichloropropene	<1	1
cis-1,3- Dichloropropene	<1	1
trans-1,3- Dichloropropene	<1	1
Ethylbenzene	<1	1
Methylene chloride	<1	1
Styrene	<1	1
1,1,2,2- Tetrachloroethane	<1	1
Tetrachloroethene	<1	1
Tolune	<1	1
1,1,1- Trichloroethane	<1	1
1,1,2- Trichloroethane	<1	1
Trichloroethene	<1	1
Trichlorofluoromethane	<1	1
Vinyl chloride	<1	1
Xylene (total)	<1	1

Appendix C. Organic Water Quality Data Summary for Location H-6 on 11/6/2002, Hopewell Furnace NHS.

Parameter	Concentration (ug/l)	Detection Limit (ug/l)
Methyl tert-butyl ether	<1.00	1
Benzene	<1.00	1
Bromobenzene	<1.00	1
Bromochloromethane	<1.00	1
Bromodichloromethane	<1.00	1
Bromoform	<1.00	1
Bromoethane	<1.00	1
Bromomethane	<1.00	1
n-Butylbenzene	<1.00	1
sec-Butylbenzene	<1.00	1
tert-butylbenzene	<1.00	1
Carbon tetrachloride	<1.00	1
Chlorobenzene	<1.00	1
Chloroethane	<1.00	1
Chloroform	<1.00	1
Chloromethane	<1.00	1
2- Chlorotoluene	<1.00	1
4- Chlorotoluene	<1.00	1
Dibromochloromethane	<1.00	1
1,2- Dibromo-3-chloropropane	<5.00	5
1,2- Dibromoethane (EDB)	<1.00	1
Dibromomethane	<1.00	1
1,2- Dichlorobenzene	<1.00	1
1,2- Dichlorobenzene	<1.00	1
1,4- Dichlorobenzene	<1.00	1
Dichlorodifluoromethane	<1.00	1
1,1- Dichloroethane	<1.00	1
1,2- Dichloroethane	<1.00	1
1,1- Dichloroethane	<1.00	1
cis-1,2- Dichloroethene	<1.00	1
trans-1,2- Dichloroethene	<1.00	1
1,2- Dichloropropane	<1.00	1
1,3- Dichloropropane	<1.00	1
2,2- Dichloropropane	<1.00	1
1,1- Dichloropropene	<1.00	1
cis-1,3- Dichloropropene	<1.00	1
trans-1,3- Dichloropropene	<1.00	1
Ethylbenzene	<1.00	1
Hexachlorobutadiene	<1.00	1
Isopropylbenzene	<1.00	1
p- Isopropylbenzene	<1.00	1

Appendix C. Organic Water Quality Data Summary for Location H-6 on 11/6/2002, Hopewell Furnace NHS. (continued)

Parameter	Concentration (ug/l)	Detection Limit (ug/l)
Methylene Chloride	<1.00	1
Naphthalene	<1.00	1
n-Propylbenzene	<1.00	1
Styrene	<1.00	1
1,1,2,2- Tetrachloroethane	<1.00	1
1,1,1,2- Tetrachloroethane	<1.00	1
Tetrachloroethene	<1.00	1
Toluene	<1.00	1
1,2,3- Trichlorobenzene	<1.00	1
1,2,4- Trichlorobenzene	<1.00	1
1,1,2- Trichloroethane	<1.00	1
1,1,1- Trichloroethane	<1.00	1
Trichloroethene	<1.00	1
Trichlorofluoromethane	<1.00	1
1,2,3- Trichloropropane	<1.00	1
1,3,5- Trimethylbenzene	<1.00	1
1,2,4- Trimethylbenzene	<1.00	1
Vinyl chloride	<1.00	1
Xylene (total)	<1.00	1

Appendix D. Organic Water Quality Data Summary for Location H-6 on 11/18/1992, Hopewell Furnace NHS.

Parameter	Concentration (ug/l)	Detection Limit (ug/l)
Benzene	<5	5
Bromodichloromethane	<5	5
Bromoform	<5	5
Bromomethane	<10	10
Carbon tetrachloride	<5	5
Chlorobenzene	<5	5
Chloroethane	<10	10
2-Chloroethylvinyl ether	<5	5
Chloroform	<5	5
Chloromethane	<10	10
Dibromochloromethane	<5	5
1,2- Dichlorobenzene	<5	5
1,3- Dichlorobenzene	<5	5
1,4- Dichlorobenzene	<5	5
1,1- Dichloroethane	<5	5
1,2- Dichloroethane	<5	5
1,1- Dichloroethane	<5	5
tans-1,2- Dichloroethane	<5	5
1,2- Dichloropropane	<5	5
cis- 1,3- Dichloropropane	<5	5
trans- 1,3- Dichloropropane	<5	5
Ethylbenzene	<5	5
Methylene chloride	<5	5
Styrene	<5	5
1,1,2,2- Tetrachloroethane	<5	5
Tetrachloroethene	<5	5
Trichlorofluoromethane	<5	5
Vinyl chloride	<10	10
Xylene (total)	<5	5

Appendix E. Organic Water Quality Data Summary for Location H-6 on 3/23/1993, Hopewell Furnace NHS.

Parameter	Concentration (ug/l)	Detection Limit (ug/l)
Acrolein	<5	5
Acrylonitrile	<5	5
Benzene	<5	5
Bromodichloromethane	<5	5
Bromoform	<5	5
Bromomethane	<10	10
Carbon tetrachloride	<5	5
Chlorobenzene	<5	5
Chloroethane	<10	10
2-Chloroethylvinyl ether	<5	5
Chloroform	<5	5
Chloromethane	<10	10
Dibromochloromethane	<5	5
1,1- Dichloroethane	<5	5
1,2- Dichloroethane	<5	5
1,1- Dichloroethane	<5	5
trans-1,2- Dichloroethane	<5	5
1,2- Dichloropropane	<5	5
cis-1,3- Dichloropropane	<5	5
trans-1,3- Dichloropropane	<5	5
Ethyl Benzene	<5	5
Methylene chloride	<5	5
Styrene	<5	5
1,1,2,2- Tetrachloroethane	<5	5
Tetrachloroethene	<5	5
Toluene	<5	5
1,1,1- Trichloroethane	<5	5
1,1,2- Trichloroethane	<5	5
Trichloroethane	<5	5
Vinyl chloride	<10	10

Appendix F. Inorganic and Biological Water Quality Data Summary on 3/27/2002, Hopewell Furnace NHS.

Site*	H-1	H-2	H-3	H-4	H-5	H-6
Parameter						
pH	5.89	6.59	6.72	6.8	6.79	6.85
SPC (uS/cm)	76.6	82.9	125.8	33.7	90.7	96
NO3-N (mg/l)	<0.013	0.088	0.13	0.072	0.178	0.525
Turbidity (FTU)	7.73	8.08	5.11	5.54	4	5.76
SO4 (mg/l)	7.78	8.3	9.6	5.04	8.49	12.87
Cl (mg/l)	6.14	5.95	13.99	1.43	7.45	3.62
Pb (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ni (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fe (mg/l)	0.063	0.062	0.027	0.031	0.095	0.041
Al (mg/l)	0.019	0.016	0.01	0.026	0.018	0.015
Ortho-P (mg/l)	0.03	0.006	<0.005	<0.005	<0.005	<0.005
Total Coliform bacteria (no./100ml)	>200	>200	>200	>200	>200	>200
Fecal Coliform bacteria (no./100ml)	<2	2	74	4	12	6

* H-1 - 25 meters downstream of the olf spillway at Hopewell Lake and Hopewell Furnace NHS boundary
H-2 - 20 meters downstream of the tailrace and French Creek confluence
H-3 - Spout Run at the crossing point of the East Headrace
H-4 - Baptism Creek at the intersection point with the East Headrace
H-5 - the intersection of the downstream Hopewell Furnance NHS boundary and French Creek
H-6 - an intermittent stream directly below the old CCC dump site

Appendix G. Inorganic and Biological Water Quality Data Summary on 11/6/2002, Hopewell Furnace NHS.

Site*	H-1	H-2	H-3	H-4	H-5	H-6
Parameter						
pH	6.28	6.63	6.73	5.7	6.61	6.71
SPC (uS/cm)	80.8	98.6	78.7	32.2	87.2	82.2
NO3-N (mg/l)	0.101	0.216	0.088	0.044	0.103	0.378
Turbidity (FTU)	2.1	8.39	1.88	1.2	3.59	1.06
SO4 (mg/l)	7.32	8.61	10.56	6.61	10.67	15.16
CI (mg/l)	8.36	7.94	9.7	1.95	8.11	2.52
Pb (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ni (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fe (mg/l)	0.042	0.058	0.026	0.061	0.102	0.073
Al (mg/l)	0.004	0.002	0.014	0.051	0.05	0.009
Ortho-P (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Total Coliform bacteria (no./100ml)	260	440	1100	1400	5600	2000
Fecal Coliform bacteria (no./100ml)	22	24	64	34	280	74

* H-1 - 25 meters downstream of the olf spillway at Hopewell Lake and Hopewell Furnace NHS boundary
H-2 - 20 meters downstream of the tailrace and French Creek confluence
H-3 - Spout Run at the crossing point of the East Headrace
H-4 - Baptism Creek at the intersection point with the East Headrace
H-5 - the intersection of the downstream Hopewell Furnance NHS boundary and French Creek
H-6 - an intermittent stream directly below the old CCC dump site

Appendix H. Inorganic and Biological Water Quality Data Summary on 11/18/1992, Hopewell Furnace NHS

Site*	H-1	H-2	H-3	H-4	H-5	H-6
Parameter						
pH	6.95	6.99	7.13	6.94	7.15	6.37
SPC (umhos/cm)	77	85.8	61.5	31.3	83.6	107.2
NO3-N (mg/l)	0.17	0.23	0.1	0.01	0.31	1.6
Turbidity (FTU)	8.2	6.2	1.0	0.6	3.4	2.5
SO4 (mg/l)	14.9	15.1	9.1	4.3	12.1	17.1
Cl (mg/l)	5.7	5.1	4.4	1.6	4.7	3
Pb (mg/l)	ND**	ND	ND	ND	ND	ND
Ni (mg/l)	ND	ND	ND	ND	ND	ND
Cd (mg/l)	0.0004	0.0003	0.0003	0.0003	ND	ND
Fe (mg/l)	0.12	0.08	0.01	0.02	0.08	0.01
Al (mg/l)	0.01	0.01	0.02	0.04	0.06	0.05
Total Coliform bacteria (no./100ml)	20	10	32	25	15	NS***
Fecal Coliform bacteria (no./100ml)	64	86	10	3	82	NS
Fecal Streprococcus bacteria (no./100ml)	122	107	22	6	23	NS

*H-1 - 25 meters downstream of the olf spillway at Hopewell Lake and Hopewell Furnace NHS boundary
H-2 - 20 meters downstream of the tailrace and French Creek confluence
H-3 - Spout Run at the crossing point of the East Headrace
H-4 - Baptism Creek at the intersection point with the East Headrace
H-5 - the intersection of the downstream Hopewell Furnance NHS boundary and French Creek
H-6 - an intermittent stream directly below the old CCC dump site
**None Detectable
***No Sample

Appendix I. Inorganic and Biological Water Quality Data Summary on 3/23/1993, Hopewell Furnace NHS.

Site*	H-1	H-2	H-3	H-4	H-5	H-6
Parameter						
pH	6.99	6.92	6.77	6.80	7.00	6.79
SPC (umhos/cm)	56.4	62.1	69.4	28.3	64.8	70.2
NO3-N (mg/l)	0.09	0.14	0.09	0.02	0.15	0.43
Turbidity (FTU)	1.7	2.8	1.7	0.7	1.8	3.6
SO4 (mg/l)	8.4	9.2	9.9	5.3	9.4	15.2
Cl (mg/l)	2.2	2.3	7.6	1.4	4.2	1.2
Pb (mg/l)	ND**	0.0001	0.0002	ND	0.001	ND
Ni (mg/l)	ND	ND	ND	0.001	ND	ND
Cd (mg/l)	0.0006	ND	ND	ND	ND	ND
Fe (mg/l)	0.015	0.026	0.029	0.014	0.036	0.062
Al (mg/l)	0.013	0.018	0.016	0.044	0.041	0.006
Total Coliform bacteria (no./100ml)	ND	4	48	11	169	NS***
Fecal Coliform bacteria (no./100ml)	ND	15	21	2	58	NS
Fecal Streptococcus bacteria (no./100ml)	ND	ND	4	ND	5	NS

*H-1 - 25 meters downstream of the olf spillway at Hopewell Lake and Hopewell Furnace NHS boundary
H-2 - 20 meters downstream of the tailrace and French Creek confluence
H-3 - Spout Run at the crossing point of the East Headrace
H-4 - Baptism Creek at the intersection point with the East Headrace
H-5 - the intersection of the downstream Hopewell Furnance NHS boundary and French Creek
H-6 - an intermittent stream directly below the old CCC dump site
**None Detectable
***No Sample

Appendix J. Inorganic and Biological Water Quality Means for 3/27/2002 and 11/6/2002, Hopewell Furnace NHS.

Site*	H-1	H-2	H-3	H-4	H-5	H-6
Parameter						
pH	6.09	6.61	6.73	6.25	6.7	6.78
H+	8.13E-07	2.45E-07	1.86E-07	5.62E-07	2.00E-07	1.66E-07
SPC (umhos/cm)	78.7	90.75	102.25	32.95	88.95	89.1
NO3-N (mg/l)	0.057	0.152	0.109	0.058	0.141	4.452
Turbidity (FTU)	4.92	8.24	3.5	3.37	3.8	3.41
SO4 (mg/l)	7.55	8.46	10.08	5.83	9.58	14.02
Cl (mg/l)	7.25	6.95	11.85	1.69	7.78	3.07
Pb (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Ni (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cd (mg/l)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Fe (mg/l)	0.053	0.06	0.027	0.046	0.1	0.057
Al (mg/l)	0.012	0.009	0.012	0.039	0.034	0.012
Ortho-P (mg/l)	0.015	0.003	<0.005	<0.005	<0.005	<0.005
Total Coliform Bacteria (no./100ml)	230	320	650	800	2900	1100
Fecal Coliform bacteria (no./100ml)	11	13	69	19	146	40

* H-1 - 25 meters downstream of the olf spillway at Hopewell Lake and Hopewell Furnace NHS boundary
H-2 - 20 meters downstream of the tailrace and French Creek confluence
H-3 - Spout Run at the crossing point of the East Headrace
H-4 - Baptism Creek at the intersection point with the East Headrace
H-5 - the intersection of the downstream Hopewell Furnance NHS boundary and French Creek
H-6 - an intermittent stream directly below the old CCC dump site

Appendix K. Inorganic and Biological Water Quality Means for 11/18/1992 and 3/23/1993, Hopewell Furnace NHS.

Site*	H-1	H-2	H-3	H-4	H-5	H-6
Parameter						
pH	6.97	6.96	6.95	6.87	7.08	6.58
H+	1.07E-07	1.10E-07	1.12E-07	1.35E-07	8.32E-08	2.63E-07
SPC (umhos/cm)	66.70	73.95	65.45	29.80	74.20	88.70
NO3-N (mg/l)	0.13	0.19	0.55	0.02	0.23	1.02
Turbidity (FTU)	4.95	4.5	1.35	0.65	2.6	3.05
SO4 (mg/l)	11.65	12.15	9.50	4.80	10.75	16.15
Cl (mg/l)	3.95	3.70	6.00	1.50	4.45	2.10
Pb (mg/l)	ND**	0.00005	0.001	ND	0.0005	ND
Ni (mg/l)	ND	ND	ND	0.0005	ND	ND
Cd (mg/l)	0.0005	0.00015	0.00015	0.00015	ND	ND
Fe (mg/l)	0.067	0.053	0.02	0.017	0.058	0.036
Al (mg/l)	0.012	0.014	0.018	0.042	0.051	0.028
Total Coliform bacteria (no./100ml)	10	7	40	18	92	NS***
Fecal Coliform bacteria (no./100ml)	32.0	50.5	15.5	2.5	70.0	NS
Fecal Streptococcus bacteria (no./100ml)	61.0	53.5	13.0	3.0	14.0	NS

*H-1 - 25 meters downstream of the olf spillway at Hopewell Lake and Hopewell Furnace NHS boundary
H-2 - 20 meters downstream of the tailrace and French Creek confluence
H-3 - Spout Run at the crossing point of the East Headrace
H-4 - Baptism Creek at the intersection point with the East Headrace
H-5 - the intersection of the downstream Hopewell Furnance NHS boundary and French Creek
H-6 - an intermittent stream directly below the old CCC dump site
**None Detectable
***No Sample