D-43

Management Guidelines for Valley Creek

Valley Forge National Historical Park

Pennsylvania

July 1996

National Park Service
United States Department of the Interior

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Acknowledgments

This document is a revised version of a final report (Gutowski et al. 1991) prepared for the National Park Service. The 1987 biological data were collected and analyzed by Dr. Jay Stauffer, Jr., Professor of Ichthyology, and Martin Gutowski, Research Assistant, both in the School of Forest Resources, The Pennsylvania State University. The report by Gutowski et al. (1991) was edited by Steve Miller, State College, Pennsylvania, and Brian Lambert, Valley Forge National Historical Park.

I. Description of the Valley Creek Basin

A. Location, Size and Physical Description

Valley Creek, which is a third order stream draining a 23.4 mi^2 (60.6 km^2) area in southeastern Pennsylvania, is illustrated in Figure 1, a map of the Valley Creek drainage basin from United States Geological Survey (USGS) quadrangle maps. Most of the basin is located in Tredyffrin and East Whiteland townships and Malvern Borough, all in Chester County with small portions in Charlestown and Schuylkill townships, Chester County and in Upper Marion Township, Montgomery County. The population of the Valley Creek drainage area (within Chester County) was approximately 15,600 in 1980 (Chester County Planning Commission 1982) and 39,300 in 1990 (Chester County Economic Profile, Chester County Planning Commission, 1992). Census results from 1980 and 1990 and projections for 2000 and 2010 (Chester County Planning Commission 1992) indicate a continuing increase in population (Table 1). In 1990, the population densities of Tredyffrin Township, East Whiteland Township and Malvern Borough were 1415, 763 and 2265 persons per square mile (Delaware Valley Regional Planning Commission 1992).

Table 1. Census results and population projections

	1980	1990	2000	2010
Chester County	317,000	376,000	426,000	460,000
Tredyffrin Township	23,000	28,000	29,500	29,400
East Whiteland Township	8,500	8,400	9,900	10,100
Malvern Borough	3,000	2,900	3,000	3,000

B. Geology

The Valley Creek drainage basin consists of carbonate rocks, such as limestones and dolomites, flanked by hills of crystalline rock, mostly quartzite, schist and gneiss, which are less likely to erode than the carbonates (Sloto 1987b). Limestones and dolomites are important for their mineral content and for water retention in aquifers, both exploited resources (Knorr 1985a). These geologic formations are 435 to 570 million years old (Sloto 1987a). Diamond Rock Hill is the watershed's highest point at 668 ft (203.6 m) and the confluence with the Schuylkill River is the lowest point at 75 ft (22.9 m) (National Geodetic Vertical Datum of 1929). The average channel slope of Valley Creek is 1.2%, with a slope of 2.0% above Church Road and 0.4% below Church Road (Reed 1990).

C. Climate

The area has a modified humid continental climate. Using data from a National Oceanic and Atmospheric Administration (NOAA) precipitation station located in the basin at Devault, PA, Sloto (1987b) estimated the average annual precipitation between the years 1951 to 1980 to be 46.92 in (1211.8 mm).

D. Land Use

From 1970 to 1990, the amount of land dedicated to residential, commercial and industrial usages in the Valley Creek drainage basin increased with a concurrent decrease in the amount of agricultural and open space land usage. The immediate effect of this change is an increase in peak discharge and runoff volume in Valley Creek related to the growth of impervious areas, such as parking lots, roads and roofs, which allows precipitation to flow quickly into the stream (Sloto 1987b). In 1987, these impervious areas covered approximately

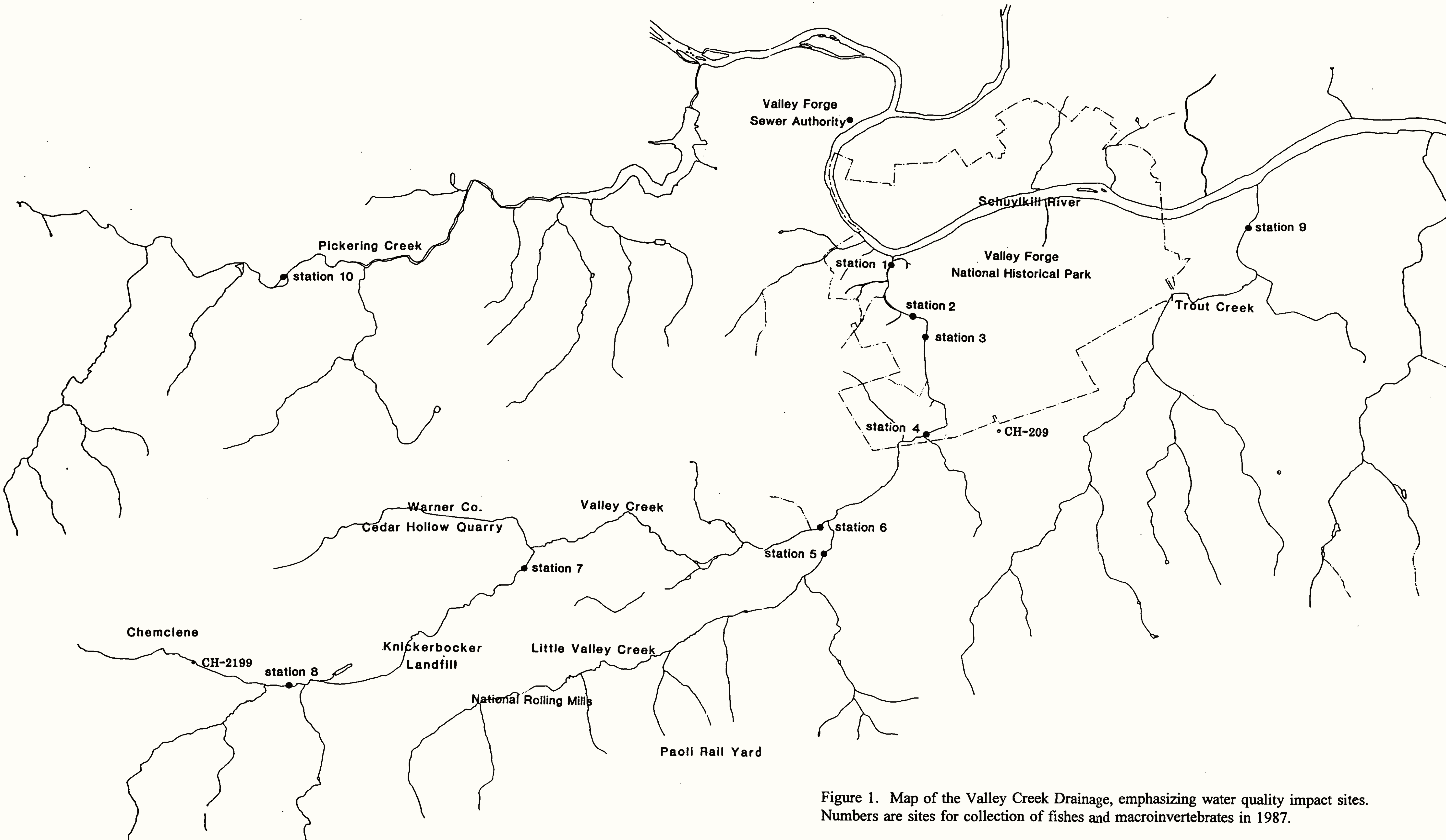


Figure 1. Map of the Valley Creek Drainage, emphasizing water quality impact sites. Numbers are sites for collection of fishes and macroinvertebrates in 1987.

9% of the Chester Valley (Sloto 1987b). Table 2 indicates the changes in land use for the municipalities comprising most of the Valley Creek Basin (Delaware Valley Regional Planning Commission 1992).

Table 2. Land usage changes 1970 to 1990

	Land Usage (acres)							
Municipality	Residential		Industrial		Commercial		Agricultural and Open Space	
	1970	1990	1970	1990	1970	1990	1970	1990
East Whiteland	1126	1069	397	826	1427	1619	4051	3462
Malvern	192	238	19	38	160	159	435	371
Tredyffrin	4224	4805	102	103	1594	3238	6790	4557

E. Water Resource Use and Development

Reed (1990) discussed historical conditions of Valley Creek's watershed, breaking it into five distinct phases (see Appendix A). Phase one existed prior to settlement by colonists (pre-1700s). The watershed was heavily wooded and stream conditions were excellent, with high rates of infiltration of precipitation into the soil and predominantly subsurface watershed runoff.

During second phase, from around 1700 until the American Revolution, there were small amounts of clearing on the valley floor for agriculture and village sites. Stream conditions were "good" to "excellent" depending on the sediment load in the stream.

Further deforestation occurred in the third phase of the watershed's history. As much as 50% of the land had been denuded by the end of the 1800s and significant increases in sediment load and peak flow rates widened the stream channel. Stream conditions were "good" to "fair".

Effects of the industrial revolution became evident in the fourth phase of Valley Creek's history. More land was cleared and marginal agricultural land was converted to residential, commercial and industrial areas. Up to 60% of the watershed was now deforested and condition was probably "fair" to "poor".

Currently (phase 5), the watershed is considered "poor" with the potential to become "fair". Conversion of marginal and prime agricultural lands to corporate centers may actually benefit the watershed through best management practices. However, without a basin-wide approach to stormwater management peak discharges will increase as impervious surfaces within the watershed increase. Channel conditions may continue to worsen as the creek adjusts to past changes in peak flows (Reed 1990).

Approximately 62% of the eastern Chester County population depends on ground water as its primary water source (Sloto 1987a). The Delaware River Basin Commission (DRBC), a cooperative body comprised of representatives from New York, New Jersey, Pennsylvania, Delaware and the federal government, is charged with maintaining stream flows and ground water levels as well as protecting overall quality of the water (Ground Water Protected Area Regulations, Southeastern Pennsylvania, DRBC, 1980). The DRBC has determined that all of the Valley Creek basin should be in a ground water protected area. In response to the increased growth in this area and the potential for the loss of ground water reserves during a drought, the DRBC has set up specific guidelines governing ground water removal by persons, firms or corporations.

F. Recreation

Fishing for stocked trout in Valley Creek was a very popular activity until stocking and harvesting of trout were halted in 1984 when fish were found to have high levels of PCBs, a class of carcinogenic chemicals. Signs were posted warning fishermen that eating fish caught in Valley Creek could be a health hazard and the stream was designated catch-and-release. Fishing activity decreased dramatically but, as the wild trout population increased due to decreased fishing pressure, the number of fishermen on the creek rose until the number of fishermen in 1995 was about the same as it was prior to 1984. Valley Creek has become a Class A fishery and has one of the few naturally reproducing populations of brown trout near a concentrated urban area (Philadelphia). Inside Valley Forge National Historical Park (VAFO), fishing is a popular and important recreational activity.

Valley Creek is also popular among hikers, joggers, and picnickers because of the natural beauty of the stream and surrounding woodlands. In addition to Valley Forge NHP, there are other parks along Valley Creek and Little Valley Creek, including Mill Road Park (Tredyffrin Township) and Valley Creek Park (East Whiteland Township). The Open Lands Conservancy, a nonprofit organization dedicated to preserving open space, owns land in the watershed which is accessible to the public. The Valley Forge Chapter of Trout Unlimited manages a conservation easement along Valley Creek between Church Road and Route 29.

II. Valley Creek Water Use and Management--Authority and Responsibilities

A. Water Quality Standards and Monitoring

The United States Environmental Protection Agency (EPA) is obligated by the Clean Water Act to periodically publish and update water quality criteria. EPA's publication "Quality Criteria for Water 1986" (EPA 440/5-86-001) provides a selective listing of literature concerning environmental contaminants and their effects on organisms and recommended levels to minimize adverse effects on aquatic life. Water quality regulations are under state control. If the EPA determines that a state is not executing the task properly, the EPA directs actions to meet water quality standards until the state program is upgraded.

Pennsylvania's Department of Environmental Protection (DEP) (formally Department of Environmental Resources) has published water quality standards listing acceptable levels for those variables and pollutants designated for regulation in Chapter 93, Water Quality Standards, of Title 25 of the PA Code. Sewage treatment plant regulations are in Chapter 94, wastewater treatment requirements in Chapters 95 and 97, and phosphorus in Chapter 101 (Knorr 1988). These water quality standards are based in part on information from the EPA. DEP also assigns criteria levels based on the use classification for each water system. Under these classifications, surface waters used for drinking water have more stringent standards than those used only for recreational purposes (e.g., a warmwater fishery). The designation for Valley Creek was recently changed from a coldwater fishery to Exceptional Value (EV) waters. Discharge of industrial wastewater and sewage effluent into an EV stream cannot degrade "existing water quality" even for social and economic reasons. "Existing water quality" varies from stream to stream, so there are no measurable values that define EV water quality. Currently, the quality of water in Valley Creek equals or exceeds the water quality criteria for coldwater fisheries, listed in Appendix B. When assessing stream conditions in Valley Creek, it is the coldwater fisheries standards that will be used for establishing "existing water quality" conditions. Some of these standards provide absolute values which may never be exceeded (e.g., arsenic, copper, pH), while others are based on daily, weekly, or monthly averages that involve several testing days (e.g., bacteria).

Chester County Health Department (CCHD) is the only public agency regularly monitoring Valley Creek, taking samples quarterly, but not on any set date. Data are public information and are available at the CCHD in West Chester. DEP monitored Valley Creek (station #157) quarterly as part of its water quality network (WQN) but discontinued this activity in 1987. The Pennsylvania Fish Commission only investigates if a fisheries management question is involved. The advanced biology class of Conestoga High School, under the supervision of Dr. Ralph Heister, conducted biological and chemical testing on Valley Creek in 1972, 1978, 1983, 1986 and 1989. Since 1988, VAFO park staff have operated a small water quality laboratory (not EPA certified), measuring several physical, chemical, and biological water quality parameters. Data gathered by these groups are listed and discussed in section IV.

B. Sewage Facilities

The Valley Forge Sewer Authority (VFSA) began operation in 1978, serving Tredyffrin, Easttown, East Whiteland, Willistown, East Pikeland, Charlestown and Schuylkill townships and Malvern Borough (Appendix C). The treatment plant, located on Pawlings Road in Phoenixville, discharges eight million gallons per day (MGD) of secondary-treated effluent into the Schuylkill River. A pumping station is located on Wilson Road in Chesterbrook just outside of VAFO's boundary. Sewage is collected by gravity through underground pipes and then pumped under pressure (30 psi) through a force main that runs parallel to Valley Creek. Inside VAFO the force main crosses under the streambed twice. The sewer main exits from beneath Valley Creek at its confluence with the Schuylkill River. Here it crosses the river and continues to Pawlings Road where it again crosses the river to the VFSA treatment plant.

Valley Forge National Historical Park uses a combination of municipal sewers, leach fields, and cesspools to manage its sewage. The use of cesspools is being phased out. Park buildings near Valley Creek with leach fields are Stirling's Quarters, Rose Cottage, Knox's Quarters and Maxwell's Quarters. Buildings with cesspools are Lafayette's Quarters, Frank Whittle house, Knox-Tindle house, Potts/Dewees house (Bakehouse), Interpreters Field Office, Valley Forge Railroad Station and the Furnace House. All buildings in Valley Forge Village are connected to the Valley Forge Sewer Authority (Lambert 1988). The eastern portion of the park is connected to the Montgomery County sewer system.

C. Permit Programs

The National Pollutant Discharge Elimination System (NPDES), established by the Clean Water Act of 1975, created a master list of all dischargers of waste into surface waters. This list is used by state agencies, under direction of the EPA, to issue permits for the purpose of regulating discharge to surface waters. In Pennsylvania, DEP issues these permits. NPDES permit holders currently discharging into Valley Creek or Little Valley Creek are listed in Appendix D. Sun Oil and Bishop Tube discharge industrial waste, all the others discharge sewage. Discharge permits are specific in listing what chemicals a permit holder may release, the quantity of discharge and the point of discharge.

DEP uses the permit process to maintain receiving waters at their designated water quality standards. Based on information supplied by the applicant, DEP proposes a draft permit which is published in the PA Bulletin. A thirty day public comment period follows from the date of publication. This process is repeated when the permits are reissued at five year intervals. In the case of an EV stream, such as Valley Creek, the public comment period includes a public hearing. Compliance with the permit is monitored and reported by the permit holder, although the DEP may do spot testing to verify compliance. The permit holder is required to notify the DEP of any violations of the permit.

III. Valley Creek Management--Valley Forge National Historical Park

A. Relationship to NPS Planning Documents

1. Authorizing Legislation: On July 4, 1976 Congress passed Public Law 94-337 authorizing the establishment of Valley Forge National Historical Park (VAFO) to "preserve and commemorate for the people of the United States the area associated with the heroic suffering, hardship, and determination and resolve of General George Washington's Continental Army during the winter of 1777-1778 at Valley Forge."

The mission of the park is to preserve those cultural resources related to the 1777-78 winter encampment at Valley Forge and to tell the story of events surrounding the encampment of the Continental Army.

2. General Management Plan (GMP): presents the general management philosophy of the park and provides strategies for addressing issues and achieving management objectives. The GMP devised a management zoning system for VAFO. In historic zones natural resources are managed to complement historic resources. In development zones natural resources are managed primarily to benefit recreational and administrative activities. There are no natural zones. Management objectives, as stated in Valley Forge's General Management Plan, include the "protection and management of natural resources through research, surveys and other means." Valley Creek is to be managed as a "natural stream associated with the historic encampment."

3. Valley Creek Management Zoning: VAFO's General Management Plan places Valley Creek in several park management zones. The entire stretch of stream inside the park is located in a historic zone, with three major sections in different subzones. A map of the

management zones is found in the GMP. From its mouth to the Knox covered bridge at Yellow Springs Road the creek is in a preservation subzone. Emphasis is on restoration, preservation, protection, and interpretation of cultural resources. This section of Valley Creek will be managed to preserve historic features. Major activity in this subzone will be interpretation of the cultural resources and quiet recreation, such as hiking, bicycling, picnicking and fishing. From the covered bridge upstream approximately 1900 stream ft (580 m) Valley Creek lies in a subzone for preservation, adaptive use and park operations where historic buildings are adapted for various park purposes and natural resources are managed to complement these historic resources. The remaining 2800 stream ft (853 m) of Valley Creek extending to the park boundary is in a preservation/public use subzone. Areas and structures of historic significance in this subzone are to be preserved and made available for public use. Spontaneous and light recreation is allowed and natural systems are preserved in a historic context. Activities include horseback riding, fishing, picnicking and hiking.

There are only two small portions within close vicinity of Valley Creek that are not in the historic zone. There is a private use zone along the creek just downstream from the Wilson Road bridge where life tenants occupy some buildings. Beginning at Wilson Road and extending approximately 400 ft upstream, Valley Creek is bordered by an active recreation zone that is used mostly by fishermen. For a graphical representation of these management zones see the management zone map in the General Management Plan.

4. NPS Management Policies (1988): provides Service-wide management strategies for national parks. These policies require management of natural resources of the National

Park Service to maintain, rehabilitate and perpetuate the inherent integrity of water resources. Some specific policy statements are:

- All water withdrawn from a park for domestic use will be returned to the park watershed system. Interbasin transfer will be avoided (Chap 4:15);
- The NPS will seek to restore, maintain, or enhance the quality of all surface and ground waters within the parks consistent with the Clean Water Act and other applicable federal, state, and local laws and regulations (4.15);
- Human activities will be managed to control erosion (Chap.4);
- The NPS will enter into agreements or compacts with other agencies and governing bodies to secure their cooperation in avoiding water pollution (4:5);
- Consistent with the rights of others, the Park Service will maintain a continuous vigilance by observing and monitoring upstream diversions, adjacent uses, and groundwater withdrawals and their effects on the occurrence, quantity, and quality of water necessary for the continued preservation of park biota and ecosystems (Chap. 4:16);
- Management of populations of exotic plant and animal species, up to and including eradication, will be undertaken wherever such species threaten park resources or public health and when control is prudent and feasible (Chap. 4:12).

5. Natural Resource Management Guidelines (NPS-77): provide detailed direction to NPS employees about implementing Servicewide policy. Its purpose is to guide the actions of park managers so that natural resource management activities comply with federal law and regulation and NPS policy. Some specific actions recommended by NPS-77 are:

- participation in a state's required triennial review of water quality standards to assure that state standards adequately protect park aquatic resources;

- notification of NPS Regional Water Resources Coordinator of upstream NPDES point source discharge applications which could impact water quality in the park;

- encourage states to apply effective anti-degradation standards and non-point sources pollution policies to streams most likely to affect park water resources;

- work with state, county and local agencies to develop and implement best management practices to non-point sources on lands upstream from the park;

- work with local, state and federal agencies to implement applicable groundwater protection programs;

- gather baseline data and monitor park water resources;

- consult with federal, state and local agencies about designing complementary and effective water monitoring networks.

B. Relationship to Federal Legislation and Regulations

1. National Environmental Policy Act of 1969 (NEPA): declares it to be a national policy that "man and nature can exist in productive harmony." Section 102 directs that, for all federal actions affecting the quality of the human environment, an environmental statement (Environmental Assessment or Environmental Impact Statement) must be prepared, evaluating the impact the action will have on the environment and considering alternatives. All proposed NPS actions, including those affecting streams and wetlands, must comply with the Act via procedures outlined in the Service's NEPA Guideline (NPS-12).

2. Federal Clean Water Act of 1972 (CWA): declares it to be a national policy to eliminate the discharge of pollutants into the nation's navigable waterways and to make all of them swimmable and fishable. Enforcement of the Act has been delegated to those states that have approved water management programs. Encroachment into waterways (Section 404) and water quality standards (Section 401) of the CWA are enforced by the Commonwealth of Pennsylvania chiefly through its NPDES and encroachment permit systems. Point and non-point discharges to Valley Creek and stream encroachments must comply with Pennsylvania's DEP regulations.

3. Executive Order 11990 (protection of wetlands, 1977) and Executive Order 11988 (floodplain protection, 1978): require that all federal agencies avoid adverse effects to wetlands and floodplain wherever there is a practicable alternative to the proposed action. The document recognizes the importance of wetlands and floodplain and establishes a federal mandate to preserve and enhance these resources. NPS guidance for compliance with both executive orders is published in "NPS Floodplain Management and Wetland Protection Guidelines."

4. Endangered Species Act (1982): There are no federally-listed threatened or endangered plants or animals at Valley Forge but in keeping with the spirit of the law and in compliance with NPS Management Guidelines (Chap. 4:11), state-listed rare plants and animals should also be identified and protected. Only one state-listed endangered species, Viburnum nudum, is known to exist in the Valley Creek watershed inside the park. The plant grows in a woodland next to a tributary. It is monitored by park staff and a fence was placed around the entire population to protect it from deer.

5. Other federal resource protection laws include the National Historic Preservation Act, the Archeological Protection Act, the Rivers and Harbors Act, and section 4f of the National Transportation Act.

C. Valley Creek Management Objectives for Valley Forge NHP:

1. Manage Valley Creek as a natural stream in accordance with the General Management Plan;
2. Meet or exceed Pennsylvania DEP standards for a coldwater fishery;
3. Meet or exceed EPA standards for appropriate water quality variables;
4. Develop alternative management strategies for all significant threats and issues and select recommended actions;
5. Establish a system for monitoring selected variables and all significant threats and issues;
6. Coordinate efforts with state and local government agencies, schools, and conservation groups which are involved in monitoring or managing Valley Creek;
7. Provide for suitable recreational activities in accordance with the GMP;
8. Protect and preserve cultural sites;
9. Identify, review, and evaluate current baseline data and collect additional data if existing baseline is deficient.

IV. Valley Creek Resources--Description and Condition

A. Water Resources

1. Quantity

According to Heister (1986), installation of the Valley Forge Sewer System caused excessive water withdrawal from the Valley Creek basin. Sewers take water from Valley Creek and send it to the Schuylkill River as treated wastewater. Knorr (1985a) listed water use for quarry operations and groundwater removal for public water supplies as other losses of groundwater. Urbanization, accompanied by the growth of impervious areas which reduces the amount of rain reaching aquifers, can also affect water levels. These issues are discussed more fully in section V, Valley Creek Management Concerns and Issues.

If the water level in Valley Creek decreases, fish and other aquatic animals will lose habitat necessary for reproduction and survival. Summer water temperatures will increase because of the reduced volume of cold spring water. Concentration of some pollutants will increase and their effects on aquatic life would be amplified. A U.S. Geological Survey continuous recording station located approximately 0.1 mi (0.16 km) upstream from the boundary of the Valley Forge National Historical Park monitors stream discharge in the upper 20.8 mi^2 (53.9 km^2) of the Valley Creek drainage, whereas the lower 2.6 mi^2 (6.7 km^2) is not gauged. Baseline water flow data from this station appear in Tables 3 and 4. Table 4 isolates the months of July and August, the time of lowest flow. Without information on precipitation these data explain little about the flow patterns of Valley Creek. A complete water budget analysis by a hydrologist should detect trends in stream flow.

Table 3. Water discharge in Valley Creek at Pennsylvania Turnpike, USGS station number 01473169, mean monthly values (cubic feet per second)

	Discharge (cubic feet per second)						
	1982	1983	1984	1985	1986	1987	1988
January		26.0	28.8	16.8	39.0	39.5	27.7
February		30.6	53.5	31.1	43.8	34.0	37.5
March		65.5	60.4	17.9	37.1	40.3	30.0
April		98.8	84.9	18.1	36.6	43.5	28.5
May		60.1	77.5	25.4	26.4	32.8	39.2
June		40.9	49.9	16.9	18.2	26.5	23.4
July		24.5	46.4	18.5	29.4	28.4	28.6
August		19.1	28.7	23.5	22.7	23.3	
September		18.9	23.6	38.1	15.4	24.6	
October	17.6	21.4	27.4	19.3	15.0	21.4	
November	24.7	29.2	22.7	32.8	48.8	30.6	
December	22.4	60.8	20.7	28.3	44.9	22.9	

Table 4. Water discharge in Valley Creek at Pennsylvania Turnpike, USGS station number 01473169, mean daily values (cubic feet per second)

Date	Discharge (cubic feet per second) July 1987	August 1987
1	80	19
2	74	18
3	28	18
4	25	18
5	24	35
6	23	48
7	26	20
8	23	19
9	28	29
10	25	84
11	25	22
12	33	20
13	24	19
14	85	19
15	34	19
16	24	18
17	23	18
18	22	18
19	21	18
20	21	17
21	20	17
22	20	20
23	19	18
24	19	17
25	19	17
26	20	17
27	19	27
28	19	33
29	18	24
30	19	18
31	20	18

The Delaware River Basin Commission (DRBC) has limited the amount of groundwater a person, firm, corporation or other entity can withdraw to 10,000 gallons (37,850 liters) per day under its Groundwater Protected Area Regulations (DRBC, Ground Water Protected Area Regulations, Southeastern Pennsylvania 1980). The Philadelphia Suburban Water Company is exempted from the DRBC rules as is the Warner Quarry which is under the jurisdiction of the DEP Bureau of Mines.

2. Quality--Chemical and Bacteriological

Although Valley Creek has had problems with water quality in the recent past, there are some positive points to report. Knorr (1985a) found no violations of the DEP chapter 93 water quality criteria in the upper reaches of Valley Creek in a study done in the fall of 1984. However, groundwater contamination is more likely in the creek's main stem because of underground solution channels in the valley's limestone/dolomite formations. Contaminants that enter these channels can move rapidly underground far from their source. Sloto (1987a) lists additional information on the geology of limestone/dolomite formations.

Fourteen sites were sampled in this study. Sites 1 through 8 were located on Valley Creek to characterize all parts of the stream. Water quality was assessed using chemical analysis and faunal surveys. One site each from Trout Creek, Pickering Creek, French Creek, the east branch of Perkiomen Creek, Swamp Creek, and Ridge Valley Creek was chosen for comparison purposes (stations 9 through 14, respectively). These sites are described in Appendix E. The site (station) numbers in Appendix E correspond to the site numbers in Appendices F, G, I, J, K, L, M, P and Q. Data in these appendices were collected and analyzed by the authors of this report and/or Pennsylvania State University personnel unless otherwise noted.

The results of the water quality testing done on July 14, 1987, at a portion of these sites are in Appendix F. Variables were recommended by VAFO personnel. These were analyzed by the Land and Water Research Institute at The Pennsylvania State University. None of the values reported in Appendix F exceed DEP standards for a coldwater fishery or EPA recommended criteria. Nitrogen as nitrate (NO_3-N) values are all below the DEP standard of 10 mg/l. Copper (Cu) levels are below 0.1 mg/l and manganese (Mn) levels are below 1.0 mg/l, both DEP standards. The measurements of nickel (Ni) and lead (Pb) are less than the chronic damage levels suggested by EPA, 0.19 mg/l and 0.01 mg/l, respectively. This means 95% of all aquatic animals are protected from harm if measurements stay at or below this level. Concentrations for nickel and lead are also below the human health criteria suggested by EPA. When factoring in the water temperature and pH recorded the day these samples were collected the levels of nitrogen as ammonia (NH_3-N) were below the suggested EPA hourly concentrations (EPA 1986). These values correspond closely with DEP standards. There is no standard for total phosphates but eutrophication (a result of high concentrations of phosphates) was not noted.

The results of coliform testing (Appendix G) by CCHD on samples collected by Penn State personnel indicate possible human fecal contamination. These data cannot be compared to DEP standards because they were not collected in the manner that the standards dictate, five consecutive samples over at least as many days.

Water quality data collected by the CCHD from 1981 to 1985 are in Appendix H. Data similar to this are available from the CCHD from their open files and should be viewed as baseline data. Since flow data were not collected, information on the most obvious form of variation is absent. Comparison of these data with standards is included in section VI.

B. Biological Resources

1. Aquatic Resources

Macroinvertebrates were collected at stations 1 through 10 on November 17 1987, using D-frame kick nets (Appendix I). Nine 20-second kick sub-samples were taken (Frost et al. 1970). Although all habitats (pool, riffle, run) were sampled, emphasis was placed on riffles and those areas with vegetation because these habitat types are commonly known to be most productive for macroinvertebrates (Rabeni and Minshall 1976). Samples were preserved in 70% isopropanol and 5% formalin and transported to the laboratory for sorting and identification. Specimens were identified to the lowest practical taxon (usually genus). Identifications were based on the following keys: Pennak (1953), Wiggins (1977), and Merrit and Cummins (1984).

On July 8, 9, 13, and 14, 1987, seines and DC electrofishing gear were used to collect fishes at each station (Appendix J). All existing habitats at a site were thoroughly sampled to obtain a representative qualitative collection (Hocutt et al. 1974). Fishes were tentatively identified in the field. Gamefishes at sites on Valley Creek were weighed, measured and released and sampling continued at each station until it was thought that further efforts would yield no additional species (Appendix K). Samples of fishes were preserved in 10% formalin, returned to the laboratory for positive identification, and permanently stored in 50% isopropyl alcohol. All specimens were catalogued into The Pennsylvania State University Fish Museum. Temperature, substrate type and habitat were recorded at each station.

Diversity indices were calculated using Brillouin's (1960) formula which is based on information theory:

$$H = (1 / N) \times (N! / N_1!N_2!...N_s!)$$

where H is equal to diversity; N is the total number of individuals in the sample; $N_1, N_2 ... N_s$, are the number of individuals in species 1, 2...s.; and s the total number of species in the sample. This index is preferred for most problems in applied aquatic ecology (Pielou 1966, Kaesler et al. 1978) because it is a measure of the diversity of the sample. The index was calculated using the computer program of Stauffer et el. (1980) which eliminated the need for an approximation of factorials. This diversity index incorporates the number of species present and the number of individuals of each species. If a collection consists of twenty species all represented by a comparable number of individuals a relatively high diversity index will be calculated. Conversely, if twenty species are collected and only one or two species comprise the majority of individuals collected, a lower diversity index will be calculated. While a higher diversity index is usually calculated when there is a high number of species present, this is not always the case.

Similarity coefficients for all stations were calculated using the formula of Jaccard (Sneath and Sokal 1973):

$$S_j = (a / (a + u))$$

where S_j is the Similarity Coefficient; a is the number of species which were present at both stations; and u is the number of mismatches.

The Jaccard similarity coefficient used in this report measures only the presence or absence of a taxon. In other words, if the first sample consists of 20 specimens of species A, 30 specimens of species B, and 1 specimen of species C, and the second sample consists of 1 specimen of species A, 5 specimens of species B, and 30 specimens of species C, the similarity coefficient between the samples is 1. They are 100% similar since they both contain taxa A, B, and C, even though the numbers of each taxa are not the same. Similarity coefficients are included for macroinvertebrates (Appendix L) and for fishes (Appendix M).

The survey of fishes included eight stations (stations 1 through 8) in the Valley Creek drainage with four located in the park. Existing ichthyofauna of Valley Creek were compared to the fauna in six comparable streams (stations 9 through 14). For eastern Pennsylvania (and most localities in the United States) there is a historical record for fishes. Earlier collections of fishes are housed in museums and can be compared to current samples. Past collections of fishes by E. L. Cooper, presently professor emeritus of Fisheries at Pennsylvania State University, are listed in Appendix N. Comparable extensive collections of insects are not available. The macroinvertebrate sampling is done primarily to determine within-stream differences in the Valley Creek drainage. This helps to isolate pollution effects and their possible point of origin. A substantial drop in diversity from one station to the next might indicate that a toxic event had occurred between the two stations.

Seventeen fish species were captured in the Valley Creek drainage basin (Appendix J). Common names of fishes for these and historical collections are located in Appendix O. Fishes were also collected at six stations outside the Valley Creek drainage but within the Schuylkill River basin. Station 9 was on Trout Creek which is the next tributary to the

Schuylkill River downstream of Valley Creek. Station 10 (Pickering Creek) and station 11 (French Creek) were on relatively large tributaries to the Schuylkill River. Stations 12 through 14 (East Branch of Perkiomen Creek, Swamp Creek and Ridge Valley Creek) were on tributaries to Perkiomen Creek with the same relative size as Valley Creek.

The Trout Creek station was characterized by extremely low flows and was littered with garbage and trash. There were a low number of both species and individuals present at this site. When the stations located in Valley Creek are compared with the remainder of the stations located outside the basin (stations 10-14) it is obvious that Valley Creek harbors a depauperate ichthyofauna. Valley Creek has fewer fish species than one would expect for a healthy stream in this biogeographic area, with 13 species detected at the stations outside of the Valley Creek watershed which were not present at any of the eight stations located in the Valley Creek basin. Only two species of fishes were captured in the Valley Creek watershed which were not present at the stations outside of this drainage. One species, *Pimephales promelas*, is a common baitfish which may have been introduced into Valley Creek. Of particular interest is the presence of *Margariscus margarita*, the pearl dace, at station 8 in Valley Creek. *Margariscus margarita* is a relatively uncommon species in the southeastern portion of Pennsylvania and efforts should be made to protect this population by protecting the habitat.

The depauperate ichthyofauna of Valley Creek is reflected by the diversity indices (0.62-1.57) and higher number of species (13-20) present at stations 10-14 than at Valley Creek (3-9) (Appendix J). Valley Creek should have a higher diversity of fishes if not for perturbations, such as the massive fish-kills that occurred in the 1960s and 1970s as a result of hazardous waste spills. This condition is further reflected by the similarity coefficients (Appendix M) which are low when the Valley Creek stations are compared with stations 10-14.

Macroinvertebrate collection results (Appendix I) also indicated that Valley Creek fauna have been disrupted. Station 10 (Pickering Creek) had a substantially higher number of taxa present (47) and a higher diversity index (2.83) than stations 1-8 (number of taxa 17-24; diversity indices 0.98-2.26). There was a greater number of individuals collected at the Valley Creek stations due to the abundance of chironomids (midges), tipulids (crane flies), nematodes (roundworms), isopods (sow bugs), and amphipods (scuds) at the Valley Creek sites. A high number of individuals of a few species is usually indicative of a toxic stress which eliminates some species. This reduces competition for those species still present in the system, permitting them to maintain a high population.

Based on extensive surveys of the Atlantic Coastal streams (streams that eventually flow into the Atlantic Ocean) in Pennsylvania, the fish fauna found at stations other than Valley and Trout creeks indicate good water quality while fauna at the Valley Creek stations indicate a stressed ecosystem.

Conditions in the stream do support a large population of brown trout. The PA Fish Commission recently reported that the biomass of brown trout in three sample locations in Valley Creek was 67 kg/ha, 71 kg/ha, and 122 kg/ha. The last site is inside Valley Forge NHP (Boyer 1990). Streams with a trout biomass of 40 kg/ha are considered by the PFC to be Class A wild trout streams. Valley Creek's brown trout biomass inside the park is three times greater than the state's Class A standard. One reason for such an outstanding trout population is the no-harvest restriction caused by contamination of fish flesh with PCBs.

Sloto (1987a) reported that trends of benthic invertebrate diversity indices are increasing on stations on Valley Creek near Valley Forge and Little Valley Creek near Howellville. He thought the overall increase in diversity since 1973 may be due to the banning of persistent insecticides, which usually accumulate in the stream bottom. Indices continued to increase when the Valley Forge Sewer System was installed in 1977 replacing smaller plants that operated along these two streams (Sloto 1987a). Our survey cannot dispute this trend although our diversity indices for 1987 were lower (Appendix I) than Moore's values of >3 for Valley Creek at Valley Forge (Sloto 1987a). This could be explained by different sampling and calculation methods since macroinvertebrate diversity indices are dependent on sampling technique and method of calculation. If an approximation of a factorial is used, the index is an estimate rather than a precise calculation. Comparisons can be made between this report and data collected in the future if the park uses the techniques described in this report.

An aquatic resource that was not systematically studied was the plant community in Valley Creek. The large beds of Elodea found in Valley Creek are common in limestone-rich streams. They are important fish habitat especially for juveniles of species such as brown trout and the sunfishes. Elodea beds, which were abundant inside the park when data for this study were first collected in 1987, have since disappeared. Observations indicate they were buried by sediment.

2. Terrestrial (Riparian) Flora/Fauna

Eight locations (sites 1 through 8) in and upstream of VAFO were sampled to identify small mammals present in the riparian zones along Valley Creek. Five Sherman live-traps were baited and placed at 10 meter intervals parallel to the stream at each location. Attempts were made to place traps in riparian vegetation typical of each sampling location and concealed so as to prevent human disturbance. Any mammals captured were identified to species with the aid of Burt and Grossenheider (1976), and released. Appendix P lists the results of two nights of trapping.

The live-trapping method employed for this survey does not provide a complete determination of local small mammal fauna. *Peromyscus leucopus*, *Peromyscus maniculatus*, and *Microtus pennsylvanicus*, all captured during this survey, are three of the most common species found in Pennsylvania. Their habitat requirements are quite general and are met by numerous different vegetative communities. Other common animals seen were white-tailed deer, muskrats, raccoons, and the northern water snake, *Nerodia sipidon*.

A visual survey of woody vegetation at each sampling location was performed by walking parallel to the stream for approximately 25 m and identifying all woody vegetation observed within approximately 30 m of the stream bank (Appendix Q). Any plants that could not be positively identified in the field with the aid of Petrides (1972) were collected for subsequent identification by Penn State faculty. While every effort was made to identify all woody vegetation present, the species list should not be considered a comprehensive inventory. A more complete listing of aquatic and riparian vegetation along Valley Creek inside the park is available in park files. Newbold (1992) reported 256 plant species from the park. No federal or state-listed threatened or endangered species were encountered. *Ranunculus ficaria* (lesser celandine), an exotic, covers large sections of floodplain during the spring. Another exotic aggressive vine, *Humulus japonicus* (Japanese hops), has invaded riparian areas along the entire one-mile stretch of Valley Creek from its confluence with the Schuylkill to the Knox covered bridge.

Stream bank vegetation serves numerous functions in both the aquatic and terrestrial communities. It provides a source of shade which helps keep stream temperature low and decreases the chance of summer fishkills of coldwater fishes such as trout. It also contributes to bank stabilization which protects adjacent roads and other man-made developments from the devastating effects of a wandering stream channel. Root systems or limbs that may reach out into the stream provide shelter for fish, especially young fish which are more vulnerable to predation. When trees and logs fall into the stream they also provide habitat and sanctuary for aquatic fauna, becoming a problem only when they change the current direction to threaten the stability of a bank.

3. Rare, Endangered and Threatened Species

No federally endangered or threatened fishes were found in this study. The bridle shiner, Notropis bifrenatus, listed as vulnerable to extinction by the Pennsylvania Biological Survey has a historical range which includes the Schuylkill River and may possibly be found here (Horwitz 1985). The ironcolor shiner, Notropis chalybaeus, listed as extirpated from Pennsylvania was historically found in the Valley Creek area (Cooper 1985).

No federally endangered or threatened reptiles, amphibians, or mammals were found in our study. There is a possibility of finding the bog turtle, *Clemmys muhlenbergii*, which is listed as endangered by the Pennsylvania Fish Commission, in the Valley Forge area (Kulp 1987). The preferred habitat for this turtle is marshy meadows and sphagnum bogs (Ernst 1985). Threatened or endangered species may exist that were not found due to small sample size.

The only federally endangered plant to have a historical range within Pennsylvania, *Isotria medeoloides*, the small whorled pogonia (U.S. Fish and Wildlife Service 1987), was not found during our study.

C. Stream Channel Characteristics and Tributaries

Stream channel characteristics of Valley Creek between the Pennsylvania Turnpike and the Schuylkill River were measured on August 27-28, 1987, when the flow was at a typical summer level. Beginning at the mouth of Valley Creek, stream measurements were made at points determined by randomly pacing between 1 and 100 steps. First, stream width was measured with a tape measure. With the width information, water depth (at low summer flow) was measured with a meter stick at 1%, 10%, 33%, 50%, 66%, 90%, and 99% of the width, starting on the southern shore. This gave a profile of the entire stream without bias to any one section for the entire length of the stream in the park. At each point substrate (silt, sand, gravel, cobble, rubble, boulder, or bedrock) and stream character (riffle, run, or pool) were noted. Eighty-four measurements were taken (Table 5). The mean values for certain sections of the stream are given in Table 6. The stream was divided into recognizable sections based on physical characteristics.

Riffles are shallow areas with higher gradients than pools and runs. Runs are deeper and are characterized by low level turbulence. Pools are deeper with slower current velocities

Table 5. Valley Creek stream profiles on August 27-28, 1987 (left to right bank facing upstream)

Width (m)	Depths at percents of widths (cm) 1%	10%	33%	50%	66%	90%	99%
			Mouth of Valley Creek				
12.5	6	16	43	18	28	21	17
6.2	10	27	52	54	47	32	3
8.2	1	4	1	19	30	18	1
8.23	2	7	28	21	14	19	2
15.5	7	50	63	24	14	6	4
11.6	1	56	82	68	20	7	11
12.6	8	34	26	26	35	24	4
9.7	5	18	38	23	24	28	1
9.5	1	31	24	16	12	8	1
			Rt. 23 bridge**				
10.3	2	17	9	27	28	12	9
12.0	6	39	>100	>100	>100	>100	>100
9.8	6	71	72	86	101	33	0.5
10.1	7	19	47	78	52	37	3
11.6	7	22	60	78	64	25	7
9.5	17	27	33	42	30	6	2
10.6	4	10	38	31	57	19	5
19.2	8	29	57	49	20	11	3
			dam				
*17.1	130	130	130	130	130	130	130
10.0	>150	>150	112	110	93	40	10
15.5	47	82	73	49	32	6	1
13.7	26	35	76	76	56	10	1
14.7	8	85	72	63	36	21	4
15.4	8	77	72	56	40	30	15
14.0	7	81	65	49	39	23	10
16.0	3	78	51	68	87	>100	14
14.4	8	61	43	42	53	58	15
12.3	14	41	47	51	64	60	11
12.3	26	48	60	51	47	31	3
10.9	10	74	79	54	38	26	7
			end of slack water behind dam				

Table 5. (continued)

Width (m)	Depths at percents of widths (cm) 1%	10%	33%	50%	66%	90%	99%
9.1	17	56	59	43	23	13	4
8.5	5	44	74	46	26	14	3
11.3	6	10	25	13	13	9	5
10.0	4	14	25	29	31	19	3
13.6	7	14	24	6	6	6	2
14.65	4	4	13	25	33	38	4
9.5	2	27	88	114	113	55	4
9.35	2	3	32	60	62	20	2
			footbridge				
11.15	8	27	41	35	32	17	5
11.1	9	13	17	18	27	10	2
11.08	3	12	26	26	20	13	4
8.9	4	18	32	26	32	25	4
11.4	3	10	6	16	10	8	2
16.0	5	24	14	12	17	9	3
13.7	1	3	20	32	44	17	4
8.35	10	7	39	48	43	16	2
			covered bridge				
8.1	2	6	9	20	14	9	3
14.4	5	11	17	7	5	0	6
9.6	5	29	64	56	25	5	3
12.3	3	10	11	13	8	30	11
8.6	5	21	33	30	19	12	1
10.2	3	14	32	37	28	10	1
10.9	2	9	18	23	24	9	2
10.95	5	7	10	15	15	11	4
12.4	4	8	11	31	8	14	4
8.7	1	18	38	24	19	18	12
9.4	4	37	31	27	26	15	3
10.8	4	7	15	10	17	0	1
12.2	8	35	49	43	47	31	8
17.8	7	13	24	25	17	18	2
10.6	3	24	40	18	25	6	3
13.0	7	12	12	6	13	10	4
10.2	1	5	17	20	2	12	2

Table 5. (continued)

Width (m)	Depths at percents of widths (cm) 1%	10%	33%	50%	66%	90%	99%
13.8	25	31	47	65	75	50	8
11.1	2	5	4	11	11	21	8
10.65	2	5	12	15	19	19	2
12.6	10	20	23	13	19	5	2
9.7	8	28	21	21	8	4	1
11.4	13	22	34	35	20	14	9
9.0	13	40	40	52	37	15	6
8.6	15	19	18	1	25	16	4
6.7	3	5	6	12	18	13	7
7.3	2	17	59	60	51	31	1
8.7	2	6	20	16	20	6	1
9.5	2	21	65	54	37	7	2
8.95	8	40	64	48	38	16	2
6.4	13	44	53	65	82	20	2
11.4	10	16	21	23	18	13	2
			park boundary				

*measured directly behind dam
**landmarks to denote stream sections

Table 6. Valley Creek stream profile means for each section

Section	Width (m)	Depths at percents of widths (cm)						
		1%	10%	33%	50%	66%	90%	99%
1	10.45	4.5	27.0	39.7	29.9	24.9	18.1	4.9
2	11.64	7.1	29.3	52.0	61.4	56.5	30.4	16.2
3	13.85	25.7	78.5	73.6	66.6	59.6	44.6	18.4
4	10.75	5.9	21.5	42.5	42.0	38.4	21.8	3.4
5	11.62	6.3	23.9	30.3	30.9	27.9	19.9	3.5
6	10.50	6.2	18.3	28.7	28.0	24.7	14.4	4.0
Overall	11.3	8.9	30.2	40.1	38.8	34.6	22.3	7.2

Sections

1 Valley Creek mouth to Rt. 23 bridge
2 Rt. 23 bridge to historic mill dam
3 historic mill dam to end of slack water
4 end of sack water to footbridge
5 footbridge to covered bridge
6 covered bridge to park boundary

and are termed depositional zones since stream sediments and detritus settle here. The exact determination of these stream habitats is very subjective. The ratio of riffles to runs to pools was 8:8:5. This shows the stream has a good gradient or vertical drop in water level per unit stream distance. Over 75% of the stream habitat is either runs or riffles. More than half of the pool sites were behind the reconstructed mill dam.

Throughout the entire stream inside the park the dominant substrate is cobble and gravel with sand and silt prevalent immediately upstream of the dam. Shallow riffles and runs with a cobble or gravel substrate make suitable spawning areas for brown trout. Valley Creek is therefore well-suited for brown trout reproduction (when other conditions such as temperature are suitable), except for the large pool behind the dam. Some small sections of Valley Creek flow over bedrock. The deepest water (up to 1.5 m) was located behind the dam.

The stream changes markedly near the covered bridge. Upstream of the bridge the land is relatively flat while below this area the stream is forced into a narrow gorge between Mount Joy and Mount Misery. Unconsolidated, high streambanks downstream from the covered bridge are a consequence of several silted-up mill ponds that once existed along this stretch of creek. Sediment deposits, which accumulated behind mill dams and which now form streambanks, are unstable and easily eroded.

Three permanent and two intermittent tributaries flow into Valley Creek in the park:

- A small, permanent stream arises near Davis Street in Valley Forge Village, flows through several backyards, and enters Valley Creek just upstream of the Route 23 bridge.

- A larger, permanent tributary, Fisher's Run, begins near Valley Forge Mountain Drive in a housing development on top of Mt. Misery. It flows past the ruins of the Hires water bottling plant, the site of Slab Tavern, and the site of a sawmill before entering the creek about 100 m downstream from Middle Dam.

- Stirling's Run, also a permanent stream, starts near Hamilton Drive in Valley Forge Mountain Estates. It flows down the south-facing side of Mt. Misery fed by at least four springs. An elaborate system of basins and pipes along this drainage formed part of a water supply system that probably served the Ligget Farm. A two acre wetland next to Stirling's Run is perched about half-way up the slope of Mt. Misery. The historic Currie Farmstead (Stirling's Quarters) is located on this stream.

- An intermittent stream, which basically serves as a storm drainage, begins on the south-facing slope of Mt. Misery and reaches Valley Creek through a culvert at the covered bridge. During intense rainstorms, water from this drainage floods Yellow Springs Road and the driveway to Maxwell's Quarters causing erosion to the roadbank. At least two small dams and a small cement reservoir supplied water to Valley Forge Farm.

- Wilson Run is an intermittent stream, which arises on the old Wilson Farm near Route 202, flows through Chesterbrook, a large housing development, and meets Valley Creek at the Wilson Road bridge. Detention basins in Chesterbrook discharge a large amount of water into Wilson Run during heavy rains. In some places the stream has been "blown-out" by floodwaters. The historic Havard home (Duportail's Quarters) is on this stream.

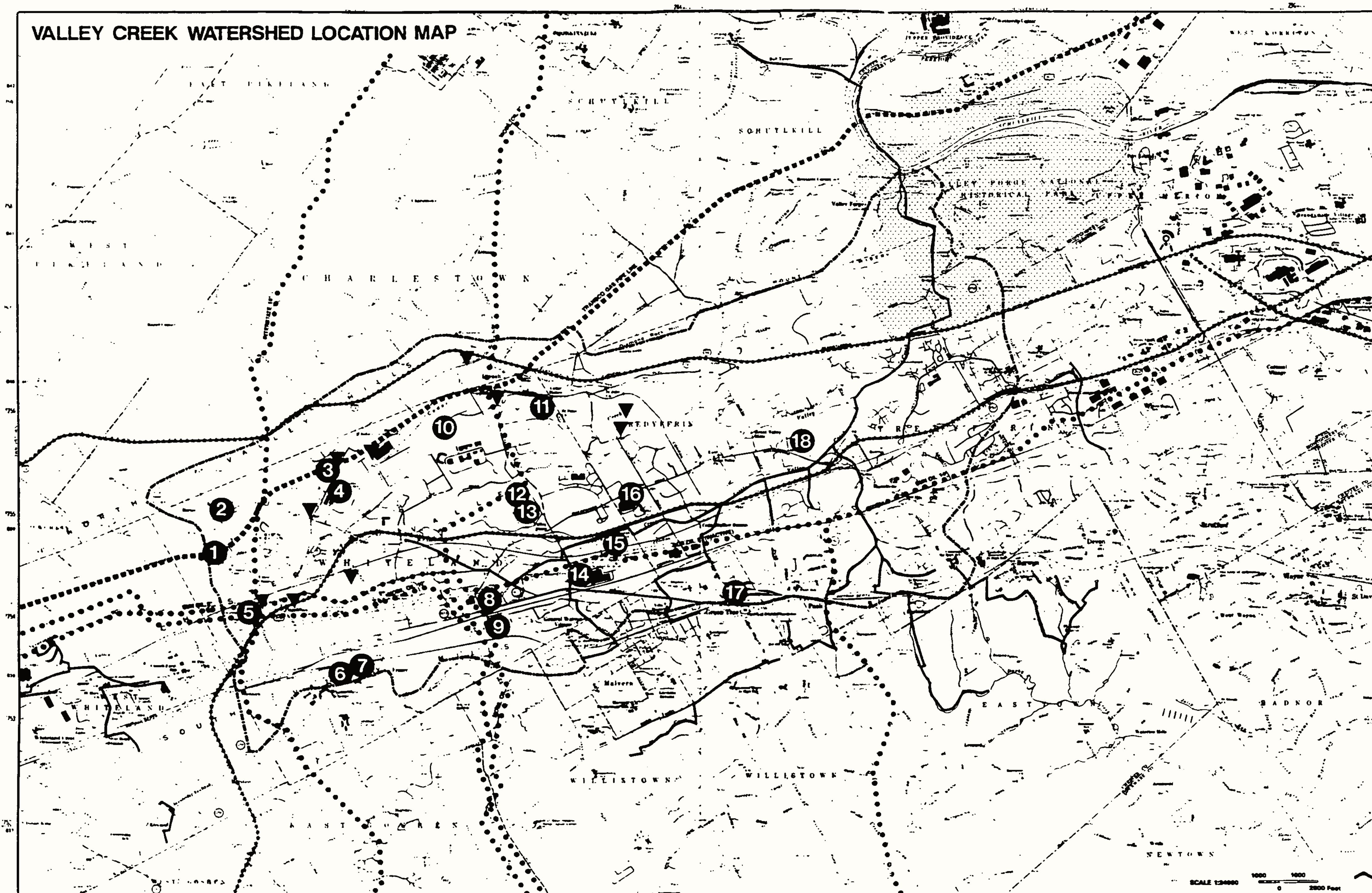
Beginning at the footbridge on Route 252 and extending approximately 200 ft downstream, there are retaining walls that protect the road and the archaeological remains of the upper forge. The walls also force the creek into a narrow chute which increases the velocity of the water. Increased water velocity has scoured the substratum leaving only large rocks. This also occurs at bridges when water is forced through a narrow gap. The alteration of the stream bottom here is acceptable because of the importance of protecting the remains of the upper forge.

A map of the entire drainage basin is provided, showing all tributaries (Figure 1). Some real and potential pollution impact sites are included. A more complete map of point/non-point source pollution and hazardous waste sites is given (Figure 2). Cultural sites and their relationship to Valley Creek are also an important part of the park's resources. Maps depicting the floodplains in relation to cultural resources are provided. Figure 3 is a map of the area near Washington's headquarters with the 100- and 500-year floodplains indicated. An inset to this figure indicates the floodplain boundaries for that portion of Valley Creek near the upper forge. Further information regarding flood preparedness and Valley Creek along with additional information on hydrology, stream channel characteristics, and erosion processes can be found elsewhere (U.S. Army Corps of Engineers 1981).

FIGURE 2.

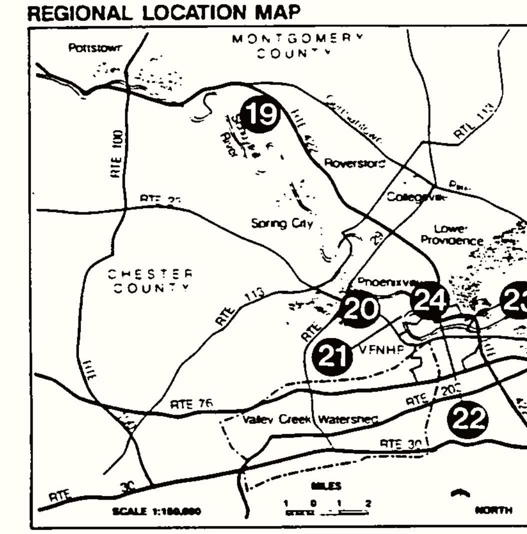
VALLEY FORGE NATIONAL HISTORICAL PARK

POINT/NON POINT SOURCE POLLUTION AND HAZARDOUS WASTE SITE LOCATIONS



1. Transcontinental Gas Corporation
Bacton Hill Road
Malvern, PA
2. Malvern Courts Mobile Home Park
Bacton Hill Road
Malvern, PA
3. Chemclene Corp. (Alias Malvern T.C.E.)
Phoenixville Pike
Malvern, PA
4. Great Valley High School
Phoenixville Pike
Malvern, PA
5. Foote Mineral Company
Swedesford & Bacton Hill Road
Frazer, PA
6. Immaculata College
Immaculata, PA
7. Camilla Hall Infirmary
Immaculata, PA
8. Bishop Tube Company
Route 30 & Malin Road
Frazer, PA
9. Sun Oil and Marketing Company
Route 30 & Malin Road
Malvern, PA
10. Glasgow Quarry
Yellow Springs Road
Malvern, PA
11. Warner Quarry Company
Yellow Springs Road
Malvern, PA
12. B.F.I. Trash Haulage Company
Morehall Road
Malvern, PA
13. Knickerbocker Landfill
Morehall Road
Malvern, PA
14. Wyeth Laboratories, Inc.
Route 30 & Morehall Road
Paoli, PA
15. National Rolling Mills
Morehall Road
Malvern, PA
16. Unisys
West Swedesford Road
Malvern, PA
17. Paoli Rail Yard
RR Service Shop
Paoli, PA
18. Ex N.I.K.E. Site
Le Boutillier Road
Malvern, PA
19. Limerick Nuclear Power Station
(Schuylkill River)
20. Cromby P.E.C.O Power Station
(Schuylkill River)
21. Valley Forge Sewer Authority
(Schuylkill River)
22. Saint Gabriel Hall
(Schuylkill River)
23. Valley Forge Terrace Mobil Home Park
(Schuylkill River)
24. Montgomery County Sewer Authority
(Schuylkill River)

REGIONAL LOCATION MAP



LEGEND

- 4 Hazardous Waste Site Locations
- Petroleum Pipeline
- Gas Pipeline
- Major Highway
- Valley Forge National Historic Park
- Valley Creek Watershed Boundary
- Sewer Line - 10" Pipe & Force Main
- ▼ Contaminated Well

Prepared by:
Thomas Comitta Associates Inc.
Planning And Design Consultants

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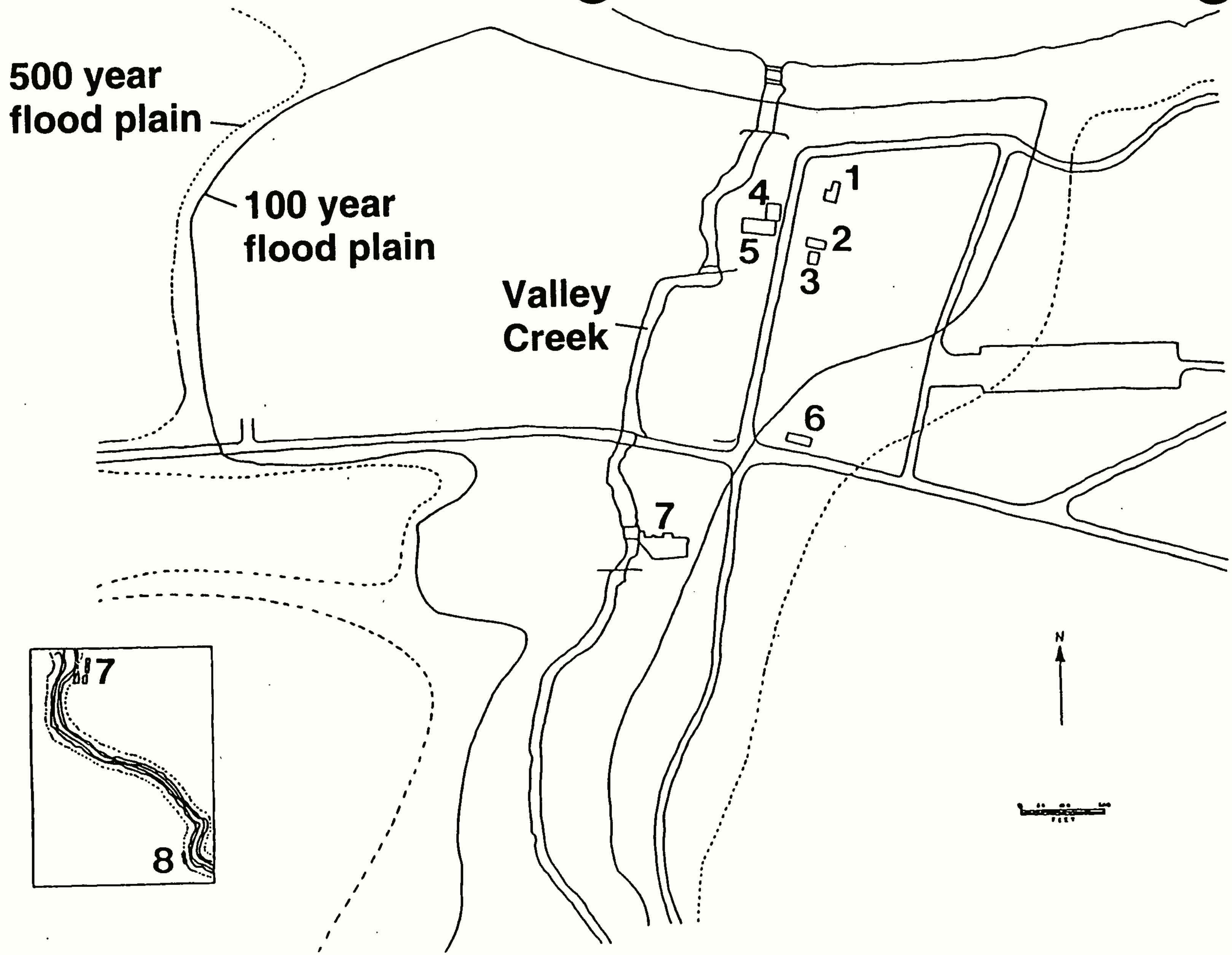

Figure 3. Map of Washington's Headquarters, Valley Forge NHP with the 100- and 500-year floodplains for Valley Creek indicated. Inset shows the upper forge area. Some important cultural resources include: 1-Washington's HQ (extant), 2-Stables (extant), 3-Barn (extant), 4-Grist Mill (archaeological site), 5-Saw mill (archaeological site) 6-Potts/Dewees House (extant), 7-Lower Forge (archaeological site), 8-Upper Forge (archaeological site).

V. Identification of VAFO Valley Creek Management Issues

A. Water Quantity

The amount of water in the Valley Creek basin may be decreasing. Sloto (1987a) documents the loss of flow in different reaches of Valley Creek. This probably is related to construction of impervious surfaces which decreases the amount of water absorbed into underground aquifers and increases stream discharges during periods of high rainfall (Sloto 1987b).

Interbasin exchange, the transfer of groundwater or surface water outside the watershed, is another process that decreases water in a drainage basin. The Valley Forge Sewer Authority facility takes wastewater from the Valley Creek basin and discharges it as treated effluent into the Schuylkill River, resulting in a loss of water in the Valley Creek watershed.

Groundwater is also lost by infiltration into the Valley Forge sewage system. The process is related to the altitude of the sewer line relative to the that of the groundwater. Groundwater that is higher than a sewer line will lose water to the line while groundwater that is lower (deeper) will receive sewage percolating down from the line (Sloto 1987a). Groundwater that is lost to the sewer system is not discharged into streams.

Groundwater pumping by Warner Quarry has led to a depression of the water table but nearby rock formations apparently confines the effect to the immediate area of the quarry (Sloto 1987a). Removal by Warner Quarry averaged 5 million gallons/day (MGD), or 19 million liters/day (MLD), in 1984 (Sloto 1987a). Catanach Quarry is located just west of Warner Quarry. The groundwater it uses is put back into a closed depression that acts as a groundwater recharge area (Sloto 1987a) reducing the amount of groundwater lost.

The operation of two high-capacity wells by Philadelphia Suburban Water Company (PSWC) may have caused water depletion in some stretches of Valley Creek and completely dried some tributaries (Sloto 1987a). Well CH-2199 is located near State Route 401 and U.S. Route 202 and well CH-209 is at State Route 202 and the PA turnpike. Their locations are shown in Figure 1. Combining the amount of water the PSWC pumps from wells, 552 MG/yr (2.1 billion liters/yr) and commercial pumping, 78 MG/yr (300 million liters/yr), the Valley Creek basin lost 630 MG (2.4 billion liters) in 1984 (Sloto 1987a).

Potential effects of these activities, including the loss of habitat for aquatic life and greater concentration of pollutants, have not yet been observed but data show that water table levels are lower and these effects are likely to become noticeable in the future (Sloto 1987a). The Chester County Board of Commissioners (1979) discussed more long range problems associated with water loss. Heister (1986) suggests that low flow could become Valley Creek's biggest problem in the future.

B. Acid Rain

In a limestone stream such as Valley Creek acid rain has very little effect. High calcium carbonate concentrations found in water from limestone formations have a high chemical buffering capacity, which neutralizes the acidic precipitation.

C. Water Quality

The effects of urbanization in eastern Chester County are pronounced in the Chester Valley (Sloto 1987a). Contamination of groundwater by organic chemicals, which easily move through limestone aquifers, is a major concern. Sources of these chemicals include industrial spills, leakage from storage tanks and discharge from septic systems, lagoons and disposal sites (Sloto 1987a). Persistent organic compounds, such as pesticides and polychlorinated biphenyls (PCBs), have accumulated in stream sediments. Stable chemicals such as these are not easily flushed from the system. Valley Creek, like most other creeks in eastern Chester County, has measurable levels of PCBs, DDE, DDD, DDT, dieldrin, and chlordane in the sediment (Sloto 1987a). Persistent hydrocarbons are usually not found in the water column but accumulate in the sediments. There are currently no criteria for stream sediments that apply to this situation. The presence of these chemicals would indicate a contaminated benthic macroinvertebrate community, which means higher order consumers, such as fish, may have accumulated these chemicals in tissues at even higher concentrations than found in the benthos. For example, PCBs were measured at 18 ppb in the sediment in 1985 (Sloto 1987a) while whole fish analysis of brown trout and white suckers have ranged from 1.00 to 3.9 ppm (1000 to 3900 ppb) (Knorr 1985a, 1986).

The primary cause of degradation of Pennsylvania's streams, including Valley Creek, is sedimentation. Nine percent of Chester Valley is covered by impervious areas (Sloto 1987b), which limits the amount of precipitation that soaks into groundwater reserves and increases the amount of stormwater flowing into streams, contributing to erosion and stream sedimentation. Most of the Valley Creek watershed is contained within two townships, Tredyffrin and East Whiteland. As of 1993, East Whiteland had no ordinances for stormwater management, wetland protection, and soil erosion and sedimentation control. Tredyffrin has fashioned ordinances in all these categories. In 1990 Chester County's Conservation District adopted an Erosion and Sedimentation Pollution Control Program devised by DEP's Bureau of Soil and Water Conservation. Lack of staff and funding to enforce these ordinances remains a problem. Since these regulations generally apply to new construction and earth moving activity, they do not regulate "old" sites, such as dirt roads and erosion in residential and industrial areas and vacant fields.

Non-point chemical and sediment pollution from agriculture, a major issue in rural townships, is a minor problem in the urbanized Valley Creek watershed. Pollution from lawn maintenance is a problem in this area.

D. Warner Quarry

The Cedar Hollow Plant of the Warner Company is a limestone mining operation located on Yellow Springs Road near PA route 29 in Devault. Large quantities of water are pumped from the bottom of the quarry and released into Cedar Hollow Creek converting it to a discharge stream that enters Valley Creek about one-half mile below the quarry's settling pond. Knorr (1985a) stated that the chemical quality of the water coming from the quarry was "good" and "not significantly different" from Valley Creek at the point at which the discharge was entering but that a potential for problems exists. He did mention in a memo (1985b) that the effect may be "greater than the biological data indicated." Two points mentioned were the reassessment of the 30 mg/l permit criteria for suspended solids (by DEP) and whether the rechannelization of Cedar Hollow Creek was permissible.

Cedar Hollow Creek's streambed is chalky-white and a whitish cast is sometimes imparted to Valley Creek as the quarry effluent enters it. Sedimentation has caused changes in Valley Creek's aquatic life below the quarry between stations 6 and 7, including lack of spawning habitat for brown trout (Knorr 1985a) and a decrease in species diversity. In addition to suspended solids, levels of magnesium, turbidity, and fecal coliforms were elevated.

John Arway (1987) of the Fisheries Environmental Services (FES) branch of the Pennsylvania Fish Commission (PFC) conducted a study of benthic macroinvertebrates near the Warner Quarry discharge on February 10, 1987. He found a much lower number of individuals below the discharge compared to above. Based on this observation, Arway (1987) advised the DEP to require daily monitoring to check levels of suspended solids for compliance with average monthly levels. DEP investigated and found no standards to be violated. Natural resource management staff from Valley Forge NHP and volunteers from the Valley Forge Chapter of Trout Unlimited intensively monitored temperature and turbidity in Cedar Hollow Creek from April 25 to August 31, 1990. Measurements were taken once every 24 hours during this four month period at different times of the day. Cedar Hollow Creek had lower turbidity levels than Valley Creek and maintained a temperature approximately equal to that of Valley Creek (Lambert, pers. comm.).

Data collected by the PFC in 1987 reflect the effects of the discharge (Table 7). In Valley Creek, the factors that did not change appreciably between sampling points upstream and downstream of the discharge were specific conductivity, pH, total alkalinity, total dissolved solids, nitrogen as nitrate, total phosphate, total hardness, calcium, magnesium, total sulfate, total iron and total acidity (constant at zero). Nitrogen as ammonia and nitrogen as nitrate decreased, probably due to biological activity in the settling pond. There was a small increase in turbidity.

Table 7. Water chemistry laboratory results from Pennsylvania Fish Commission from Valley Creek near the Warner Quarry discharge area on February 11, 1987

Valley Creek upstream of confluence with Warner Quarry discharge, Feb 11, 1987

Test	Result
specific conductivity	740.00 umhos
pH (lab)	8.30
total alkalinity ($CaCO_3$)	222.00 mg/l
total dissolved solids	396.00 mg/l
total NH_3-N	0.47 mg/l
total NO_2-N	0.43 mg/l
total NO_3-N	2.83 mg/l
total phosphate	0.05 mg/l
total hardness ($CaCO_3$)	228.00 mg/l
calcium	56.58 mg/l
magnesium	31.06 mg/l
chloride	75.00 mg/l
total SO_4	43.00 mg/l
total Fe	140.00 ug/l
total acidity	0.00 mg/l
turbidity	1.00 NTU

Warner Quarry Discharge at mouth, Feb 11, 1987

Test	Result
specific conductivity	460.00 umhos
pH (lab)	7.80
total alkalinity ($CaCO_3$)	162.00 mg/l
total dissolved solids	244.00 mg/l
total NH_3-N	0.04 mg/l
total NO_2-N	0.008 mg/l
total NO_3-N	2.63 mg/l
total phosphate	0.02 mg/l
total hardness ($CaCO_3$)	201.00 mg/l
calcium	43.42 mg/l
magnesium	30.80 mg/l
chloride	25.00 mg/l
total SO_4	29.00 mg/l
total Fe	140.00 ug/l
total acidity	0.00 mg/l
turbidity	4.40 NTU

Table 7. (continued)

Warner Quarry discharge below settling pond, Feb 11, 1987

Test	Result
specific conductivity	460.00 umhos
pH (lab)	7.80
total alkalinity ($CaCO_3$)	166.00 mg/l
total dissolved solids	258.00 mg/l
total NH_3-N	0.02 mg/l
total NO_2-N	0.006 mg/l
total NO_3-N	2.00 mg/l
total phosphate	0.02 mg/l
total hardness ($CaCO_3$)	205.00 mg/l
calcium	45.12 mg/l
magnesium	30.84 mg/l
chloride	26.00 mg/l
total SO_4	31.00 mg/l
total Fe	230.00 ug/l
total acidity	0.00 mg/l
turbidity	5.40 NTU

Site: Valley Creek below confluence with Warner Quarry discharge, Feb 11, 1987

Test	Result
specific conductivity	620.00 umhos
pH (lab)	8.00
total alkalinity ($CaCO_3$)	194.00 mg/l
total dissolved solids	360.00 mg/l
total NH_3-N	0.27 mg/l
total NO_2-N	0.022 mg/l
total NO_3-N	2.62 mg/l
total phosphate	0.04 mg/l
total hardness ($CaCO_3$)	212.00 mg/l
calcium	53.89 mg/l
magnesium	31.29 mg/l
chloride	49.00 mg/l
total SO_4	37.00 mg/l
total Fe	150.00 ug/l
total acidity	0.00 mg/l
turbidity	3.50 NTU

NTU = nephelometric turbidity units

Heister (1986) warns that in a drought year like 1966 the 3-5 MG (11.4-17.5 ML) of water the quarry takes daily would be half the water available in the watershed. In 1988, Warner Quarry was granted an expansion by the Bureau of Mining and Reclamation, DEP to expand its operation from 149 acres to 262 acres and to increase its discharge to 11.1 MGD (DEP files). This compares to the base flow of Valley Creek of 14 MGD.

E. Knickerbocker Sanitary Landfill

The Knickerbocker Sanitary Landfill (KSL) is located about one-half mile from Valley Creek in East Whiteland Township. It opened in 1958 and was designed to prevent leachate contamination of groundwater. Violations of its 1974 landfill permit reported to DEP included leachate contamination of groundwater, excessive corrosion and illegal dumping of hazardous chemicals. There were also reports of dumping liquid hazardous wastes from New Jersey. The landfill was forced to start closure procedures in 1979 (NPS files). Tests of water samples in the fall of 1978 (Heister 1979, pg. 36, Table 8) indicated that leachate flowing into Valley Creek was lethal to the common goldfish (*Carassius auratus*) in 30 minutes while a 10% solution was lethal within two hours (Heister 1979).

Knickerbocker began treating leachate in 1983 with plans to release it into the Valley Forge Sewer Authority (VFSA). KSL felt that the leachate was sufficiently treated to be discharged into Valley Creek or sprayed as irrigation (McElrane 1983). The response from the VFSA was that the leachate would be accepted as soon as it met the standards for industrial wastes and that each batch of leachate must be tested before it was released because of the likely variability of the batches. Holding lagoons were to be used for temporary storage during testing (Bateman 1984).

Table 8. Water chemistry of Valley Creek from the Knickerbocker Landfill area from fall, 1978 (Heister 1979, p. 35). Some units are expressed differently than Heister (1979) to be comparable to DEP standards

	#1	#2	#3	#4
Manganese (mg/l)	0.016	0.104	---	0.050
Nickel (mg/l)	0.012	0.026	---	0.016
Lead (mg/l)	0.016	0.018	---	0.036
Copper (mg/l)	0.002	0.002	---	0.002
Iron (mg/l)	0.00014	0.0019	0.150	0.020
Mercury (ppm)	<0.001	<0.001	<0.001	<0.001
Broad spectrum pesticides, PBB & PCB (ppb)	<0.1	<0.1	<0.1	<0.1
Specific conductance (umhos/cm^3 @ 25°C)	650	800	1100	750
Total coliforms (#/100ml)	300	433	---	---
Fecal coliform/Fecal streptococcus ratio	0.19	0.38	---	---

#1 - immediately upstream from landfill
#2 - immediately downstream from landfill
#3 - groundwater near landfill
#4 - groundwater 2000 yds downstream from landfill

From data collected November 8 and September 19 1984, Knorr (1985) found that there were elevated levels of alkalinity, dissolved solids, and ammonia nitrogen below Knickerbocker Landfill. This led him to state "concentrations on both dates...exceeded recommended 30-day averages, and may be high enough to induce chronic toxicity problems for some organisms, especially during lower stream flows" (Knorr 1985a, pg. 7).

F. Paoli Railyard

The railyard at Paoli, an EPA Superfund site, is operated by the Southeastern Pennsylvania Transportation Authority (SEPTA). PCB contamination at the railyards has been called the worst ever by the National Institute for Occupational Safety and Health (Philadelphia Inquirer, March 5, 1987). EPA is managing the site and is seeking reimbursement from SEPTA for the cost of remediation. The site is located on a tributary about one-half mile from Little Valley Creek. PCBs have entered Valley Creek, via Little Valley Creek, contaminating both.

As long as stream sediment remains contaminated with PCBs, trout and insects will also be contaminated. Sediment in Little Valley Creek near Howellville contained 15 ppm (mg/l) PCBs in 1980 (USGS computer file). A more complete analysis for persistent chemicals showed PCBs to be 18 ppb (ug/l) in the stream bottom material of Valley Creek near the Turnpike in 1985 (Sloto 1987a). PCB concentrations in Little Valley Creek are higher because it is closer to the source.

Brown trout and white suckers throughout the Valley Creek watershed are contaminated by PCBs at levels unhealthy for human consumption (Table 9), according to the Food and Drug Administration (FDA). In 1986, chemical analysis of fish fillets showed that brown

Table 9. PCB analysis from the Pennsylvania DEP (Knorr 1986, interagency memo)

Fish flesh analysis for PCBs from Little Valley Creek (all collected at Mill Road)

Sample Date	Fish Species	PCBs (ppm)
13 Dec 1979	white sucker (WF)	6.66
18 Feb 1981	white sucker (F)	2.65
	brown trout (F)	3.86
11 Mar 1982	brown trout (F)	2.30
3 Mar 1983	brown trout (WF)	5.28
9 Jan 1986	brown trout (WF)	4.50
	brown trout (F)	3.70

Fish flesh analysis for PCBs from Valley Creek

Sample Date	Species	PCBs (ppm)	Location
11 Mar 1980	WS (F)	0.70	Church Rd.*
	BT (F)	0.13	Church Rd.*
11 Mar 1980	BT (F)	0.42	Wilson Rd., VAFO**
	WS (F)	1.00	Wilson Rd., VAFO
29 Jun 1981	BT, S (F)	<0.20	hatchery truck
11 Mar 1982	BT (F)	0.52	Wilson Rd., VAFO
11 Mar 1982	BT (F)	1.90	Rt. 29
13 Aug 1982	BT (WF)	1.62	Below Little Valley Creek
3 Mar 1983	BT (F)	1.76	Wilson Rd., VAFO
28 Mar 1985	BT (F)	0.43	Wilson Rd., VAFO
	WS (F)	0.26	Wilson Rd., VAFO
9 Jan 1986	BT (WF)	2.80	Wilson Rd., VAFO
	BT (F)	2.70	Wilson Rd., VAFO

F=fillet, WF=whole fish, WS=white sucker, BT=brown trout, S=stocked
*Church Rd. is upstream of the confluence with Little Valley Creek
**Wilson Rd. is downstream of Little Valley Creek

Note: PCBs are fat soluble and collect in fatty deposits and organs in the fish. Whole fish analysis gives higher levels of PCBs when compared to fillet analysis where only muscle tissue is used.

trout had PCB levels above the FDA' s action level (2.0 ppm) for PCBs in fish for human consumption. Fish in Little Valley Creek had 3.7 ppm and fish in Valley Creek had 2.7 ppm of PCBs. Even if the concentrations were not over the FDA action level, it would be prudent for the park and the PA Fish Commission (PFC) to disallow harvest because the small number of fish sampled each time could theoretically be at the low end of the contamination continuum for fish in the watershed. The PFC had stocked trout in Valley Creek for harvest. Kaufman (1984) suggested that harvesting fish be discontinued because the FDA action level prior to 1984 (6.0 ppm) was too high and the PFC should have recognized 2.0 ppm as a dangerous level years before. Kaufman (1984) added catch-and-release would also be an effective method of informing the public of PCB contamination of wild fish in the stream. Recommendations were made to R. A. Snyder, Chief of the Fisheries Management Section of the PFC, to delete Valley Creek from the catchable trout program in 1985 (Marcinko 1985). The PFC now has Valley Creek under its pollution program which means no fish may be harvested. Since 1984, when the stream was put under no-kill restrictions, the brown trout population has increased in biomass (Marcinko 1988).

PCBs found at the railyard are the more highly chlorinated congeners 1254 and 1260 (54% and 60% chlorine respectively). These compounds are not very volatile or soluble in water and biodegrade slowly in stream sediments. In aquatic environments PCBs concentrate in sediments, where they tend to cling to fine particles (Crump-Weisner et al. 1974 in USEPA, 1980). Because of their low solubility in water, PCBs are not often acutely toxic to fish and invertebrates in static aquatic tests. A fate and transport study would indicate exactly where PCBs go in the Valley Creek food chain.

PCBs are lipophilic, which means they concentrate in fatty tissue. Bioconcentration occurs when PCBs accumulate in the fatty tissues of animals through the food chain from the surrounding water or from contaminated sediments. PCBs often reach high concentrations in animal tissues even though the water in which these organisms live has undetectable levels of the chemical (USEPA 1980). PCBs in sediments are not only ingested by bottom-feeding animals but concentrations in these organisms will increase, by orders of magnitude, in higher levels of the food web. In studies of PCBs in food, contamination by tainted fish is by far the most common (USEPA 1980). The general public is most likely to obtain dietary PCBs from fish living in contaminated streams (USEPA 1980). A wide range of ailments arise from PCB contamination. From studies of accidental poisoning of hundreds of people in Japan, it has been noted that symptoms of PCB contamination mirror those found in laboratory studies of other mammals (USEPA 1980). PCBs are currently classified as a possible human carcinogen.

G. Persistent Pesticides

The following pesticides were found in stream bottom material in Valley Creek at levels ranging from 1 to 9 ppb (ug/kg) (Sloto 1987a). Since they are persistent (resistant to biological or chemical breakdown) they bioaccumulate in the higher predators (as do PCBs). The FDA action levels listed are for concentrations in fish fillets (Federal Register, Vol. 49, No. 100, p. 21514).

Substance	FDA action level
chlordane	0.3 ppm
DDD, DDE, DDT	5.0 ppm
dieldrin	no level set
heptachlor	0.3 ppm
heptachlor epoxide	no level set

H. Chemclene (Malvern TCE)

Chemclene Corporation (currently known as Malvern TCE), located near the intersection of Route 401 and the Phoenixville Pike near the headwaters of Valley Creek, was a disposal site for hazardous wastes. Chemicals, many of which are volatile organic compounds (VOCs), have been found in nearby wells. VOCs, including perchloroethylene (PCE) and trichloroethylene (TCE), could be migrating eastward through the aquifer and entering Valley Creek via the Warner Quarry, where pumping has produced a cone of depression large enough to intercept Chemclene's plume of pollution. It is likely that most of the VOCs evaporate before reaching the creek. The Chemclene site was listed as a Superfund site by the EPA. Hazardous chemicals at the Chemclene site (Koltonuk 1987) include:

Hazardous Waste Number and Substance

U220	Methyl Benzene
U154	Methanol
U002	Acetone
U159	2-Butanone
U031	n-Butyl Alcohol
U112	Ethyl Acetate
K062	Ferrous chloride: liquor generated by steel finishing operations
U019	Benzene
U044	Chloroform
U140	2-methyl-1-propanol
U161	Methyl Isobutylketone
U239	Xylene
U080	Methylene Chloride (MeCL)
U210	Perchloroethylene (PCE)
U226	1,1,1-Trichloroethane
U228	Trichloroethylene (TCE)
F001	Halogenated degreasing solvents: TCE, PCE, MeCl, 1,1,1-T, Carbon Tetrachloride
F002	Halogenated solvents: PCE, MeCl, etc.

Chemclene is in the final stages of cleaning the site. Discussions with DEP of terms for closure of the site have delayed cleanup operations. Under current law, Chemclene is responsible for the waste at its site for 30 years (NPS files).

I. National Rolling Mills (Worthington Steel)

National Rolling Mills (NRM) is a metal processing plant on the banks of Little Valley Creek. It is located near the intersection of Routes 29 and 202 in East Whiteland Township. As early as 1964, it was implicated in adverse effects to the water quality and fauna of Little Valley Creek. On June 20, 1964, Little Valley Creek and Valley Creek were poisoned by cyanide from a spill at NRM. Valley Forge State Park staff and the PA Fish Commission, who investigated the incident, confirmed that almost all aquatic life was eliminated below NRM. Another cyanide spill at NRM on August 31, 1969, had similar effects on the fishery. Strekal (1974) conducted an investigation of Little Valley Creek at stations above and below NRM. There were increases in alkalinity and concentrations of iron, copper and zinc. Pollution sensitive species of insects had disappeared from upstream stations and Strekal (1974) termed stream conditions marginal. A fishkill (PFC #6484) occurred on July 30, 1974 below NRM. NRM and Bishop Tube were listed as possible sources of the spill (Mangialardi 1974). National Rolling Mills settled with the PFC for five-hundred dollars. Sixty trout, 20 suckers, and 1000 minnows were killed (Bednarchik 1974). On April 17, 1979, a third cyanide accident at NRM cause another massive fish kill in Little Valley and Valley creeks.

A study conducted by Knorr (1980) in 1979 showed poor stream conditions and high levels of toxic chemicals including cyanide. Levels of cyanides and fluorides below NRM are believed to be the cause of low diversity and low numbers of individuals in the aquatic communities at two sites. The DEP knew of the high levels of cyanide in the groundwater and was planning action. A conference held in 1980 (Hinkle 1980) recommended the company (NRM) contract a consultant to develop a plan to study (1) groundwater recovery, (2) treatment of this contaminated groundwater, and (3) recharge of treated groundwater back into the ground until it could be discharged into the municipal sewage system in East Whiteland. National Rolling Mills would discuss with the Valley Forge Sewer Authority and East Whiteland Township Municipal Authority the levels of cyanide in water to be discharged into the respective systems (Hinkle 1980).

In 1983, a report issued by Earth Data Incorporated described the progress of the groundwater recovery system instituted by NRM. The report noted an overall decrease of cyanide levels in local wells in the preceding four years. Little Valley Creek had cyanide concentrations low enough to dispel any concern. One conclusion was that the recovery program was successful in decreasing levels of cyanide in bedrock and the overlying weathered zone. The size of the zone of contamination had also decreased and levels were low enough (below 0.2 mg/l) for water to be discharged to the VFSA. Recommendations included continuation of the recovery program, treatment system, disposal of treated water and monitoring of wells to assure progress. Reports to the DEP and other parties were also suggested (Earth Data Incorporated 1983).

Spills of other materials occurred throughout the 1980s at NRM. Prompt action averted contamination of Little Valley Creek as employees of NRM contained an oil spill of 180 gallons (680 l) on January 31, 1983 (Winters 1983a). On April 25 and 26, 1983, approximately 100 gallons (380 l) of kerosene was spilled into Little Valley Creek (Winters

1983b). A broken flange caused the spill of pickle liquor (ferrous chloride), some of which went in Little Valley Creek, on July 30, 1986 (Freda 1986). The acidic mixture lowered the pH from 7.6 to 6.5 for a total of 30 minutes. No fishkill was reported. M. Winters (1986) reported a spill on September 8, 1986, when employees flushed 10-15 gallons of fuel oil into Little Valley Creek. Procedural changes were made to avoid repetition of the incident.

On December 30, 1986, two 30-gallon (114 l) containers of sulfuric acid were dropped and spilled into Little Valley Creek (Sinding 1986). A fishkill occurred as the pH dropped to 3.0 approximately 50 yards (46 m) below the spill. National Rolling Mills agreed to pay $1140 to the Clean Stream Fund for violation of the Clean Streams Law and $1000 to the Pennsylvania Fish Commission for violation of the Fish and Boat Code to avoid litigation (Sinding 1986). A spill of 25-30 gallons (95-114 l) of #2 diesel fuel occurred on February 18, 1988 (van Veen 1988) when an NRM employee left a truck while refueling and the fuel overflowed the tank. Appropriate persons were notified and no serious consequences were reported. Measures were taken to avoid repetition of the incident.

In 1994, NRM agreed to pay $300,000 to the U.S. EPA to settle a civil suit that accused NRM of numerous toxic waste violations.

In a recent survey of wells near NRM cyanide levels were measured (Freda 1988). The results were:

Well	Replicates (ug/l)			
MW-1	<0.03	<0.03	<0.03	<0.03
MW-2	0.07	0.08	0.08	0.08
MW-3	<0.03	<0.03	<0.03	<0.03
MW-4	0.04	0.04	0.04	0.04

These readings are all below the USEPA ambient water quality criteria for human health established by the EPA (USEPA 1986). The criterion of 200 ug/l for water protects humans from drinking water contamination and consumption of contaminated aquatic organisms. The DEP standard (see Appendix B) is not to exceed 0.005 mg/l (5 ug/l) as free cyanide ($HCN + CN^-$). There is no FDA action level for cyanide.

J. Reconstructed Mill Dam

Middle Dam, built in 1930 as a reconstruction of the original mill dam that served the lower forge, limits the potential for brown trout reproduction by eliminating riffles, a preferred spawning habitat, in the lower reaches of Valley Creek inside the park. The deep, slow water behind the dam increases the potential for reproduction of some sunfish species. This is the most "unnatural" section of the stream. The dam also blocks migration of such species as American eels and white suckers. Each spring hundreds of large brown trout (some specimens have measured greater than 24 inches) from the Schuylkill River gather in the area around the Route 23 bridge. They appear to be trying to swim upstream as they attempt to jump over the eight foot dam. Since 1994, park staff with the approval of the PA Fish Commission have opened the dam's spillway for one week during the brown trout migration in June in order to allow fish to bypass the dam and continue moving upstream. It is thought that these "river" trout move into the cooler waters of Valley Creek when the water temperature in the Schuylkill River increases in the early summer.

For cultural resource management reasons, there are no plans to remove the dam. Structural weaknesses were identified in the last two inspections by NPS engineers. If the dam is not repaired, it will crumble and breach itself. In 1994, a large piece of the dam breast fell into the creek.

K. State Route 252

Another disturbed area of Valley Creek is the stretch that flows parallel to Route 252 and the hiking path from the covered bridge to the footbridge. This section, which is shallow with no meanders, probably was straightened in the 1920s when Route 252 was upgraded from a narrow, dirt road to a wider, asphalt road. It may also have been dredged later during archaeological investigations at the upper forge site. A stream naturally meanders and cuts into banks making deeper runs and pools. When a stream is dredged and straightened it no longer meanders and water flows more uniformly. Streams that are dredged usually are widened in the process and become shallower.

Valley Creek is severely constrained by a popular hiking trail along its west bank and by state Route 252, a major commuter corridor, on its east bank. VAFO has decided the hiking path will remain and the Commonwealth of Pennsylvania has no intention of removing Route 252. A 30 inch diameter concrete force sewer main, which carries 8 million gallons/day of raw sewage from two upstream townships to the Valley Forge Sewer Authority treatment plant in Phoenixville, runs under the road. Unless Route 252, the sewer line, and the trail can be relocated, compromises have to be made when considering management actions for the creek.

L. Sewage and Coliform Contamination

Sewer installations in the 1970s lowered organic enrichment and bacterial levels (Heister 1979). Sewage treatment did not extend to the upper reaches of the watershed and there have been problems in this area with small sewage treatment plants (Knorr 1985). Package sewage treatment plants are operated by Great Valley High School, Malvern Trailer Courts, Inc., Immaculata College and Camilla Hall of Immaculata. The largest of these is Immaculata College, which recently obtained an NPDES permit to discharge 98,000 gallons/day of secondary-treated sewage into Valley Creek. The only package plant in noncompliance with its NPDES permit is Immaculata College but this will change within the next five years with construction of a new treatment facility.

There are a total of 24 on-lot disposal systems in the Valley Forge and Malvern USGS quadrangles, which encompass all of the Valley Creek drainage. An on-lot system is one that does not connect to a large sewage system but treats waste close to the source, including septic systems, aerobic tanks, seepage bed, drainfields, aerated lagoon, leach fields, spray irrigation, cesspools and tile fields. A force main for the Valley Forge Sewer Authority which follows the Valley Creek streambed along its entire length inside VAFO is not considered a factor in any existing water quality problems. Coliform sources have been identified in pasture environments. Horses that graze along Valley Creek in the park and on private property upstream are a potential source of coliforms. Kunkle (1987) suggests that a 100-foot vegetated riparian buffer zone be maintained to filter bacteria and viruses from stormwater runoff before it enters the stream.

High coliform counts, in conjunction with high levels of nitrogen, phosphorus and chlorine, are indicative of sewage input. Chlorine is part of the sewage disinfection process while nitrogen and phosphorus are nutrients which remain from insufficient treatment.

Coliforms are not intrinsically dangerous, but high levels indicate that raw sewage may be in the water suggesting the presence of dangerous pathogens and a human health hazard.

M. Erosion and Sedimentation

Past and current land use practices throughout the watershed, including management of VAFO, have caused erosion and sedimentation problems along Valley Creek. One of the biggest problems is the height and instability of streambanks inside the park. Industrialization in the stream corridor during the 19th century probably contributed to this situation. In 1830, a large mill dam was constructed just upstream of the present location of the Route 23 bridge. Sediments that accumulated behind this dam are now the unconsolidated, highly-erodible streambanks along Valley Creek, which stretch approximately one mile upstream to the covered bridge (Reed 1990).

Streambank destabilization has accelerated recently due to inadequate stormwater management in the Valley Creek watershed. Impervious surfaces, destruction of wetlands, encroachment into vegetated riparian buffer zones and the process of urbanization have increased the height and duration of peak flows. Route 252 and the Valley Creek hiking trail, which are next to the creek, are in danger of being eroded in a severe storm. In 1990, a large retaining wall protecting the road collapsed into the creek. In 1993, fifty feet of the hiking trail washed away. Valley Creek is adjusting to changes in its watershed. In order to transport increased stormwater flow, the creek is enlarging its conveyance area by cutting downward and widening its channel. The frequency and magnitude of peak flows and the accelerated nature of these events is documented in data recorded at the USGS stream gage station (ID#1473169) installed in 1982 on Valley Creek just upstream of the park boundary at the PA Turnpike. Between 1983 and 1994, 28 peak flows in excess of bankfull (665 cfs) were recorded at the stream gage. It is generally agreed that bankfull flood events determine stream channel morphology and occur about once every two years in a stable stream corridor (Reed 1990). Thus, because of inadequate stormwater management, Valley Creek is conveying approximately five times the number of floods than would occur under stable conditions.

The concentration of suspended sediment in streams is influenced by such factors as topography, geology, soil condition, intensity and duration of rainfall, and the amount and type of vegetation in the drainage basin. Levels of suspended solids may vary quite dramatically. Most flowing waters show considerable variation in the amount of suspended solids transported from day to day and year to year. Substantial variation in the level of suspended solids in different sections of a stream may occur when material carried as bed load is thrown into suspension at a narrows or falls where the velocity increases.

Most aquatic organisms have adequate means of protection against the mechanical effects of fairly high temporary concentrations of suspended solids, as long as their action is not complicated by other pollutants. Fish and other aquatic organisms continuously secrete mucus (Cole 1935) or increase their ventilation rates (Horkel and Pearson 1976) to carry away particulate matter from the gills. If the mucus barrier remains operative, water containing pulps, sawdust and other suspended solids will cause little or no mechanical injury to the gills (Cole 1935); however, there will be an energy drain. A combination of suspended solids, acids, chemical wastes, or other substances will increase the abrasive action on the gills or mat the gills with deposits which, under more favorable condition, would have been washed away by mucus (Marsson 1911).

Ecological effects of suspended solids include: (1) mechanical or abrasive action; (2) blanketing action of sedimentation; (3) reduction of light penetration; (4) availability as a surface for growth of bacteria, fungi, etc.; (5) adsorption and/or absorption of chemicals and (6) reduction of temperature fluctuations (Cairns 1968). Biologists generally agree that any of the above deleterious consequences can occur if large quantities of suspended solids are introduced into an aquatic system. However, as Hoak (1957) summarized, there is a lack of agreement as to the amount of particulate matter that can be assimilated, either in suspension or bottom accumulation, before threshold values are reached for biota. Further investigation is expected to indicate that various fishes can tolerate a wide range of concentrations of suspended solids. Cairns (1968) reported 29 fish species existed with no evidence of gill clogging or other damage in a reach of the Kansas River in 1958 when turbidity measurements exceeded 72,000 mg/l.

Wallen (1951) found that 16 fish species did not react to elevated turbidity levels until 20,000 mg/l and that one species showed no reaction until levels reached 100,000 mg/l. Most individuals tested tolerated exposures more than 100,000 mg/l of turbidity for a week or longer, but succumbed at turbidity measurements of 175,000 to 225,000 mg/l. Wallen (1951) found no evidence of gill injury even though the gills were blanketed with a layer of silt and the opercular cavities were matted with the material. All organs appeared normal. Arteries and veins were not congested and no unusual amount of mucus was secreted by the gills.

Ellis (1927) also examined fishes whose gills were coated with sediment. His description of the coating responsible for death agrees with that observed by Wallen (1951). Ellis (1927) pointed out that healthy and uninjured fish can move through very muddy water since the continuous secretion of mucus washes away the sediment particles. However, when toxic chemicals injure the gills or alter the flow of mucus, the addition of suspended silt may aggravate gill damage through increased abrasive or matting action.

In contrast to Wallen's (1951) work, other biologists concluded that turbidity concentrations had deleterious effects on fishes. Kemp (1949) attributed gill damage to various fish species at turbidity measurements up to 3,000 mg/l. As an example, he cited a flood in 1936 which created a turbidity of 6,000 mg/l in the Potomac River and lasted 15 days. The fish kill was large. Others supporting the thesis of comparatively low level turbidity measurements (100-6,000 mg/l) as limiting to fish populations are Scheberger and Jewell (1928), Ellis (1940), Doan (1942), and Munns (1948).

In summary, little sound experimental data exist and many authorities disagree on the tolerance limits of freshwater fishes to high concentrations of suspended solids. However, it is apparent that fish encounter, tolerate, and perpetuate in waters where natural man-made influences result in high turbidity measurements. As Gammon (1970) surmises "It seems fairly clear...that while eggs and fry may be quite susceptible to the direct action of suspended sediment, fingerlings and adults are quite resistant and are capable of enduring temporary periods of high concentrations of suspended solids."

Although the effects of suspended solids may be questioned, investigators have established that settleable solids, even at moderate levels, do have a negative impact on fish.

Sediment transport in stream channels can scour and fill the bed, thereby removing or burying fish embyros (Coats 1985, Lisle 1989). Fine sediment can infiltrate redds and plug spaces between gravel, thereby reducing intergravel flow of oxygenated water, impairing respiration by embryos (Cordone 1961, Everest 1987), and preventing the emergence of hatched fry from the gravel (Koski 1966). Siltation also adversely affects benthic invertebrates, lowering both number of species and individuals (Tebo 1955, Lemly 1982).

VI. Indicators and Standards of Resource Conditions

A. Water Resources

Valley Creek should meet or exceed DEP water quality standards for a cold water fishery (Appendix B) and EPA mandated water quality criteria (EPA 440/5-86-001). EPA standards are based on data from species toxicity testing and are meant to protect 95% of all aquatic life. A range of organisms is tested, including algae, protozoans and trout. Harmful effects include adverse impacts on survival, reproduction or growth. Acute toxicity levels cause immediate adverse effects to organisms. Chronic toxicity levels indicate that exposure at these levels causes harm over the lifespan of the organism. Health criteria are set to avoid risks to humans. When the suggested criterion is zero, EPA estimates the risk of contracting cancer associated with lifelong exposure of various concentrations of the contaminant. DEP has incorporated EPA's water quality criteria into the Pennsylvania Code through chapters 16 and 93 of Title 25.

B. Biological Resources

Assessment of ecosystems has evolved from the presentation of flora and fauna lists to a series of classification schemes including: species-area curves (Gleason 1922), diversity indices (Shannon and Weaver 1949, Margalef 1958, Wilhm and Dorris 1968, Cairns 1977, among others), autotrophic-heterotrophic ratios (Weber 1973), saprobian designations (Bick 1958, Cairns 1977), and biotic indices (Weber 1973, Karr et al. 1986, Ohio EPA 1987). Many of these studies were initiated to determine the effects of organic pollution. Lotic (stream) habitats have also been classified on the basis of calcium content (Ohle 1937), distribution of fauna (Smith 1971, Thompson and Hunt 1930), water zones (Illies 1961), gradient (Trautman 1942), and stream order (Kuhne 1962). However, Platts (1974) suggested that these classification systems had limited value to the management of land and water systems. A more useful technique centers on variables which predict the amount of stress a particular system can assimilate and the potential of a system to recover once a structural or functional change of the biota occurs. The concepts of inertia and elasticity (Cairns and Dickson 1977) have great potential for use in a water resource classification system as well as strong management implications. Stauffer et al. (1978) and Stauffer and Hocutt (1980) used existing information on the aquatic fauna to evaluate the inertia and elasticity of two lotic systems.

1. Calculation of Inertia Indices

Cairns and Dickson (1977) defined inertia as the capacity of a stream to withstand a particular stress without eliciting a structural or functional change, and stated that the inertia of a system is based on the following parameters: (1) whether or not the indigenous organisms are accustomed to highly variable environmental conditions; (2) the structural and functional redundancy of the stream; (3) qualities such as stream order, flow dependability and flushing capacity; (4) the presence of well-buffered water antagonistic to toxic substances; (5) proximity of the system to a major ecological transitional threshold; and (6) the presence of a drainage basin management group with a water quality monitoring program.

An estimate of the value of parameter 1 would have to be made based on a comparison of variables such as flow, temperature, dissolved oxygen and pH of Valley Creek with other neighboring lotic systems. With a rating system of one to three, a one might be used to rate an ocean system, a two for a freshwater lake, and a three for an estuarine system. A freshwater lake is subject to more variable environmental conditions than an ocean, but subject to less variable environmental conditions than an estuary, whose organisms are subjected to freshwater, saline water, and dry conditions within a 24-hour period. A similar type of analysis would have to be made for the Valley Creek watershed compared to neighboring watersheds.

Parameter 2 is an evaluation of the structural and functional redundancy of the system. Inertia is defined as the ability of a system to withstand a stress without eliciting a structural or functional change. Greater redundancy in structure implies a decreased likelihood that stress will create a measurable shift. Structural redundancy could be estimated by evaluating the number of species present in a particular genus or the number of genera in a particular family.

Life history information on the aquatic fauna must be accumulated in order to calculate functional redundancy based on characteristics such as the amount of overlap in trophic-level interactions, habitat occupied and spawning sites utilized. These data must also be compared to data from neighboring lotic systems.

Values for parameters 3 and 4 have to be assigned after a comparison of flow data, flushing capacity and buffering capacity of the Valley Creek basin.

Parameter 5 can be assigned only after the use and purpose of the watershed is determined by park personnel. For example, if it is a goal of the park to maintain the stream as a trout fishery, then a low value for this parameter must be assigned. Summer water temperatures sometimes approach the lethal threshold for brown trout and the stream has to be considered close to a major ecological transitional threshold. If the goal is not to maintain the stream as a trout fishery, since brown trout are not native to the watershed, than a high value could be assigned to this category.

Parameter 6 must also be assigned after management decisions are made by the park. If the park is to initiate a monitoring program either by itself or in conjunction with a group such as Trout Unlimited, a high value could be assigned to this parameter.

2. Calculation of Elasticity Indices

Cairns and Dickson (1977) define elasticity of a system as the capacity of a system to recover after a structural or functional displacement has occurred. Parameters important in the development of an elasticity index are: (1) existence of nearby epicenters for providing organisms to reinvade a damaged ecosystem; (2) mobility of any dispersal stages of the organisms present; (3) condition of habitat following the stress; (4) presence of residual toxicants; (5) chemical-physical environmental quality after pollution stress; and (6) management or organizational capabilities for immediate control of the damaged area.

Parameter 1 is a measure of nearby epicenters from which colonization occurs when a system is stressed. For fish, the Schuylkill River is the only epicenter from which recolonization of Valley Creek can occur. Other watersheds in the vicinity of Valley Creek can act as epicenters for most aquatic invertebrates since the majority of these forms have aerial stages.

Values of parameter 2 also depend upon whether aquatic vertebrates or invertebrates are being classified. Life history information has to be gathered for the dominant species present. For example, certain fishes, such as suckers (Catostomidae), migrate into streams to spawn, while others, such as darters (Percidae), are relatively sedentary.

A regular monitoring system would have to be established to determine both the condition of the habitat following the stress (parameter 3), the presence of residual toxicants (parameter 4), and the chemical-physical environmental quality after pollution stress (parameter 5). These three parameters can be grouped for the purposes of a management strategy.

The values for parameter 6 would have to be assigned depending on the commitment that the park makes to a monitoring program and/or the cooperation of various interest groups such as Trout Unlimited.

The concept of inertia and elasticity as conceived by Cairns and Dickson (1977) can be used to formulate a stream classification system to predict the amount of stress a particular system can assimilate and the potential for system recovery if the assimilative capacity is exceeded. The main emphasis is monitoring of biota in the system. While certain physical and chemical data are needed, biological sampling may be the only method which will detect ecosystem change. Once a change in the ecosystem has been detected, intensive chemical monitoring can be initiated to determine the source of the stress.

There is some debate as to whether fishes or macroinvertebrates should be used to monitor the biological community. Some investigators suggest that macroinvertebrates are more sensitive to pollutants at stages of their life cycles than fishes, and that they are more sedentary than fishes. Several factors would suggest fishes as the better indicator. They occupy the top of the food chain in most stream systems, and as such their presence implies the presence of many other phyletic groups. Throughout their development from larvae through adult they pass through most, if not all, trophic levels above the primary producer stage. Taxonomically, fishes have been well studied, so accurate identifications can be made easily and quickly without the aid of sophisticated equipment and there is generally more information available on their life history than for other groups.

VII. Comparison of Standards and Existing Resource Status

A. Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) may be the most dangerous pollutant in Valley Creek. PCBs have reached unhealthy levels in fish and have contaminated stream sediments. DDE, DDD, DDT, dieldrin, and chlordane (pesticides or pesticide by-products) also have been found in sediments of Valley Creek (Sloto 1987a). Other chemicals reach harmful levels only when a spill occurs.

Because PCBs are a known health hazard, EPA has set water quality criteria for aquatic wildlife and humans. For protection of freshwater aquatic life, EPA recommends that concentrations in surface waters not exceed 0.014 ppb (ug/l) as a 24-hr average and further states that acute toxicity will occur at levels of 2 ppb. To protect humans from contamination from the carcinogenic effects of exposure to PCBs from drinking water or animal consumption, EPA recommends that ambient water concentrations be zero (USEPA 1986). There are no criteria set for PCB levels in sediments.

Since zero levels are generally unattainable, the Food and Drug Administration (FDA) sets action levels for toxic substances in human and animal foods. These tolerances are based on the unavoidability of the presence of the poisonous substance in the food and are not intended to allow contamination where it is avoidable. Levels set are those at which the FDA will take legal action to remove a given adulterated product from the market. The FDA action level for PCBs in fish fillets was lowered in 1984 to 2.0 ppm (Federal Register, Vol. 49, No. 100, p. 21514).

B. Metals and Anions

Results of limited chemical testing listed in Appendix F do not indicate high levels of any of the tested variables. Nitrate concentrations are well below DEP limits of 10 mg/l. Copper (Cu) and manganese (Mn) are many times lower than DEP standards. DEP standards for lead (Pb) and nickel (Ni) both involve testing for specific organisms or site-specific bioassays. In contrast to DEP standards, EPA lists levels for protection of all aquatic life. For both lead and nickel, these criteria are relative to the hardness of the water tested. Data obtained since 1981 indicate that a mean hardness for Valley Creek is 250 mg/l $CaCO_3$ (Appendix H). Incorporating this value into the EPA criteria formulas for lead and nickel gives the appropriate standards. For nickel the acute value is 3.7 mg/l and chronic value is 0.19 mg/l. The acute value for lead is 0.262 mg/l and chronic value is 0.01 mg/l. Human health criteria for nickel and lead are 0.0134 and 0.050 mg/l, respectively, identical to drinking water standards. Neither lead nor nickel tested above 0.005 mg/l so both are within EPA limits.

Many heavy metals were analyzed by the CCHD (Appendix H). Iron (Fe) should not exceed 1.5 mg/l total and Valley Creek does not exceed this value. Values are also below the EPA criterion for protection of aquatic life, which is 1.0 mg/l. The DEP criterion for manganese (Mn) is 1.0 mg/l and no values approach this level. Most are below 0.05 mg/l. There is no standard for sodium (Na). The zinc (Zn) standard set by DEP includes a bioassay (Appendix B). EPA states that zinc levels should not reach 0.700 mg/l at any time or go above 0.047 mg/l as a 24-hour average (at a hardness of 250). All measured values are below the detection limit of 0.02 mg/l. DEP has set no standard for cadmium. EPA states that aquatic life would not be affected if acute levels are below 0.0039 mg/l and chronic values are below 0.0011 mg/l. Cadmium data reported by CCHD is difficult to interpret due to inadequate precision of methodology.

Heister (1979) attempted to demonstrate the effects of Knickerbocker Sanitary Landfill on Valley Creek (Table 8) by analyzing the water chemistry of the creek and nearby groundwater above and below the landfill. Manganese levels were higher below the landfill but remained less than the standard of 1.0 mg/l set by DEP. The concentration of nickel (0.026 mg/l) below the landfill is below the EPA suggested maximum 24-hour average of 0.19 mg/l. Copper and iron levels are both orders of magnitude below their standards. Heister (1979) measured mercury in the water but the EPA suggests mercury be monitored via the FDA action level (1.0 ppm) in fishes (USEPA 1986). Since mercury bioaccumulates, the best test is on harvested fish. The increase in conductance is probably due to ions entering from the landfill. These tests were completed ten years ago and may not reflect current conditions.

C. Ammonia

Ammonia as unionized ammonia (NH_3) has been found to be toxic to fishes and other aquatic life. It is more toxic than the ionized form (NH_4^+). The equilibrium of these two chemicals is dependent on water temperature and pH. DEP standards use these two variables to predict this equilibrium. Ammonia standards can be set according to the known pH and temperature extremes. In Valley Creek the pH ranges from 7.0 to 8.5 and temperature ranges from 0°C to 25°C. DEP standards using these four values were calculated (Appendix B). EPA has set criteria for total ammonia and unionized ammonia to protect aquatic organisms and their uses (Appendix B). One hour averages are to protect against acute effects and 4-day averages are to protect against chronic effects. Aquatic organisms are considered protected if the criteria are not exceeded more than once every three years. The three year time period is the best estimate for recovery time for an unstressed ecosystem (USEPA 1986).

At the time of the collection of ammonia samples (Appendix F), the pH in Valley Creek approached 8.5 and the temperature was near 25°C at many sites, corresponding to the worst-case scenario for ammonia concentration. The value for total ammonia recorded at station 6 (0.220 mg/l) exceeds the DEP thirty day average of 0.16 mg/l (Tables 7, 8). This value also approaches the EPA 4-day average of 0.23 mg/l (Appendix B). Although no values exceed the maximum level for acute effects, there may still be reason for concern. While high short-term concentrations can cause fishkills (acute effects), long-term concentrations above the chronic toxicity level indicate that the entire system may incur serious damage.

D. Other Chemical and Physical Measurements

As Valley Creek is a limestone stream, pH is usually high--around 8.0. CCHD has collected extensive water quality data for Valley Creek (Appendix H). A comparison of these values with DEP and EPA standards shows that pH is variable, but is consistently between the DEP standard of 6.0 and 9.0; pH fluctuation depends on the ratio of rainwater to groundwater. Dissolved oxygen levels are above the DEP minimum standard of 6 mg/l. If low dissolved oxygen levels were a limiting factor, trout would be less abundant. Total dissolved solids are regulated monthly at a mean concentration of 500 mg/l, while 750 mg/l is the instantaneous limit. Since the values in Appendix H are instantaneous measurements, we can compare them to the acute standard of 750 mg/l and most are below the standard by as much as 300 mg/l. Hardness and alkalinity are not regulated because they are dependent on natural conditions in a system. The high levels in Valley Creek are usually associated with a productive biological community.

Turbidity in Valley Creek is low, in the 1-2 NTU (Nephelometer Turbidity Unit) range, except during rainstorms when it often is above 100 NTUs. High turbidity most likely results from inadequate stormwater management and deficient erosion and sediment control structures. There is no standard for turbidity for Valley Creek, but in order to protect aquatic life, DEP recommends that turbidity not exceed 100 NTU at any time (25 PA Code 93.7).

E. Bacteria

Since construction of a regional sewer system in the mid-1970s, coliform levels in Valley Creek have decreased to the point where most sections of the stream are clean enough for water contact sports. In September, 1992, the fecal coliform count at three sample stations in Valley Creek, as reported by the Chester County Health Dept (CCHD), was 160, 365, and 145 colonies per 100ml with an average of 223. The DEP standard for water contact sports is a five-day geometric mean of 200 colonies per 100ml during the swimming season from May 1 to September 30. Significant threats to water quality from sewage pollution still occur. On August 21, 1987, an analysis for fecal coliform by CCHD of water samples taken by Penn State staff had a range of 9,000 to 40,000 per 100ml (Appendix G) and water samples collected by Heister (1986) and analyzed by CCHD had fecal coliform counts as high as 10,250.

F. Measurements of Biota

Valley Creek has fewer species of fish than other streams in the area. Stations 10 through 14 (Pickering Creek, French Creek, East Branch of Perkiomen Creek, Swamp Creek, and Ridge Valley Creek, respectively) have at least twice the number of species as Valley Creek stations (Appendix J). This could be related to the various fishkills in Valley Creek and the inability of the fishes to reestablish populations. Some of the more common species in the area, such as *Exoglossum maxillingua* (cutlips minnow), *Luxilus cornutus* (common shiner), *Notropis hudsonius* (spottail shiner), and *Ambloplites rupestris* (rock bass), which would be expected throughout the Valley Creek drainage, were collected in only a few locations. The macroinvertebrate populations are also less diverse than nearby streams, indicating a stressed system, although no specific stress is indicated.

G. Summary

Although Valley Creek is located in an urbanized environment, not only has it survived as an important natural and recreational resource but stream conditions have actually improved. The watershed contains Superfund sites, sewage package plants, industry, commercial office complexes, regional transportation corridors and residential areas. Despite these pressures, Valley Creek's water quality is good and its fishery is outstanding. Physical and chemical parameters as measured by DEP, PFC, CCHD, and VAFO are better than or equal to the state's water quality criteria for a cold water fishery with the exception of PCB contamination of fish and sediments. PCB concentration in fish fillets exceeds the FDA action level of 2.0 ppm. Occasionally, other pollutants such as fecal coliform exceed state standards for short periods. Accidental spills of industrial chemicals remain a possibility. If groundwater is depleted so that lower flow levels occur in the creek, then some pollutants, near toxic levels now, may reach those levels.

VIII. VAFO Valley Creek Management Alternatives

Water Quantity

A. Problem Statement and Background

Valley Creek is threatened by a decrease in base flow related to urbanization or development of the land. Interbasin transfer, quarry use, pumping of high-capacity wells and the growth of impervious areas contribute to this decrease. Sloto fully documents these effects on Valley Creek in a USGS report: "Effect of Urbanization on the Water Resources of Eastern Chester County, PA" (1987a). As stream flows decrease, the habitat quality degrades and pollutants become more concentrated.

B. Current Management Actions

NPS issues and actions related to water quantity are outlined in VAFO's Resource Management Plan Project Statement N-007.012. Staff and funding shortages have restricted the park's monitoring and mitigating activities to a limited review of data available from other public agencies and to a small public relations effort targeting local municipalities, regulatory agencies and environmental groups. The USGS maintains an automatic stream gauging station in Valley Creek just upstream from the park and shares discharge data with VAFO. USGS also has studied groundwater flow in the watershed and provided reports to the park. Other sources of information, such as the Chester County Water Authority, Valley Forge Sewer Authority, Chester County Planning Commission and Delaware River Basin Commission remain untapped by VAFO. Park staff are becoming involved in planning for proposed land development in the watershed and in the NPDES permitting process. Regular contacts with DEP, municipal governments, the Chester County Planning Commission and the

Chester County Conservation District and attendance at public hearings have enabled VAFO to express opinions on groundwater depletion. VAFO is committed to continued participation in a consortium of private environmental groups in order to increase the Park Service's ability to influence public policy for protection and conservation of water supplies in the Valley Creek watershed.

C. Alternative Actions and Probable Effects

1. Continue Current Action: The effects of current actions are difficult to predict as development continues in the Valley Creek watershed. Loss of water is directly tied to land development and inadequate management of water resources beyond park boundaries over which NPS has no direct control. VAFO should continue to campaign for wise stewardship of resources. It is worthwhile for the park to insist on protection of wetlands, establishment of riparian buffer zones, preservation of open land through zoning ordinances, creation of steep slope ordinances and land application of sewage effluent.

2. Fund scientific study: The NPS can be instrumental, through its own monitoring program or through funding of scientific research, in collecting data necessary to examine claims of environmental harm to Valley Creek and the surrounding area due to base flow decreases.

D. Recommended Actions

The recommended action for park management is to remain involved in the planning process by working closely with environmental groups, municipal governments, and regulatory agencies (Alternative 1), to continue its own monitoring program (Alternative 2), and to seek funds for scientific studies (Alternative 2).

Water Quality

A. Problem Statement and Background

Valley Creek has several water quality problems including high levels of sedimentation, sewage pollution from Immaculata College, groundwater contamination, toxic chemical spills and possible toxic leachate from sites such as the Knickerbocker Sanitary Landfill and Chemclene Corporation. PCB contamination at the Paoli Railyards will be addressed separately. Most of these parameters are being monitored by other agencies. Stormwater transports large amounts of sediment into Valley Creek from construction sites, dirt roads, destabilized streambanks and poorly managed open land. Most of Valley Creek's problems arise because it is surrounded by an expanding industrial, commercial, and residential community.

B. Current Management Actions

VAFO operates a small, part-time water resources laboratory. Water samples, collected seasonally at seven locations inside and upstream of the park, are analyzed for a few basic physical and chemical parameters. The park has arranged to share water quality data with USGS, which samples Little Valley Creek and Valley Creek at least once each year at Mill Road, and with CCHD, which samples Valley Creek seasonally at the Route 23 bridge inside VAFO and measures many water quality variables. Appendix H lists these variables and sampling locations. When a significant change is noticed in the parameters monitored at any of these sample stations, DEP is notified.

Since many water quality problems arise from industrial and residential development in the Chester Valley, the park has established a community relations program with local municipalities, regulatory agencies and environmental groups. The program's purpose is to protect park resources by collecting data on land use in the watershed and by informing park neighbors about our concerns and problems with respect to water resources. Major threats to Valley Creek's water quality are already being monitored by other agencies. EPA is involved with three Superfund sites in the watershed: Chemclene Corporation, the Paoli Railyard and Foot Mineral. DEP monitors Immaculata College, National Rolling Mills and the Knickerbocker Landfill. VAFO has obtained water quality data from these agencies. NPS funded a study of adjacent land use which examined how municipalities which surround VAFO manage the use and development of land resources (McBride 1995).

C. Alternative Actions and Probable Effects

1. Continue Current Actions: The community relations program has put VAFO in touch with local planning processes and has enabled the park to promote its concerns in surrounding communities. Cooperative efforts with environmental groups have resulted in mitigating some water quality problems with potential adverse effects on park resources. Contact with regulatory agencies has enabled the park to access water quality information at those sources. The adjacent land use study provides park staff with supporting data for discussions with neighboring municipalities regarding zoning ordinances, comprehensive plans and other management issues. The water resources lab produces data which can be used to monitor long term trends in the water quality of Valley Creek at a reasonable cost. The scope of the lab data is limited since it is compiled through a series of "snapshots", which capture the condition of the creek in instantaneous measurements taken seasonally at best. Also, the park lab does not follow EPA protocols in its analytical methods.

2. Institute an extensive chemical/physical testing program: The park could initiate a wide ranging chemical analysis of Valley Creek waters (the type of data as shown in Appendix H). The park would arrange for extensive chemical and physical testing of water samples either by its own employees or by outside contract. Park personnel or consultants could evaluate data and monitor trends in water quality. This option would be expensive and duplicate some tests already being performed by other agencies. Testing would cost at least $1000 per sample station. Quarterly sampling at eight stations would cost more than $30,000 per year without a guaranteed management benefit.

Even with extensive testing, pollution may go undetected. This type of testing program is designed to detect a continuous point source discharge, and is unlikely to detect a short-term (pulse) pollution event.

3. Manage a limited chemical/physical water sampling program:

Phase I: VAFO's current water resources laboratory and sampling methodology can be upgraded so that a more effective and more sophisticated, but still limited and low-cost, water sampling program is implemented. Coliform testing would be conducted in accordance with DEP procedures, compelling DEP action if levels exceed DEP limits. (The Chester County Health Department may provide free laboratory service as they did for this study). The park could monitor pH, dissolved oxygen and conductivity. Conductivity often correlates with total dissolved solids and levels of major cations, which can indicate changes in some pollutants. Examples are road salts, nitrates and phosphates in manure and sewage, and heavy metals. Conductivity differences can also help pinpoint the source of these pollutants by comparison of differences between stations. Changes in pH can also be used as an index of water quality, frequently correlating with nitrate, sulfate and chloride measurements and indicating acid spills. Quarterly sampling at the Valley Creek locations listed in Appendix E is recommended.

Phase II: If a significant change in pH, dissolved oxygen, or conductivity is detected, which would indicate a shift in the ionic composition of the water, further testing for the following chemicals would be conducted. These chemicals have either state standards (Appendix B) or EPA criteria (Section VI of this report).

Parameter	Rationale for Testing
cyanide	History of spills from National Rolling Mills
iron lead copper	These three chemicals are listed as detected in at least 75% of samples in National Urban Runoff Program, NURP (Kunkle et al. 1987)
chromium arsenic	These chemical are listed as detected in at 50% of samples in NURP (Kunkle et al. 1987)
chloride ammonia-nitrogen* nitrate-nitrogen	These chemicals are indicators of sewage

* note: When sampling for ammonia, pH and temperature must be recorded at each collection site.

These analyses can be done at a DEP-certified laboratory. Kunkle et al. (1987) have suggestions specifically for park personnel regarding sample collections and choosing proper laboratory facilities.

Phase III: Should a fishkill occur, those variables listed above would be immediately investigated in addition to:

-dissolved oxygen
-temperature (should always be measured since rapid changes can cause fishkills)
-pH

The selection of sample sites is critical for generation of meaningful data. Stations 1 through 8 (Appendix E) could be tested to obtain routine management information. When a pollution event occurs as detected by a specific indicator, such as a fishkill, park personnel would select additional sites that would encompass all potential pollution sources.

Elevated stream flows effect sampling results by diluting toxicants in the stream. A pH or conductivity reading taken on a day of high flow might be skewed toward the values of the precipitation and away from the ambient values of the stream. Any effect of dilution on the monitoring program can be avoided by taking regular samples of pH, conductivity, and dissolved oxygen during periods of normal flow. Flow conditions can be determined visually by an employee familiar with normal Valley Creek water levels.

4. Calculate inertia and elasticity indices: Inertia and elasticity indices are calculated as described in Section VI for the Valley Creek watershed. The resulting index will provide a baseline to which indices in subsequent years can be compared. We suggest that an inertia and elasticity index be calculated for a similar-sized stream within the drainage basin that is considered "pristine" either by the Pennsylvania DEP, Trout Unlimited, or the PFC. This provides reference numbers to which the values obtained for Valley Creek can be compared. A management decision may then be made to try to improve the quality of Valley Creek to within some range of these indices. Two or three evaluation periods are required to determine natural variances. Once this baseline is established, annual values calculated for Valley Creek could be compared to these indices. This is a relatively expensive protocol , estimated to cost $20,000/year for the first two years and $4000-5000/yr for subsequent years.

5. Develop a biological monitoring program using the Sequential Comparison Index: This monitoring scheme involves the use of VAFO personnel and is relatively inexpensive. A biological monitoring program would employ the Sequential Comparison Index for macroinvertebrates developed by Cairns et al. (1968) to monitor the health of biological communities. The Sequential Comparison Index is based on observations that a healthy system has higher faunal diversity than a disturbed one. This procedure has been described in Buikema et al. (1980) which is located in Appendix R. After establishing a seasonal baseline, a decline in number of individuals or taxa might indicate a decline in biological health. Comparisons are only made between collections done at the same time of the year to take into account seasonal variations within a population. This method provides VAFO with an in-house procedure for assessing the biological health of the waterway. The macroinvertebrates could be collected by park personnel quarterly at stations 1 through 8 described in Appendix E using the collection techniques described in Section V. B. 1.

6. Develop a biological monitoring program using outside consultants to monitor the biological community: In this method consultants would identify the macroinvertebrates and fishes collected by park personnel in the manner described in Alternative 5. For each collection, total numbers and number of taxa are computed. The methods outlined in this report in Section V. B. 1. could be followed. A decline in number of individuals or taxa compared to a seasonal baseline may indicate a decline in biological health. Data generated by this method differs from that of alternative 4. Simple species lists and diversity indices would be obtained, but no in-depth analysis of structural and functional redundancies would be conducted.

D. Recommended Actions

The recommended management actions are: (1) use a chemical/ physical testing and monitoring program as described in Alternative 3; (2) implement the Sequential Comparison Index biological monitoring approach discussed in Alternative 5; and (3) promote good community relations as outlined in Alternative 1.

There are various reasons why biological monitoring is suggested. As Cairns (1968) stated, "physical and chemical parameters...give the conditions existing only at the time of the test, whereas biological parameters represent a summation of the past and present environmental circumstances." Since the purpose of water quality testing is to protect the biological community, the park should monitor its health.

PCB Contamination

A. Problem Statement and Background

Polychlorinated biphenyls (PCBs), persistent chlorinated hydrocarbons that were once used in railroad transformers at the Paoli Railyards, have infiltrated the Valley Creek system. Soil in the immediate area is contaminated with PCBs and is transported off-site by stormwater into Little Valley Creek which flows into Valley Creek. PCBs are expected to remain in Valley Creek for many years due to stream sediment contamination. Most data describe high levels of PCBs only in terms associated with human contact in an occupational environment (Idler 1986, Safe 1988). Safe (1988) indicates that the general public is not at risk to environmental uptake of PCBs from stream sediments. Outside an occupational setting, the most likely source of human exposure to PCBs is consumption of contaminated fish. PCB levels in fish in Valley Creek have exceeded FDA standards and cannot be eaten. A wide range of ailments arise from PCB contamination. From studies of accidental poisoning of hundreds of people in Japan, it has been noted that many symptoms of PCB contamination mirror those found in laboratory studies of other mammals (USEPA 1980). PCBs are currently classified as a possible human carcinogen.

B. Current Management Actions

VAFO currently enforces the Pennsylvania Fish Commission's no-harvest rule and discourages wading in Valley Creek. No monitoring of PCBs is done by the park. Park staff are reviewing and commenting on EPA planning documents related to the Paoli Rail Yard site, such as the Feasibility Study and Record of Decision, in order to ensure that NPS concerns are addressed.

C. Alternative Actions and Probable Effects

1. Continue Current Action: Visitors are protected from eating contaminated fish and discouraged from wading through contaminated sediments. Elevated levels of PCBs remain in the fish and sediment. Testing of fish flesh is done occasionally by DEP. A successful NPS damage claim against the railyard would help to rehabilitate the fishery. EPA, which manages the Paoli site, has considered many of the park's concerns and included the park in the decision making process.

2. Remove PCBs: The park might attempt to remove PCBs from the stream system. Dredging operations of the magnitude required to accomplish removal would eliminate the entire food base for the fishes and would release large amounts of sediment. The condition of the stream after a procedure like this will be less desirable than the present condition. This is an impractical, probably impossible, option.

3. Increase Public Awareness: VAFO would alert the public to PCB problems by increasing the number of warning signs against wading and harvesting fish. NPS will continue to monitor stream sediments and aquatic organisms for PCB contamination. Fish harvesting will not be permitted unless PCB levels in fish flesh are below FDA action levels.

D. Recommended Actions

A combination of Alternative 1 and Alternative 3 is recommended. Valley Forge NHP has become part of the planning process. EPA, which manages the Paoli site, has been made aware of the park's concerns. It is hoped that, under pressure from NPS and other interested parties, EPA will install a long-term monitoring system so that the levels of PCBs in fish and stream sediments inside the park might be accurately determined. A successful damage claim could be used to improve the fishery and to contract for PCB testing. The best means of protection from PCB contamination for fishermen in the park is enforcement of the current no-harvest restriction.

Recreational Fishing

A. Problem Statement and Background

When stocked annually with brown trout, Valley Creek was heavily fished. In 1985, when a catch-and-release policy was instituted by the PFC because of PCB contamination, the number of fishermen visiting Valley Creek declined dramatically. Ten years later, the number of people engaged in recreational fishing in VAFO reached a level similar to the early 1980s. The PFC placed the stream in its pollution program which prohibits harvesting but allows all types of fishing (e.g., flyfishing, artificial lures, bait).

B. Current Management Actions

Fishing laws of Pennsylvania are enforced. PFC signs that warn against eating the fish have been posted.

C. Alternative Actions and Probable Effects

1. Continue Current Action: Fishing will continue as it has with no tackle restrictions.

2. Remove Brown Trout and Replace with Brook Trout: VAFO could make an effort to rid the stream of exotic (introduced) brown trout and replace them with native brook trout, at least inside the park. Currently, brook trout are found in the Valley Creek watershed in small numbers and only in headwater areas. The PFC may not allow this action and the public might object as the larger, more aggressive, brown trout are popular among fishermen. Total elimination of brown trout inside the park is probably unattainable since brown trout could return to the park from upstream. The main stem of Valley Creek may not offer a suitable environment for the reproduction of brook trout, which are less tolerant of pollution than brown trout. Park Service policy permits the presence of exotic fish in park streams when natives cannot survive.

3. Restrict Tackle to Artificial Lures Only: Fish caught on live bait are more susceptible to hooking mortality (fish death caused by a hook injury) than those caught with artificial lures. Hooking mortality might be the most common cause of death, other than natural mortality, for fish in Valley Creek. Artificial-lures-only fishing could lower the number of fish lost through hooking mortality.

4. Free License System: The park can institute a free license system requiring visitors to obtain a license at the visitors center before fishing in the park. A valid Pennsylvania fishing license will still be necessary. Anglers' names and addresses would be recorded along with other information park personnel might deem appropriate. Survey cards could be distributed for anglers to return, allowing the park staff to determine fishing pressure, type of fishing (i.e., flyfishing), size and numbers of fishes caught and locations in the park fished. Information on contamination in the stream could be given to the anglers. These same anglers may be helpful in collecting fishes for PCB analysis.

D. Recommended Actions

The recommended action is a combination of restricting fishing to artificial lures only (Alternative 3) and implementation of a free license system (Alternative 4). The former alternative preserves a valuable resource that is accessible to many people and the latter collects information on angler use patterns and the condition of the fish community.

Erosion and Stream Bank Stabilization

A. Problem Statement and Background

Erosion is a problem throughout the Valley Creek watershed. Inside the park it is most serious between the covered bridge and the footbridge, where a popular hiking trail and a heavily used commuter road are threatened. Route 252 borders the creek on the east bank and a hiking path is located on the opposite bank. Beneath the road is a thirty-inch, concrete, force sewer main, which carries eight million gallons/day of raw sewage to the Valley Forge Sewer Authority's treatment facility in Phoenixville. The Park Service views erosion as a natural process, which becomes a problem only when it threatens a park structure. Portions of both the road and trail have collapsed into Valley Creek. Guard rails along the road, telephone poles, and trees in some areas are leaning toward the creek. An important archeological resource in this stretch is the site of an 18th century forge buried under several feet of silt on the trail side near the footbridge. A retaining wall built in the mid-1940s protects this encampment-period site.

Downstream from the footbridge are several rapidly eroding banks which do not threaten any known park resource. Perhaps the most rapidly eroding location in the park is in front of Washington's Headquarters, where flood waters from the Schuylkill River compound the problem. At this site seven-foot high streambanks composed of fill material are disappearing at a rate of about one foot per year.

B. Current Management Actions

Downstream from the footbridge, no erosion control actions are planned. Tons of sediment are being washed into Valley Creek annually, but this a natural phenomenon of adjustment to changes in the watershed. A few years ago a wooden fence was installed on top of the unstable streambank in front of Washington's Headquarters to protect visitors from falling into the creek. This fence has already been moved back several times due to bank erosion.

Upstream from the footbridge several erosion control structures have been built. In 1985, gabions were installed along 200 feet of streambank in order to protect the hiking trail. An older set of gabions exists on the road side of the creek further downstream. In 1986, Trout Unlimited planted willows along streambanks near the footbridge. A retaining wall was constructed in 1990 after a portion of Route 252 fell into Valley Creek. A 100-foot section of the trail slumped into the creek in 1991 and was rebuilt with large boulders. Sections of streambank on the road side were armored with rip-rap when the Commonwealth of Pennsylvania administered the park.

A soil bioengineering demonstration project was installed in 1994 to protect the trail along 120 feet of streambank upstream from the footbridge. Live stakes were planted on the steep, seven-foot high bank. A coconut fiber roll was placed at the toe of the bank and hundreds of obligate wetland grasses and forbs were planted in and around the fiber roll.

C. Alternative Actions and Probable Effects

1. Continue Current Action: In some places the only solution to streambank destabilization is to armor it. This was done successfully when a new retaining wall was built near the footbridge. In other places rip-rap, walls, and gabions are aesthetically unappealing and sometimes cause even more erosion downstream. Walls and rip-rap destroy important riparian areas and often isolate the creek from its floodplain, further damaging an already weakened fishery. If no additional streambank stabilization action is taken, more of the trail and road will fall into the creek. Where structures are not threatened, it is better to "let nature take its course", which means allowing the

stream to meander naturally. If the bioengineering demonstration project is successful, it might be installed in other areas.

2. Stream Habitat Improvement: The park could restructure the stream in problem areas to improve habitat for brown trout and to mitigate streambank erosion. For example, there are places where stone and log deflectors could be installed to deepen the channel and to direct the current away from streambanks. Volunteers from environmental groups, such as Trout Unlimited, might assist with this project.

3. Protect Road by Using Standard Engineering Solutions: Standard engineering/construction solutions will be used for restructuring the bank, with emphasis on saving the roadway. Gabions and rip-rap would most likely be used in this alternative, resulting in adverse effects on the natural and cultural scenes.

4. Protect road by using rock gabions covered with soil and plants: With the help of PennDOT or perhaps outside consultants, park staff would investigate ways to reinforce the eastern bank of Valley Creek with standard engineering methods. Rocks covered with soil and native plants might offer the necessary stabilization without losing the natural stream appearance. Plants will protect streambanks from stormwater runoff and will act as filters of sediments and other road pollutants. The same soil/plant combination could be used to cover existing gabions.

5. Bioengineering methods: Using just soil and plants to strengthen streambanks, bioengineering methods might be attempted in some locations where banks are not too high or steep. An expert in soil engineering would be consulted if any work of this type is considered.

6. Move trail: It may feasible to move the section of trail between the covered bridge and footbridge onto the lower slope of Mount Misery. The west bank of Valley Creek would be

allowed to erode and carry away the abandoned trail. The new trail would be protected by Mount Misery's rocky slopes. Two disadvantages of this alternative are initial cost and inconvenience to certain hikers who might not be able to negotiate the increased trail grade. However, in the long run, this option would be less costly than continuous repair of the existing, eroding trail. Hikers who might have difficulty walking the new trail would still have access, as they do now, to the level section of Valley Creek trail between the footbridge and Route 23.

7. Problem evaluation: This approach will postpone any work on the stream until a separate study is done to evaluate the likelihood of success of the various approaches to bank and road stabilization. A limited study has already been done by W. B. Reed of the NPS Water Resources Division (Reed 1990, see Appendix A). Reed suggests conceptual designs for two portions of Valley Creek: the site of the upper forge and the stream reach from the upper forge to the covered bridge.

His plan to protect the streambank and control erosion at the location of the upper forge involves reestablishing the connection between the creek and its floodplain on the west bank. A mound of dirt left from a 1930s archaeological investigation and an existing wall have isolated the creek from its floodplain. Reed proposed five steps to correct this situation. The first step, already completed, was to repair the east bank retention wall that collapsed. The next three steps involve the area behind the west bank retention wall, the site of the historic upper forge. The wall would be lowered and the floodplain just downstream of the forge would be re-shaped to the same level as the floodplain. These actions are designed to dissipate the force of floodwaters by allowing the creek to flow into its old floodplain during high water events. Finally, the right-bank bridge abutment would be moved towards the road to increase the bridge span. Currently, the bridge span is less than the width of the creek. A larger cross-sectional area under the bridge will decrease water velocity.

Reed suggests a three-phase adjustment between the upper forge and covered bridge. The east bank would be protected using bioengineering techniques. The gabions would be removed from the west bank (trail side) and the footpath lowered three feet and the remaining stream segments along the west bank stabilized by bioengineering methods.

D. Recommended Actions

As streambank stabilization along Valley Creek inside the park is a complex problem, a combination of solutions is recommended.

Alternative 1: Some sections of streambank must be protected by standard engineering methods, such as retaining walls. Other sections of streambank, where no structures are threatened, can be allowed to collapse as the creek adjusts to changing conditions in the watershed. The bioengineering demonstration project will be monitored and other small bioengineering projects will be attempted using different approaches to the same erosion problems so that the success of each method can be assessed.

Alternative 2: Deflecting structures can be built in places where natural or artificial obstacles direct the stream up against the road or trail. It may be possible to remove some of these obstacles.

Alternative 3: Standard engineering solutions will be used to protect the road and sewer main where no other alternative is practical.

Alternative 4: Bioengineering may have wide application for stabilizing streambanks inside the park and elsewhere. It is a "soft", relatively inexpensive approach, which has been used successfully on other streams. It is the most natural and aesthetically pleasing alternative. An added advantage is that this method may be used to recreate wetlands and riparian areas that have been destroyed.

Alternative 5: Park management should consider relocating part of the trail onto the lower slope of Mount Misery. Although the initial cost may be prohibitive, this action would solve several problems.

Alternative 6: The span of the footbridge should be increased to remove constriction of the creek. Due to its expense, this can only be considered as a long term goal. Lowering the wall, which protects the site of the upper forge, would mitigate the force of floodwaters and is recommended. Removing the gabion and lowering the trail is an expensive option which would make the trail unusable during high water; this action is not recommended. Instead Reed's suggestion that bioengineering be employed where practicable is recommended.

Historic Cultural Resources

A. Problem Statement and Background

Valley Forge National Historical Park is a unit of the National Park System with a mission to preserve those cultural resources related to the 1777-78 winter encampment of the Continental Army. Valley Creek is important as both a natural and cultural resource with several encampment period structures and archaeological sites located along its banks. Washington's Headquarters, where George Washington was quartered during the encampment, and its stable and barn stand at the confluence of Valley Creek and the Schuylkill River. Other 18th century structures near the creek are Lafayette's Quarters and Knox's Quarters. The upper and lower encampment-period forges, which gave Valley Forge its name, exist today as archaeological sites within the creek's floodplain. In the 19th century Valley Forge was a busy industrial village. Valley Creek provided water power for several forges and mills which survive as archaeological sites. One historic dam, the Middle Dam, was reconstructed in 1930 on the site of the original mill dam for the lower forge. Management actions must take into account cultural resources associated with the creek.

B. Current Management Actions

The upper forge near the footbridge is protected from high waters by retaining walls. While there are no physical structures to protect the lower forge, it is not threatened. Lafayette's Quarters and Knox's Quarters are beyond the 500-year floodplain and require no special protection. Washington's Headquarters is just inside the 100-year floodplain. The worst flooding ever experienced at Valley Forge was during tropical storm Agnes in 1972. Water from the creek and river reached the basement windows of Washington's Headquarters. As a result, a Flood Preparedness Plan for Washington's Headquarters was developed by the U.S. Army Corps of

Engineers. Maxwell's Quarters, a 19th century country manor, is just within the 500-year floodplain; there are no special flood preparedness plans for this structure. A covered bridge built in 1865 spans the creek at Yellow Springs Road and a stone bridge built about 1930 carries Route 23 over Valley Creek. There are also two modern footbridges. It is almost certain that none of the bridges would survive a 100-year flood (Agnes was only a 25- to 50-year flood event in the Valley Creek watershed.) The historic covered bridge is owned by the Commonwealth of Pennsylvania and there are no special plans to protect it. Although no other structures are threatened by Valley Creek, several 18th and 19th century archaeological sites within the 100-year floodplain may be at risk. These areas remain unprotected and there are no plans to change the situation. Although some consideration was given to the removal of Middle Dam to allow free migration of fish between the creek and river, the current management position is that the dam should remain due to its historic significance.

C. Alternative Actions and Probable Effects

1. Continue Current Action: The retaining wall will continue to protect the upper forge site. Other archaeological sites remain protected only by their distance from the creek and the depth of silt covering them. A 100-year flood will cause light damage to Washington's Headquarters but will probably destroy every bridge on the creek inside the park. No other structures are threatened except by a catastrophic flood.

2. Remove the Dam: Removal of Middle Dam would allow a more natural stream flow. The fish assemblage in this portion of the creek will probably change from pool to riffle species. Removal should not occur during fish spawning periods to avoid affecting their populations. If the

dam were breached during high water, most of the sediment would likely be flushed into the Schuylkill River.

3. Monitor Impacts to Cultural Resources: Park personnel will monitor cultural resources near Valley Creek to document any impacts of stream erosion especially after rainstorms. A systematic, visual monitoring program should be sufficient to evaluate the condition of resources threatened by the creek.

D. Recommended Actions

Alternative 1 and Alternative 3 are recommended. Removal of the dam (Alternative 2) might be positive from a natural resource point of view but leaving it would serve an important historical purpose. There is no immediate threat to historic resources, therefore, visual monitoring should be sufficient.

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Appendix A. A copy of Reed, W. B. 1990. "An evaluation of the effects of 300 years of changing land use on the peak flows, base flow, and flood frequency of a small Pennsylvanian stream."

EASTERN REGION TECHNICAL ATTACHMENT
NO. 91-2A
FEBRUARY, 1991

AN EVALUATION OF THE EFFECTS OF 300 YEARS OF CHANGING LAND USE ON THE PEAK FLOWS, BASE FLOW, AND FLOOD FREQUENCY OF A SMALL PENNSYLVANIAN STREAM

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1. INTRODUCTION

Valley Creek flows through Valley Forge National Historical Park to its confluence with the Schuylkill River. Valley Creek at Schuylkill River has a watershed of 23.25 square miles. The watershed has undergone extensive land use changes resulting in changes in Valley Creek stream flow characteristics and associated fluvial processes. Within the park, between the covered bridge and the upper forge site, Valley Creek once migrated back and forth within a very narrow valley. In recent times, the stream has been confined by alternative uses of the valley floor, and now threatens these uses as it continues to adjust to changes in watershed conditions. Of particular concern is the potential for the undermining of Route 252 and underlying sewer main. Most recently the failure of a wall, located between the stream and the road at the upper forge site, brought the attention of park and Pennsylvania Department of Transportation staff to the problem of stream bank stability.

The Village of Valley Forge received its name from the iron forge built along Valley Creek in the 1740s. This forge was destroyed by the British in 1777 prior to the arrival of George Washington's army. The upper forge site may be the ruins of this historic forge. At this site, stone masonry walls were constructed (circa 1945) to protect the buried ruins and Route 252. However, the walls constrict the flow of Valley Creek, gradually reducing the channel width from 42.6 to 31.3 feet. This channel configuration and changing watershed conditions have resulted in: (1) a lowering of the stream channel (which had already been dredged during archeological investigations), (2) an undermining of the right-bank wall, and recently (3) a collapsing of a segment of the right-bank wall into the stream. The purpose of this paper is to present a qualitative evaluation of the effects of 300 years of changing land use within the Valley Creek watershed on the peak flows, base flow, and flood frequency of a small Pennsylvanian stream.

2. DESCRIPTION OF VALLEY CREEK WATERSHED

Valley Creek watershed is 20 miles west of Philadelphia, Pennsylvania. The watershed is located mainly in Chester County with a small portion (5 percent) in Montgomery County. Valley Creek flows for 11,000 feet through Valley Forge National Historical Park and is a perennial tributary to Schuylkill River. The mouth is near Washington's Headquarters within the park. At this confluence, the drainage area of the watershed is 23.25 square miles (Figure 1).

The watershed has a rectangular shape and is approximately 3 miles wide (north to south) and 8 miles long (west to east). The highest and lowest points in the watershed are 720 feet near Union Chapel (northwestern corner) and 70 feet (water surface elevation shown on USGS Valley Forge Quadrangle) at Schuylkill River (northeastern corner), respectively. Elevations are above National Geodetic Vertical Datum of 1929. Total channel length is 56,000 feet. Average channel slope is 1.2 percent. From highest point in watershed to Church Road (a distance of 25,900 feet), average channel slope is 2.0 percent. From Church Road to mouth (a distance of 30,100 feet), average channel slope is 0.4 percent.

The watershed is located in the Piedmont physiographic province of southeastern Pennsylvania and is typical of the narrow limestone valleys and the low hills of this region. The geology of the watershed consists of Ordovician and Cambrian sedimentary (shale, limestone, dolomite, and sandstone) and metamorphic (schist, serpentine, gneiss, and quartzite) rocks (Willard, 1962). Limestone and dolomite are quarried within the watershed.

The soils within the watershed are predominately, moderately well-drained silt loams derived from weathered limestone, schist, gneiss, and quartzite (Commonwealth of Pennsylvania, 1973). The hydrologic soil group classification for these soils is Group B [U.S. Soil Conservation Service (SCS), 1986]. The runoff potential for an undeveloped watershed with soils of this classification is low to moderate (Van Haveren, 1986).

3. DESCRIPTION OF HISTORICAL WATERSHED CONDITIONS

In general, the watershed has experienced five major phases of land use over the last 300 years:

(1) heavily forested--prior to significant settlement of the area by colonists (pre-1700s);

(2) the clearing of a small portion of the valley floor for agricultural use and village sites, approximately 4 to 20 percent of the watershed deforested--prior to the American Revolution (1700 to 1776);

(3) the clearing of the valley floor, rolling hills and other mild slopes for additional agriculture use and growing village sites, approximately 40 to 50 percent of the watershed deforested (1800s);

(4) the clearing of additional land for and the conversion of marginal agricultural lands to residential, commercial, and industrial areas, including planned communities (high-density residential areas), shopping centers, industrial parks, railroad yards, and quarries, approximately 60 percent of watershed deforested (1900 to 1985)--with accelerated development and major land use changes occurring essentially over a 15-year period from approximately 1970 to 1985; and

(5) the conversion of marginal and prime agricultural lands to commercial parks and isolated estates (low-density residential areas), approximately 60 percent of the watershed deforested--this is the current trend (1985 to possibly the year 2000).

The above scenario is generalized; therefore, there may be numerous exceptions to the sequence and description of events. It is beyond the scope of this report to quantify the exact pattern of historical land use within the watershed. However, the above generalizations and the following qualitative narratives are used to approximate historic and projected watershed conditions; thereby, permitting a preliminary analysis of the effects of changing land use on the peak flows, base flow, and flood frequency of Valley Creek.

<u>Watershed condition</u>, as defined in this paper, is the health of the watershed compared to its natural state as measured in

the terms of three characteristics (1) peak flows, (2) base flows, and (3) channel morphology. Peak flow, as used here, is the largest rate of discharge expected during a given event (for floods, the peak flow is often referred to as the flood crest). Base flow is defined as the sustained or fair-weather runoff (Chow, 1964). Channel morphology, is the width, depth, and pattern (plan form) of the channel. A watershed with characteristics typical of natural conditions is considered excellent. Whereas, a watershed with characteristics typical of moderately developed conditions (without stormwater management) is considered poor. Good and fair conditions exist between these two extremes with: good representing conditions that have only been slightly impacted by development, and fair representing conditions between good and poor.

Watershed condition for phase 1: excellent. When the watershed was heavily forested, the stream flow of Valley Creek was very different than it is today. Under these conditions, soil infiltration rates were high and watershed runoff was dominated by subsurface (interflow) processes. Overland flow, which conveys precipitation to stream channels more rapidly than subsurface flow, likely was less common. Thus, peak discharges associated with precipitation were of lesser magnitude and severe flooding was less frequent than it is today. In contrast, the base flow of Valley Creek was greater, being fed by larger soil moisture and ground water reserves during dry seasons. Because the magnitude of peak flows associated with precipitation were smaller, the stream channel was presumably neither as deep nor as wide as it is today.

Watershed condition for phase 2: excellent to good. As the colonists move into the watershed they cleared a small portion of the valley floor for agriculture. An estimate of this clearing may be as high as 20 percent (Brush, 1989) or as low as 4 percent (Defries, 1986) of all available land. Such a change in land use had a relatively mild impact upon watershed condition. This is because the areas cleared probably had very mild slopes and productive soils (well-drained, highly permeable loams), and were not major sources of runoff even after clearing.

Watershed condition for phase 3: good to fair. As deforestation continued over the next century, resulting in 40 to 50 percent of the watershed deforested (Defries, 1986), the hydrology and channel morphology of Valley Creek changed noticeably. For the first time, towns--as we know them--were founded (Chester County, 1982). The main factors causing the presumed change in the hydrology and channel morphology of Valley Creek was a significant loss in vegetative and soil cover. The reduced infiltration of impacted soils would favor overland flow. This change resulted in both a significant increase in peak flows and a significant decrease in base flows. Initially, severe flooding occurred more frequently. Eventually, the stream channel increased its capacity to convey larger flows by becoming wider and deeper.

Watershed condition for phase 4: fair to poor. During this phase, the effect of continued deforestation and the conversion of marginal agricultural lands to other purposes, began to severely threaten park natural and cultural resources. The amount of developed land in Chester County doubled from 1970 to 1985 (Chester County, 1988). At least one historically perennial tributary to Valley Creek lost its base flow due to the construction of a planned community outside of the park. Such a severe response to changing land use occurs when a large percentage of the watershed becomes impervious. This change results in reduced infiltration and greater storm runoff. Also, peak flows associated with storms become larger than in the past as the watershed's response to rainfall becomes flashier due to a shorter time of concentration. Even for moderately developed watersheds, runoff volumes may be increased by more than 50 percent and time of concentrations may be decreased by as much as 50 percent--particularly if extensive drainage "improvements" are made (Schueler, 1987).

Watershed condition for phase 5: presently poor; potential for fair. In general, only the least productive soils and steeper slopes are still forested (Chester County, 1982). Although agriculture and woodlands are the two largest land use categories in Chester County, these land uses have decreased the most since 1970 (Chester County, 1988). The conversion of marginal and prime agricultural lands to corporate parks and isolated estates, may actually improve the previous watershed condition by reducing peak flows and sediment loads through best management practices. It is assumed here that best management practices will be implemented to reduce the peak flows of all events. This will likely require the use of innovative techniques--in addition to stormwater management ponds--in that stormwater management ponds are usually only designed for events equal to or less than the 25-year frequency 24-hour single-event rainfall. The watershed condition's best potential will likely only be achieved through the establishment of a watershed committee or advisory board. Without proper stormwater management, peak discharges will increase as the impervious area within the watershed increases (Sloto, 1988).

Whereas, during this phase, hydrologic conditions may improve (assuming that stormwater runoff will be better managed), channel conditions (unless otherwise altered) will decline. This decline is because the stream channel will still be adjusting to previous changes in watershed conditions (i.e., just beginning to respond to increased flows resulting from changes which occurred during the previous phase.)

4. HYDROMETEOROLOGIC SIMULATIONS FOR SELECTED WATERSHED CONDITIONS

The hydrometeorology of Valley Creek was simulated for future and representative historical conditions using the SCS unit hydrograph method (U.S. Soil Conservation Service, 1986). Specifically, the SCS TR-55 (Urban Hydrology for Small Watersheds) graphical method was used to calculate the peak discharges for 24-hour single-event rainfalls with the following return periods: 1, 2, 5, 10, 25, 50, and 100 years. Flows were calculated for Valley Creek at Schuylkill River. (These flows are specifically for Valley Creek.) The stage of Valley Creek near its mouth (approximately the reach downstream of Route 23 on Figure 1) is affected by the Schuylkill River during high flows. The flooding that occurred at this location during Hurricane Agnes (June 1972) was primarily due to the Schuylkill River with Valley Creek contributing very little to the combined stage. A Flood Preparedness Plan has been developed for this flood prone area which includes Washington's Headquarters.

The following years were subjectively selected as representative of the five major phases of land use in recent history and near future: 1685, 1776, 1885, 1985, and 1995 (projected). The rainfall amount for each storm (Table 1) was provided by the TR-55 computer program (from file COUNTY.RF), using a county and state combination of Montgomery County and Commonwealth of Pennsylvania.

FLOOD FREQUENCY	RAINFALL (inches)
1-year	2.6
2-year	3.2
5-year	4.2
10-year	5.1
25-year	5.6
50-year	6.3
100-year	7.2

Table 1. Valley Creek watershed: 24-hour single-event rainfall.

For these events, I selected a Type III rainfall distribution which is representative of Atlantic coastal areas where tropical storms bring large 24-hour rainfall amounts.

TR-55 subroutines (TCTT and RCN) were used to calculate time of concentration and runoff curve numbers. Time of concentration is the time it takes runoff to travel from the hydraulically most distant point in a watershed to the point of interest (here the mouth of Valley Creek). Time of concentrations ranged from 4.21 hours (1685 and 1776) to 3.2 hours (1885, 1985, and 1995). Curve number is a general parameter determined by several watershed properties. The major factors that determine the curve number are: hydrologic soil group, cover type, treatment, hydrologic condition, and antecedent runoff condition (U.S. Soil Conservation Service, 1986). The curve numbers used were 55 (1685), 56 (1776), 60 (1885), 67 (1985), and 66 (1995). In general, the following watershead cover descriptions were used to obtain these values:

For 1685, the entire watershed was assumed wooded.

For 1776, the watershed was assumed described by three agricultural cover descriptions including woods.

For 1885, the watershed was assumed described by four agricultural cover descriptions including woods and farmsteads.

For 1985, the watershed was described by eleven cover descriptions including urban and agricultural land uses. This land use pattern was obtained from USGS Valley Forge and Malvern Quadrangles that were photo revised in 1981 and 1983, respectively. Therefore, the full extent of urbanization in 1985 may not have been completely realized.

For 1995, the watershed was described by nine cover descriptions including urban and agricultural land uses. However, I assumed that all cultivated agricultural lands that remained in 1985 had since been converted to corporate parks and isolated estates. Additionally, I assumed that all farmsteads that remained in 1985 had since been either converted to parks (urban open space) or subdivided and subsequently converted to planned estates.

5. RESULTS

The results of the hydrometeorologic simulations for selected watershed conditions are presented in terms of peak flows for the 2-, 50-, and 100-year events; base flow; and flood frequency. Peak and base flow have been previously defined. Flood frequency, expressed as a return period (or recurrence interval), is the average time within which the given flood will be equaled or exceeded at least once. The 2-year event has a 50 percent chance of being equaled or exceeded at least once in any given year; the 50-year event has a 2 percent chance, the 100-year event has a 1 percent chance, and the 500-year event has a 0.2 percent chance.

Peak Flows: Selected hydrologic output data of the TR-55 computer simulations are presented in Table 2. The calculated peak discharges for the 2-, 50-, and 100-year 24-hour rainfall are in cubic feet per second (cfs).

Year	2-year peak	50-year peak	100-year peak
1685	350 cfs	3,100 cfs	4,200 cfs
1776	400 cfs	3,400 cfs	4,600 cfs
1885	800 cfs	5,000 cfs	6,600 cfs
1977	------	------	7,100 cfs*
1985	1,450 cfs	6,500 cfs	8,300 cfs
1995	1,350 cfs	6,300 cfs	8,100 cfs

* This value was obtained from U.S. Army Corps of Engineers (1981) and is presented here for comparison. (Note: The watershed was still being developed at the time of the Corps study.)

Table 2. Valley Creek at Schuylkill River: peak discharges for selected watershed conditions.

The 100-year peak discharge values for 1985 and 1995, although conservative, are not as high as comparable estimates made by others (Heister, 1989; Commonwealth of Pennsylvania, 1973).

Conversely, the 2-year peak discharge values for 1985 and 1995 may be high. This is because I did not take into consideration the possible cumulative effect of the small dams--throughout the watershed--on the peak flows of small floods. If these dams had any available storage prior to such events, then the resulting peak discharges would likely be less than the values presented in Table 2.

In general, over the 300-year period from 1685 to 1985, the peak discharges were doubled. This is typical of changes in stream hydrology for a moderately developed watershed, i.e., increased peak discharges about two to five times higher than pre-development conditions (Schueler, 1987). Essentially, half of the increase occurred over the 100-year period from 1785 to 1885, and half occurred over the period from 1885 to 1985, with most of this latter increase occurring since 1970. As modeled, the present trend in land use changes may actually cause a slight decrease in current (1985) peak discharges (Figure 2). This is because I assumed that in the future stormwater runoff would be better managed, i.e., I assumed that future land uses would have a lower curve number than the current land uses they replaced. If better management practices are not used, then peak flows will continue to increase. For example, without proper stormwater management, an estimate of the future 2-year peak discharge is 2,800 cfs; almost twice the 1985 peak discharge.

An analysis using the storage routine for the TR-55 computer program, indicates that even for relatively small events (e.g., the 2-year storm), the amount of storage required to reduce peak flows from projected 1995 peaks to modeled 1885 conditions would be considerable. Reducing the discharge of the 2-year event (24-hour rainfall of 3.2 inches) from 1,350 cfs to 800 cfs would require a detention basin storage volume of 205 acre-feet.

Base Flow: Over the 300-year period from 1685 to 1985, the base flow of Valley Creek within Valley Forge National Historical Park has presumably decreased. Although data have not been presented to support this supposition, it is based upon the observation that at least one formerly perennial tributary to Valley Creek no longer flows continuously during the summer. The observed drying up of the smaller stream, and the speculated reduced Valley Creek base flow, agrees well with the changes to stream hydrology expected within a moderately developed watershed (Schueler, 1987). However, the permitted discharge from a limestone quarry within the upper watershed may have offset any decrease that would have occurred in recent years.

Additionally, the growth of public water and sewer systems has resulted in significant interbasin transfers out of the Valley Creek watershed (Sloto, 1987). Sloto (1987) estimates that the net loss of water in 1984 was 630 million gallons. Such a loss could contribute to a reduction in base flow, but would likely not cause a noticeable change.

Flood Frequency: The effects of changing land use on the flood hydrology of Valley Creek at Schuylkill River has been to increase the magnitude of floods (e.g., the calculated magnitude of the 100-year flood increased from 4,200 cfs to 6,600 cfs over the 200-year period from 1685 to 1885). Another way to interpret this hydrologic trend, is that a given magnitude flow now has a more frequent (smaller) recurrence interval and thus, a higher probability of occurring. For example, a flow with a magnitude of 6,600 cfs would have been a flood with a recurrence interval slightly greater than the 500-year flood in 1776, but would have been a 100-year flood in 1885. And if a flood of this magnitude was to occur today, it would be only a 50-year flood. One result of this trend is that although the covered bridge (located approximately

2000 feet upstream of the upper forge site) may have been designed (by chance or on purpose) for the 100-year flood at the time of its construction (1851), it now has a conveyance (below low steel) roughly equal to the 50-year flood.

6. CONCLUSIONS

The effects of changing land use between 1685 and 1885 on the hydrology and channel morphology of Valley Creek may have complemented the changes in the historical uses of the stream. Inadvertently, the smaller, gentler stream of the colonial era was gradually changed to the larger, powerful stream of the industrial era.

The effects of changing land use between 1970 and 1985 on the hydrology and channel morphology of Valley Creek have resulted in an impaired fluvial system that may not yet be in equilibrium with existing watershed conditions. Without effective stormwater management, additional urbanization in the Eastern U. S. will likely continue to adversely impact stream hydrology.

In general, it appears that present-day changes in land use from agriculture to low-density residential areas and corporate centers (the trend since approximately 1985) may have less impact on the hydrology of Valley Creek than did the previous transition from agriculture to high-density residential areas and industrial parks. However, if proper stormwater management is not implemented, then peak flows may again increase. If the current trend continues, then Valley Creek streamflow characteristics will deviate very little from existing conditions. Therefore, it may be appropriate to design slope protection and erosion control efforts for current streamflow conditions.

7. ACKNOWLEDGMENTS

The assistance provided to the author by Brian Lambert, Natural Resource Specialist, Valley Forge National Historical Park, contributed to the preparation of this report. Thanks also to Jacqueline V. Nolan, Water Operations Branch, National Park Service for drafting the figures.

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SITE DESCRIPTIONS

1a. Valley Creek at Morehall Road
1b. Valley Creek at Church Road
1d. Valley Creek at Le Boutillier Road
1e. Valley Creek near Mill Road (100 feet upstream of confluence with Little Valley Creek)
1f. Valley Creek at USGS gaging station (100 feet upstream of Pennsylvania Turnpike Bridge)
2a. Tributary to Valley Creek at Morehall Road
2b. Tributary to Valley Creek at Church Road
3c. Little Valley Creek at North Valley Road
3e. Little Valley Creek near Mill Valley Road (50 feet upstream of confluence with Valley Creek)
4c. Small Tributary to Little Valley Creek at North Valley Road

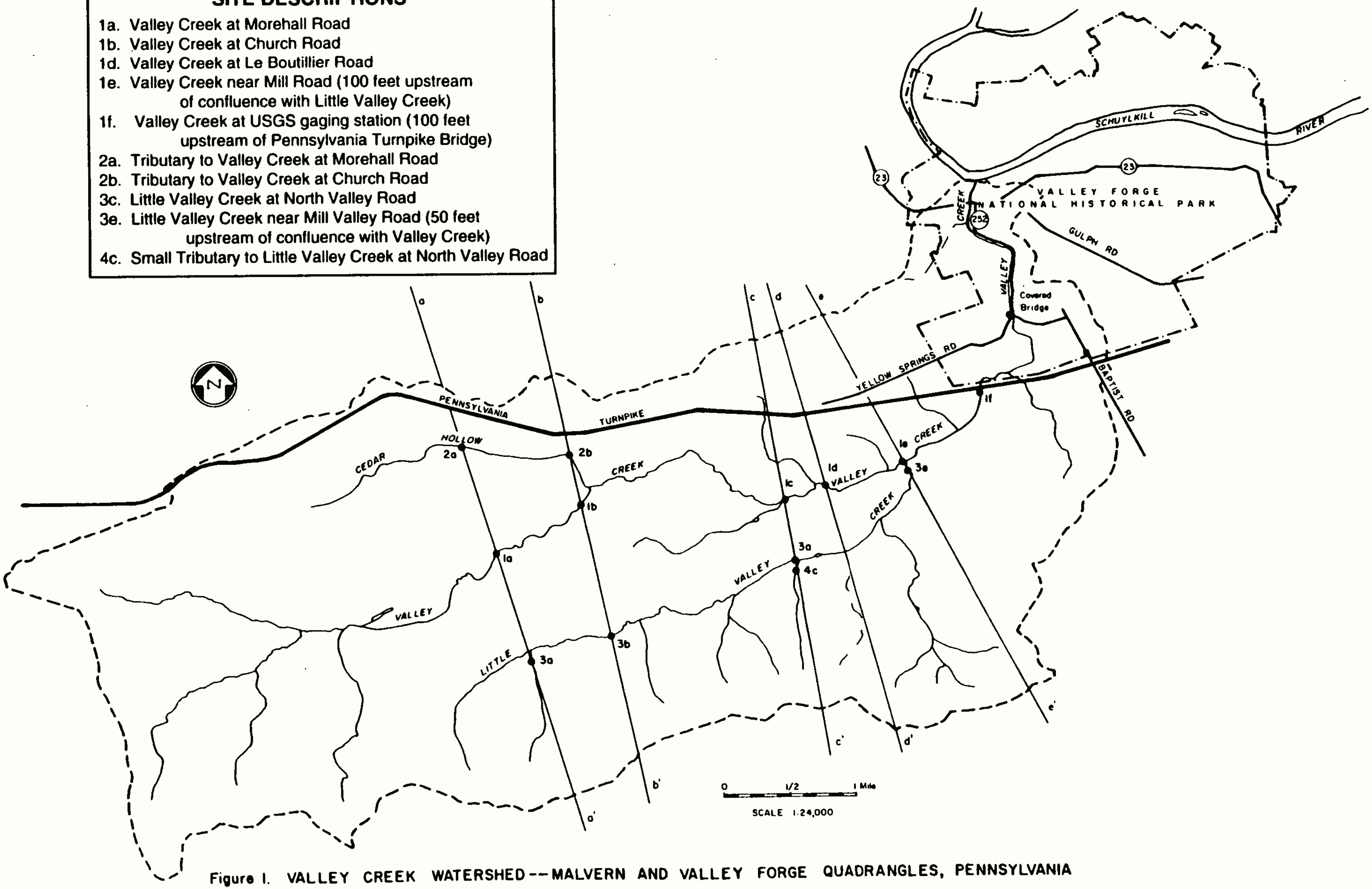

Figure I. VALLEY CREEK WATERSHED--MALVERN AND VALLEY FORGE QUADRANGLES, PENNSYLVANIA

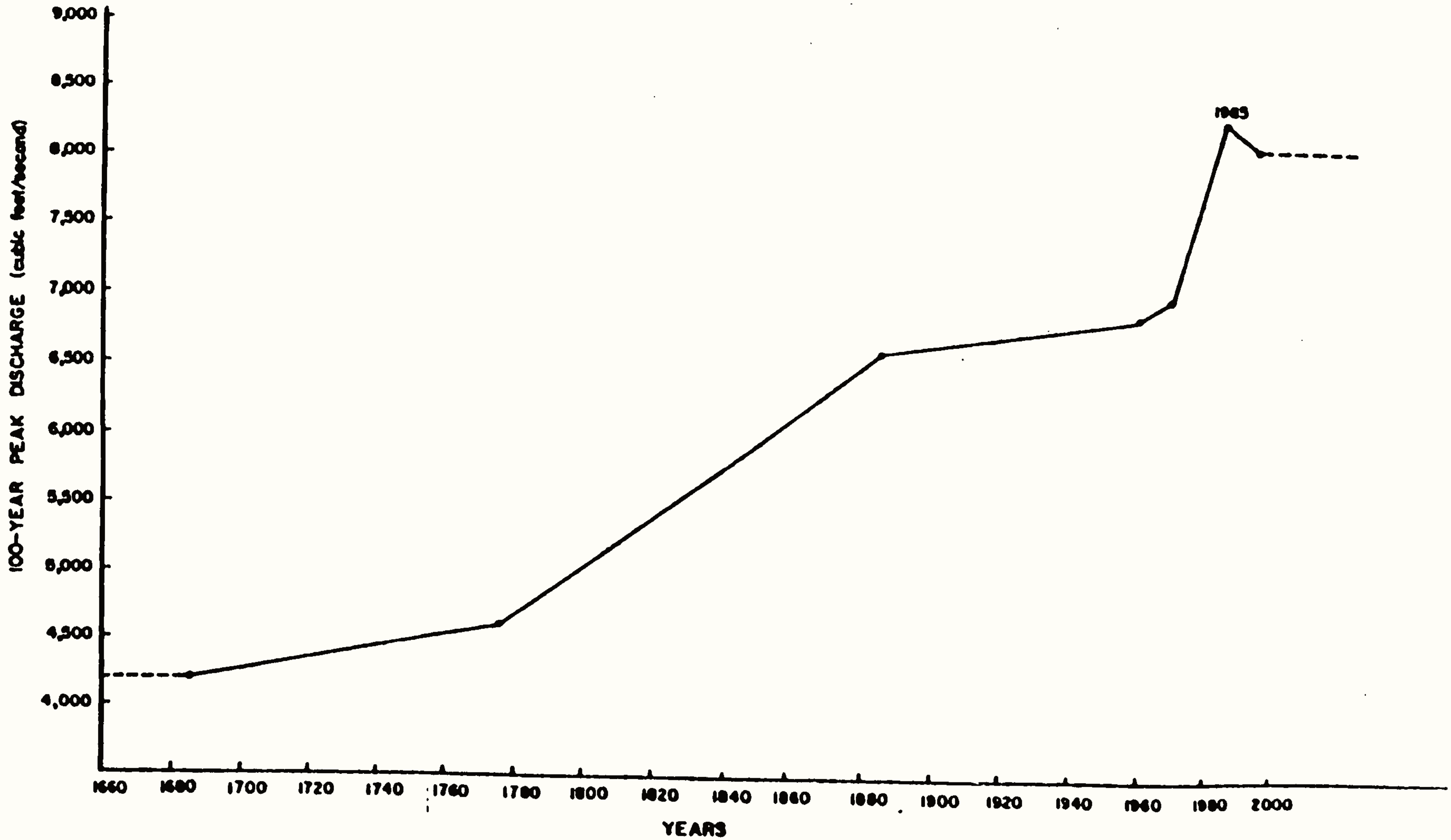

Figure 2 100-YEAR PEAK DISCHARGES -- 1685 to 1995, VALLEY CREEK at SCHUYLKILL RIVER, VALLEY FORGE NHP

Appendix B. Pennsylvania DEP coldwater fishery water quality standards (chapters 16 and 93)

Parameter	Criteria
Aluminum	Not to exceed 0.1 of the 96-hour LC50 for representative important species as determined through substantial available literature data or bioassay test tailored to the ambient quality of the receiving waters.
Alkalinity	Equal to or greater than 20 mg/l as $CaCOH_3$, except where natural conditions are less. Where discharges are to waters with 20 mg/l or less alkalinity, the discharge should not further reduce the alkalinity of the receiving waters.
Ammonia-Nitrogen	The maximum total ammonia nitrogen concentration at all times shall be less than or equal to the numerical value given by:

un-ionized ammonia nitrogen (NH_3-N) x ($\log^{-1}(pK_T - pH) + 1$), where:

un-ionized ammonia nitrogen =0.12 x f(T)/f(pH)

$$f(pH) = 1 + 10^{1.03(7.32-pH)}$$

$$f(T) = 1, \text{ if } T \geq 10°C$$

$$f(T) = \frac{1 + 10^{(9.73-pH)}}{1 + 10^{(pK_T pH)}}, \text{ if } T < 10°C$$

and

$pK_T = 0.090 + 2730/(T + 273.2)$, the dissociation constant for ammonia in water.

The average total ammonia nitrogen concentration over any 30 consecutive days shall be less than or equal to the numerical value given by:

un-ionized ammonia nitrogen (NH_3-N) x ($\log^{-1}(pK_T - pH) + 1$), where:

un-ionized ammonia nitrogen = 0.025 x f(T)/f(pH)

$$f(pH) = 1, pH \geq 7.7$$

$$f(pH) = 10^{0.74(7.7-pH)}, pH < 7.7$$

$$f(T) = 1, \text{ if } T \geq 10°C$$

$$f(T) = \frac{1 + 10^{(9.73-pH)}}{1 + 10^{(pK_T - pH)}}, \text{ if } T < 10°C$$

The pH and temperature used to derive the appropriate ammonia criteria shall be determined by one of the following methods:

(1) Instream measurements, representative of median pH and temperature--July through September.

(2) Estimates of median pH and temperature-July through September-based upon available data or values determined by the Department.

For purposes of calculating effluent limitations based on this value the accepted design stream flow shall be the actual or estimated lowest 30-consecutive-day average flow that occurs once in 10 years.

Arsenic	Not to exceed 0.05 mg/l
Bacteria	During the swimming season (May 1 through September 30), the fecal coliform level shall not exceed a geometric mean of 200 per 100 milliliters (ml) based on five consecutive samples each sample collected on different days; for the remainder of the year, the fecal coliforms level shall not exceed a geometric mean of 2,000 per ml based on five consecutive samples collected on different days.
Chromium	Not to exceed 0.05 mg/l as hexavalent chromium
Copper	Not to exceed 0.1 mg/l
Cyanide	Not to exceed 0.005 mg/l as free cyanide ($HCN + CN^-$)
Dissolved Oxygen	Minimum daily average 6.0 mg/l; no values less than 5.0 mg/l. For lakes, ponds and impoundments only, no value less than 5.0 mg/l at any point.
Fluoride	Not to exceed 2.0 mg/l.
Iron	Not to exceed 1.5 mg/l as total iron; not to exceed 0.3 mg/l as dissolved iron.

Lead	Not to exceed the lesser of 0.05 mg/l or 0.01 of the 96-hour LC_{50} for representative important species as determined through substantial available literature data or bioassay tests tailored to the ambient quality of the receiving waters.
Manganese	Not to exceed 1.0 mg/l.
Nickel	Not to exceed 0.01 of the 96-hour LC_{50} for representative important species as determined through substantial available literature data or bioassay test tailored to the ambient quality of the receiving waters.
Nitrite plus nitrate	Not to exceed 10 mg/l as nitrogen.
Osmotic Pressure	Not to exceed 50 milliosmoles per kg or criteria developed using Section 93.5 (d)
pH	Not less than 6.0 and not more than 9.0.
Phenolics	Not to exceed 0.005 mg/l. Four-day average 0.02 mg/l; one-hour average 0.1 mg/l.
Temperature	Maximum temperatures in the reeceiving water body resluting from heated waste sources regulated under Chapter 97 (relating to Industrial Wastes), and any other sources where the Department determines that temperature limits are necessary to protect designated uses, are as follows. Additionally, these wastes may not reslut in a change by more than 2°F during any 1-hour period.

Period	Temperature °F
January 1-31	38
February 1-29	38
March 1-31	42
April 1-15	48
April 16-30	52
May 1-15	54
May 16-31	58
June 1-15	60
June 16-30	64
July 1-30	66
August 1-30	66
September 1-15	64
September 16-30	60
October 1-15	54
October 16-31	50
November 1-15	46
November 16-30	42
December 1-31	40

Turbidity — Maximum monthly mean of 10 NTU, maximum 150 NTU.

Total Dissolved Solids — Not more than 500 mg/l as a monthly average value; not more than 750 mg/l at any time.

Zinc — Not to exceed 0.01 of the 96-hour LC_{50} nor the representative important species as determined through substantial available literature data or bioassay tests tailored to the ambient quality of the receiving waters.

Sample standards for ammonia set by the DEP and the EPA

DEP maximum acute concentrations of total ammonia (mg/l):

Temperature	pH	
	7.0	8.5
0°C	20.59	2.03
25°C	6.76	0.74

DEP maximum thirty day averages for total ammonia (mg/l):

Temperature	pH	
	7.0	8.5
0°C	3.5	0.45
25°C	1.15	0.16

EPA one hour average criteria: Total ammonia (mg/l NH_3)

Temperature	pH	
	7.0	8.5
0°C	28.0	2.6
25°C	16.4	1.71

EPA one hour average criteria: Un-ionized ammonia (mg/l NH_3)

Temperature	pH	
	7.0	8.5
0°C	0.023	0.065
25°C	0.093	0.26

EPA 4-day average criteria: Total ammonia (mg/l NH_3)

Temperature	pH	
	7.0	8.5
0°C	2.5	0.49
25°C	1.04	0.23

EPA 4-day average criteria: Un-ionized ammonia (mg/l NH_3)

Temperature	pH	
	7.0	8.5
0°C	0.0021	0.0216
25°C	0.0059	0.035

Appendix C. Map of regional sewer systems--
Valley Forge Sewer Authority, Chester County, Pennsylvania


REGIONAL SEWER SYSTEMS
VALLEY FORGE SEWER AUTHORITY
CHESTER COUNTY PENNSYLVANIA
LEGEND
GRAVITY SEWER
FORCE MAIN
PUMPING STATION
EJECTOR STATION
METER STATION
SEWAGE TREATMENT PLANT
PARTICIPATING AUTHORITIES
VALLEY FORGE SEWER AUTHORITY
TREDYFFRIN TOWNSHIP MUNICIPAL AUTHORITY
EAST WHITELAND TOWNSHIP MUNICIPAL AUTHORITY
EASTTOWN TOWNSHIP MUNICIPAL AUTHORITY
WILLISTOWN TOWNSHIP MUNICIPAL AUTHORITY
MALVERN MUNICIPAL AUTHORITY
SCALE 1 3/4 1/2 1/4 0 MILES
VALLEY FORGE SEWAGE TREATMENT PLANT
PERKIOMEN JUNCTION PUMPING STATION
VALLEY CREEK PUMPING STATION
PICKERING CREEK PUMPING STATION
WILSON ROAD PUMPING STATION
DEVON HUNT PUMPING STATION
EXETER ROAD PUMPING STATION
BERWYN PUMPING STATION
LANCASTER AVENUE PUMPING STATION
LEOPARD ROAD PUMPING STATION
DAYLESFORD PUMPING STATION
WHITE HORSE ROAD PUMPING STATION
FRENCH CREEK PUMPING STATION
POT HOUSE ROAD PUMPING STATION
SANDRA LANE PUMPING STATION
CHARLESTOWN ROAD PUMPING STATION
GLENN AVENUE PUMPIN STATION
DARBY ROAD PUMPING STATION
DEVON ROAD PUMPING STATION
DEVON ROAD # 2 PUMPING STATION
RUTHLAND AVENUE PUMPING STATION
POND LANE PUMPING STATION
KIMBLE DRIVE PUMPING STATION
DEER RUN LANE PUMPING STATION
KING ROAD PUMPING STATION
SCHUYLKILL
VALLEY FORGE STATE PARK
BUCHART - HORN

Appendix D. List of NPDES permit holders discharging into the Valley Creek drainage--PA DEP computer file

HIERARCHIAL NUMBER + SIDE	ADMINISTRATIVE FILE NUMBER / STREAM CODE / FACILITY NUMBER	NAME / STREAM NAME / FACILITY NAME	ESTABLISHMENT NAME / COUNTY / PROGRAM	NPDES # / MUNICIPALITY / OPER STAT	SIC / REGION / BASIN
1-031-059-000-000-00-00-00-00-0-OR	30339	CAMILLA HALL	SERVANTS OF IMM HEART OF	PA0036251	0211
	00991	TB VALLEY CREEK	CHESTER	EAST WHITELAND TWP.	NORRISTOWN
	00065837	CAMILLA HALL-18" SEWER	SN	01	03F
	30342	GREAT VALLEY HIGH S	PAOLI AREA SCHOOL DIST	PA0031739	8211
	00991	TB VALLEY CREEK	CHESTER	EAST WHITELAND TWP.	NORRISTOWN
	00065841	GREAT VALLEY HS-OUTFALL	SN	01	03F
	30343	MALVERN TRAILER COURT	MALVERN COURTS INC	PA0034100	6515
	00991	TB VALLEY CREEK	CHESTER	EAST WHITELAND TWP.	NORRISTOWN
	00065843	MALVERN TRAILER CT PK-OUTFALL	SN	01	03F
1-031-059-005-000-00-00-00-00-0-OR	30278	BISHOP TUBE CO	BISHOP TUBE CO		3317
	00995	L VALLEY CREEK	CHESTER	EAST WHITELAND TWP.	NORRISTOWN
	00071212	BISHOP TUBE-OUTFALL	IW	01	03F
	02208	FORMAL AFFAIRS	FORMAL AFFAIRS	PA0054941	9999
	00995	UNT L VALLEY CK	CHESTER	WILLISTOWN TWP.	NORRISTOWN
	00008459	FORMAL AFFAIRS-DP 001	IW	02	03F
	30338	IMMACULATA COLLEGE	SERVANTS OF IMM HEART OF	PA0050555	8221
	00995	L VALLEY CREEK	CHESTER	EAST WHITELAND TWP.	NORRISTOWN
	00065835	IMMACULATA-6"PIPE OUTFALL	SN	01	03F
	49790	NORWOOD INDUSTRIES	NORWOOD INDUSTRIES INC		4930
	00995	L VALLEY CREEK	CHESTER	EAST WHITELAND TWP.	NORRISTOWN
	00068577	NORWOOD-DITCH	IW	01	03F
	49486	SUN OIL MALVERN TERM	MONTOUR AUTO SERVICE	PA0038903	2911
	00995	TB L VALLEY	CHESTER	EAST WHITELAND TWP.	NORRISTOWN
	00071210	SUN OIL-RUNOFF	IW	01	03F

Appendix E. Valley Creek station descriptions, at the time of fish collections, done by Penn State personnel.

Station No. 1 Valley Creek 300m above the mouth (VAFO)

Date	13 July 1987
Water	slightly turbid
Vegetation	none
Width	8-10m
Bottom	boulder-rubble-cobble-some gravel
Current	riffle-run-pool
Shore	open
Depth of capture *	0-1.5m
Depth of water	0-1.5m
Method of capture	10' x 5' x 1/8" seine
Time of effort	1125-1205
Dissolved Oxygen	riffle 10 mg/l, pool 9.2 mg/l
Temperature	21.7°C
pH	8.35
Gradient	6.25m/km

Station No. 2 Valley Creek 200m above the historical mill dam (VAFO)

Date	13 July 1987
Water	slightly turbid
Vegetation	*Elodea*, *Potamageton*
Width	10-12m
Bottom	gravel-sediment
Current	pool
Shore	wooded
Depth of capture	0-2.0m
Depth of water	0.2.0m
Method of capture	10' x 5' x 1/8" seine
Time of effort	1310-1340
Dissolved Oxygen	11 mg/l
Temperature	22.7°C
pH	8.1
Gradient	6.25m/km

Station No. 3 Valley Creek at the footbridge along Rt. 252 (VAFO)

Date	13 July 1987
Water	clear
Vegetation	*Elodea*
Width	10m
Bottom	gravel-rubble-cobble-some boulder
Current	riffle-run
Shore	wooded
Depth of capture	0-1.0m
Depth of water	0-1.0m
Method of capture	DC electroshocker
Time of effort	1400-1430
Dissolved Oxygen	11 mg/l
Temperature	22.9°C
pH	8.06
Gradient	1.72m/km

Station No. 4 Valley Creek at Wilson Rd. bridge (VAFO)

Date	13 July 1987
Water	clear
Vegetation	*Elodea*
Width	8-10m
Bottom	boulder-cobble-gravel
Current	riffle-run-pool
Shore	wooded-some open
Depth of capture	0-1.0m
Depth of water	0-1.0m
Method of capture	DC electroshocker
Time of effort	1550-1625
Dissolved Oxygen	10.4 mg/l
Temperature	23.3°C
pH	8.0
Gradient	5.88m/km

Station No. 5 Little Valley Creek at Mill Rd. bridge

Date	14 July 1987
Water	clear
Vegetation	none
Width	3-5m
Bottom	cobble-gravel-rubble
Current	riffle-run-pool
Shore	wooded
Depth of capture	0-0.75m
Depth of water	0-0.75m
Method of capture	DC electroshocker
Time of effort	1010-1035
Dissolved Oxygen	9.7 mg/l
Temperature	18.7°C
pH	7.0
Gradient	6.89m/km

Station No. 6 Valley Creek at Mill Rd. bridge

Date	14 July 1987
Water	cloudy
Vegetation	none
Width	8-10m
Bottom	boulder-rubble-gravel
Current	riffle-run-pool
Shore	wooded
Depth of capture	0-1.0m
Depth of water	0-1.0m
Method of capture	DC electroshocker
Time of effort	1110-1135
Dissolved Oxygen	8.5 mg/l
Temperature	20.7°C
pH	8.17
Gradient	5m/km

Station No. 7 Valley Creek at Church Rd.

Date	14 July 1987
Water	clear
Vegetation	none
Width	5m
Bottom	gravel-cobble
Current	riffle-run-pool
Shore	wooded
Depth of capture	0-1.5m
Depth of water	0-<1.5m
Method of capture	DC electroshocker
Time of effort	1210-1235
Dissolved Oxygen	8.8 mg/l
Temperature	18.6°C
pH	7.92
Gradient	4.17m/km

Station No. 8 Valley Creek at Mill Lane

Date	14 July 1987
Water	muddy (rain)
Vegetation	duckweed, watercress
Width	5m
Bottom	boulder-gravel-mud
Current	run-riffle-pool
Shore	wooded
Depth of capture	0-1.0m
Depth of water	0-1.0m
Method of capture	10' x 5' x 1/8" seine
Time of effort	20 min
Dissolved Oxygen	8.1 mg/l
Temperature	20.0°C
pH	7.81
Gradient	3.28m/km

Appendix E. (continued, page 5 of 7)

Station No. 9 Trout Creek at Rt. 23 bridge

Date	16 June 1988
Water	clear
Vegetation	none
Width	1-3m
Bottom	gravel-sand
Current	riffle-run-pool
Shore	wooded
Depth of capture	0-0.5m
Depth of water	0-0.5m
Method of capture	10'x5'x 1/8" seine
Time of effort	0800-0825
Dissolved Oxygen	8.1 mg/l
Temperature	18.4°C
pH	7.77
Gradient	3.57m/km

Station No. 10 Pickering Ck. at Charlestown Rd

Date	8 July 1987
Water	clear
Vegetation	*Elodea*
Width	5-10m
Bottom	silt-gravel-some rubble
Current	riffle-run-pool
Shore	wooded
Depth of capture	0-0.75m
Depth of water	0-0.75m
Method of capture	10'x 5'x 1/8" seine
Time of effort	1515-1545
Dissolved Oxygen	9.6 mg/l
Temperature	20.7°C
pH	7.59
Gradient	6.13m/km

Station No. 11 French Ck. along Daisy Point Road just upstream of the intersection with Sheeder Rd., Chester Co.

Date	8 July 1987
Water	clear
Vegetation	*Potamageton, Elodea*
Width	10-15m
Bottom	cobble-rubble, some bedrock
Current	riffle-run-pool
Shore	wooded
Depth of capture	0-1.25m
Depth of water	0-1.25m
Method of capture	5' x 10' x 1/8" seine
Time of effort	1325-1410

Station No. 12 East Branch of Perkiomen Creek at bridge on Salfordville Rd., Montgomery Co.

Date	8 July 1987
Water	muddy-turbid
Vegetation	filamentous algae
Width	10-12m
Bottom	cobble-rubble-mud
Current	riffle-run-pool
Shore	open/wooded
Depth of capture	0-1.25m
Depth of water	0-1.25m
Method of capture	5' x 10' x 1/8" seine
Time of effort	1010-1100

Station No. 13 Swamp Creek along Rt. 29 just above confluence with Perkiomen Creek, Montgomery Co.

Date	8 July 1987
Water	clear
Vegetation	algae
Width	20-25m
Bottom	rubble-boulder-bedrock
Current	riffle-run-pool
Shore	wooded
Depth of capture	0-1.0m
Depth of water	0-1.0m
Method of capture	5' x 10' 1/8" seine
Time of effort	1715-1750

Appendix E. (continued, page 7 of 7)

Station No. 14 Ridge Valley Creek at bridge on Perkiomenville Rd., Montgomery Co.

Date	9 July 1987
Water	clear
Vegetation	*Elodea, Potamageton*
Width	8-15m
Bottom	rubble-boulder-bedrock
Current	riffle-run-pool
Shore	wooded-some open
Depth of capture	0-1.25m
Depth of water	0-1.25m
Method of capture	DC electroshocker
Time of effort	0900-0940

* Depth of capture is the range of depths at which fishes and macroinvertebrates were collected

Appendix F. Water quality data from selected Valley Creek stations collected 14 July 1987 by Penn State personnel.

	Station No.					
Parameter (mg/l)	1	3	4	5	6	8
NO_3-N	1.65	1.85	2.00	2.15	2.15	2.10
NH_3-N	0.100	0.100	0.120	0.010	0.220	0.045
Total phosphates	0.046	0.042	0.044	0.020	0.047	0.047
Cu	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Ni	0.001	0.002	0.005	0.004	0.005	0.004
Mn	0.01	0.02	0.01	0.01	0.02	0.02
Pb	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Appendix G. Results of coliform testing completed by the Chester County Health Department on 21 August 1987 from samples collected by Penn State personnel.

Station	Fecal coliform (MPN/100 ml)	Fecal streptococci (MPN/100 ml)	coliform/strep***
1	36,000	260	138
2	29,000	360	81
3	29,000	3,000	9.7
4	29,000	570	51
5	14,700	780	19
6	40,000	710	56
7	25,000	890	28
8a*	10,200	650	16
8b*	9,000	590	16
9**	30,000	6,000	5
10	21,000	1,030	20

* Stations 8a and 8b are upstream and downstream, respectively of a potential sewage source at Mill Lane.

** Water samples were collected at Jennifer Lane while fish and macroinvertebrates were collected 5.5 km downstream at the Rt. 23 bridge.

*** When dividing fecal coliform by fecal *Streptococcus*, a value greater than 2 indicates human contamination.

MPN is most probable number, a statistical estimate of the bacterial particles in a sample.

Appendix H. Water quality data collected by the Chester County Health Department, 1981-1985.

ID	ID number for the Chester County Health Department
DO	dissolved oxygen (mg/l)
coli.	coliforms (parts/100ml)
strept.	*Streptococcus* (parts/100ml)
spec. cond.	specific conductivity (umhos)
NH_3N	(mg/l) nitrogen as ammonia
$(NO_3\text{-}NO_2\text{-}N)/(NO_2\text{-}N)$	(unitless) nitrogen as nitrates and nitrites divided nitrogen as nitrites
Ortho PO_4-P	(mg/l) phosphorus as orthophosphates
Total PO_4-P	(mg/l) phosphorus as total phosphates
Cl-	(mg/l) choride ions
TKN	total Kjeldahl nitrogen (mg/l)
TDS	total dissolved solids
TSS	total suspended solids
COD	chemical oxygen demand (mg/l)
hard.	hardness $CaCO_3$ (mg/l)
Alk.	alkalinity $CaCO_3$ (mg/l)
Fe	Iron (mg/l)
Mn	Manganese (mg/l)
Na	Sodium (mg/l)
Zn	Zinc (mg/l)
Ca	Calcium (mg/l)
K	Potassium (mg/l)
Cd	Cadmium (mg/l)
Mg	Magnesium (mg/l)
F	Fluoride (mg/l)

Table Ha. (Page 1 of 10) Valley Creek at Morehall Rd. Chester County Health Department

Date	ID	pH	DO	Temp°C air	Temp°C water	Fecal Coli.	Fecal Strept	Total Coli.	Spec. Cond.	NH_3N	TKN	NO_3-NO_2-N NO_2-N	Orth PO_4-P	Total PO_4-P	Cl-
6/18/81	26825	7.8	19.8	25	18	1110	4800	2800	469	0.06	0.63	1.9	0.05	0.05	43.4
10/1/81	27872	7.6	5.1	13	13	*	590	530	749	0.98	1.28	1.61	0.02	0.02	88
1/26/82	28561	7.5	10.7	<0	0	110	70	190	749 L 440 F	0.58	0.74	2.4	<0.01	0.05	87.2
5/20/82	29422	7.8	7.7	24	15	940	470	4300	689	0.75	0.95	*2.26*	0.06 0.06	0.07	84.8
8/23/82	30540	7.6	7.2	23	15	900	400	10700	753 L 630 F	003	0.88	3.44	0.03	0.03	89.3
1/20/83	31651	7.11	9.6	-8	0	20	150	170	788 L 510 F	0.88	0.97	*2.5* <0.01	0.03	0.07	43.3
6/9/83	32683	7.5	8.4	17	13	670	160	2300	638 L 420 F	0.93	0.93	*2.33* 0.05	0.03	0.03	60.5
8/25/83	33793	7.6	6.2	21	15	900	660		810 L 680 F	1.23	1.23	*1.9* 0.04	0.01	0.01	92
3/26/84	35110	8.5	12	47°F	10	70	**		575 L 470 F	0.63	0.77	*2.10* <.01	0.02	0.03	60.2
6/6/84	35615	7.7	10.2	28	15	390	300		385 L 519 F	<0.01	0.20	*2.77* <0.01	<0.01	<0.01	36
8/30/84	36460	7.6	7.3	23.5	16.5	1990	980		693 L 700 F	1.19	1.24	*2.28* 0.05	<0.01	0.02	68.5
4/8/85	37493	7.9	120	8	6.5	60	20		781.2 L 500 F	1.2	0.04	*2.15* 0.02	0.04	0.09	89.28
8/5/85	38381	7.75	7.4	23	11	300	390		777.6 L	1.06	0.41	*1.82* 0.01	0.03	0.03	101.9
10/31/85	39155	7.98	12.2	14	6.2	20	50		720 L 545 F	0.55	0.33	*3.73* 0.01	0.02	0.02	83.2

* Dilution not high enough.
** Low dilution (below detectable levels)
L = Lab
F = Field

Table Ha. (Page 2 of 10) Valley Creek at Morehall Rd. Chester County Health Department (cont.)

ID	SO_4	TDS	TSS	COD	Hard.	Alk.	Fe	Mn	Na	Zn	K	Cd	F
28625	51.3	312.5	76.5	13.9	242	175	0.97	0.14	25	<0.02	3.5	<0.0	
27872	42	460	0.5	30	270	246	<0.12	0.06	68	<0.02	4.9	<0.0	
28561	47*	431	7.5	<5.0	268	206	<0.12	<0.05	43.4	<0.02	4.0	<0.0	
29472	43	509	6.5	<5.0	287	214	<0.12	<0.05	62.5	<0.02	5.2	<0.0	
30540	43	381	1.5	<5.0	313	217	0.10	0.10	59.4	<0.02	5.0	<0.0	
31651	40	433	3.0	120	280	221	<0.12	<0.05	62.5	<0.02	18.0	<0.0	
32683	17	265	7.0	<5.0	236	188	0.30	<0.05	48	<0.02	4.48	<0.0	
33793	33	438	<0.5	<5.0	285	352	0.23	<0.05	77.5	<0.02	12.0	<0.0	
35112	33	375	<0.5	<5.0	219	33	0.8	0.05	76.8	<0.02	3.9	<0.01	0.069
35615	24.0	222	3.0	<5.0	166.6	19.0	0.185	<0.05	30.25	<0.02	9.5	<0.01	0.430
36460	34	361	11.0	<5.0	239.3	194.0	0.14	0.05	58.8	<0.02	4.9	<0.01	0.098
37493	40.0	394	2.0	<5.0	256.66	233.0	0.13	0.05	96.5	<0.02	3.12	<0.025	0.054
38381	43.0	377	2.0	<5.0	276.07	226.0	<0.12	0.13	75.0	<0.02	3.7	<0.025	0.089
39155	44	406	5.5	<5.0	230	210	<0.12	<0.05	55.5	<0.02	15.0	<0.025	0.057

Table Hb. (Page 3 of 10) Valley Creek at Mill Rd. Chester County Health Department

Date	ID	pH	DO	Temp°C air	Temp°C water	Fecal Coli.	Fecal Strept	Total Coli.	Spec. Cond.	NH_3N	TKN	NO_3-NO_2-N / NO_2-N	Ortho PO_4-P	Total PO_4-P	Cl-
6/18/8	126824	7.8	19.6	23	18	2800	5000	4300	519	0.08	0.59	1.7	0.05	0.05	42.3
10/1/81	27874	8.25	5.3	12	13	20	1630	250	546	<0.01	0.28	1.77	0.02	0.02	43.5
1/26/82	28562	7.85	14.2	<0	0	1320	1190	2200	583 L 280 F	0.13	0.34	2.1	<0.01	0.03	46.7
5/26/82	29427	8.05	10	23	15	960	760	4000	530 L 480 F	0.12	0.37	*2.01* 0.05	0.03	0.03	41.4
8/23/82	30541	7.6	9.4	22	15	690	890	14000	615 L 525 F	<0.01	0.22	2.50	<0.01	0.03	53.6
1/20/83	31652	7.2	13.2	-9	0	300	1410	710	563 L 275 F	0.22	0.22	*2.23* 0.01	<0.01	0.02	
6/9/83	32684	7.7	9.3	14	14	800	290	2800	538 L 450 F	0.13	0.37	*2.2* 0.05	0.01	0.02	41.3
8/25/83	33794	8.3	9.6	20	19	2300	800		500 L 310 F	0.02	0.07	*2.03* <0.01	<0.01	<0.01	38
3/26/84	35113	8.4	11.6	45°F	9	100	**		529 L 445 F	0.13	0.13	*1.99* <0.01	<0.01	0.01	39.5
6/6/84	35616	7.9	11.2	27	15.5	1800	219		429 L 500 F	<0.01	0.19	*2.68* <0.01	<0.01	<0.01	40
8/30/84	36458	8.0	9.7	24.5	17.5	11500	1130		539 L 550 F	0.03	<0.05	*2.07* <0.01	<0.01	0.02	38.3
4/8/85	37491	8.6	13	6.5	6.5	10	<0.4		567 L 435 F	0.01	<0.01	*1.77* <0.01	0.02	0.04	61.5
8/5/85	38382	8.20	10.3	22.5	13.25	550	660		540.6 L	0.04	0.40	*1.61* <0.01	0.03	0.03	41.6

** Low dilution (below detectable levels)
L = Lab
F = Field

Table Hb. (Page 4 of 10) Valley Creek at Mill Rd. Chester County Health Department (cont.)

ID	SO_4	TDS	TSS	COD	Hard.	Alk.	Fe	Mn	Na	Zn	K	Cd	F
26824	54.8	311	58.0	19.8	256	195	0.79	0.12	30	<0.02	4.8	<0.025	<0.10
27874	46.5	326	16.3	25.5	248	194	0.25	<0.05	25	<0.02	7.1	<0.025	<0.10
28562	49*	337	17.5	<5.0	264	180	<0.12	<0.05	17.4	<0.02	4.2	<0.025	<0.10
29427	41.5	381	29	<5.0	275	185	0.18	<0.05	75	<0.02	6.4	<0.025	0.098
30541	40	299	24.5	<5.0	309	197	0.40	<0.05	19	<0.02	4.6	<0.025	0.080
31652	34	312	5.5	11.5	259	185	0.25	<0.05	31.6	<0.02	3.4	<0.01	0.080
32684	33	313	38.0	<5.0	228	183	0.50	0.14	31.0	<0.02	13.0	<0.01	0.095
33794	34	297	6.5	<5.0	240	266	<0.12	<0.05	40.0	<0.02	15.5	<0.01	0.079
35113	31	361	3.5	<5.0	229	35	0.15	0.05	30	<0.02	9.5	<0.01	0.074
35616	31	236	14.5	<5.0	156.7	24	0.55	0.10	26	<0.02	7.0	<0.01	0.180
36458	34	301	23.5	<5.0	225.8	168	0.14	<0.05	29.25	<0.02	5.1	<0.01	0.092
37491	31	301	<0.5	<5.0	220	199	0.13	<0.05	41.72	<0.02	5.64	<0.025	0.058
38382	34	282	98	<5.0	239.03	180.0	0.45	<0.05	28.5	<0.02	2.2	<0.025	0.078

Table Hc. (Page 5 of 10) Little Valley Creek at Mill Rd. Chester County Health Department

Date	ID	pH	DO	Temp°C air	Temp°C water	Fecal Coli.	Fecal Strept	Total Coli.	Spec. Cond.	NH_3N	TKN	NO_3-NO_2-N / NO_2-N	Ortho PO_4-P	Total PO_4-P	Cl-
6/9/83	32688	7.9	10.0	15	14	330	210	4600	465 L 410 F	0.01	0.13	2.86 <0.01	<0.01	0.01	44.5
8/25/83	33797	8.7	9.6	20	19	850	780		490 L 450 F	<0.01	0.06	2.59 <0.01	<0.01	<0.01	42
3/26/84	35114	8.45	12.2	46°F	9.5	40	**		477 L 400 F	0.03	0.20	2.15 <0.01	<0.01	0.01	35.7
6/6/84	35619	8.0	10.8	27	15	420	210		462 L 425 F	<0.01	0.24	2.21 0.01	<0.01	<0.01	37.6
8/30/84	36459	8.0	9.9	23	17	3100	580		484 L 480 F	<0.01	0.05	2.66 <0.01	<0.01	0.02	38.3
4/8/85	37482	8.3	13.1	6.5	6.5	30	50		111.8 L 410 F	0.41	0.38	1.77 <0.01	0.04	0.04	51.58
8/5/85	38385	8.2	11.6	25.5	13.7	270	630		540 L	0.04	0.27	1.97 <0.01	<0.01	<0.01	48.4

** Low dilution (below detectable levels)
L = Lab
F = Field

Table Hc. (Page 6 of 10) Little Valley Creek at Mill Rd. Chester County Health Department (cont.)

ID	SO_4	TDS	TSS	COD	Hard.	Alk.	Fe	Mn	Na	Zn	K	Cd	F
32688	30	262.5	3.5	<5.0	201	132	0.30	<0.05	28	<0.02	8.0	<0.01	0.19
33797	36	270	<0.5	<5.0	216	218.5	<0.12	<0.05	30.0	<0.02	5.0	<0.01	0.110
35114	28	327	3.5	<5.0	209	30.5	0.105	0.05	27.4	<0.02	5.1	<0.01	0.093
35619	28	253	15.0	<5.0	210	29	0.185	0.05	26.75	<0.02	7.0	<0.01	0.125
36459	34	277	9.0	<5.0	208.9	135	0.08	<0.05	27.9	<0.02	5.1	<0.01	0.190
37492	33	275	1.5	12.5	183.33	173	0.13	<0.05	41.32	<0.02	3.12	<0.025	0.110
38385	37.5	287	4.0	<5.0	225.57	162.5	<0.12	<0.05	32.5	<0.02	2.3	<0.025	0.24

Table Hd. (Page 7 of 10) Valley Creek at Rt. 23 Chester County Health Department

Date	ID	pH	DO	Temp°C		Fecal	Fecal	Total	Spec.			*NO_3-NO_2-N*	Ortho	Total	
				air	water	Coli.	Strept	Coli.	Cond.	NH_3N	TKN	NO_2-N	PO_4-P	PO_4-P	Cl-
6/18/81	26823	7.55	16.0	22	19	520	1360	1300	742	0.78	1.2	1.7	0.06	0.07	80.9
10/1/81	27873	8.2	5.2	11	13	20	640	1300	524	<0.01	0.04	1.72	<0.01	0.02	45.6
1/26/82	28566	7.85	15.5	<0	0	180	280	510	605 L	0.05	0.14	2.3	<0.01	0.03	48.8
									290 F						
5/20/82	29423	8.2	10.2	21	15	230	520	5000	479 L	0.08	0.3	*2.11*	0.03	0.03	42.4
									450 F			0.03			
8/23/82	30542	8.0	9.5	21	16	320	470	9000	530 L	<0.01	0.18	2.19	<0.01	0.01	45.6
									500 F						
1/20/83	31650	7.12	13.5	-8	0	110	400	400	551 L	0.13	0.15	*2.46*	<0.01	0.02	43.3
									270 F			<0.01			
6/9/83	32685	7.9	9.4	13	14	340	220	1700	482 L	0.03	0.23	*2.2*	<0.01	0.02	36.5
									410 F			0.02			
8/25/83	33795	8.3	9.7	21	19	2000	540		500 L	<0.01	0.14	*1.81*	<0.01	<0.01	42
									350 F			<0.01			
3/26/84	35115	8.3	13.1	43 F	8	20	**		426 L	<.01	<.05	*2.90*	<.01	0.01	36.7
									370 F			<.01			
6/6/84	35617	7.7	11.9	26	15	250	200		539 L	0.68	1.01	*2.08*	<0.01	<0.01	54.8
									370 F			0.01			
8/30/84	36457	8.0	10	22.5	17	7100	730		506 L	0.03	0.12	*2.01*	<0.01	0.02	32.3
									525 F			<0.01			
4/8/85	37490	8.5	13.0	7	6.5	<0.4	<0.4		541.8 L	0.01	1.37	*2.0*	0.03	0.04	37.69
									430 F			<0.01			
8/5/85	38383	8.22		21.5	13.7	350	440		529.2 L	0.01	<0.01	*1.75*	0.02	0.03	43.7
									385 F			<0.01			
10/31/85	39156	8.16	13.0	12	5.5	100	90		552.0 L	<0.01	0.25	*3.02*	<0.01	<0.01	43.7
									400 F			<0.01			

** Low dilution (below detectable levels)

L = Lab
F = Field

Table Hd. (Page 8 of 10) Valley Creek at Rt. 23 Chester County Health Department (cont.)

ID	SO_4	TDS	TSS	COD	Hard.	Alk.	Fe	Mn	Na	Zn	K	Cd	F
26823	47	397	0.25	7.5	270	230	0.29	0.05	65	<0.02	6.0	<0.025	<0.10
27873	40	301	8.3	18.5	232	179	0.18	<0.05	21	<0.02	4.2	<0.025	0.10
28566	44*	349.5	8.8	<5.0	247	161	0.2	<0.05	19.9	<0.02	1.7	<0.025	<0.10
29423	39	425	40.5	<5.0	253	166	0.5	<0.05	57.5	<0.02	8.0	<0.025	0.118
30542	34	271	4.5	<5.0	273	167	0.30	<0.05	32	<0.02	4.6	<0.025	0.093
31650	37	317	2.0	11.5	242	176	0.13	<0.05	31.6	<0.02	6.4	<0.01	0.105
32685	34	218	16.0	<5.0	224	159	0.44	<0.05	29	<0.02	13.0	<0.01	0.115
33795	25	291	5.0	<5.0	226	246	0.20	<0.05	28.75	<0.02	5.0	<0.01	0.074
35115	29	278	<.5	<5.0	160	20.5	0.75	<.05	29.6	<0.02	4.7	<.01	0.56
35617	27	323	3.5	<5.0	220	33	0.23	0.035	48.25	<0.02	13.25	<0.01	0.090
36457	32	283	28.5	<5.0	212.3	157	0.14	<0.05	27.4	<0.02	9.2	<0.01	0.100
37490	31	328	<0.5	<5.0	193	178	0.13	<0.05	38.6	<0.02	5.0	<0.025	0.066
38383	35	276	14.5	<5.0	232.3	180	0.45	<0.05	28.0	<0.02	3.0	<0.025	0.110
39156	34	307	7.5	<5.0	240	180	<0.12	<0.05	25.8	<0.02	7.4	<0.025	0.121

Table He. (Page 9 of 10) Little Valley Creek at Morehall Rd. Chester County Health Department

Date	ID	pH	DO	Temp°C air	Temp°C water	Fecal Coli.	Fecal Strept	Total Coli.	Spec. Cond.	NH_3N	TKN	NO_3-NO_2-N / NO_2-N	Ortho PO_4-P	Total PO_4-P	Cl-
6/18/81	26826	7.75	18	27	20	1160	4100	4400	360	0.02	0.26	3.6	0.05	0.03	46.8
10/1/81	27875	7.8	5.2	14	13	20	970	1200	465	<0.01	0.11	2.76	0.01	0.01	44.6
1/26/82	28563	7.85	15.1	<0°C	0°C	380	460	580	518 L	0.03	0.16	3.4	<0.01	0.03	67.5
									285 F						
5/26/82	29421	8.07	8.7	24	15	21000	51000	23000	440 L	0.13	0.11	3.06	0.03	0.01	44.5
									390 F				0.01		
8/23/82	30539	7.6	9.1	25	16	240	790	4200	456 L	0.66	0.04	3.63	0.01	0.01	55.6
									440 F						
1/20/83	31653	7.19	13.1	-6	0	90	120	140	467 L	0.1	0.11	3.61	<0.01	0.02	52.2
									238 F				<0.01		
6/9/83	32686	7.80	9.0	17	13	290	360	2800	409 L	<0.01	0.10	3.17	<0.01	0.01	42.2
									400 F				<0.01		
8/25/83	33796	8.15	8.6	21	18	1040	820		370 L	<0.01	0.07	3.84	0.02	0.02	44
									450 F				<0.01		
3/26/84	35116	8.4	12.0	48 F	11.5	10	20		472 L	<.01	0.11	2.8	<.01	<0.01	43.7
									350 F				<.01		
6/6/84	35618	7.9	10.4	29	16	490	140		506 L	0.08	0.43	2.12	<0.01	<0.01	34.5
									401 F				0.03		
8/30/84	36461	7.8	9.0	24.5	17.5	7100	1220		424 L	<0.01	<0.05	3.15	<0.01	0.01	34.3
									440 F				<0.01		
4/8/85	37494	8.4	12.2	7	6.5	40	120		478.8 L	0.02	0.19	1.85	0.03	0.04	50.59
									410 F				20.01		
8/5/85	38384	7.84	9.1	23.5	13.6	710	1600		453.6 L	0.01	0.10	2.77	0.02	<0.01	46.8
														<0.01	
10/31/85	39157	7.82	12	18	7.0	20	210		678 L	<0.01	0.10	4.76	<0.01	<0.01	43.7
									360 F				<0.01		

L = Lab
F = Field

Table He. (Page 10 of 10) Little Valley Creek at Morehall Rd. Chester County Health Department (cont.)

ID	SO_4	TDS	TSS	COD	Hard.	Alk.	Fe	Mn	Na	Zn	K	Cd	F
26826	20	218	7.0	10.0	144	91	0.12	<0.05	28	<0.02	2.7	<0.025	<0.10
27875	31	262.5	4.5	30	188	132	<0.12	<0.05	25	<0.02	2.7	<0.025	0.58
28563	35*	299	14.5	<5.0	186	111	0.35	<0.05	7.5	<0.02	<0.04	<0.025	0.792
29421	32	350	9.5	<5.0	189	110	<0.12	<0.05	75	<0.02	10.2	<0.025	0.87
30539	19	221	5.0	<5.0	206	105	0.10	<0.05	31.2	<0.02	5.0	<0.025	0.50
31653	30.5	285.5	15.25	11.5	184	115	0.13	<0.05	33.8	<0.02	5.6	<0.01	0.64
32686	28	232	7.0	<5.0	163	104	<0.12	<0.05	25	<0.02	1.93	<0.01	0.50
33796	19	206	4.0	<5.0	130	115	<0.12	<0.05	31.25	<0.02	7.5	<0.01	0.068
35116	33.5	296	1.0	<5.0	189	24.5	0.13	<.05	17.6	<0.02	5.9	<.01	0.165
35618	28	270	19.0	<5.0	220	33.0	0.27	0.035	28.25	<0.02	5.75	<0.01	0.094
36461	29	237	15.5	<5.0	158.4	108	0.08	<0.05	35.5	<0.02	16.5	<0.01	0.670
37494	25	228	<0.5	26.5	135	117	0.13	<0.05	38.6	<0.02	3.76	<0.025	0.620
38384	31	246	8.0	<5.0	178.43	120	0.18	<0.05	33.1	<0.02	0.9	<0.025	0.62
39157	34.3	282	5.0	<5.0	198.3	131.5	<0.12	<0.05	24.8	<0.02	7.0	<0.025	1.78

Appendix I. Macroinvertebrates collected on 17 November 1987 by Penn State personnel.

Station Number	1	2	3	4	5	6	7	8	9	10
Turbellaria										
Planariidae										
Cura foremannii	227	4	11	69	17	28	159	99	2	4
Nematoda	64	887	134	158	26	58	78	505		92
Annelida										14
Oligochaeta	20			1	6	9		5	3	13
Tubificidae	2			3		1				2
Diplopoda								1		1
Isopoda										
Asellidae										
Asellus	6		4	14	45	574	151	239	35	6
Amphipoda										
Gammaridae										
Gammarus	270	43	252	401	195	35	187	14	3	24
Insecta										
Plecoptera										
Capniidae										
Allocapnia										18
Taeniopterygiidae										
Strophopteryx									2	
Taeniopteryx	1								1	117
Ephemeroptera		1								
Baetidae							21			
Baetis	42		12	14	40	2	10	4	1	2
Cloeon										2
Pseudocloeon										6
Caenidae										
Caenis									1	1
Ephemerellidae	1									
Eurylophella										2
Serratella	51		76	46	466		2	1		20
Ephemeridae										
Ephemera										3
Heptageniidae										
Nixe										2
Stenacron										3
Stenonema								9		
Oligoneuridae										
Isonychia										15

Appendix I. (continued, Page 2 of 3)

Station Number	1	2	3	4	5	6	7	8	9	10
Tricorythidae										
Tricorythodes									2	5
Odonata										
Coenogrionidae									1	
Enallagma							20			
Gomphidae										
Gomphus										1
Hemiptera										
Corixidae										
Sigarra		40	98	8						
Trichocorixa	7					2				1
Veliidae										
Microvelia								1		
Homoptera sp.										1
Megaloptera										
Corydalidae										
Corydalus	1			1						
Sialidae										
Sialis	1				1					
Trichoptera										
Glossosomatidae										
Glossosoma			2		31		9			
Hydropsychidae										
Cheumatopsyche	118		8	25	6	5	15	1		21
Hydropsyche	622	16	295	758	293	139	252	2	2	102
Hydroptilidae										
Hydroptila										4
Leucotrichia										4
Limnephilidae										
Apatania										3
Philopotamidae										
Chimarra						5				
Polycentropodidae										
Cyrnellus										1
Polycentropus							1			
Phrygaenidae										
Ptilostomis										1
Psycomiidae										
Psychomyia			2							15

Appendix I. (continued, Page 3 of 3)

Station Number	1	2	3	4	5	6	7	8	9	10
Lepidoptera										
Noctuidae										
Simyra	1		1						1	
Pyralidae										
Petrophila										1
Coleoptera			1							
Dytiscidae										1
Elmidae	125	1	73	65	19	8	79	7	2	5
Dubiraphia		2	1	1			1	2		28
Optioservus	235	2	98	187	308	64	351	75	2	4
Stenelmis	37	1	27	10	4	19	2	7	1	
Hydrophilidae										
Berosus									1	5
Psephenidae										
Psephenus	5	1	1			1				
Diptera						1				
Athericidae										
Atherix								1		
Chironomidae	257	347	136	383	293	93	145	423	28	74
Culicidae										
Anopholes		1								
Psychodidae										
Pericoma			1						1	
Simuliidae										
Prosimulium				2						7
Simulium								1		
Tabanidae										
Chrysops		2					1			
Tipulidae										
Antocha	124	4	40	173	52	109	52		11	9
Tipula					3		2		1	1
Gastropoda	1	1	27			2		1	5	48
Ancylidae				3						66
Pelecypoda							1			9
No. of Specimens	2218	1353	1298	2324	1805	1155	1539	1398	106	764
No. of Species	23	16	21	21	17	19	21	20	21	45
Diversity Index	2.26	0.98	2.25	2.02	2.03	1.73	2.2	1.56	1.96	2.83

Appendix J. Fishes collected July 1987 by Penn State personnel.

Station No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Anguilla rostrata													1	9
Oncorynchus mykiss	1										5			
Salmo trutta			2	7	37+	6	79+	7			3			
Esox americanus											2			
Cyprinella analostana		2								21	1			
Cyprinella spiloptera												5	16	9
Cyprinus carpio													1	
Exoglossum maxillingua						2				7	3		8	6
Luxilus cornutus										12	19	149		1
Margariscus margarita								34						
Notemigonus crysoleucus										2			1	
Notropis amoenus										1				4
Notropis hudsonius	4									40	3	16	12	45
Notropis procne										2			1	
Pimephales promelas		2												
Rhinichthys atratulus			13	33	36	7	2	3	3	21	6	1		1
Rhinichthys cataractae	2		1	2	1	5				9		2	4	
Semotilus atromaculatus								2		21				2
Semotilus corporalis										1	15		5	6
Catostomus commersoni	1	52	18	12	3	12	11	5	4	10	1		10	57
Erimyzon oblongus												5		
Ameirus natalis												1		1
Fundulus diaphanus												7		
Ambloplites rupestris		1	3			1				14	10	16	16	23
Lepomis auritus											2	11	53	19
Lepomis cyanellus				1		1			1	1	1	11	10	1
Lepomis gibbosus						2	2	12		7	3	14	1	12
Lepomis macrochirus							3			65	15			
Micropterus dolomieui										12	2	6	7	30
Micropterus salmoides										12	1		2	6
Pomoxis nigromaculatus														1
Etheostoma olmstedi		34	13	2		1				10	3		1	8
Percina peltata		1												
No. of Specimens	9	91	50	57	77	37	97	63	8	271	97	244	149	241
No. of Species	5	5	6	6	4	9	5	6	3	20	19	13	17	19
Diversity Indices	0.99	0.83	1.29	1.08	0.83	1.57	0.62	1.21	0.7	2.37	2.23	1.45	2.02	2.21

Appendix K. Field measurements of gamefishes collected July 1987 by Penn State personnel.

Station	Fish Species	Length (cm)	Weight (g)
1	*Oncorynchus mykiss*	33	370
2	*Ambloplites rupestris*	15	85
3	*Salmo trutta*	8	*
		30	*
	Abloplites rupestris	15	90
		16	90
		8	60
4	*S. trutta*	23	100
		25	170
		30	300
		24	160
		20	100
		25	*
		10	18
5	*S. trutta*	29	280
		27	240
		25	230
		20	70
		22	90
		19	90
		22	90
		5-8	(over 30 this size)*
6	*S. trutta*	20	70
		5-10	(five this size)*
	A. rupestris	18	160
	Lepomis gibbosus	14	60
		13	6
	Lepomis cyanellus	11	30
7	*S. trutta*	25	210
		13	20
		10	10
		37	400
		27	210
		24	160
		11	15
		10	10
		38	400
		5-13	(over 70 this size)*
	L. macrochirus	11	22
		12	40
	L. gibbosus	11	30
		9	18
	S. trutta	5-12	(seven this size)*
	L. gibbosus	4-8	(12 this size)*

* These individuals escaped before measurements could be made.

Appendix L. Jaccard similarity coefficients for macroinvertebrates collected November 1987 by Penn State personnel.

Station No.	2	3	4	5	6	7	8	9	10
1	0.414	0.586	0.586	0.577	0.654	0.467	0.469	0.452	0.291
2		0.5	0.444	0.360	0.500	0.423	0.379	0.310	0.185
3			0.571	0.625	0.519	0.615	0.500	0.483	0.255
4				0.560	0.519	0.556	0.500	0.344	0.327
5					0.500	0.762	0.481	0.462	0.255
6						0.444	0.500	0.379	0.294
7							0.483	0.414	0.250
8								0.333	0.250
9									0.283

Appendix M. Jaccard similarity coefficients for fishes collected July 1987 by Penn State personnel.

Stat	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0.111	0.222	0.222	0.286	0.167	0.111	0.100	0.143	0.190	0.200	0.125	0.158	0.009
2		0.375	0.222	0.125	0.272	0.111	0.100	0.143	0.190	0.200	0.059	0.158	0.143
3			0.714	0.667	0.667	0.375	0.333	0.286	0.238	0.250	0.188	0.211	0.190
4				0.667	0.667	0.375	0.333	0.500	0.238	0.250	0.188	0.211	0.190
5					0.444	0.500	0.426	0.400	0.143	0.150	0.133	0.105	0.095
6						0.400	0.364	0.333	0.381	0.400	0.294	0.368	0.333
7							0.571	0.333	0.190	0.263	0.125	0.100	0.143
8								0.286	0.182	0.190	0.118	0.095	0.190
9									0.150	0.158	0.143	0.111	0.158
10										0.625	0.320	0.542	0.560
11											0.333	0.440	0.520
12												0.364	0.455
13													0.565

Appendix N. Historical fish collections currently catalogued in the Penn State Fish Museum, collected by Dr. E. L. Cooper, Professor Emeritus of Zoology at Penn State.

Collection #828 Valley Creek 2 mi. SE of Devault, Chester Co., 19 August 1969

Rhinichthys atratulus	7 at 1-3"
Semotilus atromaculatus	4 at 2"
Catostomus commersoni	7 at 2-10"

Collection #736 Pickering Creek 3 mi. SW of Phoenixville, PA, 19 August 1969

Exoglossum maxillingua	2
Cyprinella analostana	1
Cyprinella spiloptera	3
Rhinichthys cataractae	1
Semotilus corporalis	6
Catostomus commersoni	1
Noturus insignis	7
Ambloplites rupestris	3
Lepomis gibbosus	8
Lepomis macrochirus	8
Micropterus dolomieui	4
Etheostoma olmstedi	2
Percina peltata	3

Collection #1383 Unami Creek, Montgomery Co., tributary to Perkiomen Creek, 31 March 1971

Exoglossum maxillingua	3
Luxilus cornutus	2
Notropis hudsonius	1
Rhinichthys atratulus	4
R. cataractae	3
Pimephales notatus	1
Semotilus corporalis	16
Catostomus commersoni	1
Noturus insignis	1
Lepomis auritus	3
Micropterus dolomieui	1
Etheostoma olmstedi	10

Collection #1379 Northeast Branch Perkiomen Creek, Montgomery Co., PA, 31 March 1971

Cyprinella spiloptera	2
Cyprinus carpio	1
Exoglossum maxillingua	33
Luxilus cornutus	4
Notropis hudsonius	1
Notropis procne	3
Pimephales notatus	22
Catostomus commersoni	4
Ameiurus natalis	1
Fundulus diaphanus	6
Lepomis auritus	6
Lepomis cyanellus	4
Etheostoma olmstedi	12

Collection #1265 Skipjack Creek at Rt. 422, Montgomery Co., (tributary to Perkiomen Creek), 31 March 1971

Exoglossum maxillingua	14
Cyprinella spiloptera	5
Luxilus cornutus	6
Notemigonus crysoleucas	1
Notropis amoenus	4
Notropis hudsonius	1
Notropis procne	11
Pimephales notatus	10
Rhinichthys atratulus	21
R. cataractae	2
Catostomus commersoni	6
Ameriurus natalis	1
Fundulus diaphanus	17
Lepomis cyanellus	1
Etheostoma olmstedi	17

Collection #880 Swamp Creek, 1 mile above mouth, Montgomery Co., tributary to Perkiomen Creek, 8 July 1969

Cyprinella spiloptera	1
Cyprinus carpio	1
Exoglossum maxillingua	1
Notemigonus crysoleucas	1
Catostomus commersoni	2
Anguilla rostrata	1
Lepomis auritus	8
Lepomis cyanellus	3
Lepomis gibbosus	5
Micropterus dolomieui	3
Micropterus salmoides	1

Collection #658 French Creek at Kimberton Farm School, Chester Co., 18 April 1969

Anguilla rostrata	5
Salmo trutta	2
Cyprinella analostana	5
Exoglossum maxillingua	63
Luxilus cornutus	19
Notropis hudsonius	1
Pimephales notatus	1
Rhinichthys atratulus	2
Rhinichthys cataractae	1
Semotilus atromaculatus	1
Semotilus corporalis	17
Catostomus commersoni	X
Noturus insignis	24
Ambloplites rupestris	18
Lepomis auritus	8
Micropterus dolomieui	5
Etheostoma olmstedi	29
Percina peltata	4

Collection #735 South Branch French Creek, Chester Co., 19 August 1969

Exoglossum maxillingua	55
Cyprinella analostana	96
Luxilus cornutus	91
Notropis hudsonius	3
Notropis procne	20
Rhinichthys atratulus	48
Notropis cataractae	3
Semotilus atromaculatus	11
Notropis corporalis	7
Catostomus commersoni	62
Noturus insignis	37
Anguilla rostrata	4
Ambloplites rupestris	14
Lepomis auritus	26
Lepomis gibbosus	2
Lepomis macrochirus	2
Micropterus dolomieui	2
Etheostoma olmstedi	141

Collection #734 French Creek at Knauertown, Chester Co., 19 August 1969

Salmo trutta	2
Clinostomus funduloides	9
Cyprinella analostana	27
Exoglossum maxillingua	70
Luxilus cornutus	81
Notropis hudsonius	16
Notropis procne	14
Rhinichthys atratulus	263
Rhinichthys cataractae	57
Semotilus atromaculatus	1
Semotilus corporalis	13
Catostomus commersoni	62
Noturus insignis	37
Anguilla rostrata	9
Ambloplites rupestris	2
Lepomis cyanellus	4
Lepomis macrochirus	1
Micropterus salmoides	2
Etheostoma olmstedi	81
Percina peltata	29

Collection #733 Pine Creek, Chester Co., tributary to French Creek, 18 August 1969

Salmo trutta	2
Salvelinus fontinalis	1
Esox americanus	2
Clinostomus funduloides	203
Exoglossum maxillingua	39
Notropis cornutus	79
Rhinichthys atratulus	101
Rhinichthys cataractae	1
Semotilus atromaculatus	1
Rhinichthys corporalis	82
Catostomus commersoni	38
Noturus insignis	1
Anguilla rostrata	11
Lepomis cyanellus	3
Lepomis gibbosus	2
Etheostoma olmstedi	64

Appendix O. Common names of the fishes collected and listed in historical collections.

Anguilla rostrata	American eel
Oncorynchus mykiss I	rainbow trout
Salmo trutta E	brown trout
Esox americanus americanus	redfin pickeral
Cyprinella analostana	satinfin shiner
Cyprinella spiloptera	spotfin shiner
Cyprinus carpio E	common carp
Exoglossum *maxillingua*	cutlips minnow
Luxilus cornutus	common shiner
Margariscus margarita	pearl dace
Notemigonus crysoleucus	golden shiner
Notropis amoenus	comely shiner
Notropis hudsonius	spottail shiner
Notropis procne	swallowtail shiner
Pimephales notatus	bluntnose minnow
Pimephales promelas	fathead minnow
Rhinichthys atratulus	blacknose dace
Rhinichthys cataractae	longnose dace
Semotilus atromaculatus	creek chub
Semotilus corporalis	fallfish
Catostomus commersoni	white sucker
Erimyzon oblongus	creek chubsucker
Ameiurus natalis	yellow bullhead
Noturus insignis	margined madtom
Fundulus diaphanus	banded killifish
Ambloplites rupestris I	rock bass
Lepomis auritus	redbreast sunfish
Lepomis cyanellus I	green sunfish
Lepomis gibbosus	pumpkinseed
Lepomis macrochirus I	bluegill
Micropterus dolomieui I	smallmouth bass
Micropterus salmoides I	largemouth bass
Pomoxis nigromaculatus I	black crappie
Etheostoma olmstedi	tessalated darter
Percina peltata	shield darter

I=introduced; E=exotic

Note: For the purposes of this table, an introduced fish species is one that does not naturally occur in its recorded drainage, rather, it was transplanted there from within North America. Exotic fish species are also transplanted but come from other continents, i.e. the brown trout is originally from Europe. Original ranges of fishes were taken Lee et al. 1980. All those unmarked are within their native ranges.

Appendix P. Results of small mammal trapping by Penn State personnel on 16-17 July 1987.

Site	Date	Trap 1	Trap 2	Trap 3	Trap 4	Trap 5
1	7/16/87	P.m.		P.m.		
	7/17/87			P.m.		
2*	7/16/87	X	X	X	X	X
	7/17/87	X	X	X	X	X
3	7/16/87					
	7/17/87		P.m.	X		
4	7/16/87		M.p.			
	7/17/87					
5	7/16/87			P.m.	P.m.	
	7/17/87	P.l.		P.m.	M.p.	
6	7/16/87	P.l.			P.m.	P.m.
	7/17/87	P.l.			P.m.	P.m.
7	7/16/87		X	M.p.		
	7/17/87		M.p.			
8	7/16/87		M.p.	P.m.		P.m.
	7/17/87					

P.l. - *Peromyscus leucopus*, white-footed mouse; P.m. - *Peromyscus maniculatus*, deer mouse; M.p. - *Microtus pennsylvanicus*, meadow vole; X - sprung trap (not a trap night)

* - At this site, on both nights, all the traps were sprung and not in their origional locations. Total trap nights = 68

Appendix Q. Woody vegetation identified by Penn State personnel during summer 1987.

1. Valley Creek at Washington's Headquarters

Acer saccharum, silver maple
Acer negundo, ashleaf maple (boxelder)
Juglans nigra, black walnut
Morus alba, white mulberry
Platanus occidentalis, sycamore
Robinia hispida, bristly locust
Salix spp., willow
Tilia americana, basswood
Ulmus americana, American elm
Vitis spp., wild grape

2. Valley Creek 200m above Mill Dam

Acer negundo, ashleaf maple (boxelder)
Acer saccharum, silver maple
Cercis canadensis, eastern redbud
Juglans nigra, black walnut
Liriodendron tulipifera, tulip-tree
Morus rubra, red mulberry
Paulownia tomentosa, princess-tree
Prunus serotina, black cherry
Rhus glabra, smooth sumac
Robinia hispida, bristly locust
Ulmus americana, American elm

3. Valley Creek at footbridge along Route 252

Acer negundo, ashleaf maple (boxelder)
Acer saccharum, sugar maple
Betula nigra, river birch
Forsythia viridissima, forsythia
Hamamelis virginia, witch hazel
Liriodendron tulipifera, tulip-tree
Parthenocissus quinquefolia, Virginia creeper
Platanus occidentalis, sycamore
Quercus velutina, black oak
Tilia americana, American basswood
Ulmus americana, American elm
Ulmus rubra, slipper elm
Viburnum acerifolium, mapleleaf viburnum

4. Valley Creek at Wilson Road bridge

Acer negundo, ashleaf maple (boxelder)
Acer platanoides, Norway maple
Fraxinus pennsylvania var. *subintegerrima*, green ash
Lonicera morrowi, morrow honeysuckle
Morus rubra, red mulberry
Platanus occidentalis, sycamore
Prunus serotina, black cherry
Robinea pseudo-acacia, black locust
Rosa multiflora, multiflora rose
Salix spp., willow
Juglans nigra, black walnut
Ulmus americana, American elm
Vitis spp., wild grape

5. Little Valley Creek at Mill Road Park

Acer negundo, ashleaf maple (boxelder)
Lonicera tatarica, tartarian honeysuckle
Morus rubra, red mulberry
Platanus occidentalis, sycamore
Prunus virginiana, choke cherry
Robinia hispida, bristly locust
Rhus glabra, smooth sumac
Rubus occidentalis, black raspberry
Salix spp.,willow
Juglans nigra, black walnut
Ulmus americana, American elm
4 spp., wild grape
1 exotic (unknown)

6. Valley Creek at Mill Road

Acer negundo, ashleaf maple (boxelder)
Acer saccharum, silver maple
Betula nigra, river birch
Crataegus spp., hawthorn
Fraxinus pennsylvania var. *subintegerrima*, green ash
Lindera benzoin, spicebush
Liriodendron tulipifera, tulip-tree
Lonicera morrowi, morrow honeysuckle
Juglans nigra, black walnut
Parthenocissus quinquefolia, Virginia creeper
Platanus occidentalis, sycamore
Robinia pseudo-acacia, black locust
Rosa multiflora, multiflora rose
Salix spp., willow
Vitis spp., wild grape

7. Valley Creek at Church Road

Acer negundo, ashleaf maple (boxelder)
Acer platanoides, Norway maple
Cercis canadensis, eastern redbud
Fraxinus pennsylvania var. *subinteggerima*, green ash
Ligustrum obtusifolium, regal privet
Lindera benzoin, spicebush
Juglans nigra, black walnut
Platanus occidentalis, sycamore
Prunus serotina, black cherry
Robinia pseudo-acacia, black locust
Rosa multiflora, multiflora rose
Rubus allegheniensis, blackberry
Salix spp., willow
Rhus radicans, poison ivy
Tsuga canadensis, eastern hemlock
Ulmus americana, American elm
Vitis spp., wild grape

8. Valley Creek at Mill Lane

Ailanthus altissima, tree-of-heaven
Acer negundo, ashleaf maple (boxelder)
Acer rubrum, red maple
Cornus amomum, silky dogwood
Juglans nigra, black walnut
Platanus occidentalis, sycamore
Populus grandidentata, bigtooth aspen
Prunus virginiana, choke cherry
Robinia hispida, bristly locus
Rhus glabra, smooth sumac
Rosa multiflora, multiflora rose
Salix spp., willow
Ulmus americana, American elm
Ulmus rubra, slippery elm

Appendix R. Reprint of Buikema, A. L., Jr., K. E. Schwaab, and J. Cairns, Jr. 1980. Pollution assessment: a training manual. UNESCO's Man and the Biosphere, U.S. MAB Handbook No. 1

POLLUTION ASSESSMENT: A TRAINING MANUAL

Arthur L. Buikema, Jr., Karl E. Schwaab,

John Cairns, Jr.[1/]

Abstract. This manual provides a self-instructional method for assessing effects of pollution upon species diversity in water ecosystems. No formal taxonomic training is necessary. The method has been used successfully all over the world for both aquatic and terrestrial ecosystems. It is a useful first exercise to acquaint students with natural and stressed communities. Detailed instructions and ample illustrations have been provided.

INTRODUCTION

The elimination of organisms, animals or plants, from a given locale is often the result of introduced, human-generated pollution. More often than not, societal concern with pollution is stimulated only as a result of the effects of pollution on resident organisms, especially fishes and birds.

Examination of plant and animal life within an area can result in significant data concerning the presence of pollutants. The type of organisms disturbed and the extent of that disturbance are factors directly related to the type and quantity of the pollutant. However, assessment of the magnitude and impact of pollution on organisms has been a complex problem requiring methodologies not readily usable by all those desiring to make such assessments.

The purpose of this manual is to provide a self-instructional means by which individuals desiring to monitor aquatic or terrestrial systems can learn to assess those systems by observing the organisms present. The method employed, the Sequential Comparison Index (SCI), allows individuals ranging from members of the general public to scientists to establish a diversity index without taxonomically identifying the organisms. Comparison of a series of indices will allow the system to be assessed.

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ECOLOGICAL CONCEPTS

The validity of the Sequential Comparison Index is based on several ecological concepts. Although the use of the SCI does not require a complete understanding of the concepts, it is desirable for the user to be at least familiar with them.

The environment can be cataloged into somewhat distinct and recognizable units called ecosystems. Examples of ecosystems include lakes, ponds, forests, aquariums, terrariums, and hot houses. By definition an ecosystem is an assemblage of different kinds of organisms that interact with each other and with the nonliving or abiotic components of their environment. The nonliving components include chemical and physical parameters such as minerals, elements, water, temperature, light, and wind. The living component of ecosystems includes organisms that produce the food, organisms that consume the food, and organisms that degrade organic materials so that these materials may be reused. The most important aspect to remember about an ecosystem is that all of its functional and structural parts are interrelated.

There are many different ways to characterize an ecosystem, among which are the food chain (fig. 1) and the food web (fig. 2). The food chain and web represent the means by which energy for life (i.e., food) is passed from one organism to the next. At the base of all food chains and webs are green plants, the producers, which capture light energy and convert it into chemical energy. The chemical energy is stored by plants and is ultimately used by other organisms. Producers may be the plants that are growing in your yard or they may be the green scum that you find in various types of ponds. Producers are in turn eaten by organisms referred to as primary consumers or herbivores. Primary consumers are in turn eaten by other organisms called secondary

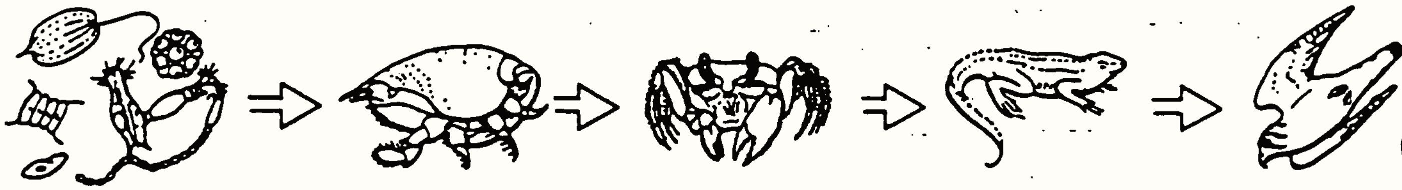


Figure 1. A simplistic sand-beach food chain.

consumers. Secondary consumers may be carnivores (meat eaters) or omnivores (plant and meat eaters). The secondary consumer may be eaten by a tertiary consumer, which in turn may be eaten by a quartenary consumer and so on until a top carnivore, an organism which has no predator, is reached. An example of a top carnivore is man. There are also detritivore organisms that feed on dead and decaying matter known as detritus. Detritivores include crayfish, turtles, and many beetles and worms. Ultimately many of the materials incorporated into the bodies of the producer and subsequently into the bodies of the consumer that fed upon the producers would be exhausted from the environment, and in all likelihood life would terminate unless these materials were recycled for reuse.

The organisms that are important in recycling these materials are called the decomposers. They degrade the detritus, body waste, dead bodies, etc., and release many of the raw materials that are then reused by the producers. These decomposer organisms include bacteria and fungi, and the materials that they release for reuse include carbon, hydrogen, nitrogen, phosphorous, and sulfur.

The life forms of the ecosystem are linked together in a series of predator-prey relationships, which are classified into two types: simple food chains and complex food webs. An example of a simple food chain is a producer which is eaten by a primary consumer, which is in turn fed upon by a secondary consumer, which is in turn fed upon by a tertiary consumer. Notice that in this food chain there is a linear relationship of one organism feeding on the next organism; thus the secondary consumer does not have an alternative food source.

A food web, on the other hand, is made up of many different types of producers and many different types of carnivores and herbivores. In this type of system no one organism is dependent upon only one source of food, but it can usually rely on many different types of food. Thus the relationships are branched, and most organisms have more than one alternative food source.

Ecosystems with complex food webs might have 25 to 50 different species of organisms that could be readily identified, and if a complete analysis were made of the particular environment, hundreds of species would be found.

In ecosystems complex food webs are the rule rather than the exception. Food chains usually exist only in experimental situations or in highly polluted situations where there has been considerable stress on the environment. In simple, less diverse, and less complex ecosystems we find simpler food webs or in fact may actually find food chain relationships among the organisms. These ecosystems have a very low diversity, and they are more susceptible to natural and unnatural, or manmade, stress.

The greater the intricacies and interrelationships of the food web, the more complex the ecosystem would be. Many ecologists have speculated that complex ecosystems are more resistant to change than simple ecosystems, possibly because they are more mature and are not undergoing a process of natural change. They happen to be in balance with their chemical and physical environment. Complex ecosystems also tend to have a high diversity; that is, they have many different kinds of organisms.

Another concept that has been used in literature to refer to complex systems is "healthiness." The more complex the ecosystem, the greater its diversity, and thus the healthier it is. Conversely, if we find an ecosystem that is not very complex, we tend to think of it as an unhealthy community. This again is related to the system's susceptibility to further stress.

Species diversity, complexity and healthiness are basic ecological concepts. The relationship between healthiness and diversity and complexity can be illustrated by the ability of a complex community to resist change on the one hand and the inability of a simple community to resist change on the other. Let's take the simple food chain where we have the producer, a primary consumer, a secondary consumer and a top carnivore. The availability of food follows a simple, straight-line path. If some sort of perturbation were to occur that disrupted the top carnivore, the impact on the rest of that food chain would be nominal. However, if we were to perturb the base of that food chain, i.e., the producer, then the impact would be quite noticeable in the sense that

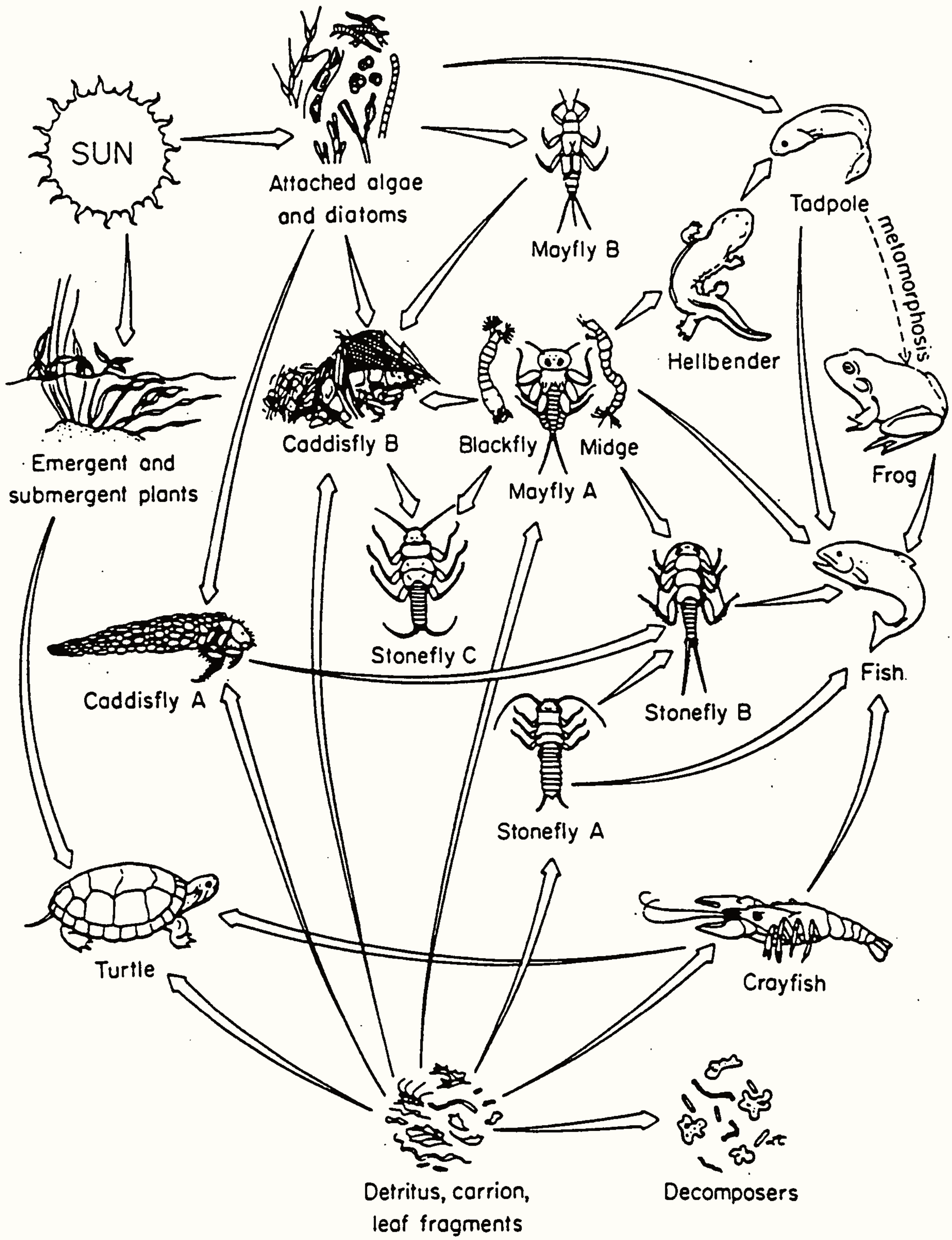


Figure 2. A simplified stream food web.

if the producer were not there, you would not have any other organisms. In this example, the food chain would be very unstable. If we take a food web in which we have many different types of producers and many different types of consumers, and we perturb that system so that only one producer at the base were moved, the impact on the complexity of that community would not be very great because other foods would be available to the secondary and tertiary organisms. Complex communities can tolerate quite a change in their population structures before there are any significant effects on the overall integrity of their systems. The reason for this is that there are many different sources of food available to the consumer organisms. Under extreme cases of pollution or other types of perturbation lasting a long time, it is possible to take a complex food web and basically reduce it to a simple system approximating a food chain. Once we have done this to a particular community, we have a system that is even more susceptible to change should any type of perturbation occur.

The emphasis of the preceding discussion has been to illustrate that complexity, healthiness and species diversity are interrelated. Thus, a healthy ecosystem has a very diverse community in which the energy flow is of the type known as a food web and which we refer to as a complex ecosystem. Because a complex community has a high diversity of organisms and many types of populations, its ability to respond to perturbations is quite great. Consequently, we say that system is healthy. Conversely, if we have a system which is not very complex with very few populations comprising the community and we have a perturbation, that system is less healthy because the removal of any member of a simple food web or food chain will have a relatively greater effect on the rest of the community. This is particularly significant when the perturbation occurs at the base of the food chain.

HISTORICAL DEVELOPMENT OF ASSESSMENT METHODOLOGIES

Until recently people interested in documenting whether a particular environment was healthy conducted simple surveys of the organisms present in that particular environment. The data they used to describe the healthiness of the situation were based on the number of organisms found and the number of taxa identified. However, evaluating systems with this methodology has its pitfalls. First of all, the technique is subjective and is somewhat dependent on the skill and experience of the person who makes the collections. Secondly, the presence or absence of a particular taxon may depend on the characteristics of the environment rather than on the impact of a perturbant on that particular environment. Thirdly, the evaluations made from these collections are based on the mere presence or absence of many organisms, and in these instances a single specimen would have as much weight as a large population.

Another methodology was based on the belief that one could characterize the impact of a perturbant on a natural system by looking for indicator species (fig. 3). Indicator species are organisms that are generally considered to be intolerant to stress. If the indicator species were found in a particular environment, the environment was judged to be healthy. The idea of the indicator species is not generally accepted today although it is possible to classify the organisms in an ecosystem as tolerant, facultative, or intolerant species. Tolerant organisms are those that can live in a polluted environment; intolerant organisms are those that cannot live in a polluted environment. Facultative organisms have a wide range of tolerance and are usually found in areas where there is a moderate level of perturbation.

The problem with studies based on indicator species is much the same as that of the earlier studies, which relied on a description of the environment based on numbers of taxa and numbers of organisms. Because of different life cycles of organisms, environmental impacts and minor environmental factors influencing the growth and reproduction of an organsim, the mere absence of an organism may not necessarily indicate that the organism has been perturbed in any way. To try to correct for some of the shortcomings of these earlier studies, methods have been proposed by which these data, number of taxa and numbers of organisms, could be integrated into an index. Many types of diversity indices have been proposed by biologists and ecologists. Unfortunately, there are some problems. First, the diversity index cannot be compared from drainage system to drainage system; therefore, the index itself has limited value except when compared within a particular system. Secondly, the diversity values which are calculated require that the organism be classified by species and that all organisms be so classified. Thirdly, the calculations are very difficult without the aid of a computer. In response to these problems another type of diversity index has been proposed.

In 1971 a paper by Cairns and Dickson was published on the diversity sequential comparison index. The Sequential Comparison Index (SCI) is a statistically valid method which does not require the investigator to know the specific name of the organism in question. The SCI only requires the investigator to have the ability to distinguish two organisms as different species or different life stages of the same species. Further, the calculation and analysis of an SCI index does not require calculators or computers. This manual discusses the Sequential Comparison Index (SCI) and its utility in evaluating ecosystems and perturbation in ecosystems. Parenthetically, we want to mention that the SCI method is so simple that even young students, as young as fifth and sixth graders, have

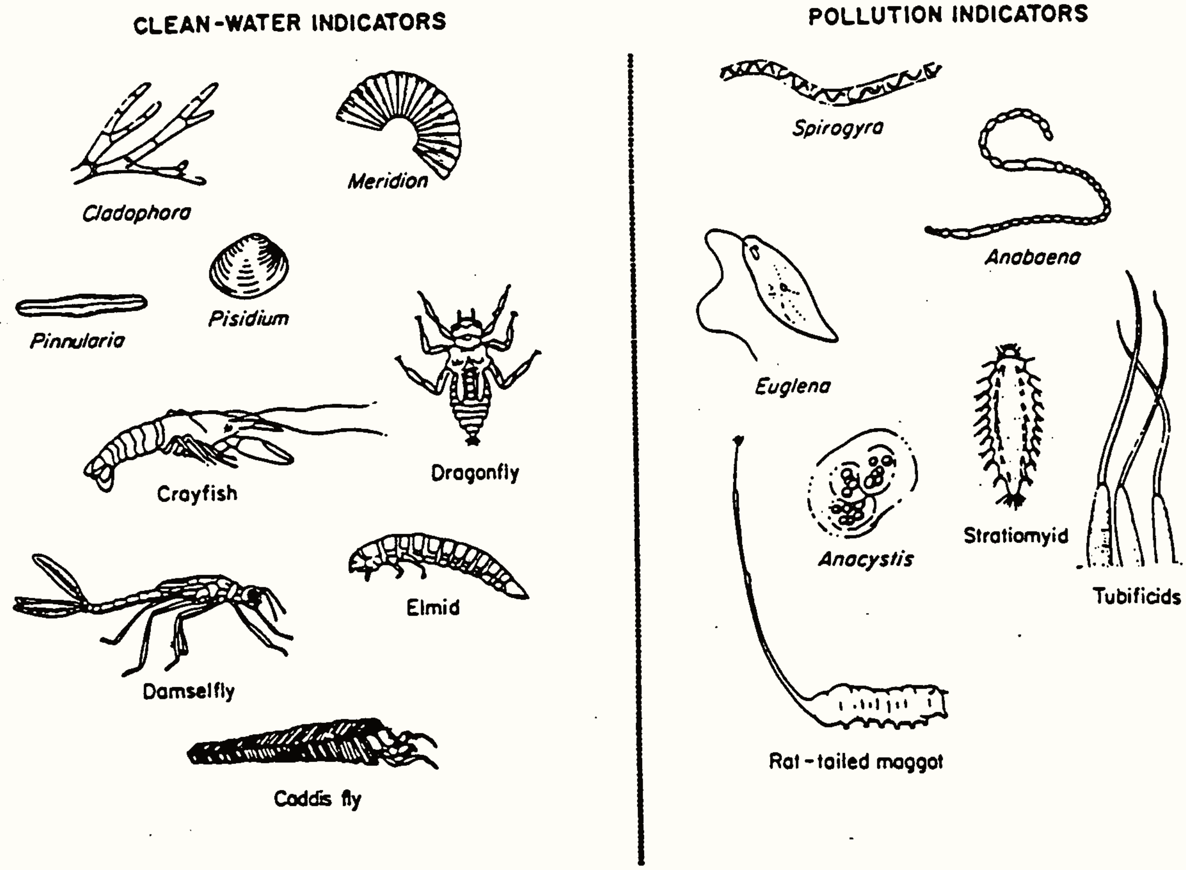


Figure 3. Examples of indicator organisms.

been able to utilize the method and to establish scientifically defensible information about a particular habitat or environment. The method is, therefore, designed to be used by people with very little biological background.

METHODOLOGY

The example below uses an aquatic ecosystem to present most of the SCI's assumptions and requirements. The SCI can be used to study other ecosystems as well. For example, streams, ponds, lakes, fields and forests are ecosystems. Most of the basic assumptions and requirements discussed below also must be met when studying other ecosystems.

The SCI is designed for comparative purposes and, therefore, an individual index value generally has little significance. Application of the SCI method has shown that a low SCI indicates less complexity and stability than a high SCI value. Proper use of the SCI requires calculating a series of separate SCI values. This series may represent points along a transect, within a study area, or over time at a given place in the ecosystem. Comparisons between the SCI values within a series will then indicate healthiness or complexity of the ecosystem being assessed. Changes occurring with regard to healthiness will also be evident.

Selecting Study Sites

The number and spacing of sampling sites is a critical decision and is dependent on each given situation. If a general survey of a stream ecosystem were being conducted, samples would be taken at intervals where the interval distance would be determined by the environment, and by time, money and labor constraints. If, on the other hand, a particular manufacturer was suspected of discharging pollutants into a stream, sample sites would be much closer, beginning above the plant and continuing for some distance downstream below the plant.

A single methodology for selecting stations cannot be given. Valid surveys will be obtained if the following points are adhered to when determining the effects of a given factory discharge on the aquatic ecosystem.

1. A baseline level of community or ecosystem healthiness must be established. Therefore, there must always be a minimum of two sampling stations above the suspected site of disturbance; one must be far above the point of discharge and one directly above the point of discharge, but not influenced by it. At least two stations are needed to determine the variability in the community and to determine if any changes occur immediately upstream from the discharge source (fig. 4).

2. A sampling station immediately downstream from the point of discharge and on the same side of the stream is required.

3. It must be determined if the discharge has an irregular pattern of entrance into the ecosystem. For example, in most streams industrial discharges often channel to one side of the stream. In such cases it is necessary to subdivide station samples into left bank, mid-channel and right bank. All data thus collected are kept separate by substations. If the industrial discharge does not channel, it may not be necessary to subdivide station samples.

4. The extent of disturbance to the ecosystem is assessed by having sample stations at various distances downstream from the point of discharge. For long-term studies of a community, such stations should be sampled a minimum of once during each annual season or during low, mid and high flow conditions.

Specific site selection also must be carefully controlled. It is important, especially where trying to determine possible pollutant effects, that each station sampled be as ecologically similar to other stations as possible. For example, aquatic stations must be similar with regard to substrate (soil, gravel, rock, etc.), depth, presence of riffles and pools, stream width, flow velocity and bank cover. In fact, it is recommended for stream studies that each site be sampled at three points: across the streams, along both banks, and in the center.

In a forest habitat it would be inappropriate to compare samples within the woods, along the edge, and near a stream cutting through the woods because these are in effect three different community types. Sample stations should be located in areas not influenced by an atypical habitat, such as that created by bridges or roads. Terrestrial habitats must be similar with regard to slope, moisture, soil type, trace metal content, direction of the sun's path and stage of succession.

Succession is important to consider, especially in terrestrial systems, because it affects the number, kind and diversity of organisms present in a particular ecosystem. Succession is defined as the process of change that occurs in communities over time. In other words, communities are subsequently replaced by other communities over a long

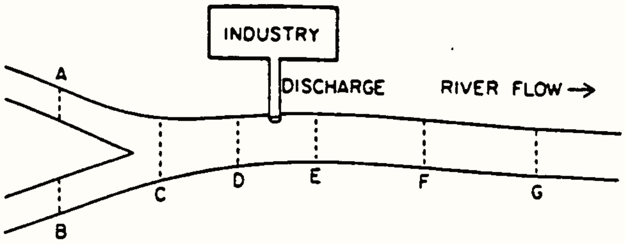


Figure 4. Example of sampling locations for evaluating the impact of industrial dischrage.

period of time until a final or mature community comes into balance with the physical and chemical aspects of its environment.

All sites should be sampled at approximately the same time for valid comparisons to be made. No more than two weeks should lapse between the first and last sampling periods.

Sampling Techniques

Once study sites have been identified, then sampling of organisms may begin. Samples for each site should be obtained by standard collection procedures specific for that ecosystem. Standard collection methods for various habitats are widely published and will not be discussed in this manual.*

Whatever organisms are chosen for collection and whatever collection method is selected, the following points should be remembered: 1) emphasis should be given to random sample collection; and 2) most reliable indices are obtained when samples contain 250 or more organisms.

An advantage of the SCI is its applicability to delicate systems that may be disrupted by removal of organisms. Each organism observed can be assigned a name, code number or letter which is recorded on an individual square of paper. A separate code must be used for each "type" of organism collected. Also, a separate record must be kept for each individual of a given type that is collected. The squares from each sample may then be placed in a container, mixed and randomly drawn from the container. Following the recording, the organisms may be returned to their habitat if it was necessary to collect them.

Data Gathering

Once samples have been obtained, they may be processed immediately in the field or upon return to the laboratory, or stored until a later date.

*See for example, Phillips, E.A. 1959. Methods of Vegetation Study. Holt, Rinehart, and Winston, Inc. N.Y.; Southwood, T.R.E. 1978. Ecological Methods. J. Wiley & Sons, Inc. N.Y.

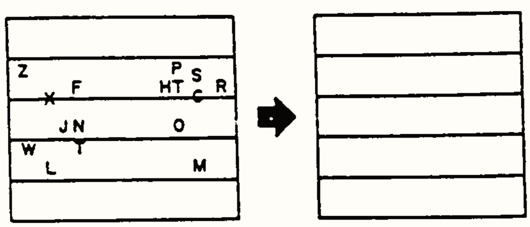
The initial step in processing the samples is to thoroughly mix each sample. It is important that organisms be randomly distributed within the sample. In the example of a stream community this may be accomplished by vigorously shaking the bottle in which each sample is stored.

The mixed sample is then poured into a container, such as a porcelain pan, which has a series of parallel lines drawn on the bottom. Clumps of organisms must be physically dispersed without any effort of placement. This may be accomplished by pouring water over them. Figure 5 illustrates possible results.

If slips of paper are used to represent the organisms, the slips may be placed in a bowl, mixed, and randomly drawn out of the bowl one at a time. Do not replace the slips once they have been drawn. As the slips of paper are removed from the bowl, the code on each paper slip should be recorded in sequence. This procedure will produce a random, linear array needed for further analysis. An alternative is to spread the slips on some type of grid system just as is done with the organism samples.

After the organisms are dispersed in the pan they must be lined up on the parallel lines (fig. 6). This is accomplished by moving each organism up or down to the closest line and maintaining the left to right sequence of organisms. This procedure should be done quickly without any conscious effort to place individual organisms. With practice the experienced investigator may be able to do this operation mentally, thus saving time.

Self Check 1: What would be the linear order of the organisms on the following grid?



After the organisms have been properly aligned, the investigator is ready to examine them individually. Starting with the upper left organism, the investigator records an "X" for this first organism. The investigator must now determine whether the second organism is the same as, or different than, the first which is its immediate predecessor. If it is the same, a second "X" is recorded; if it is different, an "O" is recorded. The third organism is then compared with the second. If it is the same, the code (X or O) of the second is repeated, and if it is different, then the code is changed. This sequential comparison is continued line by line until the last organism has been compared to the second to the last organism.

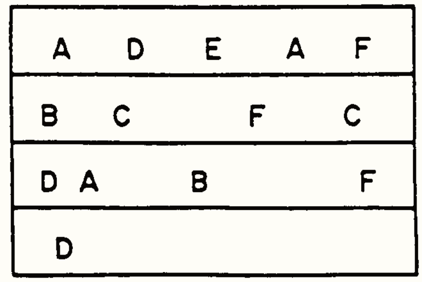


Figure 5. Initial dispersion of sample.

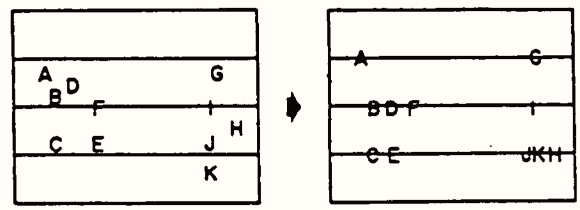
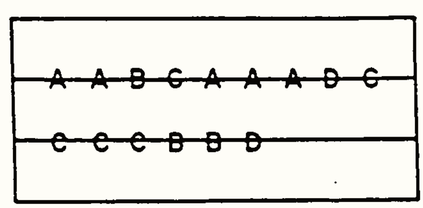


Figure 6. Method of sample adjustment for further analysis.

In each instance when an organism is the same as the previous organism, the current X or O code is repeated. When an organism is different from the previous organism, the current code, X or O, is changed and an O or X is respectively recorded. The X and O information must be recorded in a linear sequence so that the exact order in which the organisms were observed is maintained. This procedure results in data having a sequence of this type depicted in figure 7.



XXOXOOOXOOOOXXO

Figure 7. Transformation of individual organism designations to sequential comparison code.

The next step in this procedure is to determine the number of different species in the sample. This may be accomplished by segregating like organisms into distinct groups and recording the number of groups established. This number represents the "equivalent species" present in each sample. The example in figure 7 has four "equivalent species."

Calculating the SCI

The formula for calculating the SCI value is:

Sequential Comparison Index (SCI) =

$$\frac{\text{Number of runs}}{\text{No. of organisms}} \text{ (No. of equivalent species)}$$

The number of runs is determined by counting the groups of X's and O's. The first run begins with the first X and ends with the first O. The second run begins with the first O and ends with the next X that appears. In other words, every time the X-O code is changed, a new run is initiated. In the following example from figure 7 the individual runs are underlined and counted.

Number of runs =

$$\underset{1}{\underline{XX}}\ \underset{2}{\underline{O}}\ \underset{3}{\underline{X}}\ \underset{4}{\underline{OOO}}\ \underset{5}{\underline{X}}\ \underset{6}{\underline{OOOO}}\ \underset{7}{\underline{XX}}\ \underset{8}{\underline{O}} = 8$$

Self Check 2: How many runs are in the following example?

Number of runs =
XOXXOOOXXOXXXOOOXXXXXOOXO = ____

The next piece of data required is the total number of organisms, which is equivalent to the total numbers of X's and O's recorded. In figure 7 the total number of organisms is 15 and in Self Check 2 the total is 25.

The number of equivalent species has been determined previously. You will recall that this is the number of distinct groups of organisms found in the sample. The number of equivalent species for figure 7 is 4.

The SCI value for figure 7 can now be calculated:

$$SCI = \frac{8 \text{ runs}}{15 \text{ organisms}} \text{ (4 "equivalent species") } = 2.13$$

Self Check 3: What is the SCI value for the data in Self Check 2 if there are six different "equivalent species?"

Self Check 4: The following SCI values were obtained by two workers studying the same sample. How can you account for this variation in SCI values?

AAAAABBBCCCCCDD	SCI = 1
ABACADCACACBCBD	SCI = 4

The example in Self Check 4 emphasizes two important concepts. First, samples of organisms must be randomly distributed. If not, wide variations in the SCI value may be obtained and the ecological significance of the SCI value may be misinterpreted. Secondly, the smaller the sample size the greater chance that wide variation in SCI values will be obtained. Therefore, adequate sample size is important in conducting ecological assessments.

Adequate Sample Size

The number of times the above procedure is performed on each sample is dependent on the number of organisms in the sample and the confidence levels the investigator elects to achieve.

Samples containing more than 250 organisms are recommended. In this situation the SCI may be determined without examining all of the organisms. The following procedure should be used:

1. Determine the number of runs for the first 50 specimens.
2. Calculate SCI values where $SCI = \frac{\text{No. of runs}}{50}$ (No. of "species")
3. Plot SCI against the number of specimens examined (fig. 8).

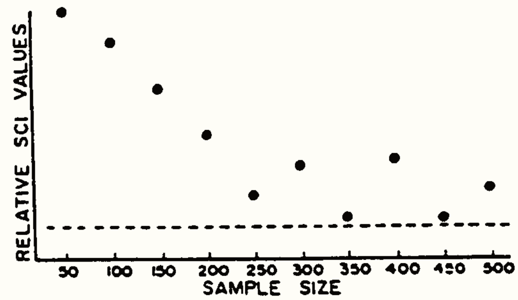


Figure 8. Relative SCI values vs. sample size.

4. Continue the analysis for the next 50 specimens.
5. Determine the total number of runs for the 100 specimens examined.
6. Calculate a new SCI value for 100 specimens (No. of runs/100)(No. of "species") as in Step 2 and plot the value obtained on the graph made in Step 3.
7. Repeat this procedure with increments of 50 specimens until the curve obtained becomes asymptotic (fig. 8). When the curve becomes asymptotic, then enough specimens have been examined and additional work will produce an insignificant change in the final SCI value.
8. Calculate a final SCI value based on the decision made at Step 7.

When less than 250 organisms are contained in the sample, the SCI is determined from the total sample.

For each sample, the SCI should be determined 2 or 3 times. The investigator may then be 95 percent confident that the mean index is within 20 percent of its true value. This level of accuracy should be sufficient for most studies. If 95 percent confidence of detecting a 10 percent difference in means is desired, the SCI will need to be determined 7 or 8 times for each sample.

Following these procedures, the sample is no longer needed and it may be returned to the community, stored for future reference, or discarded.

INTERPRETING RESULTS

The SCI results in two general types of data series. One type is a series of similar SCI values, for example, 14.5, 15.3, 13.7, 15.0, 14.1 and 14.8. This series is representative of an ecosystem that is healthy over a transect or time span sampled. The second series type is one which contains one or more significantly different SCI values, for example, 15.4, 13.5, 14.6, 6.8, 8.7, 11.5, 14.1, 13.9 and 15.1. Here we have a healthy ecosystem which becomes less healthy at or about the 6.8 sample site or time. If these data were for a stream, then the series would indicate that there is recovery of the ecosystem by the third site (14.1) following the disturbance at the site with the 6.8 value. In this second case, we have identified a potential problem. The decreased diversity or healthiness may be caused by a pollution source or by a change in the quality or quantity of factors normally present in the community (discussed in previous paragraphs). In a stream, this could be a substrate change; in a terrestrial ecosystem, it could be a nutrient deficiency. More specific investigations will then be required to determine the exact cause for the lowered diversity.

Application to Terrestrial Ecosystems

The above discussion has been on pollution stress in aquatic ecosystems. The principles that are described for the SCI when stress is monitored in an aquatic environment are also applicable to a terrestrial ecosystem. Stress due to air pollution on a terrestrial ecosystem is a good example. The SCI also can be used to study the effects of stress on microhabitats. For example, the discharges from air conditioners and heat exchangers can affect microhabitats or create new microhabitats.

Some of the problems that we had in studying aquatic environments are very similar to the problems encountered in studying the terrestrial environments. For example, similarity of habitat must be controlled as much as possible. If you are studying an area which is exposed to the sun and you are going to compare it to another area, make sure that the new area also is exposed to the sun in the same way. In selection of the habitat, you want to use as many physically common features as you can. If in your analysis you find that there are differences among your indices, you will want to go back and determine why the differences occurred. In a terrestrial habitat there may be differences in moisture content, soil type changes, succession stage, etc. The other major consideration in studying a terrestrial environment at any particular site is that the selection of the study area within that site must be chosen at random. This can be accomplished simply in a terrestrial environment by throwing sticks into an area and using these as one corner of your quadrat or as the basis for starting your transects.

Fragile terrestrial habitats may be more susceptible to damage than many aquatic habitats. Because you would not want to disrupt the environment, you might consider using numbers or slips of paper with names on them to represent the organisms that you encounter. These will then be placed into a bowl or a hat, and randomly drawn for calculation of the SCI.

In conducting studies on terrestrial habitats the methods required especially the size and number of quadrats, will vary with the type of community that is being investigated. Quadrat size must be sufficient to assure that the number of organisms will exceed 250 so that the SCI can be calculated properly. If you are looking at the weed community of a field, you will have to set up a number of one-meter square quadrats. Within these quadrats you will have to accurately count the different types of plants. In analyzing the data from these types of quadrat studies one might be interested in the species of plants; however, if this is not possible, the analysis can be done just as easily by referring to the plants as species A, B, C, etc. based on differences in external morphology. This technique is very similar to that proposed for aquatic organisms.

Within these quadrats one also may want to determine the percent of the area that the various types of organisms cover. It may also be advantageous to divide plants into annuals, perennials, shrubs and trees.

When evaluating a terrestrial community that is in the shrub stage (where you have short, woody-stemmed plants), the number and size of quadrats will have to be increased since a quadrat one meter square will contain few shrubs. It may be necessary to set up quadrats that are from 5 to 10 meters square. Again the analysis of the vegetation data would be similar to the analysis discussed for other data.

If later successional stages contain intermediate tree communities, or even possibly a climax forest, one might consider having quadrats which are minimally 10 meters square. In forest work, particularly when we are studying a climax type forest, transects are often used instead of quadrats. In a transect a very narrow, straight line is set up with a compass extending through the community. All plants in that strip or along that line will be enumerated for some fixed distance. In transect studies, signs of animals should be observed carefully in order to gain an index of the types of species present.

If you are interested in obtaining information on the various types of mammals present in terrestrial habitats, it is recommended that at least 50 live traps be used. These will need to be examined for small mammals before you leave the area and early the next day if the traps are left overnight. Many vertebrates will not be actually seen or collected, but other indications of their presence may be used in assessing the diversity of that particular habitat. Indicators, such as tracks, droppings, calls, nests, and so forth may be used. Collections of insects may be made by sweep netting.

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QUESTIONS

1. What is an ecosystem?

2. Compare and contrast a food chain and a food web.

3. Are complex communities healthy? Are they stable?

4. In conducting research on ecosystems, is it necessary to sample all types of organisms? Why?

5. An investigator conducted a survey for a one-mile section of a river. An effluent entered in the middle of this section. After calculating the SCI the investigator noted the following sequence of values as he went downstream: 4.5, 4.6, 4.0, 4.3, 1.1, 1.7, 2.3, 4.5, 4.0. What conclusions can be reached from these data?

6. After completing a study on two separate terrestrial areas in two different drainage systems, an investigator concluded that because the diversity of organisms in Area A was significantly lower than that in Area B, Area A was affected by pollution. Is this conclusion valid?

7. Assume that you had just finished surveying a river at five transects with three samples taken per transect. After calculating the SCI values, you obtained the following data:

Transect A	4.1	3.9	4.4	
Transect B	4.3	3.8	4.0	
				Discharge
Transect C	3.9	3.0	2.1	
Transect D	4.0	2.4	2.6	↓ River Flow
Transect E	4.6	3.6	5.0	

   a) What do these data tell you about impact of the waste discharge on the river biota?
   b) Why do you think that the SCI values generally are lower in the middle of the river?

8. Figure 9 represents a part of a small river basin which has several industrial discharges.

a) If you were to fully assess the impact of these discharges on the riverine biota, where would you locate your sampling stations? Why?

b) If all SCI values varied from 10 to 12 irrespective of location, what conclusions would you reach about the impact of these industries on the river?

9. If you are asked to conduct a survey on a system that has several species designated as rare or endangered, could you still use the SCI? If so, how?

10. The following questions are based on the quadrat maps (fig. 10) representing terrestrial vegetation on which the SCI will be determined. Each symbol represents a different species of plant. Assume your sample size is large enough to calculate a SCI value.

a) Calculate a SCI for each quadrat.
b) Which quadrat has the greatest density? Why?
c) Could the results be different if you conduct a transect rather than a quadrat type of survey?

11. If you compared a very early and immature or man-influenced ecosystem with a mature, natural ecosystem would you expect a relatively high or low SCI value for each of the items below?

Phenomenon	Ecosystem Immature	Man-Perturbed	Mature
species diversity	_____	_____	_____
healthiness	_____	_____	_____
number of kinds or species	_____	_____	_____
fluctuation in population numbers	_____	_____	_____

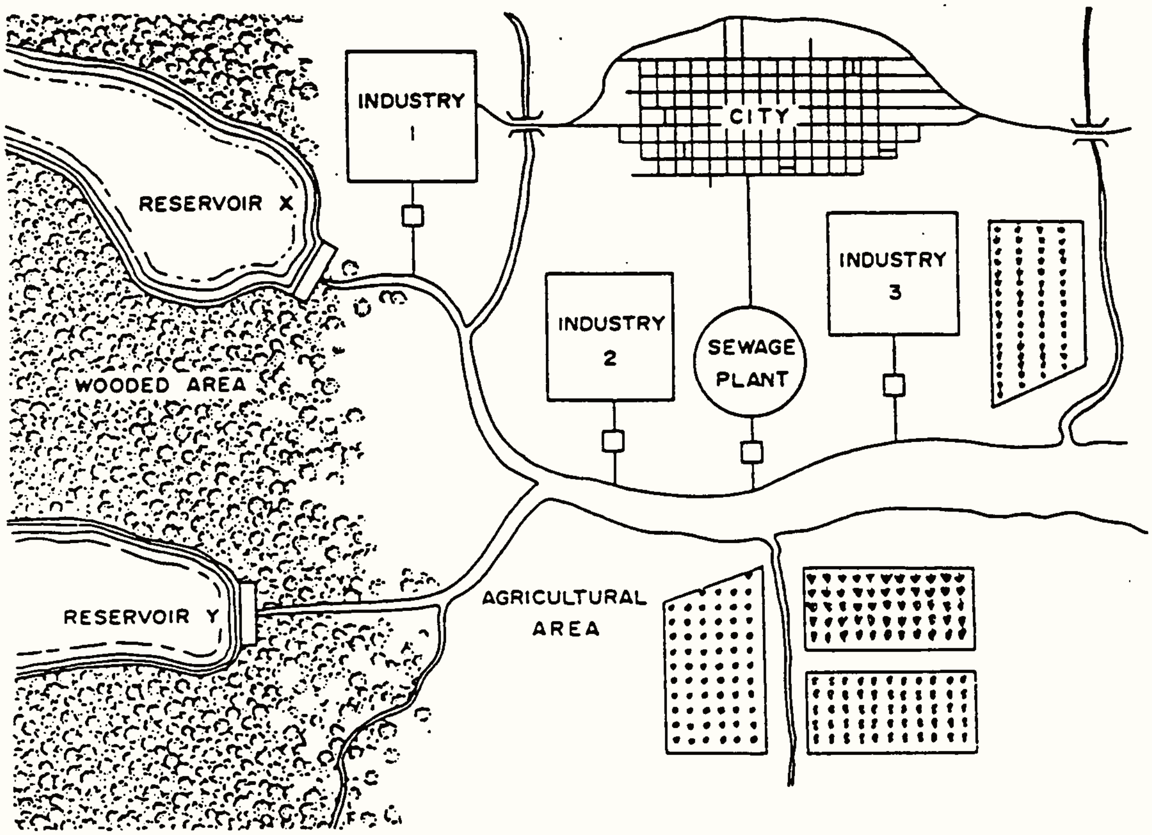


Figure 9. Example of a small river basin receiving industrial discharges.

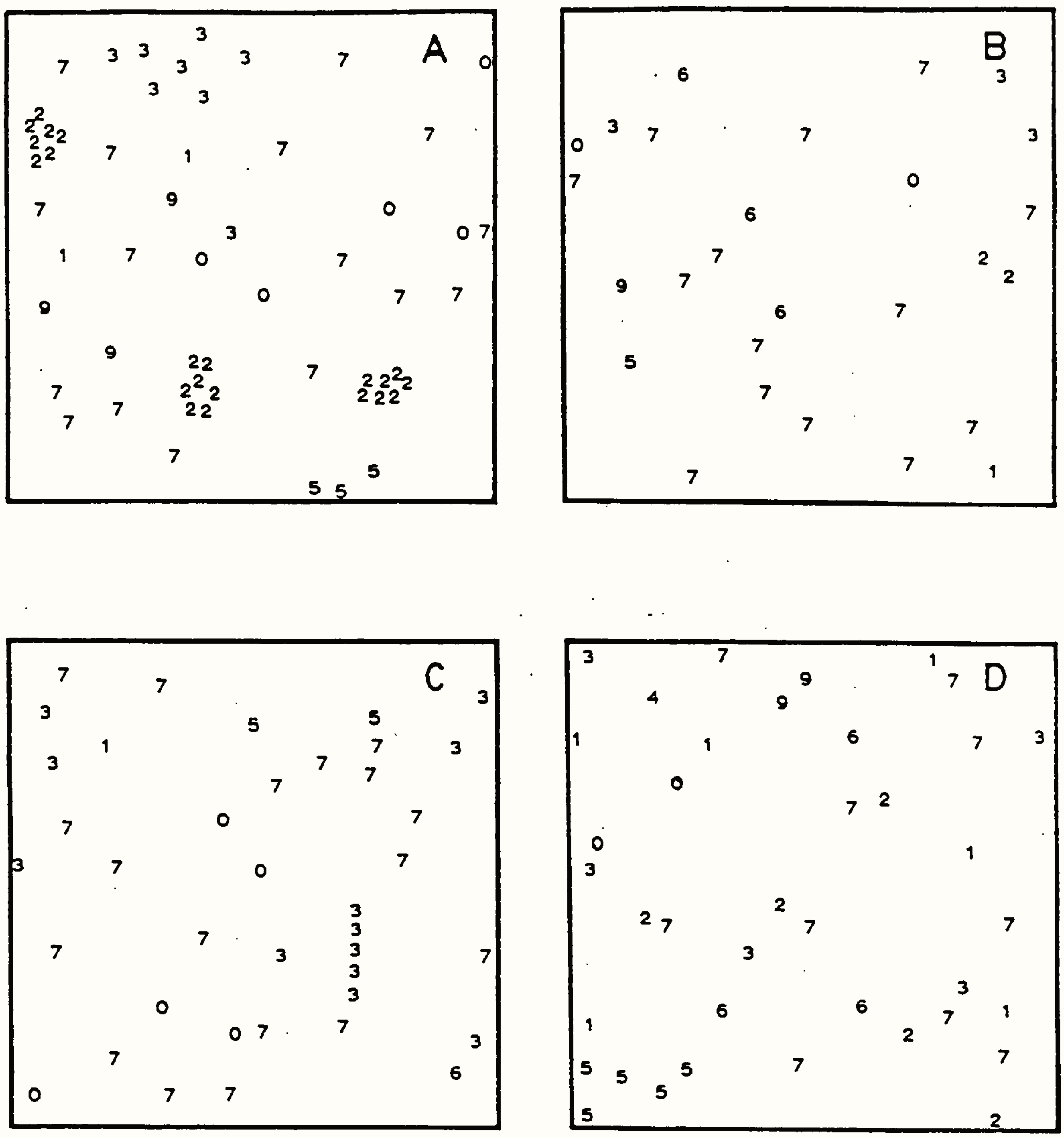


Figure 10. Sample of quadrat maps of terrestrial vegetation.

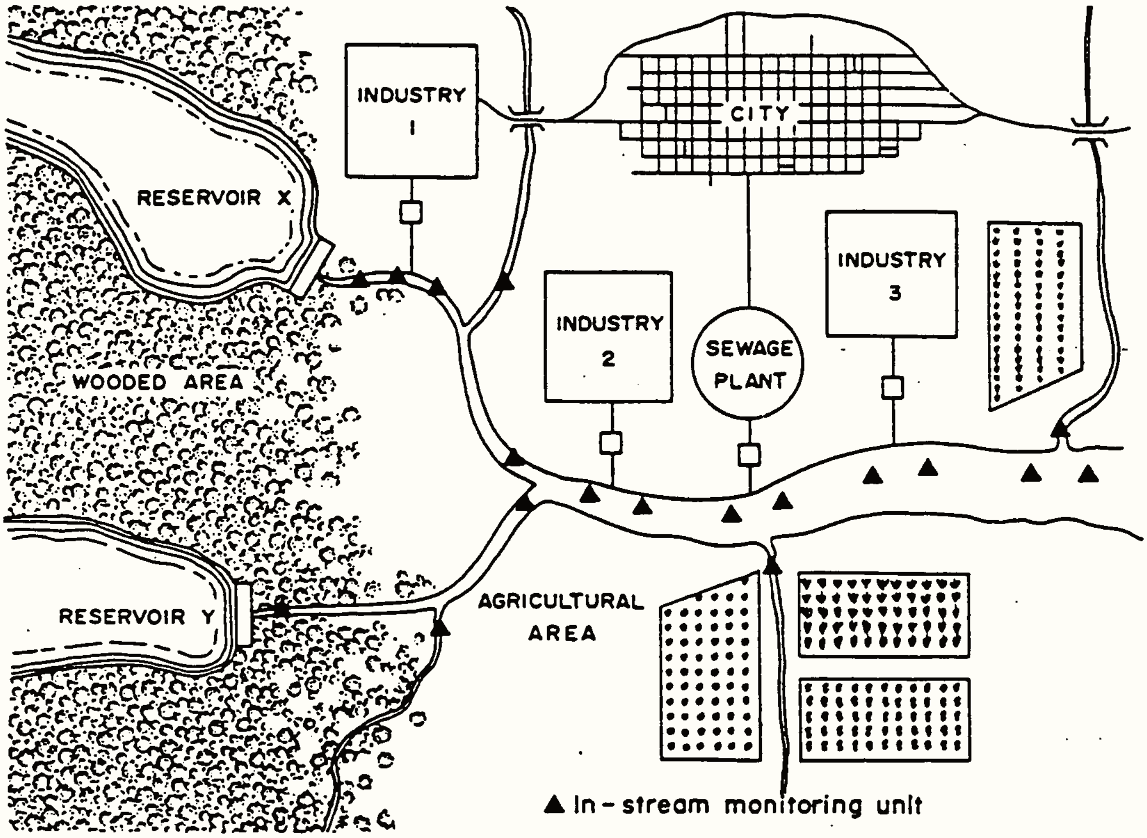


Figure 11. Suggested sampling stations for the river basin shown in figure 9.

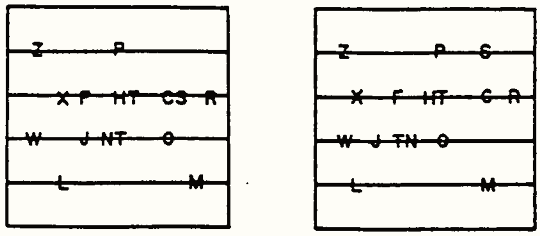
11.

Phenomenon	Ecosystem Immature	Man-Perturbed	Mature
species diversity	L	L	H
healthiness	L	L	H
number of kinds or species	H	H	L
fluctuation in population numbers	L	L	H

ANSWERS

Self Checks

1.



Slight variations are acceptable. Note the differences in the placement of S, N and T. These differences occurred because of the position of the specimen to the grid line or other specimens.

2. The number of runs is <u>12</u>.

3. The SCI value for the data in Self Check 2 is <u>2.88</u>.

4. The wide variation in SCI values occurred because the low SCI value was calculated for a nonrandom sample.

Questions

1. An ecosystem is an assemblage of different kinds of organisms that interact with each other and with the abiotic components of their environment.

2.

Food Chain	Food Web
simple system	complex system
one food source	alternative food sources
few species	many species
low diversity	high diversity
"unhealthy"	"healthy"

3. Complex communities are considered healthy because of the large number of interactions that occur among different organisms. The loss of one or two species usually will not disrupt a complex community.

4. It is not necessary to sample all kinds of organisms. A sample of the animals alone will give you a good indication of diversity and complexity because of their position in the food web.

5. Assuming that the investigator sampled similar types of habitats, i.e., riffle areas, these data indicate that the aquatic ecosystem was perturbed about midway. Because the values rose further downstream, the perturbed communities recovered from the stress.

6. The conclusion is not valid because the investigator only calculated one diversity value per area. More research is needed to document pollution, including more measurements of the SCI; chemical and physical parameters need to be measured to be sure that the habitats that were sampled were comparable.

7. a) These SCI values indicate that there was an effect on the biota below the discharge. The data also indicate that the discharge plume spread to mid-river at Transect D. Recovery occurred by Transect E.

   b) The SCI values are lower in the center of the river because the current velocity is faster in the middle of a river.

8. a) The needs of each sampling program must be evaluated before designing a study. The example given in Figure 11 is designed to assess potential water pollution. Note that sampling stations located on tributaries may contribute organisms to the main river, above and below each discharge pipe and some distance downstream from the last discharge.

   b) If all the SCI values vary from 10 to 12, chances are that the impact of industrial discharge on the diversity of the biota is negligible.

9. Yes, the SCI can be used in areas containing designated rare or endangered species. Symbols on slips of paper would be used for each species identified. When working with rare and endangered species, one must be careful not to disrupt critical habitats.

10. a) The approximate SCI values are:

    Quadrat A (2.9)
    Quadrat B (5.4)
    Quadrat C (3.2)
    Quadrat D (7.2).

    b) Quadrat D, because it had nine species randomly distributed.

    c) The results would be different if the transect were too short because the probability of finding different species would decrease. However, if the transect were long, the SCI value should approach the SCI value for the quadrat.