National Park Service
U.S. Department of the Interior

Natural Resource Stewardship and Science

Valley Forge National Historical Park Natural Resource Condition Assessment

Natural Resource Report NPS/VAFO/NRR—2013/737

ON THE COVER
Photograph of a palustrine forested wetland habitat near the Pawling Farm taken May 2007.
Photograph by: Bill Moses

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Natural Resource Report NPS/VAFO/NRR—2013/737

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November 2013

U.S. Department of the Interior
National Park Service
Natural Resource Stewardship and Science
Fort Collins, Colorado

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Please cite this publication as:

Sherwin, L. S., K. Brubaker, PhD, P. Sharpe, PhD, J. Kozak, M. May, A. Lashaway, K. Jensen, and K. L. Gordon. 2013. Valley Forge National Historical Park Natural resource condition assessment. Natural Resource Report NPS/VAFO/NRR—2013/737. National Park Service, Fort Collins, Colorado.

NPS 464/122916, November 2013

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Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xvii) for more information.

Executive Summary

Valley Forge National Historical Park is nationally significant as the site of the 1777-78 winter encampment of General George Washington and the Continental Army. The park protects and preserves many significant cultural resources, including cultural landscapes, historic buildings and structures, archeological sites, and archives and collections. The park's proximity to numerous revolutionary war sites and to Philadelphia, places it at the center of some of the most culturally and historically rich areas in the eastern United States. As development in the area has increased, the park has also gained significance as a refuge for many species of plants and animals, a destination for renewal and recreation, and a place of outstanding natural scenic beauty. The park boundary was established in 1976 by enabling legislation transferring ownership of Valley Forge State Park (the first Pennsylvania State Park created in 1893) from the Commonwealth to the National Park Service. The national park comprises 3,452 acres, including 270 acres of non-federal ownership such as in-holdings, utilities, and roads.

Natural resource conditions in Valley Forge National Historical Park (NHP) must be considered within the context of its physiographic location, legislative mission, history, and current management objectives. The park's mission is to educate the American people about a defining moment in our nation's history and to preserve the natural and cultural resources that commemorate the Continental Army encampment at Valley Forge in 1777-1778. The park spans portions of Chester and Montgomery Counties and five townships: Schuylkill and Tredyffrin Townships to the west and south in Chester County; and Lower Providence, West Norriton, and Upper Merion Townships to the north and east in Montgomery County. The historic character of the landscape surrounding Valley Forge NHP was a predominant mixture of forest and agricultural lands. However, these lands have been gradually converted to residential, commercial, and industrial uses to meet the needs of the city of Philadelphia and neighboring communities. These landscape scale changes place a greater importance on Valley Forge NHP as a vital nesting, resting, breeding, and/or escape location for many species of plants and animals within Chester and Montgomery Counties. These land use changes also create additional stressors on the park ecosystems by adversely impacting the soundscape, lightscape, water quality/quantity of park waterways, introducing invasive exotic pests, pathogens, and species, and affecting the overall air quality within the park.

Valley Forge NHP is a member of the Mid-Atlantic Inventory and Monitoring Network, one of 32 such networks developed and operated by the National Park Service throughout the country. These networks are charged with coordinating the inventory and long-term monitoring of various habitats and biota within the parks under their charge. Through this program and the efforts of the park staff at Valley Forge NHP, numerous long term studies have been conducted on habitat quality and species populations within the park, thus creating a rich data set that can be mined for the purposes of determining the condition and trends in the natural resources of Valley Forge NHP.

Approach

This assessment provides a broad overview of the critical processes, habitats, and species of management importance within Valley Forge NHP and attempts to provide where possible a

quantitative assessment of those resources using the vital signs and their associated metrics developed by the National Park Service Inventory and Monitoring Program and a suite of additional metrics covering natural resources of park significance developed in consultation with the Penn State NRCA team, park biologists, and regional NPS scientists. The broad resource categories assessed in this document are air resources, water resources, biological resources, geologic resources, soundscape and lightscape, consistent with key resources identified in the park General Management Plan (NPS 2007). The nine principle natural resource categories identified below reflect the main natural resources of management focus and VAFO , these natural resources are:

- Air quality
- Water quality/quantity
- Wetlands
- Forests Plant Communities
- Grasslands
- Native Wildlife Communities
- Geologic resources
- Soundscape
- Lightscape

This condition assessment utilized existing data sets and mapping products that had been produced over the past decade for the park and adjacent lands and did not rely upon any "new" data sources produced by the NRCA team. Reference conditions and/or threshold criteria for each metric were determined based on published scientific literature, state/federal guidelines, historic data, and expert opinion where necessary. Where consistent long-term data existed metric scores were calculated and the raw data was assessed to determine what, if any, trends or patterns could be discerned and thus reported, as well as our general confidence in the data used. In cases where little or no long-term data existed for a particular resource, the data gaps were identified and recommendations were made for how the park could address those deficiencies in the future.

Overall condition and trends for the above categories were assessed using recent draft guidance (July 2013) from NPS water resources division. To determine the combined condition for a resource, each red symbol in the summary table was assigned zero points, each yellow symbol assigned 50 points, and each green symbol 100 points. A simple average was calculated, and applied to the following scale to determine the resulting overall score:

0-33 Red (Significant Concern)
34-66 Yellow (Moderate Concern)
67-100 Green (Good)

Overall trends for the same broad categories were determined using the same draft NPS guidance (July 2013). The trends calculation followed a similar basic formula by subtracting the total number of down arrows from the total number of up arrows. If the result is 3 or greater, the overall trend is up. If the result is -3 or lower, the overall trend is down. If the result is between 2 and -2, the overall trend was considered unchanging. In many cases individual metrics didn't display a clear trend or no

trend was available, therefore caution must be exercised when interpreting the overall trends evaluation.

Park Threats

Threats and stressors to Valley Forge NHP can be categorized into three broad areas: internal, watershed wide, and regional. Internal threats include stressors coming from within the park itself (e.g. visitor impacts from social trails), watershed wide threats include stressors acting within the Valley Creek or Schuylkill River Watershed that may directly or indirectly impact park resources (e.g. increases in impervious surface), and regional threats are those coming from outside the watershed scale that impact the entire region such as air quality. A recent example of an internal threat to the park are the impacts to forest habitat arising from white-tailed deer herbivory. Watershed wide threats are primarily associated with changes in land use resulting in an increase in impervious surface area. For example, in the Valley Creek watershed between 1937 and 1997, the amount of land in agricultural uses declined from 50% to 7% and the amount of developed land increased proportionally from 4% to 48% over the same time period (CCWRA 2002). Increased impervious surface area associated with development has altered natural processes associated with the water cycle important to maintaining watershed health including runoff, infiltration, and evapotranspiration. For example, increased impervious surface area in the Valley Creek watershed has resulted in increased surface water (or stomrwater) runoff leading to more frequent and intense flood events, warmer stream temperatures, increased streambank erosion and sedimentation, increased pollutant loads, and damage to infrastructure such as roads and sewer lines along the creek. Regional threats to Valley Forge NHP are also associated with urbanization of the surrounding landscape and primarily stem from changes in air quality, climate change, introduction of non-native species, and sound/lightscape degradation.

Overall Current Condition of Valley Forge NHP Natural Resources

1. **Air quality** – All air resource metrics at Valley Forge NHP are in a ***Significant Concern*** condition ranking with an overall ***Improving Trend***. Ozone concentrations utilizing the 4th highest 8-hr ppb values from 2003-2007, 2004-2008, and 2005-2009 showed improving conditions. Wet deposition of nitrogen and sulphur oxides while also in the significant concern category displayed improving trends since enactment of the Clear Air Act which is good for acid sensitive plants and biota.

2. **Water quality and quantity** – Overall water quality/quantity was rated as ***Good Condition*** for Valley Creek and the Schuylkill River combined with an overall ***UnchangingTrend***. There was limited fish community and benthic macro-invertebrate data for the Schuylkill River, but Valley Creek possessed a robust, long-term macro-invertebrate data set and there were a number of individual long term water quality metrics for both water bodies. Current development activities within the Valley Creek watershed may cause some or many of the metrics assessed in this document to show degrading trends, therefore, the park is strongly encouraged to continue long term monitoring efforts along Valley Creek within the park, and generate a separate overall condition score and trend for Valley Creek and the Schuylkill River.

3. **Wetlands** – The wetlands assessment for this NRCA was basic as it relied upon the Sharpe et al. (2012) inventory, therefore our confidence in this portion of the assessment is low. Based on the

single metric score overall wetland quality was rated in the ***Good Condition*** category with an ***Unchanging Trend***. Invasive plant species and excessive nitrogen deposition are likely two parkwide threats and stressors interactively impacting the overall ecological condition of park wetlands, however, no data has been collected on these metrics as of the publishing of this assessment.

4. **Forest Plant Communities** – Based on the latest Inventory and Monitoring report data (2013) VAFO forests had a combined average score of 63 which places the park in the ***Moderate Concern*** category with an overall ***Improving Trend***. Our confidence in this assessment is medium as long term data is still be collected and assessed. Additionally, the scaling up calculation used in this assessment gives equal weight to all of the metric scores which can be very misleading as we feel forest regeneration is more indicative of long term forest health than say snags per hectare. We encourage the park staff to focus more on the individual metric scores related to forest health than the overall condition and trend summarized here as a result of these "scaling up' difficulities. The current deer management plan appears to have had some positive impact on forest health at Valley Forge NHP which also benefits from a low incidence of diseases, pests, and pathogens suggesting that the long-term prognosis for these ecosystems is good. Additional long term inventory and monitoring data acquired in future park visits will greatly improve the trends component of the individual metric scores and allow for a stronger trend and assessment evaluation to be made and should improve our overall confidence in the data used to assess forest condition.

5. **Grasslands** – Overall condition and trends for park grassland communities was rated as ***Moderate Condition*** with an ***Unchanging Trend*** based on an assessment of meadow patch size and native plant species occurrence. Approximately 60% of the fields within Valley Forge NHP are greater than 100 acres in size which is optimal for many species of obligate grassland birds. However, park grassland communities are generally deficient regarding the abundance of native plant species which scores the park in the "significant concern" category for that metric and providing a moderate overall habitat score, based on reliable GIS analysis of patch size and a recent comprehensive grasslands assessment (Latham, 2009) our confidence in this assessment is high.

6. **Native Wildlife Communities** – Overall condition and trends for park wildlife utilizing data for amphibians, reptiles, forest/grassland birds, and white-tailed deer was rated overall as ***Good Condition*** with an ***Improving Trend*** (trend data based solely on 2012 deer density values), giving us a low confidence in the trend assessment. This category of the NRCA was the most difficult to address as detailed, long-term data sets were not available for many of the species of plants and animals residing within the park boundary. Additionally, this overall score does not include aquatic species metrics such as the Brown trout community biomass or the various benthic IBI's as they were used in the water quality/quantity assessment. Our overall confidence in this assessment is low as a result of these data limitations.

7. **Geologic Resouces -** Overall condition and trends for the park's geologic resources was rated as ***Poor*** with an ***Unknown Trend***. Little if any detailed inventory and monitoring data currently exists for the parks karst feartures and while there is a more comprehensive inventory of the paleontological features of the park many of these resources are considered to be in poor condition. Based on an

overall lack of a comprehensive baseline inventory of these features within the park our confidence in this assessment is low.

8. **Soundscape –** The data supporting the overall condition assessment score of ***Good Condition*** was limited to a single study run from 2001-2003, which also precludes a trend assessment score. Additional soundscape monitoring is recommended in order to provide the park with an accurate picture of data trends and to provide the park with good baseline data. Our overall confidence in this assessment is thus low.

9. **Lightscape –** Currently there is no data available to assess lightscape at VAFO, though the park acknowledges that natural lightscapes are an important component to maintaining healthly natural environments. It is recommended that the park consider including a long term lightscape monitoring component into its annual natural resource monitoring efforts.

Note: These overall condition summaries were produced as a means of illustrating to the park possible ways of combining and reporting overall summaries for their originally scoped natural resources. During the course of the State of the Parks workshop (held November 2013), some of these summaries were modified at the park's request to better reflect more recent data (e.g. Air Quality) and park focus (e.g. Wildlife Communities split into smaller sub-categories).

Acknowledgments

The authors thank Kristina Heister, Amy Rhue, and Kate Jensen of Valley Forge National Historical Park for discussions and providing access to natural resource reports and documents. Sheila Colwell, Alan Ellsworth, Jim Comiskey, Sarah Wakamiya, Charles Roman, Holly Salazer, and David Vana-Miller who kindly provided information and data for inclusion in the assessment. Special thanks are extended to the peer reviewers who reviewed and graciously offered constructive comments on previous drafts. This study was funded by the National Park Service and administered by The Pennsylvania State University at University Park, PA.

Prologue

Publisher's Note: Some or all of the work done for this project preceded revised standards and guidance posted in 2009 and 2010. Consequently, aspects of this project's study approach and some report format and/or content details may not be consistent with the revised guidance, and may differ in comparison to what is found in more recently published reports from this series.

List of Terms

Attribute: Any living or non-living feature, natural resource or process of the environment that can be measured or estimated and that provides insights into the state of the ecosystem. The term **Indicator** is reserved for a subset of attributes that is particularly information-rich. (see below).

Indicator: A selected subset of the physical, chemical, and biological elements and processes of natural systems derived from the attributes that are designated to represent the overall health of the system.

Vital Sign: terminology used by the NPS Inventory and Monitoring Network to identify an Indicator.
Measure: The specific variables used to quantify the condition or state of an Indicator. For example stream acidity may be the Indicator, while pH units are the Measure. Often used interchangeably with the term “metric”.

Desired Condition: Broad, management-focused statement established by the park from its General Management Plan which cannot be changed, but can be quantified and made more specific (see Target Value.)

Stressors: Physical, chemical, biological, or anthropogenic perturbations to a system that are either

(a) foreign to that system or (b) natural to the system but applied at an excessive or deficient level to

cause significant changes in the ecological components, patterns, and processes of natural systems.

Threshold: An established, quantifiable value of a measure or metric at which stressors trigger significant changes to natural systems and processes

Publisher's Note: Some or all of the work done for this project preceded the revised guidance issued for this project series in 2009/2010. See Prologue (p. xvii) for more information.

Chapter 1. Valley Forge NHP NRCA Introduction

Natural Resource Condition Assessment Program

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks". These condition analyses also report on trends (where possible), critical data gaps, and general level of confidence for study findings. The resources and indicators emphasized in the project work depend on a park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators for that park, and availability of data and expertise to assess current conditions for the things identified on a list of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement, not replace, traditional issue and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope - However, the breadth of natural resources and number/type of indicators evaluated will vary by park
- employ hierarchical indicator frameworks - Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures - conditions for indicators - condition summaries by broader topics and park areas
- identify or develop logical reference conditions/values to compare current condition data against - NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers")
- emphasize spatial evaluation of conditions and GIS (map) products - As possible and appropriate, NRCAs describe condition gradients or differences across the park for important natural resources and study indicators through a set of GIS coverages and map products
- summarize key findings by park areas - In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on a area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested
- follow national NRCA guidelines and standards for study design and reporting products

Although current condition reporting relative to logical forms of reference conditions and values is the primary objective, NRCAs also report on trends for any study indicators where the underlying data and methods support it. Resource condition influences are also addressed. This can include past activities or conditions that provide a helpful context for understanding current park resource

conditions. It also includes present-day condition influences (threats and stressors) that are best interpreted at park, watershed, or landscape scales, though NRCAs do not judge or report on condition status per se for land areas and natural resources beyond the park's boundaries. Intensive cause and effect analyses of threats and stressors or development of detailed treatment options is outside the project scope.

Credibility for study findings derives from the data, methods, and reference values used in the project work—are they appropriate for the stated purpose and adequately documented? For each study indicator where current condition or trend is reported it is important to identify critical data gaps and describe level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject matter experts at critical points during the project timeline is also important: 1) to assist selection of study indicators; 2) to recommend study data sets, methods, and reference conditions and values to use; and 3) to help provide a multi-disciplinary review of draft study findings and products.

NRCAs provide a useful complement to more rigorous NPS science support programs such as the NPS Inventory and Monitoring Program. For example, NRCAs can provide current condition estimates and help establish reference conditions or baseline values for some of a park's "vital signs" monitoring indicators. They can also bring in relevant non-NPS data to help evaluate current conditions for those same vital signs. In some cases, NPS inventory data sets are also incorporated into NRCA analyses and reporting products.

In-depth analysis of climate change effects on park natural resources is outside the project scope. However, existing condition analyses and data sets developed by a NRCA will be useful for subsequent park-level climate change studies and planning efforts.

NRCAs do not establish management targets for study indicators. Decisions about management targets must be made through sanctioned park planning and management processes. NRCAs do provide science-based information that will help park managers with an ongoing, longer term effort to describe and quantify their park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning efforts such as the Resource Stewardship Strategy (RSS) but study scope can be tailored to also work well as a post-RSS project and help parks report to government accountability measures. While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

Due to their modest funding, relatively quick timeframe for completion and reliance on existing data and information, NRCAs are not intended to be exhaustive. Study methods typically involve an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in our present data and knowledge bases across these varied study components.

NRCAs can yield new insights about current park resource conditions but in many cases their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is credible and has practical uses for a variety of park decision making, planning, and partnership activities.

Over the next several years, the NPS plans to fund a NRCA project for each of the ~270 parks served by the NPS Inventory and Monitoring Program. Additional NRCA Program information is posted at: http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm

Valley Forge National Historical Park was selected as a pilot park for development of a Resource Stewardship Strategy (RSS) and initial planning for this project began in July 2008. The RSS is considered a critical planning tool linking the park General Management Plan (GMP) to the more detailed, 5-year strategic plan (DO-2-1). The comprehensive strategies developed in the RSS to achieve park-specific desired future resource conditions will be used as a template for developing detailed program and project needs and for determining the park's long-term needs for changes in budget allocations, funding outside of park base, and staffing capabilities. Development of quantifiable, measurable objectives also will serve to inform long-term monitoring geared toward evaluating success in achieving desired resource conditions. Knowledge of current resource condition, existing threats and stressors, and identification of reference conditions and critical data gaps is essential to the development of comprehensive strategies that will promote the long-term protection, preservation, and restoration of important park resources. Therefore, when Valley Forge NHP was also selected as a pilot park for development of a NRCA in September 2008, every effort was made to coordinate these two efforts (e.g. identification of key natural resources, indicators, metrics, etc.) and development of the RSS was stalled to allow the NRCA to move forward with the anticipated benefit of a more informed, scientifically supported RSS document.

Park Resource Setting

Valley Forge NHP is located in southeastern Pennsylvania, 18 miles northwest of center city Philadelphia. Situated in rapidly growing suburbs, the park spans portions of two counties: northeastern Chester County and southwestern Montgomery County (Figure 1). The park also is part of five townships: Schuylkill and Tredyffrin Townships to the west and south in Chester County; and Lower Providence, West Norriton, and Upper Merion Townships to the north and east in Montgomery County. Chester and Montgomery Counties are located within the Greater Philadelphia Area, comprised of three additional counties: Bucks, Delaware, and Philadelphia.

Valley Forge is nationally significant as the site of the 1777-78 winter encampment of General George Washington and the Continental Army. It protects many significant cultural resources, including cultural landscapes, historic buildings and structures, archeological sites, and archives and collections. The park's proximity to numerous revolutionary war sites and to Philadelphia, places it at the center of some of the most culturally and historically rich areas in the eastern United States. As development in the area has increased, the park has gained significance as a refuge for plants and

animals, a destination for renewal and recreation, and a place of outstanding natural scenic beauty. As a result, a substantial percentage of park visitors are recreational visitors who come as much to reconnect with the natural world as they do to learn and appreciate the important historic events preserved and interpreted throughout the park.

The national park preserves the site of the 1777-78 winter encampment of General George Washington's Continental Army which was a pivotal juncture in the struggle to achieve national independence. The park boundary was established in 1976 by enabling legislation transferring ownership of Valley Forge State Park (the first Pennsylvania State Park created in 1893) from the Commonwealth to the National Park Service. The national park comprises 3,452 acres, including 270 acres of non-federal ownership such as in-holdings, utilities, and roads. The last 2-miles of the Valley Creek, a 23.4 square mile watershed containing a Class A wild trout fishery and designated an Exceptional Value waterway in Pennsylvania, flows through the western quadrant of the park to its confluence with the Schuylkill River which traverses a three-mile corridor through the northern sector of the park (Figure 1).

Enabling Legislation

On July 4, 1976, President Gerald Ford signed Public Law 94-337, which established Valley Forge National Historical Park. In 1977, the NPS assumed control with a mandate to "preserve and commemorate . . . the heroic suffering, hardship, and determination and resolve of Washington's Continental Army"

Valley Forge NHP is located in the Piedmont physiographic province (adjoining the Great Valley province), an area characterized by elevations of 100 to 500 feet above sea level, low hills and gently rolling slopes, fertile valleys, and well-drained calcareous soils. These features, combined with a mild climate, abundant average annual precipitation of 46 inches, and a long, frost free- growing season, made this area a major agricultural production center from the earliest colonial times. As suburban sprawl increasingly covers the land around Valley Forge NHP, the park also increases in value as a biorefuge for plants and animals. Supporting over 1,300 species of flora and fauna, habitats within the park include oak/tulip forests, tall grass meadows/grasslands, wetlands, forested floodplains, the Schuylkill River, and numerous streams and springs. Many natural features of the landscape also are culturally significant.

A Cultural Landscape Inventory (CLI) for the park was completed in 1999, documenting all known cultural and natural features that contribute to the National Register significance of the park. The encampment landscape retains integrity of landform, topography, views, and aspect, including Mounts Joy and Misery and the Grand Parade; natural systems and features, including the Schuylkill River, Valley Creek, and numerous springs; and circulation elements, such as Valley Forge Road (PA Route 23), Gulph Road, Baptist Road trace, Yellow Springs Road trace, and the river. More difficult to see but still present is physical evidence of the pre-encampment settlement patterns, including field boundaries, portions of some farm clusters, and remnants of the once-thriving iron forge industry. Much evidence remains of the military adaptations made to support the encampment and fortify the position, including portions of the inner and outer line defenses, the known sites of earthen forts and road systems, and various buildings and structures that were used for officers' quarters, storage, or livestock. These are more than sufficient to convey the story of the encampment and its meaning.

Mission Statement

Valley Forge National Historical Park educates the American people about one of the most defining events in our nation's history and preserves the natural and cultural resources that commemorate the encampment of the Continental Army at Valley Forge in 1777-78

The encampment was a temporary military overlay upon an existing agricultural and industrial landscape that itself was based on a confluence of natural features and systems. Features such as heights, slope, and water were critical to the selection of sites for encampment fortifications, roads, and shelter. As is common with military sites from the revolution, many of the detailed elements no longer survive. The most critical landscape features, those that drew General Washington to this strategic site, remain, however, and have a high degree of integrity.

Examples of how the presence of key natural features and resources are directly tied to the long history of land use at Valley Forge and the selection of this site for the winter encampment of the Continental Army include:

• Iron forges, after which the area is named, were located based on the availability of water power (Valley Creek) and nearby forested areas that were unsuitable for agricultural development (slopes of Mount Joy and Mount Misery) and could provide a source of fuel;

• The presence of the Schuylkill River provided a means of transportation, potential source of food, and served as a key defensive feature of the landscape;

• An agricultural landscape created clear views of approaching enemies and provided areas suitable for troop lodging and training;

• Forested areas of the landscape offered sufficient wood to support the building of huts and provided firewood for 20,000 men and camp followers;

• Abundant springs provided a source of clean drinking water;

• Topography (hills and ridgelines) provided excellent defensive features including high points that served as lookouts and low points that provided protected areas for training.

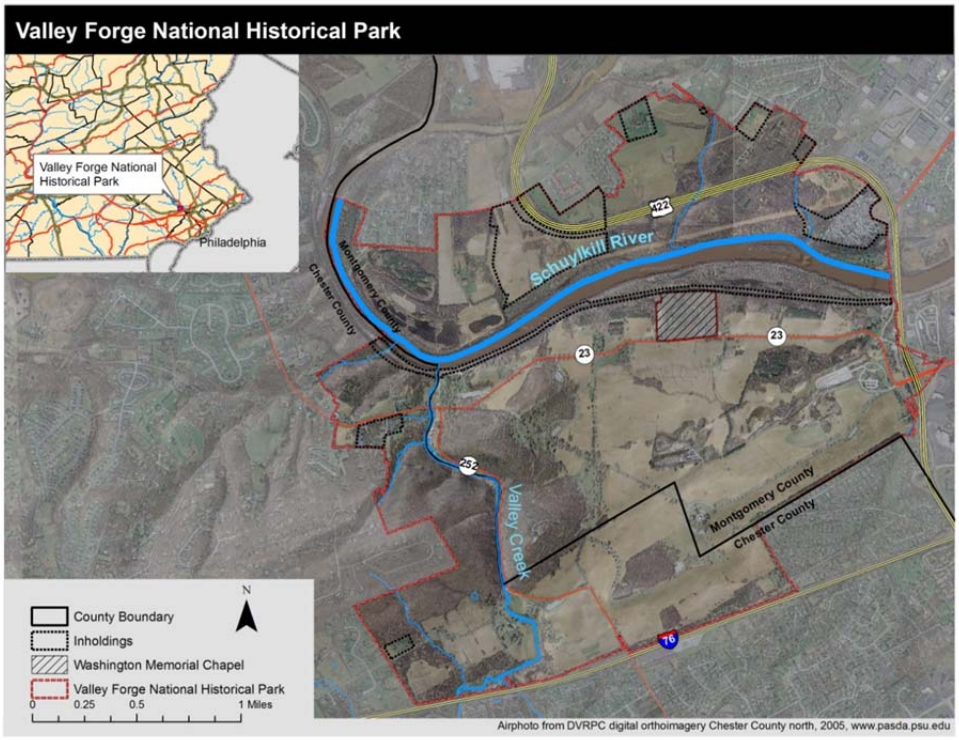
During the encampment period, many natural resources were devastated as what would become the fifth largest city in the country at the time, was built to house and maintain the Continental Army. For example, every tree within an estimated three miles of the park boundary was removed to build huts, provide firewood, etc. The park landscape most readily visible today reflects neither the wretched devastation that characterized most of the duration of the encampment nor the prosperous industrial village, farmsteads, and agricultural fields that were present both when the encampment began and also within a few years of its conclusion. Instead, the landscape today most closely reflects the state park commemorative period. During this period, a romanticized view of the past led the park commission to alter or erase most of the characteristic agricultural and industrial elements, including most of the historic structures, fences, walls, hedgerows, and farm and village lanes. A reforestation program was implemented for Mounts Misery and Joy, and commemorative groves of dogwood and allées of oaks and lindens were planted.

The current approach to management of the park landscape is preservation of the major features of the cultural landscape but within these broad landscape features management objectives focus on promoting the long-term protection, preservation, and restoration of the natural abundance, distribution, structure, and composition of native plant and animal communities and the natural processes that sustain them (e.g. forest regeneration). For example, the park maintains the existing mix of forest and field as a key feature of the cultural landscape but meadows/grasslands are specifically managed to "enhance their high habitat values" (NPS 2007). This approach acknowledges the long history of land use at Valley Forge which has so greatly altered the park environment over time and is reflected in the various cultural landscape layers present (e.g. industrial, agricultural, encampment, commemorative, etc.). It also reflects the increasing local and regional importance of natural resources at Valley Forge and the fact that many regional visitors appreciate it as a place of recreation and renewal, with approximately 80% of park visitors enjoying the park while walking, biking, boating, fishing, horseback riding, and picnicking.

This integrated cultural and natural resource management approach also facilitates integration with and contribution to regional strategies to preserve natural communities and species for whom park boundaries are arbitrary such as declining populations of obligate grassland bird species in the

eastern United States. In turn, the condition of park natural resources is often directly or indirectly influenced by resource availability and condition and threats to resources originating outside the park boundary. As a result, park management strategies also promote active involvement in efforts outside the park boundary that directly relate to the protection, preservation, and restoration of natural resources within the park boundary.

The Valley Forge NHP General Management Plan (2007) specifically directs that whole-watershed management strategies be utilized to protect the park's water resources and that park staff actively participate in local and regional initiatives to protect, enhance, and restore the water quality of Valley Creek and the Schuylkill River and their tributaries. A regional/landscape scale approach to water resources is based on the location of Valley Forge at the lower portions of the Valley Creek and Schuylkill River watersheds and the relative importance of these resources to park management. Encompassing 23.4 square miles, the last two miles of Valley Creek flow through the western quadrant of the park and directly in front of Washington's Headquarters to its confluence with the Schuylkill River. The Valley Creek was designated an Exceptional Value waterway in 1993, by the Pennsylvania Environmental Quality Board and is afforded the highest Clean Water Act "non-degradation" regulatory status by the Pennsylvania Department of Environmental Protection. It also received the highest possible designation from the Pennsylvania Fish and Boat Commission as a 'Class A' wild trout stream. The Schuylkill River traverses a three-mile corridor which bi-sects the park into northern and southern sectors and is the park's largest and most important water body (Figure 1). Approximately 100 miles of the Schuylkill River is located above the park boundary. It represents the largest tributary to the Delaware River (> 1,900 square mile watershed) and Valley Forge represents <0.03% of the watershed land base. The Schuylkill was the first river in Pennsylvania to be designated as a Pennsylvania Scenic River and it is the spine of a state and nationally designated heritage corridor (NPS 2007).



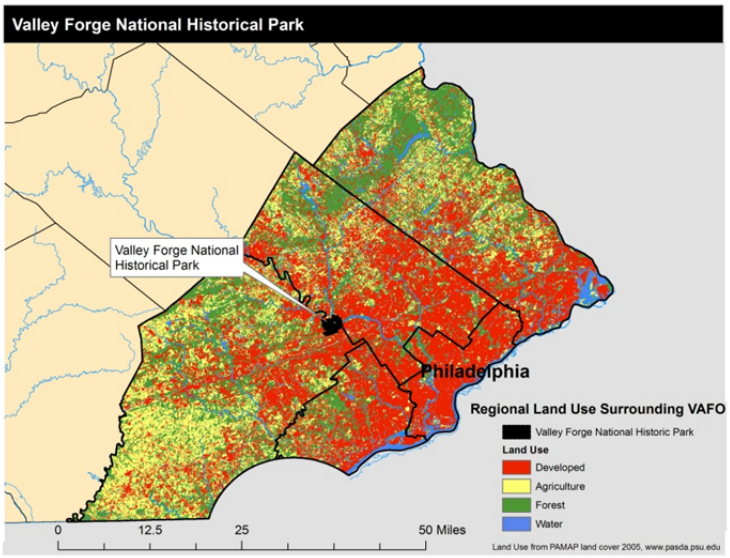


Figure 1. Map of Valley Forge National Historical Park and the land area immediately surrounding the park boundary (upper map). The lower map displays the regional land use around the park in the Greater Philadelphia five county area.

Condition Assessment Approach

Preliminary information for the NRCA, including the identification of focal resources and development of an initial indicator framework was completed by NPS staff during scoping for the Resource Stewardship Strategy (RSS) for Valley Forge NHP. Work on the RSS was initiated in

February 2008, with an interdisciplinary NPS team composed of park, regional and WASO level staff. In September 2008, an initial framework for the RSS was developed including definitions, identification of focal resources (natural and cultural) and desired resource conditions, and identification of associated resource attributes and potential indicators. Although focal resources and attributes were initially organized by management zone (e.g. parkwide, north side zone, mixed resources zone), natural resources were ultimately treated parkwide due to the minimal nature of differences in desired natural resource conditions between management zones described in the park General Management Plan (2007). Certain aspects of RSS planning (e.g. identification of strategies to address differences in desired and existing resource condition) were delayed to allow the NRCA to move forward and the RSS Coordinator was assigned an oversight role in NRCA development to ensure the process successfully provided information and data needed to inform the RSS.

The initial RSS framework was based on focal resources and desired resource conditions described in the park GMP that were organized using the NPS Inventory & Monitoring (I&M) Program's "Ecological Monitoring Framework" (EMF) (Fancy et al. 2009). The EMF was developed to organize and promote a systems-based approach to monitoring within the NPS, and itself is based on a variety of frameworks, including the EPA's Essential Ecological Attributes (EPA 2002). This 6-category framework is used to organize and report on NPS I&M Program vital signs within the following categories: 1) Air and Climate, 2) Geology and Soils, 3) Water, 4) Biological Integrity, 5) Human Use, 6) Landscapes (ecosystem pattern and processes). A vital sign is defined as "…a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources…" (Comiskey and Callahan 2008). The RSS framework also incorporated high priority vital signs and their associated metrics associated with the various natural resources of management interest and the desired resource condition statements for Valley Forge NHP.

Valley Forge NHP is included in the Mid-Atlantic I&M Network (MIDN) which consists of 10 parks distributed from southern Pennsylvania to southern Virginia, and extending from the Blue Ridge to the Coastal Plain. A total of 43 vital signs were identified for parks in the MIDN and ranked based on ecological significance and management significance on an ascending scale of 1-5 from lowest significance to highest. Vital signs ranking was also completed individually for Valley Forge NHP to capture potential differences between vital signs that are important at Valley Forge NHP but may not be a high priority when ranked across network parks. Vital signs that were in the top 20% at the park level and those selected by the park and/or MIDN for long-term monitoring reflect, to a large extent, key natural resources and park management issues at Valley Forge NHP and provide a science-based foundation for the NRCA assessment framework (Table 1). Organizing the assessment indicators into this framework helps ensure consistency with the NPS' I&M program which will serve as the primary means of collecting and analyzing data for assessing natural resource condition and trends over time, particularly for small parks with few natural resource staff.

The initial RSS framework was provided to an interdisciplinary team of graduate students and faculty affiliated with the Center for Watershed Stewardship (CWS) at The Pennsylvania State University in September 2008. A series of site visits and scoping meetings were held to ensure understanding of

park resources, threats, and management strategies, refine the NRCA framework, identify existing sources of information, and ensure coordination with the park RSS. A visit to Valley Forge NHP was organized on December 15, 2008 for the CWS team to have a first-hand perspective of the park's environmental setting and gain insight on the resources, management priorities, challenges, and constraints resource managers considered to be of greatest importance and relevance to their stewardship mission. Park staff provided copies of various management documents, baseline inventory products, research reports/theses, and environmental monitoring data files and GIS spatial data as well as contact information of NPS personnel and others (non-NPS) that could provide information and data that may contribute to assessment of existing resource conditions. Valley Forge NHP managers also provided the CWS team with a prioritized list and description of park vital signs (including attributes, indicators, and potential metrics) and an annotated bibliography.

The CWS team conducted conference calls to discuss data available through the MIDN, discuss the existing vital signs framework, existing protocols, and potential metrics under development to assess resource conditions. The MIDN Coordinator also recommended and provided copies of pertinent NPS natural resources reports, published scientific literature, and other documentation on many subjects related to natural resources within Valley Forge NHP and the Valley Creek watershed. The team also was provided access to NatureBib to acquire technical and lay publications, media articles and other background materials on natural resource management issues. Team members conducted a thorough literature review to identify the most recent published research on scientifically-grounded resource condition metrics on their assigned topics and used bibliographies from published research conducted at Valley Forge NHP and the nearby region to cross reference source materials.

Scoping sessions with CWS and NPS staff (park, regional, WASO) were held in April 2009 and August 2009. In April 2009, a two-day scoping workshop with CWS and NPS staff (park, regional, WASO) representing resource specialists from various disciplines was held at University Park to discuss terminology and definition of terms, (e.g. desired condition, indicator), the resource categories for analysis and consideration of the specific metrics or quantifiable measures to be applied in the NRCA.

A separate matrix of potential natural resource attributes, condition indicators and associated metrics are under development for application in Resource Stewardship Strategy (RSS) planning and the NRCA was introduced at the April 2009 meeting by Kristina Heister, park Natural Resource Manager, with the intent of working toward reconciling differences in the resource planning/management framework and the long term monitoring program. An important distinction of RSS/NRCA projects was the reliance on existing data and the fact that the Vital Signs suite of indicators/metrics would involve implementation of new and expanded long term monitoring efforts to acquire the data needed to employ the metrics and assess conditions. In essence, the working framework merged elements from the Valley Forge NHP General Management Plan/Resource Stewardship Strategy (Resources/Values), the Vital Signs monitoring program (Indicators), and the various metrics jointly proposed by NPS units and by the Penn State NRCA team. The working framework presented by Kristina Heister had been developed on the basis that usable data were known to exist for a high percentage of the proposed metrics (Table 1).

The April 2009 work group discussed many of the initial framework's elements and reached consensus on a substantial portion of the document. Although a final determination was not reached on several key components, the NRCA team gained valuable input from the discussions and was given a charge at the close of the session to continue to flesh out the assessment framework in coordination with Valley Forge NHP staff and NPS support entities such as Air Resources and Water Resources Division. The resource attribute matrix ultimately produced is shown as Table 1.

The issue of scale was challenging at the outset as the earliest NRCA guidelines from the NPS Natural Resources Program Center specifically described "watershed" scale assessments which in the case of Valley Forge NHP could be interpreted to mean reporting resource conditions of a 23 square mile Valley Creek watershed area. Similarly, air quality attributes within the park are determined by conditions and stressors originating from a much larger Philadelphia air-shed. Valley Forge NHP has sponsored and collaborated in many on-site natural resource research reports and monitoring efforts to generate a rich data base, however many other monitoring sites and data bases are located outside the park's boundaries. As the project went forward with additional feedback and guidance from NPS staff emphasizing the linkage of the NRCA to serve "condition-based" management objectives within park boundaries, it was determined to focus on the park landscape as the primary scale while utilizing a larger scale regional context for water and air resources considered to be transient across park boundaries. The external location of some natural resource data collection sites such as USGS stream gauges, a National Water Quality Assessment Program (NAWQA) research site on the Schuylkill River and groundwater monitoring well sites in northeast Chester County necessitated the use of data collected in close proximity to Valley Forge NHP and deemed likely to be representative of conditions in the national park. Data collected within Valley Forge NHP were given preference as source information in assessing natural resource conditions.

Upon receipt of a final draft by the Penn State team the National Park Service NRCA program Northeast Region program lead (Dr. Peter Sharpe), modified and rewrote several sections of the document in cooperation with Dr. Jim Comiskey and VAFO park staff including the overall summary matrix of the NRCA results, and the overall presentation and structure of the condition assessment information. Several metrics chosen initially by the Penn State team and park staff were removed from consideration due to data limitations and obvious redundicies with other metrics (e.g. water quantity metrics in Valley Creek, wetland assessment metrics, and forest condition metrics). The wetland and forest community assessment portions of this document were updated with the latest condition and trends information 2011-2013, and new symbology and calculations of overall resource condition were calculated following the latest draft guidance from the water resources division (Jeff Albright – July 2013).

NRCA Study Methods

A total of 65 metrics across 9 major natural resource assessment categories were included from multiple data sources (Table 1). Of these 65 metrics – 8 had no data and were included in this NRCA and overall summary table as data gaps, therefore, a sub-total of 57 metrics were used in this assessment. The 9 principle natural resource categories assessed in this document were: air resources, water resources, wetlands, forests, grasslands, native wildlife communities, geologic resources,

soundscape, and lightscape. Based on the availability of data and the relative significance of the resource, the water quality assessment for Valley Forge NHP was sub-divided into separate assessments of Valley Creek and the Schuylkill River. The native wildlife category was not comprehensive of all organisms occurring or potentially occurring within the park, but was focused instead on only those organisms for which sufficient data were available to make a reasonable assessment of current condition.

Within each major category of this assessment a description of the park resource is summarized with all relevant research and monitoring activities highlighted. The metric(s) and associated threshold criteria used to derive a current condition are described and a summary of our level of confidence in the findings is included with each evaluation. Where adequate time series data was available we have also included a summary of the general trend in the data as stable, improving, or declining.

Following recent NPS guidance (Jeff Albright – July 2013), a simple mean was calculated across the range of individual metric scores within a given natural resource category (Vital Sign Level 1 from Table 1). Each red symbol was assigned zero points, each yellow symbol was assigned 50 points, and each green symbol was assigned 100 points. The resulting sub-scores where then averaged, rounded to the nearest whole number, and applied to the scale below to determine the resulting color/condition.

Score 0 to 33	Score 34 to 66	Score 67 to 100
Red	Yellow	Green

Where possible the overall data trend was summarized in a similar manner by subtracting the total number of down arrows from the total number of up arrows. If the result is 3 or greater, the overall trend was designated as improving. If the result was -3 or lower, the overall trend was listed as deteriorating. If the result was between 2 and -2, the overall trend was determined as unchanging. Metrics with no trend assessment for the data were not included in this calculation.

The evaluation of condition against accepted metrics adopted by NPS, PADEP, USEPA and the scientific community in general is done quantitatively when supported by recent, reliable data and are rated at various scales to reflect a gradient of resource condition. Different rating scales are used for specific resources depending on the terminology and nomenclature used in the applicable metric for a given resource category. Where ever possible we have tried to utilize a consistent nomenclature based on the NPS State of the Parks and Natural Resource Condition Assessment criteria. The NPS uses the qualitative ratings of “good”, “moderate concern”, and “significant concern” to describe the status of a given metric with trends categorized as either “Improving,” “Unchanging,” or “Deteriorating.” A qualitative assessment of our confidence in the data utilized to derive at a given condition/trend is also a key component of this assessment. The categories designating data confidence are “High,” “Medium,” and “low” and are primarily based on the best professional judgment of the collaborators and NPS participants of this project, as such caution should be exercised when utilizing this information to make broad inferences about a given resources condition.

Table 1. Resource Condition Summary table for vital signs at Valley Forge National Historical Park, 2013.

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign or NRCA specific metric)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Air and Climate	Ozone	Ozone Human Health (5yr Average of annual 4th Highest 8-hr)		**79.5 ppb** based on 2006- 2010 Air Resources Division Data. The data trend is based on observations of the 4th highest 8-hr ppb values from 2003-2007, 2004-2008, and 2005-2009 which shows improving conditions based on interpolated data therefore our trend confidence is low.	≤ 60.0 ppb = Good Condition 61-75 ppb = Moderate Concern ≥ 76 ppb = Significant Concern [1]	37
Air and Climate	Ozone	Ozone Vegetation Injury / Natural Ecosystems (Sum/06)		**32 ppm-hr** based on 1999 Air Resources Division Data – interpolated for the park. No clear trend in the data appears to be evident and given the age of the information our confidence in this metric is low.	Natural Ecosystems 8 - 12 ppm-hr (foliar injury) = Significant Concern [2]	37
Air and Climate	Ozone	Ozone Vegetation Injury / Tree Seedlings (Sum/06)		**32 ppm-hr** based on 1999 Air Resources Division Data – interpolated for the park. No clear trend in the data appears to be evident and given the age of the information our confidence in this metric is low.	Tree Seedlings 10 - 16 ppm-hr (1-2% reduction in growth) = Significant Concern [2]	37
Air and Climate	Ozone	Ozone Vegetation Injury (W126)		**41 ppm-hr** based on 1999 Air Resources Division Data – interpolated for the park. No clear trend in the data appears to be evident and given the age of the information our confidence in this metric is low.	5.9 ppm-hr = Highly Sensitive Species 23.8 ppm-hr = Moderately Sensitive Species 66.6 ppm-hr = Low Sensitivity [2]	37

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign or NRCA specific metric)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Air and Climate	Ozone	Ozone Vegetation Injury (N100)		52 hr based on data collected and interpolated from 1994-1999 for the park. No clear trend in the data appears to be evident and given the age of the information our confidence in this metric is low.	6 hr = Highly Sensitive Species 51 hr = Moderately Sensitive Species 135 hr = Low Sensitivity [2]	37
Air and Climate	Wet Deposition	Wet Deposition – Nitrogen 5 Yr. Average (kg/ha/yr)		**4.9 kg/ha/yr** based on 2006-2010 5-year average estimates. The data shows an improving trend and our confidence in the assessment is medium.	< 1 = Good Condition 1-3 = Moderate Condition > 3 = Significant Concern [3]	39
Air and Climate	Wet Deposition	Wet Deposition – Sulfur 5 Yr. Average (kg/ha/yr)		**5.2 kg/ha/yr** based on 2006-2010 5-year average estimates. The data shows an improving trend and our confidence in the assessment is medium.	< 1 = Good Condition 1-3 = Moderate Condition > 3 = Significant Concern [3]	39
Air and Climate	Wet Deposition	Wet Deposition – Mercury Mean Annual Deposition ($\mu g/m^2$)		**11.4 $\mu g/m^2$** Annual Average calculated from 2000-2007. No mercury criteria index has been formally adopted by NPS ARD, therefore this Condition Status is provisional and our confidence in the data is medium – no reliable trend could be determined for the park.	No Reference Values available	41

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign or NRCA specific metric)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Air and Climate	Visibility	Haze Index – deciviews (dv)		**11.8 dv** G50 Visibility minus natural conditions from 2005-2009. Interpolation of five year averages from monitoring locations outside the park boundary suggest we rate our confidence in this assessment at medium.	< 2 dv = Good Condition 2-8 dv = Moderate Concern > 8 dv = Significant Concern [4]	43
Water (Valley Creek)	Water Quality	Seasonal Range (min/max) Daily Water Temperatures (^{0}C)		2011 data for Valley Creek indicate that the maximum monthly temperature threshold (PA Code Chapter 93 – page 93-21) was exceeded at least once every month from April-August 2011. Data are still provisional and only show one years worth of information, therefore, our confidence in this assessment is medium and no trend could be reported.	PA Code Title 25, Chapter 93 Water Quality Standards – $Temp_1$ CWF	51
Water (Valley Creek)	Water Quality	Dissolved Oxygen (mg/L)		11.79 mg/L (annual Fall baseflow values 1971-2007). Trend is stable but based on fall data which doesn't reflect potential diminishment of DO levels in summer months. Confidence in this assessment is medium.	PA Code Title 25, Chapter 93 Water Quality Standards – DO_4 HQ-CWF/EV waters.	53
Water (Valley Creek)	Water Quality	pH		Annual fall range between 6 and 9 from 1971-2007 suggesting good condition and a stable trend. Confidence in this assessment is high.	PA Code Title 25, Chapter 93 Water Quality Standards – CWF Page 93-20	54

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Water (Valley Creek)	Water Quality	Specific Conductivity (µS/cm)		Annual values from fall sampling (1971-2009) indicate a gradual upward trend above the recommended threshold value. Due to the limestone influence high values are expected, though this situation should continue to be monitored based on the annual trend. High data confidence.	Range of 15-500 µS/cm [5]	55
Water (Valley Creek)	Water Quality	Alkalinity (mg/L as concentration of $CaCO_3$)		Annual fall sampling values above 150 mg/L from 1982-2009. Confidence in Assessment is good.	PA Code Title 25, Chapter 93 Water Quality Standards (minimum standard) and Botts (2005) [6]	56
Water (Valley Creek)	Water Quality	Total Dissolved Solids		No TDS standard available for Valley Creek. Potable water sources in PA are required to not exceed 500 mg/L as a monthly average and not to exceed a maximum value of 750 mg/L	PA Code Title 25, Chapter 93 Water Quality Standards	57
Water (Valley Creek)	Water Quality	Ammonia (mg/L)		Annual fall sampling from 1981-2006 shows consistent values below the 0.2 mg/L threshold. Due to potential seasonal variation not captured by this dataset our confidence in this assessment is medium.	≤ 0.02 mg/L [7]	58
Water (Valley Creek)	Water Quality	Chloride (mg/L)		Annual fall sampling from 1981-2006 shows consistent values below the PADEP potable water supply threshold of 250 mg/L maximum value. Due to potential seasonal variation not captured by this dataset (e.g. winter road salt run-off) our confidence in this assessment is medium.	< 250 mg/L [8]	60

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Water (Valley Creek)	Water Quality	Nitrite/Nitrate (mg/L)		Annual fall sampling from 1981-2003 shows consistent values below the PADEP potable water supply threshold of 10 mg/L maximum value. Due to potential seasonal variation not captured by this dataset our confidence in this assessment is medium.	< 10 mg/L - PA Code Title 25, Chapter 93 Water Quality Standards	61
Water (Valley Creek)	Water Quality	Phosphorus (mg/L)		Annual fall sampling from 1981-1992 shows consistent values below our proposed threshold value of 0.1 mg/L maximum value. Confidence in the data is low as seasonal variation and data age may not reflect actual conditions.	< 0.1 mg/L = Good Condition >0.1 mg/L = Significant Concern [9]	62
Water (Valley Creek)	Water Quality (Biota)	Aquatic Macroinvertebrates Limestone Stream – Index of Biotic Integrity (IBI)		**Average Index score of 59.0** putting it into the moderate concern range of 46-68. Based on the age of the data and lack of time series points for this score there is no trend to report and our confidence is medium. Trends for this metric were not calculated.	≥ 69 = Good Condition 46-68 = Moderate Concern < 46 = Significant Concern [10]	66
Water (Valley Creek)	Water Quality (Biota)	Aquatic Macroinvertebrates Brillouin's Diversity Index (BDI)		**Mean score of 2.44** based on fall data collected from 1973-2001. Age of data and general time of collection (Fall Sampling) limit our confidence to medium. Trends for this metric were not calculated.	3.0-5.0 = Good Condition 1.0-3.0 = Moderate Condition < 1.0 = Significant Concern [11]	66

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Water (Valley Creek)	Water Quality (Biota)	Aquatic Macroinvertebrates Hilsenhoff Biotic Index (HBI)		**Mean score of 4.92** based on fall data collected from 1973-2001. Age of data and general time of collection (Fall Sampling) limit our confidence to medium. Trends for this metric were not calculated.	0-4.5 = Good Condition 4.51-8.51 = Moderate Concern 8.51-10 = Significant Concern [12,14]	66
Water (Valley Creek)	Water Quality (Biota)	Aquatic Macroinvertebrates Shannon Diversity Index (SDI)		**Mean score of 1.80** based on on fall data collected from 1973-2001. Age of data and general time of collection (Fall Sampling) limit our confidence to medium. Trends for this metric were not calculated.	Values range from 0 – 4.9 using natural log (ln). Higher scores suggest greater diversity [13]	66
Water (Valley Creek)	Water Quality (Biota)	Aquatic Macroinvertebrates Evenness		**Mean score of 0.60** based on fall data collected from 1973-2001 Age of data and general time of collection (Fall Sampling) limit our confidence to medium. Trends for this metric were estimated indicated a generally stable trend.	≥ 0.59 = Good Condition [13] [14] [15]	66
Water (Valley Creek)	Water Quality (Biota)	Aquatic Macroinvertebrates %EPT Taxa		**Mean score of 46.80%** based on fall data collected from 1973-2001 Age of data and general time of collection (Fall Sampling) limit our confidence to medium. Trends for this metric suggested a deteriorating trend	25% = Good Condition < 25% = Significant Concern [11] [14] [15] [16]	66

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Water (Valley Creek)	Water Quality (Biota)	Aquatic Macroinvertebrates Total EPT Taxa		**Mean score of 6.32** based on fall data collected from 1973-2001 Age of data and general time of collection (Fall Sampling) limit our confidence to medium. Trends for this metric suggested an improving trend	≥ 8.0 = Good Condition ≤ 8.0 = Significant Concern [11] [14] [15] [16]	66
Water (Valley Creek)	Water Quality (Biota)	Aquatic Macroinvertebrates %Dominant Taxa		**Mean score of 39.35%** based on fall data collected from 1973-2001 Age of data and general time of collection (Fall Sampling) limit our confidence to medium. Trends for this metric suggested an improving trend.	< 47% = Good Condition ≥ 47% = Significant Concern [11] [14] [15] [16]	66
Water (Valley Creek)	Water Quality (Biota)	Aquatic Macroinvertebrates Total Taxa		**Mean score of 17.64** based on fall data collected from 1973-2001 Age of data and general time of collection (Fall Sampling) limit our confidence to medium. Trends for this metric were estimated suggested an improving trend.	≥ 22 Good Condition [11] [14] [15] [16]	66
Water (Valley Creek)	Water Quality (Biota)	Fish Communities Brown Trout Biomass		**2002 Biomass of 57.31 kg/ha** is above the 40 kg/ha threshold value established by the PFBC for Class A Wild Trout Waters. This value represents a steep decline from the 1990 estimate of 120.21 kg/ha. Assuming comparability of sampling methodologies this represents a declining trend and should be monitored.	> 40 kg/ha = Good Condition < 40 Kg/ha = Significant Concern [17] [18] [19]	75

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Water (Valley Creek)	Water Quality (Biota)	Fish Communities Index of Biotic Integrity (IBI)		**2003 Fish IBI score of 39** falling within the moderate concern category. Age of data and discrepencies in sampling methods precluded reliable trend analysis and suggested low confidence in this assessment.	≥ 45 = Good Condition 34-44 = Moderate Concern 12-33 = Significant Concern [20]	75
Water (Schuylkill River)	Water Quality	Temperature (^{0}C)		No Data	See $Temp_2$ Critical Monthly Values Jan-Dec. PA Code Title 25, Chapter 93 (WWF – DO_2)	80
Water (Schuylkill River)	Water Quality	Dissolved Oxygen (mg/L)		**Average value of 10.8 mg/L** (1970-2004) indicates a good condition and Improving trend. Age of last recorded value (2004) places this data in the medium confidence level category.	Minimum Daily Average = 5.0 mg/L and minimum value 4.0 mg/L PA Code Title 25, Chapter 93 (WWF – DO_2)	80
Water (Schuylkill River)	Water Quality	Acidity (pH)		No Data	Minimum 6.0 Maximum 9.0 PA Code Title 25, Chapter 93 (WWF)	81
Water (Schuylkill River)	Water Quality	Specific Conductivity (µS/cm)		No Data	No WWF standard in PA Code Title 25, Chapter 93 (WWF)	82

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Water (Schuylkill River)	Water Quality	Alkalinity (mg/L as concentration of $CaCO_3$)		No Data	Minimum 20 mg/l as CaCO3, except where natural conditions are less. PA Code Title 25, Chapter 93 (WWF)	82
Water (Schuylkill River)	Water Quality	Turbidity/Total Suspended Solids (mg/L)		Median score of 2 mg/L data show a long term and stable trend. Our confidence in the data is high.	40 mg/l as a monthly average value. PA Code Title 25, Chapter 93 (WWF)	83
Water (Schuylkill River)	Water Quality	Ammonia (mg/L)		No Data	See - PA Code Title 25, Chapter 93 (WWF)	84
Water (Schuylkill River)	Water Quality	Chloride (mg/)L		No Data	Maximum 250 mg/L for PWS See - PA Code Title 25, Chapter 93 (WWF)	84
Water (Schuylkill River)	Water Quality	Nitrate+Nitrogen (mg/L)		Short term median score 3.2 mg/L (1990-2005) **Long Term median score 3.2 mg/L** (1970-2005). The data show a stable trend and our confidence in this information is high.	Maximum 10 mg/L PA Code Title 25, Chapter 93 (WWF)	85

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Water (Schuylkill River)	Water Quality	Phosphorus (mg/L)		Short term median score 0.23 mg/L (1990-2005) **Long term median score 0.23 mg/L** (1970-2005). Data show an improving trend. Confidence in this assessment is high.	Maximum median value 0.1 mg/L	86
Water (Valley Creek)	Water Quality (Habitat)	Stream Habitat Quality (EPA/DEP/RBP aggregate score)		**Average aggregate score 124.8** (2002 data) – Moderate Condition. Based on data age and lack of long term monitoring plan confidence in data is medium.	200-151 = Good Condition 150-101 = Moderate Concern ≤ 100 = Significant Concern [21]	87
Water (Valley Creek)	Water Quantity (Habitat)	Mean Annual Discharge (cfs)		**Mean Annual Discharge** ≥ 33.45 (1983-2009) and lowest annual measurement above Q7-10 guidelines of 10.7 cfs. Confidence in data is medium the trend appears to be stable, but there is considerable variation in the data.	Park Established Mean Annual Threshold of 33.45 cfs based on the (1983-2009) historic data. Q7-10 minimum flow threshold from PADEP.	93
Water (Parkwide Resources)	Water Quality (Habitat)	Riparian Buffer width and composition (Grass vs. Forested)		91% of VAFO waterways possess a forest buffer of at least 100 feet in width	≥100 foot forested/grassland buffer = Good condition [22]	97
Water (Parkwide Resources)	Water Quality	Impaired Waters Designations (303d Impaired Waters)		6.18 miles of a total of 13.95 miles within VAFO park boundaries on 303d list, confidence in data is medium, no trend analysis possible	Park Goal – no miles within VAFO boundary on 303d list.	98

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Biological Integrity	Focal plant communities	Wetlands Extent of WetlandsTotal Area (ac)		A detailed parkwide wetland inventory was published in 2012 and found 51 individual palustrine wetlands covering 63.96 acres. Confidence in the data is high and based on the 2012 inventory the wetland extent in park is considered to be stable.	NPS Director's Order #77.1 Goal – No Net Loss of Wetland Habitat	99
Biological Integrity	Focal plant communities	Forests - Regeneration (Tree Seedlings / m^2)		**Seedling regeneration stocking index < 2 seedling / m^2** - shows a slight upward trend between Census 1 (2007) and Census 2 (2011 and 2012). Confidence in data is medium pending the results of continued monitoring.	≥ 8 Seedlings / m^2 = Good Condition 7.9-2.1 Seedlings / m^2= Moderate Concern ≤ 2 Seedlings / m^2 = Significant Concern	106
Biological Integrity	Focal plant communities	Forests Soil Chemistry (Ca/Al ratio)		**Median Ca:Al ratio of 1.56** [2012 Data] – The extraction method utilized in this analysis is currently under review – our confidence in the data is thus medium. No trend data available, medium confidence in data.	Good: Ca:Al > 4 in O-A horizon Cronan and Griegel (1995) Mod. Concern: Ca:Al < 4 in O-A horizon	106
Biological Integrity	Focal plant communities	Forests Soil Chemistry (Median C:N ratio)		**C:N ratio of 20.31** [23]. No trend data available, medium confidence in data.	C:N ratio > 25 in O and A horizon or in upper depth = Good Condition 20-25 = Moderate Concern <20 = Significant Concern	106

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Biological Integrity	Focal plant communities	Forests – Invasive Species (Average number of key species per plot)		**2.10 invasive exotic indicator species per plot** [23]. Limited trend data available that suggests stable conditions. Medium confidence and a stable trend in the data pending continued monitoring.	< 0.5 invasive exotic indicator species per plot = Good Condition 0.5 to < 3.5 key species per plot = Moderate Concern ≥ 3.5 key species per plot = Significant Concern	106
Biological Integrity	Focal plant communities	Forests –Coarse Woody Debris (% of Live tree Volume)		**19% CWD volume to live tree volume** [23]. Limited trend data available that suggests stable conditions. Medium confidence and a stable trend in the data pending continued monitoring.	CWD volume > 15% of live tree volume = Good Condition	106
Biological Integrity	Focal plant communities	Forests –Snags (Snags / ha ≥ 30 cm)		**7.14 snags / ha ≥ 30 cm** [23]. Limited trend data available that suggests stable conditions. Medium confidence and a stable trend in the data pending continued monitoring.	>10% trees ≥ 30 cm are snags based on natural disturbance in Northeast Region = Good Condition	106
Biological Integrity	Focal plant communities	Forests - Stand Structure (% Late Succession)		**58% late successional forest structure** across the park [23]. Limited trend data available that suggests stable conditions. Medium confidence and a stable trend in the data pending continued monitoring.	≥25% late successional forest = Good Condition	106
Biological Integrity	Focal plant communities	Forests - Canopy Tree Condition (Condition Index)		**71% of plots are classified as having Good canopy tree condition** [23]. Limited trend data available that suggests stable conditions. Medium confidence and a stable trend in the data pending continued monitoring.	Index based on tree and leaf condition, and the presence and type of pests and pathogens	106

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Biological Integrity	Focal plant communities	Grasslands (Native Species Occurrence % Cover)		**25% proportion of sample plots possessing meadow/grassland specialists**. Based on (Draft Latham 2009 report). No trend data available our confidence in the assessment is high.	≥ 80% Proportion of sample plots = Good Condition 70-79% Proportion of sample plots = Moderate Concern < 70% Proportion of sample plots = Significant Concern	112
Biological Integrity	Focal plant communities	Grasslands (Meadow Patch Size (ac))		60% of the fields within VAFO are ≥100 ac in size. 37% of the fields fall in the moderate concern category (100-12 acres) and 3% of the remaining fields fall into the (<12 acre range) and are significant concern. Confidence in the data is high and the trend is stable (no significant land use changes occurring or planned)	If ≥ 50% of the total grassland area within the park ≥ 100 acres = Good Condition If < 100-12 acres = Moderate Concern If < < 12 acres = Significant Concern [24]	112
Biological Integrity	Infestations and Disease	Pests and Pathogens Occurrence		Forest pests are present within the park. Based on canopy tree condition the Hemlock Wooly Adelgid and past disturbance from Gypsy Moths are cause for concern, but currently are not exhibiting a strong adverse impact on forest health at VAFO. Our confidence in the data is medium – stable trend.	Park Goal – No pests occur within the park limits	108

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Biological Integrity	Focal Species or Communities	Amphibians (Species Richness)		≥ 15 amphibian species present based on a parkwide inventory. No long term data available that was collected using a consistent sampling scheme. Our confidence in the data is low.	Park goal – no net loss of amphibian species	114
Biological Integrity	Focal Species or Communities	Reptiles (Species Richness)		≥ 15 reptile species present based on a parkwide inventory. No long term data available that was collected using a consistent sampling scheme. Our confidence in the data is low.	Park goal – no net loss of reptile species	114
Biological Integrity	Focal Species or Communities	Forest Birds (BCI Forest Habitat)		**Mean BCI Score – 0.59 ± 0.017**, just under the threshold value of 0.6 for a "Good" condition score. No trend data available therefore our confidence is medium.	> 0.6 BCI Score [25]	118
Biological Integrity	Focal Species or Communities	Grassland Birds (BCI Grassland Habitat)		**Mean BCI Score – 47.8 ± 1.64**, this score is the baseline value by which the park has set as its desired future condition assessment score	≥ 47.8 BCI Score [26]	118
Biological Integrity	Focal Species or Communities	White-tailed deer (Population Density)		**Deer/mile^2 = 54** (bases on 2012 data), score is a marked improvement from 2009 density estimates of 241 Deer/mile^2 indicating an improving trend. Our confidence in the dat123a is high.	Low Deer Density = 13-21 Deer/mile^2 = Good Condition Moderate Deer Density = 22-55 Deer/mile^2 High Deer Density = 56-64 Deer/mile^2 [27]	120

Priority Resource or Value (Vital Sign Level 1 Category)	Indicator of Condition (Vital Sign Level 2 Category)	Specific Measure (MIDN Vital Sign)	Condition Status/Trend	Rationale and Data Sources for Resource Condition	Reference Condition and Data Source	Page
Geology and Soils	Geology	Paleontological Resources (# of sites in good condition)		# of paleontological features within the park protected and monitored and preserved for park interpretation	100 % of paleontological resources documented, protected, and monitored following PRPA guidelines = Good Condition	123
Geology and Soils	Geology	Karst Features (# of sites protected)		# of karst features within the park protected and monitored for potential hazard	100% of karst features in park identified and monitored = Good Condition	122
Soundscape	Noise	Noise Abatement (FHWA Leq (h)*)		**Noise levels – 49-58 dBA.** Below 60-110 dBA threshold for Interpretative/Living History talks. Based on a single two year study 2001-2003 and no follow up monitoring, therefore our confidence in the data is low.	< 60-110 dBA Interpretative Living (Good) see Table 20 [28]	127
Lightscape	Night Sky	Bortle Dark Sky Scale		No Data	Class 7 – Bortle Dark Sky for Sururban/Urban Transition or Full Moon	129

Symbol Key Legend:

Condition Status		Trend in Condition		Confidence in Assessment		Responsibility for Updating Future Data	
	Warrants Significant Concern		Condition is Improving		High		Park Responsibility or Co-Responsibility
	Warrants Moderate Concern		Condition is Unchanging		Medium		Non-Park Responsibility
	Resource is in Good Condition		Condition is Deteriorating		Low		
	Condition Status Unknown; Consequently, Trend is also Unknown and Confidence is Low						

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Chapter 2. Air Resources

Special note – During the State of the Parks workshop held at VAFO November 2013, updated Air resources division data was presented. That information was used to inform the current condition and trends at VAFO for the state of the parks workshop and as such the information presented herein should be considered as background only and not the most up to date source of air quality within the park. The reader is referred to the State of the Parks report for VAFO for the most recent published data summary and condition.

Air Quality

Ambient air quality and attributes such as ozone concentrations, wet and dry deposition of chemical compounds, and visibility have important implications for the vegetation, soil and water chemistry, and aquatic organisms in the park as well as cultural resources such as monuments, and potential effects on visitor health and enjoyment of Valley Forge NHP's cultural amenities and natural assets. Typical of the other NPS units in the northeastern US and mid-Atlantic region, the precursors which directly influence air quality locally at Valley Forge NHP result from anthropogenic sources associated with the densely populated urban area and the surrounding industrialized metropolis that extends the length of the Atlantic Coast from Washington D.C. to Boston, Massachusetts. Anthropogenic sources also extend westward to the upper Ohio Valley with its concentration of fossil-fueled electrical power generation plants. Given the large regional scale involved to influence and manage air resources conditions, NPS Air Resources Division (ARD) collects and analyzes on-site and off-site monitoring data for a set of air quality parameters from several national networks and maintains and periodically updates long term data bases to assess air quality conditions and trends. These data are used to assist park managers in evaluating and addressing air quality problems and assist the state and the U.S. Environmental Protection Agency (US EPA) determine compliance with National Ambient Air Quality Standards (NAAQS) which were established to protect human health and the environment. Six NAAQS have been established, including four of particular concern to NPS natural resource managers: ozone, particulate matter, nitrogen oxide (NO), and sulphur oxide (SO). The NAAQS "primary" standards are human health related and "secondary" standards were created to protect the environment including biological resources such as vegetation.

The ARD monitoring program has three primary components: gaseous pollutants (ozone), atmospheric deposition of wet and dry pollutants (SO and NO compounds, mercury, and particulate matter), and visibility. A Pennsylvania Atmospheric Deposition Monitoring Network site funded by Pennsylvania Department of Environmental Protection (PA DEP) has been in operation at Valley Forge NHP since 1982. A Mercury Deposition Network (MDN) site also funded by PA DEP established at Valley Forge NHP in 1998 collects precipitation analyzed for mercury. Ozone and particulate matter monitoring data collected by PA DEP are acquired at Norristown, Pennsylvania within 5 km of Valley Forge NHP. Visibility is monitored by the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. The closest IMPROVE monitor to Valley Forge NHP is 115 km southeast at the Edwin B. Forsythe National Wildlife Refuge in New Jersey.

Ozone

Relevance and Context

Ground-level ozone is produced in the atmosphere when volatile organic compounds react with nitrogen oxides in the presence of sunlight (Maniero 2004). Ozone is a respiratory health concern for human visitors to the park, and it is also a concern to the vegetation in the park (Lefohn et al. 1997). Major sources of ozone-forming chemicals are industrial emissions, motor vehicle exhausts, gasoline vapors, and chemical solvents. Ozone levels within Valley Forge NHP are mainly contributed by the urban areas that surround the park and a regional airshed extending to the industrial Ohio River Valley. Ozone is a respiratory concern for human users in the park who exert themselves by physical activity such as hiking or jogging. Plant leaves exposed to ozone demonstrate a visible spotting on the upper surface of the leaves indicating reduced plant vigor (Maniero 2004).

The ARD interpolated ozone data within at least a 30 km monitoring distance for all NPS sites to help determine air quality conditions in the NPS units. ARD uses all available monitoring data over a five-year period to generate interpolations for NPS units in the continental United States. The interpolated values are then used to determine and assign one of three condition index values (Significant Concern, Moderate Condition, or Good Condition) for each type of air quality data collected by the networks. The primary ozone standard of 75 parts per billion (ppb) is the benchmark for the condition index values and range of concentration levels shown in Figure 2 and Table 2.

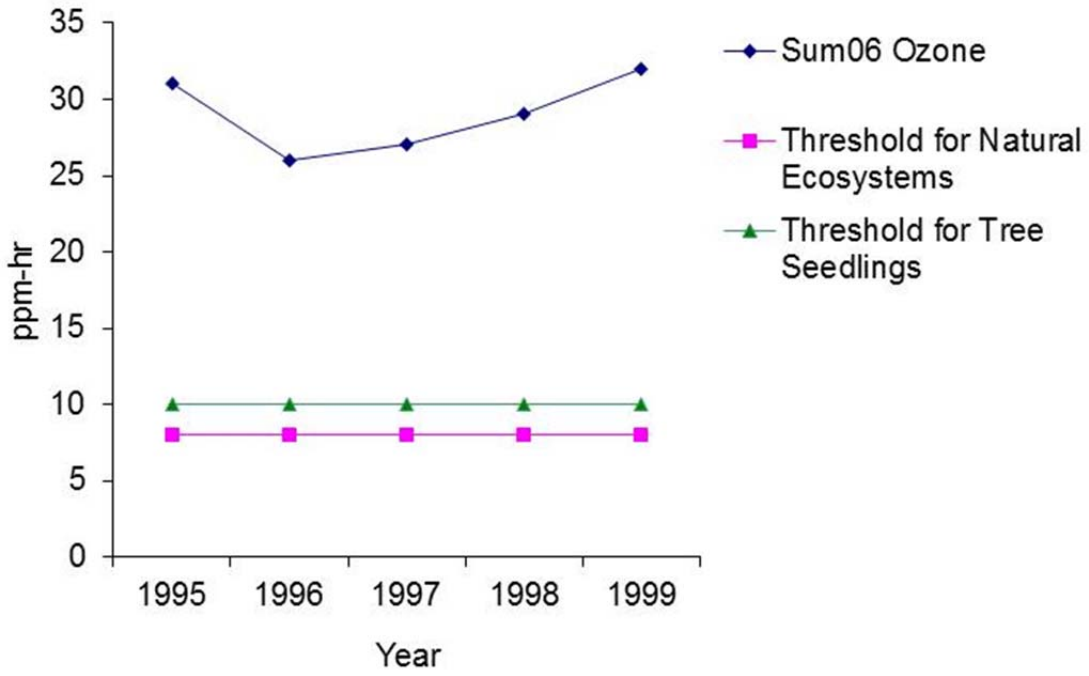

Figure 2. Sum06 ozone levels with thresholds for natural ecosystems and tree seedlings (MIDN 2004).

Table 2. Threshold values assessing ozone condition relative to regulatory primary standard as determined by the NPS ARD.

Ozone Condition	Ozone Concentration
Significant Concern	≥ 76 ppb
Moderate Condition	61-75 ppb
Good Condition	≤ 60 ppb

Methods

The procedure for assigning these condition categories is described on the ARD website at http://www.nature.nps.gov/air/planning/index.cfm?tab=2#TabbedPanels1 in the report entitled "Rating Air Quality Conditions". As described in the report, to produce an estimate of ozone conditions at NPS units, the five year average of the annual 4th highest 8 –hour ozone concentration is determined from the monitoring network interpolated data described above. If the resulting five-year average is greater than or equal to 76 ppb (threshold value for "non-attainment status of the current NAAQS), the condition of *Significant Concern* is assigned to that NPS unit. *Moderate Condition* for ozone is assigned to NPS units in compliance with NAAQS and with concentrations greater than 80 percent of the standard (61-75 ppb). *Good Condition* is assigned to NPS units with concentrations less than 80 percent of the standard (60 ppb or less). The ARD protocol of a 5-year average deviates from the 3-year average used to determine attainment of the NAAQS standard, because a 5-year average may have more utility to assess condition trends over time.

The EPA primary ozone standard was established at 75 ppb in 2008 and was under review in 2011 to be more protective of human health. The primary and secondary ozone standards are identical at present, however in 2010 the EPA proposed more stringent revisions to both standards The proposed new standards require a different methodology (Ozone W126 statistic expressed as ppm-hours) to determine index values for the secondary ozone standard to better protect sensitive vegetation from adverse affects from cumulative ozone exposure during the summer months when daytime ozone concentrations are highest. The proposed more stringent primary and secondary standards have been reviewed by the EPA Clean Air Scientific Advisory Committee (US EPA 2010). The public comment period on the proposed revisions closed in spring 2010 and it was expected that EPA would promulgate the new more stringent standards by August 2010. However, the proposed new standards remain under review at this writing. Once new standards are promulgated, the NPS will revise its guidance for evaluating ozone conditions.

As noted above, in addition to the primary human health standard, vegetation sensitivity to ozone is considered in rating air quality condition at Valley Forge NHP. Some plant species are more sensitive than humans and the current 2008 primary standard is not protective of some vegetation, including sensitive species which may function as bioindicators of foliar injury (Table 3). A risk assessment completed in 2004 rated NPS units at *low, moderate, or high risk* for ozone injury to vegetation. The assessment was based on an integrated model of three variables: (1) the presence of highly sensitive species; (2) ozone exposures over the growing seasons which significantly exceed the thresholds for foliar injury and; (3) soil moisture factors which foster gas exchange and the uptake of ozone by plants (Mid-Atlantic Network, 2004). Ozone exposure data for 1995 through 1999 were obtained from on-site monitoring where available or, for most MIDN units like Valley Forge NHP that lack on-site ozone monitors, data were used from nearby monitors. Ozone exposure was then statistically estimated using a technique known as kriging.

Three indices were applied to the ozone exposure variable in the 2004 risk assessment because a consensus does not exist within the scientific research community on a single index to characterize a threshold for foliar injury. The methodology and threshold values produced by each index (referred to as Sum, W126, and Designated N) and the detailed discussion of the indices may be found in the source ARD report (Mid-Atlantic Network, 2004). The soil moisture variable of the risk assessment model was considered to be the most critical among many environmental variables. Since site-specific soil moisture data are not available for Valley Forge NHP, the USDA Palmer Z Index, a measure of the short-term departure of soil moisture from the long term mean of the area, was selected for the risk assessment.

Table 3. Plant species sensitive to ozone in Valley Forge National Historic Park. * denotes species recommended as bioindicator species (Mid-Atlantic Network 2004).

Family	Latin Name	Common Name
Simaroubaceae	*Ailanthus altissima*	Tree-of-heaven*
Asclepiadaceae	*Asclepias syriaca*	Common milkweed*
Fabaceae	*Cercis canadensis*	Redbud*
Oleaceae	*Fraxinus americana*	White ash*
Hamamelidaceae	*Liquidambar styraciflua*	Sweetgum
Magnoliaceae	*Liriodendron tulipifera*	Yellow-poplar*
Vitaceae	*Parthenocissus quinquefolia*	Virginia creeper
Hydrangeaceae	*Philadelphus coronarius*	Sweet mock-orange
Platanaceae	*Platanus occidentalis*	American sycamore*
Rosaceae	*Prunus serotina*	Black cherry*
Anacardiaceae	*Rhus copallina*	Flameleaf sumac
Fabaceae	*Robinia pseudoacacia*	Black locust
Rosaceae	*Rubus allegheniensis*	Allegheny blackberry*
Asteraceae	*Rudbeckia laciniata*	Cut-leaf coneflower*
Caprifoliaceae	*Sambucus canadensis*	American elder*
Lauraceae	*Sassafras albidum*	Sassafras
Vitaceae	*Vitis labrusca*	Northern fox grape*

Threshold Criteria

The representative ozone plant injury thresholds established were as follows:

Sum

The running 90-day maximum sum of the 0800-2000 hourly ozone concentrations equal to or greater than 0.06 parts per million (ppm). Index is in cumulative ppm-hr.

Natural Ecosystems	8-12 ppm-hr	(foliar injury)
Tree Seedlings	10-16 ppm-hr	(1-2% reduction in growth)
Crops	15-20 ppm-hr	(10% reduction in 25-35% of crops)

W126 and N100

A cumulative index of exposure that uses a weighting function to give added significance to higher concentrations of ozone while retaining and giving less weight to mid and lower concentrations. The number of hours over 100 ppb (N100) is also considered in assessing the possible impact of the exposure. The W126 index is in cumulative ppm-hr.

	W126	N100
Highly Sensitive Species	5.9 ppm-hr	6
Moderately Sensitive Species	23.8 ppm-hr	51
Low Sensitivity	66.6 ppm-hr	135

The procedure for site specific assessment of the risk of foliar ozone injury at Valley Forge NHP was described as follows (excerpted from Mid-Atlantic Network 2004):

"The risk of foliar ozone injury…was determined by analyzing the plant, exposure and moisture data. The process was not quantitative, but based upon three primary evaluations: the extent and consistency by which the ozone injury thresholds were exceeded by the Sum06 and W126 exposure indices, the nature of the relationship between exposure and soil moisture, and the extent to which soil moisture conditions constrained the uptake of ozone in high exposure years…Sites receiving a risk rating of *high* have a probability of experiencing foliar injury in most years, while those ranked *low* are not likely to receive injury in any year. A rating of *moderate* was assigned to sites where analysis indicated injury was likely to occur at some point in the five-year period, but the chance of injury occurring consistently was low."

Current Condition

The most recent ozone primary standard value is reported by ARD for the period 2006-2010 on the NPS ARD website at http://www.nature.nps.gov/air/Maps/Air/IM_materials.cfm. For Valley Forge NHP, the reported value is 79.5 ppb which falls within the Significant Concern category. The value is consistent with the non-attainment status of Chester and Montgomery Counties surrounding the park. The reported value is consistent with the longer term trend in improving ambient ozone conditions at Valley Forge NHP (82.97 ppb in 2003-2007, 82.8 ppb in 2004-2008, and 81.5ppb in 2005-2009) and is consistent with a longer term trend of improving ambient ozone conditions at Valley Forge NHP reported by ARD to be on the order of a 2.00 ppb reduction (statistically significant p-value) in ambient ozone concentrations over the 1998-2008 timeframe. (NPS ARD 2010).

The EPA 2008 Air Quality Index (AQI) Reports for Chester and Montgomery County indicate that ozone was the "main pollutant" (defined as the pollutant with the highest daily value for a given day's AQI) on 196 days in the region around Valley Forge NHP (US EPA 2009).

The 2004 results of the foliar injury risk assessment (Mid-Atlantic Network, 2004) ranked Valley Forge NHP to be in the High Risk category based on the

evaluation of estimated ozone exposure data for five years compared to the three ozone injury thresholds. The Sum06 index values significantly exceeded the threshold for foliar injury in natural ecosystems and for tree seedling growth each of the five years (Figure 2). Likewise, the W126 index values exceeded the thresholds for both Highly Sensitive and for Moderately Sensitive plant species each of the five years (Table 4). The N100 concentration values are also above the threshold for foliar injury to Highly Sensitive species each of the five years (Table 4).

Table 4. Estimated annual ambient ozone exposure values at Valley Forge NHP from 1995-1999 affecting natural ecosystems and tree seedlings (Sum06 index) and highly sensitive and moderately sensitive plants (W126 and N100 indices) (NPS ARD 2004).

Index	Year				
	1995	1996	1997	1998	1999
Sum06	31	26	27	29	32
W126	35.8	28.8	34.0	41.5	40.7
N100	44	17	39	30	52

In summary, Valley Forge NHP is subject to high ambient ozone concentrations above accepted air quality thresholds that can consistently produce adverse impacts on both human health and a wide range of plant species. Those adverse impacts affect Highly Sensitive and Moderately Sensitive plant species as well as tree seedlings so that native plant diversity, forest regeneration, and related natural ecosystem processes are negatively impacted. The long term trend shows slight reductions in ozone concentrations at a pace which would require several decades to approach attainment of the 2008 primary standard.

Wet Deposition of Nitrogen and Sulphur

Relevance and Context

The National Atmospheric Deposition Program/ National Trends Network (NADP/NTN) is a network of precipitation monitoring sites from across the nation. The program is a collaboration of many federal agencies, including the NPS. The Valley Forge NHP site established in 1982 is one of a relatively few NADP sites located within a park boundary. Acid weathering associated with wet deposition can have cultural and facilities impacts to park resources such as the National Memorial Arch (featured here) as well as the natural resources at Valley Forge. To aid in the protection and management of these sensitive park resources the NADP/NTN network collects data on the chemistry of precipitation in order to monitor geographical and temporal long-term trends. The precipitation at each station is collected weekly, and then sent to the Central Analytical Laboratory in Illinois where it is analyzed for hydrogen (acidity as pH), sulfate (SO4), nitrate (NO3), ammonium (NH4), and several base cations (Maniero 2004). The NADP/NTN has also expanded its sampling to include the Mercury Deposition Network (MDN) formed in 1996, which currently has over 100 sites, including a Valley Forge NHP site which began operating in 1999. The MDN collects weekly

samples of precipitation, which are analyzed for total mercury. The MDN provides a nationally consistent survey of mercury wet-deposition concentrations and fluxes, identifies long-term pattern changes over time and space, and provides high quality data for estimation of wet-deposition rates locally or between sites.

Methods

The specific wet deposition parameters assessed for Valley Forge NHP are limited to nitrogen, sulphur and mercury compounds because of their prevalence in the region and potential relevance to Valley Forge NHP biota, ecosystem processes, and natural resource desired conditions identified by park managers. The environmental implications of the acids, nutrients and toxins associated with wet deposition involve complex and interrelated mechanisms affecting soil and groundwater chemistry, nutrient cycling and contaminant loadings, altered micro-fauna and flora and aquatic community species composition, direct toxicity in some cases, forest regeneration problems, and human health concerns from consumption of contaminated fish tissue.

Threshold Criteria

ARD resource condition scores of atmospheric deposition of nitrogen (N) and sulphur (S) compounds are derived from wet deposition data because dry deposition data are not generally available. Natural background deposition estimates and deposition effects on certain sensitive ecosystems are considerations in rating wet deposition conditions. Estimates of natural background deposition within total deposition are approximately 0.50 kg/ha/yr in the eastern United States. For wet deposition only, this is roughly equivalent to 0.25 kg/ha/yr in the eastern United States. Some sensitive ecosystems such as poorly buffered uplands of the Appalachian Mountains and Allegheny Plateau respond negatively to wet deposition of N and S of about 1.5 kg/ha/yr (Fenn et al. 2003 BioScience 53: 404-420 cited in NPS ARD 2010).

A determination that no scientific evidence is currently available demonstrating that wet deposition below 1 kg/ha/yr causes harm to ecosystems has been adopted as the basis for rating wet deposition conditions of both N and S (NPS ARD 2010). Accordingly, parks with wet deposition less than 1 kg/ha/yr are rated to be in *Good* condition; parks in the range of 1-3 kg/ha/yr are rated to be in *Moderate* condition; parks with wet deposition greater than 3 kg/ha/yr are considered to have a *Significant Concern* for deposition of N and S.

Current Condition

For the 2006-2010 5-year Average Air Quality Estimates (NPS/ARD 2011), Total-N and Total-S deposition at Valley Forge NHP is reported as 4.9 kg/ha/yr and 5.2 kg/ha/yr, respectfully. Both values fall into the Significant Concern category. These values are generally in line with recent trends since 2001 showing steadily improving levels of wet deposition of N and S (Table 5). A MIDN/I&M report cited PA NAPD data collected at Valley Forge NHP since 1982 to conclude that "…wet concentration and deposition of SO4 have decreased substantially, wet concentration and deposition on NO3 have decreased slightly…" (Maniero 2004). These findings suggest an improving trend with regards to nitrogen and sulfur deposition at Valley Forge NHP.

Table 5. Total Nitrogen and Sulfur wet deposition (kg/ha/yr) at Valley Forge NHP derived from four 5-year average air quality estimates (NPS ARD 2011). All values in Significant Concern category.

Years	Total N Wet Deposition	Total S Wet Deposition
2001-2005	5.65	6.41
2003-2007	5.70	6.38
2004-2008	5.42	6.32
2005-2009	5.04	5.74

To illustrate how Valley Forge NHP compares regionally, a technical report prepared by the principal investigators of the PA NAPD site at Valley Forge NHP (PA60) analyzed long term trends of sulfate and nitrate ion concentrations from 1983-2006 to compare conditions before and after implementation of Title IV of the Clean Air Act Amendments of 1990 (Lynch et al, 2007). The amendments imposed phased reductions in sulphur dioxide and nitrogen oxide emissions from all electric power utilities nationally, resulting in a reduction from 17.3 million tons of sulphur dioxide annually in 1980 to 9.4 million tons in 2006 and a similar percentage reduction in nitrogen oxide emissions (EPA 2007). Mean annual wet deposition comparisons for the PA60 site at Valley Forge NHP site confirm statistically significant reductions in nitrogen and sulphur ion loadings over a 23-year period (Table 6). The Valley Forge NHP values were also lower than the statewide mean annual reduction calculated for all 12 NAPD sites in Pennsylvania .

Table 6. Comparison of mean annual sulfate ion and nitrate ion wet depositions at Valley Forge NHP (PA60) atmospheric deposition monitoring station in Pennsylvania before (1983-1994) and after (1995-2006) implementation of Title IV of the Clean Air Act Amendments of 1990 (adapted from Lynch et al. 2007). Asterisk denotes statistically significant trend.

	Pre-CAAA Mean	Post-CAAA Mean	Difference
Sulfate Ion Wet Deposition (kg/ha)	30.327	22.236	-8.092*
Nitrate Ion Wet Deposition (kg/ha)	20.248	16.942	-3.307*

In summary, although wet deposition levels of nitrogen and sulphur have stabilized and are showing signs of gradual improvement over time, they are still within the Significant Concern rating. Information for these metrics is available online at: http://www.nature.nps.gov/air/Maps/AirAtlas/docs/Air_Atlas_Values_Tables/Wet_Deposition/NPS_AQC_WetDep_0610_PRISM_web.pdf

Wet Deposition Condition Assessment (Mercury)

Relevance and Context

Human exposure to mercury occurs largely through fish consumption and Pennsylvania currently has a statewide advisory against fish consumption for all rivers and lakes due to methyl-mercury contamination. The statewide advisory was first initiated in 2001 (US EPA 2008). Mercury is transported vast distances, even globally, in three forms (elemental, particulate, and gaseous) and all forms can be deposited to foliage, surface waters, and the land. Deposition is enhanced by high ground level ozone, forest cover, and proximity to sources, all of which occur at Valley Forge NHP (Driscoll et al 2007). About 36% of mercury emissions originate from coal-fired power plants. The Electric Power Research Institute (EPRI 2006) estimates that 40% of mercury releases to the atmosphere are emitted as highly reactive, water-soluble oxidized mercury potentially convertible by microorganisms to toxic methylmercury which can be bioaccumulated in fish, wildlife and human tissue.

Methods

A technical report prepared by the principal investigators of the PA NAPD site at Valley Forge NHP (PA60) in operation since 1999 summarized precipitation chemistry and wet deposition data collected weekly at Valley Forge NHP and seven other mercury monitoring sites in Pennsylvania (Boyer et al. 2010). Mean annual and seasonal wet mercury deposition measured in ug/m^2 (micrograms per square meter) at PA60 from 1999 through 2008 is shown in Table 7. Mean concentrations in precipitation show definite seasonal patterns at Valley Forge NHP and throughout the monitoring network. Spring total mercury concentrations and deposition values are generally higher than any other seasonal period and about 1.5 to 2.0 times those observed in the fall and winter periods. In calendar year 2008, average wet atmospheric mercury deposition at the Pennsylvania sites ranged from 7.08 ug/m^2 in Tioga County to 11.39 ug/m^2 at Valley Forge NHP which typically receives the highest amount of wet mercury deposition among the monitoring stations in Pennsylvania (Boyer et al. 2010). A statistically derived analysis of trends was done for two stations with the longest period of record (11 years) and determined a significant

decreasing trend of 2.08% annually at those sites. Unfortunately, a rigorous trend analysis was not performed using the Valley Forge NHP data by the investigators and is beyond the scope of this natural resource condition assessment. It would be speculative to conclude that Valley Forge NHP experienced the same decreasing trend, particularly since Valley Forge NHP's urban setting and the related high ozone, heavy automotive emission and industrial loading of mercury in the surrounding region differs greatly from the rural, sparsely populated, low ozone concentrations at the Tioga County and Cambria County data monitoring sites where the trend analysis was performed.

Table 7. Annual and seasonal wet deposition (ug/m^2) of mercury at Valley Forge NHP (PA60) from 1999-2008 (adapted from Boyer et al. 2010).

Season	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Winter		1.691	2.951	1.147	1.786	1.446	2.055	2.269	1.862	2.970
Spring		4.023	2.898	3.704	3.402	4.772	1.767	3.193	6.234	3.709
Summer		3.263	2.352	2.562	4.453	4.467	2.456	4.274	3.596	3.038
Fall	0.315	2.865	0.851	1.647	3.519	2.277	3.308	3.691	2.179	2.053
Annual		12.613	8.447	9.843	12.779	12.521	9.910	13.439	12.351	11.395

Threshold Criteria

Despite its documented human health risks for pregnant women, developing fetuses, and young children, as well as, adverse affects on fish and wildlife, there is no definitive air quality standard to serve as a condition assessment benchmark for wet deposition of mercury. Likewise, NPS ARD has not adopted a condition rating index for mercury wet deposition.

Current Condition

Based on the serious biological, ecological and human health hazards associated with mercury contaminants, and the rank of Valley Forge NHP as the highest deposition locale among all NAPD monitoring sites in Pennsylvania in calendar year 2008, it is recommended by the NRCA team that a provisional "*Significant Concern"* ranking be applied pending a definitive scientific determination of a mercury deposition threshold value.

Visibility

Relevance and Context

Degraded visibility is a direct consequence of atmospheric particulate matter, an air pollutant in the form of solid particles and liquid aerosol droplets. The NPS examines the clearest days and haziest days to measure visibility conditions. The Environmental Protection Agency (EPA) uses these measures to assess progress toward the national goal of remedying any existing and preventing any future human-caused visibility impairment in protected Class I areas and to provide monitoring information for non-Class I areas (e.g. Valley Forge NHP) as well.

Methods

In response to mandates of the Clean Air Act, in 1985 the Interagency Monitoring of Protected Visual Environments (IMPROVE) program and monitoring network was established to protect visibility in designated federal Class I areas. "Class I areas" are federal lands that were in existence on August 7, 1977 that encompassed wilderness areas larger than 5,000 acres, national parks greater than 6,000 acres and any international parks. Smaller NPS units including Valley Forge NHP were designated as non-Class I (e.g. Class II). A majority of non-Class I parks do not have on-site IMPROVE network monitors although many parks in urban areas may have a PM2.5 monitoring site nearby. Non-Class I parks like Valley Forge NHP are still protected under the Clean Air Act, however, they fall under less stringent protection guidelines compared to Class I parks. As noted above particulate matter is monitored at the Norristown site within 5 km of Valley Forge NHP.

Threshold Criteria

As described in the guidance "Rating Air Quality Conditions" (NPS/ARD 2010), visibility condition is expressed in terms of a Haze Index in deciviews (dv) on an ascending scale of numbers as visibility worsens. Valley Forge NHP scores for visibility are based on the deviation of the current Group 50 visibility conditions from estimated Group 50 natural visibility conditions (background levels in the absence of anthropogenic-caused impairment), where Group 50 is defined as the mean of visibility observations falling within the 40th through the 60th percentile range. Current visibility is estimated from the interpolation of the five-year averages of the Group 50 visibility. *Good* condition is assigned to parks with a visibility condition 5-year average estimate of less than 2 dv above estimated natural conditions. Parks with estimates ranging from 2 to 8 dv above natural conditions are considered to be in *Moderate* condition, and parks with visibility estimates greater than 8 dv above natural background levels are considered to have a *Significant Concern* ranking.

Current Condition

The NPS/ARD 5-year Average Air Quality Estimates of G50 Visibility expressed in Haze Index deciviews (dv) encompassing the 2001-2009 time period are shown in Table 8. All 5-year average estimates are ranked as *Significant Concern* for visibility conditions at Valley Forge NHP although the three most recent reported values of the 5-year average show an improving trend in visibility conditions Table 9.

Table 8. Five-year average air quality estimates of G50 visibility expressed in Haze Index deciviews (dv) at Valley Forge NHP, 2001-2009.

Years	G50 Visibility Minus Natural Conditions
2005-2009	11.8
2004-2008	12.3
2003-2007	12.5
2001-2005	10.3

Table 9. Summary of condition estimates of air quality parameters at Valley Forge NHP

Air Quality Parameter	NPS ARD Condition Thresholds	Valley Forge NHP Condition Value
Ozone (Primary)	Good: ≤ 60.0 ppb	79.5 ppb
	Moderate: 61-75 ppb	(significant concern)
	Significant Concern: ≥ 76 ppb	
Ozone (Vegetation) 2004 Foliar Injury Assessment Report		
SUM06	8 ppm-hr	32 ppm-hr (sig. concern)
W126	5.9 ppm-hr	41 ppm-hr sig. concern)
N100	6 hr	52 hr (sig. concern)
Total N Wet Deposition	Good: < 1 kg/ha/yr	4.9 kg/ha/yr
	Moderate: 1-3 kg/ha/yr	(significant concern)
	Significant Concern: > 3 kg/ha/yr	
Total S Wet Deposition	Good: < 1 kg/ha/yr	5.2 kg/ha/yr
	Moderate: 1-3 kg/ha/yr	(significant concern)
	Significant Concern: > 3 kg/ha/yr	
Visibility (Haze Index)	Good: < 2 dv	11.8 dv
	Moderate: 2-8 dv	(significant concern)
	Significant Concern: > 8 dv	
Mercury (Boyer et al. 2010)	None Established	11.4 ug/m^2
		(significant concern)

Chapter 3. Water Resources

Valley Creek

Valley Creek-Physical Water Quality

Valley Creek was designated an "Exceptional Value" waterway in 1993 (CCWRA 2002); providing it the highest level of protection from the Pennsylvania Department of Environmental Protection (PADEP). Valley Creek is also a designated Coldwater Fishery (CWF) in Pennsylvania and is regulated for the "maintenance or propagation, or both, of fish species including the family Salmonidae and additional flora and fauna which are indigenous to a cold water habitat" (PA Code Title 25, Chapter 93 Water Quality Standards). It is also important to note that Valley Creek has been designated a "Class A Wild Trout Fishery" by the Pennsylvania Fish and Boat commission. This classification denotes that water quality can sustain a population of naturally reproducing trout of sufficient size and abundance to support a long-term fishery (PA Fish and Boat Commission 2007). However, Valley Creek is also 303(d) listed by the commonwealth because of PCB contamination, turbidity, sedimentation, nutrients, and flow alteration (NPS 2007).

The Valley Creek watershed encompasses 23.4 square miles located throughout the suburban Philadelphia area, in Chester County, Pennsylvania (Figure 3). The last two miles of Valley Creek pass through Valley Forge NHP flowing northeast, passing directly in front of George Washington's Headquarters just before reaching the confluence with the Schuylkill River. Approximately 30 tributaries flow into the main stem of Valley Creek. Of these 30 named and unnamed tributaries, half are perennial streams (streams with continuous flow all year round during years of normal rainfall) with Little Valley Creek being the main tributary (CCWRA 2002) (Figure 4). The watershed is bounded on the north and south by hills of resistant crystalline rock. The floor of the watershed is a carbonate (or karst) valley, underlain by Cambrian and Ordovician limestone and dolomite, representing sixty-eight percent of the basin (D'Antonio and Jantz 2008, CCWRA 2002, Sloto 1989) (Figure 5).

Valley Creek is considered a limestone stream, and groundwater comprises a large percentage of flow to the waterway arising from numerous springs within the stream corridor. During the 1983 to 1987 period of record, groundwater was found to comprise 76% of the baseflow of Valley Creek. Significant groundwater recharge supports a cold water aquatic community for trout. Limestone also provides a high buffering capacity, minimizing impacts from acid rain, and affects water quality parameters including alkalinity, temperature, pH, and biological communities. Proximity of water-bearing zones to the land surface and porosity also make the watershed highly susceptible to groundwater contamination. This is important to consider when establishing reference criteria/thresholds as state water standards currently do not differentiate between limestone and freestone streams.

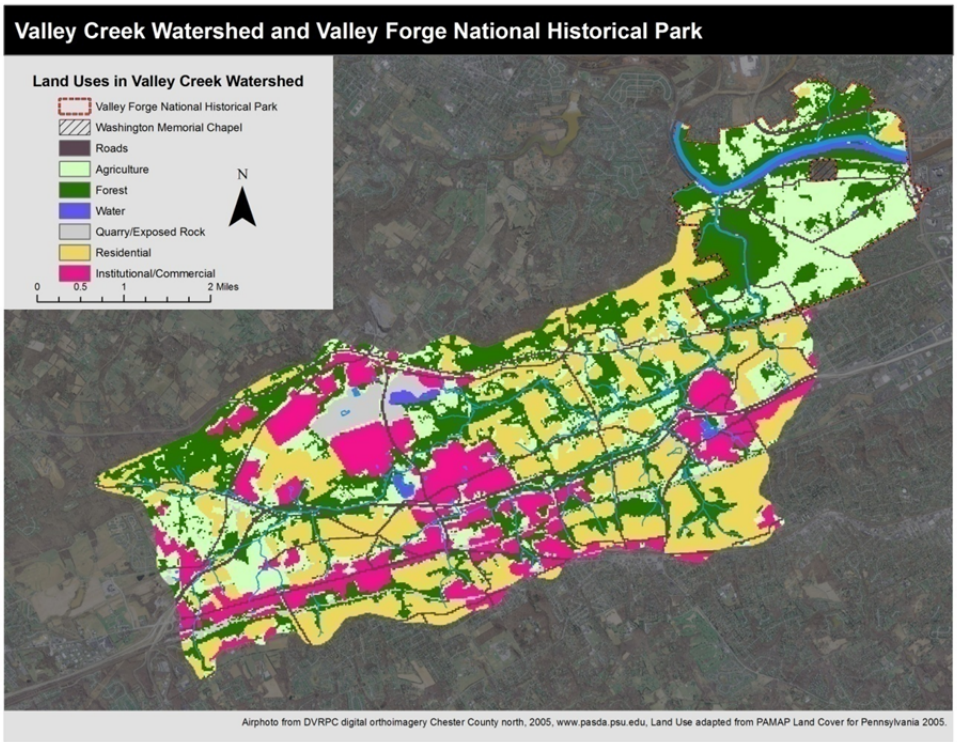

Figure 3. Land use in the Valley Creek watershed (PaMAP Land Cover 2005).

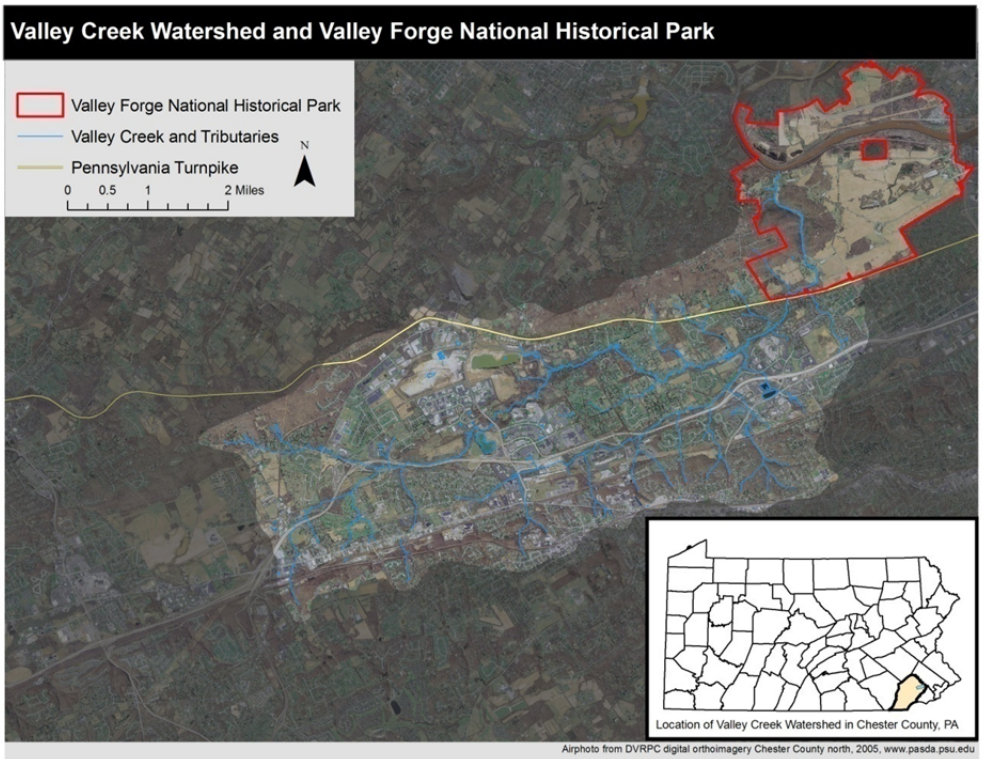

Figure 4. Valley Creek watershed with tributaries.

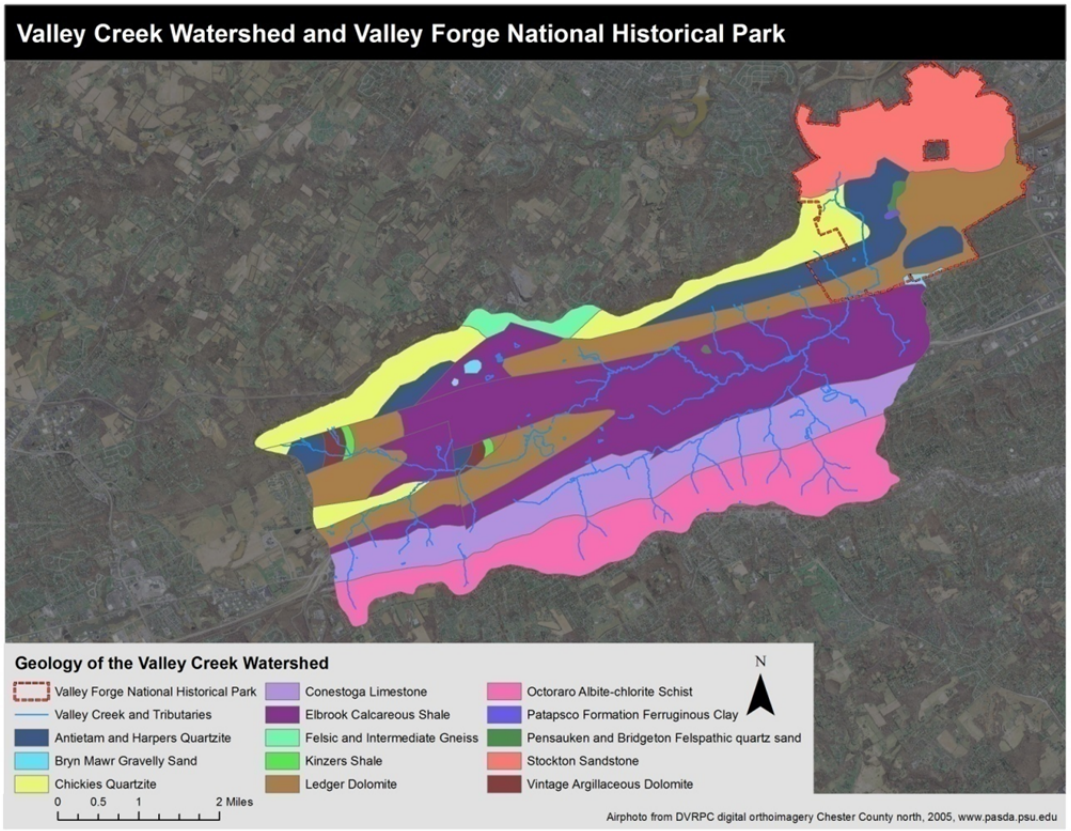

Figure 5. Geology of the Valley Creek watershed.

Increasing human population and associated urbanization poses many water quality and water quantity challenges in trying to maintain the health of Valley Creek watershed. Over the years, the Valley Creek stream channel has changed considerably (which can be attributed to both human and natural processes). Changes in land use and urbanization of the watershed, from a primarily agricultural and forested countryside to a more industrial, corporate, business, residential, and highway-laden landscape, have predominated over the past 50 years (Figure 3); however, the streams and tributaries predominantly continue to exhibit high water quality. The Chester County Water Resources Authority (CCWRA) estimates that with the land use changes that have taken place within Valley Creek watershed, estimates of total impervious surface area (any part of the landscape that prevents the infiltration of water into the soils) range from 17% to 24%, with a predicted Total Impervious Surface of 26% by the year 2020 (Booth et al. 2002, CCWRA 2002) (Figure 6). The conversion of this once pastoral landscape to a landscape characterized as up to 24% impervious surface area has great implications for the integrity of both the terrestrial and aquatic ecosystems. Urbanization alters the natural hydrology, water quality, riparian buffer, topography, soils, and vegetation of the watershed and increases pollutant loads (Booth et al. 2002, CCWRA 2002, D'Antonio and Jantz 2008). A continuous stream gage was installed by the United States Geological Survey (USGS) in 1982 just upstream of Valley Forge NHP (Figure 7). This gage represents 20.8 square miles of drainage area for the watershed (D'Antonio and Jantz 2008). The three major

quarrying operations located in the Valley Creek watershed, have significantly influenced the hydrological component of the watershed as well.

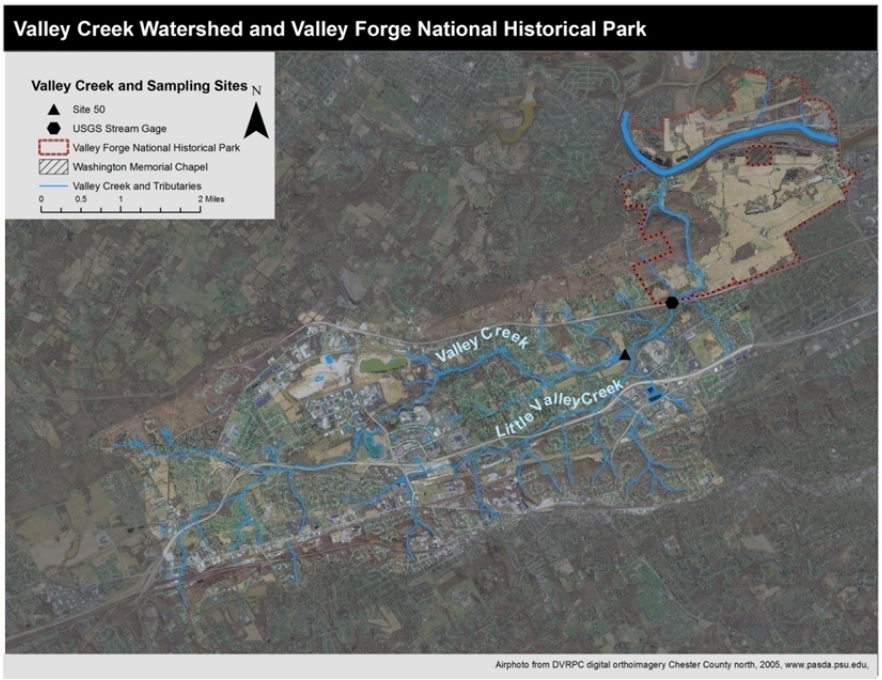

Figure 6. Valley Creek watershed with USGS gage and sampling sites.

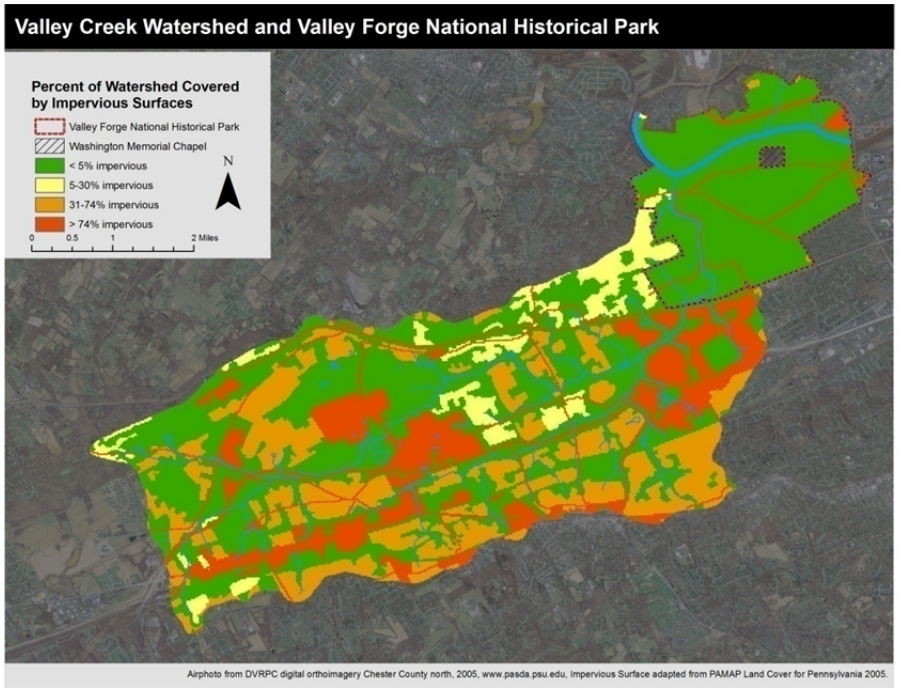

Figure 7. Percent impervious surface within Valley Creek watershed (PaMAP Land Cover 2005).

The most common standards used to assess water quality relate to drinking water, safety of human contact and for the health of ecosystems. Water quality standards vary significantly due to different environmental conditions, ecosystems, and intended human uses. Toxic substances and high populations of certain microorganisms can present a health hazard for non-drinking purposes such as irrigation, swimming, fishing, boating, and industrial uses. These conditions may also affect the wildlife that use the water for drinking or as habitat. Modern water quality laws generally specify protection of fisheries and recreational use and require, as a minimum, retention of current quality standards. Additional information regarding the Valley Creek watershed can be found online at:< http://www.chesco.org/index.aspx?NID=1989>. Table 10 provides a summary of the physical water quality metrics used in this assessment.

Table 10. Summary of physical water quality thresholds used in the Valley Forge National Historical Park natural resource condition assessment for Valley Creek, data used in this assessment were collected annually from 1982-2009.

Metric	Threshold Criteria	Assessment Value	Assessment	Threshold Source
Alkalinity	> 140 mg/L	206.8 mg/L	Good	Wurts and Durborow 1992, Murphy 2002, Botts 2005
Ammonia	≤ 0.03 mg/L	0.039 mg/L	Significant Concern	Wilkes University Center for Environmental Quality 2004, Murphy 2002
Boron	≤ 1,200 mg/L	61.47 mg/L	Good	Mason 2002, Chester County Water Resources Authority 2004, Moss and Nagpal 2003
Chloride	≤ 41 mg/L	52.16 mg/L	Significant Concern	PADEP 2001, Ludlow 2004
Dissolved Oxygen	≥ 10 mg/L	11.79 mg/L	Good	Diaz 2001, PADEP 2001, Murphy 2002
Nitrate+Nitrite	2.2 mg/L	1.95 mg/L	Significant Concern	Holmes et al. 1980, PADEP 2001, Murphy 2002
pH	6-9	7.90	Good	Wurts and Durborow 1992, Murphy 2002, Botts 2005
Phosphorus	< 0.1 mg/L	0.02 mg/L	Moderate	Abrams and Jarrell 1995, Correll 1998
Specific Conductance	150-500 µS/cm	563 µS/cm	Significant Concern	U.S. EPA 2009
Temperature	$3 \leq {}^{0}C \leq 19$	10.61 ^{0}C	Good	Baltz et al. 1991, PADEP 2001, Lessard and Hayes 2003

Temperature

Relevance and Context

Temperature is a measure of molecular vibrational energy (Baltz et al. 1991). The temperature of water has extremely important ecological consequences. In general, increasing water temperature results in greater biological activity and rapid growth (Lessard and Hayes 2003); however, Valley Creek is a cold water fishery that supports a variety of cold-adapted species like trout. Groundwater flowing into the Valley Creek maintains water temperature at or around 12 ºC (55 ºF). All aquatic organisms have a preferred temperature in which they can survive and reproduce optimally. For example, trout typically prefer waters in the (10ºC-15.6ºC) range which may not be available in shallow waters during the summer (Baltz et al. 1991). Temperature is also an important influence on water chemistry. Rates of chemical reactions generally increase with increasing temperature. The solubility of important gases, such as oxygen and carbon dioxide increases as temperature decreases.

Water temperature can be influenced by several factors but those most relevant to Valley Creek are surface water runoff and lack of groundwater infiltration, both of which are closely linked to urban development. Impervious cover in the Valley Creek watershed has increased from 9% in 1987 to 18% in 1995 and is estimated to continue increasing to approximately 26% by 2020, dramatically reducing the area available for groundwater recharge and substantially increasing the volume of surface water entering the creek. As the land in the watershed is converted into impervious surface and demands on local water supply increases, the volume of temperature stable groundwater entering valley creek is expected to decrease and input of warmer surface water runoff increase, impacting the overall temperature of the stream.

Threshold Criteria

To maintain a cold water fishery, the threshold requires a temperature maximum /minimum temperature range from a low of 3°C(37.4 ºF) in winter to a high of 19°C(66 ºF) in summer (PADEP 2001) (Table 11).

Table 11. PA code title 25, chapter 93, cold water fishery temperature criteria.

MONTH	$TEMP_1$ CWF	MONTH	$TEMP_1$ CWF
February 1-29	38	August 1-15	66
March 1-31	42	August 16-30	66
April 1-15	48	September 1-15	64
April 16-30	52	September 16-30	60
May 1-15	54	October 1-15	54
May 16-31	58	October 16-31	50
June 1-15	60	November 1-15	46
June 16-30	64	November 16-30	42
July 1-31	66	December 1-31	40

Current Condition

In 2011, HOBO temperature loggers were installed at 17 sites throughout the Valley Creek, recording temperature readings every 15 minutes throughout the year. Though data is still being compiled and analyzed, in 2011 the 19°C (66 ºF) CWF threshold was exceeded at some point every month between April and September. Additionally, in July and August mean temperature is just 0.6°C and 0.5°C (respectively) below 19°C and two different logger locations recorded temperatures exceeding the daily maximum stress threshold for resident trout (24.4°C) (Figure 8). Though trout can tolerate thermal stress as long as the temperature doesn't exceed the maximum threshold for a sustained period longer than 24-48 hours, these recent data indicate that the summer high temperatures exceeding 19°C (66 ºF) should be carefully monitored. Based on this information we would place this metric into the moderate concern category. Additionally, with only one year of data, trends cannot be determined at this time. The regional Inventory and Monitoring program has also installed a multi-parameter SONDE at the park boundary to measure temperature, pH, specific conductivity, and DO of waters entering the park. These data have yet to be reported but will provide additional information on trends in water quality overall aquatic ecosystem health within Valley Creek.

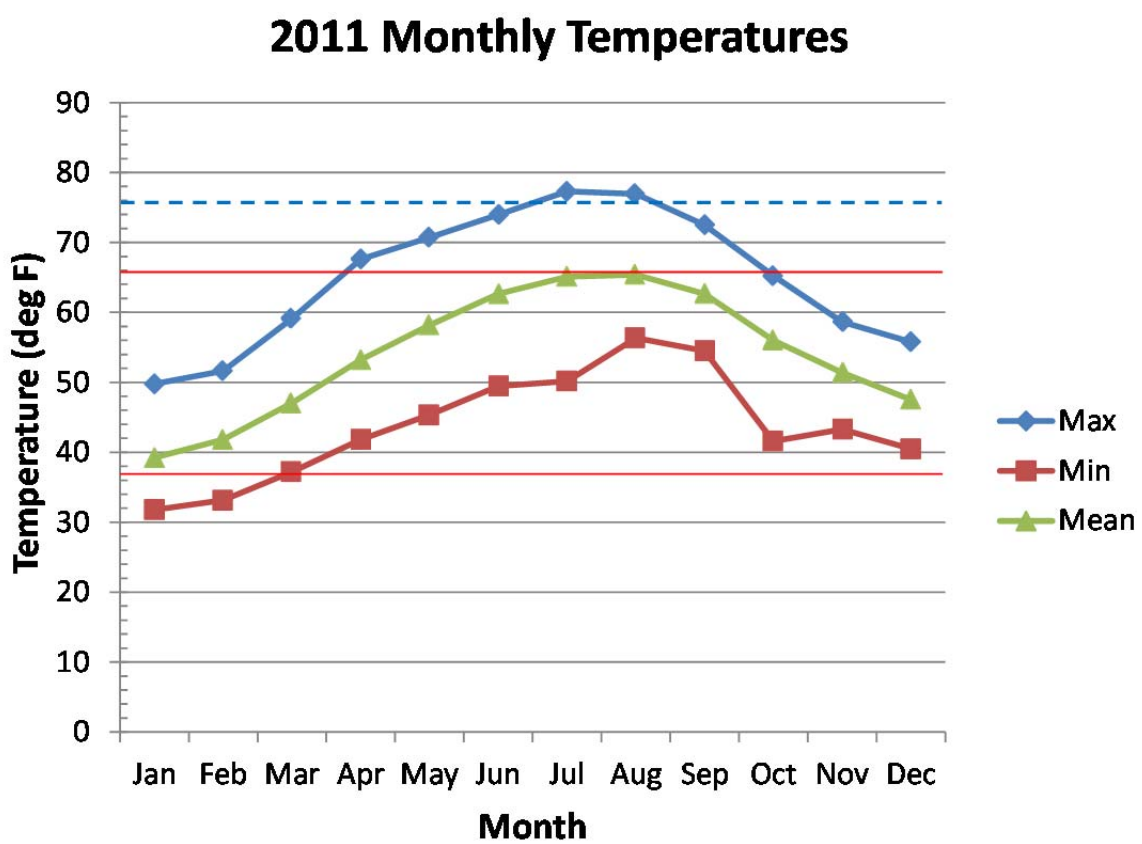

Figure 8. 2011 Temperature data from HOBO continuous data loggers deployed throughout Valley Creek, temperature readings recorded every 15 minutes; mean averaged across all 17 sites; upper (19°C / 66°F) and lower (3°C / 37°F) CWF thresholds in red and maximum daily stress threshold for trout (24.4^{0}C/76^{0}F/) in dotted blue.

Dissolved Oxygen

Relevance and Context

Dissolved oxygen refers to the amount of gaseous oxygen dissolved in an aqueous solution. Oxygen gets into water by diffusion from the surrounding air, by aeration, and as a waste product of photosynthesis. Dissolved oxygen is an important indicator of a water body's ability to support aquatic life and adequate amounts are necessary for good water quality (Murphy 2002). Oxygen is a necessary element to all forms of life. Natural stream purification processes require adequate oxygen levels in order to provide for aerobic life forms. As dissolved oxygen levels in water drop below 5.0 mg/L, many aquatic organisms become stressed including trout species. The lower the concentration of dissolved oxygen, the greater the stress will be. Oxygen levels that remain below 1-2 mg/L for a few hours can result in large fish kills (Diaz 2001). Nutrient run-off from adjacent lands as either point source (e.g. food processing plant discharge) or non-point source (e.g. lawn fertilizers, agricultural waste/fertilizers) can promote excessive algal growth within the water column. When the algae dies and begins decomposing the microbes that begin this process consume oxygen. Though this cycle of growth, death, and decomposition is a natural process under high nutrient conditions that create an inordinate amount of dead and decaying algal material the available oxygen within the water column can be quickly consumed , thus creating a fatal or stressful environment for aquatic taxa like trout which require high dissolved oxygen levels. Low dissolved oxygen concentrations combined with other stressors like high water temperatures can create a lethal mix for sensitive aquatic species.

Threshold Criteria

The PA Code - Title 25, Chapter 93 -Water Quality Standards (2001) recommends a threshold of 7.0 mg/L of dissolved oxygen for high quality cold water fishery (HQ-CWF) and Exceptional Value (EV) waters (Figure 9).

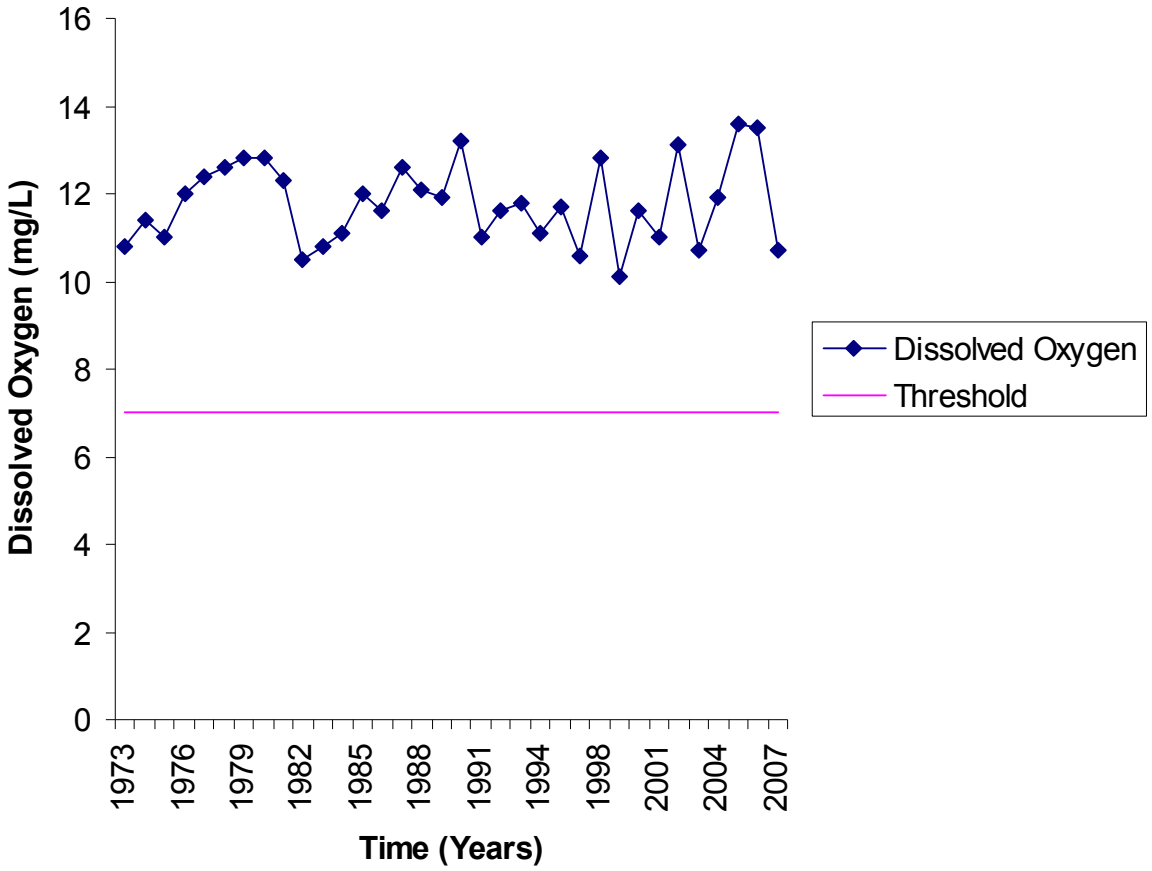

Figure 9. Dissolved oxygen levels in Valley Creek with threshold from 1973 to 2007. The data were collected annually in either October or November (NPS Site 50), therefore these values are representative of fall baseflow conditions within Valley Creek.

Current Condition

Dissolved oxygen data collected from Valley Creek from 1973 to 2007 showed consistent readings above 10 mg/L, well above the threshold value of 7.0 mg/L for an HQ-CWF and EV water, indicating good conditions for this metric. The overall data trend was stable with dissolved oxygen values generally between 10 and 12 mg/L over time. Our confidence in this assessment is high.

Acidity (pH)

Relevance and Context

pH is the measure of the concentration of hydrogen ions in a sample. pH is based on a logarithmic scale of 1 (acidic) to 14 (basic) with 7 being neutral (Figure 10). Water column pH values influence what organisms can live in streams as the pH of water determines its solubility and biological availability of nutrients and heavy metals (U.S. EPA 2009). For example, pH can determine how much and what form of phosphorus is most abundant in water and what aquatic life can use it. Toxicity of heavy metals also becomes a problem at lower pH because they are more soluble. Stream water pH lower than 5.0, if persistent, is stressful and potentially lethal to aquatic taxa (Wurts and Durborow 1992).

Threshold Criteria

A pH threshold range of 6.0 to 9.0 is recommended for Cold Water Fisheries in Pennsylvania (PADEP 2001).

Current Condition

Valley Creek pH levels measured from 1971 to 2008 (Figure 10) show a very consistent trend between the PADEP threshold values of 6 and 9. These data indicate a good water quality condition for pH within Valley Creek. Our confidence in this data is high.

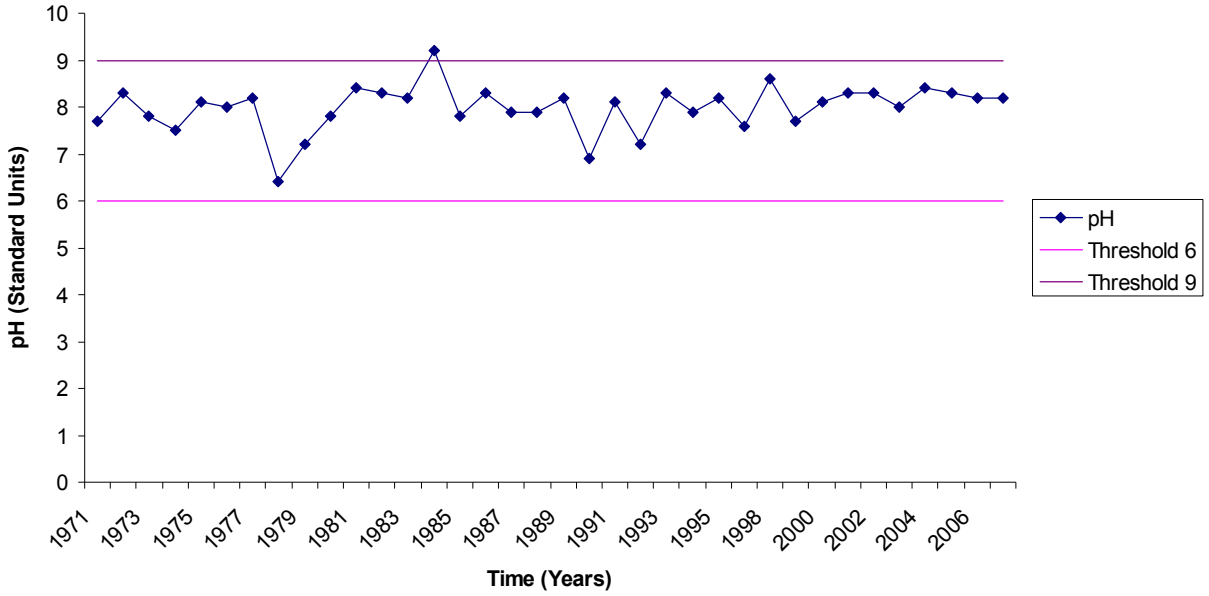

Figure 10. pH levels at Valley Creek with minimum and maximum threshold values from 1971 to 2008. The data were collected annually in either October or November (NPS Site 50), therefore these values are representative of fall baseflow conditions within Valley Creek.

Specific Conductance

Relevance and Context

Conductivity is the ability of water to pass an electrical current. Streams tend to have a relatively constant range of conductivity, that once established, can be used as a baseline (U.S. EPA 2009). Therefore, significant changes in conductivity could indicate that a discharge or another source of pollution has entered the stream and thus this parameter can be a very good, low cost means of monitoring changes within a stream system. In limestone streams like Valley Creek there is natural tendency for background conductivity readings to be high as a result of the ready dissolution of available calcium and carbonate minerals in the water column.

Threshold Criteria

There are no water quality standards for specific conductance in Pennsylvania, instead the concentration of total dissolved solids (TDS) is regulated. Specific conductance can be easily

obtained and may serve as a cost-effective parameter that provides a good indication of the amount of dissolved solids in the water column. As such, this parameter can be used to detect potential contaminants in water. A suggested threshold of specific conductance would be a range between 150-500 µS/cm (U.S. EPA 2009). Conversely, if the park already has a reliable long-term dataset of conductivity measurements in Valley Creek, those data could be used as a baseline, by which perturbations from the normal range could be compared against. Utilizing the latter threshold would take into account naturally elevated conductivity conditions arising from the limestone geology (Figure 11).

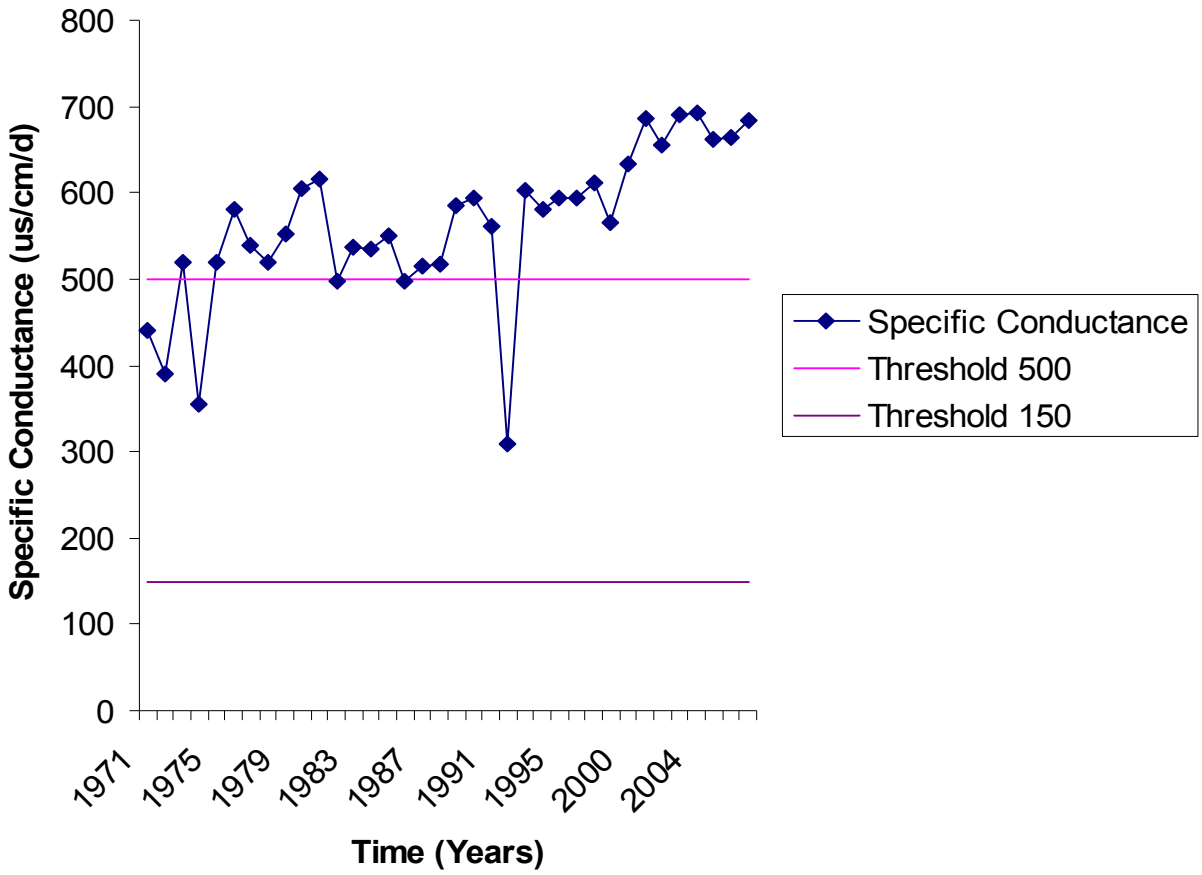

Figure 11. Specific conductance in Valley Creek with threshold values. The data were collected annually in either October or November (NPS Site 50), therefore these values are representative of fall baseflow conditions within Valley Creek.

Current Condition

Annual specific conductance data collected from Valley Creek from 1971 to 2009 appears to be showing a gradual deteriorating trend beyond the suggested 500 µS/cm threshold, and above the annual maximum from 1971-2000. With few exceptions, specific conductance in Valley Creek has been above 500 µS/cm since 1975, lending support to the idea that it possesses naturally high background conductivity values due to its limestone geology theory. However, because the data

seems to be showing a consistent annual increase since 2000 the park is encouraged to continue monitoring this parameter with greater frequency (monthly or bimonthly at a minimum) to ensure that the integrity of Valley Creek is maintained within the park. More frequent monitoring will also help to isolate any potential sources of contamination.

Alkalinity

Relevance and Context

Alkalinity is the measure of the ability of a solution to neutralize acids (Wurts and Durborow 1992, Murphy 2002). Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater protecting against rapid pH changes that may harm fish and other aquatic life that function best in a pH range of 6.0 to 9.0 (Wurts and Durborow 1992, Murphy 2002). Alkalinity does not refer to pH, but instead refers to the ability of water to resist change in pH that may make the water more acidic, known as the "buffering capacity." Carbonates naturally enter the water column from the geologic formations in the Valley Creek watershed. When these carbonates enter the system, waters will often have high alkalinity (Murphy 2002).

Threshold Criteria

The PA Code - Title 25, Chapter 93 Water Quality Standards (2001) recommend a minimum alkalinity threshold of 20 mg/L as $CaCO3$ for cold water fisheries. Botts (2005) suggests that to maintain limestone reference stream criteria, alkalinity should optimally maintain a minimum of 140 mg/L throughout the year.

Current Condition

Alkalinity data collected from Valley Creek from 1982 to 2009 shows water quality levels consistently above the alkalinity criteria for both a CWF and a limestone stream (Figure 12). The data also show a very stable trend over time with most values falling slightly above or below 200 mg/l. These results suggest that Valley Creek is in good condition with regards to alkalinity. Our confidence in the assessment of this metric is high.

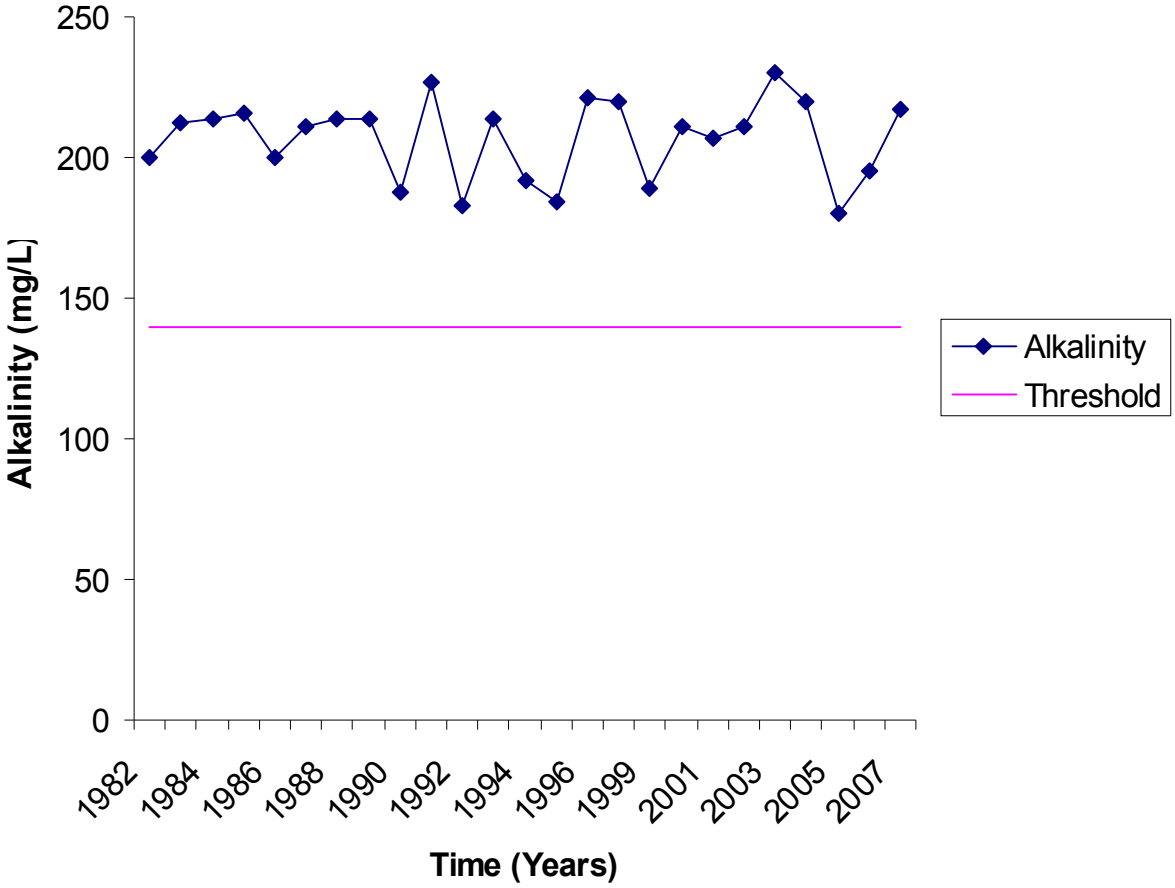

Figure 12. Alkalinity levels in Valley Creek with threshold value from 1982 to 2009. The data were collected annually in either October or November (NPS Site 50), therefore these values are representative of fall baseflow conditions within Valley Creek.

Turbidity/Suspended Solids (TDS)

Relevance and Context

Total Dissolved Solids (TDS) are the total amount of mobile charged ions, including minerals, salts or metals dissolved in a given volume of water. TDS is the combined content of all inorganic and organic substances contained in a liquid which are present in a molecular, ionized or micro-granular suspended form (Hall 1971). TDS is directly related to the purity of water and the quality of water purification systems and affects everything that consumes, lives in, or uses water, whether organic or inorganic, whether for better or for worse (Hall 1971).

Threshold Criteria

The threshold for aquatic life in a cold water fishery is a maximum of 750 mg/L and/or 500 mg/l as a monthly average value (PA Code Title 25, Chapter 93).

Current Condition

As of the date of this report, the park does not have data on TDS in the Valley Creek and the condition of this parameter is unknown. Our recommendation is that the park invest it's time and resources into more intensive conductivity monitoring. The conductivity readings can then be converted into an estimated TDS value simply by multiplying the conductivity reading by the appropriate conversion factor. The conversion factors range from 0.55 to 0.90 depending on the type of dissolved solid present. A basic conversion factor of 0.67 can be used for the Valley Creek in the absence of a more park specific conversion factor derived from dividing an actual in-stream TDS measurement from a conductivity measurement (same time and location) at 25°C.

Ammonia

Relevance and Context

Ammonia (NH3) is an inorganic form of nitrogen, an element required by all organisms for basic processes of life (e.g., to make proteins, to grow, and to reproduce.). Nitrogen is very common and found in many forms in the environment. In addition to Ammonia, other inorganic forms of Nitrogen include nitrate (NO3), nitrite (NO2), and nitrogen gas (N2) (Murphy 2002). Contributors of ammonia to Valley Creek are often human waste (e.g., malfunctioning septic systems, household cleaning products,), fertilizer runoff, and animal wastes. As stated earlier these nutrients encourage the growth of oxygen consuming microbes within the water column thereby reducing available dissolved oxygen for other aquatic species which can cause stress or death.

Threshold Criteria

The threshold of ammonia is a maximum concentration of 0.2 mg/L as higher values can be toxic to trout (Wilkes University Center for Environmental Quality 2004).

Current Condition

Ammonia levels measured annually within Valley Creek from 1981 to 2006 showed values consistently below the 0.2 mg/l threshold indicating good conditions within Valley Creek for this parameter (Figure 13). The overall trend in the data was stable with Ammonia values showing consistent variation around 0.05 mg/l. The most recent ammonia value was 0.039 mg/L recorded in 2007. Our confidence in the assessment of this metric is high.

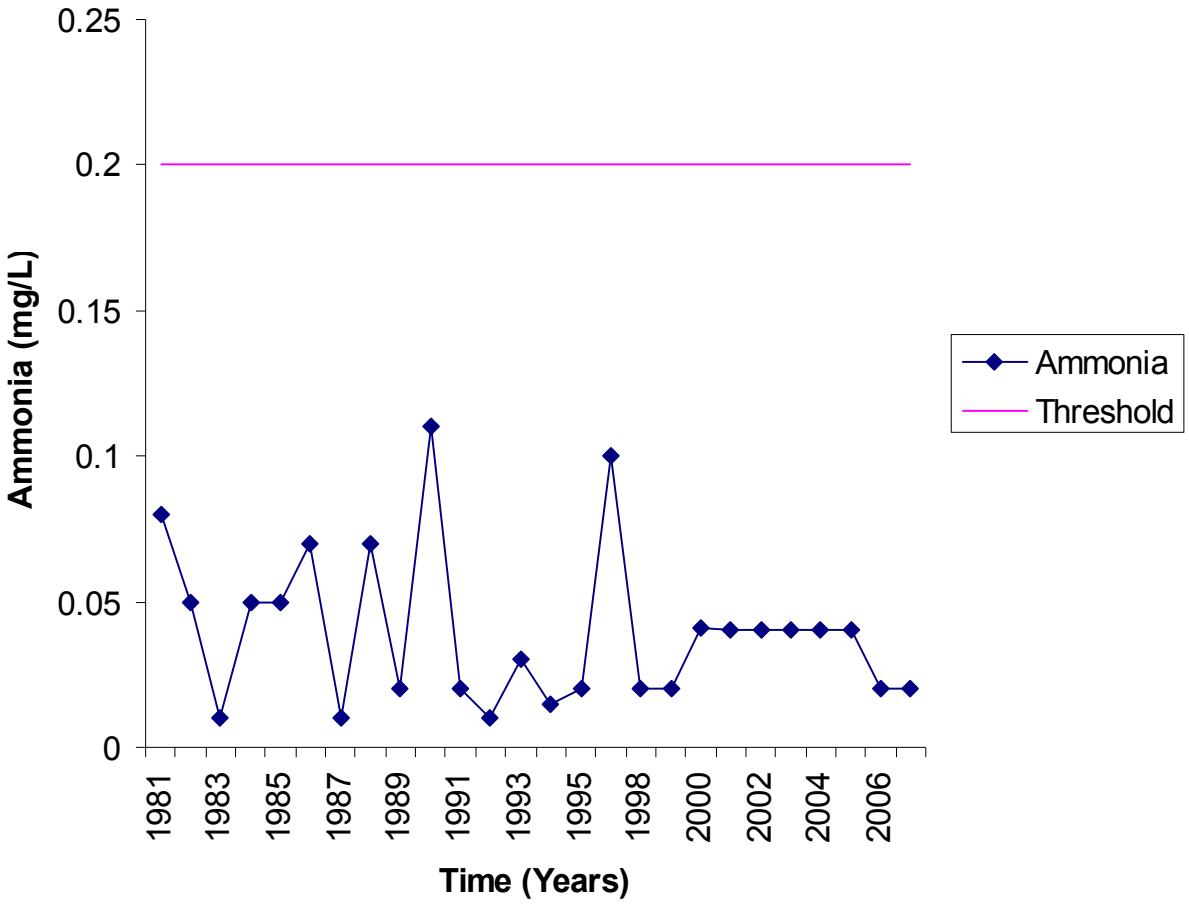

Figure 13. Ammonia levels in Valley Creek with threshold value from 1981 to 2008. The data were collected annually in either October or November (NPS Site 50), therefore these values are representative of fall baseflow conditions within Valley Creek.

Chloride

Relevance and Context

Chlorides are salts resulting from the combination of chlorine gas with various metals. In combination with a metal such as sodium it becomes essential for life. Small amounts of chlorides are required for normal cell functions in plants and animals. Chloride is present in all natural waters, but the concentration is usually low. Elevated concentrations of chloride indicate anthropogenic effects such as pollution from failing septic systems, road salt, or industrial waste (Ludlow 2004).

Threshold Criteria

The threshold for chloride is a maximum of 250 mg/L in special protection waters (PADEP 2001 - Figure 14).

Current Condition

Chloride levels measured from 1981-2008 were well below PADEPs threshold criteria for special protection waters (Figure 14). However, as shown in Figure 14 chloride levels measured in Valley

Creek appear to be steadily increasing from 40 mg/L measured in 1981 to 80 mg/L in 2008. This upward trend in chloride appears to have begun in the late 1990s (1997-1998). The observed trend in chloride concentrations are also coincident with the increase in conductivity readings over a similar time span, suggesting that possible increases in impervious surfaces within the Valley Creek watershed and the accompanying runoff is contributing additional salts into Valley Creek. It's advised that the park continue to monitor this metric closely. Our confidence in this assessment is high.

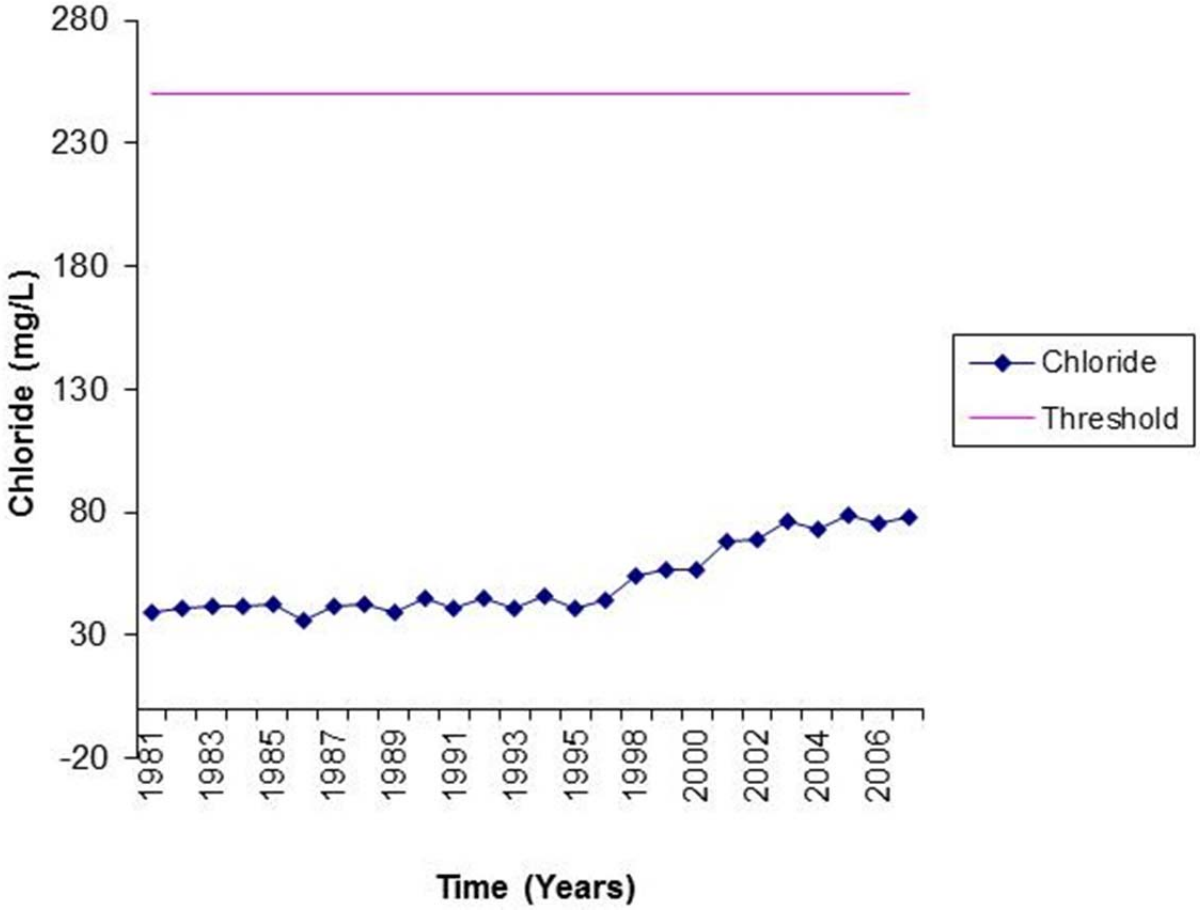

Figure 14. Chloride levels in Valley Creek with threshold value from 1981 to 2008. The data were collected annually in either October or November (NPS Site 50), therefore these values are representative of fall baseflow conditions within Valley Creek.

Nitrite + Nitrate

Relevance and Context

Nitrogen is the most common element in the Earth's atmosphere and is present in all living organisms. Nitrite and nitrate are common forms of nitrogen and they are essential to aquatic organisms; however, excess nitrogen can damage stream ecosystems. Nitrite (NO2) is relatively

short-lived in water because it is quickly converted to nitrate by bacteria; while, nitrate (NO3) dissolves easily in water and is stable over a wide range of environmental conditions (Holmes et al. 1980). It is easily transported in streams and ground water. Nitrate feeds aquatic plants, which are then eaten by invertebrates and fish (Murphy, 2002). Excess nitrogen in the water column can create massive algal blooms that inhibit the growth and reproduction of aquatic macrophytes and fish. Once these algal species dieback the resulting oxygen consumption by bacteria can significantly deplete the dissolved oxygen available and kill or extirpate the aquatic fauna.

Threshold Criteria

The PA Code - Title 25, Chapter 93 Water Quality Standards (2001) recommends a maximum threshold for nitrite + nitrate of 10 mg/L as Nitrogen.

Current Condition

Total nitrate and nitrite levels measured from 1981 to 2003 were consistently below the ecological threshold value of 10 mg/L Nitrogen (Figure 15). The overall trend in the data appears to be stable with the majority of the values falling at or around 2.0 mg/L suggesting that nutrient levels within Valley Creek are in good condition overall. Our confidence in this assessment is high, based on the data available.

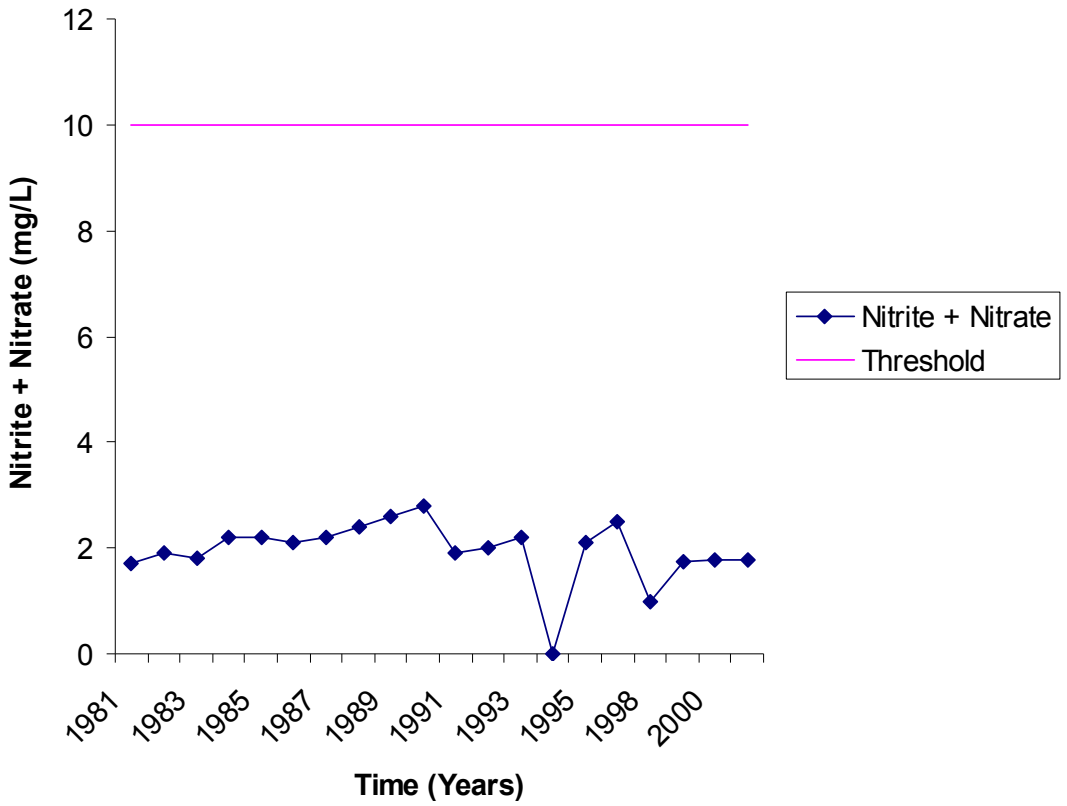

Figure 15. Total nitrate + nitrite levels with Valley Creek with threshold values from 1981 to 2003. The data were collected annually in either October or November (NPS Site 50), therefore these values are representative of fall baseflow conditions within Valley Creek.

Phosphorus

Relevance and Context

Phosphorus has been measured in two forms in the Valley Creek watershed, Total Phosphorus and Orthophosphate. Total phosphorus is the measure of all forms of phosphorus in a water sample, while orthophosphate is the soluble inorganic phosphorus taken up by plants (Correll 1998). Phosphorus is a natural element and is required by all organisms for the basic processes of life. When there is too much phosphorus in water, it can accelerate eutrophication (a reduction in dissolved oxygen in water bodies caused by an increase of mineral and organic nutrients) of rivers and lakes (Correll 1998). Land use activities that can promote phosphorus pollution are commonly associated with excess fertilizer runoff from agricultural and residential sources (e.g. lawns).

Threshold Criteria

To date, there are no state water quality standards for total phosphorus or orthophosphate. Background phosphorus thresholds in streams are typically less than 0.1 mg/L and anything above this threshold value is considered unnatural (Abrams and Jarrell 1995, Correll 1998).

Current Condition

Annual phosphorus levels measured in Valley Creek from 1981 to 1992 show levels consistently below the 0.1 mg/L threshold (Figure 16). Our confidence in this assessment is low, however, as nutrient contamination is very difficult to detect with simple annual measures. In many Pennsylvania streams phosphorus and nitrogen contamination occurs during storm events of sufficient severity to generate runoff from the landscape and into the receiving stream. The best method to capture these events and determine if Valley Creek was episodically exposed to high nutrient spikes is to collect storm event water quality samples. The park is encouraged to discuss such a program with their regional Inventory and Monitoring support staff and the USGS if the biota within Valley Creek beginning to show signs of heavy nutrient influences. The park is also encouraged to continue to monitoring phosphorus levels in Valley Creek on an annual basis as their last recorded measurement was from 1992 and conditions with Valley Creek and it's contributing watershed may have changed significantly in that time.

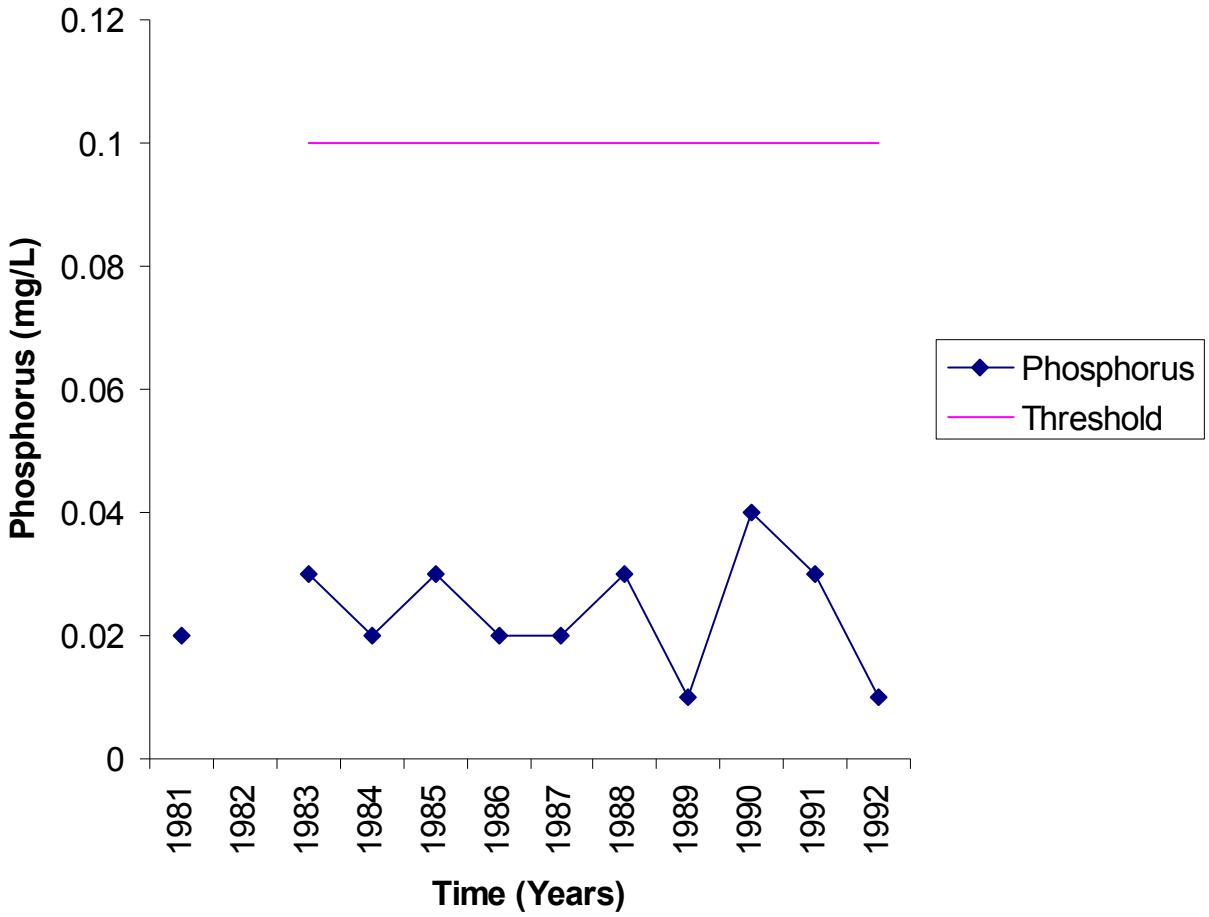

Figure 16. Total Phosphorus levels in Valley Creek showing the water quality impairment threshold value from 1981 and 1992. The data were collected annually in either October or November (NPS Site 50), therefore these values are representative of fall baseflow conditions within Valley Creek.

Biotic Integrity – Valley Creek

Relevance and Context

Stream condition, in many studies, is also measured by using indicators like biological richness and aquatic macroinvertebrate community composition. Macroinvertebrates are considered an important component of aquatic ecosystems. Benthic macroinvertebrates live on the bottom (benthos) of waterways and are used as a means of assessing water quality and watershed health for a number of reasons: they live in water for most of their lives, are easy to collect, have limited mobility, often live for more than one year, are easy to identify, and differ in their tolerance of certain types of pollution (Hilsenhoff 1977, EPA 2009). Nutrients, pesticides, and heavy metals are examples of pollution types commonly encountered in the mid-Atlantic region. These types of pollution can exhibit unique impacts on the macroinvertebrate species found in a given stream, thus creating an environment that is favorable to only a few tolerant organisms (Hilsenhoff 1977, D'Antonio and Jantz 2008).

The aquatic macroinvertebrate metrics used in this assessment are based on a combination of the NPS I&M Program macroinvertebrate standards (currently under development), the United States Geological Survey (USGS) established protocol and the U.S. EPA rapid bioassessment techniques (Plafkin et al. 1989). Beginning in 1969, the Chester County Water Resources Authority (CCWRA), along with the USGS, developed a long-term water quality monitoring network under the "Stream Conditions of Chester County Biological Monitoring Network"; where physical, chemical, and biological data are collected annually for the Valley Creek Watershed in Chester County, Pennsylvania (Lium 1977, Moore 1989). The USGS established a monitoring site along Valley Creek (USGS Site 50) and began collecting benthic macroinvertebrate data annually from 1973 until 2001. The metrics and analysis described in this section draw solely upon this data-set and as such may not reflect the current biotic community present within Valley Creek (2013).

Threshold Criteria

As evidenced in Table 1 this assessment utilizes several different metrics in an effort to obtain a comprehensive picture of stream health within Valley Creek. The macroinvertebrate scores calculated at the USGS station near Valley Forge NHP varied among years. The data obtained from this monitoring station was compared against a historic baseline benthic assemblage of Valley Creek when it was deemed an Exceptional Value stream, in 1993, (target value) and to a reference limestone stream (desired condition) (Botts 2005). The macroinvertebrate index of biological integrity (IBI) scores we calculated ranged from 20 to 84 (entire scale 1-100), with a score of ≥69 considered to be comparable to a reference stream as well as to the 1993 target value. The first range below the reference (<69-46) is classified as non-reference quality (Botts 2009). Therefore, for purposes of fitting this criteria into the NPS framework IBI scores ≥69 fall into the "Good" category, values ranging from 68 – 46 fall within the "Moderate Concern" category, and values below 46 are considered "Significant Concern."

Benthic macroinvertebrate samples were also identified to the lowest taxonomic level possible, enabling calculation of Brillouin's Diversity Index (BDI) (Lium 1974, Moore 1987, Reif 2000) and several other metrics over that same span of years including the total number of organisms, total number of taxa, maximum diversity, minimum diversity, EPT taxa – Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies), EPT total, percent EPT, Hilsenhoff Biotic Index (HBI), percent dominant taxa, and evenness (D'Antonio and Jantz 2008).

Brillouin's Diversity Index assesses the aquatic community sensitive to organic wastes. It is based on the different kinds of organisms present in a community, their relative abundances, and measures the effect of community stress. Ranging from zero to infinity, but usually below five, the Brillouin's Diversity Index will be higher if there are many taxa present (lower if few taxa present) and their abundances are evenly distributed (lower if unevenly distributed) (Moore 1987). Waters receiving heavy levels of organic wastes have a Brillouin's diversity value of below 1.0 (significant concern). Values between 1.0 and 3.0 are associated with waters receiving moderate levels of organic wastes (moderate concern), and values between 3.0 and 5.0 are waters receiving little or no organic wastes (Good Condition) (Wilhm 1970, Moore 1987, Reif 2000).

Another metric used to assess macroinvertebrate condition was the Hilsenhoff Biotic Index (HBI). This index provides a measure of macroinvertebrate community sensitivity toward existing water quality – specifically tolerance to organic pollution (Hilsenhoff 1987). The HBI measures physical stress and lack of suitable habitat (Reif 2000). Tolerance values are assigned to each species of macroinvertebrate depending on their ability to endure organic wastes. Values range from zero, for those organisms that are very intolerant of organic wastes, to ten, for those organisms that are very tolerant of organic wastes (Plafkin et al. 1989, Bode et al. 1996, Mackie 2004). HBI values from 0 to 4.5 are associated with nonimpacted sites (Good Condition), 4.51 to 8.50 with slightly impacted sites (Moderate Concern), and 8.51 to 10 with severely impacted sites (Significant Concern) (Reif, 2000a – modified by P. Sharpe following NPS, good, moderate, significant concern categories).

Additional metrics focusing primarily on the structure of the macroinvertebrate communities can also provide additional insight of the benthic community as it relates to water quality. Evenness describes the observed degree of uniformity of the distribution of individuals among the taxa in the collection. An evenness score of 0.5 or below indicates an unbalanced community (Significant Concern) (Moore 1987, Reif 2000). Shannon-Wiener Diversity Index values (H) can range from 0 to ≈4.6 using the natural log (ln). A value near 0 would indicate that the relative abundances of all species are similar (significant concern). A value near 4.6 would indicate that species abundances are very dissimilar (some rare and some common species) within the sample (good condition). A healthy benthic community typically has increasing taxa richness, increasing EPT percent, high HBI values, and a high BDI (Table 1) (Moore 1989, Bode et al. 1991, Reif 2000).

Possible Aquatic Species of Special Concern within Valley Creek: Cambarus [Puncticambarus] species

A crayfish survey for Valley Creek in Valley Forge NHP was completed in the fall and spring of 2003. After examining the species collected, it was determined that (Cambarus [Puncticambarus] species (sp.)) belonging to the C. acuminatus complex was present (Lieb et al. 2007). According to Lieb et al. (2007), this species had never been reported north of the Patapsco River basin in Maryland and possibly represented a new crayfish record in Pennsylvania waters. The newly discovered species is part of a highly variable species complex (C. acuminatus) that is difficult to delineate due to poor or non-existent type specimens and lost type localities. In 2012, Fetzner and Crandell attempted to determine the evolutionary history and conservation status of the new Valley Creek species by conducting mitochondrial gene sequencing on representative samples throughout the range of the C. acuminatus complex. Results indicate that the Pennsylvania populations (Valley, Pickering and Darby Creeks) are closely related to one another and shared several haplotypes unique to the state. These populations are also more closely related to samples from Virginia than Maryland, indicating that one of the populations (either VA or PA) may be introduced; however, significant genetic variation found in the C. acuminatus complex and current taxonomic confusion on the genus Cambarus leaves the origin of the newly discovered crayfish species unresolved. Additional analysis is required to determine if Cambarus [Puncticambarus] sp. represents an undescribed species or an introduction (Fetzner and Crandell 2012).High numbers of C. (P.) sp.. were documented in shallow, low-current velocity waters of Valley Creek where sand was scarce and silt was abundant.

In addition to the potentially new crayfish species, the exotic rusty crayfish (Orconectes rusticus) was also documented in the Valley Creek, an invasive species that can significantly impact aquatic biological diversity. Native to the Ohio River basin in Ohio, Tennessee, Indiana, Illinois, and Kentucky, the rusty crayfish has continued to expand its range into the Northeast since the 1930s. Rusty crayfish tend to displace native crayfish species, reduce aquatic plant and invertebrate diversity, and some fish populations (Capelli and Munjal, 1982). The park evaluated several methods to protect the biological integrity of the Valley Creek and a possible new crayfish species, and decided todesignate the section of Valley Creek through the park as a no bait fishing area and establish a volunteer program called the 'Crayfish Corps' to remove rusty crayfish. The objective of the Crayfish Corps program is to suppress the Rusty Crayfish population and maintain the 80% "native" to 20% rusty crayfish ratio above the dam in the Valley Creek. The maintenance of this ratio is the target condition for this metric. Due to the uncertainty of the status of the newly discovered crayfish species, the park has not developed objectives specific to this species.

As of 2012, over 10,000 Rusty crayfish have been removed from Valley Creek over the last 3 years and the 80:20 has been maintained. The park has also developed and widely distributed an interpretative brochure that describes the rusty crayfish problem and the importance of the current park management strategy to the general public. Other threats to species diversity include increases in urbanization, habitat alterations, influxes of toxic chemicals and sediment (Kemp and Spotila 1997; Lieb and Carline 1999, 2000).

Current Condition

The results shown in Table 1 indicate that the averaged benthic macroinvertebrate metric scores fall within the Moderate Concern category for the park with an overall unchanging trend. These results are consistent with the Valley Creek Technical Commpendium (July 2004) which found similar results for the USGS Site 50 data used in this assessment. The authors of the Valley Creek Technical Commpendium note from their analysis a general improving trend in benthic HBI scores suggesting a gradual improvement in water quality. Though we did not feel confident performing a similar trend analysis on those particular scores we did assess other individual metric scores over time (see Figures 17 and 18). From this basic analysis one can see a variety of potentially encouraging trends in the data that lend support to the Tech Commpendium findings. For example, Figure 17A and F and Figure 18B and D show annual limestone IBI, Annual Percentage of Shredders, Total EPT Taxa, and Total Taxa scores generally trending upward toward the "Good" or "Moderate" conditions indicating that as of the last sampling dates in 2001 these biotic metrics were displaying favorable trends. Additionally, the percentage of dominant taxa within the samples (Figure 18C) displayed a strong downward trend suggesting a healthy long-term prognosis for Valley Creek biota.

Our confidence in this assessment is medium, and as such, the park is encouraged to re-start the long-term biological monitoring program at USGS Site 50 again following the same fall sampling protocol as before to help verify these assertions. The park is also encouraged to initiate this instream biological sampling protocol at NPS Site 50 in the summer months in order to capture within season variability in the macro-invertebrate populations within Valley Creek and thus provide a more complete picture of the Valley Creek benthic community.

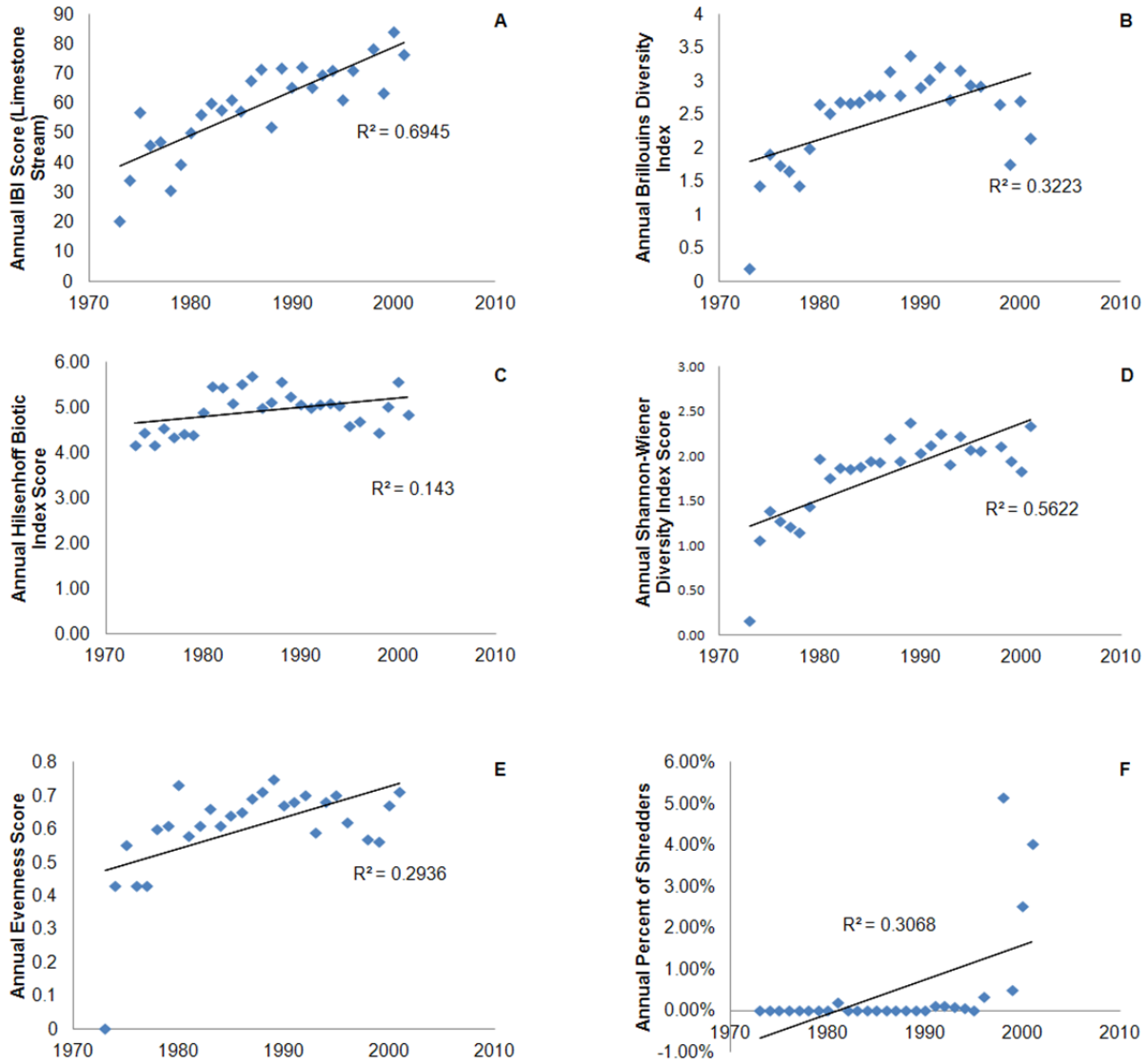

Figure 17. Long-term biological water quality data for Valley Creek (NPS Site 50), collected from 1973-2001 in the Fall of each year (either November or October). A linear regression line has been fit to the data and it's R^2 value added to illustrate the relative trend in the data for given instream biotic metric (Panels A-F) over time.

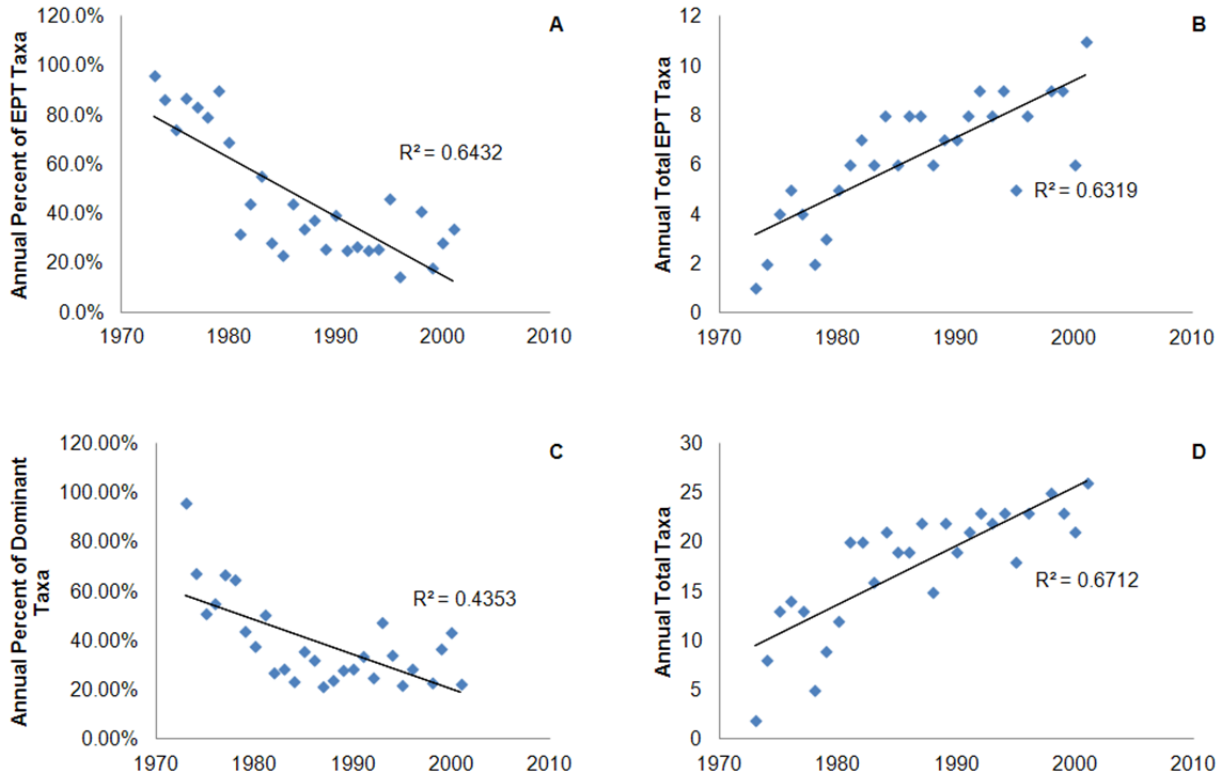

Figure 18. Long-term biological water quality data for Valley Creek (NPS Site 50), collected from 1973-2001 in the Fall of each year (either November or October). A linear regression line has been fit to the data and it's R^2 value added to illustrate the relative trend in the data for given instream biotic metric (Panels A-D) over time.

Fish Communities (Valley Creek and the Schuylkill River)

Relevance and Context

Analyzing fish species abundance and distribution provides another useful indication of the overall health of park water resources. Pollution tolerant species, such as white suckers, flourish where environmental stressors eradicate or diminish sensitive (intolerant) species such as trout in cold water fisheries like Valley Creek. In general, the richer the diversity of fish species, the better the water quality and habitat. Several surveys of fish communities within Valley Forge NHP have occurred prior to this condition assessment. Most of the baseline data is associated with the main stem of Valley Creek within the park. The Pennsylvania Fish and Boat Commission (PFBC) maintains a long term monitoring transect with emphasis on the brown trout fishery on a section of Valley Creek just upstream of its crossing with State Route 23. In addition to the PFBC surveys, Drexel University (Kemp and Spotila, 1997), and the National Park Service (Atkinson 2008) have conducted fish community sampling in the park (Figure 19 and Table 12). These data were incorporated into this analysis of fish community health. Most sampling efforts were conducted using either backpack or towboat electro-shocking equipment (exception Schuylkill River sampling, which employed boat mounted electro-fishing gear) and employed a single pass (~80 m) collection technique. Fish community sampling within the Schuylkill River was also conducted at four sites along the River in

2004, as part of the Mid-Atlantic Network (MIDN) fish inventory. This sampling effort included the three mile section of the Schuylkill River that flows through Valley Forge NHP, between the Route 422 bridge (downstream limit) to the Pawling Road Bridge (upstream limit).

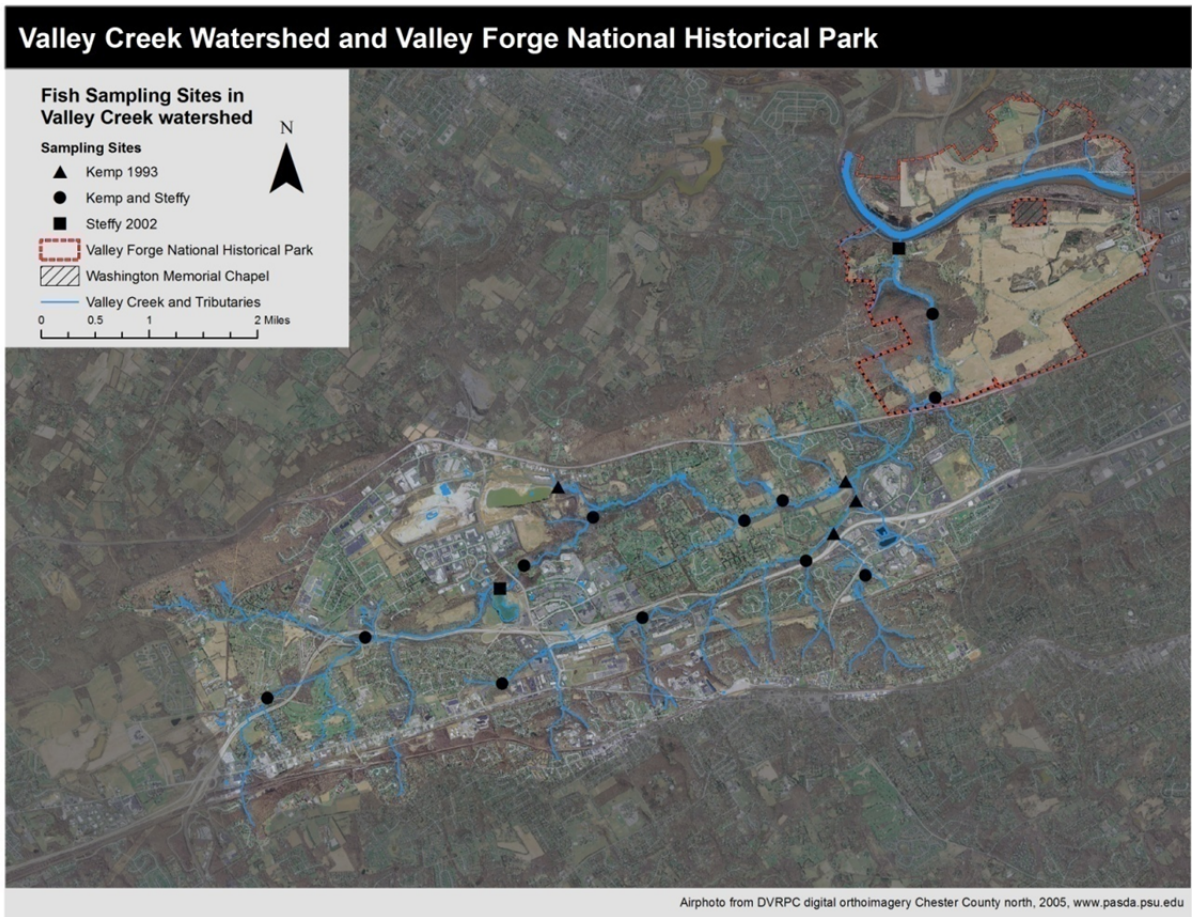

Figure 19. Fish sampling sites within Valley Creek watershed.

A total of 34 fish species have been documented in the Valley Creek watershed (Valley Creek and Little Valley Creek) (Table 12). Eight species were encountered in each of the past studies conducted in the Valley Creek watershed, including: white sucker (Catostomus commersoni), green sunfish (Lepomis cyanellus), pumpkinseed (Lepomis gibbosus), bluegill (Lempomis macrochirus), cutlips minnow (Exoglossum maxillingua), blacknose dace (Rhinichthys atratulus), longnose dace (Rhinichthys cataractae), and brown trout (Salmo trutta). Two species of note include the fathead minnow (Pimephales promelas), encountered exclusively by Kemp and Spotila (1997) and Satinfin shiner (Cyprinella analostana), observed only by The Pennsylvania State University (1996). Fathead minnows are native to western Pennsylvania, but exotic to the Atlantic slope of Pennsylvania, the result of bait releases and/or hatchery escapement. Spotfin shiners are exclusive to Valley Forge NHP within MIDN parks (Atkinson, 2008).

Table 12. Fish species observed in Valley Creek, Little Valley Creek, and the Schuylkill River, Pennsylvania.

Family	Common Name	Species	Kemp and Spotila (1997)	Steffy and Kilham (2006)	Pennsylvania Fish & Boat Commission (2002)	Atkinson (2008) Schuylkill River
Anguillidae	Eel, American	Anguilla rostrata				S
Catostomidae	Sucker, White	Catastomus commersoni	X	X	X	XS
Catostomidae	Chubsucker, Creek	Erimyzon oblongus			X	
Catostomidae	Sucker, N. Hognose	Hypentelium nigricans		X		
Centrarchidae	Bass, Rock	Ambloplites rupestris	X	X		X
Centrarchidae	Sunfish, Redbreast	Lepomis auritus				
Centrarchidae	Sunfish, Green	Lepomis cyanellus	X	X	X	X
Centrarchidae	Pumpkinseed	Lepomis gibbosus	X	X	X	X
Centrarchidae	Bluegill	Lepomis macrochirus	X	X	X	X
Centrarchidae	Bass, Smallmouth	Micropterus dolomieui	X	X		XS
Centrarchidae	Bass, Largemouth	Micropterus salmoides	X			X
Cyprinidae	Goldfish	Carassius auratus				
Cyprinidae	Shiner, Satinfin	Cyprinella analostana				S
Cyprinidae	Shiner, Spotfin	Cyrprinella spiloptera				XS
Cyprinidae	Carp, Common	Cyprimus carpio	X			S
Cyprinidae	Minnow, Cutlips	Exoglossum maxillingua	X	X	X	X
Cyprinidae	Shiner, Common	Luxilus cornutus	X	X		X
Cyprinidae	Shiner, Golden	Notemigonus crysoleucus				
Cyprinidae	Shiner, Spottail	Notropis hudsonius				X
Cyprinidae	Minnow, Bluntnose	Pimephales notatus				X
Cyprinidae	Minnow, Fathead	Pimephales promelas	X			

Table 12. (continued) Fish species observed in Valley Creek, Little Valley Creek, and the Schuylkill River, Pennsylvania.

Family	Common Name	Species	Kemp and Spotila (1997)	Steffy and Kilham (2006)	Pennsylvania Fish & Boat Commission (2002)	Atkinson (2008) Schuylkill River
Cyprinidae	Dace, Blacknose	Rhinichthys atratulus	X	X	X	X
Cyprinidae	Dace, Longnose	Rhinichthys cataractae	X	X	X	X
Cyprinidae	Chub, Creek	Semotilus atromaculatus	X	X		X
Cyprinidae	Fallfish	Semotilus corporalis				
Cyprinidae	Dace, Pearl	Semotilus margarita	X		X	
Esocidae	Pickerel, Redfin	Esox a. americanus				
Ictaluridae	Bullhead, Yellow	Ameiurus natalis				
Ictaluridae	Bullhead, Brown	Ameiurus nebulosus				X
Percidae	Darter, Tessellated	Etheostoma olmstedi	X	X		XS
Percidae	Darter, Shield	Percina peltata				S
Salmonidae	Trout, Rainbow	Oncorhynchus mykiss	X	X		
Salmonidae	Trout, Brown	Salmo trutta	X	X	X	X
Salmonidae	Trout, Brook	Salvelinus fontinalis	X	X		

The fish species of perhaps greatest importance to the general public within Valley Creek is the brown trout. Brown trout are a non-native species to Pennsylvania and are the result of intentional stocking programs which began in North America as far back as the late 1800's (Sea Grant, 2011). However, brown trout have become a naturalized, self-reproducing species throughout many of Pennsylvania's streams and lakes. They provide recreational and economic opportunities to the Commonwealth and appear to be unofficially adopted as a "keystone species" for the state. Their value in Valley Creek and its tributary waters is of such importance that Valley Creek was granted the highest designation of stream protection by both the PA DEP (Exceptional Value Coldwater Fishery) and the PFBC (Class A Wild Trout Waters), based on the abundance of brown trout and their recreational and economic value. However, their presence can "have a significant negative effect on other fish, including other trout, and amphibians" (US Forest Service, 2011). These effects have impacted one of Pennsylvania's native coldwater species and its official state fish, the eastern brook trout (Salvelinus fontinalis). Additional information on the eastern brook trout is included in the "Species of Special Concern" section of this chapter.

The PFBC has conducted brown trout biomass samplings at multiple stations within the Valley Creek watershed since 1983. Fish biomass is expressed as a mass per unit area (i.e., kilograms per hectare). Sampling was conducted in 1984, 1990 and 2002 on Valley Creek. Based on these data it appears that resident brown trout biomass in Valley Creek has decreased from 1984 to 1990 (CCWRA, et al., 2004). Potential reasons for this decline include land use changes (e.g. increased impervious surfaces), droughts (which diminish wetted perimeter and increase water temperatures), and hurricane Floyd (severe flooding) (CCWRA, et al., 2004).

The eastern brook trout (Salvelinus fontinalis) is a fish species native to coldwater streams within the Schuylkill River drainage system. Historical accounts of fish surveys within the watershed reveal brook trout were present and may continue to persist in some of the headwater tributary streams. PFBC records document a native brook trout population existed in Crabby Creek prior to 2002. However, a 2002 fish survey observed no brook trout present in this stream. According to a personal communication by M. Kaufmann of the PFBC, brook trout were likely eliminated by flushing of Hurricane Floyd. Crabby Creek has a higher slope than other tributaries in the watershed and this may have added to the extirpation of brook trout (CCWRA, 2004). Additionally, the primary fish species managed and protected in this watershed is the non-native brown trout. In fact, it is their presence and economic and recreational value that granted Valley Creek the highest state protection designation, Exceptional Value Coldwater Fishery (EV-CWF).

This may conflict with any potential brook trout restoration efforts, as brown trout aggressively compete for resources and habitat and negatively impact brook trout and other native fish species. NPS units across the United States have taken steps toward restoring native fish populations, such as greenback cutthroat trout (Oncorhynchus clarki stomias) in Rocky Mountain National Park and Yellowstone cutthroat trout (Oncorhynchus clarkii bouvieri) in Yellowstone National Park, and have committed significant resources to eradicate non-native fish species when deemed to be biologically feasible and practically attainable management goals. Given the various competitive advantages of brown trout compared to brook trout such as greater tolerance of impaired water quality, the lack of a

wild brook trout gene pool at the park, the policy of the PFBC directed at maintaining the status quo (class A wild brown trout fishery), and the severely limited potential habitat available for reintroducing a viable, wild brook trout presence, such efforts would be impractical and unsuccessful in the opinion of the NRCA team.

Two other rare fishes found within Valley Forge NHP include Spotfin shiners (Cyprinella spiloptera) and bridle shiners (Notropis bifrenatu). Spotfin shiners are exclusive to Valley Forge NHP within MIDN parks (Atkinson, 2008) and prefer cool, fast headwaters and small streams. It is more tolerant of increased turbidity, siltation, and pollution than other species of shiners and thrives in the absence of competition from these other species. The bridle shiner (Notropis bifrenatu) is found within Valley Forge NHP and is listed as a state endangered fish. It is found in small, warm-water creeks and ponds to large lakes and rivers with clear to moderately turbid waters. It is usually over mud, silt, or detritus in sluggish pools, or in backwaters in moderate to abundant vegetation.

Threshold Criteria

According to PA Code 57.8a for a waterway to be removed from the Class A Wild Trout Streams designation, total trout biomass shall be documented below the following set of criteria for two consecutive stream examinations for Brown Trout, meeting these criteria places this metric in the "Good" condition category.

- Total brown trout biomass of at least 40 kg/ha (35.6 lbs/acre).
- Total biomass of brown trout less than 15 cm (5.9 inches) in total length of at least 0.1 kg/ha (0.089 lbs/acre).
- Brown trout biomass shall comprise at least 75% of the total trout biomass.

The condition assessment for the fish communities of Valley Forge NHP incorporated basic community metrics such as abundance, richness, and evenness and then utilized these metrics with additional data to perform an Index of Biotic Integrity (IBI). The IBI provides a standardized means of rating the health of the fish community and aquatic systems. For example, species richness takes no account of the number of individuals of each species present, so a species with one individual receives the same value, or weight, as a species with 1, 000 individuals. However, the Index of Biotic Integrity for Northern Mid-Atlantic Slope Drainages (Daniels et al. 2002) takes into account the number of species present, as well as the abundance of each species.

An IBI serves as a bioassessment tool that integrates several attributes of stream fish assemblages and provides a rapid and relatively inexpensive way to assess the general health of streams and evaluate environmental change (Karr et al. 1985). IBI scoring is based on a comparison to a regional reference standard that is based on fish communities present at sites with little or no impact (i.e., external stressors). Each metric receives a "value" score of five (5) points if it is similar to the expected fish community characteristics for a system with little external stressors, a score of one (1) if departs significantly from reference conditions, and a score of three (3) for an intermediate value (Karr, 1991). The sum of these scores produces a total site score which corresponds to a qualitative site classification (good, significant concern, etc…). Since IBIs are based on a comparison to a regional standard, the Index of Biotic Integrity for Northern Mid-Atlantic Slope Drainages was used

as the reference standard since it was applicable to the drainages of Valley Forge NHP and its surrounding watersheds, and it encompasses the Northern Piedmont physiographic province (Daniels et al. 2002).

However, of the 12 metrics measured using the Karr (1991) IBI methodology, two were not recorded during the previously conducted fish surveys. Accordingly, the total site scores were modified to reflect these changes and a modified form of the IBI of Northern Mid-Atlantic Slope Drainages was employed. This detracts from the reliability of the IBI, but still serves as a general characterization of species present and overall stream health. Additionally, as with fish population estimates, the IBIs for each study should be interpreted independently.

Threshold criteria adapted by Dr. Peter Sharpe from the Kerr (1991) IBI (see Table 3 of the published manuscript) for this NRCA are:

- Total IBI Score (out of 50)
- Good Condition – ≥ 45
- Moderate Concern – 34-44
- Significant Concern – 12-33

There have been four recent fish community studies conducted within Valley Forge NHP, including seven years of sampling data between 1990 and 2003 (Table 13). Approximate locations of the primary fish community sampling sites within Valley Forge NHP are displayed in Figure 19. Due to differences in sampling methodology and sampling locations, the primary utility in these studies are as "stand-alone" snapshots of stream health in proximity to given sampling vicinity. However, all of the studies provided sufficient data to compute species abundance, richness, and evenness for each respective study (Table 13). The data compiled by Kemp and Spotila (1997) and Atkinson (2008) additionally provided fish species inventory which allowed for separate calculations of the Index of Biotic Integrity (IBI) ratings for these two years (Table 14).

Table 13. Fish Community Data of Valley Creek within Valley Forge National Historical Park, between 1997and 2006.

Surveyor	Year	Abundance	Richness	Evenness
Drexel University	1993	412	14	0.76
	2001	62	10	0.79
	2002	102	9	0.8
	Average	192	11	0.78
National Park Service	2003	969	18	0.83

Current Condition

Researchers from Drexel University performed independent fish community surveys in 1993 (Kemp and Spotila, 1997) and in 2001-2002 under drought conditions (Steffy and Kilham, 2006). The latter work by Steffy and Kilham (2006) replicated the earlier Kemp and Spotila (1997) survey, utilizing the same sites and sampling methodology. Three of the study sites are located within Valley Forge NHP boundaries (Figure 19). Due to the similarities of these studies, this data set provides some additional insight into potential trends in fish community dynamics that may have occurred on Valley Creek within Valley Forge NHP during this time frame.

Another fish survey available for assessment was conducted in 2003 on Valley Creek, within Valley Forge NHP, by the National Park Service (Atkinson, 2006). These efforts included four sites along Valley Creek from the confluence with the Schuylkill River upstream to a section adjacent to the Park boundary near Lafayette's Quarters. Unlike the drought conditions experienced during the 2001 and 2002 studies, sampling in 2003 was conducted amidst above average and slightly turbid flows, which created difficult conditions for sampling. Thus the Atkinson (2006) work did not replicate the methodology from the previous Drexel University studies to allow for direct comparisons to be made.

The trend for resident brown trout biomass within Valley Forge NHP on Valley Creek has varied from 1984 to 2002. According to PFBC study data, resident brown trout biomass has fluctuated in Valley Creek at Valley Forge NHP from 24 kg/ha in 1984 to 120.21 kg/ha in 1990 and down to 57.31 kg/ha in 2002. Potential causes for the varying brown trout biomass totals are seasonal and annual differences in precipitation and water flow. Additionally, Steffy et al. (2004) stated that localized changes from construction work and quarry operations in the watershed have a significant impact on the stream flow of Valley Creek. The impacts from the quarries are difficult to quantify as they impact ground water movement as well as surface flows. Resident brown trout biomass was calculated most recently in 2002. Based on the survey results of 57.31 kg/ha, the PFBC categorizes Valley Creek within Valley Forge NHP as a Class A Wild Trout Stream and is considered in Good Condition; however, the drop from 120.21kg/ha in 1990 to 57.31kg/ha in 2002 indicates declining condition.

The available data on brown trout biomass only covered three years of data, with the most recent data covering 2002. The data for fish abundance, richness, and evenness covered seven years, between 1990 and 2003. In order to conduct a thorough assessment of fish community population dynamics, fish sampling needs to be conducted routinely and should include a focus on all fish species. Past trout surveys generally recorded non-trout species as incidental observations and records of their presence and abundance could be viewed as negatively biased. Valley Forge NHP's management objectives of their fish populations will dictate whether the non-native brown trout will remain as the primary species in Valley Creek and its tributary waters. If the extant population of naturally-reproducing wild brown trout remain as a top priority, this species should be routinely sampled and managed to maintain the PFBC's designation of Class A for wild trout reproduction (biomass volume: 40 kg /ha; evidence of two age classes and reproduction including yearling-age fish less than 15 cm length). Confidence in the assessment of condition was limited.

The overall stream health of Valley Creek, within Valley Forge NHP only, in the 1993 survey (Kemp and Spotila, 1997) was indicative of moderate concern conditions. The aggregate IBI score was 36, which falls in the upper limits of the moderate concern classification (Table 14), meaning that the stream shows signs of few intolerant species, skewed trophic structure (e.g., high percentage of generalist feeders), a low percentage of top carnivores, and a high percentage of tolerant species. Although Valley Creek scored well on several of the IBI metrics, including species richness, number of benthic-insectivorous species, number of water column species, number of terete minnow species, percentage of dominant species, and percentage of top carnivores, the overall site score was moderate concern, due primarily to the very low scores for the trophic composition categories. This sampling event revealed a very high percentage of white suckers, often an indicator of degraded systems, as they are highly tolerant to pollution, a high percentage of generalist feeders, and a low percentage of insectivores.

The associated IBI score for the National Park Service's 2002 survey (Atkinson, 2008) produced an overall stream health score of 39 (Table 14). This placed the stream health into the 'fair' classification. This could interpret to mean species richness is below expectation, with the loss of most intolerant fish species. It also implies sub-optimal abundances and size distributions, plus a stressed or skewed trophic structure. Similar to the Drexel University survey (Kemp and Spotila, 1997), this IBI scored positively for species richness, number of benthic-insectivorous species, number of water column species, number of terete minnow species, percentage of dominant species, and percentage of top carnivores. Overall, these aggregate scores are indicative of fair stream health, characterized by few intolerant species, skewed trophic structure (e.g., high percentage of generalist feeders), a low percentage of top carnivores, and a high percentage of tolerant species. As mentioned previously, the fish surveys are subject to variability of the investigator(s) and as such cannot be used for direct comparison or long-term trends analysis, therefore our confidence in the data is low.

A total of 213 individual fish representing 11 taxa were observed during the Schuylkill River sampling event (Table 12). The most abundant species included: common carp (*Cyprinus carpio*), American shad (*Alosa sapidissima*), and channel catfish (*Ictalurus punatus*). The American shad encountered were fingerlings migrating downriver from stock associated with the shad restoration program taking place on the Schuylkill River. It is also noted in this study that fish observed during sampling in VAFO, particularly Valley Creek, had a higher incidence of lesions and deformities than the other MIDN parks sampled (Atkinson, 2006). These features were present primarily on brown trout (*Salmo trutta*), white suckers (Catastomus *commersoni*), and cutlips minnows (*Exoglossum maxillingua*), but were found on all species within Valley Forge NHP except for blacknose dace (*Rhinichthys atratulus*) and tessellated darter (*Etheostoma olmstedi*). As we did not possess adequate time series fish abundance/species data for the Schuylkill River at the time of the analysis portion of this assessment, no individual biotic metrics were assessed as a means of determining water quality or habitat conditions within the Schuylkill River. Future assessments should consider this deficiency and consider collecting and including fish data suitable for an Index of Biotic Integrity along the Schuylkill River segment within the park.

Table 14. Summary Worksheet for IBI Calculations of Fish Surveys on Valley Creek in Valley Forge National Historical Park and Valley Creek Watershed. Condition Scoring (1 = Poor, 3 = Fair, 5 = Good).

Metric Number	Index of Biotic Integrity Metric	Valley Creek within Valley Forge NHP		Valley Creek Watershed	
		1993[1]	2003[3]	1993[1]	2002[2]
		Value (condition score 1, 3, or 5)			
1	Total Number of Fish Species	14 (5)	18 (5)	19 (5)	11 (5)
2	Number of Benthic-Insectivorous Species	6 (5)	6 (5)	6 (5)	6 (5)
3	Number of Water Column Species	4 (5)	5 (5)	4 (5)	3 (5)
4	Number of Terete Minnow Species	3 (5)	4 (5)	4 (5)	2 (5)
5	Percentage of Dominant Species	33% (5)	28% (5)	39% (5)	29% (5)
6	Percentage of Individuals that are White Suckers	28% (1)	18% (1)	19% (1)	22% (1)
7	Percentage of Individuals that are Generalist Feeders	66% (1)	66% (1)	63% (1)	63% (1)
8	Percentage of Individuals that are Insectivores	11% (1)	27% (3)	11% (1)	27% (3)
9	Percentage of Individuals that are Top Carnivores	22% (5)	7% (5)	25% (5)	10% (5)
10	Fish per Sample	392 (3)	646 (4)	19 (2)	26 (2)
	IBI total score	36	39	35	37
	Integrity class	Moderate	Moderate	Moderate	Moderate

1. Kemp and Spotila, 1997
2. Steffy and Kilham, 2006
3. Atkinson, 2008

Schuylkill River

Schuylkill River-Physical Water Quality

The Schuylkill River is arguably the most significant water feature within Valley Forge NHP. The Schuylkill River is a designated Warm Water Fishery (WWF) in Pennsylvania and is regulated for the "maintenance and propagation of fish species and additional flora and fauna which are indigenous to a warm water habitat" (PA Code Title 25, Chapter 93 Water Quality Standards). The river has also been designated as a Migratory Fishes (MF) water body, meaning it is also regulated for the protection of "passage, maintenance and propagation of anadromous and catadromous fishes and other fishes which move to or from flowing waters to complete their life cycle in other waters."

As described in the Valley Forge NHP General Management Plan, the 130-mile long Schuylkill River was the first waterway to be designated as a Pennsylvania Scenic River, and is also a nationally designated heritage corridor (NPS 2007). Approximately three miles of the river flows easterly through Valley Forge NHP. The Schuylkill River watershed encompasses approximately 1,916 square miles, most of which is located upstream of Valley Forge NHP. The park comprises 0.3% of the watershed), and is located near the bottom (at approximately mile 100) of the watershed. As a result, the condition of the river mostly depends on activities which occur outside of the park's boundaries and beyond the control if the NPS. Land use patterns within the watershed vary among forested, agricultural, and urban. It becomes increasingly urbanized from upstream to downstream. Within the park, the riverbanks are largely buffered by forest to varying degrees. This mosaic of land uses common to almost every river system within the United States creates benefits as well as impacts to water quality depending on the location within the channel. Approximately 34 miles of the Schuylkill River have been designated impaired by the PA DEP, including the three miles that flow through Valley Forge NHP. This listing is due to PCB and chlordane contamination occurring outside of the park boundary (NPS 2007).

The USGS maintains 10 stream gages along the Schuylkill River and published the *State of the Delaware Basin* technical report in June 2008, that incorporates this gage station data, as well as, information compiled in collaboration with the Delaware River Basin Commission, Partnership for the Delaware Estuary, US EPA, and a consortium of the four land-grant universities (Cornell University, Pennsylvania State University, Rutgers University, and University of Delaware) that represent the states in the Delaware basin (Kauffman, 2008). Since this is the most recent and comprehensive information available on the Schuylkill River, this report was synthesized to provide a condition assessment for the river.

The Delaware River Basin is composed of 21 subwatersheds, of those, the Schuylkill River watershed comprises 3 of them (SV1, SV2, and SV3 identified in the State of the Delaware Basin Report, June 2008). The lower portion of the Schuylkill River watershed (identified as SV3 in the Delaware Basin report) starts upstream near Pottstown and continues downstream to the tidewater at Philadelphia, the river monitoring station is located in Philadelphia at Falls Bridge (WQN 110).

This region is described as the 4th most populous subwatershed in the Delaware basin with almost 1,100 people per square mile within the 894 square mile area that constitutes this region. Over 28%

of the subwatershed is developed in suburban Montgomery and Chester Counties. Farming (36%) and forest (34%) diminishes as the Schuylkill River flows toward Philadelphia.

The Delaware Basin report collected water quality data based on each state's portion of the Delaware basin; Pennsylvania's portion is 50%. The report describes the average water quality over short-term (since 1990) and long-term (since 1970) time intervals for each subwatershed, including the lower portion of the Schuylkill River, which includes Valley Forge NHP. What follows is a summary of the "*State of the Delaware Basin Report*"(June 2008) following the framework established by the principal authors of that document for summarizing water quality within the Schuylkill River. For purposes of brevity we have modified the summary to focus mainly on the parameter assessed and relevant condition to avoid repeating background information (e.g. relevance and context) from the Valley Creek portion of this assessment. As the Schuylkill River is a WWF some of its water quality standards will differ from Valley Creek (CWF), the reader is referred to PA Code Title 25, Chapter 93 Water Quality Standards for any specific questions related to water quality threshold criteria differences (CWF versus WWF) not described in this document.

Temperature

Relevance and Context

As stated previously in the Valley Creek water quality section, temperature can have direct and indirect impacts on water quality and thus aquatic biota health. For more specific background information the readers is referred to those sections of the document.

Threshold Criteria

Specific threshold criteria of temperatures within the Schuylkill River are defined in PA Code Title 25 (Table 15), Chapter 93 Water Quality Standards based on a maximum monthly basis in below and may not exceed theses threshold values by more than 2^0F during a 1 hour period.

Table 15 PA code title 25, chapter 93, warm water fishery temperature criteria.

MONTH	TEMP1 CWF	MONTH	TEMP1 CWF
January 1-31	40	August 1-15	87
February 1-29	40	August 16-30	87
March 1-31	46	September 1-15	84
April 1-15	52	September 16-30	78
April 16-30	58	October 1-15	72
May 1-15	64	October 16-31	66
May 16-31	72	November 1-15	58
June 1-15	80	November 16-30	50
June 16-30	84	December 1-31	42
July 1-31	87		

Current Condition

At the time of this assessment there was no long term temperature data available for the Schuylkill River at this location, therefore, no condition assessment score for this metric was determined.

Dissolved Oxygen

Relevance and Context

As with the other water quality parameters shared with Valley Creek, the reader is referred to the preceeding water quality section for additional background information on the importance of dissolved oxygen for water quality and biota. The Delaware Basin Report defined short and long term trends in water quality parameters by plotting the 5-year median concentration of each parameter for half decade increments (e.g. 1971-1975, 1976-1980…2001-2005). Medians tend to be preferred for statistical analysis of many water quality parameters as they are less sensitive to extreme values compared to means.

Threshold Criteria

Specific threshold criteria for dissolved oxygen within warm water fisheries like the Schuylkill River are defined in PA Code Title 25, Chapter 93 Water Quality Standards based on flowing waters possessing a minimum daily average of 5.0 mg/L and no individual values falling below 4.0 mg/L, any values meeting this criteria score in the "Good Condition" category. Any scores falling below these values would rate in the "significant concern" category as low oxygen levels are fatal for most aquatic species if they are maintained for even a relatively short (hours) period of time.

Current Condition

Short-term dissolved oxygen levels (data collected since 1990) scored 'good' (10.8 mg/L), with levels above the PA water quality standard of 8.0 mg/L. Long-term dissolved oxygen data (data collected since 1970) for the Schuylkill River remained constant (Figure 20) at 10.8 mg/L and was also given a 'good' score. Our confidence in this assessment is medium due to the lack of current data.

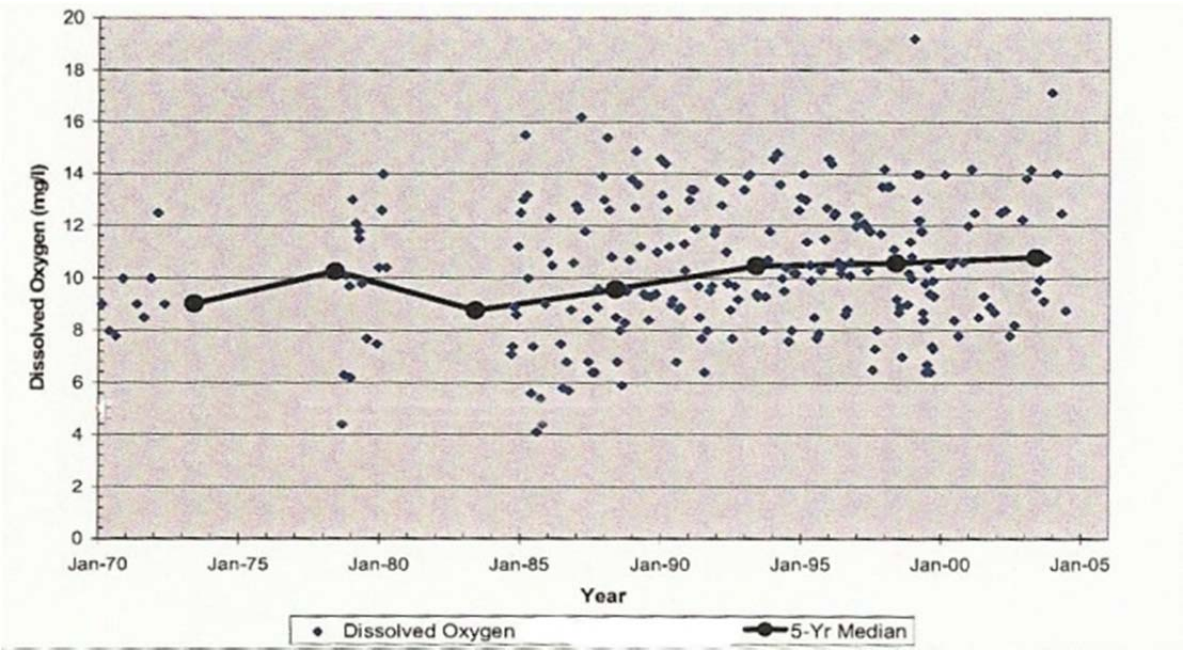

Figure 20. Dissolved Oxygen, Schuylkill River from 1970-2005 at Philadelphia, PA (Schuykill Valley 3) Falls Bridge, Pennsylvania Department of Environmental Protection, Water Quality Network 110.

Acidity (pH)

Relevance and Context

As stated previously in the Valley Creek water quality section, acidity can have direct and indirect impacts on water quality and thus aquatic biota health. For more specific background information the readers is referred to those sections of the document.

Threshold Criteria

Specific threshold criteria for acidity within the Schuylkill River are defined in PA Code Title 25, Chapter 93 Water Quality Standards based on a maximum and minimum range of values (6.0 minimum to 9.0 maximum). Ideal water quality scores fall within this acceptable range and would be considered to be within the "Good Condition." Any pH values that exceed or fall below this range would be in the "Significant Concern" category.

Current Condition

At the time of this assessment there was no long term pHdata available for the Schuylkill River at this location, therefore, no condition assessment score for this metric was determined.

Conductance

Relevance and Context

As stated previously in the Valley Creek water quality section, conductivity has a variety of uses and is frequently employed as an inexpensive indictor of perturbations within the water column and an estimate of total dissolved solids. For more specific background information the readers is referred to those sections of the document.

Threshold Criteria

There are no specific threshold criteria of conductivity measurements for warm water fisheries like the Schuylkill River. As with Valley Creek, the park is encouraged to begin monitoring long term trends and using the data to develop a baseline condition of conductivity under different flow rates and times of year. Any significant deviations from this baseline could then be identified and park staff would be a better position to address any potential water quality issues within the river.

Current Condition

At the time of this assessment there was no long term conductivity data available for the Schuylkill River at this location, therefore, no condition assessment score for this metric was determined.

Alkalinity

Relevance and Context

As stated previously in the Valley Creek water quality section, alkalinity is another potentially useful indicator of overall water quality.

Threshold Criteria

The threshold criteria for alkalinity is identical to cold water fisheries in Pennsylvania. The objective for "Good Condition," waters is to achieve a minimum value of 20 mg/L as $CaCO_3$ except where natural conditions are less.

Current Condition

At the time of this assessment there was no long term alkalinity data available for the Schuylkill River at this location, therefore, no condition assessment score for this metric was determined.

Turbidity/Suspended Solids (TSS)

Relevance and Context

The final criterion evaluated in the Delaware basin report of immediate relevance to Valley Forge NHP was Total Suspended Solids. Solids in water are all matter except the water contained in liquid materials, a more practical definition in management terms would be the matter that remains as residue upon evaporation and drying of a water sample at 103 to 105 ^{0}C (217-221^{0}F). Within the Schuylkill River, agricultural land uses tend to be most closely associated with observed TSS levels in the river (Philadelphia Water Department, 2006).

Threshold Criteria

There is currently no specific water quality concentration standard for TSS within the Pennsylvania Water Quality Standards (Chapter 93). A proposed standard for TSS concentrations within the Schuylkill River for this park are median monthly values below 40 mg/L, below this value would score the park in the "Good Condition" category and median values falling above this criteria would place this parameter into the "Significant Concern" category.

Current Condition

Long-term and short-term median trends for this region were reported at 2 mg/L. These results were considerably lower than the NRCA proposed standard of < 40 mg/L. Accordingly, both the short and long term time periods received a score of 'good' for total dissolved solids (Figure 21). Our confidence in this assessment is medium.

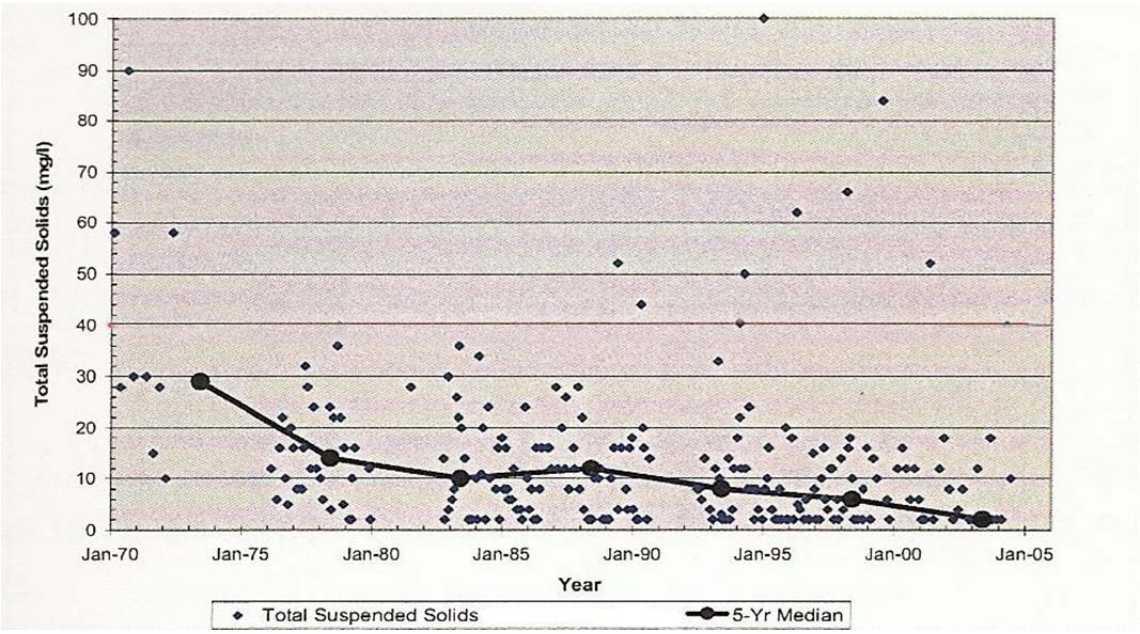

Figure 21. Total Suspended Solids, Schuylkill River from 1970-2005 at Philadelphia, PA (Schuylkill Valley 3) Falls Bridge, Pennsylvania Department of Environmental Protection, Water Quality Network 110.

Ammonia

Relevance and Context

As stated previously in the Valley Creek portion of this assessment Ammonia (NH_3) is an inorganic form of nitrogen and is important biologically in basic life functions. An excess of this nutrient can lead to biologic stress. A recent summary of water quality conditions in the Schuylkill River (Philadelphia Water Department, 2006), determined that between 1990 and 1999 (the period of record for this parameter) overall ammonia levels were decreasing within the Schuylkill River. However, an associated analysis of the 303(d) listed streams within the watershed suggest that

nutrients are still one of the top three leading sources of water quality impairment in the lower half of the Schuylkill River.

Threshold Criteria

The U.S. EPA has recently published new criteria governing ammonia limits in freshwater (April 2013). It is important to note that pH and temperature interact to affect ammonia levels and must both be taken into account when monitoring this analyte. Besides consideration given to pH and temperature levels, there are also separate acute toxicity and chronic toxicity criteria. The acute criteria is represented by a one-hour average and the chronic criteria is a 30-day rolling average with a with the additional restriction that the highest 4 day average within the 30 days be no greater than 2.5 times the chronic criterion magnitude. These values are not to be exceeded more than once in 3 years on average. For Schuylkill River we suggest using the base EPA average of 17 mg TAN/L and a chronic criterion magnitude of1.9 mg TAN/L at pH 7 and 20°C, with the stipulation that the chronic criterion cannot exceed 4.8 mg TAN/L as a 4-day average (TAN stands for Total Ammonia Nitrogen).

Current Condition

At the time of this assessment there was no long term ammonia data analyzed for the Schuylkill River at this location, therefore, no condition assessment score for this metric was determined. However, based on the general summary of ammonia conditions from 1990-1999 in the Philadelphia Water Department, 2006 report ammonia levels appear to be improving over time within the river.

Chloride

Relevance and Context

Chlorides occur in all natural waters but varying concentrations depending on the location (e.g. high gradient mountain streams versus low gradient river systems), channel morphology, and proximity to salt sources like the oceans. At levels above 250 mg/L chlorides make a salty taste to water, which is typically not preferred for drinking water supplies. At sustained concentrations above 500 mg/L the river system will exhibit more saline characteristics and aquatic flora and fauna adapted to strictly freshwater conditions will be adversely affected.

Threshold Criteria

The threshold criteria for chloride concentrations for potable water supplies in Pennsylvania which would also be a useful starting threshold value for the Schuylkill River at this location is 250 mg/L.

Current Condition

At the time of this assessment there was no long term Chloride data available for the Schuylkill River at this location, therefore, no condition assessment score for this metric was determined.

Nitrate+Nitrogen

Relevance and Context

Nitrate-Nitrogen levels and their significance have already been previously described in this document (see Valley Creek Relevance and Context). As with Valley Creek, nutrient contamination is one of the principal water quality issues facing the lower Schuylkill River.

Threshold Criteria

Pennsylvania Code, Title 25, Chapter 93 Water Quality standardThe threshold for nitrate-nitrogen concentrations for potable water supplies in Pennsylvania is a maximum of 10 mg/L.

Current Condition

Nitrate+Nitrogen levels detected in the Valley Forge NHP portion of the Schuylkill River have been below PADEP water quality standards since 1970 (long-term) and since 1990 (short-term) ending in 2005, with both time periods showing median trends of 3.2 mg/L. Median nitrogen levels displayed an increasing trend between 1970 and 1990, but seem to be remaining constant since 1990 in the short term (Figure 22). The PA water quality standard for this criterion is less than 10 mg/L. Both time periods received a score of Good Condition based on this assessment, our confidence in this data is high.

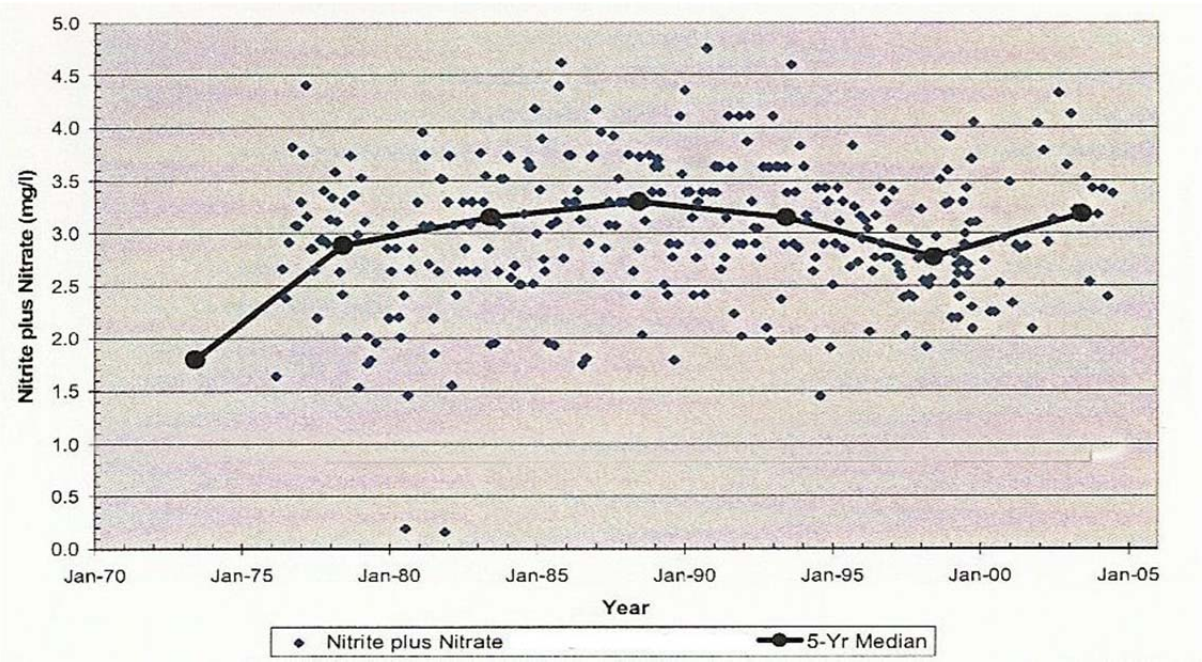

Figure 22. Nitrite plus Nitrate, Schuylkill River from 1970-2005 at Philadelphia, PA (Schuylkill Valley 3) Falls Bridge, Pennsylvania Department of Environmental Protection, Water Quality Network 110.

Phosphorus

Relevance and Context

Phosphorus levels and their water quality significance have already been previously described in this document (see Valley Creek Relevance and Context). As with the various nitrate species described previously for this river system, phosphorus is another nutrient commonly associated with agricultural run-off and is another analyte of water quality concern facing the lower Schuylkill River.

Threshold Criteria

There is no currently identified phosphorus water quality standard listed in the Pennsylvania code for potable water or warm water fisheries like the Schuylkill River, however, as with Valley Creek the same background phosphorus thresholds criteria may be applied here (0.1 mg/L) with any significant deviations above this threshold value to be considered in the moderate or significant concern category (Abrams and Jarrell 1995, Correll 1998).

Current Condition

Median phosphorus levels in the lower portion of the Schuylkill River showed decreasing trends within the watershed (Figure 23), although both long-term and short-term median values were reported at 0.23 mg/L which still exceeds the maximum ecological threshold value of 0.1 mg/L for flowing waterways. Though no criteria has been mentioned for giving a Moderate Condition score, our opinion is that the median values do not warrant a categorical rating of "significant concern" at this time. If the trend ceases to show improvement the park may wish to consider downgrading the condition to "significant Concern." Our confidence in this assessment is high.

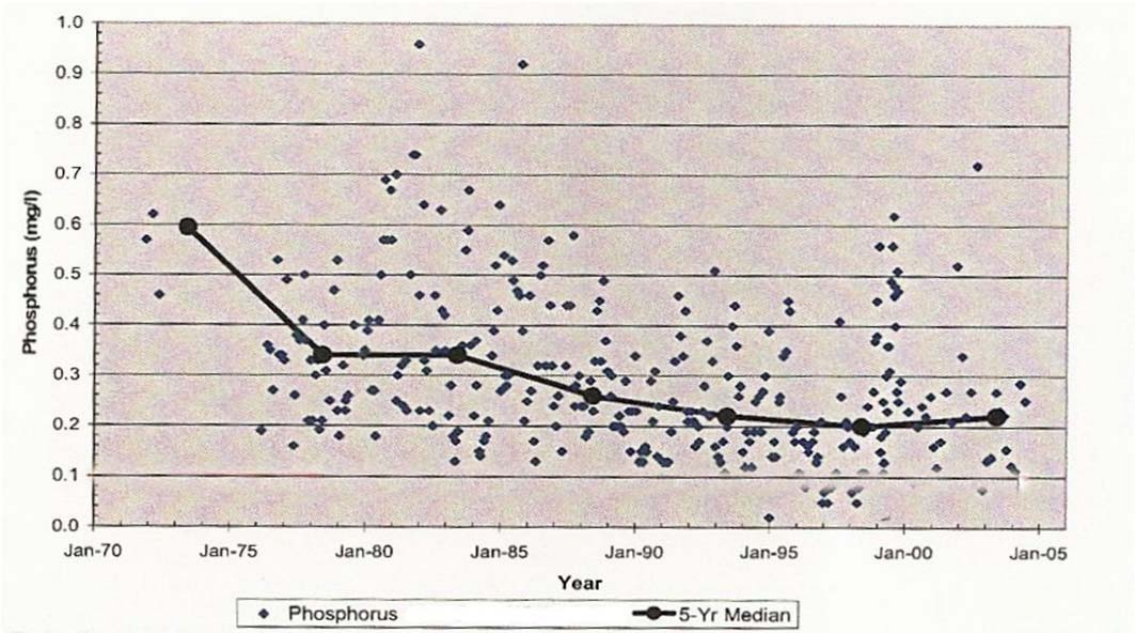

Figure 23. Phosphorus, Schuylkill River from 1970-2005 at Philadelphia, PA (Schuylkill Valley 3) Falls Bridge, Pennsylvania Department of Environmental Protection, Water Quality Network 110.

Stream Channel Characteristics: Habitat Quality – Valley Creek

Relevance and Context

The most recent habitat assessment of the riparian zones within the boundaries of both the Valley Creek watershed and Valley Forge NHP was conducted in 2002, by the Pennsylvania Fish and Boat Commission (PFBC) and Pennsylvania Department of Environmental Protection (PADEP). This assessment utilized an U.S. Environmental Protection Agency (US EPA) Stream Assessment Protocol (Barbour et al. 1999) to evaluate the Valley Creek watershed at 27 different locations on Valley Creek (VACR), Little Valley Creek (LVACR), and Crabby Creek (CRCR). Crabby Creek is a tributary to Little Valley Creek.

Threshold Criteria

Habitat assessments of waterways involve classifying stretches either riffle/run (high gradient) predominant or glide/pool (low gradient) predominant. The assessment then rates ten habitat parameters on a scale of 0 to 20. Parameters examined include fish and aquatic insect cover, channel alteration, sediment deposition, substrate, embeddedness, channel flow status, frequency and quality of riffles, pool variability and substrate composition, bank stability, bank vegetation, and riparian zone width. The cumulative score (out of a total possible of 200) categorizes the stream reach as poor (0-50), marginal (51-100), sub-optimal(101-150) or optimal(151-200). Stream habitat condition in Valley Forge NHP will be based on this existing habitat assessment framework with scores between 151-200 considered good condition, 101 – 150 are moderate condition and any score of 100 or lower is significant concern. Each parameter's scoring also helps determine specific limiting factors related to habitat in the stream stretch (Barbour, et al., 1999).

Current Condition

Several reaches along the main stem of Valley Creek and the Valley Creek tributary, including five sites in Valley Forge NHP (Figure 24) and two tributaries (Little Valley Creek and Crabby Creek), were assessed with the aforementioned protocol to correspond with the areas chosen by the Pennsylvania Fish and Boat Commission for fish surveys (Valley Creek Trustee Council, 2004). The average aggregate score for all 27 reaches sampled within the Valley Creek watershed was 131.7, approximately the mid-point of the 'sub-optimal' category (Tables 16 and 17). On average, the four highest scoring parameters were: 1) channel alterations; 2) channels flows; 3) frequency of riffles or channel sinuosity; and 4) velocity/depth or pool variability. These rankings indicate that Valley Creek's fundamental "flow" characteristics are adequate. Conversely, the four lowest scoring parameters were: 1) bank stability; 2) riparian vegetative zone width; 3) epifaunal substrate; and 4) sediment deposition (Tables 16 and 17). These rankings point toward sedimentation from banks and riparian areas resulting in degradation of the creek's "in-stream characteristics".

Figure 24.Pennsylvania Fish and Boat Commission's 2002 one-time stream habitat rapid bioassessment protocol sampling sites along Valley Creek in Valley Forge NHP.

Table 16. Average aggregate score for PFBC's 2002 U.S. EPA Rapid Bioassessment Protocol for Valley Creek watershed.

STREAM	NUMBER OF SITES	AVERAGE TOTAL SCORE	CONDITION
Valley Creek (Valley Forge NHP)	5	124.8	Sub-Optimal
Valley Creek (main stem)	11	125.9	Sub-Optimal
Little Valley Creek	8	137.4	Sub-Optimal
Crabby Creek	3	151.7	Optimal
Valley Creek Watershed	27	131.7	Sub-Optimal

Optimal: 200-151; Sub-Optimal: 150-101; Marginal: 100-51; Poor: 50-0.

Table 17. PFBC's 2002 U.S. EPA Rapid Bioassessment Protocol average metrics scores by stream reach for Valley Creek watershed (VACR: Valley Creek; LVCR: Little Valley Creek; CRCR; Crabby Creek).

	Substrate Metrics		Stream Channel Metrics				
Stream	**Epifaunal**	**Embedded**	**Vel/Dep (H); Pool Var (L)**	**Sediment**	**Channel Flow**	**Channel Alterations**	**Freq Riffs (H); Channel Sinuosity (L)**
VACR (in Valley Forge NHP)	13	13.6	16.2	11.4	15	14.2	14.4
VACR (main stem)	10.2	11.1	14.4	11.6	14.4	15.7	13.5
LVCR	12.8	14.6	15	12.9	15.6	15.8	15.8
CRCR	12.3	16.7	11.3	12.3	14	15.3	17.7
OVERALL	11.7	13.2	14.6	12	14.8	15.4	14.8

	Bank/Riparian Corridor Metrics						
Stream	**Bank Stability (Left)**	**Bank Stability (Right)**	**Veg Protection (Left)**	**Veg Protection (Right)**	**Riparian Width (Left)**	**Riparian Width (Right)**	**RBP Metric Totals**
VACR (in Valley Forge NHP)	3	5	4.8	6.4	4	3.8	124.8
VACR (main stem)	5.6	5.0	6.3	6.1	6.0	6.0	125.9
LVCR	5.1	5.6	6.4	6.6	5.3	6	137.4
CRCR	7.3	8.7	9	9	9	9	151.7
OVERALL	5.2	5.6	6.3	6.6	5.7	5.9	131.7

Assessing the five sites along Valley Creek, within Valley Forge NHP, the average aggregate score was 124.8 which was slightly below the mid-point of the 'sub-optimal' category. Consistent with the rest of Valley Creek, the areas inside Valley Forge NHP that scored the highest were channel alterations, velocity/depth or pool variability, channels flows, frequency of riffles, and channel sinuosity, while bank stability, epifaunal substrate, riparian vegetative zone width, sediment deposition, and vegetative protection received the lowest scores. Valley Creek in Valley Forge NHP results indicated that the stream's primary stream flow characteristics were satisfactory, while in-stream characteristics were degraded from banks and riparian zones contributing to substrate sedimentation (Tables 16 and 17). It should be noted here that PA 252 and a park trail both run parallel to Valley Creek on either side of the waterway for 1.5 miles (0.9 mi. trail, 0.6 mi. road) within the park and are contributors to the low riparian width and vegetative protection scores compared to the watershed wide habitat assessment.

Evaluating mainstem Valley Creek outside of Valley Forge NHP, the average aggregate score for the 11 reaches assessed was 125.9. This score falls slightly below the mid-point of the 'sub-optimal' category. Outside of Valley Forge NHP, Valley Creek's average parameter scores were similar to those of the Valley Creek in Valley Forge NHP. Stream habitat assessment scores of Valley Creek outside Valley Forge NHP indicate that the primary stream flow characteristics are adequate, while in-stream characteristics are degraded from banks and riparian zones contributing to substrate sedimentation (Tables 16 and 17).

Little Valley Creek, the largest tributary to Valley Creek, was sampled at 8 sites and received an average aggregate score of 137.4. This was above the mid-point of the 'sub-optimal' category and a higher average score than the watershed or Valley Creek at Valley Forge NHP. The individual parameters of Little Valley Creek demonstrated favorable conditions for stream channel characteristics. Substrate parameters revealed natural in-stream structures (epifaunal substrate) could improve, but sediment deposition was adequate.

Crabby Creek, a tributary stream to Little Valley Creek, was also assessed at three different reaches. This stream scored higher than all other waters assessed during this period, with an average aggregate score of 151.7. For this score, Crabby Creek received an 'optimal' classification. On average, Crabby Creek exhibited very good bank and riparian corridor characteristics, but scored less favorably on stream channel velocity and sediment deposition, and showed habitat limitations regarding epifaunal substrate. Similar to Little Valley Creek, Crabby Creek may be contributing to sediment deposition to downstream reaches of the Valley Creek within Valley Forge NHP.

The most current stream habitat assessment (2002) of Valley Creek watershed was sub-optimal, receiving an average cumulative score of 131.7. During this assessment, the five sites within Valley Forge NHP received a sub-optimal classification, with an average overall score of 124.8. The lowest scoring parameters included bank stability, riparian width, vegetative protection and sedimentation. The average cumulative score of the 11 Valley Creek watershed sites outside of Valley Forge NHP was 125.9, falling into the sub-optimal category. Little Valley Creek was sampled at eight sites and rated as sub-optimal, with an overall average score of 137.4. Crabby Creek was classified as 'optimal' with an average cumulative score of 151.7, based on 3 sampling sites. Crabby Creek could

serve as a useful reference reach for park staff if it's decided that the portions of Valley Creek flowing through the park are in need of restoration.

No assessment of trend is currently possible for this metric. The only available data were from a one-time study throughout the Valley Creek watershed. Regular monitoring of the streams within Valley Forge NHP and the watershed is a key data gap. Our confidence in the assessment of stream habitat conditions within Valley Forge NHP and Valley Creek specifically were limited as a result.

Stream Water Dynamics– Discharge Valley Creek

Relevance and Context

Valley Forge NHP is located at the bottom of the Valley Creek watershed, at its confluence with the Schuylkill River and has a watershed area of 24 square miles with 34 total miles of stream length (CCWRA, 2002). The bedrock is primarily limestone and dolomite which means the area is influenced by karst topography that could impact water quantity through the watershed.

The desired condition of water quantity in Valley Forge NHP is that natural hydrologic flows are preserved or restored whenever possible. There are several factors impacting current hydrologic flows through the park including urbanization, impervious surfaces in the watershed, historic water obstructions (e.g. dams), and discharges from quarry operations. Another factor complicating the understanding of water quantity in the watershed is the karst nature of the region which makes using traditional watershed scale models problematic. A total of 172 springs have been located in the watershed, it is estimated that 82% of the baseflow for Valley Creek comes via groundwater, much of which is expressed through these various spring flows (McGinty 2003). Also, the groundwater and surface water divide do not coincide for Valley Creek, with groundwater from the Brandywine drainage flowing into the Valley Creek watershed (CCWRA 2004). It is estimated that 0.75 million gallons per day (mgd) from west of the basin flow into the Valley Creek watershed, and the watershed loses approximately 0.85 mgd to the southeast in groundwater (CCWRA 2004).

Several operating and abandoned quarries in the watershed have had significant impacts on the water budget and hydrology of Valley Creek. The three major operations in the watershed are the Cedar Hollow Quarry, the Catanach Quarry, and the Glasgow Quarry. The Cedar Hollow Quarry in particular has been in operation for over 100 years and has recently closed down. This quarry impacted adjacent lands within the watershed by pumping large amounts of groundwater thereby depressing the local water table, and discharging that water directly into Valley Creek. In the case of Valley this may have had some positive impacts particularly during extended drought periods as it likely helped alleviate the impacts of low flow conditions experienced watershed wide. Until 2001, the Cedar Hollow Quarry pumped between 4 and 6.7 cubic feet per second (cfs) of groundwater into Valley Creek (CCWRA 2004). The quarry has been subsequently filled in to form a lake and pumping has ceased, raising the local water table about 40 feet (CCWRA 2004). Warner Quarry, although no longer in operation, has also had a dramatic impact on baseflow in Valley Creek. Average daily flows from the quarry were approximately 6.7 cfs, or about 4.5 million gallons per day (mgd) until 2001 (Valley Creek Trustee Council 2004). As of 2004, the quarry was pumping into Valley Creek at the rate of 4 cfs. It should be noted that when low flows at the USGS gauge

approached historical lows of 10 cfs, the Warner Quarry discharge of between 4 cfs and 6.7 cfs contributed a large percentage of the flow of Valley Creek.

Another major factor influencing hydrology in the Valley Creek Watershed is urbanization, which has increased impervious surfaces and stormwater run-off. Impervious surfaces alter hydrology by impeding infiltration and increasing run-off, particularly following large rain events. This can cause increases in water temperature and lead to increased pollution levels, in addition to creating larger flood events, increased stream velocity, and decreased groundwater levels which can lead to decreases in base flow. Valley Creek watershed has been experiencing rapid growth since the 1950s, although that is now leveling off. It was estimated in 2003 that impervious surfaces cover between 18% and 24% of the watershed (Figure 7) which puts it in danger of being severely degraded (Schueler and Galli 1992). Adding to this is the fact that much of the watershed development occurred during the 1950s and 1960s before stormwater best management practices (BMPs) were in place. Reed (1990) completed a report to predict the impact of changing land use on peak flows in the Valley Creek watershed. Using the Natural Resources Conservation Services TR-55 model which simulates urban hydrology in small watersheds, 2 year peak discharge increased from 400 cfs in 1776 to about 1350 cfs in 1995. Sloto (1989) predicted that with 25% impervious cover, the runoff would increase 52 % from 1988 values and peak discharge would increase an average of 55%.

Threshold Criteria

Baseflow in Valley Creek is augmented by the discharge of quarry water throughout the year. Average baseflow in Valley Creek between 1983 and1987, was 26.15 cubic feet per second (cfs). Many regulatory agencies use a short-term measure called Q7-10 to describe extreme low flow conditions in streams when assessing the ability of the stream to maintain viable aquatic habitat. The Q7- flow is based on average 7-day flows over 7 consecutive days, as opposed to average annual flows (reported here for this assessment). These 7-day average flows (Q7) can be analyzed for their recurrence interval as well. A Q7-1 would represent the lowest base flow expected to occur over a 7-day period in any given year. The Q7-10 base flow is the lowest average 7-day flow expected to occur once every 10 years. The Q7-10 threshold for Valley Creek is 10.7 cfs, below this value Valley Creek would fall into a “significant concern,” category. In addition the park has established an average annual flow based on the 1983-2009 period of record from the USGS water quality/quantity monitoring station (Site 50). Like the Q7-10 threshold criteria this measure is binary (good or significant concern), any average annual flows at or above 33.45 cfs score in the “good condition,” category. Any average annual flows that fall below this score would fall into the “significant concern,” range.

Annual peak discharge is another metric of potential use to the park. Though not highlighted in the overall park assessment (Table 1), it would provide the park with an assessment of waterway “flashiness” under storm flow conditions. We propose using atarget condition for discharge to not exceed 1500 cfs more than three times every ten years (Good Condition). Peak discharge values that exceed 1500 cfs more than 3 times every 10 years would constitute a significant concern to the park.

Current Condition

The USGS has maintained a gaging station at the Pennsylvania Turnpike bridge since October, 1982 (Figure 6, Figure 25). Because the watershed is covered by 18-24% impervious surface, hydrologic regimes are not likely to return to historic conditions, though as the watershed begins to redevelop opportunities exist to improve stormwater management and potentially restore the watershed to a more "natural" surface/groundwater flow state . Mean annual discharge for Valley Creek 91983-2009) was 33.45 cfs. Figure 26 shows the annual mean discharge from 1983 to 2009. Mean annual discharge for 2008 and 2009 was 30.7 and 29.9 cfs respectfully, which is below the target mean annual discharge measurement, and highlights the data variability and limitations in drawing inference from using the average annual discharge metric.

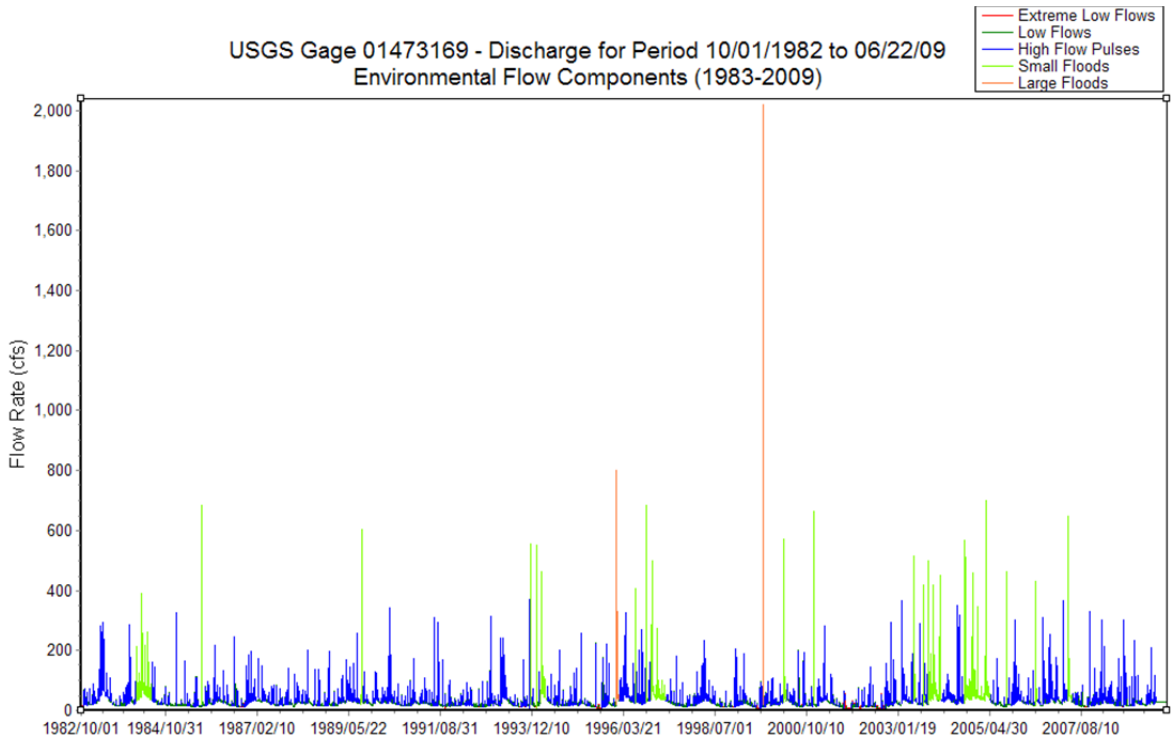

Figure 25. Flow records from the USGS gaging station located at the Turnpike Bridge near Valley Forge National Historical Park from 1983 to 2009.

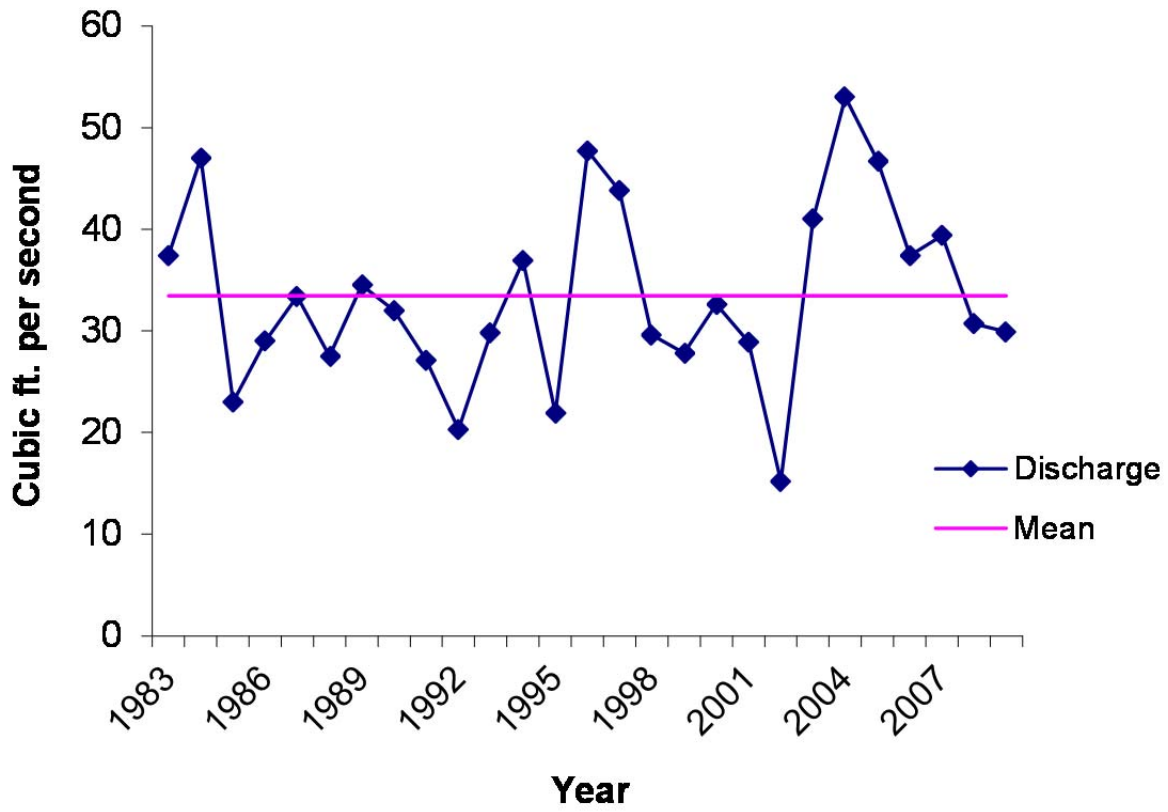

Figure 26. Mean annual discharge of Valley Creek from the USGS gaging station (01473169) located at the Turnpike Bridge from 1983 to 2009.

Annual peak discharage, a metric expected to increase with increased urbanization and climate change, is shown in Figure 27. Annual peak discharge has exceeded 1500 cfs 9 times in the past 26 years. Between 1999 and 2009, this level was exceeded 6 times, which is in the significant concern condition if the park chooses to adopt this proposed metric. It is important for the park to keep in mind that peak discharges in excess of 1500 cfs in Valley Creek into the future, may be largely dependent on climatic conditions and watershed development – both factors are largely out of the park's immediate control. However, the timing from baseflow condition to peak flow condition experienced within the park waterways or "Flashiness" can be controlled to a certain extent through the implementation of BMPs within and outside the park. To maintain minimum flows necessary for aquatic life in Valley Creek, we suggest that at a minimum baseflows be maintained following PA DEP Q7-10 guidelines. Therefore, Valley Creek Q7-10 flows of 10.7 cfs should be maintained at a minimum.

In order to reduce the frequency and severity of high flow events and increase the time required to reach peak flow, Valley Forge NHP should continue working with local municipalities and NGO interests in the watershed to reduce impervious cover, promote infiltration, and implement BMPs that increase stormwater retention time. There has been a recently completed Act 167 Stormwater Management Plan for the VACR Watershed. The plan makes an effort to satisfy the requirements of

the Pennsylvania Stormwater Management Act, Act 167 of 1978, and to establish scientifically-based stormwater management implementation strategies that restore and protect the water resources and maintain safe and productive communities. Implementation of this plan within the Valley Creek Watershed should help maintain appropriate water flows within the stream. The park is encouraged to continue supporting long-term water quantity monitoring efforts within the stream to ensure effective implementation of this watershed wide initiatives.

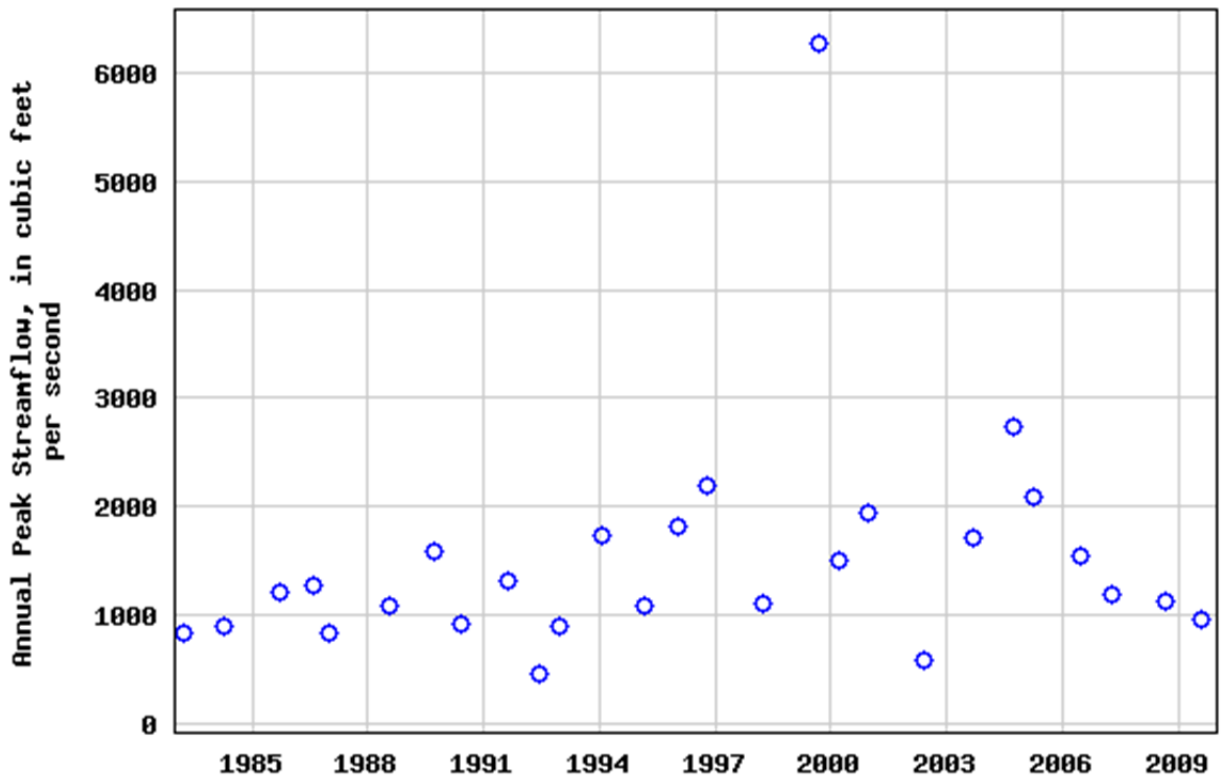

Figure 27. Annual peak stream flow at the Valley Creek Pennsylvania Turnpike Bridge USGS gage 01473169.

Riparian Buffers

Relevance and Context

Riparian buffers are a complex assemblage of plants and other organisms in an environment adjacent to water. Without definitive boundaries, it may include stream banks, floodplain, and wetlands, as well as sub-irrigated sites forming a transitional zone between upland and aquatic habitat (Lowrance, et al., 1985). Mainly linear in shape and extent, they are characterized by laterally flowing water that rises and falls at least once within a growing season. Natural riparian buffers are composed of grasses, trees, or both types of vegetation.

Vegetated buffers filter nonpoint source pollutants from incoming runoff and provide habitat for a balanced, integrated, and adaptive community of riparian and aquatic organisms (Welsch, 1991). These filtering and habitat functions are often best provided by natural vegetation such as trees and associated plants in the zone directly adjacent to the waterway. While there is general agreement about the benefits of buffers, the specific design criteria, such as buffer width, types of vegetation, and management, are the subject of considerable debate.

Regarding buffer vegetation type, it has been generally assumed that forested buffers provide the most benefit to riparian buffer function. However, a 2005 synthesis of 14 comprehensive and regional reviews of riparian buffer literature conducted by US EPA (Mayer, 2006), revealed grassland can serve as an effective nitrogen filter, while work by Schnabel (1997) showed "three grassed riparian zone sites each had higher denitrification rates than the single wooded site" in his study. While buffer vegetation type remains a topic of debate, research validates forested and grassland buffers are effective components of a functional riparian buffer.

Riparian areas throughout the park are ecologically significant in terms of providing critical habitat to a variety of plant and animal species. Many of the plant and animal species of concern found within the park rely on riparian habitats for their continued survival including Pennsylvania listed species such as the Great Egret (*Ardea alba*), and the Bridle Shiner (*Notropis bifrenatu*). Many of the frogs and reptiles of high conservation value utilize stream banks, rivers and ponds, and wetlands. Possum haw (*Viburnum nudum*), a state endangered plant, is associated with wetland and riparian areas specifically in Valley Forge NHP (NPS 2007).

Threshold Criteria

Width is considered the most important controllable variable in determining the effectiveness of buffers in reducing pollutants and protecting stream health. Buffers that are too narrow may not be sustainable or effective at protecting stream banks. Conversely, buffers that are wider than necessary, not only limit the economic use of adjacent land, but may be unpopular with landowners without providing substantial additional benefit to the stream. Complicating the determination of design buffer widths are the effects of varying site characteristics associated with topography, hydrology, geology, and land use. Additionally, other factors, such as the value of the water resource and adjacent land, must be considered when determining widths. The most commonly approved buffer width for water quality and habitat maintenance is a minimum of 100 feet. This width is recommended by the "Chester County, Pennsylvania Technical Compendium" (2001), "Chesapeake Bay Riparian Handbook" (CBP 1999), "PA Stream ReLeaf" guidelines (PADEP 1998), PA Association of Conservation Districts BMP Manual (PACD 1999), USDA "Riparian Forest Buffers" guidance document (USDA 2000), and is supported by documented research in resource management in publications and scientific literature (Todd 2000, Castelle and Johnson 2000).

The landscape of the Park and management zone objectives of Valley Forge NHP may preclude a 100-foot buffer as a viable option. Therefore, a threshold scale for buffer widths in Valley Forge NHP has been proposed as follows:

- ≥100 foot forested/grassland buffer = Good
- 35-99 foot forested/grassland buffer = Moderate
- < 35foot forested/grassland buffer = Significant Concern

For this report, the broad vegetation categories of grassland and meadow refer to areas that are dominated by herbaceous plants, and have soils that are not saturated year-round (Latham 2009). It should be noted that the land use classification employed for this analysis did not differentiate between maintained (i.e., mowed) and unmaintained grasslands, but rather classified land as 'developed', 'forested', 'water', or 'meadow'. For this analysis, all 'meadow' land use was considered grassland.

Regarding a target value for percentage of riparian buffer zone classified as forested/grassland, it is suggested that management objectives aim for at least 95% of stream/river miles in the park have a 100 foot forested or grassland buffer zone (good condition).

Current Condition

The current condition of riparian zone buffers was 'good' for 91% of two miles of Valley Creek located within Valley Forge NHP. The current condition of 91% of the combined 7.55 miles of the Schuylkill River, Welch Run, Meyer's Run, and Lamb Run located within Valley Forge NHP were 'good'. Additionally, in 2000 the Heritage Conservancy surveyed 38 miles of Valley Creek within the Valley Creek watershed. They found 10.2 miles (27%) of 38 miles lack buffers (less than 50-foot-wide forest and less than 50 % canopy closure). No assessment of trend is currently possible for this metric. The only available data were from an analysis of the riparian zone buffers using the current National Hydrography Dataset and land use classification completed by Podiesinski in 2005 and an assessment performed by the Heritage Conservancy in 2000. The two aforementioned studies were conducted a decade apart and the methodologies employed were too dissimilar in several aspects to draw an accurate comparison between the two. Regular monitoring of the riparian buffer zones within Valley Forge NHP and the Valley Creek watershed are key data gaps if park staff are interested in tracking buffer changes over time. Confidence in the current assessment was fair, while the confidence in the Heritage Conservancy assessment was low.

Impaired Water Designations

Relevance and Context

Section 303 (d) of the Clean Water Act requires states to report waters as impaired or threatened where required pollution controls are not sufficient to attain or maintain required water quality standards. Individual states are required to develop their own water quality standards based on the designated use of the water way and the level of water quality needed to protect those uses. Water quality standards for the state of Pennsylvania are outlined in Chapter 93 - Water Quality Standards and Chapter 16 - Water Quality Toxics Management Strategy of PA Code - Title 25 on

Environmental Protection. After a water body is designated as impaired or threatened, the state is required to develop the Total Maximum Daily Load (TMDL) which calculates the maximum amount of pollutant a body of water can receive and still meet water quality standards. TMDL calculations allocate pollution load between different sources (point and non-point sources) in a way that will achieve water quality standards.

Threshold Criteria

No current threshold criteria exist for this metric within the Mid Atlantic I&M network, however the current park goal is to achieve no miles of impaired waterways within the VAFO boundary. Impaired or threatened waters may be taken off of the 303d list after a TMDL has been developed or water quality has improved to the point where it meets current water quality standards.

Current Conditions

6.18 miles out of the 13.95 total miles or 44.3%of water ways within the VAFO boundary are designated as impaired on the 303 d list. Impaired stream segments include all of the Schuylkill River, Valley Creek, Fisher's Run, Myer's Run, Lamb Run and Trout Run within VAFO boundaries. No assessment of trend is possible for this metric.

Chapter 4. Biological Resources

Wetland Communities

Relevance and Context

A total of 51 unique palustrine wetlands totaling 63.96 acres occur within Valley Forge NHP(Figure 28). These wetlands include forested wetlands, vernal pools, springs, and emergent meadow wetlands. The largest wetland areas are forested wetlands along the north and south banks of the Schuylkill River – though some significant palustrine emergent wetland areas exist within the Grand Parade Grounds of the park (Ellsworth and Noon, 2009; P. Sharpe personal communication, 2011). The wetland found on the south bank of the Schuylkill River between the railroad tracks and the river is roughly 4500 ft long and 600 ft wide at its widest point (NPS 2007). In the northwest portion of the park, there is an extensive area of vernal pools and forested, emergent, and unconsolidated bottom wetland systems. All of these habitats are various forms of palustrine wetlands defined by Cowardin et al (1979) as inland, freshwater, non-tidal wetlands characterized by trees, shrubs, and emergent vegetation. A comprehensive wetland delineation for the entire park was headed by Dr. Peter J. Sharpe using the Eastern Mountains and Piedmont Region supplement to the Corps of Engineers Wetland Delineation Manual from 2-13 May 2011. The wetlands data used in this assessment is based off of the Sharpe et al. (2012) wetlands inventory for the park (see Figure 28).

Threshold Criteria

The Northeast Temperate Inventory and Monitoring Network (NETN) has proposed several metrics for assessing and monitoring wetland condition as a part of the vital signs monitoring program (Faber-Langendoen 2009). This methodology is composed of both GIS based metrics such as patch size, connectivity, and adjacent land use, and field metrics such as vegetation community measures. At the time of this report, the best information available was the spatial GIS data from Sharpe et al. (2012), therefore using this data as the new park baseline and utilizing the Director's Order #77.1 guidelines of no net loss of wetland habitat in our national parks the current objective is to maintain or even expand the spatial extent of wetland habitats within the park. As time and funds allow we hope to expand the long term monitoring efforts of wetland habitats within the park to include some or all of the proposed plant community metrics developed by Faber-Langendoen (2009) for the VAFO wetland habitats.

Current Condition

Using the most current wetland wetland inventory available (Sharpe et al. 2012) and the baseline goal of having no net loss of wetland habitat within the park, we are currently meeting that goal and the wetland communities are in a "good" condition. However, identifying and then maintaining the spatial extent of wetland habitat within the park is only a first step. Little if any quantitative data exists on the status of the individual vegetation communities themselves, future data needs include long-term status and trends data on wetland structure, invasive species occurrence,

Figure 28. Wetlands at Valley Forge NHP.

Forest Plant Communities

Relevance and Context

The forest communities of Valley Forge NHP are dominated by five primary types as defined by the National Vegetation Classification System.

- Modified Successional Forest (Valley Forge NHP-type) – 456 acres
- *Liriodendron tulipifera* [tuliptree] Forest Alliance – 374 acres
- *Quercus alba* [white oak] Forest Alliance – 204 acres
- *Quercus prinus* [chestnut oak] Forest Alliance – 186 acres
- *Platanus-Fraxinus* [sycamore-ash] Floodplain Forest – 170 acres

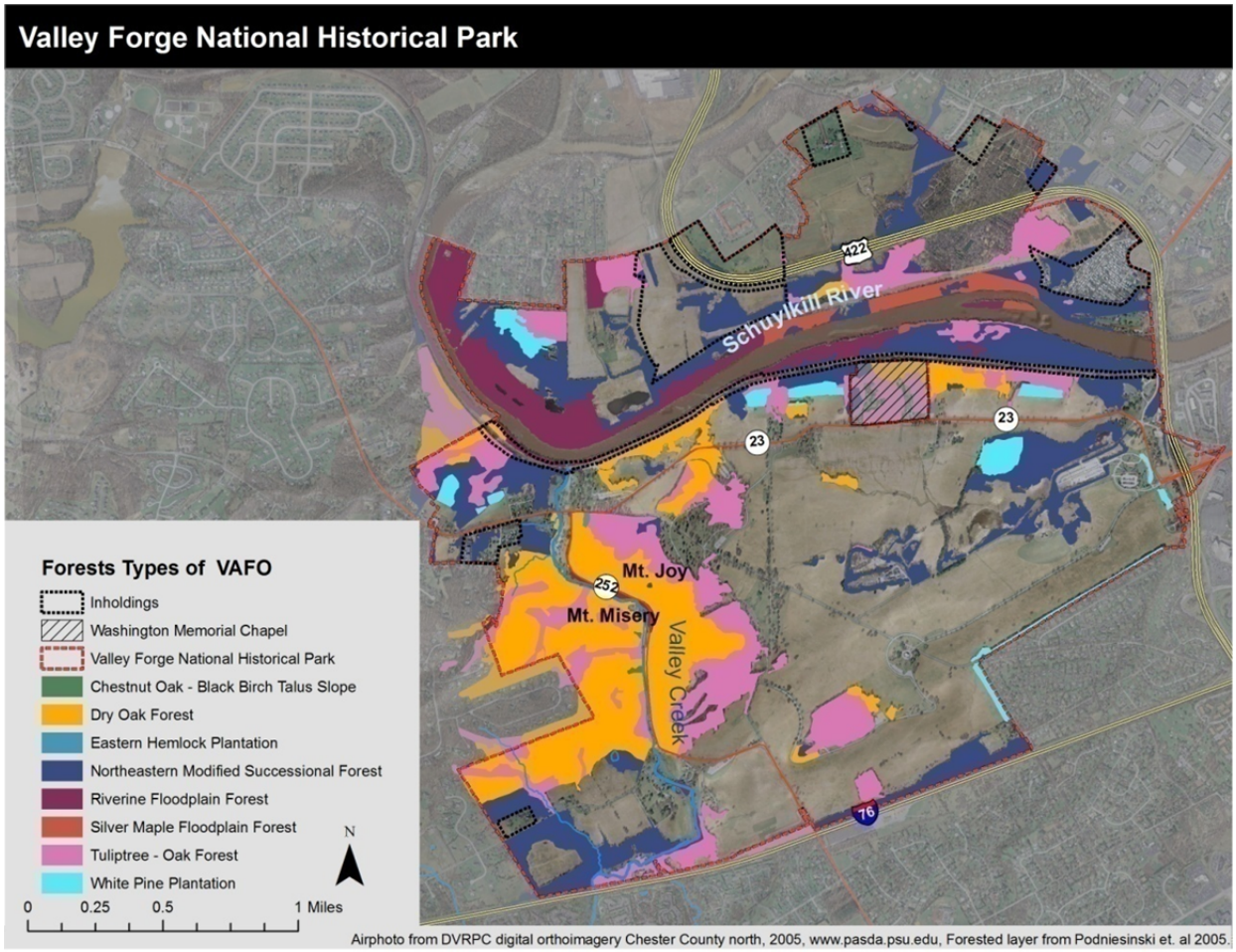

Figure 29. Forest types within Valley Forge NHP, classified according to Podniesinski et al. 2005.

The two largest areas of relatively intact forestland within Valley Forge NHP are the Mt. Misery and Mt. Joy areas in the southwestern part of the park. These areas are located on raised ridge areas underlain by resistant quartzite, phyllite, and schist and are separated by Valley Creek. Mt. Misery was formed from the Cambrian aged Chickies Formation, and Mt. Joy was formed from the Cambrian aged Antietam and Harpers Formation. Both of these rock formations are metamorphic and tend to weather to acidic, well drained soils that are not particularly fertile. Despite their similar geology, slopes on Mt. Joy are more moderate and the area is more suitable for agriculture than the rockier, steeper slopes of Mt. Misery. Mt. Joy is covered by a mix of dry oak forests and tuliptree successional forests, while Mt. Misery contains primarily dry oak forests. There is also a much more diverse understory present under the forests of Mt. Joy than can be found at Mt. Misery.

The remaining forested areas within the park are found in the floodplain of the Schuylkill River or in isolated patches throughout the park. Most of the area along the Schuylkill River, as well as all areas in the park north of the Schuylkill River are underlain by the Triassic-aged Stockton Formation which consists primarily of sedimentary sandstone, siltstone, and mudstone. The remaining forested patches are scattered throughout the park and are in areas underlain by dolomite of the Cambrian-

aged Ledger Formation. Dolomite tends to weather into soils that are much more suitable for farming with a higher pH. Most of this land was historically farmed, and some of these forested areas have been planted

Invasive nonnative plants pose a significant threat to the integrity of natural ecosystems across the United States. Spread of these species may impact native plant and animal communities by reducing the amount of light, water, nutrients, and available space. These changes in the native plant community would decrease habitat quality for native wildlife, alter hydrological patterns, soil chemistry, moisture-holding capacity, and erodibility, and may cause changes in the fire regime (Randall 1996). The nonnative problem is particularly acute in urban parklands where extensive forest fragmentation and creation of "edge" environments, frequent human disturbance, and high deer densities enhance opportunities for invasive, nonnative plants to become established (NPS 2004).

At Valley Forge NHP approximately one-third of plants are considered nonnative and 32 species are considered high priority invasive species. These plants invade a broad range of habitats, from forests and meadows to wetlands and roadsides. Removal of native species through selective deer browsing has provided nonnative species a competitive advantage resulting in significant spread of certain species of the past two decades. Large areas of the forest understory at the park are currently dominated by nonnative invasive plant species that outcompete and replace native plant species and disrupt wildlife habitat. Problem species in forested areas of the park include bush honeysuckle (*Lonicera mackii*), garlic mustard (*Alliaria petiolata*), Japanese barberry (*Berberis thunbergii*), Japanese honeysuckle (*Lonicera japonica*), Japanese stilt grass (*Microstegium vimineum*), mile-a-minute weed (*Persicaria perfoliata*), multi-flora rose (*Rosa multiflora*), Oriental bittersweet (*Celastrus orbiculatus*), privet (*Ligustrum* spp.), and tree of heaven (*Ailanthus altissima*) (NPS 2007). The Mid-Atlantic Exotic Plant Management Team (EPMT) completed identification and prioritization of nonnative plants at Valley Forge NHP in 2007. Efforts to manage and control these species are conducted primarily through the Mid-Atlantic EPMT, park staff and volunteers. Apart from the invasive species previously described, the park also contains four plant species that are PA state-threatened or endangered, as well as one species that is currently unlisted but is proposed to be listed as state endangered. Those species include Possumhaw viburmum (*Viburnum nudum*), tawny ironweed (*Vernonia glauca*), toothcup (*Lowland rotala*), and sweet scented bedstraw (*Galium triflorum*), while sand blackberry (*Rubus cuneifolius*) currently has a status of tentatively undetermined but may be state endangered in the future.

Outbreaks of insect herbivores or diseases in Pennsylvania's forests (referred to as pests and pathogens in this NRCA) have caused catastrophic mortality of important forest species (Latham et al. 2005). For example, in the early 1900s, the American chestnut (*Castanea dentata*), one of Pennsylvania's most abundant forest trees, was attacked by a Eurasian fungus that ultimately killed almost every chestnut tree in the eastern United States. During a recent visit from U.S. Forest Service (USFS) staff, no significant insect damage or disease condition was observed in Valley Forge NHP forests. Insect and disease problems identified that may impact forested communities in the future

are: gypsy moth, hemlock woolly adelgid, emerald ash borer, elongate hemlock scale, ash yellows, and ash decline (USFS 2007).

Gypsy Moth — Gypsy moths (*Lymantria dispar*) target a number of tree species found in the park including chestnut oak, white oak, red oak, black oak, scarlet oak, American beech, and various hickories. Gypsy moth caterpillars feed on the leaves of these hardwood trees and can cause complete defoliation of a tree, affecting the vigor and general health of forests, and sometimes leading to tree death. Tree death subsequently alters wildlife habitat and affects water quality and quantity. Gypsy moths first caused heavy defoliation of Pennsylvania forests in 1969 (McManus and McIntyre 1981) and subsequent outbreaks have been episodic with lower tree mortality. The USFS conducts aerial surveys to quantify gypsy moth defoliation on an annual basis. No evidence of significant gypsy moth infestation has been documented within the park since 1992.

Hemlock Woolly Adelgid — The hemlock woolly adelgid (*Adelges tsugae*) feeds by sucking sap from young needles, which causes them to drop prematurely. Extensive tree death is accompanied by detrimental environmental effects, such as the loss of ecological function, the loss of wildlife habitat (in the northeast United States, 96 bird and 47 mammal species are associated with hemlock forests for some critical component of their life cycle [Yamasaki, DeGraaf, and Lanier 1999]), soil erosion, changes in water quality, loss of aesthetics, and diminished recreational opportunities. Impacts on regeneration are attributed primarily to reduced seed production in infested areas. Hemlock woolly adelgid first appeared in Pennsylvania in 1967 (PA DCNR, 2013)and has moved slowly toward northwestern portions of the state.

Emerald Ash Borer — The emerald ash borer (*Agrilus planipennis*) is a newly arrived beetle from Asia found attacking and killing ash (genus Fraxinus) trees in Canada, Michigan, Ohio, Indiana, and recently in western and central Pennsylvania (USFS 2007). The USDA, in cooperation with state governments, has placed a quarantine on affected counties to reduce the likelihood of transporting the beetle outside the currently infested areas (USDA 2006). This pest has not been sited within the park.

Elongate Hemlock Scale — The elongate hemlock scale (*Fiorinia externa*) is an armored scale insect pest from Japan that affects mainly eastern hemlocks (*Tsuga canadensis*) and Carolina hemlocks (*Tsuga caroliana*) throughout the eastern U.S. This pest is present within Valley Forge NHP and the insect causes dieback of the limbs and eventual death within ten years. Maintaining hemlocks in healthy conditions discourages the buildup of scale populations. Although control of the pest is not possible in forests, declining hemlocks can be treated or removed to prevent the spread of scale populations (USFS 2007).

Ash Yellows and Ash Decline — There has been a significant decline of ash trees in both urban and woodland settings due to a variety of factors resulting in poor health and loss of tree vigor (Feeley 2001). Ash yellows is one contributing factor to the decline of ash trees causing severe growth reductions and dieback of white and green ash trees in the Great Plains and Rocky Mountain regions of the United States (Walla et al. 2000). Ash yellow is widespread in southeastern Canada and was first documented in the eastern Great Plains in 1993 (Walla et al. 2000). Currently, there is no known

way to prevent or cure ash yellows (Scarbrough and Juzwik 2004), though luckily this pest has not been observed within Valley Forge NHP.

All forests within Valley Forge NHP would be considered fragmented, typical of suburban environments. Forested areas in the park vary in size from less than 10 acres to over 200 acres with the majority of forested tracts being 20 - 60 acres in size (based on canopy acres). The current mix of field and forest is considered an important element of the cultural landscape as reflected in the General Management Plan objectives (NPS 2007). Characteristics of fragmented forests are captured in existing descriptions of park vegetation and long-term monitoring of forest plant communities. No significant change in the amount of forested land in the park is expected to occur in the future. Management of park forests would include maintenance of existing forest stands (ensuring regeneration) and maintaining the current pattern of field and forest as described in the park General Management Plan (NPS 2007).

Threshold Criteria

In order to assess the condition of forests at Valley Forge NHP, tree regeneration was selected as the overall indicator of forest condition. The desired condition for Valley Forge NHP forests is that forested plant communities will be dominated by native species, include a diverse mix of native herbaceous plants, and demonstrate a level of tree and shrub regeneration sufficient to ensure a diverse forest structure. This desired condition was established during development of the white-tailed deer management plan/EIS for Valley Forge NHP. Other metrics utilized to make this condition assessment including forest regeneration are:

- Forest regeneration (Seedlings / m^2)
- Soil chemistry Ca:Al and C:N ratios
- Invasive exotic species
- Coarse woody debris
- Snags (Snags / ha $\geq$ 30cm)
- Stand Structure (% late succession)
- Canopy tree condition
- Pests and pathogens (VAFO documented presence/absence).

These measures were chosen due to their direct impact on forest health/forest plant communities and because they are assessed as part of the long-term inventory and monitoring program at the park. Specific threshold criteria are summarized in Table 1 and in the current condition section discussion below.

In 2007, the Mid-Atlantic Inventory and Monitoring Network (MIDN) began establishing permanent plots in Valley Forge NHP as part of the forest vegetation monitoring protocol. Between 2007 and 2010, 28 permanent plots were established in Valley Forge NHP, with each plot being a 20m x 20m square, with three nested microplots and 12 quadrats in each plot (Figure 30). In addition, transects were placed through each plot to measure CWD. As part of the MIDN forest monitoring protocol, each site is revisited every four years. Data collected for each plot includes data on trees, saplings, and herbaceous species. It is the data from the first complete census (Comiskey and Wakamiya 2011)

that is utilized in this condition assessment of forest health at VAFO, with data from the first revisits used to evaluate tentative trends (Comiskey 2013). As noted by Comiskey (2013) any temporal trends presented by the MIDN data are for only one-half of the total number of plots established by the network, therefore, our confidence in this data is low-medium.

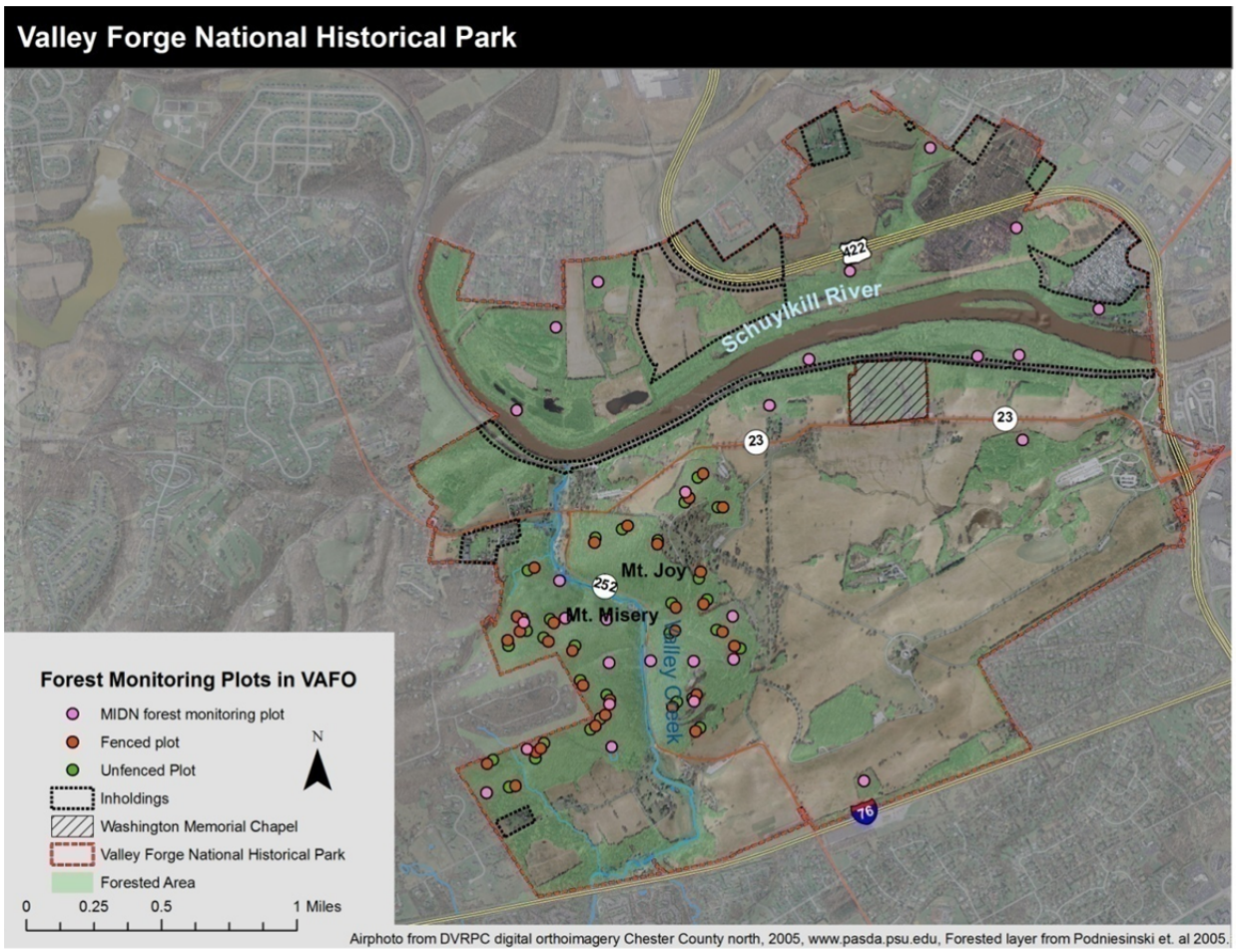

Figure 30. Forest plots within Valley Forge NHP. Plots include fenced and unfenced plots for a long-term white-tailed deer study and MIDN forest monitoring plots.

Current Condition

1. Forest Regeneration - Forest regeneration is considered the primary measure of success for the management of white-tailed deer at Valley Forge NHP (NPS 2009). The forest regeneration threshold established in the deer management plan (NPS 2009) was determined based on the recommendations of the Forest Inventory and Analysis (FIA) program implemented by the United States Forest Service and Pennsylvania Bureau of Forestry, Pennsylvania Forest Regeneration Study (PRS). The FIA program and the PRS have adopted the threshold of adequate stocking rate to be 25 seedlings per 12.57 square meters or about 2 seedlings per 1m² in low deer-density areas, and 96 seedlings per 12.57 square meters or 8 seedlings per $1m^2$ in high deer-density areas. For this reason,

the NPS considers forest regeneration to be "Good" if the stocking rate is above 8 per m^2, "Moderate Concern" if less than eight but greater than 2 per m^2, and "Significant Concern" if stocking is below 2 per m^2. Despite the recent reduction in deer densities since implementation of the deer management plan at VAFO we would recommend using the more conservative high deer-density threshold of 8 seedlings per m^2, until it can be conclusively determined that the resident deer population within the park is consistently at or below their target density value (NPS 2009).

The Comiskey (2013) forest vegetation monitoring report found a "slight increase" in the tree seedling regeneration score from Census 1 (2007 and 2008) to Census 2 (2011 and 2012). However, this increase was still below an average weighted seedling score of 2 seedlings / m^2 putting regeneration in the significant concern category.

2. Forest Soil Chemistry – Two commonly utilized measures of soil health and thus plant community health in forested ecosystems in the northeast are Ca:Al and C:N ratios. Calcium (Ca) is vital micronutrient for plant health and can be scarce in forest soils that are poorly buffered (e.g. derived from non-carbonate bearing rock) and have experienced chronic acid deposition (see air quality section) that leaches the Ca and other important base cations such as magnesium (Mg) and potassium (K) out of soil matrix which increases the availability of aluminum (Al) for plant uptake. Excessive uptake of Al by plants leads to stress and eventual death, with a concurrent decline in forest regeneration. The deposition of atmospheric nitrogen (N) onto forest soils can also lead to detrimental effects to forest communities. Excessive nitrogen can reduce plant vigor and affect root:shoot ratios (less root growth and more shoot growth), leaving trees vulnerable to blow down effects from severe weather events.

Comiskey (2013) established a "Good" Ca:Al ratio of > 4.0 in the O and A soil horizons (upper depth). Because of current uncertainty with NPS contracted laboratory methods compared to others, namely Cronan and Grigal (1995), the MIDN doesn't currently use Moderate or Significant Concern criteria for Ca:Al ratios. A "Good" C:N ratio is > 25 measured in the O and A horizons or upper depth, "Moderate Concern" is 20-25, and "Significant Concern" is < 20. Median Ca:Al ratios for VAFO forest plots as reported by Comiskey (2013) were 1.56 which places the metric well below the target threshold of > 4.0, but slightly above the 1.0 ratio value reported by Cronan and Greigal (1995) as having a 50% risk of adverse impact on tree growth. Carbon and nitrogen ratios at the park fell within the Moderate Concern range of 20-25. No trend data is available for either metric

3. Invasive Exotic species – MIDN forest health monitoring currently has 29 invasive exotic indicator species that are surveyed within VAFO. Comiskey and Wakamiya (2011) found a mean number of exotic species per plot at VAFO to be 2.10 which is higher than the target threshold value of < 0.5 species per plot, putting the park in the Moderate Concern category. The most commonly observed invasive exotic species within the forest monitoring plots was Japanese stilitgrass (*Microstegium vimineum*). Limited trend data from recent revisits to plots suggests that invasive exotic species are stable (Comiskey 2013).

4. CWD – Coarse woody debris refers to large branches and entire downed trees. This metric provides an indication of wildlife habitat availability when compared against the proportion of live

tree volume (Comiskey, 2013). Good, Moderate, and Significant Concern condition scores for this metric are > 15%, 5-15%, and < 5% of live tree volume respectively. Comiskey and Wakamiya (2011) reported a 19% score for VAFO indicating park forests were in a "good" condition for CWD. Limited trend data from recent revisits to monitoring plots suggests that CWD condition is stable (Comiskey 2013).

5. Snags – Standing dead biomass (snags) provide vital habitat for cavity nesting and insectivorous bird species and invertebrates. The proportion of snags in relative to live standing trees and shrubs (DBH ≥ 10 cm) can indicate higher or lower mortality for a given forest community (Comiskey and Wakamiya 2011). Snag condition is assessed in the following way in the MIDN:

Good: At least 10% of all standing trees and shrubs ≥ 10 cm DBH in a park or group of plots are snags <u>and</u> at least 10% of all medium-large (≥ 30 cm DBH) standing trees in a park or group of plots are snags.

Moderate Concern: Less than 10% of standing trees and shrubs ≥ 10 cm DBH in a park or group of plots are snags <u>or</u> less than 10% of all medium-large (≥ 30 cm DBH) standing trees in a park or group of plots are snags

Significant Concern: Fewer than five medium-large snags (≥ 30 cm DBH) per hectare, calculated for the park or a group of plots. Limited trend data from recent revisits to plots suggests that snag proportions in VAFO forests are stable (Comiskey 2013).\

Snag density ranked as Moderate Concern, with an average of 7.14 snags ≥ 30 cm were documented per hectare in VAFO (Comiskey and Wakamiya 2013). Limited trend data from recent revisits to plots suggests that snag proportions in VAFO forests are stable (Comiskey 2013).

6. Stand structure – The stand structure metric assesses the forest stage distribution (based on plot data) in relation to expected distribution under natural disturbance regimes (Comiskey 2013). In other words, this metric can serve as an indicator of altered disturbance regimes and be an indication of forest habitat suitability for forest species dependent on a particular forest structural stage. Comiskey (2013) rate forest structural stage based on the expected percentage of late-successional forest stages across the landscape and then assigned a "good condition" if at least 25% of the total number of surveyed plots possess a total plot basal area ≥ 67% of canopy trees in mature plus large sizes, with more basal are in large than mature size (see Comiskey, 2013 for more detail). At VAFO 58% of the plots surveyed fell within the "Late-Successional Stage Class," therefore the park was rated at a good condition for this metric (Comiskey and Wakamiya 2011). Limited trend data suggest that stand structure is stable (Comiskey 2013).

7. Canopy Tree Condition – The foliage condition of trees at VAFO is also assessed in an effort to help identify the impacts of past and current pest and pathogen damage to the forest community. A "Good" condition assessment score would be when <10% of canopy stems have foliage problems and no high priority pests and pathogens are detected; "Moderate Concern" when 10-50% of trees have foliage problems or low priority pests are detected (hemlock wolly adelgid, elongate hemlock scale, or butternut canker); and, "Significant Concern" when >50% of trees have foliage problems or

high priority pests are detected (Asian long-horned beetle, emerald ash borer, and sudden oak death; Comiskey 2013) . Currently 71% of the MIDN forest plots are classified as having good canopy tree condition. Limited trend data for this metric trend data suggests that conditions are stable, however, because the I&M network is still in the early stages of collecting time series data our confidence in this metric was medium.

8. Pests and Pathogens – This primarily relates to forest pests and pathogens which are assessed as part of the canopy tree condition metric (Comiskey, 2011). VAFO has a park goal of having no pests/pathogens within the boundary. Of the list of pest/pathogen species that are on the MIDN watch list, only the hemlock wooly adelgid is currently known to exist within the park. As this particular metric has no gradation in scale (e.g. pest/pathogens are either present in the park or they are not), we consider this to be of moderate concern based on the fact that the species appears to be under control and its principal host tree (hemlocks) do not make up a significant component of the forest communities at VAFO apart from the eastern hemlock plantation forest type within the park.

Grassland Community

Relevance and Context

After forested lands, grasslands (*Festuca* herbaceous alliance) comprise the second largest percentage of the Valley Forge NHP landscape (Figure 31). This particular vegetation community includes mowed lawn and tall grass meadows. Valley Forge NHP's tall grass meadows represent one of the largest occurrences of remnant grasslands in eastern Pennsylvania and have been identified as important habitat for breeding grassland bird species (Yahner et al. 2001). In 2007, a meadow inventory documented the presence of 325 plant species, dominated by warm and cool season grasses. The cool season meadow community is generally dominated by nonnative grass species and the warm season meadow community is dominated by native grasses. (Furedi 2008)

In addition to grasses, forbs and woody species are also present in the fields. Some commonly encountered forbs were boneset (*Eupatorium* spp.), common yarrow (*Achillea millefolium*), common milkweed (*Asclepias syriaca*), thistles (*Cirsium* spp.), common yellow oxalis (*Oxalis stricta*), mountain mint (*Pycnanthemum* spp.), horse nettle (*Solanum carolinense*), and goldenrod (*Solidago* spp.). Forbs not only increase species diversity in the fields but also provide a food source for butterflies and other insects. In addition to grasses, forbs such as milkweed, thistle, and common mullein (*Verbascum thapsus*) provide vertical structure in fields. Vertical structure in meadows is particularly important during the breeding season of grassland birds (e.g., vocalization) and in predator-prey relations (e.g., visibility). Woody species were present in the fields but mostly uncommon (Furedi 2008).

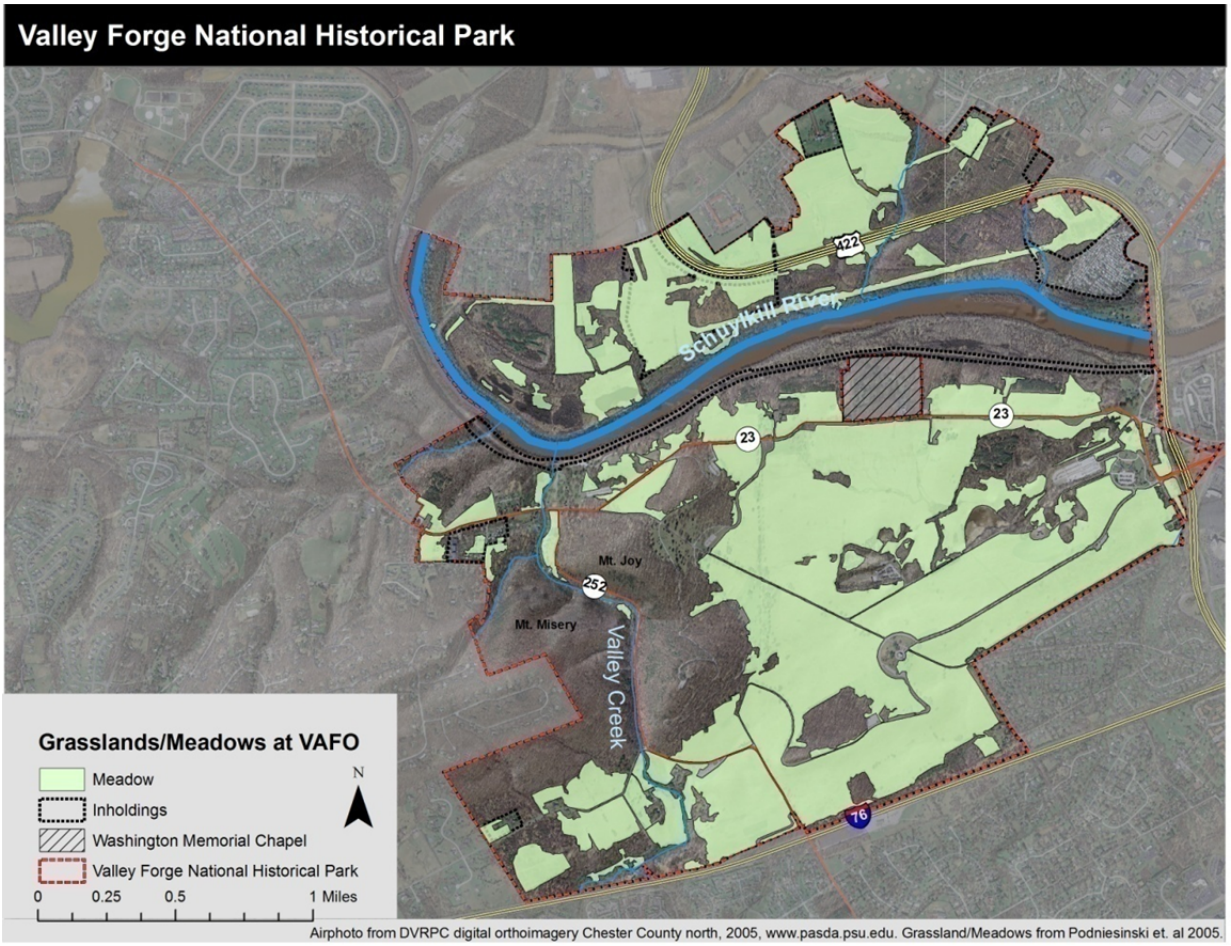

Figure 31. Areas covered by grasslands or meadows at Valley Forge NHP (Podniesinski et al. 2005).

In 2007, a detailed inventory of Valley Forge NHP grasslands was completed (Furedi 2008). A total of 175 - 5m x 5m plots were established in 77 fields to sample herbaceous vegetation. In addition to the plots, a meandering search technique was used to identify additional species that may be present in the areas surrounding the various plots. In addition to the general inventory, an invasive species assessment was conducted to monitor for 21 priority invasive species identified in consultation with the park manager (Table 18). A total of 325 plant species were identified in the fields/meadows in the park, of which 60% were native species in Pennsylvania. At the plot level, nonnative plant species represented 68% of total cover and, on average, account for 52% of the species (Latham 2011). Several species of management concern were found during the survey: Elliot's bluestem (*Andropogon gyrans*), soft fox sedge (*Carex conjuncta*), lowland rotala (*Rotala ramosior*), and sand blackberry (*Rubus cuneifolius*). None of these species are state or federally listed as threatened or endangered. A 2008 rare plant survey completed by Timothy Draude also found two populations of Tawny ironweed a state-listed endangered species, in an isolated meadow on the southwestern park boundary.

Table 18. Priority invasive species found in grasslands/meadows at Valley Forge NHP (Furedi 2008).

Scientific Name	Common Name	% of cells with invasives present (N = 222)
Ailanthus altissima	tree-of-heaven	17
Alliaria petiolata	garlic mustard	6
Artemisia vulgaris	common wormwood	17
Berberis thunbergii	Japanese barberry	24
Celastrus orbiculatus	oriental bittersweet	91
Cirsium arvense	Canada thistle	51
Cirsium vulgare	bull thistle	66
Coronilla varia	purple crownvetch	23
Elaeagnus umbellata	autumn olive	69
Humulus japonicus	Japanese hops	1
Lespedeza cuneata	Chinese lespedeza	5
Ligustrum sp.	privet	1
Lonicera japonica	Japanese honeysuckle	87
Lonicera morrowii	Morrow's honeysuckle	2
Microstegium vimineum	Japanese stilt grass	91
Miscanthus sinensis	zebra grass	21
Phalaris arundinaceae	reed canarygrass	14
Phragmites australis	common reed	3
Polygonum perfoliatum	mile-a-minute vine	20
Rosa multiflora	multiflora rose	90
Rubus phoenicolasius	wineberry, wine raspberry	31

In general, the fields within Valley Forge NHP were shown to have a "mostly similar" composition, although some differences were seen primarily in fields north of the Schuylkill River, perhaps because those fields have been established more recently and display a higher proportion of annual and other early successional species (Furedi 2008). Latham (2009) divided up the identified grassland species into the following functional groups:

- native long-lived perennial warm-season grasses (11 species)
- native long-lived perennial grassland/ meadow forbs and cool-season grasses (57 species)
- native annual, biennial and short-lived perennial grassland/meadow forbs and grasses (19 species)
- nonnative annual, biennial and short-lived perennial forbs and grasses (36 species)
- nonnative long-lived perennial forbs and grasses (51 species)
- nonnative woody plants (11 species

In the Valley Forge NHP General Management Plan, future management actions for the existing grassland communities will focus on enhancing the "high habitat values" of these areas for wildlife species, while maintaining the historic field/forest pattern. As such, Latham (2009) completed a report detailing what future conditions may be at Valley Forge NHP if the attempt is made to restore native grassland/meadow communities. Restoring native grassland communities would greatly improve native wildlife communities, particularly insects, butterflies, and birds. With regular management efforts such as mowing, removing non-native invasive species, and keeping the white-tailed deer population under control, it will be possible to restore native tall-grass communities to Valley Forge NHP (Latham 2009).

Threshold Criteria

The threshold criteria for grasslands are based on maintaining and enhancing ecological integrity and native species biodiversity while preserving the historical landscape that is central to the park's enabling legislation. To achieve this, target conditions associated with native vegetation and wildlife habitat were selected since conditions that promote these metrics will provide the greatest benefit and ecological function to the most number of species. In order to establish a target value for the grassland vegetation community at Valley Forge NHP, a reference site was selected at Fort Indiantown Gap (FIG) in Lebanon County, PA. In native grassland/meadows at FIG, about 83% % of the plot cover was by native species. Using this information, the Good Condition threshold for native vegetation at Valley Forge is set at ≥ 80% native cover, Moderate Condition is 70% < 79.9% native cover and Significant Concern is <70% native cover. (Latham 2011)

The major metric for obligate grassland birds is meadow size and connectivity. Contiguous fields of 100-250 acres are necessary to support entire grassland bird communities with fields less than 12 acres are avoided by grassland birds (Herkert 1994, Winter and Faaborg 1999). Additionally, trees and other vertical structures over 5m (16ft.) tall are avoided by grassland bird species (as they serve as perches for larger predatory birds), these structures should be removed or shortened when appropriate, to promote native grassland bird species. Using aerial photography from 2005 as the base data, a patch size analysis was completed by the NRCA team using GIS which identified 20 distinctive field areas covering a total of about 1,100 acres within the park (Figure 32). Fields were considered distinct if they were separated by a road or a tree line. There are currently no criteria for an "ideal" ratio of 100+ acre patches within cultural resource parks such as Valley Forge NHP. Additionally, increasing grassland patch size beyond the current levels within the park may not be possible as expanding grassland area/connectivity would likely come at the expense of other habitats, such as forest lands or involve the elimination of park roads, which would impact visitor access. Therefore, a reasonable baseline goal for grassland patch size would be to maintain the existing patch size distribution within the park, "moderate" condition and to also assess vertical structure in the fields. If the percentage of large ≥ 100 acres patches were to increase to ≥ 50% of the total grassland area within the park (1,100 acres) this would be considered a "good" condition, while a decline in patch size below the existing level as of this assessment could be rated as "significant concern."

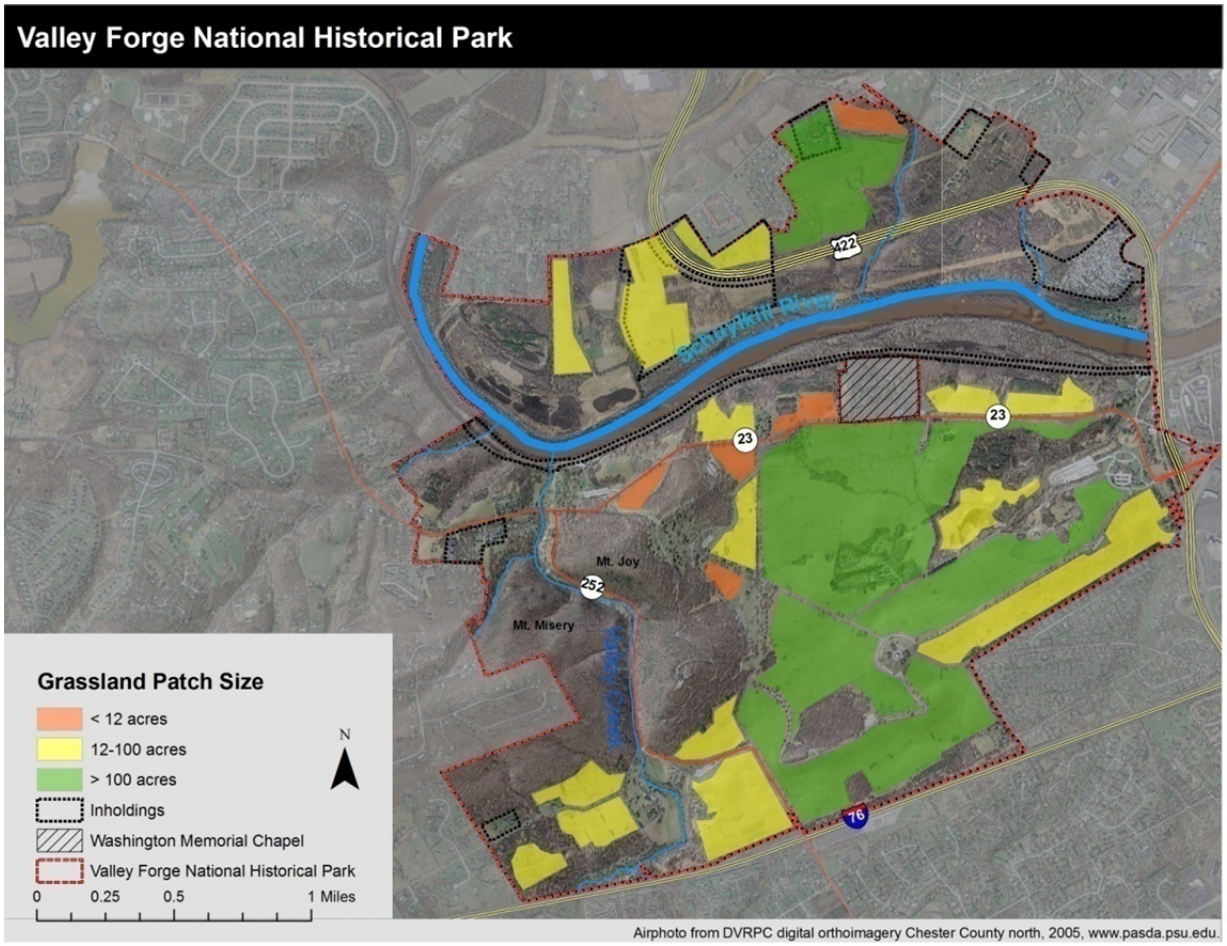

Figure 32. Grassland patch size at Valley Forge NHP. Patches greater than 100 acres are ideal.

Current Condition

Currently less than 50% of the meadows are dominated (plots having aerial coverage ≥ 90% native species) by native species (Latham 2009) which puts grasslands in the "significant concern" category. Our patch size analysis found 5 out of the 23 fields assessed within Valley Forge NHP were approximately 100 acres or larger in size. Based on a simple percentage of the total area grassland area within the park (1,100 acres), approximately 50% of fields are currently managed in patches greater than 100 ac, with 5 fields being slightly less than 12 acres indicative of the baseline "moderate concern" rating for the park. The park is encouraged to focus on improving the quality of the patches by emphasizing warm season grass growth and diversity, increasing nectar species, modifying or eliminating vertical structures over 5m and eliminating non-native cold season grass communities. Though these activities may not be ideal for obligate grassland bird species that require grassland patches greater than 100 acres in size, the improvements to the habitat will benefit facultative grassland bird species, small mammals, invertebrates, and overall plant species richness within the park.

Reptile and Amphibian Communities

Relevance and Context

Amphibians, due to their relatively sedentary lifestyles, porous and highly permeable skin and multi-stage life histories that utilize diverse habitat types, are considered to be valuable response indicators and predictors of environmental stress (Petranka et al. 2003, Lutcher et al. 1996, Grant et al. 1992). In some cases, detection of certain species can be difficult due to their elusive nature (Lutcher et al. 1996). In the forests of eastern North America, the Eastern Red-Backed Salamander (RBS) is the most abundant amphibian species and accounts for more vertebrate biomass than any other group (Burton and Likens 1975; Conant and Collins 1991). The abundance, longevity, territoriality, and sensitivity of this lungless salamander makes it a cost effective and appropriate candidate for long-term monitoring and indicator of forest ecosystem health (Welsh and Droege, 2001). This species has increasingly been used as an indicator of forest health (deMaynadier and Hunter 1998, Moore et al. 2002, McKenny et. al. 2006, Homyack 2011) and studies indicate that, due to high capture rates and behavioral adaptations, this genus may have a statistical advantage over other species for monitoring long-term forest health (welsh and Droege, 2001). Stream bank salamander assemblages are also suggested as excellent ecological indicators, if properly selected and evaluated, and may provide another biological tool for the assessment of the first and second order small headwater streams such as Welch Run, Meyer's Run, and Lamb Run (Rocco and Brooks 2000). Many aspects of the park's herptefaunal community are well understood; however, a continuous monitoring plan and community assessment tool, are still required.

Early amphibian life stages and reproduction are vulnerable periods even in the absence of environmental toxicants (Carey and Bryant 1995). Environmental toxicants may cause death and disease in the larval stages, slower metamorphosis, and may impair future reproduction (Carey and Bryant 1995). In Pennsylvania, agriculture and urbanization are the major spatial processes driving habitat fragmentation and shrinkage (Forman 1995). Other threats to reptiles and amphibians within Valley Forge include collectors, climate change, and unauthorized trails (social trails) in the park.

Threshold Criteria

The park is currently developing a standardized long-term monitoring program for Red-backed salamanders to assessment population condition and trends within Valley Forge NHP. At the time of this document, the research design was being developed and objectives refined; however, the lack of information on herpetile populations is a key data gap that should be addressed. Currently, the park has set a threshold of no net loss of reptile and amphibian species in the park but threshold criteria are expected to expand with the new monitoring program.

Current Condition

Given the lack of a consistent sampling scheme we were unable to develop condition categories or an overall assessment for amphibians and reptiles at Valley Forge NHP. However, it is important that, at a minimum, species of management concern continue to be inventoried and that these inventories follow a consistent set of sampling points, times, and trapping/capture methods so that the park can build upon the Tiebout (1999-2001) and Carfioli (2006) inventories.

Fifteen amphibian and fifteen reptile species are known to inhabit Valley Forge NHP, including 1 PA Threatened Species (Red-bellied turtle) and 3 Pennsylvania Species of Special Concern (Eastern Box Turtle, Northern Copperhead and Queensnake) (Table 19). Encountered species were recorded during the most recent herpetofauna surveys by Tiebout (1999-2001) and Carfioli (2006). A number of survey methods were used during the Tiebout survey to ensure a variety of habitats were sampled (i.e. coverboards, drift fences, anuran callings, aquatic trapping, etc.). Two amphibian species (Eastern Spadefoot and Northern Leopard Frog), and 2 reptile species (Eastern Ratsnake and Spotted Turtle) are known to occur nearby from historical records and though not detected in recent herpetological surveys, have a better than average probability of occurring within the park.

Habitat use by herpetofauna species varies widely in Valley Forge NHP. Tiebout (2003) reported that, on average, a given species could be found in a ran ge from one to nine habitat types. Of the nine habitat types, the two most species-rich were the lowland forest and wetlands (Figure 33), accounting for 76% of the amphibian species found at Valley Forge NHP while the three anthropogenic habitat types (developed areas, roads, and railroad beds) included the least (Tiebout 2003). Additionally, adult, juvenile and hatchling individuals of the PA State Listed threatened red-bellied turtle (*Pseudemys rubriventris*) were documented in Valley Forge NHP (Carfioli et al. 2007). Red-Bellied turtles are presumably breeding within Valley Forge National Historical Park and it is important, for the preservation of this species, to maintain the habitat of river debris and rocky shoreline and to maintain the aquatic vegetation by the S.R. 422 bridge as it is critical nursery habitat (Cypher et al. 1985 and A. Rhue personal communication 2013).

The park is encouraged to continue to manage its existing lowland forest and wetland communities in a manner supportive of existing herpetofaunal species and to expand future inventories to cover the additional wetland areas described in the Sharpe et al. (2012) wetland inventory report.

Table 19. Reptiles and Amphibians present or historically present in Valley Forge NHP (Tiebout).

Group	Common Name	Scientific Name	Present During 1999-2001 Survey	Present in Historical Records
Salamanders				
	Eastern (Red-Spotted) Newt	*Notophthalmus viridescens viridescens*	X	--
	Four-Toed Salamander	*Hemidactylium scutatum*	--	--
	Jefferson Salamander	*Ambystoma jeffersonianum*	--	--
	Longtail Salamander	*Eurycea longicauda longicauda*	X	X
	Marbled Salamander	*Ambystoma opacum*	--	--
	Mudpuppy	*Necturus maculosus maculosus*	--	--
	Northern Dusky Salamander	*Desmognathus fuscus fuscus*	X	X
	Northern Red Salamander	*Pseudotriton ruber ruber*	X	X
	Northern Spring Salamander	*Gyrinophilus porphyriticus porphyriticus*	--	--
	Northern Two-Lined Salamander	*Eurycea bislineata*	X	X
	Red-Backed Salamander	*Plethodon cinereus*	X	X
	Slimy Salamander	*Plethodon glutinosus*	X	X
	Spotted Salamander	*Ambystoma maculatum*	-	--
Toads and Frogs				
	American Bullfrog	*Lithobates catesbeiana*	X	X
	Eastern American Toad	*Anaxyrus americanus americanus*	X	X
	Gray Treefrog	*Hyla versicolor*	X	X
	Eastern Spadefoot	*Scaphiopus holbrooki holbrooki*	--	X
	Fowler's Toad	*Anaxyrus fowleri*	X	X
	New Jersey Chorus Frog	*Pseudacris triseriata kalmi*	--	--
	Northern Cricket Frog	Acris crepitans crepitans	--	--

Table 19. (continued) Reptiles and Amphibians present or historically present in Valley Forge NHP (Tiebout).

Group	Common Name	Scientific Name	Present During 1999-2001 Survey	Present in Historical Records
	Northern Green Frog	Lithobates clamitans melanota	X	X
	Northern Leopard Frog	Lithobates pipiens	--	X
	Northern Spring Peeper	Pseudacris crucifer crucifer	X	X
	Pickerel Frog	Lithobates palustris	X	X
	Southern (Coastal Plain) Leopard Frog	Lithobates sphenocephalus utricularia	--	--
	Upland Chorus Frog	Pseudacris triseriata feriarum	--	--
	Wood Frog	Lithobates sylvatica	X	X
Turtles				
	Bog Turtle	Glyptemys muhlenbergii	--	--
	Northern Map Turtle	Graptemys geographica	X	--
	Eastern Musk Turtle	Sternotherus odoratus	X	--
	Eastern Snapping Turtle	Chelydra serpentina serpentina	X	X
	Eastern Box Turtle	Terrapene carolina carolina	X	X
	Eastern Mud Turtle	Kinosternon subrubrum subrubrum	--	--
	Eastern Painted Turtle	Chrysemys picta picta	X	X
	Red-Bellied Turtle	Pseudemys rubriventris	X	X
	Red-Eared Slider	Trachemys scripta elegans	X	X
	Spotted Turtle	Clemmys guttata	--	X
	Wood Turtle	Glyptemys insculpta	--	--
Lizards				
	Broadhead Skink	Eumeces laticeps	--	--
	Five-Lined Skink	Eumeces fasciatus	--	--
	Eastern Fence Lizard	Sceloporus undulates	--	--

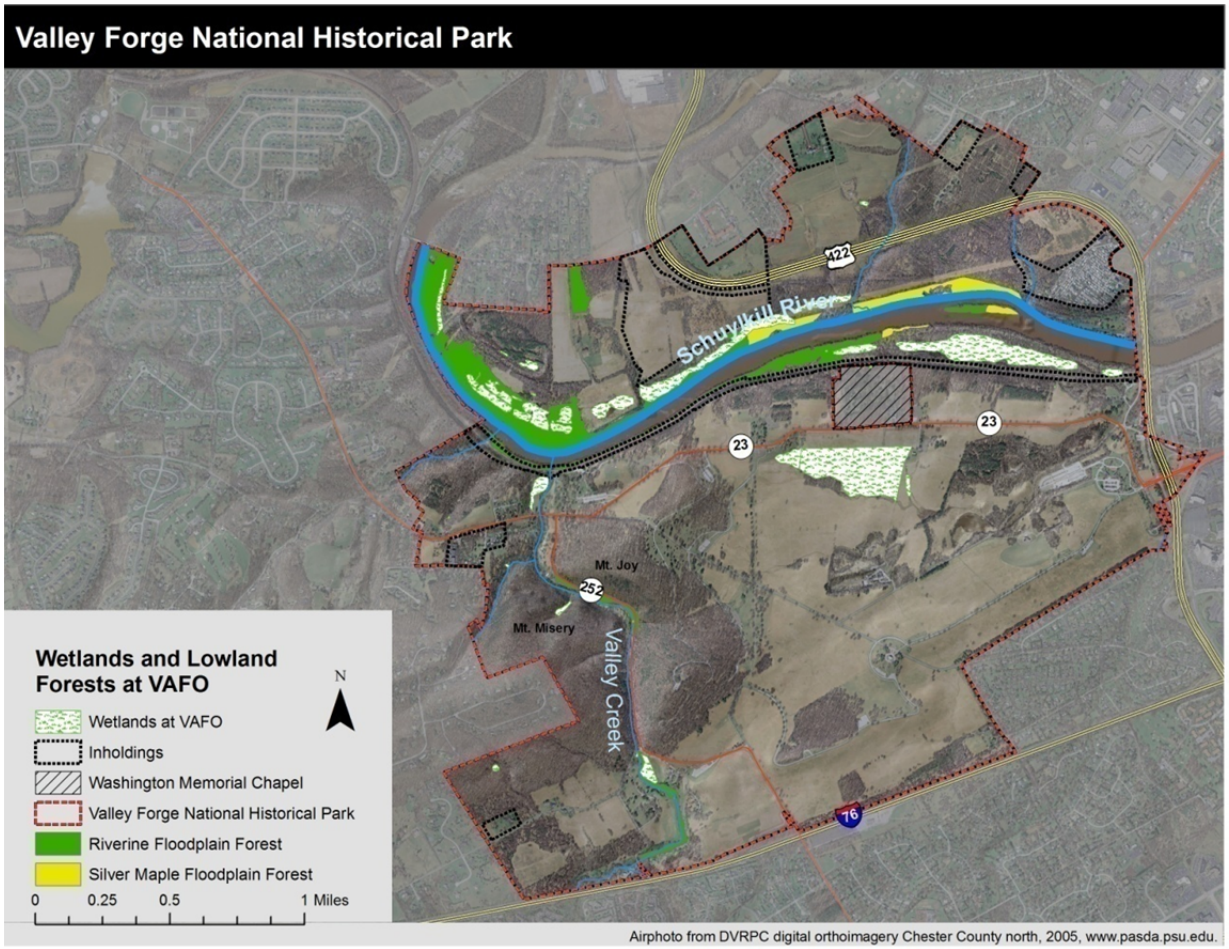

Figure 33. Wetlands and lowland forests at Valley Forge NHP. These two ecosystems are the most species rich for amphibian populations, containing 76% of the species present in the park.

Bird Communities

Relevance and Context

Monitoring trends and status of the breeding bird communities are important because birds, particularly breeding birds, are especially sensitive to habitat features such as canopy structure, nesting sites, food supplies and escape cover (Conner and Dickson 1997). Some species of birds, such as woodpeckers, may serve as indicators of overall bird diversity (Mikusinski et al. 2001). Birds generally have been shown to be useful indicators of ecosystem health, and this is especially true where ecosystems are heavily impacted (Bradford et. al. 1998; O'Connell et al. 2001). Beginning with authorization of Valley Forge National Historical Park in 1976, the NPS conducted field observations and produced a checklist of bird species observed within the park by staff, members of the Audubon Society, and volunteers. This "Bird Sightings List" includes 227 bird species and is reflected in the NPS I&M Program NPSpecies database which lists 226 species of birds as being either historically or presently found in Valley Forge NHP.

Partners in Flight, a cooperative effort to address the conservation of birds, produced a list of species of conservation concern in their North American Landbird Conservation Plan (Rich et al. 2004). They define two sets of species of concern, "Watchlist" species that face immediate threats due to habitat alteration, declining populations, small population size, and limited distributions, and "Stewardship" species that are representative species of avifaunal biomes that may or may not be in immediate danger.

The Pennsylvania State University completed a three-year bird inventory in the park between May 1999 and May 2001, Valley Forge NHP was one of six national park units in Pennsylvania to be inventoried by the university over the same time period. A combination of survey methods was used: point-count, vehicular-road, diurnal raptor and vulture, riparian bird, and owl surveys. For the purpose of this condition assessment, only birds present during the breeding season were examined because the status of breeding habitat is much more indicative of the actual condition of the natural resources within Valley Forge NHP (Mitchell et al 2006).

Threshold Criteria

In 2009 Valley Forge NHP was selected as a pilot park for long-term, volunteer-based, avian monitoring by the MIDN I&M program (Goodwin and Wakamiya 2010). Metrics selected as indicator values include abundance metrics and a community-wide assessment of species composition (a "Bird Community Index" or BCI) that informs on ecosystem integrity by evaluating the relative composition of different guilds in the community structure. BCIs are designed to represent major habitat types, as bird communities shift markedly by ecosystem. BCI scores are based on measuring different bird guilds and assessing the diversity of guilds that exist in an ecosystem. Two major habitat types dominate the parks sampled in the 2009 avian monitoring season in the Mid-Atlantic Network; forest and grassland. O'Connell et al. (2003) developed a forest integrity index for the mid-Atlantic piedmont and coastal plain ecoregions that can be applied to the points that fall in forested areas. The Good condition for forest BCI in Valley Forge NHP is greater than 0.6, which would indicate a largely intact forest community – any scores significantly below this measure would fall into a "significant concern" category. Coppedge et al. (2006) developed a grassland integrity index in mixed prairie habitat in Oklahoma. The Good condition for grassland BCI is to maintain or improve on the current value of 47.8, any scores are diminishing trends below this baseline level would constitute a "moderate – significant concern" rating depending on park management goals. Detailed methodology for calculating these BCIs is described in MIDN Breeding Bird Monitoring annual report (Goodwin and Wakamiya 2010).

Current Condition

A total of sixty-one bird species were detected across the park, with 46 species detected in forest habitat, and 53 species in grassland habitat. Current forest BCI value is 0.597 ± 0.017 SE which has been classified by Goodwin and Wakamiya as a moderately disturbed forest community (Goodwin and Wakamiya 2010). Guild categories that were particularly associated with the moderately disturbed ranking included pine associated guild and ground gleaning guilds which both contained low abundances, and the urban/suburban and nest disrupting guilds which both has high abundances. This could be due to several factors, including the low frequency of mature pine in the park, the

urban/suburban environment around the park, and the lack of an understory layer due to deer herbivory (Goodwin and Wakamiya 2010).

Valley Forge NHP had a relatively high grassland bird BCI with a score of 47.8 (± 1.64 SE). This was the highest score of the three parks that were included in the pilot testing (Fredericksburg and Spotsylvania National Military Park, Booker T. Washington National Monument). If this score is broken down by guild, the high score relative to the other parks seems to be due to the lack of forest associated species within the grassland setting. This may be due to the relatively large areas of grassland within Valley Forge NHP. confidence in this metric is high? Trend?

Additionally, three species from the Partners in Flight "Watchlist" were found in Valley Forge NHP, while seven species from the "Stewardship" list were found. "Watchlist" species were the Willow Flycatcher and Blue-winged Warbler which were both identified in one monitoring station, and Wood Thrush which was identified in 20 stations. Species on the "Stewardship" that were located in the park were the Brown Thrasher, Carolina Wren, Eastern Towhee, Indigo Bunting, Red-bellied Woodpecker, White-eyed Vireo, and Yellow-throated Warbler.

White-tailed deer population

Relevance and Context

The mammalian species of greatest concern within Valley Forge NHP is not a rare, threatened, or endangered species, but rather an organism common throughout the northeast region, the white-tailed deer (*Odocoileus virginiana*). White-tailed deer are of special concern in Valley Forge NHP due to their high population density and the threat that this poses to native flora and fauna within the park. White-tailed deer have flourished in Valley Forge NHP due to the abundance of their preferred habitat – open meadow and forest edge –and the absence of predators and human hunting pressure that could keep the population in check (Latham 2009). Figure 34 shows the trend in Valley Forge NHP deer population size between 1997 and 2008 (NPS 2009). Overall, between 1986 and 2008, deer density within the park has increased from 31-35 deer per square mile to an estimated 241 deer per square mile. This unregulated population growth has resulted in unacceptable changes in the species composition, structure, abundance and distribution of native plant communities; high browse pressure that has halted forest regeneration; and an elevated risk of Chronic Wasting Disease occurrence in the park (NPS 2009). To address these issues, the NPS developed the White-tailed Deer Management Plan / Environmental Impact Statement (Plan/EIS), selecting an alternative to reduce and maintain the deer population using combined lethal and non-lethal methods. In 2010, the park initiated lethal reduction activities; these actions are on-going as of this publication.

Threshold Criteria

Within the Mid-Atlantic Region, low deer density has been defined as 13 to 21deer per square mile and high deer density as 56 to 64 deer per square mile (Horsley and Marquis 1983). To maintain natural forest regeneration, estimates of appropriate deer density range from 10 to 40 deer per square mile (Tilghman 1989; Marquis, Ernst, and Stout 1992; deCalesta 1994; Horsley and Marquis 1983; Sage, Porter, and Underwood 2003).

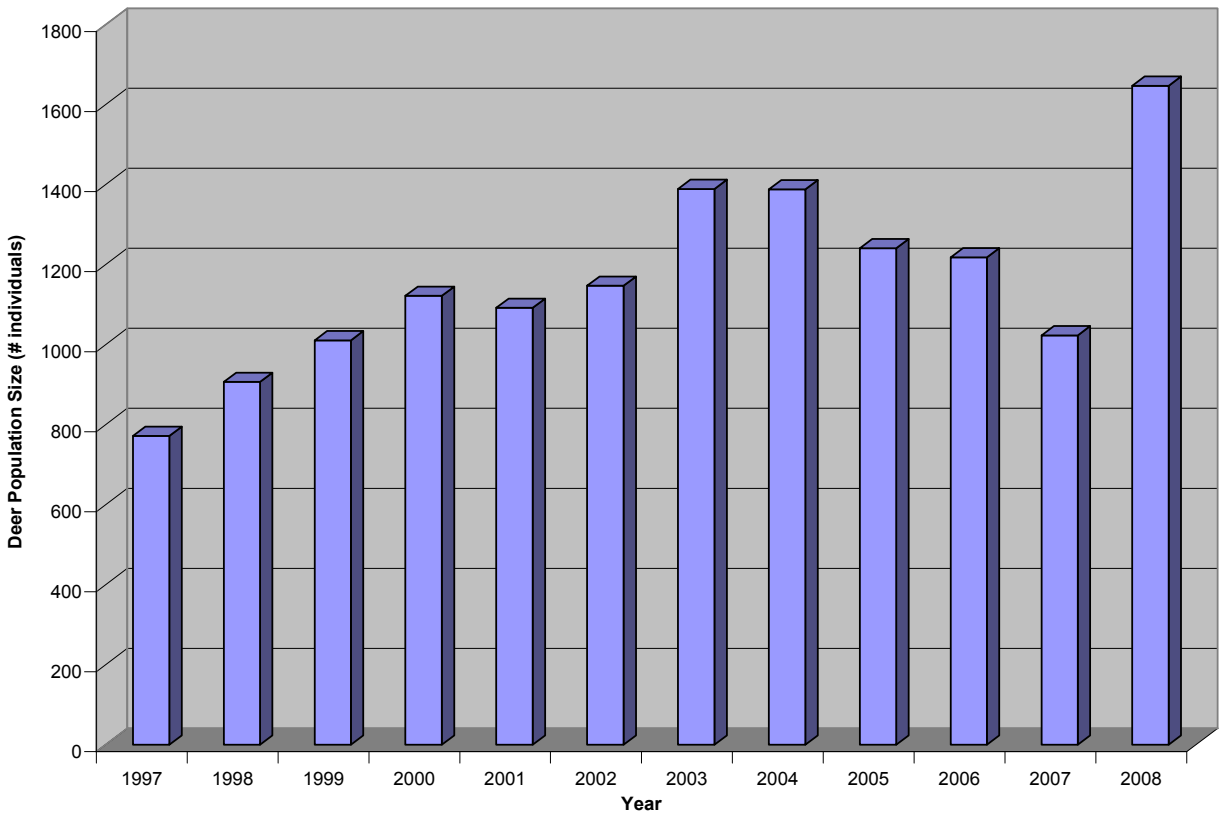

Figure 34. White-tailed deer population estimates within Valley Forge NHP from 1997 through 2008.

The Plan/EIS selected forest regeneration as a primary measure for determining sustainable deer population and established an initial target density of 31-35 deer/ sq.mile, the estimated herd density when forests were last considered in excellent condition (Cypher, Yahner, and Cypher 1985) and recommended in scientific literature to promote forest regeneration. However, the Plan/EIS outlines an adaptive management strategy, with target density adjusting either higher or lower based upon forest regeneration success and disease response. Therefore, the good condition threshold for white-tailed deer populations is initially set as 31-35 deer/sq. mile; however, this may be adjusted overtime depending on ecosystem response. Moderate condition will be 35 – 45 deer/ sq. mile and over 45 deer/sq. mile is a significant concern.

Current Condition

Prior to reduction activities, deer density was estimated at 241 deer/sq. mile in 2009; however, as of 2012 deer density at Valley Forge NHP is estimated at 54 deer/sq mile.

This number represents significant progress toward achieving the established target but still reflects a high deer density and is cause to continue to put this metric in the “significant concern” category. Our confidence in this metric is high.

Chapter 5. Park Geology

Geologic Resources

Relevance and Context

Geology provides the foundation for the entire ecosystem, not only influencing the types and distribution of species in the landscape but also the distribution of people. Since American Indians first inhabited the region, humans have come to Valley Forge to take advantage of its natural resource, including geological resources. At Valley Forge, human land disturbances are very apparent, prospectors dug pits and quarries in search of limestone, mountains and valleys were logged and cleared for agricultural use, and dredged river sediments now line riparian zones. Even Washington selected Valley Forge as the site of his winter encampment based on landscape features, features shaped by geologic processes. The combination of natural geologic processes and human impacts to the landscape directly relate to the resource management challenges the park faces today.

Valley Forge National Historical Park is located in the eastern Piedmont physiographic province, near the junction with the Atlantic Coastal Plain. It is comprised of three dominant bedrock types: Stockton Sandstone found in the northern portion of the park, quartzites of the Antietam, Harpers, and Chickies Formations found on Mt. Misery and Mt. Joy, and Ledger Dolomite in valley region south of the River. The geologic issues of highest resource management importance at Valley Forge are karst, water and sediment, and paleontological resources (Thornberry-Erhlich, 2010). This section will concentrate on karst and paleontological resources as water and sediment are discussed in another section.

Karst refers to a characteristic terrain produced by the chemical erosion of limestone or dolostone over an area. Dolomite, or dolostone, is unique in that it is calcium carbonate based and therefore easily dissolved by surface and groundwater, forming caves, caverns, sinkholes, solution holes, pinnacles and cave formations characteristic of karst topography. Two-thirds of Valley Forge NHP is underlain by karst; the park contains five small caves and at least 100 sinkholes, although a comprehensive inventory of these features has not been completed (Thornberry-Erhlich, 2010). Other karst processes like subsidence, sinkhole formation, intermittent stream disappearance, and dissolution also affect the park and are most apparent in the Grand Parade Grounds (Figure 35). Karst presents challenges for resource management, particularly as it can impact infrastructure, health, and human safety. Common issues associated with karst include flooding, subsidence, and collapse. Until 2004, park policy included filling in all sinkholes; however, currently the park will only fill in sinkholes that pose a true safety concern (Kenworthy 2006).

Threshold Criteria

The target condition for karst resources is that the park's caves and karst features are preserved, restored and protected where possible (GMP 2007). Although karst features are sometimes considered a natural hazard due to the chance of sinkhole formation or collapse, features will be preserved unless an important structure is threatened or in cases in which human safety cannot be protected by any other means.

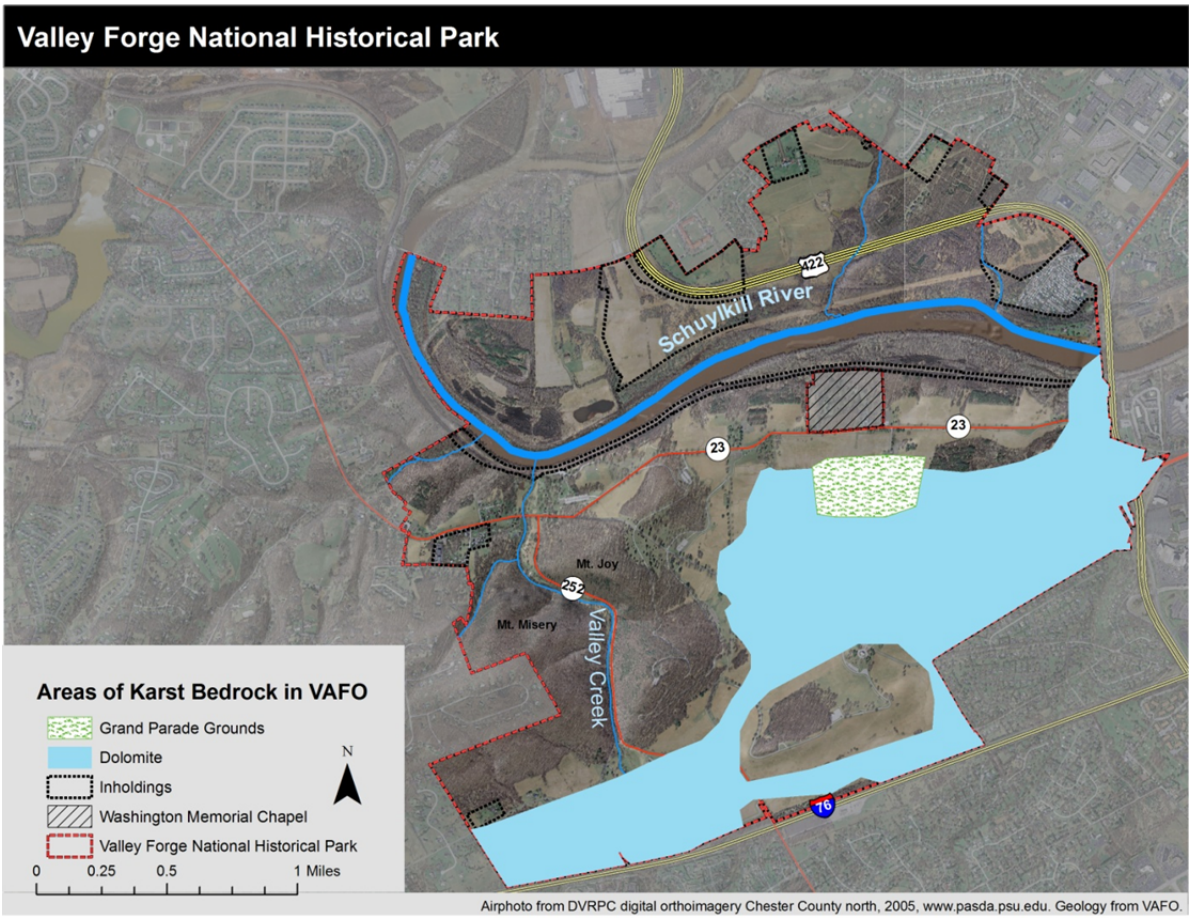

Figure 35. Areas of Valley Forge NHP underlain by dolostone that may exhibit karst topography.

Current Condition

The current condition of park caves and karst features are unknown. Since park management has stopped the practice of filling sinkholes, karst features are considered protected and assumed in stable condition. A comprehensive cave and karst inventory and a sinkhole identification and evaluation methodology are needed to meet resource management objectives and to inform future building projects (Thornberry-Erhlich, 2010).

Paleontological Resources

No formal, field-based paleontological resource inventory has been completed for the park and Valley Forge holds no museum collection of paleontological specimens other than of a few on long-term loan from the Drexel Academy of Natural Science in Philadelphia (Academy). However, the geologic units in the park are known to contain fossils regionally and four fossil deposits have been documented within the park. (Kenworthy 2006). The four known paleontological sites are Bone Cave aka Port Kennedy Cave, exposed bedrock along a quarry wall in the lower visitor lot, exposed bedrock along the Valley Creek Trail near the Upper Forge Site, and in the building stone of a park structure. Bone Cave is one of the most significant middle Pleistocene fossil localities in North America and was discovered in the1870s during limestone quarrying operations. It is not a true cave

but a limestone sinkhole that was briefly open to the surface approximately 750,000 years ago. Following its discovery, several excavations from 1870 to 1894 yielded over 1,200 different fossils specimens of plants and animals, including the type locality of several species. At the time, collecting focused on the large and intact mammal specimens, few insects and plants were collected, and the fossiliferous deposit was never fully excavated. . Infiltration of groundwater slowed recovery efforts and water saturated bones were described as having the consistency of "over-ripe pears". Excavation at the site ceased when the amount of incoming water was greater than that which could be pumped. The site was eventually covered by industrial waste from a nearby asbestos plant and was lost for 110 years before being rediscovered in 2004 (Kenworthy 2006).The majority of excavated fossils are held at the Academy (Thornberry-Erhlich, 2010)

A second site is the wall of an olddolostone quarry which contains Cambrian stromatolite fossils. Stromatolites are formed from layers of matted silt trapped by ancient cyanobacteria. The third site is found on stone used to build the restroom in the lower Welcome Centre parking lot. The rocks came from a local quarry and are known to contain Skolithos worm borrows, which often indicate the boundary between the Precambrian and Cambrian periods. A fourth site is located on Mt. Misery also contains Skolithos fossils, documented in 1993 and again in 2005, in exposures of the Chickies Formation along the Valley Creek Trail (Kenworthy 2006).

Threshold Criteria

The target condition will be to manage, and protect paleontological resources using scientific principles and expertise as required under the Paleontological Resource Protection Act (PRPA). To achieve this, the park will need to develop and implement plans for inventory, monitoring, protection, and educational use of paleontological resources.

Current Condition

Currently, paleontological resources are not actively managed and the park has no plans related to their inventory, monitoring and protection. The locations of Bone Cave, quarry wall Stromatolite Site, and Skolithos in the building wall have been documented but an inventory of park paleontological resources could yield other deposits (Kenworthy 2006). The condition of fossils removed from Bone Cave are unknown; however, based on reports during the excavation, those fossils were in poor condition but assumed stable under curation of the Academy. Due to its inaccessibility and unknown status Bone Cave is also considered in poor condition. The quarry wall stromatolite site and the Skolithos worm borrows in the lower lot walls are considered in fair condition but confidence in the condition assessment is low. The condition of the Skolithos site on Mt. Misery is unknown (K. Heister, personal communication).

Mineral Resources

The dolostone in Valley Forge NHP has been mined historically for agricultural use and for its magnesium content. There are several historic quarries located within the park. Recently, there has been concern regarding mineral rights to eastern parks due to new sources of natural gas and increasing interested in gas development. Although Valley Forge NHP is not within the Marcellus Gas play, there could be other mineral resources of interest to right holders. Mineral rights and ownership within the park should be assessed if this hasn't already been done.

Chapter 6. Park Soundscape and Lightscape

Soundscape

Relevance and Context

A soundscape refers to the total acoustic environment of an area. In the National Park setting, both natural and human sounds may be desirable and appropriate depending on the purpose and values of the park (NPS 2008c). For example, at Valley Forge NHP human induced cultural and historic sounds, such as cannon shots or musket fire, are appropriate and important components during re-enactment events. The soundscape, like water, scenery, or wildlife, is a valuable resource that can easily be degraded by inappropriate noises or noise levels and as a result the soundscape requires careful management just as any other park resource (NPS 2008c). Noises can adversely affect park resources by modifying or intruding upon the natural soundscape, and can also indirectly impact resources by interfering with sounds important for animal communication, navigation, mating, nurturing, predation, and foraging functions. Noise can also adversely impact park visitor experiences by intruding upon or disrupting experiences of solitude, serenity, tranquility, contemplation, or a completely natural or historical environment (NPS, 2007).

NPS Management Policies 2006 state that the NPS will strive to preserve the natural quiet and natural sounds associated with the physical and biological resources of parks. NPS policy requires the restoration of degraded soundscapes to the natural condition whenever possible, and the protection of natural soundscapes from degradation due to noise (undesirable human-induced sound). The NPS is specifically directed to "take action to prevent or minimize all noise that, through frequency, magnitude, or duration, adversely affects the natural soundscape or other park resources or values, or that exceeds levels that have been identified as being acceptable to, or appropriate for, visitor uses at the site being monitored" (NPS Management Policies, 2006).

The National Park Service, collectively, remains in the research and development phase as it pertains to a systematic approach to monitoring and evaluating soundscapes in park settings. However, several parks within the NPS system have initiated programs to monitor this park resource. In 2006, Minute Man National Historical Park (MIMA) began working with the NPS Natural Sounds Program to develop a Soundscape Management Plan, largely because of perceived inappropriate and excessive sound intrusions from aircraft and vehicles. Preliminary soundscape management zones, objectives, and indicators were developed for several management zones. In 2007, MIMA initiated acoustic (attended audibility logging) monitoring at sites. Attended audibility logging involved listening and logging the sources of all sounds heard during a 45-60 minute session. Metrics included identification of sources of sounds, percent time non-natural sounds were above natural ambient sounds, percent time natural/non-natural sounds were audible, noise-free intervals, duration of natural/non-natural sounds, and number of non-natural events. Although each park is unique in its resources, attributes, and concerns, it is believed the research conducted at MIMA could prove to be valuable baseline data in the development of Valley Forge NHP's park soundscape management objectives (Table 20).

Table 20. Proposed management zones and objectives for soundscape at Valley Forge NHP (MIMA, 2009).

Zone	Soundscape Management Objectives	Soundscape Management Indicators and Standards		
		Time Audible[1]	Time Above Ambient [2] (dBA)	Max dBA [3]
Interpretive/Living History*	Natural sounds dominate the soundscape. Frequent interpretive sounds can be heard. Interpretive programs and events can be conducted without interruption from noise. Sound of management and visitor activities in this zone will be mitigated to the greatest possible degree by using quiet technologies and by running vehicles and equipment the minimum time necessary.	Up to 50%	Up to 50%	<60 dBA 110dBA during interpretive programs
Developed/Visitor Facilities	Human-caused sounds are common in this zone. Natural sounds can also be heard. The sound of management and visitor activities in this zone will be mitigated to the greatest possible degree by using quiet technologies and by running vehicles and equipment the minimum time necessary for performing a function. Some noise-free intervals occur, and human-caused sound may be muted at times to accommodate the need for quality visitor experiences or sound-sensitive values to be appreciated.	Up to 75%	Up to 75%	<60 dBA
Natural/Cultural Landscape	The natural sounds dominate the area, although human-caused sounds are evident in some areas within the zone including areas adjacent to motorized travel corridors, open fields, and visitor use areas. The sound of management activities in this zone will be mitigated to the greatest possible degree using quiet technology and minimum impact practices.	<25%	<20%	<60 dBA

* 110dBA during interpretive programs (muskets, cannons), <60 dBA at other times.

1 Time Audible: percent time non-natural sounds are audible.
2 Time Above Ambient: percent time non-natural sounds are greater than natural ambient.
3Max dBA: maximum sound level.

Soundscape concerns for Valley Forge NHP include aircraft associated noise from nearby airports and vehicular traffic from Route 76, Route 422, Route 252, and smaller roads within the Park's transportation infrastructure that detract from the historic character of the park. Potential future activities at Valley Forge NHP include proposed improvements to the trail network within the park

that may increase recreational activities. Improved connections to the Schuylkill Valley Trail and the Chester Valley Trail would improve accessibility to the park for bicyclists. It is anticipated, by Valley Forge NHP management staff, that this would increase pedestrian and bicycle traffic within the park, but would also reduce vehicular visitor trips and therefore positively affect the soundscape. Also, minor acoustic benefits would likely occur through the implementation of an Alternative Transportation System in conjunction with seasonal closures of park roads. Traffic calming measures on PA Routes 23 and 252 and the resulting reduction in average speed would result in a minor decrease in ambient noise level. Localized noise sounds could increase, however, due to larger vehicles decelerating and accelerating near the traffic calming measures. Lastly, the substantial change in traffic volume on PA Route 23 and Pawlings Road related to the improvements to Pawlings Road Corridor and construction of the 422 ramps will impact the soundscape. It is expected that local improvements on PA Route 23 would occur and some soundscape degradation along the Pawlings Road Corridor would result because of the increase in traffic volume.

Threshold Criteria

Table 20 describes the threshold criteria proposed for Valley Forge NHP based on separate NPS criteria and specific management objectives for:

- Interpretive/Living History*
- Developed/Visitor Facilities
- Natural/Cultural Landscape.

Current Condition

Noise measurements related to traffic studies were conducted at Valley Forge NHP in August 2001 and March 2003. Equivalent noise levels (Leq) represent average sound levels from a sound energy standpoint expressed in decibels on the A-weighted scale (dBA). Highly significant highway noise was noted in several locations along exterior and interior portions of the park. Within 300 feet of PA Route 23, noise levels remained relatively constant ranging from 49 dBA at night to 58 dBA during rush hour. These sounds are comparable to the indoor sound of a dishwasher in the next room. Another sampling point was taken between PA Route 23 and the Norfolk & Southern Railroad corridor. This point experienced a noticeably wider range of sound levels, 46-75 dBA. This higher range is attributed to rail noise. The relatively quiet Schuylkill River corridor was regularly affected by rail noise. The louder noises are comparable to someone shouting within one meter of the listener. High noise levels were also identified close to Pawlings Road. Within 100 feet of the road, sounds ranged from 58-65 dBA. These levels were slightly higher at the western approach to the park (67 dBA). Measurements taken along Outer Line Drive ranged from 49 to 55 dBA during peak hours. Although Outer Line Drive has relatively low traffic levels, field observations indicate that the noise impacts are a combination of local sounds with noise from other sources, such as the PA Turnpike. The southern portion of the park was identified as having a much narrower range of noise levels, from 53 to 54 dBA, attributed to the closeness of the turnpike. Turnpike noise at Lafayette's Quarters is particularly intrusive (NPS 2007).

Incorporating the management concerns and objectives of the staff at Valley Forge NHP, this report focused on the ability of human guests to hear the voices of park interpreters during presentations.

This is a concern, due to the location of the park's primary interpretive trail (Joseph Plumb Martin trail) along Route 23 and other roadways. Utilizing noise measurements related to traffic studies conducted at Valley Forge NHP in 2001 and 2003 and Soundscape Management Indicators and Standards developed by MIMA in 2006, this report found soundscape to be "moderate" at Valley Forge NHP. Within 300 feet of PA Route 23, noise levels remained relatively constant ranging from 49 dBA at night to 58 dBA during rush hour. MIMA standard for interpretive/living history zones was a maximum dBA of <60 dBA Up to 110dBA (Table 20). The only available data was from a two year study conducted at Valley Forge NHP, therefore regular monitoring of the noise levels is a key data gap, especially with relatively constant development occurring around the vicinity of the park. Confidence in the assessment of soundscape condition was limited due to a lack of recent and comprehensive data.

Lightscape

Relevance and Context

A "natural lightscape," such as a dark night sky, is an environment that is undisturbed by light and air pollution. Dark night skies have natural, cultural, and scenic importance. Wildlife is impacted by light pollution because animals often depend on darkness in order to hunt, conceal their location, navigate, or reproduce. For nocturnal animals, light pollution also means habitat disruption. Additionally, many species have far more sensitive vision than humans. Plants are affected by artificial light because it disrupts their natural cycles. Dark night skies are also culturally important because they are a resource common to all cultures on Earth, and are a metaphor for countless myths and religions. They have inspired innumerable works of art, literature, and connections to the cosmos. Natural lightscapes, including dark night skies, are a scenic resource integral to many people's national parks experience (NPS Yosemite, 2011).

According to the 2007 Valley Forge NHP General Management Plan, present and reasonably foreseeable future projects that could contribute to the cumulative impact to existing lightscapes include Road Construction Consents and the PA Turnpike widening. Both include the addition or modification of roadways both adjacent to and within the park boundaries. The new roadways would introduce additional sources of artificial lighting in areas that are already impacted. However, these projects also offer an opportunity, through NPS-required mitigation, to offset and minimize existing impacts. The park could work with the Pennsylvania Department of Transportation to establish vegetative buffers and recommend dark-sky fixtures (Valley Forge NHP, 2006).

Threshold Criteria

Similar to the progress on soundscapes, the National Park Service, collectively, remains in the research and development phase as it pertains to a systematic approach to monitoring and evaluating lightscapes in park settings. However, parks within the NPS system have initiated programs to monitor this park resource. Several of these parks have adopted a system for measuring sky brightness to quantify the source and severity of light pollution. This system, developed with the assistance from professional astronomers and the International Dark-sky Association, utilizes a research-grade digital camera to capture the entire sky with a series of images. Data clearly shows that even remote national parks are not immune from stray artificial light. Sky brightness is measured

in astronomical magnitudes in the V-band, abbreviated as "mags". The V-band measures mostly green light, omitting purple through ultraviolet and orange through infrared. The magnitude scale is a logarithmic scale. A difference of 5 magnitudes corresponds to a 100x difference in brightness. Lower values (smaller or more negative) are brighter (NPS Great Basin, 2011). Further information on astronomical magnitudes can be found on the Sky and Telescope online magazine webpage (Sky and Telescope, 2011). Aside from the complexity of the magnitude scale, it is noted by expert astronomer John Bortle, that this method relies on naked-eye limiting magnitude, which is a poor criterion. It depends too much on a person's visual acuity (sharpness of eyesight), as well as on the time and effort expended to see the faintest possible stars. One person's "5.5-magnitude sky" is another's "6.3-magnitude sky." Moreover, deep-sky observers need to assess the visibility of both stellar and nonstellar objects. A modest amount of light pollution degrades diffuse objects such as comets, nebulae, and galaxies far more than stars. In lieu of the magnitude scale, Bortle created a more straightforward method for monitoring and evaluating lightscapes. The Bortle Dark-Sky Scale classification system utilizes a nine-level scale and is based on nearly 50 years of observing experience. Figure 36 provides the Bortle Dark-Sky Scale. Considering the Park's proximity to large urban centers, as well as its objective to provide a natural setting to park visitors, it is recommended that Valley Forge NHP strive for Class 7 (Suburban-Urban Transition) of this classification system.

Current Condition

No current condition is available for lightscapes at Valley Forge NHP. However, it is recommended that the park strive for Class 7 (Suburban-Urban Transition) which can be found in Figure 36. No assessment of trend is currently possible for this metric. No data were available for this metric. Regular monitoring of the lightscape at Valley Forge NHP is a key data gap. Confidence in this assessment is not applicable, since there are no data available.

Class	Title	Color key	Naked-eye limiting magnitude	Stellar limiting magnitude (with 12.5" reflector)
1	Excellent dark-sky site	black	7.6–8.0	19 at best
2	Typical truly dark site	gray	7.1–7.5	17 at best
3	Rural sky	blue	6.6–7.0	16 at best
4	Rural/suburban transition	green yellow	6.1–6.5	15.5 at best
5	Suburban sky	orange	5.6–6.0	15 at best
6	Bright suburban sky	red	5.1–5.5	14.5 at best
7	Suburban/urban transition or Full Moon	red	4.6–5.0	14 at best
8	City sky	white	4.1–4.5	13.5 at best
9	Inner-city sky	white	4.0 at best	13 at best

Figure 36. Bortle Dark Sky Scale (from: www.astronomyisrael.com).

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NPS 464/122916, November 2013

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