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A METHODOLOGY FOR THE CHARACTERIZATION AND MANAGEMENT OF NONPOINT SOURCE WATER POLLUTION

THESIS

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The views expressed in this thesis are those of the authors and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

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A METHODOLOGY FOR THE CHARACTERIZATION AND MANAGEMENT OF NONPOINT SOURCE WATER POLLUTION

THESIS

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Master of Science in Engineering and Environmental Management

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Preface

The purpose of this study was to develop a comprehensive package on Nonpoint Source water pollution useful to Air Force base managers. Impetus for this effort is the continual strengthening of legislative and regulatory requirements concerning Nonpoint Source water pollution.

Models were proposed to characterize and predict Nonpoint Source water pollution loading. Results of these models indicate they can provide a useful Nonpoint Source water pollution management tool. However, the stormwater runoff sampling program conducted at the Air Force Academy for validation proved inconclusive. The Best Management Practices proposed are mitigation measures accepted by the United States Environmental Protection Agency.

In this research effort we received assistance from many sources, most notably, our faculty committee, and the Air Force Academy. Specifically, Lt Col Mark N. Goltz, our advisor, provided the needed technical assistance and direction to complete the research. The sampling and analysis program would not have been accomplished without the extraordinary effort of Ms. Martha Shelby, from the Air Force Academy's Environmental Management office. Finally, we owe a word of thanks to each other for persevering to completion, and to our families for tolerating the long hours away from home.

David M. Praner   Gordon M. Sprewell

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Abstract

The purpose of this thesis research was development of a methodology for characterization and management of Nonpoint Source (NPS) pollution. Section 319 in the Water Quality Act of 1987 requires states to develop management programs for reduction of NPS pollution via Best Management Practices (BMPs).

Air Force installations are expected to abide by federal, state, and local environmental regulations. Currently, the Air Force does not have a methodology to identify and quantify NPS pollution, or a succinct catalog of BMPs. Base Civil Engineers and Environmental Managers need a package that can assist them in meeting the legislative and regulatory requirements associated with NPS pollution.

Ten NPS pollutants characteristic of urban runoff, as identified in the Nationwide Urban Runoff Program (NURP), were selected as those constituents of concern for modeling and sampling. This thesis proposes two models to characterize NPS pollution.

The results of the models were compared with results from a water sampling and analysis program conducted at the Air Force Academy. Additionally, a compendium of Best Management Practices was developed to offer USEPA endorsed mitigation measures to Air Force base managers.

A METHODOLOGY FOR THE CHARACTERIZATION
AND
MANAGEMENT OF NONPOINT SOURCE POLLUTION

I. Introduction

This chapter introduces the concept and definition of Nonpoint Source water pollution, describes its environmental significance, and presents legislative and regulatory background. Also included in Chapter I are the problem statement, objectives of the research, research questions, scope of the research, limitations, assumptions, and definitions.

Definition of Nonpoint Source Pollution

Pollution is the introduction of material or energy into the environment in excess of environmental assimilative capacity, resulting in detrimental effects to biological systems.

The environment naturally accommodates certain amounts of natural waste produced by biological organisms. The environment also possesses substantial buffer capacity to accommodate inputs from events such as volcanos and forest fires. As the rate of pollutant input to the environment becomes greater than natural treatment capacity, the environmental processes shift toward a new state in which higher levels of pollutant exist. Eventually these increased concentration levels of pollutants detrimentally affect biological systems.

Nonpoint Source water pollution (hereafter termed NPS pollution) enters the environment in such a fashion that there is no discrete or specific entry point. NPS pollution is defined by the United States Environmental Protection Agency (USEPA) "as diffuse pollution from land runoff, precipitation, atmospheric deposition, drainage, and seepage..." (42:66).

The concept of NPS pollution can be clarified by contrast to point source pollution. Point source pollution is emitted or discharged from a specific location or point, such as a wastewater treatment plant effluent outfall or a stormwater discharge pipe. There is no such discrete point from which NPS pollution emanates or where it could be intercepted.

Examples of NPS pollution include 1) pesticide laden rainwater runoff from a farmer's field; 2) lead leaching into a ground water table from a target shooting range; and 3) runoff from airfield pavements. In cases such as these, although it may be possible to determine where the pollution originated, there is no specific point where the pollutant enters the environment.

NPS pollution may be introduced into the environment over an extended area. Insecticide from an agricultural operation can enter a river directly via rainwater runoff from a field several square miles in area. Lead from a target shooting range may be dissolved by rainwater soaking through lead contaminated soil. This dissolved lead would then be carried into an aquifer by the percolating rainwater. Airfield pavement runoff, carrying high concentrations of salts, metals, and petroleum products, will enter the watershed drainage flow destined for a receiving river or lake.

Background

NPS pollution has become a more significant concern because of the success of the Clean Water Act of 1972 in addressing point source pollution. The Clean Water Act of 1972 created the National Pollutant Discharge Elimination System (NPDES) program. This program required that point sources of water pollution, typically municipal and industrial waste management facilities, apply for and receive permits to discharge pollutants. Furthermore, these permits placed legal restrictions on the allowable quantity of pollutant a waste management facility could discharge into receiving waters. The National Pollutant Discharge Elimination System (NPDES) program, in conjunction with associated federal grants to upgrade treatment plants, greatly reduced point source pollution with a corresponding increase in water quality.

With the reduction of point source pollution, attention turned to NPS pollution as the next major contributor to water quality degradation.

The Clean Water Act of 1972, in addition to other facets of pollution control, stipulated that

> each State shall prepare and submit to the Administrator...a description of the nature and extent of nonpoint sources of pollutants, and recommendations as to the programs which must be undertaken to control each category of such sources, including an estimate of the costs of implementing such programs. (19:456-457)

Although this legislation clearly included NPS pollution, initial efforts were almost exclusively focused on point source pollution. This occurred primarily because point source pollution was easy to identify, quantify, and manage, while NPS pollution was considerably more elusive. Consequently, NPS pollution remained unaddressed and largely unchecked (42:66).

The Water Quality Act of 1987 attempted to rectify the neglect of NPS pollution concerns by mandating that states assess and report their NPS pollution, and that they develop NPS pollution management programs. These amendments authorized application of the National Pollutant Discharge Elimination System (NPDES) permitting program to stormwater discharges and included authorization for federal loans and grants to facilitate implementation of USEPA approved state management programs (42:66).

Congressional support for NPS pollution management is exemplified by recent federal funding action. In fiscal year 1992 Congress added $27.5 million to the original $25.0 million federal NPS pollution control program budget request, increasing total funding to $52.5 million (57:2).

In 1989 the USEPA published a report, Nonpoint Sources: Agenda for the Future. This report revealed that NPS pollution was responsible for "76 percent of impaired acres of lakes, 65 percent of impaired stream miles and 45 percent of the square miles of impaired estuaries..." (42:66). The report further addressed the substantial complexity and magnitude of NPS pollution, including the high degree of temporal and spatial variability (42:66).

Further legislation directly addressing NPS pollution occurred with the passage of the Coastal Zone Act Reauthorization Amendments of 1990 (49:1-3). These amendments require states to

> "... develop and implement management measures for nonpoint source pollution to restore and protect coastal waters, working in close conjunction with other State and local authorities." (49:1-5)

The momentum of legislation addressing NPS pollution has increased as restrictions become tighter and regulation more intense. This regulatory environment substantially impacts operations of the Air Force.

Air Force installations are expected to abide by federal, state, and local environmental regulations. These regulations include within their scope implementation of Best Management Practices (BMPs) to control NPS pollution.

These BMPs can be characterized as "methods, measures, or practices designed to reduce [NPS] pollution" (27:201).

In May 1987, Mr Gary Flora, USAF/LEE, stated in a letter to all Major Command Civil Engineers: "You should identify NPS pollution problems on your installations by 1 September 1987 and have NPS pollution control programs in place by 1 January 1988" (17:1). This policy letter clearly establishes the requirement for NPS pollution management programs on Air Force installations.

Problem Statement

Section 319 of the Water Quality Act of 1987 requires states to develop NPS pollution management programs to reduce NPS pollution via Best Management Practices (BMPs) (19:498-499). Air Force policy requires the identification of NPS pollution and implementation of control programs. To comply with governmental legislation and Air Force policy, Air Force installations must identify and quantify their NPS pollution, and be able to select appropriate BMPs.

Currently, the United States Air Force does not have a methodology to identify and quantify NPS pollution, or a succinct catalog of BMPs. Base Civil Engineers and Environmental Managers need a package that can assist them in meeting the legislative and regulatory requirements associated with NPS pollution.

Research Objectives

The purpose of this research is two-fold: to develop a methodology to identify and quantify NPS pollution on an Air Force base; and to provide a compendium of USEPA recognized Best Management Practices to effectively manage NPS pollution.

This methodology will provide an Air Force base with an effective tool to characterize NPS pollution generated within the base confines. With the base NPS pollution clearly defined, it will be possible to respond to legislative and regulatory requirements. In addition, a compendium of BMPs and associated applications will provide a selection of control measures for the base management to choose from.

Information was collected to accomplish the research objectives by answering the following investigative questions:

1) What typical NPS pollutants are generated on an Air Force base by various activities and land uses?

2) What are the unit quantities identified in the literature for typical NPS pollutants?

3) What results are obtained when modeling is used to predict total NPS pollutant loading?

4) What results are obtained from a water sampling and analysis program to determine existing NPS pollutant loading?

5) How do results from water sampling and analysis compare with model results, and can the models be used to predict NPS pollutant loading on an Air Force base?

6) What BMPs recommended by the United States Environmental Protection Agency for Nonpoint Source pollutant management are applicable to Air Force operations?

Scope

This study examines typical activities and land use areas, and the associated NPS pollutant profiles generated by Air Force operations. It examines those USEPA recognized Best Management Practices that may be applied in a management program to reduce typical NPS pollutants on an Air Force base.

The United States Air Force Academy sponsored this research effort, and it was at that installation where this research was validated. Validation of the developed methodology was accomplished by implementation of a water sampling and analysis program.

The Air Force Academy presents an ideal environment in which to validate research on NPS pollution. The base contains a major watershed, several tributary watersheds, a significant land area, forest land, urban-like and residential areas, an industrial complex, an airfield, and large open areas.

Limitations

It was not the intent of this study to address activities and NPS pollutants whose profiles have not been established. Neither does this study consider NPS pollution contributions generated by non-Air Force activities. Additionally, there is no evaluation or integration of a long term water sampling and testing program.

The sampling and analysis of NPS pollutants was limited to surface water runoff and did not address their presence elsewhere, such as in ground water. Analysis was further limited to the ten pollutants that are characteristic of urban NPS pollution as determined by the Nationwide Urban Runoff Program (NURP) study. These are listed on page 20.

Although pesticides, toxins, and other potential NPS pollutants may be present, the Nationwide Urban Runoff Program (NURP) study did not find such constituents to be characteristic of urban NPS pollution. These materials occurred infrequently and generally in insignificant concentrations (59:6-44, 6-56). While these pollutants may indeed occur on an Air Force base, their frequency of occurrence and concentration should be similar to what is found in an urban environment.

Assumptions

An Air Force base may be modeled as an urban environment. Further, Air Force bases generally do not have significant agricultural, silvicultural, or mining activities.

The effectiveness and applicability of BMPs have been adequately validated by the USEPA and other organizations.

Rainfall, as measured at the Air Force Academy weather station, was representative of total rainfall over the entire Air Force Academy grounds.

Although ground water contributes to stream flow and pollutant loading at the Air Force Academy, it is assumed that the ground water contribution to total pollutant load is minor.

Definitions

1. Nonpoint Source water pollution, as stated previously, is pollution which enters the hydrological environment in such a fashion that there is no discrete or specific entry point.

2. Best Management Practices (BMPs) are defined in Federal Regulation 40 CFR 130.2(m) as

> "methods, measures, or practices selected by an agency to meet its nonpoint source control needs. BMPs include, but are not limited to, structural and nonstructural controls and operations and maintenance procedures." Examples of BMPs include use of porous pavement (structural), development of new regulations and public education programs (nonstructural), and street sweeping (operations & maintenance). (5:30)

3. Watersheds are regions or areas drained by a river or stream, or areas whose runoff converges to a particular watercourse.

4. Nationwide Urban Runoff Program (NURP) is a study performed in 1978 to consolidate and expand existing knowledge of urban runoff characteristics.

5. The Clean Water Act of 1972, officially titled the Federal Water Pollution Control Act (FWPCA), established the basic framework for federal water pollution control regulation. "In 1977, Congress renamed the FWPCA the Clean Water Act (CWA)..." (3:65).

6. Water Quality Act of 1987 was an extensive amendment to the Clean Water Act of 1977. The Water Quality Act of 1987 was passed, in part

> to improve water quality in areas where compliance with nationwide minimum discharge standards was insufficient to assure attainment of the CWA's water quality goals. (3:65)

7. Best Available Technology (BAT) is that best technology or treatment that can be applied effectively in the field. This concept also considers costs that may or may not make the process prohibitively expensive.

8. Silviculture or silvicultural operations are characterized as forestry or timber harvesting activities.

9. First flush is that residual NPS pollution, accumulated over the time since the last rainstorm, that results in peak pollutant concentration during the first few minutes of rainstorm runoff.

II. Literature Review

This chapter examines current literature on NPS pollution to determine existing knowledge of the subject.

Background

This first section of the literature review examines legislation and policy, state programs, and current stormwater permit initiatives.

Legislation and Policy. As stated previously, the Clean Water Act of 1972 required states to delineate the extent of their NPS pollution problems and to recommend control programs to address those problems (19:456-457). The Water Quality Act of 1987 re-emphasized NPS pollution concerns by mandating that states assess and report their NPS pollution, and that they develop NPS pollution management programs. This legislation also included authorization for federal loans and grants to facilitate implementation of USEPA approved state management programs (42:66).

In addition to the Clean Water Act, the Coastal Zone Act Reauthorization Amendments of 1990 addressed NPS pollution as a major area of emphasis (49:1-3). Section 6202(a) of the Coastal Zone Act Reauthorization Amendments contains a set of findings by Congress including:

> "Nonpoint source pollution is increasingly recognized as a significant factor in coastal water degradation. In urban areas, stormwater and combined sewer overflow are linked to major coastal problems, and in rural

areas, runoff from agricultural activities may add to coastal pollution." (49:1-4)

The intent of NPS pollution provisions in the Coastal Zone Act was not to replace existing NPS pollution management programs, but rather to supplement and expand them, and ensure close coordination with other coastal zone management programs.

The USEPA is required to publish final guidance by mid 1992 concerning implementation of the Coastal Zone Act Reauthorization Amendments of 1990 (49:1-6). States then have 30 months to develop their own coastal NPS pollution control programs and receive approval of those programs from USEPA and the National Oceanic and Atmospheric Administration.

In 1992 the Clean Water Act is due for reauthorization, proposed as the Water Pollution Prevention and Control Act (56:4-5). This proposed legislation will considerably strengthen the Clean Water Act provisions addressing NPS pollution. In particular, "proposed actions include provisions to improve the control of nonpoint sources on all lands owned or managed by the federal government" (56:4-5).

In spite of these legislative efforts, low dissolved oxygen, and increased phosphorus and nitrogen concentrations continue to be recorded at monitoring stations throughout the U.S. (37:400). Senator Durenberger of Minnesota, in his 17 July 1991 address to the Subcommittee on Environmental Protection, of the Committee on Environmental and Public

Works, United States Senate, offered his views of what direction the Water Pollution and Prevention and Control Act should take (56:7,8). He stated that existing legislation on NPS pollution has not improved water quality. Senator Durenberger's menu for corrective action included specific water quality criteria for NPS pollution, state programs to measure NPS pollution impacts, watershed plans carefully defining necessary NPS pollutant load reductions to achieve water quality standards, and enforcement requirements applicable to both the public and private sectors. "The solutions are site-specific, water quality related, and in need of constant maintenance and adjustment" (56:8).

This ongoing and extensive legislative impetus has prompted establishment of Air Force policy requiring NPS management programs on Air Force installations (17:1).

State Programs. The United States Congress left regulation and control of NPS pollution in the hands of the states because of geographical variability and the site specific nature of NPS pollution. This resulted in the initiation of numerous state programs during the 1980s. Three states that established NPS pollution management programs were North Carolina, Florida, and Pennsylvania (40:51).

North Carolina implemented a subsidy program to promote BMPs among participating farmers. This program picks up 75 percent of the cost involved in BMP implementation (40:51).

Although this program may be considered a financial incentive, it is also the result of one state's approach to exercising its regulatory power.

The State of Florida has five water management districts (40:52). Three of the districts have established stringent permitting programs requiring permits for increases in land use activities. The program is enforced by inspectors conducting surveillance with helicopters, and in-house lawyers to prosecute violators.

Pennsylvania, in 1972, promulgated regulations addressing earth-disturbing activities and requiring pollution control plans in an attempt to limit erosion and sediment (40:52). These regulations were amended in 1985 to authorize delegation of program responsibility to county Conservation Districts. This program, at both state and local levels, is aimed primarily at urban rather than rural NPS pollution violators. Although these pollution control plans are not legally considered permits, plan implementation failures have resulted in criminal prosecution.

<u>Current Stormwater Initiatives</u> (38:52-56). Momentum has been building over the past 20 years to provide federal regulation for stormwater runoff. This has culminated in the Water Quality Act of 1987 - a reauthorization of the Clean Water Act of 1972, and the basis for current National Pollutant Discharge Elimination System (NPDES) permit regulations for stormwater.

In the past, the public's attention, and consequently that of politicians, has been directed toward wastewater discharges rather than stormwater runoff discharges. Additionally, the National Pollutant Discharge Elimination System (NPDES) has been primarily focused on regulating effluent quality of wastewater treatment plants. The fact that stormwater runoff contains considerable amounts of sediment, biochemical oxygen demand, bacterial contamination, and various chemical pollutants has prompted the National Pollutant Discharge Elimination System (NPDES) to initiate the inclusion of stormwater runoff discharges into the permit system.

The National Pollutant Discharge Elimination System (NPDES) permit application regulations were published in the November 16, 1990 Federal Register, making public the requirement for 173 cities, 47 counties, and approximately 100,000 industries to submit National Pollutant Discharge Elimination System (NPDES) permit applications for stormwater discharge. This process is to occur during 1992-1993 and is the initial step in the regulation of NPS pollution resulting from stormwater runoff.

The degree to which dischargers will be required to comply is variable. Municipal storm sewer systems will have to reduce pollutant discharge to the "Maximum Extent Possible" while industrial dischargers are required to use the "Best Available Technology." Industrial dischargers are also required to obtain their own permits rather than being included in a municipal wastewater permit. Industrial dischargers may apply for a permit as a single entity, as a member of a group of similar dischargers, or may opt for a baseline general permit.

Sources and Components

In this section sources and components of NPS pollution are discussed. The United States Environmental Protection Agency has categorized NPS pollution sources as urban, agricultural, silvicultural, and mining (58:28).

Urban. Historically, the greatest concern regarding urban runoff has been the possibility of flooding. When land is converted from its natural state to that of urban usage, large areas of pervious surface are replaced with impervious surfaces (such as roofs, pavements, etc.). A typical city block generates nine times more runoff than an equivalent size woodland (46:2). The consequence of conversion from natural woodland to urban environment is an increase in volume and velocity of stormwater runoff. Both of these factors contribute to concern about flooding, but they also affect erosion rates of unprotected soil surfaces (59:1-1).

Section 208 of the Clean Water Act requires the development and implementation of area-wide waste treatment management plans to improve water quality (19:422-423). Any plan prepared under this section must also include wastewater collection and urban stormwater runoff systems.

> As point source discharges were increasingly brought under control and funds for the construction and upgrading of municipal sewage treatment plants were granted, the awareness of nonpoint sources (including urban runoff) as potential contributors to water quality degradation was heightened. (59:1-1)

Urban NPS pollution has many origins (49:4-1). Six major sources of urban NPS pollution identified by the USEPA are 1) construction sites, 2) septic tank discharges, 3) households, 4) roads and highways, 5) golf courses and parks, and 6) gas stations.

Construction sites, seemingly harmless, produce a variety of NPS pollutants including phosphorus, nitrogen, pesticides, petroleum products, construction chemicals, solid wastes, and sediments (60:40965). Construction activities "can contribute more sediment to streams than was deposited previously over several decades" (60:40965). Septic tank effluent contributes nutrients and biological contaminants. Poor management of household material, such as lawn fertilizer, pesticides, and various wastes, allow potential pollutants to enter the environment unchecked. Roads and highways contribute metals and petroleum products. Excessive fertilizer and pesticide applications on golf courses and parks result in contaminated stormwater runoff. Finally, gas stations release numerous petroleum products into the environment.

Studies over the past 15 years have confirmed the contributions of urban stormwater runoff to NPS pollution (23:A1-A15). These contributions include not only common pollutants such as Biochemical Oxygen Demand (BOD), sediment, nitrogen and phosphorous, but also metals such as lead, chromium, copper, nickel, and zinc. Numerous pesticides are also present in urban runoff.

An example of urban NPS pollution can be found in the Ohio River Valley (36:44). The Ohio River Valley Water Sanitation Commission determined that NPS pollution sources have, in some cases, contributed sufficient pollution to impair designated uses of portions of the Ohio River. Additionally, the Ohio River Valley Water Sanitation Commission found the urban NPS pollution contribution to comprise a significant portion of the total NPS pollution load.

Nationwide Urban Runoff Program (NURP). The unknowns involved with defining urban runoff were of such magnitude, and cost estimates were so high, that federal funding for stormwater treatment was deleted from the Clean Water Act of 1977 (59:1-1).

> The Congress stated that there was simply not enough known about urban runoff loads, impacts, and controls to warrant making investments in physical control systems. (59:1-1 - 1-2)

In 1978, the USEPA determined that a consolidated effort was necessary to integrate stormwater runoff studies accomplished by the technical community and other agencies involved with the Clean Water Act Section 208.

The Nationwide Urban Runoff Program (NURP) was established to

> build upon pertinent prior work and to provide practical information and insights to guide the planning process, including policy and program development and implementation. The NURP program included 28 projects, conducted separately at the local level, but centrally reviewed, coordinated, and guided. While these projects were separate and distinct, most share certain commonalities. All were involved with one or more of the following elements: characterizing pollutant types, loads, and effects on receiving water quality. (59:1-2)

Urban Runoff Pollutant Characteristics. The NURP study adopted the following pollutants as those standard pollutants characterizing urban runoff: (59:5-3)

TSS - Total Suspended Solids
BOD - Biochemical Oxygen Demand
COD - Chemical Oxygen Demand
TP - Total Phosphorus
SP - Soluble Phosphorus
TKN - Total Kjeldahl Nitrogen
NO_x - Nitrite & Nitrate
T Cu - Total Copper
T Pb - Total Lead
T Zn - Total Zinc

There are several points of interest resulting from the analysis of the NURP study data.

Based on analysis of the data according to the land use categories of residential, mixed, commercial, industrial, and open/non-urban,

> one is forced to conclude that land use category does not provide a useful basis for predicting differences in site EMC [Event Mean Concentration] values, at least for this project. (59:6-28)

The Event Mean Concentration (EMC) is defined as the total pollutant constituent mass discharge divided by the total runoff volume (59:5-4). Analysis indicates that variability in storm events substantially overshadows land use effects. (59:6-32)

Another point of interest is there is no significant linear correlation between Event Mean Concentration (EMC) and runoff volume (59:6-41). In other words, greater runoff does not necessarily mean higher or lower concentrations of pollutant.

Based on the fact that geographic location, land use, or any other single factor was insufficient to predict runoff characteristics, the general characterization of urban runoff was obtained by pooling data for all sites (excluding open/non-urban) (59:6-43). This information is contained below in Table 1.

Table 1.

Water Quality Characteristics of Urban Runoff (59:6-43)

Constituent (mg/l)	EMC for Median Urban Site	EMC for 90% Urban Site
TSS	100	300
BOD	9	15
COD	65	140
TP	0.33	0.70
SP	0.12	0.21
TKN	1.50	3.30
NO_x	0.68	1.75
T Cu	0.034	0.093
T Pb	0.144	0.350
T Zn	0.160	0.500

As discussed above, the Event Mean Concentration (EMC) is the total pollutant constituent mass carried away by a particular runoff event, divided by the total runoff volume. On Table 1, for the median urban site, the Event Mean Concentration of Total Suspended Solids in a liter of runoff would be 100 mg (59:5-4).

The second column in Table 1 gives the 90% level of pollutant concentration for sites in the NURP study. This indicates that 90% of all sites included in the study produced median Event Mean Concentrations equal to, or less than, the concentrations shown.

The information on Table 1 is "recommended for planing level purposes as the best description of the characteristics of urban runoff" (59:6-43).

Annual Urban Runoff Loads. Estimates of annual urban runoff unit loadings are shown in Table 2. These annual unit load computations "are based on site mean pollutant concentrations for the median urban site and on the specified values for annual rainfall and runoff coefficient" (59:6-63). The annual rainfall used in constructing Table 2 was 40 inches per year.

The Runoff Coefficient (Rv), used in Table 2, is defined as "the ratio of runoff volume to rainfall volume" over the area of concern (59:6-57). The Rv is a function of topography, soil type, vegetative cover, and degree of imperviousness.

The Rv is an essential element in determining the NPS pollutant loading. This value must be adjusted, based on empirical data, to reflect variance in area of impervious surfaces or permeability of the soil. For a very compact base with large paved areas the Runoff Coefficient would be higher than for a base with large areas of woodlands. The NURP study used a value of .35 (the median value over twenty NURP projects) as a typical mean runoff coefficient for a mean annual average rainfall of 40 inches (59:6-62). For equivalent site conditions (same Rv) but site specific climatology, the loads presented in Table 2 should be factored by a ratio of actual rainfall to the 40 inches used in the table.

> Typical values for mean runoff coefficient [(Rv)] (based on NURP data) have been assigned for residential land use (Rv = 0.3), commercial land use (Rv = 0.8), and for an aggregate urban area which is assumed to have representative fractions of the total area in residential, commercial, and open uses (Rv = 0.35). (59:6-63)

The Concentrations and Annual Loadings in Table 2 are based on 40 inches of rainfall per year. Additionally, the hecta-acre in Table 2 is a measurement of land containing 10,000 square meters and is approximately equal to 2.49 acres.

Total pollutant loadings were determined using the Event Mean Concentration (EMC) and the total runoff volume.

Event Mean Concentrations were determined by analysis of pollutant constituent concentrations in flow proportional samples of the particular event.

Table 2

NURP Unit Quantity Runoff Loads (59:6-64)

Constituent	Site Mean Conc.(mg/l)	Residential Kg/HA/Yr	Commercial Kg/HA/Yr	All Urban Kg/HA/Yr
Assumed Rv		0.3	0.8	0.35
TSS	180	550	1460	640
BOD	12	36	98	43
COD	82	250	666	292
TP	0.42	1.3	3.4	1.5
SP	0.15	0.5	1.2	0.5
TKN	1.90	5.8	15.4	6.6
NOx	0.86	2.6	7.0	3.6
T Cu	0.043	0.13	0.35	0.15
T Pb	0.182	0.55	1.48	0.65
T Zn	0.202	0.62	1.64	0.72

> where sequential discrete samples were taken over the hydrograph, the event mean concentration was determined by calculating the area under the loadgraph (the curve of concentration times discharge rate over time) and dividing it by the area of the hydrograph (the curve of runoff volume over time). (59:5-4)

The annual load estimates given in Table 2 are comparable to those reported in the literature (59:6-63). However, as previously noted,

> the land use category does not have a significant influence on site concentrations of pollutants, on a unit area basis total pollutant loads are significantly higher for commercial areas because of the higher degree of imperviousness typical of such areas. (59:6-63)

Agriculture. Agricultural NPS pollution is cited throughout the literature as the major contributor to NPS pollution. Duda reported "almost all" states consider their most significant source of NPS pollution to be agricultural (15:228). Vigon stated that 68 percent of the nation's watersheds are impacted by agricultural NPS pollution, contrasted with 52 percent impacted by urban sources (62-:180). The USEPA states simply that "agriculture is the nation's largest contributor of nonpoint source pollution" (49:2-1).

Agricultural NPS pollution presents a significant problem in the assessment and control of pollutants due to the vast number of private farmers distributed throughout the country. Often, the farmers see regulation and direction associated with management of NPS pollution as a violation of their property rights (40:51). United States House of Representatives member, Pat Roberts, from Kansas' First District stated in a 1985 national conference on NPS pollution that

> the last thing the farmer needs in these difficult economic times is a massive new set of Federal regulations to tell him how to control runoff. And, you cannot expect the farmer to bear the entire cost of controlling nonpoint sources of pollution while most of the benefits will accrue to society as a whole. (50:3,4)

At the same national conference, the Secretary of the United States Department of Agricultural cited erosion control and water quality, both related to NPS pollution, as the agency's top two priorities (50:5).

States and local authorities throughout the nation have varied methods of enforcing legislation and regulatory requirements within the agricultural community. One federal program created to control agricultural NPS pollution and ease the burden on the farmers is the Rural Clean Water Program, started in 1980. The Rural Clean Water Program is a BMP cost sharing program administered by the United States Agricultural Stabilization and Conservation Service (26:207). This program has shown effective agricultural BMPs must be part of a comprehensive resource management plan able to balance water quality with agricultural productivity (7:240). Simply stated, farmers must perceive an economic benefit to be enthusiastic about NPS pollution control measures.

The three primary objectives of the Rural Clean Water Program are 1) cost effective improvement of water quality in conjunction with agricultural production, 2) assistance to rural landowners and farmers in NPS pollution control measures, and 3) development and testing of programs, policies, and procedures to control agricultural NPS pollution (52:18). USEPA has identified technical assistance and education as the key to successful voluntary programs to control agricultural NPS pollution (52:19).

In addition to the Clean Water Act, the Safe Drinking Water Act, the Coastal Zone Act Reauthorization Amendments, and the 1990 Farm Bill contains strong provisions concerning water quality (51:2,3). Many experts agree that the 1990 Farm Bill is the "most environmentally sound agricultural legislation ever passed by Congress" (51:2). That portion of the bill directed at controlling NPS pollution is the Water Quality Incentives Program. This program requires the United States Department of Agricultural to provide technical assistance and payments of up to $3,500 to farmers who have developed and implemented water quality programs. Acceptable water quality programs are defined as those which

> "protect water quality by mitigating or reducing the release of agricultural pollutants, including nutrients, pesticides, animal waste, sediments, silts, biological contaminants and other materials into the environment." (51:3)

The literature groups agricultural NPS pollution into four areas of concern: 1) erosion and sediment from cultivated fields; 2) confined animal facilities including feedlots, dairies, and poultry farms; 3) nutrient loadings from cropland and cattle farms; and 4) pesticide application (49:2-8).

In 1984, ninety percent of the states reported sedimentation due to soil erosion causing significant impairment of water uses (15:225-228). Cultivated fields are identified as the primary cause of turbidity and sediment (44:427). Additionally, farming states such as Illinois and North

Carolina reported eighty percent of soil erosion, with attendant sedimentation, to be due to cropland use. Sediment, which includes clays, silts, sands, rocks, and organic materials, results in disruption of the food chain by reducing light penetration and thus plant growth. Extensive sedimentation due to cropland erosion in a Tennessee watershed resulted in, not only reduced fish populations, but also the worst water quality of any major river in the state. Up to $270 million in damage to water storage capacity is caused annually by cropland erosion (63:925).

In an attempt to control NPS pollution from feedlots and dairies, 40 CFR 122.23 requires a federal National Pollutant Discharge Elimination System (NPDES) permit for those operations with a capacity of over 1,000 animal units (53:15-16). An animal unit is equivalent to one mature cow, or 1000 chickens (4). However, as individual states are taking over the National Pollutant Discharge Elimination System (NPDES), the requirements are varied. Minnesota requires a permit for more than 10 animal units. Illinois requires a permit for all feedlots identified as contributing to water pollution, and has restrictions on where feedlots may be located with respect to populated areas (55:13). Wisconsin requires all feedlots identified as contributing to ground or surface water pollution due to improper management, in addition to those over 1,000 animal units, to obtain a permit (54:20). The Wisconsin Department of Natural Resources characterizes improper management subject to mandatory corrective action as

> overflow from an animal waste storage facility, over application of animal wastes, direct runoff of animal waste from the operation, discharge of leachate from a manure stack, seepage from an animal waste storage facility, or construction of an animal waste storage facility in permeable soils over fractured bedrock with a liner of inadequate design. (54:20)

The poultry industry, also a source of agricultural NPS pollution from confined animal facilities, is working with the United S*ates Department of Agriculture and the USEPA to eliminate water quality problems caused by improper disposal of dead birds and litter (56:11,12).

Another area of agricultural NPS pollution concern is nutrient loading. Nitrogen and phosphorous from fertilizer are the two major agricultural nutrients that degrade water quality (51:8). Literature surveyed identified cropland as the primary source of nutrient NPS pollution. However, dairy and beef cattle farms also contribute and are the principal source of nutrient loading into Lake Okeechobee, Florida (6:15).

The predominant issue in prevention of cropland nutrients from degrading water quality is the determination of optimal fertilizer application (51:8,9). Excessive application of water soluble fertilizer contributes to the nutrient loading carried by rainwater runoff. This form of agricultural NPS pollution is the source for approximately 67 percent of nitrogen and 39 percent of phosphorous entering

Chesapeake Bay. Farmers have been using "more fertilizer than is necessary and applying it at a less effective stage of plant growth" (51:8). Nutrient management programs have been initiated in three states to reduce agricultural NPS pollution in Chesapeake Bay (51:8).

Water quality programs were the initiative behind a 200 million pounds per year reduction in nitrogen application in Iowa during 1989-1990 (58:18-19). During the same time, nitrogen application rates stayed the same elsewhere in the corn belt. Education and technical assistance showed the Iowa farmers how to use fertilizer more efficiently while maintaining production and profits. "Each dollar spent for education saved farmers eight dollars in fertilizer costs" (58:19).

The final major agricultural NPS pollution area of concern identified in the literature is pesticide application. Pesticides, including insecticides, herbicides, and fungicides, are used to control pests and ultimately to enhance production (49:2-6). The agricultural community is the largest consumer of pesticides in the United States, and often applies these compounds near bodies of water (7:239).

These pesticides can harm the environment by limiting desirable organisms. Detrimental effects caused by pesticides include structural changes in the organism, destruction of food sources, disruption of the food chain, and bioconcentration of toxins (49:2-6). Some states are developing integrated pest management plans, similar to nutrient management programs, to effectively control the excessive or harmful application of pesticides for agricultural purposes (51:10).

> The key concept for water quality and environmental protection is that with proper use of soil conservation practices, the risk of pesticide loss to surface waters is greatly reduced. (15:231)

Silviculture. Silvicultural operations, or timber harvesting, contribute significant NPS pollution to streams unless adequate control measures are implemented. "Sediment from roads and landslides, loss of shade from stream canopy removal, woody debris jams..., increased channel erosion, and increased bedload sediments" caused by silvicultural activities all contribute to NPS pollution loading (49:3-1). These silvicultural consequences are increased total suspended solids, turbidity, wood accumulation on stream bottoms, increased stream temperature, alteration of stream structural habitat from fallen trees and other debris obstructions, and nutrient and toxic pollutant accumulation (49:3-1). Of those NPS pollutants resulting from silviculture, turbidity has been identified as having the most significant impact on water quality (11:42).

As is the case with agricultural NPS pollution, states have adopted various approaches to manage NPS pollution from silvicultural operations (57:9-15). The USEPA identified voluntary BMP programs and state forestry rules and regulations as two state approaches (49:3-2). The State of Montana has passed legislation called the 1991 Streamside Management Act and published a booklet titled Montana Forestry BMPs: Forest Stewardship Guidelines for Water Quality. The Montana plan provides the following synopsis of how silvicultural operations adversely impact the environment through NPS pollution:

> Excessive runoff and sedimentation into streams can increase filtering costs for drinking water, interfere with irrigation systems and increase flood potential. Fish eggs laid in stream gravels become buried in sediment and suffocate. Removing shade from streamsides can raise water temperatures which effects fish and other aquatic life. Streamside damage also affects wildlife which rely on these habitats. (57:10)

Montana's 1991 Streamside Management Plan establishes Streamside Management Zones, at least 50 feet on each side of the body of water, as special protection areas to prevent silvicultural NPS pollution from degrading water quality (57:10). Some activities forbidden within this zone are off-road operations of wheeled or tracked equipment, clear cutting, construction of roads, and the deposit of tree debris.

Guidelines to assist in the development of water quality monitoring plans in forested areas have been developed for the Pacific Northwest states by The USEPA Region X (57:12). Region X's guidelines have the goal of maintaining or restoring the integrity of the aquatic ecosystem (57:12). West Virginia has adopted a four year program for implementation by the State Forestry Division to improve water quality. The essence of West Virginia's plan is technical

BMP assistance through both formal logger workshops and landowner workshops stressing the importance of proper timber harvesting procedures. Pennsylvania has developed silvicultural BMPs applicable to public and private silvicultural activities and aimed at the State's specific water quality problems (11:42).

USEPA notes that many water quality problems resulting from silviculture today are not due to the ineffectiveness of BMPs, but instead are due to inappropriate implementation (49:3-2). The National Association of State Foresters has taken an active role to ensure that loggers and landowners are properly educated on the implementation of BMPs and the impacts of poor water quality (58:13). State foresters in 40 states are actively involved with their state's NPS pollution programs (58:13).

Mining. The impact of NPS pollution from mining operations can be exceptionally severe on receiving waters. Polluting substances are generated or released by exposure of waste rock and tailings to air, rain, groundwater, and microbial reactions. These pollutants include sediment, toxic metals, acids, and radioactive material. Phosphate mining contributes to the release of concentrated biological nutrients (9:55-57).

Mining activities, although significant NPS pollution contributors, are not typical of Air Force activities or installations. As such, they are not considered further in this study.

Best Management Practices

This section covers representative BMPs for urban, agricultural, and silvicultural sources of Nonpoint Source pollution. The technical aspects of individual BMPs are not addressed.

The Federal Regulation 40 CFR 130.2(m) defines BMPs as:

> "Methods, measures, or practices selected by an agency to meet its nonpoint source control needs. BMPs include, but are not limited to, structural and nonstructural controls and operations and maintenance procedures." Examples of BMPs include use of porous pavement (structural), development of new regulations and public education programs (nonstructural), and street sweeping (operations and maintenance). (5:30)

The United States Department of Agriculture, in conjunction with the Agricultural Stabilization and Conservation Service, the Soil Conservation Service, the Agricultural Research Service, and the USEPA, is aggressively working to solve problems of soil erosion and runoff, pesticide and herbicide leachates, and nutrient influx into receiving waters (34:50). The overall objective of implementing BMPs is to maintain or improve water quality. BMPs may be characterized as "methods, measures, or practices designed to reduce [nonpoint source] pollution" (27:201). These practices may be a combination of individual procedures and may impact more than one source of pollution. Appendix A of this thesis provides a compendium of BMPs from which Air Force base managers may choose mitigation measures.

<u>BMPs for Urban NPS Pollution</u>. The implementation of BMPs is a necessary component of a management plan to control Nonpoint Source pollution in urban areas. Studies indicate that typical urban pollutants include copper, lead, mercury, nickel, silver, zinc, and polycyclic aromatic hydrocarbons (5:28). Polycyclic aromatic hydrocarbons are "byproducts of incomplete combustion primarily from automobile engines" (5:28). The NURP study identified all of these materials as components of urban NPS pollution. However, of the above materials, the NURP study includes only copper, lead, and zinc among the ten NPS pollutants characterizing urban runoff (59:5-3).

<u>Urban BMPs</u>. The actual selection and implementation of BMPs for urban areas depend on several factors: 1) water quality improvement; 2) peak discharge reduction; 3) site suitability; 4) cost effectiveness; 5) maintenance requirements; 6) effect on other resources; and 7) public acceptance (33:3.4-1 - 3.4-3). Urban BMPs can be categorized as structural, nonstructural, and operations and maintenance control measures.

Structural BMPs are those requiring physical construction activities to implement. Two examples of structural BMPs related to the control of urban NPS pollution are detention ponds and oil/grit separators (33:4.1-1, 4.6-1).

"Detention ponds are one of the most effective BMPs available for treatment of urban runoff" (33:4.1-1). Detention ponds are permanent pools of water designed to temporarily catch and detain stormwater runoff. Polluted stormwater entering the pond is mixed and diluted with the existing pond water. This diluted mixture then exits through a designated outfall. The pollutants in the retained pond water settle to the bottom (33:4.1-1). The remaining clean water then awaits future stormwater to dilute.

> Oil/grit separators are typically used in urban areas with heavy traffic or high potential for petroleum spills such as parking lots, gas stations, roads, and loading areas. (33:4.6-1)

Oil/grit separators are connected to the storm sewer system (33:4.6-2). This structural BMP for urban NPS pollution control is effective in removing floating oils and greases along with coarse sediments from storm runoff (33:-4.6-1).

Oil/water separators, common to Air Force installations, are similar to oil/grit separators. Oil/water separators are stormwater runoff catchments used to skim floating petroleum contaminants from the surface of runoff prior to discharging into a storm drainage system.

Nonstructural BMPs are those associated with regulatory and educational programs (5:28-30). Examples of nonstructural urban BMPs are identified in the implementation phase of the city and county of San Francisco BMP plan. Regulatory control measures are aimed at developing and strengthening regulations controlling discharge of NPS pollutants, including discharges from private homeowners. Educational control measures are aimed at the general public. Examples of educational BMPs are workshops for businesses, integration of BMPs into curriculums for school children, and public relations programs aimed at households. The focus of these educational BMPs is to identify impacts, proper use, and effective safeguarding procedures for potential Nonpoint Source pollutants.

The final category of urban BMPs addressed in the literature is operations and maintenance BMPs. The Minnesota Pollution Control Agency refers to urban operations and maintenance BMPs as "housekeeping BMPs" (33:vii). Two representative operations and maintenance BMPs for urban Nonpoint Source pollution are litter control and de-icing chemical use and storage (33:5.2-1, 5.5-1).

The BMP for litter control means collecting garbage, leaves, and lawn clippings from streets before debris is moved into waterways by wind or rain (33:5.2-1). A study in Minneapolis revealed a 30 to 40 percent reduction in phosphorus levels in area lakes when street gutters were kept free of leaves and lawn clippings.

The BMP for controlling de-icing chemical use and storage involves the exercise of correct application and storage procedures (33:5.5-1). Preventing excessive application will preclude unnecessary NPS pollution since "virtually all salt applied for de-icing eventually enters surface or ground water" (33:5.5-1). NPS pollution may also be prevented by proper storage of de-icing chemicals, such as storing in a shed or covering piles with polyethylene.

Urban BMP Plan (5:28-33). The city and county of San Francisco has developed a BMP plan to control NPS pollution. The plan is divided into three main areas: "implementation, study, and special monitoring" (5:28). The implementation phase consists of educational, regulatory, and public agency control measures. In the study phase, additional BMPs found to be cost effective and operationally effective will be recommended for implementation. The final phase, special monitoring, will determine the effectiveness of implemented BMPs in maintaining or improving water quality.

BMPs for Agricultural NPS Pollution. BMPs are required to control agricultural NPS pollutants to meet water quality standards. The literature reveals implementation policies for BMP plans to be an important issue in the control of agricultural NPS pollution (12:499; 30:68; 31:70; 40:51-57).

Agricultural BMP Implementation. In accordance with the Water Quality Act of 1987, states have the authority to administer their own NPS pollution program. A significant part of the program is to determine which problems to target for controls and implementation of BMPs. Dickinson and others suggest, that as a whole, NPS pollution control efforts have not been directed at those agricultural areas producing the greatest pollution load (12:499). However, regardless of which areas are targeted for control, state policies vary on requirements for the implementation of BMPs (16:263; 30:68; 31:70; 40:51-57).

BMP implementation policies vary from state to state, and from county to county within states, depending on several variables. These variables include the state's regulatory requirements, funds available for subsidies, and the significance of the NPS pollution problem (16:263; 30:68; 40:51). States have difficulty implementing regulations requiring farmers to use particular BMPs because farmers may perceive the direction as a violation of their property rights (40:51). Some states provide direct financial assistance to farmers for BMP implementation or fund BMP demonstration projects (30:68; 40:51). Another BMP implementation policy used to control agricultural Nonpoint Source pollution is the requirement of specific BMPs in watersheds with poor water quality (16:263).

Jim Baumann of the Wisconsin Department of Natural Resources provides an appropriate summary of the issue of BMP implementation policies for agricultural areas:

> My feeling is the farmers are willing to go along if the landowner has adequate opportunity to voluntarily sign an agreement to do what's needed, and if they get reasonable financial and technical assistance. (31:70)

In addition, a survey of over 700 farmers in three states found they favored technical assistance as a policy to control NPS pollution (40:57). Technical assistance was followed, in order of most favor, by cost sharing, requiring BMPs, and permitting programs.

Agricultural BMPs. BMPs capable of blending in with existing farming practices or providing economic or labor saving benefits are more likely to be implemented by farmers (27:203). Agricultural BMPs can also be categorized as structural, nonstructural, and operations and maintenance controls.

Structural BMPs to control agricultural NPS pollution include terraces and vegetative filter strips (8:595; 27:20-2). Terraces are a traditional erosion control practice and are effective in reducing phosphorus levels in adjacent waterways (27:202). A vegetative filter strip is a permanent strip of vegetation between a pollution source and a waterway (49:2-73). These vegetation areas detain sediment, nutrients, and other potential pollutants (13:420). Properly installed filter strips can remove a variety of pollutants from runoff, including nitrogen, phosphorus, and heavy metals (8:595; 27:202). The Federal Vegetative Filter Strip Program is one technique of combining a structural BMP with cost sharing to combat agricultural NPS pollution from cropland.

> This program was designed to reduce soil erosion, improve water quality and wildlife habitat, and eliminate production of excess commodities. Participating farmers receive an annual rental payment of $75 to $200/ha for land enrolled in the program. (13:420)

Nonstructural BMPs are those resulting from regulations and education programs. Typical nonstructural BMPs controlling NPS pollution from agricultural operations are fertilizer and pesticide application controls (18:6-10 - 6-27). Local municipalities and local county agricultural extension services provide education to property owners concerning the proper timing and concentration of fertilizers and pesticides to be applied (18:6-11, 6-25). In addition, the USEPA approves pesticide labels. Compliance with label instructions is mandated by law.

Operations and maintenance BMPs are the final category of agricultural BMPs to be discussed. Two typical operations and maintenance BMPs are the timing of manure application as fertilizer and integrated pest management practices (8:595; 27:203). A seven year study in Vermont showed springtime application of manure on land planted in corn resulted in acceptable phosphorous concentrations, while winter and fall application exceeded acceptable levels (8:595). Integrated pest management practices are designed to reduce pesticide use, and therefore pollution, by "a combination of control methods based on a thorough understanding of the life system of the pest" (18:6-27). Pesticides should be applied only when wind speed is less than 7 mph and the air temperature is between 40 degrees and 80 degrees Fahrenheit (18:6-24).

BMPs for Silvicultural NPS Pollution. Silviculture has a dramatic impact on a watershed area. Increases in nitrate, potassium, temperature, and turbidity can typically be expected in waterways near silvicultural operations (11:41). State Department of Forestry agencies can be expected to enforce silvicultural BMP requirements (49:3-2). Corbett and Lynch state "by employing BMPs, forests can be harvested with minimal impact on stream quality" (11:51).

Silviculture BMPs. Silviculture BMPs may be categorized as nonstructural and operations and maintenance. Four typical BMPs to control NPS pollution from silvicultural operations are 1) protective buffers, 2) block harvesting, 3) siting of landing sites, 4) and siting and retirement of logging roads (11:42-43).

Maintaining a protective buffer of undisturbed trees 100 feet wide on each side of streams reduces the effects of turbidity and water temperature from silvicultural operations (11:42-51). The 100 feet width is significant because it is normally sufficient to keep wind thrown trees from falling across streams and minimizes the impact of erosion from uprooted trees.

Block harvesting is also a BMP to reduce the impacts of Nonpoint Source pollution from silvicultural operations (11:42). A large tree harvest should be divided into blocks, and harvesting within a block should be completed before starting another. Block harvesting provides a control to ensure an operator has done an efficient job before continuing the tree cutting operation.

Another typical BMP for silvicultural operations is the siting of landing sites (11:43). Landing sites are the locations where fallen trees are loaded onto trucks. These sites should be selected by a professional forester and should be at least 300 feet from any stream.

Site selection and removal of logging roads is the final representative BMP for control of Nonpoint Source pollution from silvicultural operations (11:43). The routes should be selected by a professional forester and constructed before tree harvesting, to allow settlement. Additionally, the roads should be returned to pre-harvesting conditions when the logging operations are completed.

Computer Models

It is critical to know where pollutants originate and their subsequent movement, under varying conditions, through a watershed. Effective implementation of Best Management Practices may require determination of NPS pollutant loadings as a function of pollutant source variation.

Numerical simulation models are a useful tool in the analysis of watershed contributions to NPS pollution loads and transport mechanisms. These models have been developed to address many different land uses, including agricultural, urban, and mixed watersheds. In addition to general simulation models, there are a number of models that address specific pollutants or circumstances (23:14-21).

> Models can be helpful in understanding, projecting, and abating non-point-source problems. However, modeling must be a part of an integrated attack on a problem, not its focus. (35:49)

<u>NPS Pollution Simulation Models</u>. Numerous computer models have been developed to simulate NPS pollutant transport and contribution in both urban and agricultural settings. Development of a successful model requires "analysis of the complete environmental system" (61:10). Model development problems can be grouped into three broad categories (61:10).

The first category is the difficulty in understanding processes through which materials may become NPS pollutants (61:10). This includes such facets as fertilizer and pesticide application, animal waste, and mining activities. "The main concern in model development is the optimization of the amount and the timing of the chemical application in order to minimize expenses" (61:10).

The second problem category of model development is the determination of pollutant accumulations, whether physical as in siltation processes, or biological as in bioaccumulation of heavy metals in fish tissue (61:10). Because of the long time frames for

> these types of pollutants, the quantification methods and predictive models are simple, usually empirical, and average annual information is sufficient for developing nonpoint source management plans. (61:11)

The last problem category is concerned with toxic materials or chemicals whose environmental and health effects are liable to occur over a short period of time (61:11). These models "require an extensive program of monitoring and data collection" (61:11). "They usually are expensive to use, difficult to calibrate, and time consuming" (61:11).

Implementation of an NPS pollution simulation model may also incur several potential problems. Algorithms in NPS models are usually empirical or semi-empirical in nature requiring a "precise knowledge of many coefficients and reaction rates" (61:13). General ranges or orders of magnitude are often the only estimates for these required inputs. Calibration and verification of the model components requires an accurate set of measured data. Additionally, extensive field sampling and testing may be required to provide the model input data. These requirements may prove very time consuming and expensive to generate if such information does not already exist. (61:13)

The decision to use a computer model in evaluation of NPS pollution must address cost, model accuracy, ease of use, calibration difficulty, pollutant types, land uses, and model specificity (61:37). Some of the available models are "pollutant, pollutant process, and land use specific [or else are] valid only in the geographic areas for which they were developed" (61:37).

Simulation models for NPS pollution

> also require specially trained personnel to input the data into the model and to run the program. Generally, the use of these models has been limited to aiding in setting water quality objectives in an area and selecting the best management programs to meet water quality objectives. (61:37)

Conclusion

NPS water pollution remains a major water quality problem in spite of almost 20 years of legislation. Investigations have concluded that as much as 50 percent of receiving water degradation is the result of NPS pollution. Both urban and rural sources have been shown to be contributing factors.

Current legislation, specifically the Water Quality Act of 1987, has been instrumental in the effort to control NPS pollution. The states, tasked with the responsibility of managing NPS pollution, are implementing a variety of programs, ranging from financial incentive to legal punitive. Various federal agencies, such as the United States Department of Agriculture and USEPA, are developing and implementing programs to assist and enhance state efforts. Additionally, National Pollutant Discharge Elimination System (NPDES) permits are now required for stormwater discharge.

Urban, agricultural, silvicultural, and mining activities produce a variety of NPS pollutants. The NURP identified ten pollutants, including suspended solids, oxygen depleting constituents, nutrients, and metals as characterizing urban pollution. The unit quantities and overall loading estimates for these ten urban pollutants were also identified in the study.

NPS pollution resulting from agriculture, silviculture and mining activities contributes to impairment of water quality. Agriculture is identified in the literature as the greatest contributor of NPS pollution in the United States. However, the large scale of agriculture, silviculture, and mining operations discussed within the literature would not be expected to exist on an Air Force base.

The literature indicates a broad range of Best Management Practices can be implemented to control the impacts of NPS pollution from urban, agricultural, and silvicultural operations. Overall measurement of effectiveness for BMPs is how well they maintain or prevent deterioration of water quality. Policies chosen by states to achieve the desired results vary from requiring BMPs to total voluntary programs (30:68; 40:51-57).

Computer models are available that simulate NPS pollutant transport and total NPS pollutant loading to provide a measure of water quality. Numerous models are available. Many are focused on specific pollutants or geographies and are not generalizable to other situations. The level of experience and expertise required to use these models varies, but is usually high.

III. Methodology

As stated in Chapter I, it is imperative that Air Force base managers be able to determine NPS pollution loading generated on their installation in order to respond to federal, state, and local legislation. This requires development of a methodology for characterization and management of NPS pollution including identification and quantification of pollutants, and recognized Best Management Practices which can be applied as pollutant control measures.

This chapter presents the methodology used to meet the objectives of the research and answer the investigative questions outlined in Chapter I. The following investigative questions were posed:

1) What typical NPS pollutants are generated on an Air Force base by various activities and land uses?

2) What are the unit quantities identified in the literature for typical NPS pollutants?

3) What results are obtained when modeling is used to predict total NPS pollutant loading?

4) What results are obtained from a water sampling and analysis program to determine existing NPS pollutant loading?

5) How do results from water sampling and analysis compare with model results, and can the models be used to predict NPS pollutant loading on an Air Force base?

6) What BMPs recommended by the United States Environmental Protection Agency for Nonpoint Source pollutant management are applicable to Air Force Operations?

Answers to these investigative questions were used to develop a tool for the Base Civil Engineer or Environmental Manager to use in meeting legislative and regulatory requirements associated with NPS pollution.

NPS Pollutant Identification

The first investigative question involves identification of typical NPS pollutants generated on an Air Force base. This requires a delineation of Air Force activities and land uses that generate NPS pollutants. Activities which generate pollutant constituents unique to a particular installation are not addressed by this study. Significant NPS pollutant generating Air Force activities and land uses are divided into the following nine categories.

Category 1 - Pavements. Pavements, including airfield surfaces, streets and roads, parking lots, and open storage areas act as impervious surfaces concentrating and channeling rainwater runoff. This runoff carries with it contaminants that have accumulated on the pavement surface.

Category 2 - Roofs. Roofs act as an impervious surface similar to pavements. Roof surfaces contribute dissolved metals to rainwater runoff and increase runoff quantity and velocity.

Category 3 - Industrial. Industrial operations include aircraft, vehicle, and weapons maintenance complexes; painting and corrosion control shops; roads and grounds shop; and washracks. Other operations of an industrial nature, such as fuel storage and distribution, warehouses, and munitions storage areas may be located at various locations throughout a base. Central heat plants, potable water plants, wastewater treatment plants, and power generating facilities are industrial in the context of this study. Small arms firing ranges are also considered industrial as their operation involves direct injection of lead and other metals into the environment.

Category 4 - Fertilized Areas. Fertilizer is applied around facilities, on outdoor recreation areas, parks, golf courses, and in residential areas.

Category 5 - Residential. Residential areas encompass both multi-unit and single-unit housing areas. Some common household materials which may contribute to NPS pollution include car waxes, paints, detergents, insecticides, degreasers, motor oil, gasoline, drain cleaners, and toilet cleaners (46:2). Additionally, piles of leaves and grass clippings contribute NPS pollution by release of phosphorus and nitrogen.

Category 6 - Construction Sites. Open construction activities, less than five acres in area, which disturb existing soil conditions cause extensive silt and sediment contributions to NPS pollution. Construction sites greater than five acres are considered by Congress to be point sources of pollution (22:7).

Category 7 - Pesticide Application. Pesticides include insecticides, fungicides, and herbicides, and may be applied throughout an Air Force base.

Category 8 - Silviculture. Silviculture operations, or tree farming, may take place on large Air Force bases that contain significant forest acreage.

Category 9 - Agriculture. Agriculture refers to large scale commercial farming. This may occur through programs that allow farmers to plant and harvest crops on Air Force property.

Some Air Force bases contain substantial acreage of unused, undeveloped land retained in its original state. Contributions of naturally occurring NPS pollutants from this category of land are minimal and were not considered in this study.

Categorized activities and land uses described in the literature fall under three general headings of Urban, Agricultural, and Silvicultural. The majority of Air Force activities and land uses are found in the Urban category. This is reasonable when one considers that an Air Force base is very similar to a small community. An Air Force base typically contains single-unit family housing areas, multi-unit dwelling areas, community activity areas, shopping facilities, service stations, large parking areas, an airport, parks and playgrounds, and other facilities that make it a self-contained urban community.

Although commercial agriculture and silviculture may occur on some Air Force bases, the limited occurrence of these operations relegates them to the unique category. Additionally, large scale agricultural and silvicultural operations are uncharacteristic of an urban environment. As such, they will not be included in this study. Small scale agriculture, such as personal gardens, and individual tree clearing are included in the urban context.

Because of the similarity between an Air Force base and an urban community, the results of the NURP study were applied. As such, the ten pollutants identified in the NURP study, listed on page 20, were the pollutants selected as target NPS pollutants of this research.

Determination of Unit Quantities

Determination of typical NPS pollutant unit quantities generated on an Air Force base was the next investigative question. Unit quantities are measures of the NPS pollutants generated per area of land use, for example, the quantity of phosphorous generated per acre per year from a golf course.

Identification of typical NPS pollutant unit quantities was determined through the literature review. Unit quantities for the ten characteristic urban NPS pollutants were presented in the results of the NURP study as shown below in Table 3. As previously discussed, this study's results are applicable based on the assumption that an Air Force base resembles an urban environment.

Table 3

Unit Quantity Runoff Loads - KG/HA/YR (59:6-64)

Constituent	Residential Kg/HA/Yr	Commercial Kg/HA/Yr	All Urban Kg/HA/Yr
Assumed Rv	0.3	0.8	0.35
TSS	550	1460	640
BOD	36	98	43
COD	250	666	292
TP	1.3	3.4	1.5
SP	0.5	1.2	0.5
TKN	5.8	15.4	6.6
NOx	2.6	7.0	3.6
T Cu	0.13	0.35	0.15
T Pb	0.55	1.48	0.65
T Zn	0.62	1.64	0.72

The runoff coefficient (Rv) values are required in the determination of NPS pollutant loads from Table 3. As mentioned previously, the Rv value is a function of topography, soil type, vegetative cover, and degree of imperviousness. Values of unit quantity runoff loads on Table 3 were calculated "based on site mean pollutant concentrations for the median urban site and on the specified values for annual rainfall and runoff coefficient [Rv]" (59:6-63). The annual rainfall used by the NURP study to calculate the values in Table 3 was 40 inches.

For urban areas incurring annual rainfall different than 40 inches, the load calculations must be adjusted by a ratio of actual rainfall to the 40 inches used in the study. It is unlikely that the Rv calculation for a site will result in an Rv exactly the same as those in Table 3. Linear interpolation should be used to arrive at loadings for Rv values other than those presented in Table 3.

Modeling

Two methods of modeling were employed to predict total NPS pollutant loading. The results from the two models were compared to those obtained from a water sampling and analysis program.

The first model, referred to as the Unit Quantity Model, consists of determining an Rv value, land area, and annual rainfall in order to use Table 3 to predict NPS pollutant loads. As stated previously, Rv values are determined by an assessment of the physical characteristics of the watershed. Additionally, adjustments will be required if annual rainfall is different from the 40 inches used to obtain the results in Table 3.

An example of the Unit Quantity Model to predict Total Suspended Solids (TSS) for a site of 200 hecta-acres, with an Rv of 0.30, and total yearly rainfall of 40 inches is shown below:

550 Kg/HA/Yr (from Table 3) x 200 HA = 110,000 Kg/Yr.

The second model is a computer model called ProStorm (14). ProStorm was developed as a personal computer version of the U.S. Army Corps of Engineers' Storage, Treatment, and Overflow Runoff Model (STORM) computer simulation model, to be used as a National Pollutant Discharge Elimination System (NPDES) permit analysis software package. This model provided loads and concentrations for Total Suspended Solids, combined TKN and NO_3, and Biochemical Oxygen Demand. Input data required by ProStorm included rainfall data, topography, soil type, degree of imperviousness, vegetative cover, and land area.

Sampling

A water sampling and analysis program was conducted at the United States Air Force Academy (AFA) to verify the existence, and determine the concentration and loading, of the ten targeted NPS pollutants. Results of sample analysis were compared to results obtained from modeling.

Sampling points were determined for water flows entering and leaving the base. This allowed for isolation of NPS pollution contributed by United States Air Force Academy (hereafter referred to as AFA) operations.

Sampling Plan. The thesis authors conducted the water sampling program, with the support of the AFA Civil Engineering Squadron, from 8 June 1992 through 23 June 1992. A certified contract laboratory, Industrial Laboratories of Colorado Springs, provided analysis of the samples.

Five sampling points were established at the four continuously flowing streams on the AFA. These five locations were selected to isolate the NPS pollution generated by Air Force Academy operations. Samples from these locations were used to establish an NPS pollutant baseline resulting from dry weather, or "normal", flow conditions and to determine NPS pollutant loading contributed from Air Force Academy operations in stormwater runoff from rainstorm events. NPS pollution contribution was determined by subtracting the baseline pollutant loading from the rainstorm event pollutant loading.

Although the AFA contains several dry water courses that flow intermittently, it was deemed impractical to set up samplers for dry stream beds.

<u>Samples for Baseline Data</u>. At four of the sampling points flow proportional samples were taken at designated flow quantity intervals and combined to yield a composite daily sample. The stream flow quantity was recorded on the flowmeter hydrograph plots as individual samples were collected. The fifth sampler was incapable of drawing flow proportional samples and was set to draw 200 ml per hour. Three daily flow measurements were conducted to obtain representative stream flow during the sampling period.

These daily samples were used to establish a baseline of targeted NPS pollutant concentrations and loads. Eight such daily samples were taken from each sampling point during periods before, or at least one day after, rainfall events. Analysis of these samples provided a measure of the ten targeted NPS pollutants without rainfall runoff contributions.

Samples for Runoff Data. Samples were taken during three rainstorm events to determine contributions of the ten targeted NPS pollutants due to runoff. The flow proportional samplers continued to draw samples for a specified flow quantity. However, that specified flow quantity occurred over less time due to stormwater runoff contribution. At each location, four samples covering approximately four hours, were collected and analyzed. These samples were the first four samples pulled after the flowmeter hydrograph indicated increased flow due to stormwater runoff.

The non-flow proportional sampler was incapable of drawing samples into individual sample bottles. Therefore, a daily composite sample was used as in baseline sampling. The increased flow due to stormwater runoff was measured manually.

Sample Collection and Analysis. Samples were collected in containers previously rinsed with distilled water, and kept cool with ice until delivery to the laboratory. The laboratory kept the samples refrigerated at 3 degrees celsius until analysis was performed. Quality control was established by providing a split sample to the lab for seven of the eight baseline sampling periods.

Best Management Practices

A compendium of USEPA recommended Best Management Practices was extracted from the literature review. USEPA publications and USEPA endorsed programs from Florida, Minnesota, and Colorado were reviewed by the authors to identify Best Management Practices. The compiled BMPs are those identified by the literature and determined applicable to manage or control Nonpoint Source pollution generated on an Air Force base. For example, one United States Environmental Protection Agency recommended BMP is to increase street sweeping frequency. Increased street sweeping decreases sediment, metals, and BOD delivery to receiving waters. The relative effectiveness of BMPs, as delineated in the literature, is also discussed.

IV. Results and Analysis

Overview

This chapter presents two models used to compute NPS pollutant loading and compares their predictions to results of a water sampling and analysis program. The comparison indicates whether these models can successfully predict NPS pollution loading.

The Unit Quantity Model, based on the NURP study, is a manual model used to predict annual NPS pollutant loading for a given set of land uses.

The second model, ProStorm, is a computer model that calculates pollutant loads and concentrations for Suspended Solids, Settleable Solids, BOD, Nitrogen, Orthophosphate, and Total Coliform (47:C-2). Of these, the NURP study addresses BOD, and both Suspended and Settleable Solids as a single parameter, Total Suspended Solids. Total Kjeldahl Nitrogen addressed by the NURP and considered in the Unit Quantity Model is a measure of organic and ammonia Nitrogen (1:383). Nitrate and Nitrite are combined in the NURP report as the parameter NO_x. The Nitrogen pollutant incorporated in ProStorm consists of organic nitrogen, ammonia nitrogen, and nitrate nitrogen (47:C-2). The fraction of nitrite nitrogen is usually small compared to nitrate nitrogen (32:258). This allows comparison of ProStorm nitrogen with the TKN plus NO_x, predicted by the Unit Quantity Model.

Modeling

Unit Quantity Model. This model is based on analysis of the NURP study data and uses the unit quantity load results of that study to arrive at total annual NPS pollutant loading. Factors of a site specific nature that must be determined are 1) Runoff Coefficient (Rv), 2) extent of the area of concern, and 3) average annual rainfall.

Runoff Coefficient. The Runoff Coefficient (Rv) is a ratio of the amount of runoff to the amount of rainfall (2:32). The Runoff Coefficient Method, as well as STORM [ProStorm], estimates runoff volume (28:445). Of the three site specific factors mentioned above, the runoff coefficient (Rv) is the most difficult to determine and the least precise (2:47). The Rv is influenced by "a host of variables including infiltration, ground slope, ground cover, surface and depression storage, evaporation, transpiration..." (2:32).

Infiltration of rainfall into permeable soils will reduce the amount of runoff. This infiltration may accommodate as little as 0.01 inch per hour of rainfall, in the case of dense clays, to as much as 1.0 inch per hour of rainfall for sandy, open structured soil (2:47). As more rain soaks into the soil, less rain is available to contribute to runoff, and the Rv is reduced. Thus, Rv is inversely proportional to permeability.

Ground slope affects both the quantity and the velocity of rainfall runoff. Greater slopes allow rainfall less time to infiltrate into the soil, providing for increased runoff and a greater Rv. Thus, Rv is directly proportional to slope.

Vegetation reduces the Rv by a factor that may range from 0.01 to 0.50 depending on the density of growth (2:47). The denser the growth, the more rainfall is retained by vegetation, and the smaller the Rv value. Thus, Rv is inversely proportional to degree of vegetative cover.

Retention of rainfall in surface depressions further contributes to reduction of the Rv.

> The first excess rainfall fills depressions present on essentially all surfaces. Retention in forest litter may be as much as 0.3 in; in good pasture, 0.2; and, in smooth cultivated land, 0.05 to 0.10. In urban areas of moderate grade, recent gagings show retention to be about 0.05 in. for impervious surfaces. Retention has been assumed to be 0.10 in. for pervious surfaces such as lawns and normal urban pervious surfaces. (2:48)

Evaporation and transpiration are generally considered insignificant during the relatively short time frame of runoff events and consequently are ignored (2:48).

The use of an "overall" Rv reflecting the composite nature of a site has been found to yield acceptable results without attempting to quantify the component factors of the Runoff Coefficient (2:48). These average site coefficients are shown in Table 4.

It may be necessary to arrive at a "composite runoff coefficient based on the percentage of different types of surface in the drainage area" (2:48). Runoff Coefficients for various surface types are shown in Table 5.

Table 4

Area Runoff Coefficients (2:48; 43:5-01)

Area	Runoff Coefficients
Business:	
Downtown areas	0.70 to 0.95
Neighborhood areas	0.50 to 0.70
Residential:	
Single family areas	0.30 to 0.50
Multi units, detached	0.40 to 0.60
Multi units, attached	0.60 to 0.75
Residential (suburban)	0.25 to 0.40
Apartment dwelling areas	0.50 to 0.70
Industrial:	
Light areas	0.50 to 0.80
Heavy areas	0.60 to 0.90
Parks, cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Golf Courses	0.10 to 0.35
Railroad yard areas	0.20 to 0.40
Unimproved areas	0.10 to 0.30

Various land uses that exist on an Air Force base may require integration of Rv factors from both Table 4 and Table 5 to arrive at a composite basewide Rv factor. For example, the family housing Rv factor may be taken from Table 4 while the Rv factor for the airfield may have to be calculated from Table 5. The final selection of an Rv value depends upon the engineer's judgment in consideration of the site specific factors previously mentioned.

Table 5

Surface Runoff Coefficients (2:48-49; 43:5-01)

Surface	Runoff Coefficients
Streets:	
Asphaltic	0.70 to 0.95
Concrete	0.80 to 0.95
Brick	0.70 to 0.85
Unpaved, Compacted	0.25 to 0.70
Drives and walks	0.75 to 0.85
Roofs	0.75 to 0.95
Lawns; Sandy Soil:	
Flat, 2% grade	0.05 to 0.10
Average, 2% to 7% grade	0.10 to 0.15
Steep, 7% grade	0.15 to 0.20
Lawns; Heavy Soil:	
Flat, 2% grade	0.13 to 0.17
Average, 2% to 7% grade	0.18 to 0.22
Steep, 7% grade	0.25 to 0.35
Earth surfaces;	
Sand - uniformly graded, some silt or clay:	
Bare	0.15 to 0.50
Light vegetation	0.10 to 0.40
Dense vegetation	0.05 to 0.30
Loam - sandy, gravelly, to clayey:	
Bare	0.20 to 0.60
Light vegetation	0.10 to 0.45
Dense vegetation	0.05 to 0.35
Gravel - clean to gravel with silt and clay:	
Bare	0.25 to 0.65
Light vegetation	0.15 to 0.50
Dense vegetation	0.10 to 0.40
Clay - coarse sandy or silty to pure colloidal:	
Bare	0.30 to 0.75
Light vegetation	0.20 to 0.60
Dense vegetation	0.15 to 0.50

Area. Area is the second site specific factor in the Unit Quantity Model and is the most precise of the three Unit Quantity factors. The size of the area of concern is determined from maps or by actual measurement.

Average Annual Rainfall. The final element in the Unit Quantity Model is average annual rainfall. This is calculated as the arithmetic average of yearly rainfall over the number of years such records have been kept.

Unit Quantity Model Calculation. NPS pollutant loading for a given set of land areas and characteristics may be accomplished using the following steps:

1. Characterize the impact of soil type, vegetative cover, ground slope, and topography on Rv values.

2. Determine the area for each discrete land use or surface, using maps or actual measurements.

3. Determine Runoff Coefficients (Rvs) from Tables 4 and 5, for those discrete land use areas or surfaces with differing characteristics.

4. Calculate a composite basewide Rv by summing the area weighted individual Rv values.

5. Using the composite Rv value determined above, determine the unadjusted pollutant loading for the ten targeted NPS pollutant constituents by linear interpolation from Table 3, or directly from Figures 1 through 10.

6. Determine average annual rainfall for the Air Force base. This information is available upon request from either the base weather station or the National Weather Service. Divide the average annual rainfall by 40 inches to yield the rainfall factor, allowing use of the NURP study results.

7. Multiply the rainfall factor from step six, the unadjusted pollutant loadings obtained in step five, the land area in acres for which the composite Rv was determined in step four, and divide by 2.49 acres per Hecta-Acre. This yields total pollutant loading in Kg/Yr for the area of concern.

Unadjusted NPS Pollutant Loading Calculation. The unadjusted NPS pollutant loading may be determined by linear interpolation from Table 3, or directly from Figures 1 through 10, as stated in step five above.

Linear interpolation of unadjusted pollutant loading for a given Rv value is based on the assumption of linearity between Rv values and pollutant loading on Table 3. The equation relating Rv and unadjusted Unit Quantity Runoff Load is in the form $y = a + b(x)$ where

y = Rv
a = 0, no pollutant is carried if there is no runoff
b = the regression coefficient, or slope
x = the unadjusted Unit Quantity Runoff Load

Regression coefficients determined from Table 3 for the 10 targeted urban NPS pollutants are shown below in Table 6.

Table 6

Pollutant Regression Coefficients

Pollutant	Regression Coefficient (b)
TSS	0.00055
BOD	0.0082
COD	0.0012
Total Phosphorus	0.23
Soluble Phosphorus	0.67
TKN	0.052
NO_x	0.11
Total Copper	2.3
Total Lead	0.54
Total Zinc	0.49

After a composite Rv value is determined, it is used to solve for "x" from the equation, $y = a + b(x)$. For example, with a composite Rv of 0.26, the unadjusted pollutant loading for TSS is $y + b$, as $a = 0$, or $0.26 + 0.00055 = 473$

Kg/HA/Yr. This unadjusted loading ignores factored rainfall and total area of concern.

Alternatively, with the composite Rv value known, it is also possible to read values for unadjusted NPS pollutant loading directly from graphs of Rv versus pollutant loading in Figures 1 through 10. As an example, Figure 13 in Appendix B shows unadjusted TSS pollutant loading for an Rv value of 0.26 to be 473 Kg/HA/Yr.

Unit Quantity Model Application. The Unit Quantity Model was applied to the Air Force Academy to determine total annual loading of the ten targeted NPS pollutants. Rv parameters, discrete area descriptions with associated Rv values, basewide composite Rv, and factored rainfall were analyzed and determined to arrive at total annual NPS pollutant loading. Detailed analysis and calculations performed for the AFA example are contained in Appendix B.

Air Force Academy Annual NPS Pollutant Loading. Analysis of the Air Force Academy, as detailed in Appendix B, revealed a composite Rv value of 0.26, a total area of concern of 9,488 acres, and a factored rainfall coefficient of 0.375. Unadjusted NPS pollutant loadings were determined by linear interpolation from Table 3, multiplied by the total area of concern and factored rainfall, and divided by 2.49 acres per Hecta-Acre to yield total annual NPS pollutant loading in Kg/Yr. The results are contained in Table 7 below.

Table 7

Unit Quantity Model Air Force Academy NPS Pollutant Loading

Pollutant	Total Annual Load (Kg/Yr)
TSS	680,000
BOD	46,000
COD	310,000
Total Phosphorus	1,600
Soluble Phosphorus	560
TKN	7,100
NO_x	3,400
Total Copper	160
Total Lead	690
Total Zinc	760

Figures 1 through 10 show plots of Rv versus pollutant loading for the ten targeted pollutants. The loading intercept is at zero, indicating there is no NPS pollutant due to rainstorm runoff if the Rv value is zero. An Rv value of zero indicates there is no runoff. Once a composite Rv value is determined, a horizontal line is drawn to intersect the pollutant curve. The pollutant loading value at this point is the Unit Quantity loading in Kg/HA/Yr.

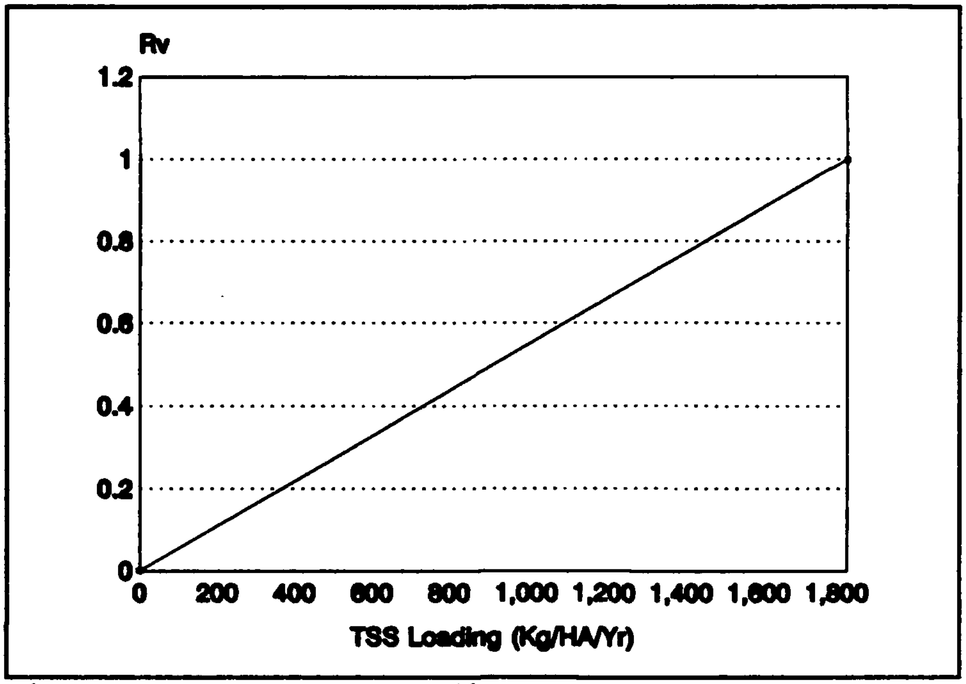

Figure 1. Rv vs TSS Loading

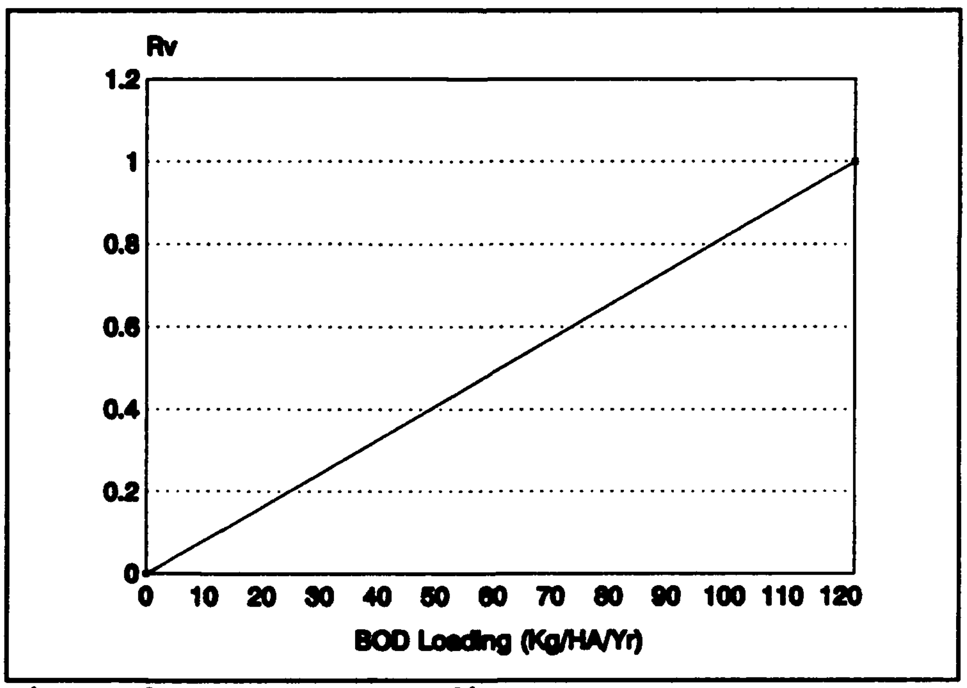

Figure 2. Rv vs BOD Loading

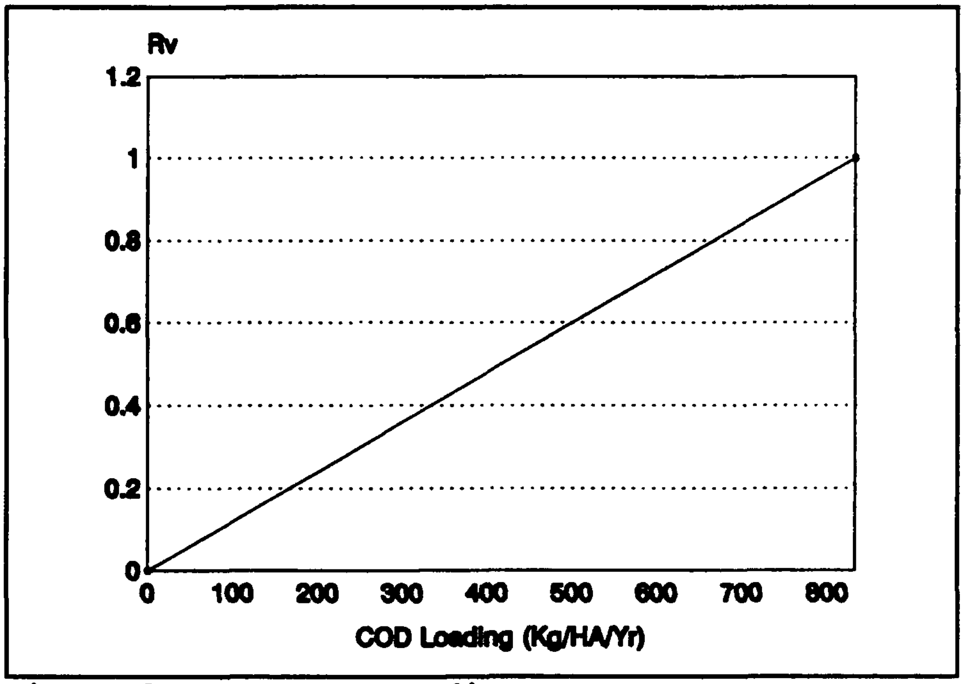

Figure 3. Rv vs COD Loading

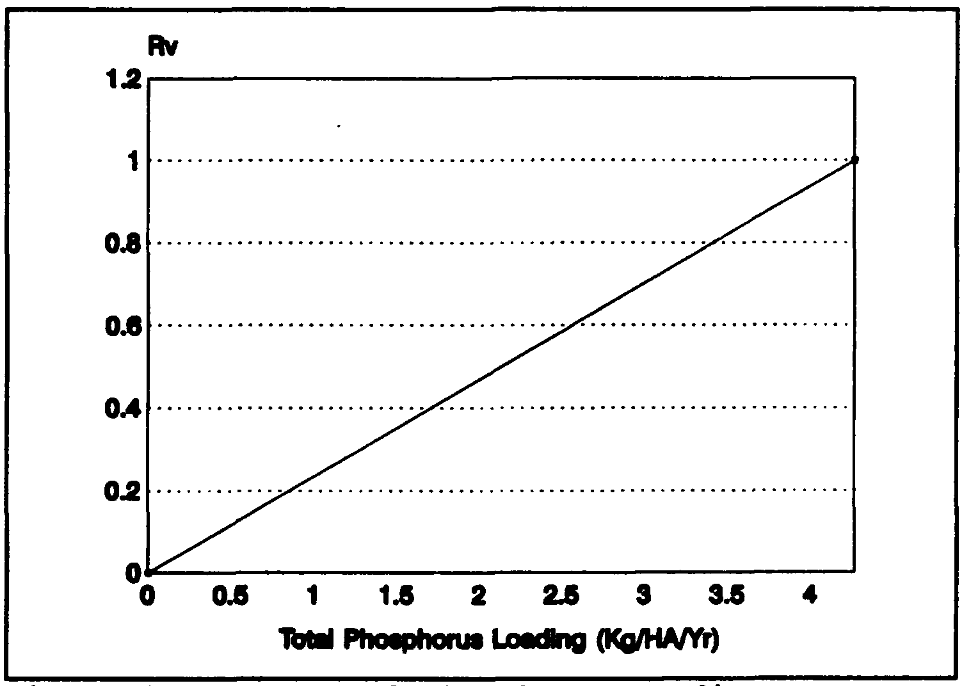

Figure 4. Rv vs Total Phosphorus Loading

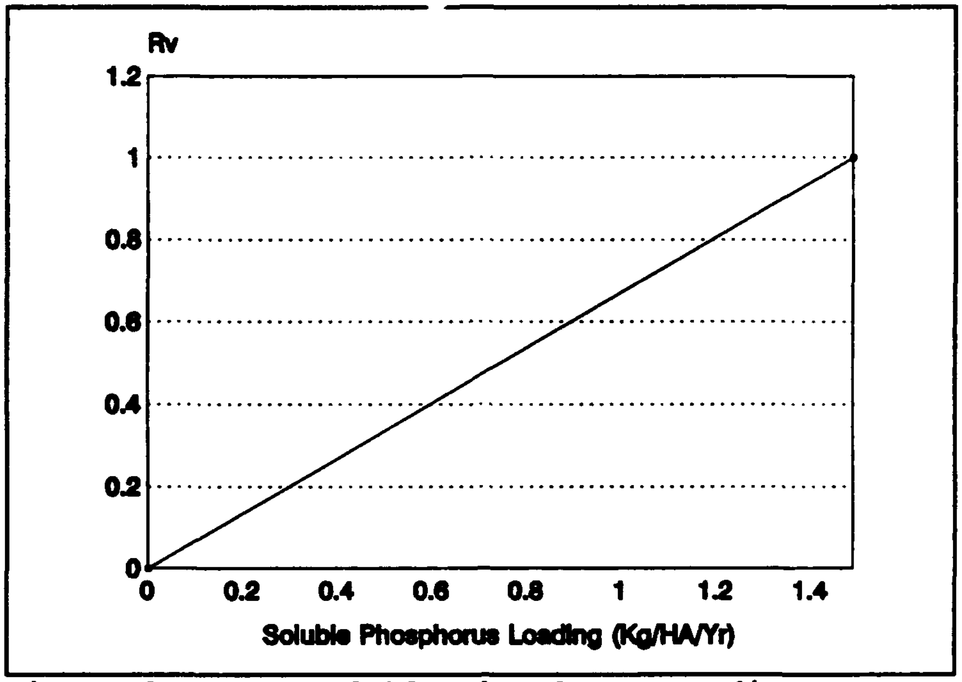

Figure 5. Rv vs Soluble Phosphorus Loading

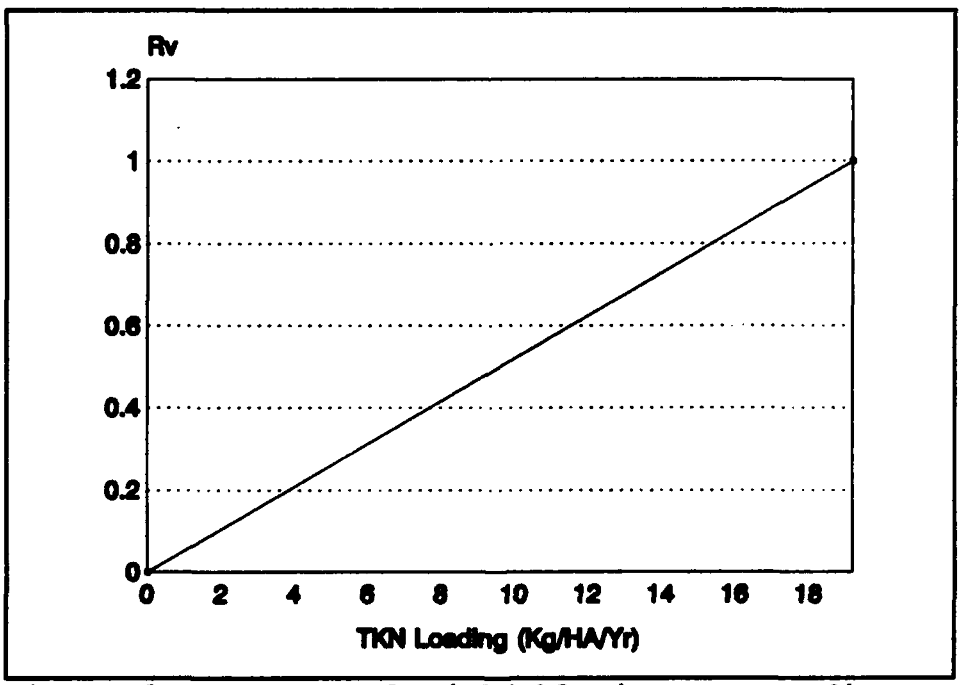

Figure 6. Rv vs Total Kjeldahl Nitrogen Loading

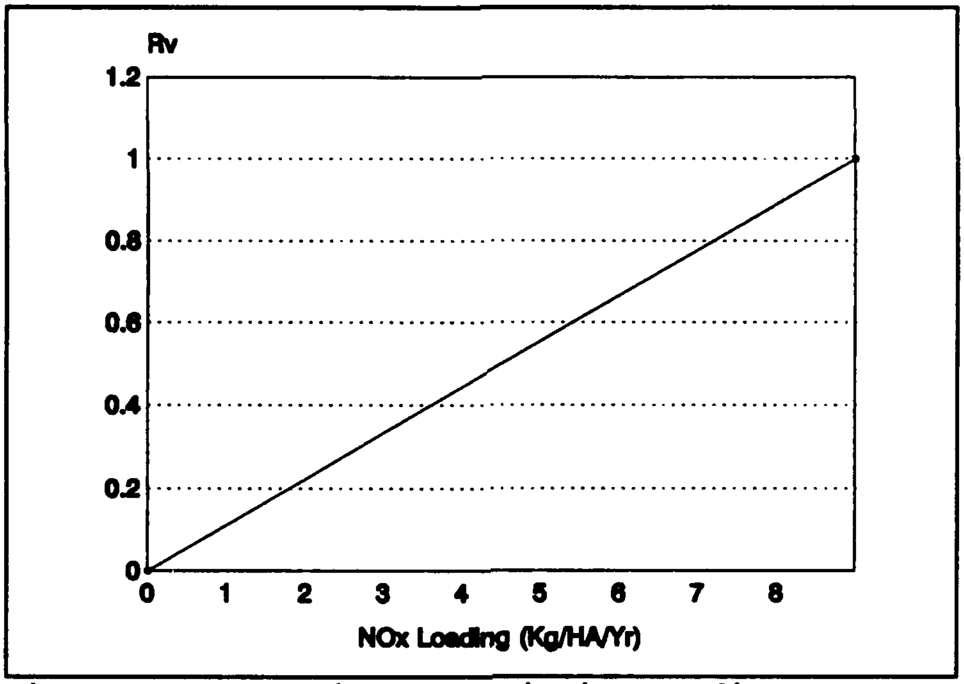

Figure 7. Rv vs Nitrate & Nitrite Loading

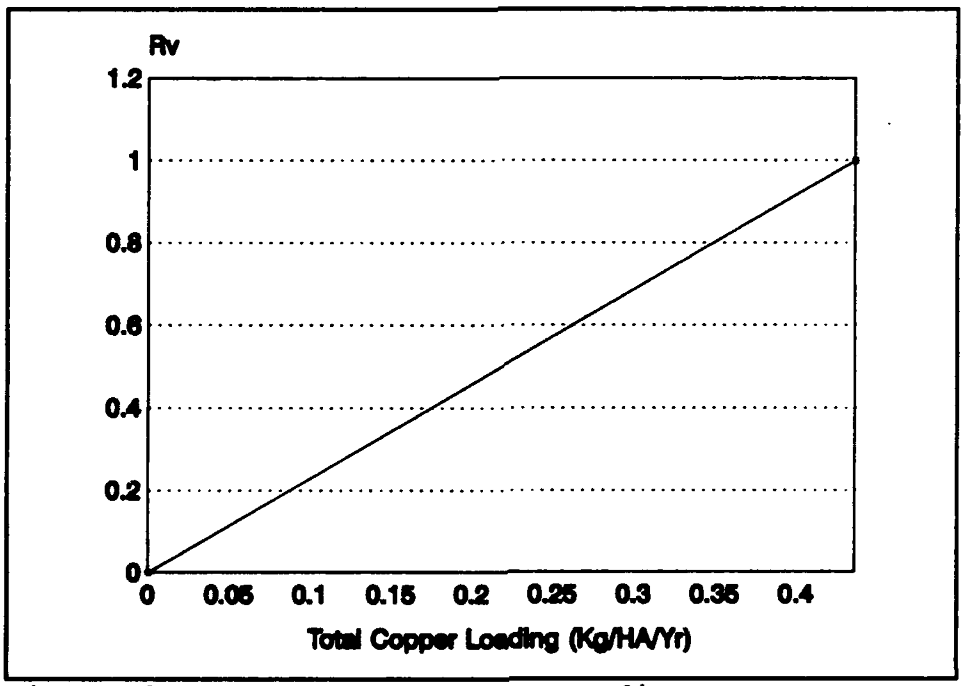

Figure 8. Rv vs Total Copper Loading

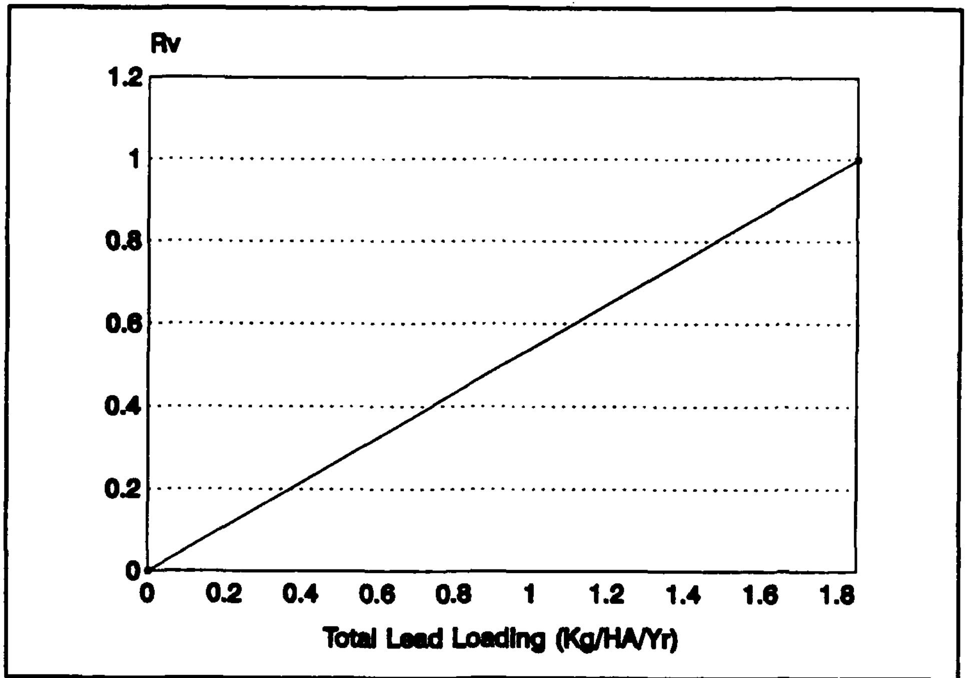

Figure 9. Rv vs Total Lead Loading

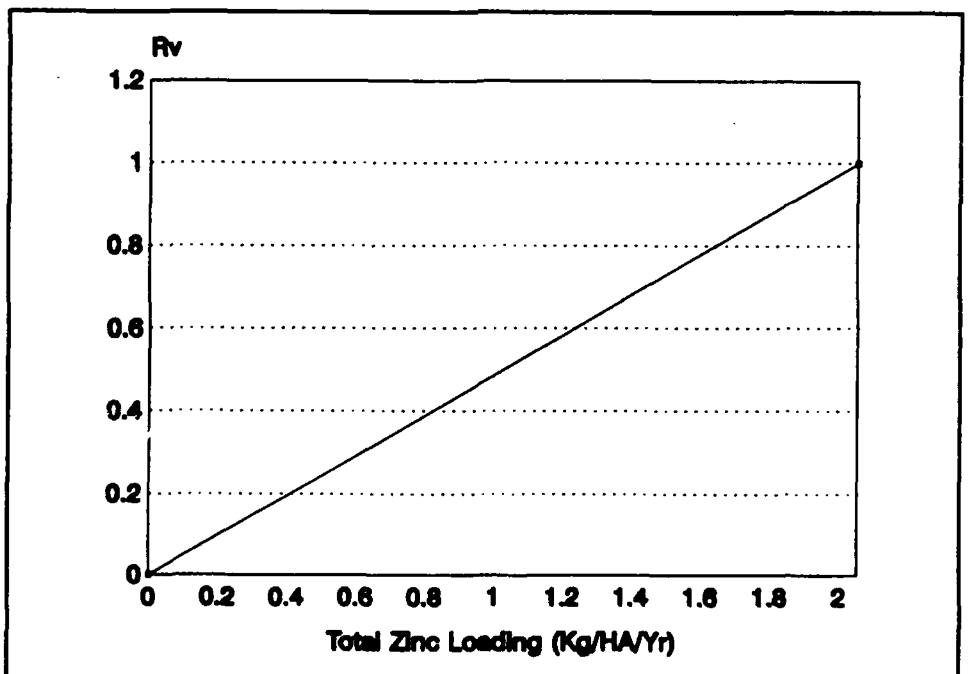

Figure 10. Rv vs Total Zinc Loading

A compact and urban-like Air Force base may find it appropriate to use the "All Urban" Rv value of 0.35. This may be more pragmatic as it would allow computation of NPS pollutant loading while foregoing the extensive calculations required to determine a site specific Rv. Using the "All Urban" value would provide results in the same order of magnitude and could save the time and effort required to calculate an Rv. However, for bases with large areas of differing land use it may be more appropriate to calculate a composite Rv.

As stated previously, the Rv calculated for the Air Force Academy is 0.26 while the "All Urban" Rv specified in the NURP study is 0.35. In the case of the Air Force Academy example, the "All Urban" Rv is 26 percent greater than the calculated Rv of 0.26. Since the relationship between Rv and total Pollutant loading is linear, an Rv of 0.35 would result in annual NPS pollutant loadings 26 percent greater than those predicted by an Rv of 0.26. For example, TSS annual loading would increase from 680,000 Kg/Yr to 857,000 Kg/Yr. Engineering judgement should be used on a case by case basis in deciding if the "All Urban" Rv of 0.35 should be used in lieu of calculating a composite Rv.

<u>ProStorm</u> <u>Computer</u> <u>Model</u>. This model was developed as a proprietary version of the U.S. Army Corps of Engineers' computer simulation Storage, Treatment, and Overflow Runoff Model (STORM), modified to run on a personal computer, and

designed for use as a National Pollutant Discharge Elimination System (NPDES) permit analysis software package.

ProStorm provides loads and concentrations for six different pollutants. Of these six, those of concern in this study are BOD and Suspended and Settleable Solids combined as Total Suspended Solids. The remaining three pollutants addressed in ProStorm, not addressed in this study, are Orthophosphate, Nitrogen, and Total Coliform.

<u>ProStorm</u> <u>Input</u> <u>Data</u>. Input data required by ProStorm includes rainfall, temperature, pan evaporation rates, pollutant production values for the land uses under study, degree of imperviousness, and size of land use areas. Daily precipitation records and daily max/min temperatures are required for the time period of concern. Pan evaporation rates are a measure of the amount of moisture that evaporates from the soil. Pollutant production values for various land uses are provided by the ProStorm User's Manual as shown in Table 8. The degree of imperviousness is related to the runoff coefficient, Rv, discussed extensively under the Unit Quantity Model above. Finally, the size in acres of individual land uses is required.

Res #1 is low density housing, two to five dwelling units per acre; Res #2 is medium density housing, from five to ten dwelling units per acre; and Res #3 is high density housing, with more than ten dwelling units per acre. Local determinations will be required for Suspended Solids and

Settleable Solids for areas other than residential, as these values are not provided.

Table 8

Pollutant Accumulation Rates (Pounds per Acre per Day) (47:C-2)

Land Use	Sus Solids	Set Solids	BOD	Nitrogen	PO_4	Coliform*
Res #1	0.12	0.09	0.04	0.007	0.0042	1.200
Res #2	0.45	0.18	0.07	0.028	0.0063	1.260
Res #3	3.16	1.00	0.13	0.025	0.0200	9.800
Commercial	____	____	0.46	0.212	0.0400	9.000
Industrial	____	____	0.39	0.209	0.0300	10.000
Open/Rural	____	____	0.02	0.007	0.0020	1.000
Pasture	____	____	3.10	0.392	0.3500	120.000
Farming	____	____	0.02	0.044	0.0002	0.500
Forests	____	____	0.01	0.002	0.000024	0.001

* 10^9 Most Probable Number (MPN) per acre per day.

Computer Model Application. The ProStorm Model was applied to the Air Force Academy to determine total annual loading of two of the ten targeted NPS pollutants; Total Suspended Solids and BOD. Detailed input data and results of ProStorm for the AFA example are contained in Appendix C.

ProStorm Pollutant Loading for Air Force Academy. Analysis of the Air Force Academy by the ProStorm program yielded results shown below in Table 9.

Table 9

ProStorm Model Air Force Academy NPS Pollutant Loading

POLLUTANT	TOTAL ANNUAL LOAD (Kg/Yr)
TSS	446,000
BOD	68,000
Nitrogen (TKN and NO_3)	32,000

Sampling

A water sampling and analysis program was conducted at the Air Force Academy from 8 June through 23 June 1992 to determine concentration and loading of the ten targeted NPS pollutants. These results were then compared to the total annual loading results obtained from the Unit Quantity Model and the ProStorm model to provide a measure of validity of the two models.

To obtain a measure of NPS pollution generated by Air Force Academy operations, sampling and analysis were required for dry weather flow, as well as during rainstorm events, for each of the sampling locations shown in Figure 11. The total Air Force Academy contribution to NPS pollution could then be determined by subtracting dry weather, or baseline, loading from rainstorm loading. Details of the sampling and analysis program and the laboratory results are contained in Appendix D.

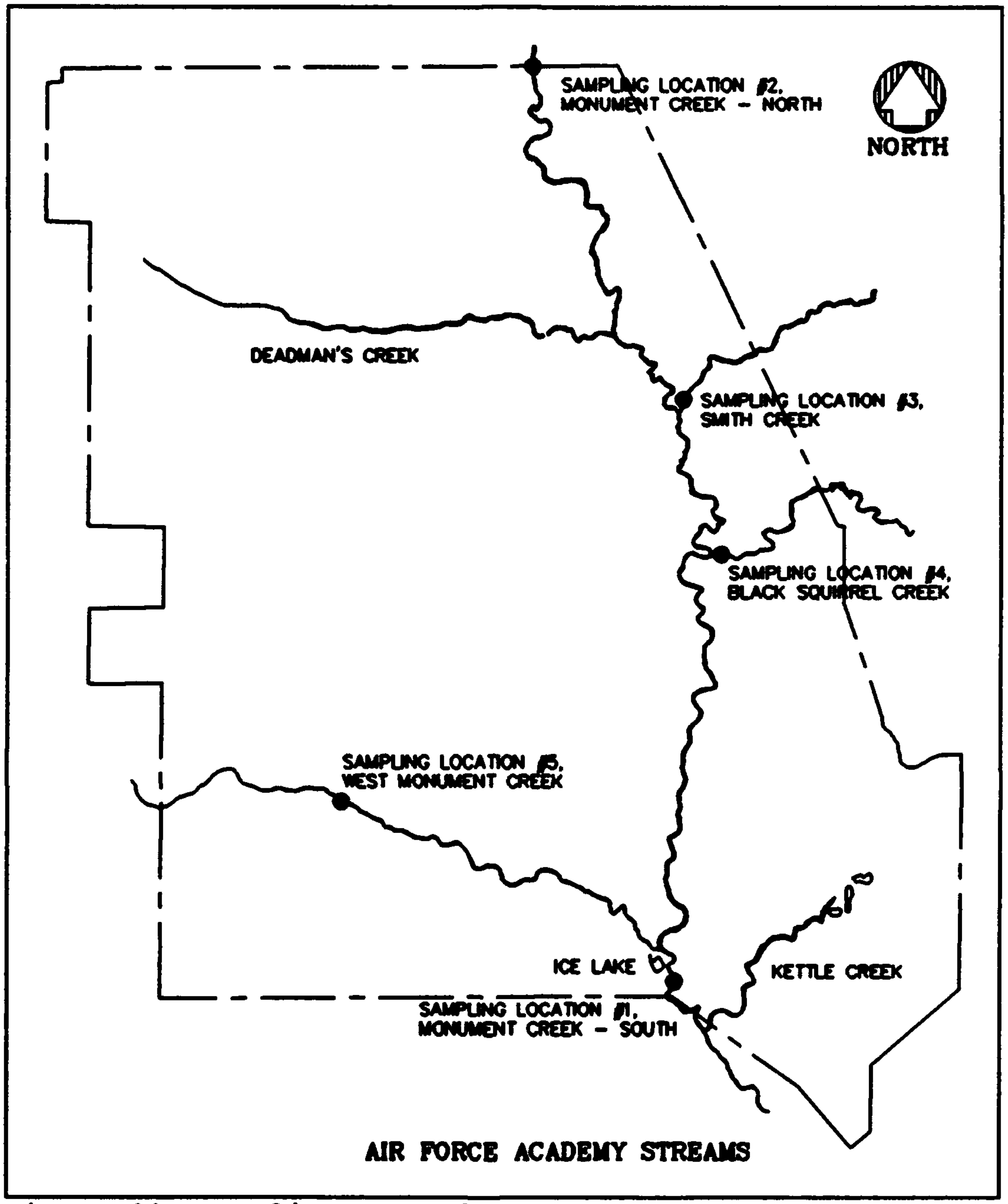

Figure 11. Sampling Network

The total NPS pollutant loading from the Air Force Academy operations, as determined from the sampling and Analysis program is shown below in Table 10.

Table 10

Air Force Academy NPS Pollutant Loading

as Determined from Sampling

Pollutant	Total Annual Load (Kg/Yr)
TSS	1,268.00
BOD	0.00
COD	0.00
Total Phosphorus	44.50
Soluble Phosphorus	-----
TKN	0.00
NO_x	0.00
Total Copper	2.61
Total Lead	4.57
Total Zinc	2.61

Discussion of Sampling Results. The results obtained from the sampling and analysis program are somewhat in doubt due to questionable laboratory analysis and difficulties incurred during rainstorm event sampling.

Laboratory Results. The laboratory analysis results from the rainstorm events were deemed questionable due to several circumstances. First, there were significant differences in the analysis results of split samples collected during baseline sampling. As discussed in Appendix D, split samples were used as a quality control measure by providing the same composite sample to the laboratory in two differently labeled containers. The analytical results were expected to be nearly identical. Instead, the standard deviations of the split sample analysis varied considerably. The mean and standard deviation of the differences between split sample constituent concentrations are shown below in Table 11.

Table 11

Split Sample Analysis Variance

Constituent	Number of Split Samples	Mean Difference	Std Deviation
TSS	6	8.00	8.14
BOD	6	7.50	8.98
COD	6	3.42	4.12
Total Phosphorus	6	0.24	0.20
TKN	6	0.59	0.41
NO_x	6	1.05	1.22
Total Copper	6	0.00	0.00
Total Lead	6	0.00	0.00
Total Zinc	6	0.00	0.00

The trace metal analyses were all below their threshold detection limits. As such, all values reported by the laboratory were identical.

Another reason for questioning the validity of the laboratory analysis is the relation shown between Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Chemical Oxygen Demand, as a measure of total material capable of being oxidized, is expected to be higher than BOD, which is a measure of only that material bacteria can oxidize. "The measured value of COD is higher than BOD, though for easily biodegradable matter the two will be quite similar" (29:126). During the sampling and analysis program, only 48 of 80 sample analysis results showed a COD value greater than BOD. Inaccurate analysis would be a possible explanation for the BOD values exceeding the COD values in 32 out of 80 samples.

Interestingly, all 48 samples with BOD concentrations less than COD concentrations were from rainstorm events. None were from baseline samples. One possible explanation would be the two day holding time for two of the three rainstorm event samples. Even though the samples were iced down during this time they may not have been kept sufficiently cool, below 4 degrees Celsius (1:484). Consequently bacteria may have started consuming the existing material. The result would be an abnormally low BOD value compared to the COD value.

Conversely, the third rainstorm samples were delivered to the laboratory within three hours, well ahead of the six hour time limit recommended by <u>Standard Methods For the Examination of Water and Wastewater</u>. These samples also showed the abnormally low BOD values (1:484). It was observed, during a visit to the laboratory, that these rainstorm samples were kept in a room temperature storage cabinet, and had been there for an undetermined period of time. It was requested that the samples be properly refrigerated. However, the damage may already have been done.

<u>Stormwater Runoff Sampling</u>. Stormwater sampling was conducted at the AFA during three rainstorm events in support of this research effort, as detailed in Appendix D.

Sampling equipment failure at one location made one of the rainstorm event sampling efforts unusable. Additional equipment limitations and time constraints may have also adversely impacted the results of those samples deemed useful.

One of the assumptions made at the beginning of this research effort was that rainfall measured by the AFA weather station, located in the airfield complex, was representative of rainfall over the entire AFA grounds. There may have been considerable variation in rainfall from the afternoon and evening thunderstorms that developed during the sampling period. Rain gauges at each sampling location would have provided a better profile of rainfall, and this consideration is recommended for future studies. Isco rain gauges are available. These gauges can be connected to the Isco 3230 flowmeters, the flowmeters used in this study, and are capable of recording rainfall in 0.01 inch increments (24:7).

The first flush of stormwater runoff is that initial runoff surge, after a rainstorm event occurs, when the concentration of pollutants reaches maximum level (39:398-399). High loadings of residual pollutants that accumulated since the previous rainstorm event are carried away by the initial stormwater runoff, resulting in an early peak concentration. This first flush depends on factors such as topography, degree of imperviousness, and intensity of rainfall, and may occur within minutes of the start of the rainstorm. The first flush of the rainstorm event may have passed before samples were captured.

In 1991 the Water Environment Federation Research Foundation's Utility Council identified development of a representative and cost effective sampling protocol for NPS pollution as one of its ten highest priority projects selected for research (21:61). Thus, the difficulties of sampling stormwater runoff have been documented by experts within the water pollution research field. The National Stormwater Director of HDR Engineering, Inc recommends sampling three rainstorm events of at least 0.10 inches occurring at least one month apart (41:10). The time constraint of completing this research effort dictated sampling rainstorm events as they occurred during the three week sampling and analysis program.

Comparison

A comparison of the results obtained from the Unit Quantity Model and ProStorm computer model to the results obtained from the water sampling and analysis program is shown below in Table 12.

Table 12 reflects a significant difference in the results obtained from sampling in comparison to results predicted by the models. The potentially invalid laboratory results and the rainstorm event sampling procedures are discussed above as possible causes of this wide discrepancy in results. There are other possible causes.

In addition to the questionable laboratory procedures previously discussed, many baseline dry weather loadings at a particular sampling location are actually greater than the rainstorm event loading at the same location. These specific figures are illustrated in the Data Analysis section of Appendix D.

Table 12

Comparison of Model Results With Sampling Results (Kg/Yr)

Pollutant	Unit Quantity Model	ProStorm	Sampling
TSS	680,000	446,000	< 0
BOD	46,000	68,000	< 0
COD	310,000	---	< 0
Total Phosphorus	1,600	---	< 0
Soluble Phosphorus	560	---	----
TKN	7,100	32,000*	7
NO_x	3,400**	---	< 0
Total Copper	160	---	< 0
Total Lead	690	---	< 0
Total Zinc	760	---	< 0

* - Total Nitrogen (TKN and NO_3) from Prostorm
** - NO_x includes both NO_3 and NO_2.

It is conceivable that rainstorm event loading could be not much greater than baseline loading if the first flush was missed, however it is unexplainable that baseline loading is consistently greater than rainstorm event loading at individual sampling locations. The most obvious explanations for this phenomenon is inaccurate laboratory results within the baseline and rainstorm event analysis as supported by the high variability of split sample results and other laboratory inconsistencies previously discussed.

The Unit Quantity Model results compare well with ProStorm results. ProStorm, compared to the Unit Quantity Model, is within 34 percent and 48 percent, respectively for Total Suspended Solids and BOD. For Nitrogen, ProStorm results are 205 percent greater than the sum of TKN and NO_x predicted by the Unit Quantity Model. As stated earlier, ProStorm includes TKN and NO_3 while the Unit Quantity Model includes TKN, NO_3, and NO_2. This comparison of Nitrogen predictions from ProStorm and the Unit Quantity Model is based upon the fact that NO_2 loading can be considered insignificant compared to NO_3 loading (32:258). The differences between the two models in nitrogen loading appears to be due to the different pollutant loading values and the model algorithms.

V. Conclusions and Recommendations for Further Study

Conclusion

The research objectives outlined in Chapter 1 were achieved. First, by assuming that an Air Force base could be characterized as an urban environment, one can anticipate that the ten NPS pollutants common to urban environments, as identified by the Nationwide Urban Runoff Program (NURP), could be generated. The expected unit quantities of the ten targeted pollutants were then identified from the literature.

Two models were then used to predict total NPS loading. Each of the two models was used to determine expected NPS pollutant loading on the Air Force Academy. The first model, the Unit Quantity Model, is a manual model developed by the thesis authors from the results presented in the NURP study. This model is presented as a generic model appropriate for any geographic location. The model considers the amount of stormwater runoff expected from individual land uses and predicts unit quantity pollutant loadings in Kilograms per hecta-acre per year. Adjustments must be made for average yearly rainfall and land area to yield annual pollutant load of the targeted pollutants in Kilograms. As mentioned previously, it may be reasonable to simply use the "All Urban" Rv value of 0.35, as presented in the NURP study, rather than accomplishing the extended computations necessary to determine a site specific Rv.

A computer model, ProStorm, was presented as an alternate modeling technique. ProStorm, a personal computer version of the U.S. Army Corps of Engineers Storage, Treatment, and Overflow Runoff Model (STORM), calculates loading for six pollutants including four of the ten targeted NPS pollutants. ProStorm can also be used for any geographic location, but requires a considerable amount of local input data concerning climatological, topographical, and watershed features.

A water sampling and analysis program was conducted at the AFA to obtain field data for comparison with the results predicted by the two models. The sampling and analysis program was established such that NPS pollutant contributions from the Air Force Academy operations could be isolated from outside contributions. A network of sampling locations was established to collect samples during dry weather stream flow reflecting "normal" pollutant loadings, in addition to sample collection during rainstorm events. The Air Force Academy NPS pollution contributions were then determined by subtracting the dry weather pollutant loading from the rainstorm pollutant loading.

Pollutant loading results determined from the sampling and analysis program were considered to be of no value. Possible reasons for the vast differences in results were discussed in Chapter IV as discrepancies in laboratory analysis and insufficient resources and time available to accomplish proper rainstorm event sampling. The sampling and analysis program results do not add credibility to the models. However, due to the previously mentioned reasons, the models are not proven to be invalid. It is the contention of this thesis, though not validated and requiring further study, that the models presented provide an adequate means of characterizing NPS pollution on an Air Force base.

Problems encountered in this study point out the need for caution in establishing and carrying out a stormwater monitoring program. Air Force bases establishing sampling and analysis programs to meet permit requirements must ensure proper quality control and quality assurance procedures are followed.

To complete this comprehensive package providing a methodology to characterize and manage NPS pollution, a compendium of Best Management Practices is presented in Appendix A. The BMPs presented have been accepted by the USEPA in state NPS pollution management programs, or included in actual USEPA publications. The BMPs appropriate to mitigate the contribution of Air Force Nonpoint Source pollutant generators as specified in Chapter III were included in the compendium.

This thesis provides Air Force Base Civil Engineers and Environmental Managers with a means of identifying and quantifying NPS pollutants, and offers accepted measures to mitigate the impacts of NPS pollution. Specifically, two relatively simple models (one manual model and one computer model) can be used to quantify NPS pollution loading on an Air Force base. The ability to quantify NPS pollution loading will prove useful in the National Pollutant Discharge Elimination System (NPDES) permitting process for stormwater runoff and will provide the necessary information required to effectively implement Best Management Practices targeting those pollutants of concern. Additionally, the models used to predict NPS pollution loading, and the selection of Best Management Practices, provide tools which enable a quick and thorough response to NPS pollution regulatory requirements.

Recommendations for Further Research

In the process of completing this research effort, four areas related to this study, and to NPS pollution in general, have surfaced as requiring further investigation. These recommended areas should support the Air Force's effort to effectively manage NPS pollution.

Validate Procedure. The procedures developed in this study were tested at the AFA. Further research is required to validate the models with a more extensive water sampling and analysis program. This further research may be considered at a base more representative of the majority of Air Force bases, such as Seymour Johnson AFB, or Moody AFB.

Although this study assumed the AFA is characteristic of an urban environment when each separate land use is analyzed individually, it could be argued that a more representative base would more closely resemble an urban environment.

Stormwater Runoff Sampling. There is obviously a problem with the sampling and analysis program, as indicated by the results, and further research is required toward a stormwater runoff sampling program. The Water Environment Federation is currently working on a stormwater sampling protocol (21:60). A sampling and analysis program based on such a protocol should be used and the results compared with the model results.

National Pollutant Discharge Elimination System (NPDES) Permitting. Although NPDES permitting of stormwater discharge was not specifically addressed by this research effort, this research is directly related to the permitting process. NPDES permits for stormwater discharges from industrial and municipal sources are required to be submitted in 1992-1993. The Air Force currently does not have a methodology for compliance with NPDES permitting of stormwater. Research is required to determine the Air Force's role in the NPDES stormwater permitting program and to develop a methodology to assist the appropriate management level with compliance. NPDES permitting will include stormwater sampling and modeling similar to that discussed in this research.

BMP Evaluation. The BMPs contained in Appendix A require an evaluation of their effectiveness for use on an Air Force base. Those BMPs which have measures of relative effectiveness specified in Appendix A were evaluated for circumstances different from typical Air Force bases, such as large metropolitan areas or large scale agricultural operations. Research is required to determine the relationship between specific BMPs and associated reduction of NPS pollutants.

Appendix A: Compendium of Best Management Practices

A compendium of Best Management Practices (BMPs) is provided to assist the Base Civil Engineer or Environmental Manager in management of Nonpoint Source Pollution generated on an Air Force base. The BMPs presented here were extracted from USEPA publications and USEPA endorsed NPS pollution management programs from Florida, Minnesota, and Colorado. Home state NPS pollution management programs may offer additional alternatives. Relative effectiveness of individual BMPs is presented in this compendium where available from the source.

Considerations to be taken into account when selecting BMPs are 1) anticipated water quality improvement, 2) site suitability, 3) cost effectiveness, 4) maintenance requirements, 5) impact on other resources, and 6) public acceptance (33:3.4-1 - 3.4-3). Additionally, some BMPs may provide effective results when used in conjunction with others, such as irrigation water management and fertilizer management. Many of the BMPs listed within each Air Force Nonpoint Source pollution generating category are also effective BMPs in other categories. For instance, erosion control techniques may apply in both construction and silvicultural categories. BMPs potentially applicable in multiple categories are shown in a matrix at the end of this appendix.

Category 1 - Pavements

A. Street Sweeping (48:67; 33:5.4-1, 5.4-2). Street sweeping removes solids from streets, parking lots, or other paved surfaces, preventing the debris from entering waterways. Coarser dust and litter items are those materials most effectively removed.

Target Pollutants - Pollutants reduced by street sweeping are sediment, suspended solids, nutrients, and oxygen demanding material.

Effectiveness - Street Sweeping is generally ineffective in improving overall water quality. Minnesota recommends street sweeping as a BMP at only two times during the year, after snowmelt to remove sand and other debris, and in the fall after leaves have accumulated.

B. Litter Control (33:5.2-1, 5.2-2). Litter control involves the removal of leaves, lawn clippings, pet wastes, trash, oil, and chemicals. Litter control incorporates refuse and leaf collection, street sweeping, and catch basin cleaning. Recycling programs should be implemented as applicable.

Target Pollutants - Pollutants reduced by litter control include phosphorus and other nutrients, oxygen demanding material, and bacteria.

Effectiveness - A study in Minnesota has shown that phosphorus levels were reduced by 30 to 40 percent in local lakes when street gutters were kept free of leaves and lawn clippings. However, the overall effectiveness of a litter control program is dependent upon the commitment of housing residents, building custodians, grounds maintenance personnel, and general basewide citizens to participate in the program.

C. De-Icing Chemical Use and Storage (33:5.5-1). Prevention of over application, and proper storage practices are the two most obvious ways to reduce pollution resulting from de-icing chemical use. Over application can be controlled by proper calibration of spreading equipment and monitoring the need for de-icing chemical application on low traffic and straight level areas. Stockpiles of de-icing chemical should be stored in a covered shelter or covered with polyethylene. Additionally, any runoff from stockpiles should be contained.

Target pollutants - Pollutants reduced by proper de-icing chemical use and storage are sodium chloride and trace metals.

Effectiveness - Up to 80 percent of the environmental damage caused by de-icing chemicals has been attributed to inadequate storage facilities and practices. Any reduction in use or prevention of over application of de-icing chemicals can have a significant positive impact since "virtually all salt applied for de-icing eventually enters surface or ground water" (33:5.5-1).

D. Concrete Grid and Modular Pavement (18:6-48 - 6-52). Concrete grid and modular pavement consists of paving materials with regularly interspersed voids filled with permeable material such as gravel, sand, or sod. This type of pavement can be used for most low volume traffic areas. The result is reduced runoff volume, reduced peak rate of runoff flow, and reduction of runoff pollutant loads. This BMP should not be used in areas where infiltration may degrade groundwater.

Target Pollutants - Pollutants controlled by concrete grid and modular pavement systems are the same pollutants expected to be associated with impervious pavements such as sediment, nutrients, trace metals, and oxygen demanding materials.

Effectiveness - Effectiveness of this particular BMP has not been documented. However, the reduction of runoff pollutant loads will directly impact surface water quality.

Category 2 - Roofs

Rooftop Runoff Disposal (18:6-224 - 6-229). Various techniques are available to contain rooftop runoff and reduce peak runoff volume and rates with associated pollutants. This BMP is especially applicable to rooftop drainage systems connected directly to storm or sanitary sewer systems. Available BMP techniques are dispersion of rooftop runoff onto the ground to allow infiltration into permeable soils, subsurface infiltration with downspouts feeding exfiltration trenches and perforated pipe, and rooftop collection and storage systems, such as downspouts connected to an underground cistern.

Target Pollutants - Pollutants controlled by rooftop runoff disposal systems are trace metals, airborne pollutants, and other pollutants which are increased by an increase in runoff volume and rate.

Effectiveness - The effectiveness of this BMP has not been specifically demonstrated.

<u>Category 3</u> - <u>Industrial</u> / <u>Category 9</u> - <u>Agricultural</u>

A. <u>Irrigation Water Management</u> (10:59; 49:2-68 - 2-84). Irrigation water management may improve water quality by efficiently controlling the application methods, rate, amount, timing, and runoff of irrigation water. Irrigation water management can be subdivided into proper scheduling, application, and runoff management.

The rate, amount, and timing of irrigation water can be determined only after understanding the moisture environment required by the particular soil and plants being irrigated. A technician's estimate based on historical experience is no longer adequate for management of irrigation water. Items to be considered include the daily water use of the plants, water holding capacity of the soil, and lowest acceptable soil moisture for individual plant/soil combinations. Evaporation and runoff should be minimized, and adjustments in the application schedule should be made for changes in weather conditions.

The application of irrigation water is generally through a drip/trickle system or a sprinkler system. The drip/trickle system provides water directly to the plant root zone and minimizes evaporation, runoff, erosion, and water quality degradation. Excessive application through drip/trickle systems, especially with chemical application for pest control or fertilizer, can present a hazard to groundwater. The above ground sprinkler system is more susceptible to evaporation, runoff, erosion, and water quality degradation. However, proper management can minimize any significant impacts. Management techniques, in addition to proper scheduling discussed above, include runoff control and incremental application of nutrients through irrigation. Poor management of a sprinkler system may cause pollution of surface and ground water by excessive application of pesticides and fertilizers through the sprinkler system.

Irrigation water runoff may be recovered in detention basins and reused if an adequate distribution system is available or can be provided. Filter strips may be constructed if the runoff water is not recovered. Filter strips, discussed below, are vegetative areas between a source of NPS pollution and a waterway to remove sediment, organic matter, and other pollutants in the runoff.

Targeted Pollutants - Pollutants controlled by irrigation water management are sediments, suspended solids, metals, phosphorus, nitrogen, pesticides, salts, nutrients, and bacteria and other microorganisms.

Effectiveness - The USEPA discussion of irrigation water management is in the context of large agricultural operations. High reductions (61 to 95 percent) of sediment loadings have been attributed to irrigation water management. The cost to install a water management system for pollution control is identified as approximately $103 per acre served.

B. Terracing (48:53-54; 49:2-17 - 2-26). Terracing involves the construction of embankments across a slope to control erosion, and is particularly applicable on land with up to 12 percent slope. Terraces reduce the slope, preventing erosion, and store or divert surface runoff flow to prevent pollutants from entering surface water. Improperly designed terraces may decrease water quality by providing an outlet channel for surface runoff or facilitating groundwater recharge by retaining water ponds.

Target Pollutants - Pollutants controlled by terracing include sediment, suspended solids, phosphorus, nitrogen, and pesticides.

Effectiveness - Terracing is more effective in reducing erosion and sediments than in reducing total runoff volume. Terraces applied to agricultural activities have been shown to reduce sediment by up to 90 percent and phosphorus by up to 75 percent.

C. Oil/Grit Separators (33:4.6-1 - 4.6-2). Oil/grit separators are chambers installed underground and remove sediment and hydrocarbons from a storm sewer inlet before discharging to the storm sewer network or other outlet. They should be located close to a source of high urban traffic or areas with a high potential for petroleum spills such as gas stations or aircraft refueling areas. Oil/grit separators may cost as much as $15,000.

Target Pollutants - Pollutants controlled by oil/grit separators are floating oils, coarse sediments, and floating debris.

Effectiveness - Oil/grit separators have been shown to be moderately effective in removing coarse sediment, oil, and greases. Only limited removal should be expected for fine grained sediment, trace metals, and nutrients. Oil/

grit separators are ineffective in removing soluble pollutants.

D. Buffer/Filter Strip (48:95; 49:4-21, 7-3; 33:4.8-1 - 4.8-2). Buffer/filter strips are areas of grass or other close growing vegetation located between a source of NPS pollution and a waterway. A minimum width of 20 feet is generally desired. A buffer/filter strip reduces runoff velocity and acts as a filter to remove sediment and suspended solids. Soluble pollutants are removed to the extent that runoff infiltrates the soil during the extended contact time. To be effective buffer/filter strips must be constructed to ensure that runoff flows uniformly across the strip and is not channeled. Buffer/filter strips are commonly used in combination with other BMPs, such as being used at terrace outlets.

Target Pollutants - Pollutants controlled by buffer/filter strips are sediment, suspended solids, nutrients, and pesticides.

Effectiveness - Buffer/filter strips have been shown to reduce sediment by as much as 85 percent.

E. Grassed Waterway (48:97-98; 18:6-401). Grassed waterways are drainage channels covered with erosion resistant grasses such as Kentucky 31 tall fescue or reed canary grass. This practice is only applicable to intermittent flowing streams or channels. The vegetative cover is mainly to protect the channel bed from erosion, but it also contributes to sediment reduction by acting as a sediment trap.

Target Pollutants - Pollutants reduced by grassed waterways are sediments and suspended solids.

Effectiveness - Grassed waterways can reduce suspended solids and sediment by as much as 60 to 80 percent.

F. <u>Interception/Diversion</u> (48:101-102; 33:6.8-1 - 6.8-4; 18:6-346 - 6-347). Interception/diversion structures are constructed channels to intercept and divert runoff before it reaches an erosion sensitive soil surface. Typically, interception/diversion structures are constructed across a slope with a supporting downslope ridge, similar to a terrace, to divert up-slope runoff away from a source of NPS pollution. In other words, it keeps runoff from washing over a pollutant source by diverting the runoff around the pollutant source. Diverting runoff can also eliminate concentrated runoff flow that inhibits vegetative growth.

Target Pollutants - Pollutants reduced by interception/diversion structures are suspended solids, phosphorus, nitrogen, and pesticides.

Effectiveness - Effectiveness of interception/diversion structures depends on physical characteristics of the site and climatic factors, but can reduce the target pollutants entering adjacent waterways by 30 to 60 percent.

G. <u>Riprap</u> (48:103 - 104; 18:6-421 - 6-427). Riprap is a permanent cover of large angular stone placed over the soil to prevent erosion of the soil surface. Riprap protects soil from concentrated runoff, enhances infiltration by slowing runoff velocity, and stabilizes slopes. Potential areas for riprap use are storm drain outlets, channel banks and bottoms, ditches, and lake shores. Geo-fabric or vinyl should be placed under riprap to prevent erosion of the supporting underneath surface.

Target Pollutants - Pollutants reduced by riprap are sediment and suspended solids.

Effectiveness - Riprap is very effective in reducing erosion on unstable waterway banks.

H. <u>Storm Drain Inlet Protection</u> (48:105-106; 18:6-325 - 6-334; 33:6.5-1 - 6.5-5). Storm drain inlet protection is a sediment trap placed around storm drain inlets. The sediment traps are temporary structures placed near or within disturbed areas to detain course sediment particles and prevent clogging of the storm sewer system. Sediment traps may be constructed of sandbags, straw bales, silt fence fabric, concrete blocks and gravel, or wire mesh and gravel. Periodic removal of accumulated sediment is required. Additionally, the storm drain inlet protection should be removed when the drainage area has been stabilized. This

BMP is recommended only for drainage areas of less than one acre.

Target Pollutants - The pollutants reduced by storm drainage inlet protection are sediment and suspended solids.

Effectiveness - Storm drain inlet protection is relatively good to very effective in trapping medium to course sized sediments. Fine sediment is more difficult to trap, but can be removed by silt fence fabric.

I. Outlet Protection (18:6-411 - 6-417; 33:6.15-1 - 6.15-2). Outlet protection consists of protective measures placed at the outlet of culverts or paved channels to slow runoff velocity, thus preventing erosion. The structure usually consists of an apron lining of the outlet area made of riprap, concrete, or grouted riprap. The most desirable configuration for the outlet design is a straight section. However, the best design will depend on factors such as slope, velocity, and capacity of the pipe or channel. Design by a qualified engineer is recommended.

Target Pollutants - Pollutants reduced by outlet protection are sediment, suspended solids, and turbidity.

Effectiveness - Properly designed and constructed outlet protection is effective in preventing scour erosion and reducing the effects of turbidity and sedimentation in downstream waterways.

J. <u>Landscape Management</u> (46:11-15). The objective of this BMP is to landscape with plants and grasses suited to the local climate and soil. Landscaping with plants suitable to local conditions reduces the need for irrigation, fertilizer, and pesticides. Plants and grasses native to the local area will withstand diseases and insect problems better than those imported from elsewhere, thus eliminating the need for special care and extensive irrigation. Local vegetation may not always be the most attractive to all people, but it will keep NPS pollutants to a minimum and save annual maintenance funds as well as manpower. The local county Cooperative Extension agent can provide required information for individual locations.

Target Pollutants - The pollutants reduced by landscape management are sediment, suspended solids, nitrogen, phosphorus, and pesticides.

Effectiveness - Source reduction of irrigation watering, fertilizer, and pesticides will reduce the target pollutants.

<u>Category 4 - Fertilizer Application</u>

A. <u>Fertilizer Management</u> (48:45; 49:2-41 - 2-42; 33:5.1-1 - 5.1-3). Fertilizer management involves control of fertilizer application rates, timing, and methods. Proper application is required to ensure plant nutrient needs are met while minimizing surface and groundwater pollution. Soil testing is required to determine the amount of phosphorus and nitrogen found within the local soil. This information is essential in determining the amount of fertilizer needed to supplement existing phosphorus and nitrogen to meet plant nutrient needs. In general, more frequent applications are preferable to a single large quantity application. Fertilizer should never be applied to frozen ground or on adjacent pavements, and should not be washed off the site by excessive irrigation watering. Additionally, Air Force personnel should be aware it is in the best interest of a fertilizer sales person or landscape contractor to recommend more fertilizer than is required to meet plant nutrient needs.

Target Pollutants - Pollutants reduced by fertilizer management are nitrogen, phosphorus, oxygen demanding material, salts, and bacteria.

Effectiveness - Fertilizer management can effectively reduce the amount of nitrogen and phosphorus contamination in surface and ground water. USEPA identifies fertilizer management as the "most cost-effective BMP for reducing nutrient losses...reduce the capital invested in fertilizer, and may reduce the manhours and equipment and fuel cost of applying it" (48:45).

B. <u>All-Natural Fertilizer</u> (46:14; 49:2-41 - 2-42). All-natural fertilizer is readily available in products such as Arnold Palmer's All-natural Fertilizer Mix containing bone meal, feather meal, wheat germ, soya, muriate of potash, enzymes, and soil microorganisms. This fertilizer mix has cut fertilizer applications in half, kept vegetation green longer, and increased the soil's ability to hold water on the 20 golf courses owned by Arnold Palmer.

Target Pollutants - Pollutants reduced by all-natural fertilizer are nitrogen, phosphorus, oxygen demanding material, salts, and bacteria.

Effectiveness - All-natural fertilizer use is effective in reducing the target pollutants.

<u>Category 5 - Residential</u>

A. <u>Lawn and Landscaping Management</u> (49:4-30 - 4-31; 46:11-14). Lawn and landscaping management involves selecting grasses and plants suitable for local conditions, lawn maintenance, fertilizer applications, watering, pesticide application, and erosion control. A healthy lawn helps the environment by preventing erosion, filtering stormwater runoff, and minimizing dust. Organic, non-chemical fertilizers and biological pest controls can help produce a healthy lawn and are also environmentally safe. The following practices are suggested as components of a lawn and landscaping management program for residential areas.

1. Grasses and plants should be suited to the local soil and climate. The county Cooperative Extension agent can provide assistance in determining vegetation native to the local area. Native vegetation will require less fertilizer, pesticides, watering, and little special care to achieve healthy growth.

2. Grass clippings should be left on the ground to provide nutrients to the lawn. Weeds should be pulled by hand.

3. Slowly soluble natural fertilizers such as blood meal or organic mixes should be used. Fertilizers should not be applied immediately before a heavy rain. Additionally, the soil should be tested for existing nitrogen and phosphorus content to determine the appropriate amount of fertilizer required. Smaller, more frequent, doses of fertilizer are preferable to large single doses.

4. Watering should occur only when absolutely necessary, and in the morning rather than the afternoon.

5. Pesticide application can be reduced by using native plants. However, if required, pesticides should not be applied before imminent precipitation or on windy days.

6. Soil erosion can be minimized by not mowing within five feet of a water body, planting ground cover in bare areas, and reducing soil disturbances as much as possible.

Target pollutants - Pollutants reduced by lawn and landscáping management include nitrogen, phosphorus, pesticides, sediment, and suspended solids.

Effectiveness - Source reduction of fertilizer and pesticides will reduce nitrogen, phosphorus, and pesticides. However, quantitative effectiveness data has not been reported.

B. Household Toxics Management (49:4-30 - 4-31; 46:7-9). Household toxics management involves source reduction and proper use, storage, and disposal of common household chemicals.

Common household chemicals include 1) automotive products such as oil, battery acid, brake fluid, antifreeze, and gasoline; 2) horticultural products such as fertilizers, pesticides, rodenticides, fungicides, and herbicides; 3) pet products such as flea collars and shampoos; 4) cleaning products such as spot removers, furniture polishes, deodorizers, drain cleaners, oven cleaners disinfectants, moth repellents, and ammonia; and 5) maintenance supplies such as paint, varnish, lacquer, turpentine, wood stains, and wood preservatives.

Measures to reduce household chemicals include purchasing nontoxics such as nonphosphate detergents, biodegradable and recyclable products, multipurpose products such as detergents that both clean and bleach, and nonaerosol sprays. Some beneficial practices for use of the chemicals include using only the amount needed, cleaning up any spills with an absorbent such as cat litter, and no use near water bodies.

Storage of household chemicals should be in a well ventilated secure location out of direct sunlight. Disposal should be in accordance with a local hazardous household material disposal program, and never down drains in the home, poured onto the ground, or into storm drains.

Target Pollutants - Pollutants reduced by effective household toxics management include petroleum products, solvents, pesticides, nitrogen, and phosphorus.

Effectiveness - Source reduction and other household toxic management techniques will reduce the target pollutants entering surface and groundwater. However, quantitative impacts of this BMP have not been reported.

C. Pet Waste Management (49:4-30 - 4-32; 46:10). Animal wastes, containing high levels of nitrogen and phosphorus, bacteria, and viruses, can be kept out of surface waters by picking up after the pet and disposing of the material in the garbage or the toilet.

Target Pollutants - Pollutants reduced by pet waste management include nitrogen, phosphorus, bacteria, fecal coliform, BOD, and viruses.

Effectiveness - Pet waste management has been shown to achieve greater than 50 percent removal of nutrients and pathogens (49:4-32).

D. Automobile Care (46:9). Care of automobiles includes disposal of fluids and car washing procedures. "The four quarts of oil it takes to fill your car's engine can form an 8 acre oil slick if spilled into the environment" (46:9). Oil should be put into a sturdy container, labeled, and taken to the nearest garage or oil recycling center. Antifreeze should be disposed of similarly to oil. Antifreeze contains ethylene glycol which is poisonous to people, fish, cats, dogs, and natural wildlife. Car washing should be accomplished with non-phosphate detergents, on paving blocks or gravel to reduce detergent runoff, and with a bucket instead of a hose. Additionally, car washes should be accomplished only when necessary and at a commercial car wash when possible.

Target Pollutants - Pollutants reduced by proper automobile care are petroleum products, ethylene glycol, metals, solvents, and detergents.

Effectiveness - Prober automobile care will reduce the amount of target pollutants from entering surface and groundwater. However, quantitative results of proper automobile care are not available.

E. A Homeowner's Guide to Preventing Nonpoint Source Pollution (49:4-30; 46:1-20). A homeowner's guide to preventing NPS pollution would consist of a manual provided to military family housing residents describing actions residents should take within their household to reduce NPS pollution. This guide could be similar to Handle With Care, Your Guide to Preventing Water Pollution, developed by The Terrene Institute for the USEPA.

The guide should be written in easy to understand language and explain the basics of how household activities can lead to water pollution from stormwater runoff. Topics to be covered include proper use and disposal of household chemicals, care of automobiles, lawn care and landscaping, and the cleanup of pet wastes.

Target Pollutants - Pollutants potentially reduced by a homeowner's guide to preventing NPS pollution include nitrogen, phosphorus, pesticides, sediment, oil, greases, paint, solvents, bacteria, fecal coliform, viruses, ethylene glycol, metals, and detergents.

Effectiveness - The reduction of NPS pollutants within residential areas depends largely upon the resident's education and commitment to participate in environmental stewardship. This guide would provide the residents with simple, easy to follow, practices that are effective in reducing NPS pollution. A quantitative measure of this BMP is not available.

Category 6 - Pesticide Application

A. Integrated Pest Management (46:18-21). Integrated pest management consists of natural methods of pest management such as predators, pest resistant vegetation, and elimination of pest breeding grounds. The following practices are suggested methods of an integrated pest management program.

1. Plant vegetation to attract native predatory insects that are biological enemies of existing pests. This can only be accomplished after a thorough study of the existing pests.

2. Weeds should be pulled by hand or controlled by mechanical means wherever possible.

3. If crops are grown on the installation, ensure they are rotated each year, and shift yearly planting dates.

4. Minimize standing pools of water, fallen fruit, and garbage pick up waiting times.

5. Use chemicals only after natural pest control has proved inadequate, and ensure application is within strict compliance with label instructions.

6. Purchase, mix, and use only the amount of pesticide required for one application. This will prevent the problem of storage and disposal of leftover pesticide.

7. Spills of pesticide should never be hosed down. They should be surrounded with dirt or sprinkled with absor-

bent material, and collected in a sturdy plastic bag for hazardous waste collection.

8. Disposal of pesticides must be in accordance with produce label instructions, or if not available, in accordance with local environmental authority direction.

Target Pollutants - Pollutants reduced by an integrated pest management plan consist of pesticides.

Effectiveness - Integrated pest management can reduce agricultural pesticide pollutant loadings by 20 to 40 percent (48:48).

Category 7 - Construction Sites

A. Gravel Construction Site Entrance (18:6-302 - 6-304). A gravel construction site entrance is a stabilized gravel pad at vehicle entrance/exit points of the site. The intent of this BMP is to reduce the amount of sediment carried onto public roads from construction vehicles and runoff. The action of vehicle tires on the gravel should remove the majority of mud from the vehicle before it enters onto an off site paved road. If this action is insufficient it may be necessary to remove the mud with water hoses.

Target Pollutants - Pollutants reduced by gravel entrances/exits are sediment and suspended solids.

Effectiveness - Preventing mud from being carried onto paved roads will reduce sediment and suspended solids in nearby waterways. A quantitative measure of effectiveness is not available.

B. Revegetation (10:74; 33:6.20-1 - 6.20-2). Revegetation is the prompt establishment of permanent vegetative cover on construction sites to stabilize the soil and prevent future erosion. Revegetation also reduces runoff volume by increasing the infiltration capacity of the soil.

Target Pollutants - Pollutants reduced by revegetation include sediment and suspended solids.

Effectiveness - Permanent vegetative cover can reduce soil erosion by up to 99 percent, significantly reducing the target pollutants.

C. Soil Stabilization (48:61-62; 10:75). Soil stabilization refers to non-vegetative techniques used to stabilize soil surfaces in order to prevent erosion. Soil stabilization may be a temporary measure used prior to revegetation or used independently as a permanent solution. Temporary measures to stabilize soil include mulches, netting, and textile blankets and mats. Permanent soil stabilization is required when vegetation cannot be used due to steep slopes, graded areas with groundwater seepage, toxic soil, or high velocity concentrated flow channels. Permanent measures include stone used as riprap in wire baskets, interlocking blocks, pavements, and retaining walls.

Target Pollutants - Pollutants reduced by soil stabilization include sediment and suspended solids.

Effectiveness - Soil stabilization can reduce erosion by 75 to 90 percent.

D. Sediment Barriers (10:77; 32 6.3-1 - 6.4-3). Sediment barriers are installed to trap sediment on site, prevent sheet erosion, and in some cases to direct runoff to stabilized channels. These barriers filter sediment out as the runoff passes through. Two common sediment barriers are silt fences and straw bales. A silt fence is a filter fabric sediment barrier attached to supporting posts and trenched into the ground at the bottom. The filter fabric is specified in terms of the apparent opening size (AOS) of the fabric. The appropriate AOS is site dependent. It should have small enough openings to trap desired sediment yet large enough openings to maintain an acceptable flow. In most cases an AOS of 70 will trap 90 percent of sediment in the runoff. Additional requirements of a silt fence include a drainage area less than two acres, less than 150 feet of uncontrolled slope above the fence, sheet flow runoff, a single span of less than 600 feet, and an expected use of less than six months. Silt fences are generally preferable to straw bales because they are more effective, have a longer life, and have a lower failure rate.

Straw bales are also a sediment trap that slows runoff and detains sediment. The bales must be entrenched, anchored, and have joints stuffed with straw to be effective. Adequate construction supervision is encouraged since improper installation can actually increase erosion by concentrating runoff, resulting in gully erosion. Additionally, straw bales trap only medium and course grained sediment and should be used for sheet flow runoff for areas less than two acres, and provide a short-term solution.

Target Pollutants - Pollutants reduced by sediment barriers are sediment and suspended solids.

Effectiveness - Silt fences will trap up to 90 percent of sediment in runoff while straw bales can be moderately effective in trapping larger sized sediment particles. However, sediment barriers are ineffective if not installed properly.

E. Temporary Sediment Basin (10:79; 33:6.1-1 - 6.1-20). A temporary sediment basin, or retention pond, is an impoundment that temporarily stores runoff from a construction site to allow sediment to settle out before entering a water body. Temporary sediment basins are typically used for large disturbed areas, or construction sites from five acres to 250 acres, and for a period of less than two years. This BMP is a significant construction measure in itself and should be designed by a qualified engineer.

Target Pollutants - Pollutants reduced by temporary sediment basins include sediment and suspended solids.

Effectiveness - Temporary sediment basins can remove up to 70 percent of the target pollutants.

F. Temporary Seeding (33:6.20-1 - 6.20-2). Temporary seeding involves the quick establishment of vegetative cover over a disturbed site to protect against erosion until permanent stabilization is provided. Fast growing vegetative seeding is used, generally for sites inactive for greater than 45 days and less than 100 days.

Target Pollutants - Pollutants reduced by temporary seeding include sediment and suspended solids.

Effectiveness - Temporary seeding can reduce sheet erosion by up to 90 percent.

Category 8 - Silvicultural

A. Debris Removal (48:81; 49:3-1). Debris removal involves the removal of slash, tree tops, and other debris during and after tree harvesting operations to ensure such debris cannot reach nearby waterways. Silvicultural debris can accumulate in streams, impeding the waterway, and cause significant sediment loading from stream banks. Any deflection or restriction of water flow increases bank and channel erosion, and thus sediment loading. Old "natural" debris not caused by silvicultural operations should not be removed.

Target Pollutants - Pollutants controlled by debris removal include sediment, suspended solids, turbidity, and increased temperature.

Effectiveness - Debris removal will ensure minimum debris buildup in streams due to logging activities, and will therefore prevent an increase in the target pollutants.

B. Transportation System Management (48:83-84; 49:3-8 - 3-9). Roads and trails supporting silvicultural operations should be located and designed to minimize potential sediment delivery to nearby streams. Roads have been identified as the largest cause of sediment due to logging activities. Roads should not be located along streams within 25 feet of the average annual high water level. Additionally, roads should be constructed across slopes, with artificial drainage systems where normal drainage is significantly impacted, and covered with gravel. The number of skid trails should be minimized, and eliminated altogether on steep slopes.

Targeted Pollutants - Pollutants controlled by proper transportation system management are sediment, suspended solids, and thermal pollution.

Effectiveness - Transportation system management can significantly reduce the impact of the target pollutants. One study indicated a sediment loss from roadbeds without gravel covering was eight times the loss from roadbeds covered with 15-20 cm of gravel.

Table 13 presents a BMP activity matrix illustrating the applicability of specific BMPs to multiple categories of Nonpoint Source pollution generators.

Table 13

Best Management Practice Activity Matrix

NPS Generating Category/BMP	Applicable Category
Category 1 - Pavements	
Street Sweeping	1, 3, 5, 7
Litter Control	1, 3, 5, 7, 8
De-Icing Chemicals	1, 5, 7
Grid & Modular Pavements	1, 7
Category 2 - Roofs	
Rooftop Runoff Discharge	2
Category 3 - Industrial / Category 9 - Agricultural	
Irrigation Water Management	3, 4, 5, 7, 8, 9
Terracing	3, 7, 8, 9
Oil/Grit Separators	3
Buffer/Filter Strips	3, 4, 7, 8, 9
Grassed waterways	3, 7
Riprap	3, 7, 8
Storm Drain Inlet Protection	3, 7
Outlet Protection	3, 7
Landscape Management	3, 5
Category 4 - Fertilizer Application	
Fertilizer Management	4, 5, 7, 8, 9
All-natural Fertilizer	4, 5, 7, 8, 9
Category 5 - Residential	
Lawncare & Landscaping	4, 5, 6, 7
Household Toxics	3, 5
Pet Waste Management	5
Car Care	5
Homeowner's Guide	4, 5, 6

Table 13 (Cont.)

Best Management Practice Activity Matrix

NPS Generating Category/BMP	Applicable Category
Category 6 - Pesticides	
Integrated Pest Management	5, 6, 8, 9
Category 7 - Construction	
Gravel Entrance/Exit	7, 8
Revegetation	7, 8
Soil Stabilization	7, 8
Sediment Barriers	7, 8
Temporary Sediment Basin	7
Temporary Seeding	7, 8
Category 8 - Silviculture	
Debris Removal	7, 8
Roads & Trails	7, 8

Appendix B: Unit Quantity Model - Air Force Academy Example

Total annual NPS pollutant loading for the ten targeted pollutants identified in the NURP study was determined for the Air Force Academy (AFA). The steps delineated in Chapter four for Unit Quantity Model calculation were followed to arrive at the total annual loadings.

Rv Parameters

Parameters that impacted the Rv were evaluated for the Air Force Academy. Soil type was determined to be sandy with an overall high degree of permeability, although there are isolated areas in the Southwest corner where high clay content reduces permeability (45:3-5,7). However, the overall high permeability of the Air Force Academy soils tends to lower Rv values.

Vegetation is generally light with sparse tree growth in the forested areas and thin natural ground cover. Vegetative cover on undeveloped areas is "adapted to sandy soils with low fertility and low water holding capacity" (45:3-31). Table 5 shows the Rv is generally higher for bare surfaces and lower with greater degrees of vegetation cover. The light vegetative cover on the Air Force Academy tends to raise Rv values.

Topographical slopes in developed areas on the AFA range from 2% to 7%, designated as average in Table 5.

However, slopes of undeveloped areas are generally greater than 7%, characterized as steep in Table 5. As previously stated, steeper slopes contribute to a higher Rv value.

Area Descriptions and Associated Rv Values

Potential NPS pollution generating areas on the Air Force Academy grounds were delineated as shown in Figure 12. Individual area dimensions and their associated Rv values were then determined. The delineation of areas used in this study was based on the authors' judgement and scaled from topographic maps.

Area one is the cadet area including 135 acres of athletic fields, 30 acres of parade ground, and the 120 acre academic complex. This area can be categorized on Table 4 with playgrounds representing the athletic fields, parks representing the parade ground, and downtown business areas representing the academic complex.

Table 4 indicates Rv values ranging from 0.20 to 0.35 for playgrounds, from 0.10 to 0.25 for parks, and from 0.70 to 0.95 for downtown business areas.

For the athletic fields, considered playground, surrounded by medium to steep slope, with compacted soil and light vegetation, an Rv value of 0.35 was selected. For the parade ground, considered a park, also surrounded by medium to steep slope, with compacted soil and light vegetation, an

Rv value of 0.25 was selected. For the academic complex, with a medium to steep slope and impervious surfaces an Rv of 0.95 was selected.

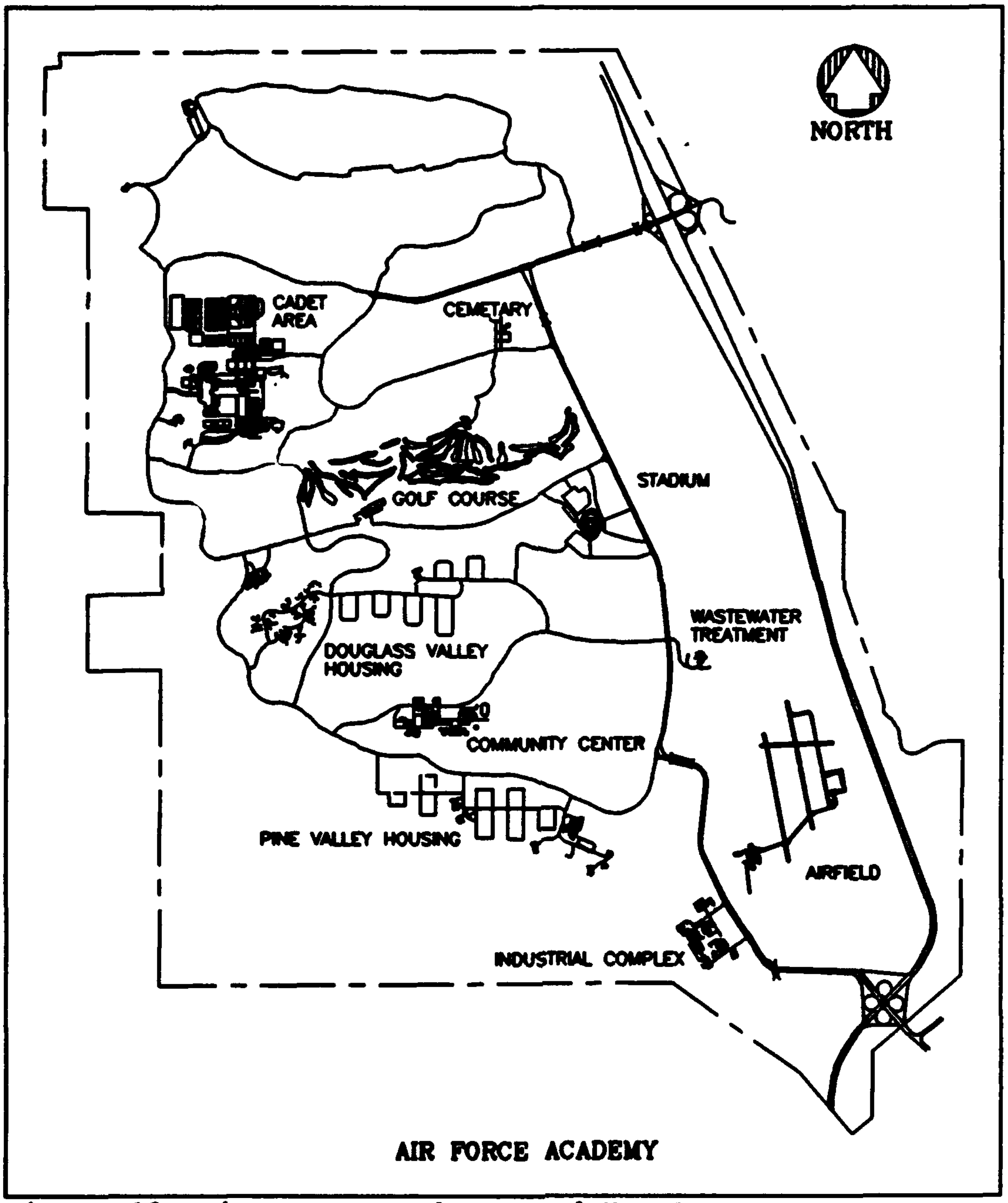

Figure 12. Air Force Academy Land Use Areas

The composite Rv for the entire cadet area is [(135 x 0.35) + (30 x 0.25) + (120 x 0.95)] + 285 = 0.59.

Area two is the cemetery and encompasses approximately 15 acres. Table 4 indicates Rv values ranging from 0.10 to 0.25 for cemeteries. Considering the steep surrounding slope, the medium cemetery slope, sandy soil, and a maintained lawn surface, an Rv value of 0.15 was selected.

Area three is 380 acres containing the thirty six hole golf course and adjacent Visiting Officer Quarters, Bachelor Officer Quarters, and Officer's Open Mess. Table 4 indicates Rv values ranging from 0.10 to 0.35 for golf courses. Considering the steep slope, sandy soil, imperviousness of the adjacent facilities, and the well maintained ground cover, an Rv of 0.30 was selected.

Area four is the three acre stadium complex and associated 155 acre parking areas. The stadium complex can be characterized on Table 5 as a concrete surface and the parking areas as unpaved compacted surfaces.

Table 5 indicates Rv values ranging from 0.80 to 0.95 for concrete surfaces and 0.25 to 0.70 for unpaved compacted surfaces.

For the stadium facility, considering the permeable playing surface, an Rv of 0.90 was selected. For the unpaved compacted parking areas, considering a medium slope and bare vegetative cover, an Rv of 0.50 was selected.

The composite Rv for the stadium complex is $[(3 \times 0.90) + (155 \times 0.50)] \div 158 = 0.51$.

Area five is a 335 acre tract encompassing Douglass Valley housing and senior officer housing, five acres containing the Douglass Valley School, 20 acres containing a park, and five acres containing the hospital complex. From Table 4 the housing area can be categorized as suburban residential, and the school as neighborhood business. The hospital complex can be categorized on Table 5 as impervious roofs and asphaltic surfaces.

Table 4 indicates Rv values for a suburban residential area ranging from 0.25 to 0.40, for a neighborhood business from 0.50 to 0.70, and for a park from 0.10 to 0.25. Table 5 indicates Rv values for roofs as ranging 0.75 to 0.95 and for asphaltic surfaces from 0.70 to 0.95.

For the housing area, considering the higher than average slope, sandy soil, and light ground cover, an Rv of 0.40 was selected. For the school, considering impermeability, medium slope, compacted surfaces, and sparse vegetative cover, an Rv of 0.70 was selected. For the park, considering the medium slope, sandy soil, and light vegetative cover, an Rv of 0.25 was selected. For the hospital complex, considering the steep surrounding slope, sandy soil, and light vegetative cover, an Rv of 0.90 was selected.

The composite Rv for the Douglass Valley area is

$$[(335 \times 0.40) + (5 \times 0.70) + (20 \times 0.25) + (5 \times 0.90)] \div 365 = 0.40.$$

Area six comprises 11 acres encompassing the sewage treatment plant. This facility can be categorized as light industrial on Table 4 with indicated Rv values ranging from 0.50 to 0.80. Considering the relatively high slope, facility impermeability, sandy soil, and light vegetative cover, an Rv of 0.65 was selected.

Area seven contains 73 acres of community facilities including the preparatory school, and 15 acres of athletic fields. This area can be categorized on Table 4 with neighborhood business areas representing the community center and preparatory school, and playgrounds representing the athletic fields. Table 4 indicates Rv values ranging from 0.50 to 0.70 for neighborhood business areas and from 0.20 to 0.35 for playgrounds.

For the community center and preparatory school, considering high degree of imperviousness, sandy soil, light vegetative cover, and low slope, an Rv value of 0.60 was selected. For the athletic fields an Rv of 0.25 was selected.

The composite Rv for area seven is

$$[(73 \times 0.60) + (15 \times 0.25)] + 88 = 0.54.$$

Area eight comprises the 197 acre Pine Valley Housing development, 16 acres of school facilities, 12 acres of park, and 43 acres of playgrounds and athletic fields.

From Table 4 the housing area can be categorized as suburban residential, the schools as neighborhood business, and the playgrounds and athletic fields as playgrounds.

Table 4 indicates Rv values for a suburban residential area ranging from 0.25 to 0.40, for a neighborhood business from 0.50 to 0.70, for a park from 0.10 to 0.25, and for a playground from 0.20 to 0.35.

For the housing area, considering the medium slope, sandy soil, and well maintained ground cover, an Rv of 0.30 was selected. For the schools, considering high impermeability, medium slope, compacted surfaces, and sparse vegetative cover, an Rv of 0.65 was selected. For the park, considering medium slope, sandy soil, and light vegetative cover, an Rv of 0.20 was selected. For the athletic fields and playground, considering compacted surfaces, medium slope, and light vegetative cover, an Rv value of 0.25 was selected.

The composite Rv for the Pine Valley area is $[(197 \times 0.30) + (16 \times 0.65) + (12 \times 0.20) + (43 \times 0.25)] \div 268 = 0.31$.

Area nine contains the airfield complex, with 40 acres of paved airfield surface, 20 acres of unpaved compacted soil surface, 494 acres of grassy field, and 24 acres of maintenance hangers and fueling facilities. Paved and compacted surfaces are delineated in Table 5 and the grassy field can be classified on Table 5 as sandy loam with light vegetation. Maintenance and fueling facilities can be categorized as light industry on Table 4.

Table 5 indicates Rv values ranging from 0.70 to 0.95 for asphaltic surfaces, from 0.25 to 0.70 for unpaved compacted surfaces, and from 0.10 to 0.45 for sandy loam with light vegetation. Table 4 indicates Rv values ranging from 0.50 to 0.80 for light industry.

For the paved airfield surface, considering the high impermeability, an Rv of 0.95 was selected. For the unpaved surfaces, considering compacted soil, and bare vegetative cover, an Rv of 0.70 was selected. For the grassy field, considering the small slope, sandy soil, and light vegetation, an Rv of 0.28 was selected. For the maintenance and fueling facilities, considering the flat slope, high degree of impermeability, sandy soil, and the fact that the surrounding areas are impermeable, an Rv of 0.80 was selected.

The composite Rv for the Air Force Academy airfield is [(40 x 0.95) + (20 x 0.70) + (494 x 0.28) + (24 x 0.80)] + 578 = 0.36.

Area 10 is approximately 57 acres and includes the civil engineering and transportation complex. This area can be characterized on Table 4 as light industrial with Rv values ranging from 0.50 to 0.80. Considering the medium slope, high degree of imperviousness, sandy soil, and light vegetative cover, an Rv of 0.80 was selected.

Area 11 is the grassy median along North Gate Boulevard, Stadium Boulevard, and South Gate Boulevard. The slope of these areas is 2% or less for 15 acres, and between 2% and 7% for 11 acres. This area can be characterized in Table 5 as sandy soil lawn. Table 5 specifies Rv values ranging from 0.05 to 0.10 for flat slopes and from 0.18 to 0.22 for average slopes. Rvs of 0.08 an 0.13 were selected for the flat sloped areas and the medium sloped areas, respectively.

The composite Rv for the entire median strip is $[(15 \times 0.08) + (11 \times 0.13)] \div 26 = 0.10$.

Area 12 consists of paved street surfaces not considered in specifically addressed areas. These streets are located in areas with slopes ranging from flat to much greater than 7%. Table 5 presents the Rv for asphaltic streets as ranging from 0.70 to 0.95. The Rv values selected are 0.70 for 42 acres of streets with flat slopes less than 2%, 0.83 for 63 acres of streets with average slopes ranging between 2% and 7%, and 0.95 for 52 acres of streets with steep slopes greater than 7%.

The composite Rv for these streets is $[(42 \times 0.70) + (63 \times 0.83) + (52 \times 0.95)] \div 157 = 0.83$.

Area 13 is 7,067 acres intertwined with areas one through 12 and must be considered in the composite base Rv calculation. Area 13 is generally undeveloped but contains isolated facilities, activity areas, dirt roads, and other characteristics which lend themselves to the generation minimal NPS pollution.

Table 4 indicates Rv values for this type of terrain range from 0.10 to 0.30. Area 13 has an average to steep slope, permeable soils, and light vegetation indicating an overall mid range Rv for undeveloped land. An Rv of 0.20 was selected.

A total of 9,000 acres were excluded from this study, as they fall outside the boundaries of consideration, and were not included in the composite Rv calculation. Portions of this area are undeveloped natural land not characteristic of an urban environment, while others are not part of the Air Force Academy operations. This includes natural land along the Rampart mountain range west of developed areas, and the area encompassing Interstate 25 along the East side of the base.

Composite Rv Value

The overall composite Rv for the Air Force Academy is

[(285 acres x 0.59) + (15 acres x 0.15) +

(380 acres x 0.30) + (158 acres x 0.51) +

(365 acres x 0.40) + (11 acres x 0.65) +

(88 acres x 0.54) + (268 acres x 0.31) +

(578 acres x 0.36) + (57 acres x 0.80) +

(26 acres x 0.10) + (157 acres x 0.83) +

(7,067 acres x 0.20)] + 9,488 acres = 0.26

Factored Rainfall

Average annual rainfall of 15 inches, based on a period of thirty years, was obtained from climatological records supplied by the AFA weather station. This was divided by the 40 inches (15 + 40 = .375) used in the NURP study to arrive at the applicable factored rainfall contribution.

Unadjusted Pollutant Loading

The equation relating Rv and Unit Quantity Runoff Load is in the form y = a + b(x) where

y = Rv
a = 0
b = the regression coefficient, or slope
x = the Unit Quantity Runoff Load

The regression calculations were stipulated to set the y intercept equal to zero. This is reasonable considering that with the Rv equal to zero the quantity of runoff is equal to zero, and corresponding NPS pollution is therefore also equal to zero. The resulting values for the regression coefficients are shown below in Table 14.

Table 14

Pollutant Regression Coefficients

Pollutant	Regression Coefficient (b)
TSS	0.00055
BOD	0.0082
COD	0.0012
Total Phosphorus	0.23
Soluble Phosphorus	0.67
TKN	0.052
NO_x	0.11
Total Copper	2.3
Total Lead	0.54
Total Zinc	0.49

After the composite Rv value was determined, it was used to solve for "x" from the equation y = 0 + b(x), as shown below.

x = y + b

The total <u>unadjusted</u> annual NPS pollutant loading from the Air Force Academy is calculated below.

y = Rv = Runoff Coefficient = 0.26.
b = Regression Coefficient from Table 14.

Total unadjusted pollutant load = Rv + b

TSS Load = 0.26 + 0.00055 = 473 Kg/HA/Yr

BOD Load = 0.26 + 0.0082 = 32 Kg/HA/Yr

COD Load = 0.26 + 0.0012 = 217 Kg/HA/Yr

Total Phosphorus Load = 0.26 + 0.23 = 1.1 Kg/HA/Yr

Soluble Phosphorus Load = 0.26 + 0.67 = 0.39 Kg/HA/Yr

TKN Load = 0.26 + 0.052 = 5.0 Kg/HA/Yr

NO_x Load = 0.26 + 0.11 = 2.4 Kg/HA/Yr

Total Copper Load = 0.26 + 2.3 = 0.11 Kg/HA/Yr

Total Lead Load = 0.26 + 0.54 = 0.48 Kg/HA/Yr

Total Zinc Load = 0.26 + 0.49 = 0.53 Kg/HA/Yr

These results can also be obtained by reading the unadjusted pollutant loads directly from Figures 13 through 22, shown below.

Figures 13 through 22 depict plots of Rv versus constituent pollutant loading, and the determination of the unadjusted pollutant loading for an Rv value of 0.26. Also shown are the data points, from Table 3, for Rv values and pollutant constituent loadings provided in the NURP study.

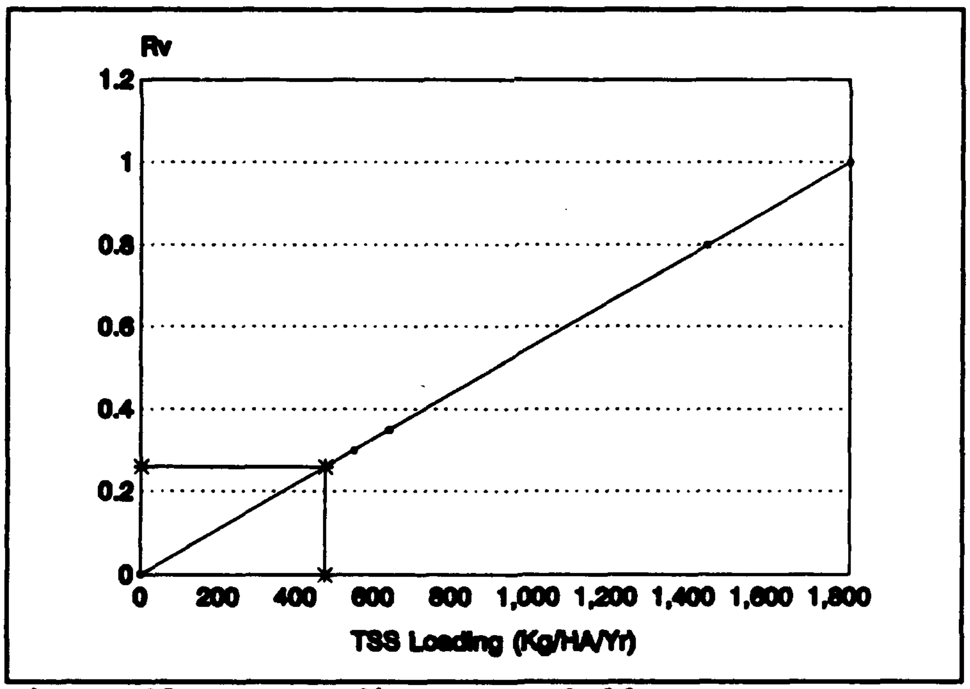

Figure 13. TSS Loading, Rv = 0.26

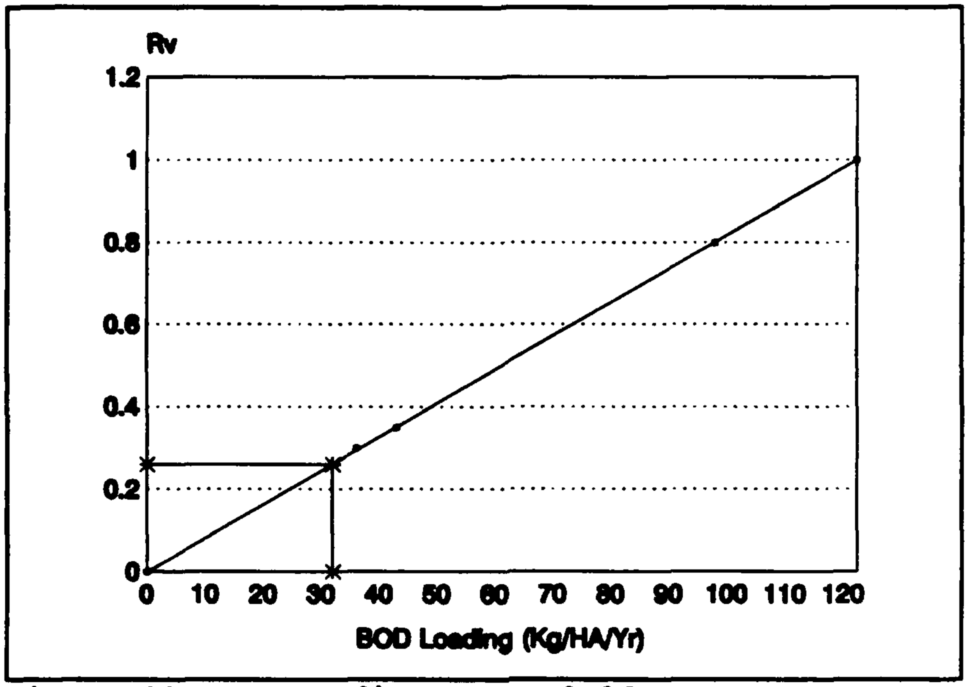

Figure 14. BOD Loading, Rv = 0.26

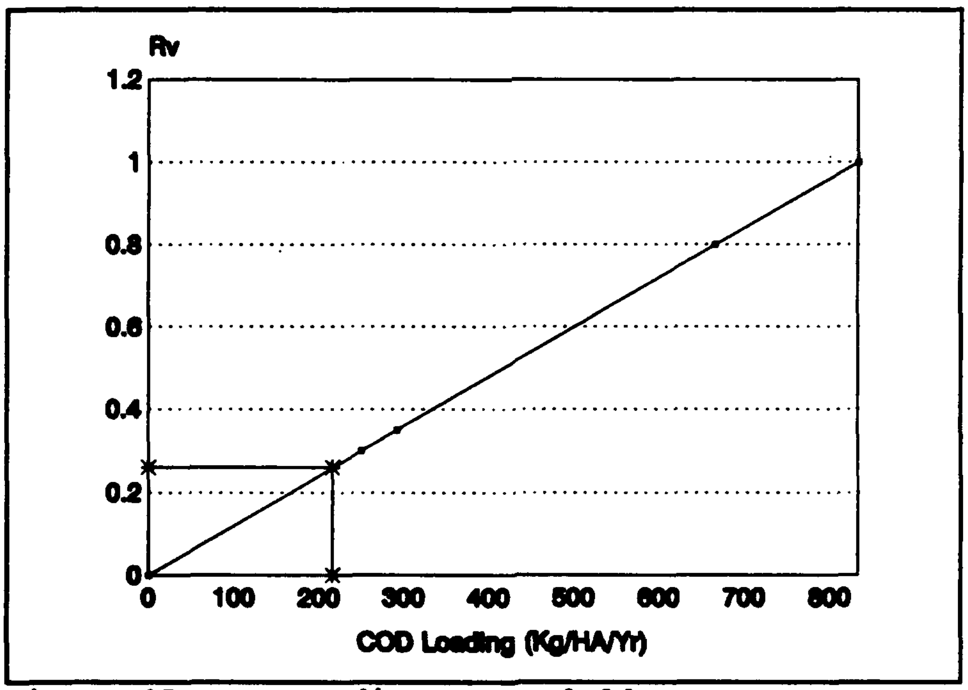

Figure 15. COD Loading, Rv = 0.26

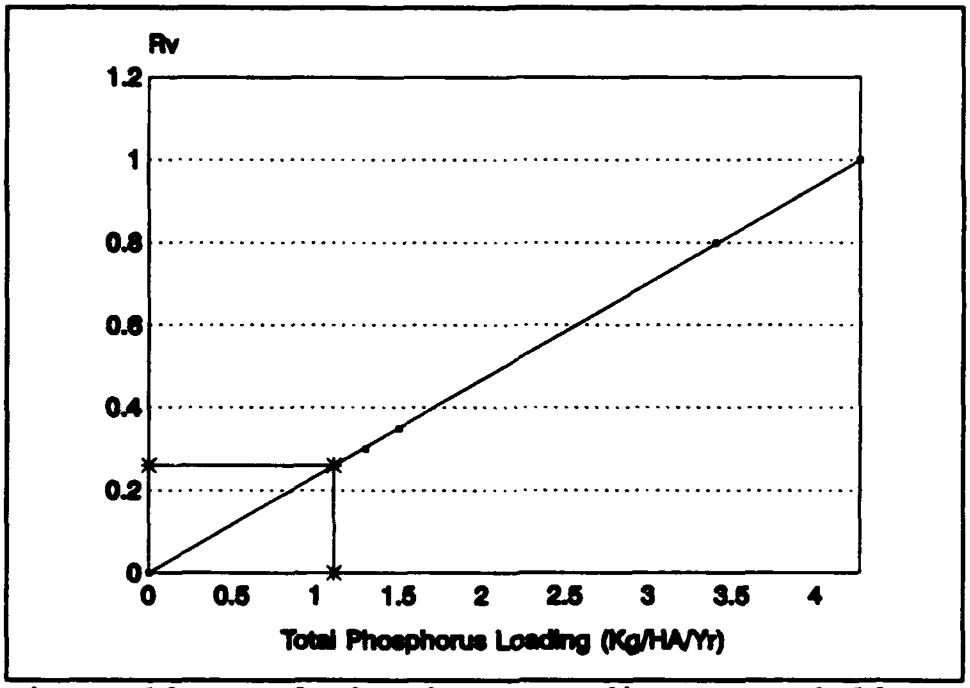

Figure 16. Total Phosphorus Loading, Rv = 0.26

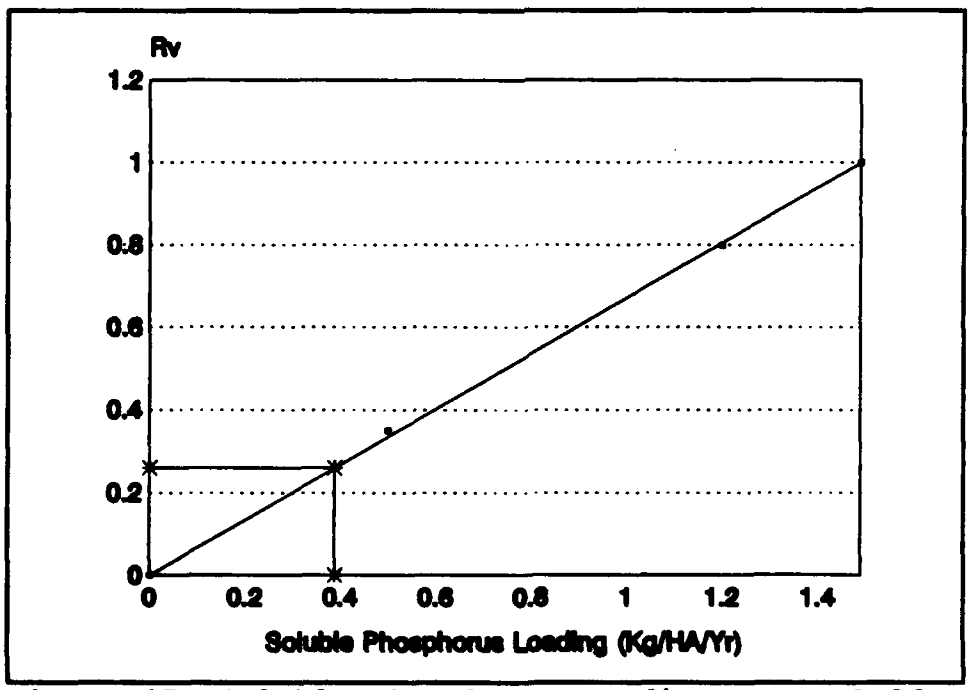

Figure 17. Soluble Phosphorus Loading, Rv = 0.26

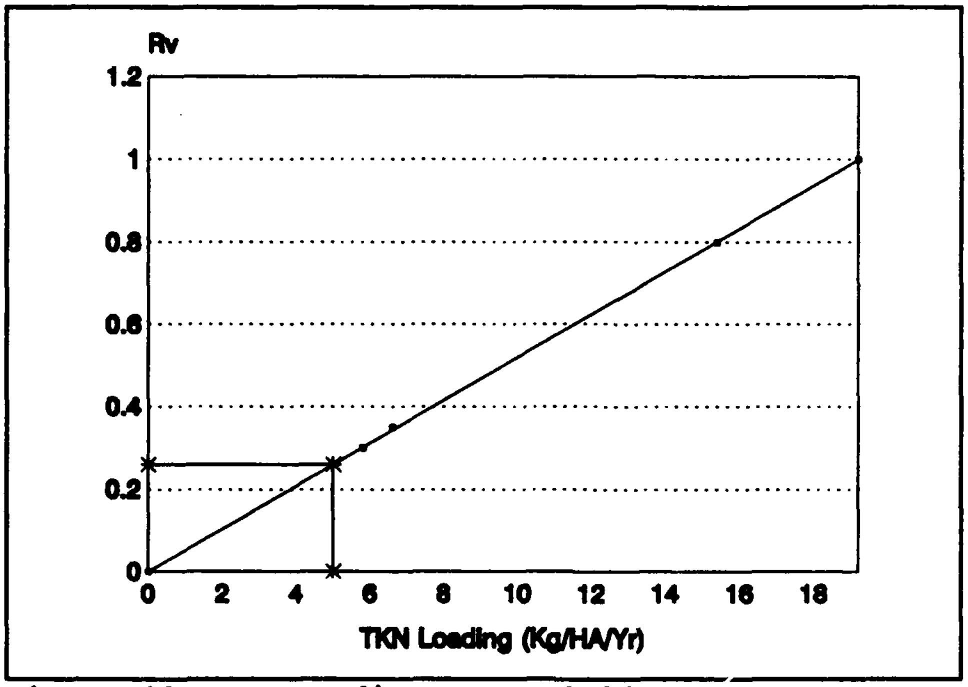

Figure 18. TKN Loading, Rv = 0.26

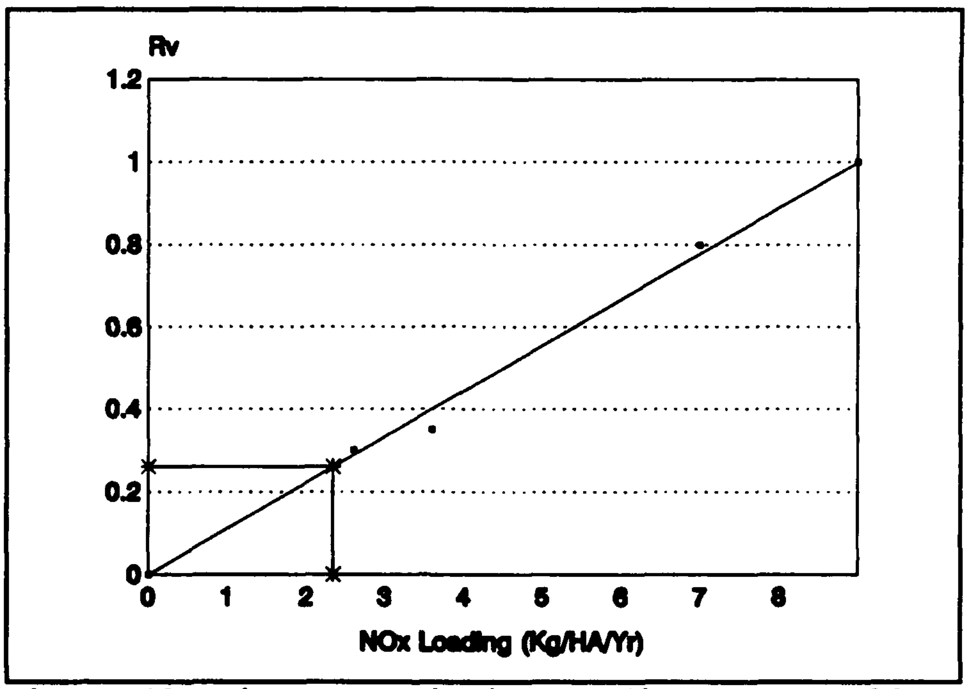

Figure 19. Nitrate & Nitrite Loading, Rv = 0.26

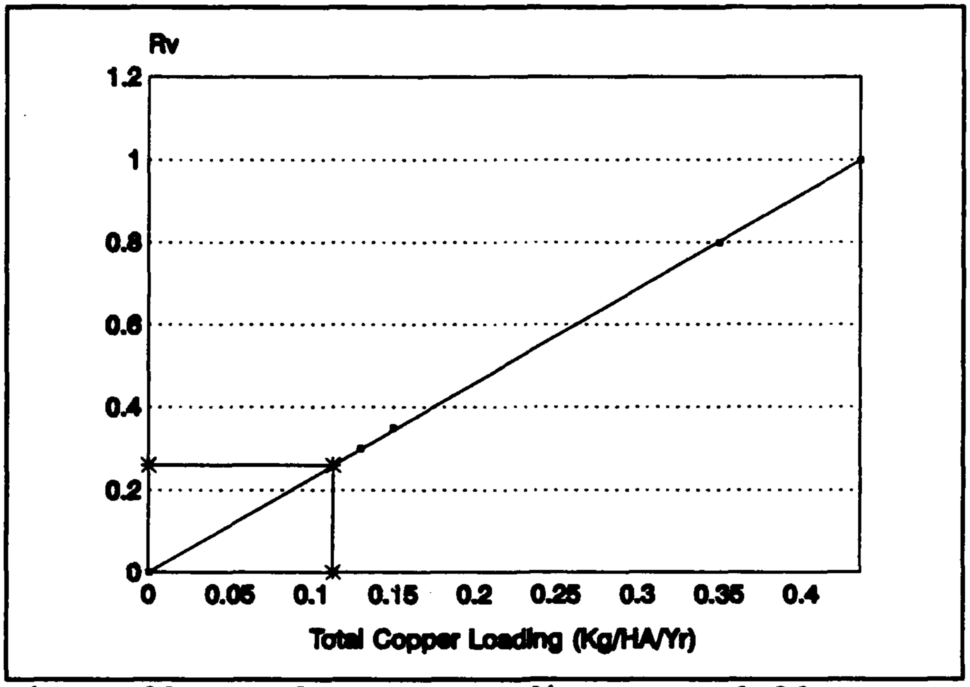

Figure 20. Total Copper Loading, Rv = 0.26

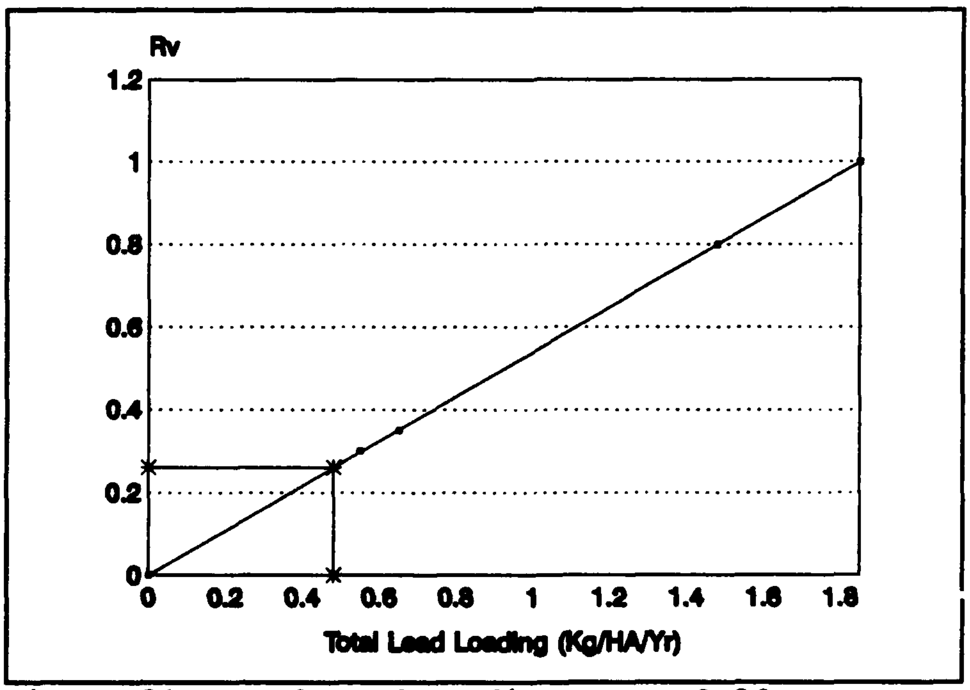

Figure 21. Total Lead Loading, Rv = 0.26

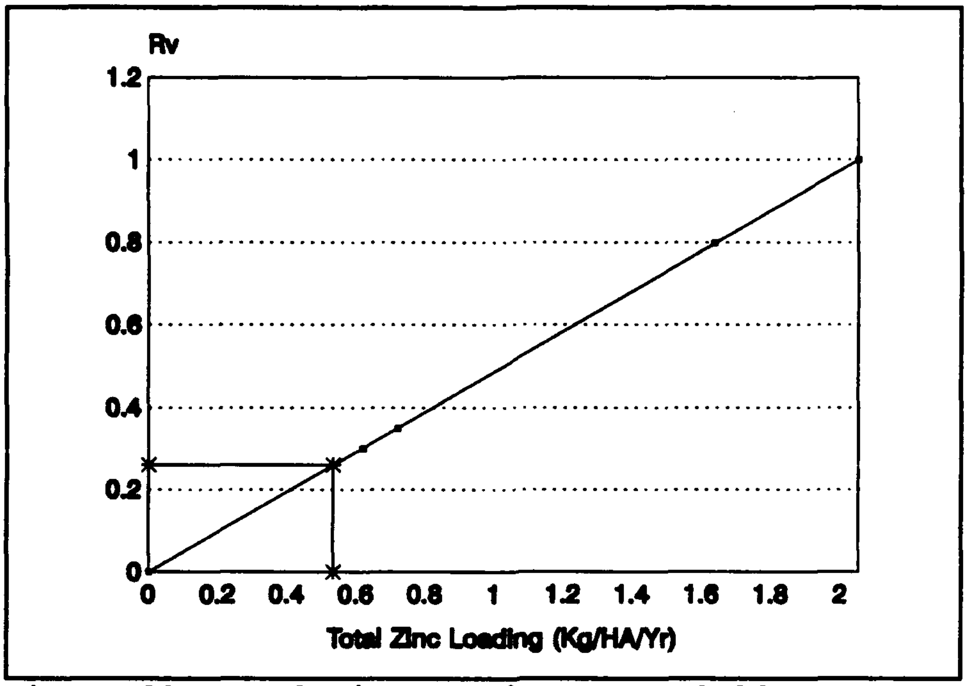

Figure 22. Total Zinc Loading, Rv = 0.26

Total NPS Pollutant Loading Calculation

The above results were multiplied by the area of concern (9,488 acres) and by the factored rainfall (0.375), and divided by 2.49 acres per Hecta-Acre to arrive at a total annual NPS pollutant load in Kg/Yr.

Total Annual Pollutant Load = Unadjusted Pollutant Load x Area (9,488 acres) x Factored Rainfall (0.375) + 2.49 acres per Hecta-Acre = Unadjusted Pollutant Load x 1,429.

TSS Load = 473 Kg/HA/Yr x 1,429 = 680,000 Kg/Yr

BOD Load = 32 Kg/HA/Yr x 1,429 = 46,000 Kg/Yr

COD Load = 217 Kg/HA/Yr x 1,429 = 310,000 Kg/Yr

Tot Phos Load = 1.1 Kg/HA/Yr x 1,429 = 1,600 Kg/Yr

Sol Phos Load = 0.39 Kg/HA/Yr x 1,429 = 560 Kg/Yr

TKN Load = 5.0 Kg/HA/Yr x 1,429 = 7,100 Kg/Yr

NO_x Load = 2.4 Kg/HA/Yr x 1,429 = 3,400 Kg/Yr

Tot Copper Load = 0.11 Kg/HA/Yr x 1,429 = 160 Kg/Yr

Tot Lead Load = 0.48 Kg/HA/Yr x 1,429 = 690 Kg/Yr

Tot Zinc Load = 0.53 Kg/HA/Yr x 1,429 = 760 Kg/Yr

The total NPS pollutant loading from the Air Force Academy, predicted by the Unit Quantity Model, is shown below in Table 15.

Table 15

Unit Quantity Model Air Force Academy NPS Pollutant Loading

Pollutant	Total Annual Load (Kg/Yr)
TSS	680,000
BOD	46,000
COD	310,000
Total Phosphorus	1,600
Soluble Phosphorus	560
TKN	7,100
NO_x	3,400
Total Copper	160
Total Lead	690
Total Zinc	760

Appendix C: ProStorm Model - Air Force Academy Example

Discretionary input values used to define parameters for the AFA are shown below in Table 16. Other required input values not shown on Table 16 were default values provided in the ProStorm program.

Table 16

Input Values for ProStorm, Air Force Academy Example

Input Variable	Value	Description
NWSHD	13	Number of subbasins.
ISNO	1	Include snowmelt computations.
ISED	0	Exclude land erosion computations.
IQUAL	1	Perform runoff quality computations.
IODWF	0	Exclude dry-weather (sewer) flow.
LDATE	-4	Dry days before first rain in data.
METRIC	2	Denotes input variables as English.
IFREZ	34°	Temperature of snow formation, °F.
MXLG	Variable	Number of land uses per subbasin.
IPACUM	2	Pollutant contribution-pounds/day/acre.
AREA	Variable	Area of subbasins.
RECVERT	Variable	Pan evaporation rate, monthly average in inches/day. This information is available from ETAC, DSN 576-4044, Scott AFB. The rates used in this case are those for the Pueblo City Reservoir, Pueblo, Colorado.
LOSSEQ	1	Computational method, coefficient.
CPERV	0	Runoff coefficient for pervious areas.
CIMP	1	Runoff coefficients for pervious areas.
DEPRS	0	Estimated maximum depression storage.
FRACTN(L,1)	____	Suspended solids, lb/day/ac.
FRACTN(L,2)	____	Settleable solids.
FRACTN(L,3)	____	BOD.
FRACTN(L,4)	____	Nitrogen.
FRACTN(L,5)	____	Orthophosphate.
FRACTN(L,6)	____	Coliform organisms.

Table 16 (Cont.)

Input Values for ProStorm, Air Force Academy Example

Input Variable	Value	Description
MAX	1	Number of treatment rates assumed to occur. The treatment amount was designated as .01 inches of rain. This would approximate the settling of material as the runoff was detained by various obstructions.
TRATER	0.01	Treatment rate in inches per hour.
CAPR	0.01	Storage capacity in inches. This value would approximate the amount of rainfall stored in depressions and catchments.

Specific pollutant contributions from different land uses, variable name "FRACTN(L,x)", were taken from Table 17, shown below.

Table 17

Pollutant Accumulation Rates, (Pounds/Acre/Day) (47:C-2)

Land Use	Sus Solids	Set Solids	BOD	NO_x	PO_4	Coliform*
Res #1	0.12	0.09	0.04	0.007	0.0042	1.200
Res #2	0.45	0.18	0.07	0.028	0.0063	1.260
Res #3	3.16	1.00	0.13	0.025	0.0200	9.800
Commercial	____	____	0.46	0.212	0.0400	9.000
Industrial	____	____	0.39	0.209	0.0300	10.000

Table 17 (Cont.)

Pollutant Accumulation Rates, (Pounds/Acre/Day) (47:C-2)

Land Use	Sus Solids	Set Solids	BOD	NO_x	PO_4	Coliform*
Open/Rural	____	____	0.02	0.007	0.0020	1.000
Pasture	____	____	3.10	0.392	0.3500	120.000
Farming	____	____	0.02	0.044	0.0002	0.500
Forests	____	____	0.01	0.002	0.000024	0.001

* 10^9 Most Probable Number (MPN) per acre per day.

Res #1 is low density housing, two to five dwelling units per acre; Res #2 is medium density housing, from five to ten dwelling units per acre; and Res #3 is high density housing, with more than ten dwelling units per acre.

Values of Suspended and Settleable Solids for other than residential land uses were not presented in Table 9 nor were they available for the various discreet areas of concern on the AFA. Accordingly, for heavy traffic areas such as athletic fields, community and cadet areas, schools, and the industrial complex, values of 3.16 pounds per acre per day of Suspended Solids and 1.00 pounds per acre per day of Settleable Solids were assigned from the high density housing category, Res #3. This is reasonable considering that activity in these areas, with the exception of the industrial complex, involves primarily vehicle traffic and pedestrian foot traffic, as would be found in a high density residential area. The industrial complex itself contains only shops, vehicle maintenance facilities, storage facilities, and large parking areas.

The results from the ProStorm model are shown below in Table 17 for the AFA example. Each of the 13 land use areas used in ProStorm were also used in the Unit Quantity Model calculations. As mentioned above, Suspended Solids and Settleable Solids are combined in Total Suspended Solids.

Table 18

Results of Prostorm for Air Force Academy Land Uses
(Pounds per 5.62 Inches of Rainfall)

AREA	SUSPENDED SOLIDS	SETTLEABLE SOLIDS	BOD
1	82,559	17,711	13,290
2	138	74	28
3	4,109	2,129	918
4	48,014	10,296	10,429
5	5,315	2,271	1,632
6	137	69	369
7	23,497	5,076	5,086
8	19,171	4,866	3,032
9	6,495	3,340	2,127
10	19,301	4,078	3,966
11	220	119	43
12	2,030	1,015	502
13	69,731	36,799	14,740
TOTALS	280,717	87,843	56,162

The above results were obtained using climatological data from 1 January 1992 through 31 May 1992. This time frame includes a total rainfall of 5.62 inches but does not encompass an entire year. Therefore it must be adjusted by the 15 inches per year average rainfall at the AFA. The adjusted loading results are shown below in Table 19.

Table 19

ProStorm Air Force Academy NPS Pollutant Loading (Kg/Yr)

Constituent	Loading
TSS	446,000
BOD	68,000
Nitrogen	32,000

Air Force Academy Data File for ProStorm

The entire data input file for the ProStorm Model is shown below.

```
A1              Air Force Academy NPS Pollution Analysis
A2              Test for 13 subbasins
A3                       - File AFA1.IHS -
B1    13       1               1       1
B2    30       3       1      -4       0       1       2
C1 AFA Weather Station Records         5       0  920101       0       1
C2920101
C2920102  0   0  0  0  0  0  0  0  0  2  0  0  0  0  0  0  0  0  0  0
C2920107  0   0  0  0  0  0  0  0  0  1  0  0  0  0  0  1  0  0  0  0
C2920108  0   0  0  0  0  0  0  0  0 30  0  0  0  0  0  1  0  0  0  0
C2920113  0   0  0  0  0  0  0  0  0 20  0  0  0  0  0  0  0  0  0  0
C2920115  0   0  0  0  0  0  0  0  0  2  0  0  0  0  0  0  0  0  0  0
C2920117  0   0  0  0  0  0  0  0  0  0  0  0  0  0  0  1  0  0  0  0
C2920118  0   0  0  0  0  0  0  0  0  1  0  0  0  0  0  1  0  0  0  0
C2920203                              1                 3
C2920204                              1                 1
C2920223                              3                 2
C2920225                                                1
C2920226                              2
C2920303                                                            1
C2920304                             18                50
C2920305                             11                 1
C2920306                              1
C2920309                             75
C2920310                              9
C2920311                             18
```

```
C2920318                                   1
C2920319                                   1
C2920325                                   1
C2920331                                   1
C2920401                                   1
C2920402                                                              1
C2920408                                   1
C2920412                                   2              1
C2920413                                   1
C2920414                                                              1
C2920416                                  75              1
C2920417                                  10
C2920418                                   3              1
C2920419                                   1
C2920420                                   1
C2920422                                                              1
C2920423                                   2
C2920504                                   1
C2920507                                   1
C2920508                                   1
C2920509                                   1
C2920511                                  22
C2920513                                   1
C2920515                                   1
C2920516                                   1
C2920517                                   1
C2920518                                  19
C2920521                                                              4
C2920524                                                  1
C2920525                                                  1
C2920526                                   7
C2920527                                  57              2
C2920528                                  24              2
C2
D1      5      0      34      .50          1      .07
74531920101 47 15
74531920102 47 15
74531920103 46 17
74531920104 46 17
74531920105 42 19
74531920106 45 25
74531920107 30 25
74531920108 31 17
74531920109 33 10
74531920110 47 15
74531920111 53 24
74531920112 53 24
74531920113 29  2
74531920114 33  3
74531920115 21 14
74531920116 49 33
74531920117 27 19
74531920118 28  7
74531920119 46 10
74531920120 48 13
74531920121 47 23
74531920122 34 20
74531920123 43 23
74531920124 55 38
74531920125 40 19
74531920126 49 34
74531920127 38 17
```

74531920128	53	24
74531920129	48	24
74531920130	51	24
74531920131	60	22
74531920201	57	21
74531920202	50	32
74531920203	37	30
74531920204	42	16
74531920205	42	3
74531920206	45	23
74531920207	45	20
74531920208	44	18
74531920209	49	23
74531920210	43	25
74531920211	47	28
74531920212	51	28
74531920213	51	27
74531920214	49	33
74531920215	48	27
74531920216	40	29
74531920217	39	28
74531920218	39	24
74531920219	50	14
74531920220	54	35
74531920221	54	35
74531920222	52	25
74531920223	37	32
74531920224	47	17
74531920225	39	28
74531920226	50	30
74531920227	55	37
74531920228	56	31
74531920229	62	28
74531920301	65	42
74531920302	58	35
74531920303	55	29
74531920304	36	32
74531920305	44	28
74531920306	55	33
74531920307	59	38
74531920308	51	37
74531920309	24	19
74531920310	41	6
74531920311	44	19
74531920312	49	30
74531920313	53	28
74531920314	55	29
74531920315	60	30
74531920316	60	36
74531920317	56	34
74531920318	40	34
74531920319	41	30
74531920320	57	21
74531920321	57	21
74531920322	57	21
74531920323	53	28
74531920324	50	34
74531920325	55	32
74531920326	59	33
74531920327	53	33
74531920328	53	33
74531920329	53	33

74531920330	61	25
74531920331	51	33
74531920401	51	24
74531920402	50	30
74531920403	64	31
74531920404	67	33
74531920405	64	34
74531920406	68	33
74531920407	58	33
74531920408	67	35
74531920409	69	33
74531920410	72	34
74531920411	62	33
74531920412	39	36
74531920413	76	43
74531920414	71	50
74531920415	59	43
74531920416	50	40
74531920417	65	32
74531920418	45	37
74531920419	47	45
74531920420	52	30
74531920421	61	25
74531920422	60	28
74531920423	64	34
74531920424	55	24
74531920425	56	25
74531920426	61	27
74531920427	76	33
74531920428	73	43
74531920429	76	37
74531920430	83	43
74531920501	81	62
74531920502	58	42
74531920503	66	34
74531920504	70	42
74531920505	71	38
74531920506	68	38
74531920507	76	47
74531920508	71	48
74531920509	69	41
74531920510	69	41
74531920511	70	42
74531920512	60	47
74531920513	72	45
74531920514	69	40
74531920515	76	44
74531920516	73	40
74531920517	68	37
74531920518	78	49
74531920519	77	43
74531920520	77	43
74531920521	73	47
74531920522	53	48
74531920523	44	43
74531920524	56	45
74531920525	48	43
74531920526	51	36
74531920527	40	37
74531920528	46	32
74531920529	61	37
74531920530	61	37

```
74531920531 61 37
E1 Area # 1.            3      2.0       .7     1.67        1        2
E2   285       1.0      0
E3   .13       .15    .19      .23      .30      .35      .35      .30      .25
   .18
E3   .11       .13
E4     1
F1PLAYGR       47.    35.
F2            3.16    1.0      .02     .007     .002      1.0
F1PARK         11.    25.
F2             .12    .09      .02     .007     .002      1.0
F1COMMCL       42.    95.
F2            3.16    1.0      .46     .212      .04      9.0
T1     1
T2   .01         1      1        0        3                          0
T3   .01
T4     1
E1 Area #2.             1      2.0       .7     1.67        1        2
E2    15       1.0      0
E3   .13       .15    .19      .23      .30      .35      .35      .30      .25
   .18
E3   .11       .13
E4     1
F1CMTRY       100.    15.
F2             .12    .09      .02     .007     .002      1.0
T1     1
T2   .01         1      1        0        3                          0
T3   .01
T4     1
E1 Area #3              1      2.0       .7     1.67        1        2
E2   380       1.0      0
E3   .13       .15    .19      .23      .30      .35      .35      .30      .25
   .18
E3   .11       .13
E4     1
F1GLFCRS      100.    30.
F2             .12    .09      .02     .007     .002      1.0
T1     1
T2   .01         1      1        0        3                          0
T3   .01
T4     1
E1 Area #4              2      2.0       .7     1.67        1        2
E2   155       1.0      0
E3   .13       .15    .19      .23      .30      .35      .35      .30      .25
   .18
E3   .11       .13
E4     1
F1STADUM        2.    90.
F2             .12    .09      .46     .212      .04      9.0
F1PRKING       98.    50.
F2            3.16    1.0      .46     .212      .04      9.0
T1     1
T2   .01         1      1        0        3                          0
T3   .01
T4     1
E1 Area #5              4      2.0       .7     1.67        1        2
E2   335       1.0      0
E3   .13       .15    .19      .23      .30      .35      .35      .30      .25
   .18
E3   .11       .13
E4     1
```

```
F1MFH        92.     40.
F2           .12     .09     .04     .007    .0042    1.2
F1SCHOOL     1.5     70.
F2           3.16    1.0     .46     .212    .04      9.0
F1PARK       5.      25.
F2           .12     .09     .02     .007    .002     1.0
F1HOSPTL     1.5     90.
F2           .12     .09     .04     .007    .0042    1.2
T1      1
T2    .01    1       1       0       3                          0
T3    .01
T4      1
E1 Area #6           1       2.0     .7      1.67     1        2
E2     11    1.0     0
E3    .13    .15     .19     .23     .30     .35      .35      .30      .25
   .18
E3    .11    .13
E4      1
F1WWTP       100.    65.
F2           .12     .09     .39     .209    .03      10.0
T1      1
T2    .01    1       1       0       3                          0
T3    .01
T4      1
E1 Area #7           2       2.0     .7      1.67     1        2
E2     88    1.0     0
E3    .13    .15     .19     .23     .30     .35      .35      .30      .25
   .18
E3    .11    .13
E4      1
F1COMCNT     83.     60.
F2           3.16    1.0     .46     .212    .04      9.0
F1PLAYGR     17.     25.
F2           .12     .09     .02     .007    .002     1.0
T1      1
T2    .01    1       1       0       3                          0
T3    .01
T4      1
E1 Area #8           4       2.0     .7      1.67     1        2
E2    268    1.0     0
E3    .13    .15     .19     .23     .30     .35      .35      .30      .25
   .18
E3    .11    .13
E4      1
F1PV-MFH     74.     30.
F2           .12     .09     .04     .007    .0042    1.2
F1SCHOOL     6.      65.
F2           3.16    1.0     .46     .212    .04      9.0
F1PARK       4.      20.
F2           .12     .09     .02     .007    .002     1.0
F1PLAYGR     16.     25.
F2           3.16    1.0     .02     .007    .002     1.0
T1      1
T2    .01    1       1       0       3                          0
T3    .01
T4      1
E1 Area #9           4       2.0     .7      1.67     1        2
E2    578    1.0     0
E3    .13    .15     .19     .23     .30     .35      .35      .30      .25
   .18
E3    .11    .13
E4      1
```

```
F1RUNWAY      7.      95.
F2            .12     .09     .04     .007    .0042    1.2
F1OVRRUN      3.      70.
F2            .12     .09     .04     .007    .0042    1.2
F1FIELD       86.     28.
F2            .12     .09     .02     .007    .002     1.0
F1FACLTS      4.      80.
F2            .12     .09     .39     .209    .03      10.0
T1     1
T2    .01     1       1       0       3                          0
T3    .01
T4     1
E1 Area #10           1       2.0     .7      1.67     1         2
E2    57      1.0     0
E3    .13     .15     .19     .23     .30     .35      .35       .30      .25
  .18
E3    .11     .13
E4     1
F1CIVENG      100.    80.
F2            3.16    1.0     .39     .209    .03      10.0
T1     1
T2    .01     1       1       0       3                          0
T3    .01
T4     1
E1 Area #11           2       2.0     .7      1.67     1         2
E2    26      1.0     0
E3    .13     .15     .19     .23     .30     .35      .35       .30      .25
  .18
E3    .11     .13
E4     1
F1MEDSLP      57.     8.
F2            .12     .09     .02     .007    .002     1.0
F1LOWSLP      43.     13.
F2            .12     .09     .02     .007    .002     1.0
T1     1
T2    .01     1       1       0       3                          0
T3    .01
T4     1
E1 Area #12           3       2.0     .7      1.67     1         2
E2    157     1.0     0
E3    .13     .15     .19     .23     .30     .35      .35       .30      .25
  .18
E3    .11     .13
E4     1
F1STRET1      27.     70.
F2            .12     .09     .02     .007    .002     1.0
F1STRET2      40.     83.
F2            .12     .09     .02     .007    .002     1.0
F1STRET3      33.     95.
F2            .12     .09     .02     .007    .002     1.0
T1     1
T2    .01     1       1       0       3                          0
T3    .01
T4     1
E1 Area #13           1       2.0     .7      1.67     1         2
E2    7067    1.0     0
E3    .13     .15     .19     .23     .30     .35      .35       .30      .25
  .18
E3    .11     .13
E4     1
F1OTHER       100     20
F2            .12     .09     .02     .007    .002     1.0
```

T1	1					
T2	.01	1	1	0	3	0
T3	.01					
T4	1					

Appendix D: Sampling and Analysis Program

A water sampling and analysis program was conducted at the Air Force Academy during June 1992 to determine concentration and loading of the ten targeted NPS pollutants.

Sampling Points

The following five locations, shown in Figure 23, were selected as sampling points. These were in streams with continuous year-round flow and were selected to isolate the NPS pollution generated by Air Force Academy operations.

1. Monument Creek - North. The Monument Creek-North sampling location was at the north boundary of the Air Force Academy and upstream of Air Force Academy operations.

2. Smith Creek. The Smith Creek sampling location was on Smith Creek, approximately 50 feet upstream from the intersection with Monument Creek. There are no Air Force Academy operations on Smith Creek upstream from the sampling location, however Smith Creek drains a rural watershed adjacent to the east side of Air Force Academy grounds.

3. Black Squirrel Creek. The Black Squirrel sampling location was on Black Squirrel Creek, approximately 100 feet upstream from the intersection with Monument Creek. There are no Air Force Academy operations upstream from this

sampling location. However, Black Squirrel Creek drains a large undeveloped natural watershed on the AFA.

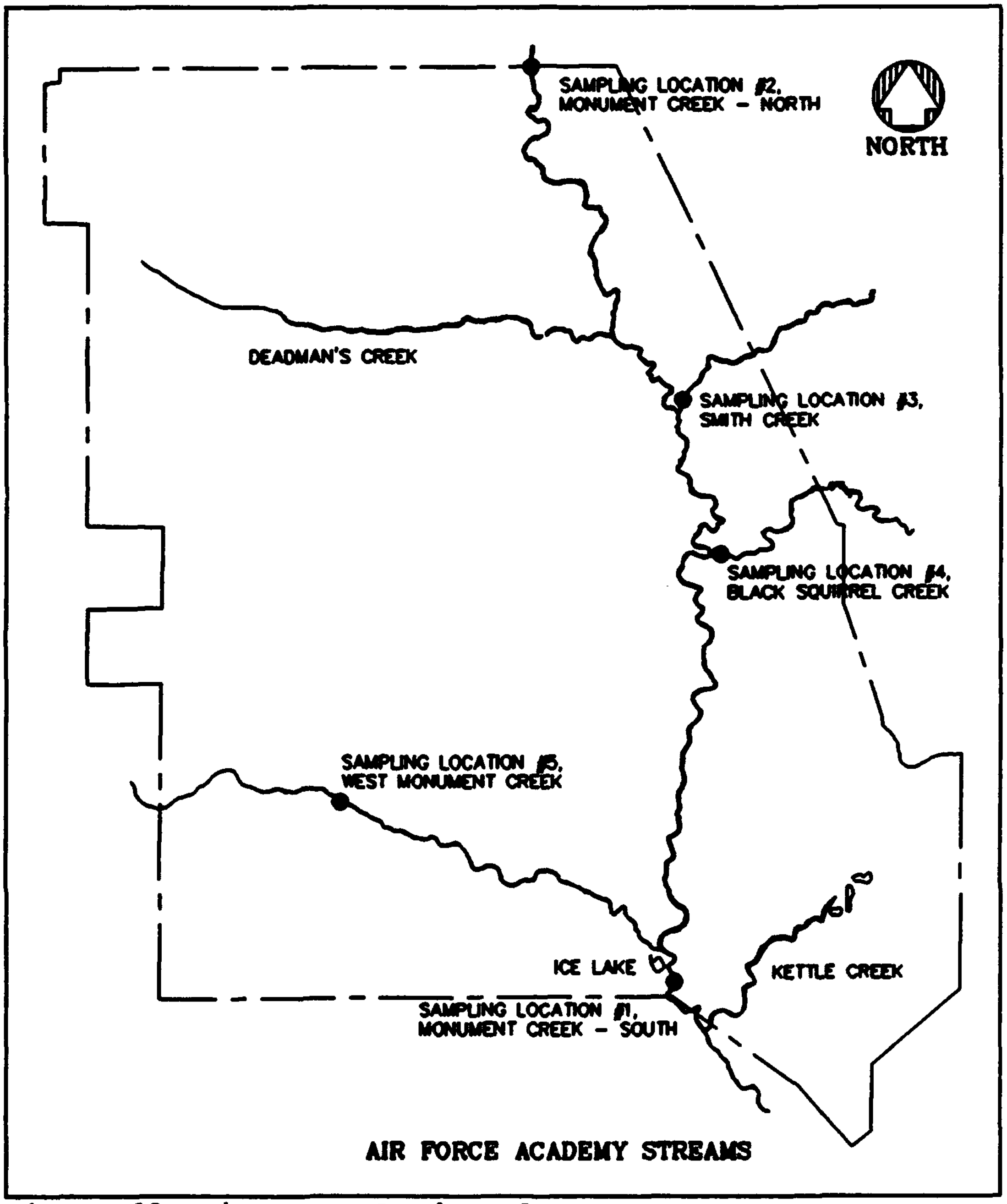

Figure 23. Air Force Academy Streams

4. West Monument Creek. The West Monument Creek sampling location was located West of Pine Valley housing and downstream from both the Colorado Springs Municipal water plant and tunnel construction activities on the East face of the Rampart Range.

5. Monument Creek - South. The Monument Creek-South sampling location was on Monument Creek near the southern boundary of the Air Force Academy. Monument Creek exits Air Force Academy property at the eastern side of the base's southern boundary. At this sampling point Monument Creek contains all surface water drainage from the Air Force Academy grounds in addition to that introduced from the above mentioned streams.

Kettle Creek drains a small watershed in the Southeast corner of the Air Force Academy. As no Air Force operations occur in this watershed, and since Kettle Creek enters Monument Creek south of the Air Force Academy boundary, it was not included in the sampling and analysis program.

Deadman's Creek originates within the Air Force Academy boundary and drains a watershed in the northern portion of the installation. Although it is not a continuously flowing stream, it was flowing during the sampling and analysis program. Flow data from Deadman's Creek was obtained periodically. However, since the creek originates on Air Force Academy property and contains no off base flow or runoff contribution, sampling and analysis for the NPS pollutants was not required.

NPS pollutant loading generated by Air Force Academy operations was obtained by subtracting the NPS pollutant loading carried onto the Air Force Academy by the four entering streams from that carried away by Monument Creek at the south boundary.

Equipment

The water sampling equipment available for use in this study included four Isco Model 3700 portable samplers, four Isco Model 3230 flowmeters with plotters, one Isco Model 2710 portable sampler, and one Marsh-McBireny Model 201D portable water flowmeter. The Isco 3700 samplers and 3230 flowmeters, which are capable of flow proportional sampling, were procured by the Air Force Academy in support of this NPS pollution analysis effort. The Air Force Academy Bioenvironmental Engineering office provided the Isco Model 2710 sampler, which is capable of only timed sampling. The Marsh-McBirney portable flowmeter was loaned to the Air Force Academy, in support of this project, by Armstrong Laboratories located at Brooks Air Force Base, Texas.

Setup

The water samplers and flowmeters were programmed and set at their designated sampling locations during 8-11 June 1992. These locations were selected, as previously discussed, to allow isolation of NPS pollution generated by Air Force Academy operations from that generated by other sources. Specific sites at each sampling location were selected at points where the streams flow in a single channel with an approximate rectangular cross section. This would allow for a simple flow rate calculation and the use of the Manning formula for natural channels in the Isco flowmeter program (20:99-107).

Flow proportional samples were programmed for flow-paced sequential sampling (25:4-25). This type sampling collects a sample in a separate bottle upon a prompt from the accompanying flowmeter.

The Isco flowmeters were programmed to instruct the accompanying sampler when to draw a sample. In order to program the Isco flowmeter, the existing flow rate was first measured. The cross sectional area of flow was measured manually, and the flow velocity was measured with the Marsh-McBirney portable flowmeter. For example, Monument Creek-South had a dry weather average depth of 6.5 inches, a width of 13 feet, and an average flow velocity of 2.87 feet per second measured at one half the flow depth. The resulting flow quantity, Q, is calculated as shown below.

$$Q = \text{depth} \times \text{width} \times \text{velocity}$$

$$0.54 \text{ ft} \times 13.0 \text{ ft} \times 2.87 \text{ ft/sec} = 20.21 \text{ ft}^3\text{/sec}$$

The dimensions of the stream were then entered into the flowmeter program. The flowmeter calculated flow based upon the channel dimensions and the Manning formula for gravity flow in open channels. The Manning formula is

$$Q = (1.49 \times A \times R^{2/3} \times S^{1/2}) + n$$

where

Q = flow in cubic feet per second
n = Manning roughness coefficient
A = cross sectional area in square feet
R = hydraulic radius, or cross sectional area divided by the wetted perimeter
S = slope of the hydraulic gradient.

The Manning Roughness Coefficients for natural channels are shown below in Table 20.

Table 20

Manning Roughness Coefficients for Natural Channels (20:105)

	Minimum	Normal	Maximum
A. Fairly Regular Section	0.030	0.050	0.070
B. Irregular Section With Pools	0.040	0.070	0.100

A Manning Coefficient in the maximum range is indicative of a rough channel, leading to a smaller quantity of flow than a smooth channel. The roughness coefficients selected for the Air Force Academy streams were all fairly regular sections with normal roughness.

After a flowmeter was programmed, it calculated a flow quantity based on input values and the Manning Formula. Slope and roughness were the variables of concern in programming the flowmeter. These values were adjusted until the flow calculated by the flowmeter matched the measured flow value. This initial input served as calibration of the flowmeter, enabling it to calculate changes in actual flow as a function of flow depth.

Stream sections with regular geometry and normal roughness Manning Coefficients were selected for sampling locations, and the stream slope was varied to arrive at flow corresponding to measured flow.

Additional calculations were necessary to determine the quantity of flow after which the flowmeter would prompt the sampler to draw a sample. Since the Isco 3700 samplers were limited to 24 discrete samples, consideration was given to ensure that no more than 24 samples were requested during a 24 hour period. With this limitation, the equipment was set to draw approximately 20 samples during a 24 hour period. This allowed for increase in flow without exceeding the capacity of the samplers. An example calculation made for Monument Creek-North is shown below.

1. Measured flow, Monument Creek-North = 9.27 ft^3/sec

2. Selected flow, sample calculations = 12.0 ft^3/sec

3. (12.0 ft^3/sec) x (3600 sec/hr) = 43,200 ft^3/hr

This programming sequence instructed the flowmeter to count the cubic feet of flow through the channel and inform the sampler after each 43,200 ft^3 had passed. By using a higher than anticipated flow, 12.0 ft^3 versus 9.27 ft^3, to program the system, the sampler would not, barring exceptional flow, exceed the sampling capacity and would collect less than 24 samples during a 24 hour period. These samples would still be flow proportional. In this case, one sample was pulled for each 43,200 ft^3 of flow that passed by.

The non-flow proportional sampler was programmed to draw a 200 ml sample every hour. Flow measurements were accomplished manually using the Marsh-McBirney portable flowmeter. These flow velocity measurements were taken at the midpoint of the creek depth at each measuring point. Thus, if measurements were to be taken at a point where the creek was six inches deep, the flowmeter was positioned at a depth of 6 + 2, or three inches. These flow measurements were averaged and considered as representative of the sampling period flow. For example, 12 June flow measurements at Black Squirrel Creek were as follows:

Width = 2′ 2"

Depth (inches)	Velocity (feet/sec) at Depth + 2
3.0	1.1
3.75	1.2
2.50	0.78
3.08 average	1.03 average

The flow rate, Q, was then calculated as Width x Depth x Velocity.

$$Q = 2.17 \text{ ft} \times (3.08 \text{ in} \div 12 \text{ in per ft}) \times 1.03 \text{ ft/sec}$$

$$Q = 0.574 \text{ ft}^3\text{/sec}$$

Sample Collection

Samples were collected daily from each sample location on an approximate 24 hour cycle. A short checklist, an example of which is shown below in Table 21, was developed to insure that proper procedures were followed, human error was minimized, and required operations were carried out during the sampling process. This checklist was referred to and annotated during each sampling event throughout the program. The laboratory analysis results were added to the form when the results were received.

Samples were kept cool with ice during both collection and transit. Ice was placed in each sampler in the space provided to keep samples cool during the sampling period. Additionally, collected samples were placed on ice from the time of collection until delivery to the laboratory. Typically, the samples were delivered to the laboratory within two hours of sample collection.

Table 21

Sampling Checklist

Sample Location # __ : ________________________.
Date - __________, Time - ____
Sample Type - Baseline ____ Rainstorm ______
Number of Bottles Filled In Sampler - __
Mixing Bucket Cleaned ____
Sample Bottles Cleaned ____
Sample Container Identified ____
Split Sample Taken - ____, Identification ______
Ice Added To Sampler ____
Sampler Reset ____
Sample Cooled With Ice ____
Batteries Changed - ____
Date/Time Delivered to Laboratory - __________________
24 Hour Flow - ____ x 10^6 ft^3

Laboratory Results

Constituent	Concentration (mg/l)	Split Sample
TSS	____	____
BOD	____	____
COD	____	____
TP	____	____
SP	____	____
TKN	____	____
NO_x	____	____
TCu	____	____
TPb	____	____
TZn	____	____

A strict cleaning procedure was followed to prevent sample contamination. All sample collection bottles, mixing containers, and lab delivery containers were rinsed with distilled water and drained. This was accomplished during each sample collection activity.

Analysis

Analysis of the water samples was performed by a certified laboratory, Industrial Laboratories of Colorado Springs, under contract to the Air Force Academy. Each sample delivered to the laboratory was analyzed for concentrations of nine of the ten targeted NPS pollutants. The laboratory did not test for soluble phosphorus due to a contractual discrepancy. The delivered samples were usually kept refrigerated in the laboratory at 3 degrees celsius until they were analyzed. Standard Methods For the Examination of Water and Wastewater specifies that samples should be stored at or below 4 degrees celsius (1:484). There was an incident involving the storm event samples when it was found that the samples were stored at room temperature under a sink in the laboratory. The impacts of this incident are discussed in Chapter IV.

Quality control was established by providing split samples for analysis. A split sample is essentially two different samples for analysis, poured from a single composite sample. The samples were identified but the laboratory was not informed of the split. This provided a means of determining the consistency of laboratory results. The means and standard deviations of the split sample differences are shown in Table 11, and discussed in Chapter IV.

Baseline Sampling

A baseline loading of the ten targeted NPS pollutants was established for each sampling location. This baseline, or "normal", pollutant loading exists in the streams during dry weather conditions and is not caused by stormwater runoff.

Baseline Sample Collection. Baseline samples were collected daily from each sampling location on approximately a 24 hour cycle. Although the original sampling plan called for eight samples from each location to be collected there were several factors, such as equipment failure and uncooperative weather, that resulted in less than the planned eight. The inclusion of split samples provided more than eight analysis in two cases.

Those samplers with discrete sampling capability were set to draw 1000 ml per sample. As previously stated, samples were taken after a specified amount of flow (or time for non-flow proportional samplers) had passed. During sample collection, the collected samples were mixed in a mixing tub and at least 1500 ml were transferred to a laboratory delivery container. The flow for each sample was recorded on the flowmeter plotter.

The sampler without discrete sampling capability was set to draw 200 ml per hour. This sample was thoroughly mixed in the large sample container before filling the lab delivery container. The flow at this sampling location was measured three times daily with the Marsh-McBirney portable flowmeter.

Baseline Flow Quantity. The total quantity of dry weather surface water flow on the AFA was calculated by subtracting the incoming stream flow (Monument Creek-North, Smith Creek, Black Squirrel Creek, and West Monument Creek) from the outgoing flow (Monument Creek-South). As shown below in Table 22, the quantity of water flowing off base is approximately 30 percent greater than the water flowing onto the base.

Table 22

Average Baseline Dry Weather Flow (Ft^3/Day)

Creek	Inflow	Outflow
Monument Creek - North	7.52×10^5	
Smith Creek	1.48×10^4	
Black Squirrel Creek	5.40×10^4	
West Monument Creek	2.36×10^5	
Monument Creek - South		1.51×10^6
Difference		4.53×10^5
Percent Unaccounted for		30 %

Measurements of flow from Ice Lake outfall and Deadman's Creek were taken over a two day period. The inclusion of this additional measured flow reduced the inflow-outflow differential to approximately 13 percent during those days. The remaining flow differential may be explained by a combination of small intermittently flowing streams and groundwater effluent. A search for other contributing sources revealed only three small streams, and these were too shallow to yield accurate flow measurements. The majority of excess flow appears to be due to groundwater.

Baseline Load. The analysis results for baseline samples are contained in Table 23 below. These results are the average constituent loadings for each creek over the dry weather baseline sampling period.

Table 23

Average Baseline Dry Weather Loading

Constituent	Baseline Load (Kg/Yr)
TSS	205,000
BOD	170,000
COD	87,600
Total Phosphorus	1,500
Soluble Phosphorus	-----
TKN	146
NO_x	83,600
Total Copper	237
Total Lead	471
Total Zinc	237

The inflow-outflow differential in Table 22 serves to highlight apparent outside contributors to flow, such as groundwater, and may explain a considerable portion of the baseline loading differential shown above.

The baseline loadings include only dry weather flow. This loading includes the erosive effects of normal stream flow, and possible groundwater pollutant contributions as discussed above. Stormwater runoff, the transport mechanism of NPS pollution as addressed in this study, was not incorporated in the baseline, or dry weather, loading.

Rainstorm Event Sampling

Samples were collected during three rainstorm events. These events occurred on 19, 20, and 21 June, during the late afternoon and evening, and delivered respectively 0.23, 0.30, and 0.07 inches of rainfall as measured by the AFA weather station. Recommended practice dictates rainstorm event sampling of only those events greater than 0.10 inches and occurring at least one month apart (41:10). However, the time constraints of completing this research effort dictated sampling rainstorm events as they occurred. Additionally, equipment failure at one sampling location made the 21 June sample results unusable.

NPS pollutant loads resulting from Air Force Academy operations and carried by the stormwater runoff were determined by subtracting the baseline loadings, shown in Table 23, from the stormwater runoff loadings.

Storm Event Sample Collection. Storm event samples were collected during rainfall events sufficient to cause increased flow due to stormwater runoff as measured by the flowmeters. These flowmeters and the connected samplers span the entire Air Force Academy area of concern, and as such, increased flow due to stormwater runoff would indicate a storm of sufficient magnitude to transfer NPS pollutants into the water courses.

Samples of 1000 ml each were collected for analysis from each flow proportional sampling location. These samples from flow proportional samplers were identified as those samples drawn after the flowmeter hydrograph indicated increased flow. A composite sample was taken at the location with the non-flow proportional sampler.

These discrete storm event samples for each location were not mixed, but analyzed separately to yield load data for nine of the ten targeted NPS pollutants analyzed by the laboratory. Again, the non-flow proportional sampler was incapable of providing unmixed storm event samples.

Rainstorm Flow Quantity. The total quantity of surface water flow resulting from rainstorm events were determined from the flowmeter hydrograph recorders. The flow proportional samplers took a sample after a predetermined amount of flow had passed the sampling location. The recorder annotated the time and total flow whenever a sample was drawn. Thus, the exact flow quantity, and time required for that flow to pass, were recorded allowing flow proportionality in the sampling.

Stormwater Runoff Load. The analysis results for rainstorm event samples are contained in Table 24 below. The concentration and flow for each individual sample were used to obtain the load carried during that individual sample time period. These individual loads were then summed to obtain the total load at a particular location for a particular rainstorm event, yielding pollutant loads for the nine analyzed targeted pollutants, for the actual measured rainfall amount. The baseline load for this rainstorm time period, determined from the baseline results in Table 23, was then subtracted from the total rainstorm load to yield that constituent loading due exclusively to runoff transport. Results from the two usable rainstorm events were averaged to yield the Stormwater Runoff Load shown below in Table 24.

Table 24

Stormwater Runoff Loading

Constituent	Pollutant Load (Kg/Yr)
TSS	31,097
BOD	1,976
COD	48
Total Phosphorus	84
TKN	153
NO_x	< 0
Total Copper	11
Total Lead	24
Total Zinc	11

The NPS pollution load generated by Air Force Academy operations is shown below in Table 25. This loading was determined by subtracting the baseline load in Table 23 from the stormwater load in Table 24.

Table 25

Sampling Program Air Force Academy NPS Pollutant Loading

Constituent	Pollutant Load (Kg/Yr)
TSS	< 0
BOD	< 0
COD	< 0
Total Phosphorus	< 0
TKN	7
NO_x	< 0
Total Copper	< 0
Total Lead	< 0
Total Zinc	< 0

Data Analysis

Baseline Sample Analysis Summary

The baseline sample data and analysis is shown below.

Sampling Location #1, Monument Creek - South

Concentration (mg/l)

Date	TSS	BOD	COD	TP	TKN	NOx	TCu	TPb	TZn	Flow-Ft^3
6/13	28.00	37.00	15.70	0.23	1.00	8.40	0.05	0.10	0.05	1.36e+06
6/14	26.00	29.00	12.30	0.35	0.70	21.01	0.05	0.10	0.05	1.46e+06
6/14*	26.00	30.00	5.00	0.25	1.00	21.01	0.05	0.10	0.05	1.46e+06
6/15	23.00	28.00	9.00	0.28	0.40	8.61	0.05	0.10	0.05	1.51e+06
6/16	25.00	51.00	13.40	0.69	0.28	6.21	0.05	0.10	0.05	1.46e+06
6/17	19.00	41.00	12.70	0.34	0.36	5.91	0.05	0.10	0.05	1.36e+06
6/18	20.00	41.00	25.20	0.35	0.41	10.10	0.05	0.10	0.05	1.48e+06
6/18*	32.00	36.00	14.00	0.50	0.86	9.80	0.05	0.10	0.05	1.48e+06
6/19	32.00	34.00	19.00	0.12	0.68	8.40	0.05	0.10	0.05	1.69e+06
6/23			Analysis results not available							1.87e+06
Avg	25.67	36.33	14.03	0.35	0.63	11.05	0.05	0.10	0.05	1.51e+06
Var	18.89	47.56	29.36	0.02	0.07	30.08	0.00	0.00	0.00	2.16e+10

* - Split Samples

The average concentration, in mg/l, was multiplied by the average flow, in Ft^3/Day, and a conversion factor K to arrive at a load in Kg/Day.

$$K = 28.32\ l/Ft^3 \times 1\ Kg/1\times10^6\ mg = 2.832 \times 10^{-5}$$

Load (Kg/Day)

Const	Concentration (mg/l)	Flow (Ft^3/Day)	Load
TSS	25.67	1.51e+06	1099.77
BOD	36.33	1.51e+06	1556.82
COD	14.03	1.51e+06	601.30
TP	0.35	1.51e+06	14.81
TKN	0.63	1.51e+06	27.09
NOx	11.05	1.51e+06	473.47
TCu	0.05	1.51e+06	2.14
TPb	0.10	1.51e+06	4.28
TZn	0.05	1.51e+06	2.14

Sampling Location #2, Monument Creek - North

Concentration (mg/l)

Date	TSS	BOD	COD	TP	TKN	NOx	TCu	TPb	TZn	Flow-Ft^3
6/13	11.00	38.00	15.00	0.65	1.00	9.03	0.05	0.10	0.05	8.02e+05
6/14	16.00	32.00	13.00	0.30	0.90	22.44	0.05	0.10	0.05	8.14e+05
6/15	21.00	25.00	10.00	0.05	0.90	9.25	0.05	0.10	0.05	8.27e+05
6/15*	27.00	32.00	9.30	0.52	1.00	5.65	0.05	0.10	0.05	8.27e+05
6/16	9.00	52.00	12.70	0.23	2.10	4.85	0.05	0.10	0.05	8.19e+05
6/17	22.00	42.00	12.70	0.62	0.50	5.64	0.05	0.10	0.05	8.19e+05
6/17*	21.00	43.00	12.60	0.57	1.01	6.44	0.05	0.10	0.05	8.19e+05
6/18	29.00	42.00	21.70	0.34	0.56	9.22	0.05	0.10	0.05	8.75e+05
6/19	12.00	36.00	21.70	0.57	0.13	6.41	0.05	0.10	0.05	9.15e+05
6/23	Analysis results not available									5.09e+05
Avg	18.67	38.00	14.30	0.43	0.90	8.77	0.05	0.10	0.05	7.52e+05
Var	44.67	55.33	18.13	0.04	0.26	25.92	0.00	0.00	0.00	1.06e+10

* - Split Samples

Load (Kg/Day)

Const	Concentration (mg/l)	Flow (Ft^3/Day)	Load
TSS	18.67	7.52e+05	397.54
BOD	38.00	7.52e+05	809.27
COD	14.30	7.52e+05	304.54
TP	0.43	7.52e+05	9.11
TKN	0.90	7.52e+05	19.17
NOx	8.77	7.52e+05	186.77
TCu	0.05	7.52e+05	1.06
TPb	0.10	7.52e+05	2.13
TZn	0.05	7.52e+05	1.06

Sampling Location #3, Smith Creek

Concentration (mg/l)

Date	TSS	BOD	COD	TP	TKN	NOx	TCu	TPb	TZn	Flow-Ft^3
6/15	10.00	28.00	21.40	0.05	0.50	7.01	0.05	0.10	0.05	2.16e+04
6/16	6.00	56.00	24.50	0.24	4.10	5.20	0.05	0.10	0.05	1.56e+04
6/17	13.00	45.00	25.50	0.44	1.35	4.90	0.05	0.10	0.05	1.47e+04
6/18	8.00	39.00	26.00	0.07	0.30	9.01	0.05	0.10	0.05	8.81e+03
6/19	24.00	31.00	26.80	0.11	0.63	6.40	0.05	0.10	0.05	7.66e+03
6/23	Analysis results not available									2.07e+04
Avg	12.20	39.80	24.84	0.18	1.38	6.50	0.05	0.10	0.05	1.48e+04
Var	40.16	101.36	3.51	0.02	1.98	2.16	0.00	0.00	0.00	2.82e+07

Load (Kg/Day)

Const	Concentration (mg/l)	Flow (Ft^3/Day)	Load
TSS	12.20	1.48e+04	5.11
BOD	39.80	1.48e+04	16.68
COD	24.84	1.48e+04	10.41
TP	0.18	1.48e+04	0.08
TKN	1.38	1.48e+04	0.58
NOx	6.50	1.48e+04	2.73
TCu	0.05	1.48e+04	0.02
TPb	0.10	1.48e+04	0.04
TZn	0.05	1.48e+04	0.02

Sampling Location #4, Black Squirrel Creek

Concentration (mg/l)

Date	TSS	BOD	COD	TP	TKN	NOx	TCu	TPb	TZn	Flow-Ft^3
6/13	33.00	31.00	13.00	0.65	1.40	9.51	0.05	0.10	0.05	5.18e+04
6/14	27.00	29.00	13.00	0.05	0.80	16.11	0.05	0.10	0.05	4.93e+04
6/16	4.00	43.00	18.00	0.25	2.00	3.80	0.05	0.10	0.05	4.32e+04
6/17	27.00	48.00	22.00	0.06	1.13	5.60	0.05	0.10	0.05	4.58e+04
6/18	43.00	30.00	22.50	0.05	2.50	9.51	0.05	0.10	0.05	5.84e+04
6/19	46.00	30.00	17.20	0.16	0.22	6.21	0.05	0.10	0.05	9.16e+04
6/19*	22.00	3.00	17.80	0.05	1.06	5.51	0.05	0.10	0.05	9.16e+04
6/23	Analysis results not available									9.56e+04
Avg	28.86	30.57	17.64	0.18	1.30	8.04	0.05	0.10	0.05	5.40e+04
Var	168.98	174.53	12.29	0.04	0.49	14.73	0.00	0.00	0.00	4.56e+08

* - Split Sample

Load (Kg/Day)

Const	Concentration (mg/l)	Flow (Ft^3/Day)	Load
TSS	28.86	5.40e+04	44.13
BOD	30.57	5.40e+04	46.75
COD	17.64	5.40e+04	26.98
TP	0.18	5.40e+04	0.28
TKN	1.30	5.40e+04	1.99
NOx	8.04	5.40e+04	12.29
TCu	0.05	5.40e+04	0.08
TPb	0.10	5.40e+04	0.15
TZn	0.05	5.40e+04	0.08

Sampling Location #5, West Monument Creek

Concentration (mg/l)

Date	TSS	BOD	COD	TP	TKN	NOx	TCu	TPb	TZn	Flow-Ft^3
6/15	14.00	26.00	0.00	0.05	0.80	9.00	0.05	0.10	0.05	2.55e+05
6/16	6.00	46.00	4.00	0.22	2.00	4.20	0.05	0.10	0.05	2.46e+05
6/16*	11.00	42.00	6.60	0.79	0.64	3.90	0.05	0.10	0.05	2.46e+05
6/17	20.00	47.00	2.80	0.05	0.41	5.60	0.05	0.10	0.05	2.33e+05
6/18	19.00	32.00	1.50	0.05	0.30	9.10	0.05	0.10	0.05	2.23e+05
6/19	12.00	3.00	2.50	0.05	0.30	6.40	0.05	0.10	0.05	2.21e+05
6/23			Analysis results not available							2.32e+05
Avg	13.67	32.67	2.90	0.20	0.74	6.37	0.05	0.10	0.05	2.36e+05
Var	22.89	232.56	4.24	0.07	0.35	4.30	0.00	0.00	0.00	1.38e+08

* - Split Sample

Load (Kg/Day)

Const	Concentration (mg/l)	Flow (Ft^3/Day)	Load
TSS	13.67	2.36e+05	91.34
BOD	32.67	2.36e+05	218.33
COD	2.90	2.36e+05	19.38
TP	0.20	2.36e+05	1.35
TKN	0.74	2.36e+05	0.96
NOx	6.37	2.36e+05	42.55
TCu	0.05	2.36e+05	0.33
TPb	0.10	2.36e+05	0.67
TZn	0.05	2.36e+05	0.33

AFA NPS Contribution During Dry Weather Flow (Kg/Day)

Const	MCN	SM	BSC	WMC	MCS	Daily Load
TSS	397.54	5.11	44.13	91.34	1099.77	561.65
BOD	809.27	16.68	46.75	218.33	1556.82	465.78
COD	304.54	10.41	26.98	19.38	601.30	239.99
TP	9.11	0.08	0.28	1.35	14.81	3.99
TKN	19.17	0.58	1.99	4.96	27.09	0.40
NOx	186.77	2.73	12.29	42.55	473.47	229.13
TCu*	1.06	0.02	0.08	0.33	2.14	0.65
TPb*	2.13	0.04	0.15	0.67	4.28	1.29
TZn*	1.06	0.02	0.08	0.33	2.14	0.65

* - Metal loading is based on concentrations below test threshold limits according to the laboratory. As such, the loads shown here are maximum possible.

The Daily Load is the sum of input stream loads subtracted from the Monument Creek - South load.

Rainstorm Sample Analysis Summary

The rainstorm sample data and analysis are shown below.

Sample Collection Times. The times that samples were collected at each sampling location are shown below.

19 June 1992, 0.23" Rainfall

Location	#2	#3	#4	#5	#1
Time-Hours	1900	Composite	1906	1920	1906
	2004	Composite	2017	2047	2012
	2109	Composite	2131	2215	2119
	2212	Composite	2248	2343	2225

20 June 1992, 0.30" Rainfall

Location	#2	#3	#4	#5	#1
Time-Hours					1502
					1609
					1710
					1814
	1822	Composite	1757	1918	1924
	1923	Composite	1911	2043	2026
	2025	Composite	2028	2208	2128
	2126	Composite	2129	2332	2225

21 June 1992, 0.07" Rainfall

Location	#2	#3	#4	#5	#1
Time-Hours	----*	Composite	1409	1429	1938
	----*	Composite	1535	1554	2043
	----*	Composite	1700	1719	2146
	----*	Composite	1826**	1846**	2246
					2347
					0047

* - Equipment failure
** - Analysis not accomplished by laboratory

19 June 1992 Rainstorm Event Analysis

Sampling Location #1, Monument Creek - South

Const	Load (Kg) 4.42 hours	Baseline Load (Kg/Day)	Storm Load (Kg/0.23" Rainfall)
TSS	438.39	1099.77	235.85
BOD	17.84	1556.82	-268.87
COD	125.66	601.30	14.92
TP	0.66	14.81	-2.06
TKN	6.98	27.09	1.99
NOx	4.69	473.47	-82.51
TCu	0.51	2.14	0.12
TPb	1.02	4.28	0.23
TZn	0.51	2.14	0.12

Sampling Location #2, Monument Creek - North

Const	Load (Kg) 4.23 hours	Baseline Load (Kg/Day)	Storm Load (Kg/0.23" Rainfall)
TSS	248.42	397.54	178.36
BOD	12.18	809.27	-130.46
COD	69.53	304.54	15.86
TP	2.81	9.11	1.21
TKN	1.74	19.17	-1.64
NOx	1.85	186.77	-31.07
TCu	0.24	1.06	0.06
TPb	0.49	2.13	0.11
TZn	0.24	1.06	0.06

Sampling Location #3, Smith Creek

Const	Load (Kg) 24 hours	Baseline Load (Kg/Day)	Storm Load (Kg/0.23" Rainfall)
TSS	5.20	5.11	0.08
BOD	0.87	16.68	-15.82
COD	7.19	10.41	-3.22
TP	0.06	0.08	-0.01
TKN	0.29	0.58	-0.29
NOx	0.09	2.73	-2.64
TCu	0.02	0.02	0.00
TPb	0.04	0.04	0.00
TZn	0.02	0.02	0.00

Sampling Location #4, Black Squirrel Creek

Const	Load (Kg) 4.82 hours	Baseline Load (Kg/Day)	Storm Load (Kg/0.23" Rainfall)
TSS	19.03	44.13	10.17
BOD	0.99	46.75	-8.40
COD	14.83	26.98	9.41
TP	0.14	0.28	0.08
TKN	0.35	1.99	-0.04
NOx	0.06	12.29	-2.41
TCu	0.04	0.08	0.02
TPb	0.08	0.15	0.05
TZn	0.04	0.08	0.02

Sampling Location #5, West Monument Creek

Const	Load (Kg) 5.77 hours	Baseline Load (Kg/Day)	Storm Load (Kg/0.23" Rainfall)
TSS	49.75	91.34	27.79
BOD	2.45	218.33	-50.04
COD	14.64	19.38	9.98
TP	0.27	1.35	-0.05
TKN	1.75	4.96	0.56
NOx	0.20	42.55	-10.03
TCu	0.08	0.33	0.00
TPb	0.16	0.67	0.00
TZn	0.08	0.33	0.00

Total Composite Load From 0.23" of Rain (Kg)

Const	MCN	SC	BSC	WMC	MCS	Load	Load/15" Rainfall
TSS	178.36	0.08	10.17	27.79	235.85	19.45	1,268.0
BOD	-130.46	-15.82	-8.40	-50.04	-268.87	< 0.0	< 0.0
COD	15.86	-3.22	9.41	9.98	14.92	< 0.0	< 0.0
TP	1.21	-0.01	0.08	-0.05	-2.06	< 0.0	< 0.0
TKN	-1.64	-0.29	-0.04	0.56	1.99	< 0.0	< 0.0
NOX	-31.07	-2.64	-2.41	-10.03	-82.51	< 0.0	< 0.0
TCu*	0.06	0.00	0.02	0.00	0.12	0.04	2.61
TPb*	0.11	0.00	0.05	0.00	0.23	0.07	4.57
TZn*	0.06	0.00	0.02	0.00	0.12	0.04	2.61

* - Metal loading is based on concentrations below test threshold limits according to the laboratory. As such, the loads shown here are maximum possible.

20 June 1992 Rainstorm Event Analysis

Sampling Location #1, Monument Creek - South

Const	Load (Kg) 4.15 hours	Baseline Load (Kg/Day)	Storm Load (Kg/0.30" Rainfall)
TSS	922.67	1099.77	732.50
BOD	84.11	1556.82	-185.09
COD	130.75	601.30	26.78
TP	5.38	14.81	2.82
TKN	1.17	27.09	-3.51
NOx	36.80	473.47	-45.07
TCu	0.51	2.14	0.14
TPb	1.02	4.28	0.28
TZn	0.51	2.14	0.14

Sampling Location #2, Monument Creek - North

Const	Load (Kg) 4.09 hours	Baseline Load (Kg/Day)	Storm Load (Kg/0.30" Rainfall)
TSS	143.70	397.54	75.95
BOD	25.57	809.27	-112.34
COD	67.22	304.54	15.32
TP	0.26	9.11	-1.30
TKN	1.17	19.17	-2.10
NOx	80.25	186.77	48.42
TCu	0.24	1.06	0.06
TPb	0.49	2.13	0.12
TZn	0.24	1.06	0.06

Sampling Location #3, Smith Creek

Const	Load (Kg) 24 hours	Baseline Load (Kg/Day)	Storm Load (Kg/0.30" Rainfall)
TSS	25.94	5.11	20.83
BOD	4.54	16.68	-12.14
COD	14.07	10.41	3.66
TP	0.10	0.08	0.02
TKN	0.43	0.58	-0.15
NOx	0.20	2.73	-2.53
TCu	0.03	0.02	0.01
TPb	0.06	0.04	0.02
TZn	0.03	0.02	0.01

Sampling Location #4, Black Squirrel Creek

Const	Load (Kg) 4.86 hours	Baseline Load (Kg/Day)	Storm Load (Kg/0.30" Rainfall)
TSS	28.55	44.13	19.61
BOD	1.59	46.75	-7.88
COD	17.21	26.98	11.74
TP	0.07	0.28	0.01
TKN	0.25	1.99	-0.15
NOx	6.43	12.29	3.94
TCu	0.04	0.08	0.02
TPb	0.08	0.15	0.05
TZn	0.04	0.08	0.02

Sampling Location #5, West Monument Creek

Const	Load (Kg) 5.68 hours	Baseline Load (Kg/Day)	Storm Load (Kg/0.30" Rainfall)
TSS	20.39	91.34	-1.23
BOD	2.85	218.33	-48.82
COD	11.54	19.38	6.95
TP	0.08	1.35	-0.24
TKN	0.33	4.96	-0.84
NOx	5.83	42.55	-4.24
TCu	0.08	0.33	0.00
TPb	0.16	0.67	0.00
TZn	0.08	0.33	0.00

Total Composite Load From 0.30" of Rain (Kg)

Const	MCN	SC	BSC	WMC	MCS	Load	Load/15" Rainfall
TSS	1017.10	20.83	19.61	-1.23	732.50	< 0.00	< 0.0
BOD	-249.60	-12.14	0.81	-7.88	-185.09	< 0.00	< 0.0
COD	24.54	3.66	11.74	6.95	26.78	< 0.00	< 0.0
TP	1.90	0.02	0.01	-0.24	2.82	0.89	44.5
TKN	1.87	-0.15	-0.15	-0.84	-3.51	< 0.00	< 0.0
NOx	-78.50	-2.53	3.94	-4.24	-45.07	< 0.00	< 0.0
TCu	0.13	0.01	0.02	-0.25	0.14	< 0.00	< 0.0
TPb	0.26	0.02	0.05	-0.51	0.28	< 0.00	< 0.0
TZn	0.13	0.01	0.02	-0.25	0.14	< 0.00	< 0.0

Sampling Checklists and Results

Sample Location # 1 : Monument Creek - South.
Date - 13 June 92, Time - 0755
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 13
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification ______
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - YES
Date/Time Delivered to Laboratory - 13 June, 1010 Hours
24 Hour Flow - 1.36 x 10^6 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	28.0 mg/l	N/A
BOD	37.0 mg/l	N/A
COD	15.7 mg/l	N/A
TP	0.23 mg/l	N/A
SP	-----	N/A
TKN	1.0 mg/l	N/A
NO_x	8.4 mg/l	N/A
Tcu	< 0.05 mg/l	N/A
Tpb	< 0.10 mg/l	N/A
Tzn	< 0.05 mg/l	N/A

Sample Location # 1 : Monument Creek - South.
Date - 14 June 92, Time - 0700
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 15
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - YES, Identification - # 5
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 14 June, 0900 Hours
24 Hour Flow - 1.46 x 10^6 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	26.0 mg/l	26.0 mg/l
BOD	29.0 mg/l	30.0 mg/l
COD	12.3 mg/l	5.0 mg/l
TP	0.35 mg/l	0.25 mg/l
SP	----	N/A
TKN	0.7 mg/l	1.0 mg/l
NO_x	21.01 mg/l	21.01 mg/l
TCu	< 0.05 mg/l	< 0.05 mg/l
TPb	< 0.10 mg/l	< 0.10 mg/l
TZn	< 0.05 mg/l	< 0.05 mg/l

Sample Location # 1 : Monument Creek - South.
Date - 15 June 92, Time - 0830
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 17
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ______
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 15 June, 0910 Hours
24 Hour Flow - 1.51 x 10^6 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	23.0 mg/l	N/A
BOD	28.0 mg/l	N/A
COD	9.0 mg/l	N/A
TP	0.28 mg/l	N/A
SP	----	N/A
TKN	0.4 mg/l	N/A
NO_x	8.61 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 1 : Monument Creek - South.
Date - 16 June 92, Time - 0925
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 16
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ______
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 16 June, 1007 Hours
24 Hour Flow - 1.46 x 10^6 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	25.0 mg/l	N/A
BOD	51.0 mg/l	N/A
COD	13.4 mg/l	N/A
TP	0.69 mg/l	N/A
SP	----	N/A
TKN	0.28 mg/l	N/A
NO_x	6.21 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 1 : Monument Creek - South.
Date - 17 June 92, Time - 1003
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 16
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ______
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 17 June, 1025 Hours
24 Hour Flow - 1.36 x 10^6 ft^3 {check flow}

Laboratory Results

Constituent	Concentration	Split Sample
TSS	19.0 mg/l	N/A
BOD	41.0 mg/l	N/A
COD	12.7 mg/l	N/A
TP	0.34 mg/l	N/A
SP	----	N/A
TKN	0.36 mg/l	N/A
NO_x	5.91 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 1 : Monument Creek - South.
Date - 18 June 92, Time - 0900
Sample Type - Baseline X Rainstorm ______
Number of Bottles Filled In Sampler - 15
Mixing Bucket Cleaned X
Sample Bottles Cleaned X
Sample Container Identified X
Split Sample Taken - YES, Identification - # 6
Ice Added To Sampler X
Sampler Reset X
Sample Cooled With Ice X
Batteries Changed - YES
Date/Time Delivered to Laboratory - 18 June, 0935 Hours
24 Hour Flow - 1.48 x 10^6 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	20.0 mg/l	32.0 mg/l
BOD	41.0 mg/l	36.0 mg/l
COD	25.2 mg/l	14.0 mg/l
TP	0.35 mg/l	0.50 mg/l
SP	----	N/A
TKN	0.41 mg/l	0.86 mg/l
NO_x	10.11 mg/l	9.81 mg/l
TCu	< 0.05 mg/l	< 0.05 mg/l
TPb	< 0.10 mg/l	< 0.10 mg/l
TZn	< 0.05 mg/l	< 0.05 mg/l

Sample Location # 1 : Monument Creek - South.
Date - 19 June 92, Time - 0913
Sample Type - Baseline X Rainstorm ______
Number of Bottles Filled In Sampler - 18
Mixing Bucket Cleaned X
Sample Bottles Cleaned X
Sample Container Identified X
Split Sample Taken - NO, Identification - ______
Ice Added To Sampler X
Sampler Reset X
Sample Cooled With Ice X
Batteries Changed - NO
Date/Time Delivered to Laboratory - 19 June, 0938 Hours
24 Hour Flow - 1.69 x 10^6 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	23.0 mg/l	N/A
BOD	34.0 mg/l	N/A
COD	19.0 mg/l	N/A
TP	0.12 mg/l	N/A
SP	----	N/A
TKN	0.68 mg/l	N/A
NO_x	8.40 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 1 : Monument Creek - South.
Date - 23 June 92, Time - 1027
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 20
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification ______
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - N
Date/Time Delivered to Laboratory - 23 June, 1056 Hours
24 Hour Flow - 1.87 x 10^6 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	Results unavailable at publishing.	
BOD		
COD		
TP		
SP		
TKN		
NO_x		
TCu		
TPb		
TZn		

Sample Location # 2 : Monument Creek - North.
Date - 13 June 92, Time - 0838
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 17
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 13 June, 1010 Hours
24 Hour Flow - 801.83 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	11.0 mg/l	N/A
BOD	38.0 mg/l	N/A
COD	15.0 mg/l	N/A
TP	0.65 mg/l	N/A
SP	----	N/A
TKN	1.0 mg/l	N/A
NO_x	9.03 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 2 : Monument Creek - North.
Date - 14 June 92, Time - 0737
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 18
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ______
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 14 June, 0900 Hours
24 Hour Flow - 814.02 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	16.0 mg/l	N/A
BOD	32.0 mg/l	N/A
COD	13.0 mg/l	N/A
TP	0.30 mg/l	N/A
SP	----	N/A
TKN	0.9 mg/l	N/A
NO_x	22.44 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 2 : Monument Creek - North.
Date - 15 June 92, Time - 0745
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 19
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - YES, Identification - # 4
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - YES
Date/Time Delivered to Laboratory - 15 June, 0910 Hours
24 Hour Flow 827.34 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	21.0 mg/l	27.0 mg/l
BOD	25.0 mg/l	32.0 mg/l
COD	10.0 mg/l	9.3 mg/l
TP	< 0.05 mg/l	0.52 mg/l
SP	----	N/A
TKN	0.9 mg/l	1.0 mg/l
NO_x	9.25 mg/l	5.65 mg/l
TCu	< 0.05 mg/l	< 0.05 mg/l
TPb	< 0.10 mg/l	< 0.10 mg/l
TZn	< 0.05 mg/l	< 0.05 mg/l

Sample Location # 2 : Monument Creek - North.
Date - 16 June 92, Time - 0805
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 19
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ______
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 16 June, 1007 Hours
24 Hour Flow 819.39 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	9.0 mg/l	N/A
BOD	52.0 mg/l	N/A
COD	12.7 mg/l	N/A
TP	0.23 mg/l	N/A
SP	----	N/A
TKN	2.1 mg/l	N/A
NO_x	4.85 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 2 : Monument Creek - North.
Date - 17 June 92, Time - 0915
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 19
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - YES, Identification - # 6
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 17 June, 1025 Hours
24 Hour Flow 819.39 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	22.0 mg/l	21.0 mg/l
BOD	42.0 mg/l	43.0 mg/l
COD	12.7 mg/l	12.6 mg/l
TP	0.62 mg/l	0.57 mg/l
SP	----	N/A
TKN	0.5 mg/l	1.01 mg/l
NO_x	5.64 mg/l	6.44 mg/l
TCu	< 0.05 mg/l	< 0.05 mg/l
TPb	< 0.10 mg/l	< 0.10 mg/l
TZn	< 0.05 mg/l	< 0.05 mg/l

Sample Location # 2 : Monument Creek - North.
Date - 18 June 92, Time - 0805
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 21
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ____
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 18 June, 0935 Hours
24 Hour Flow 874.97 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	29.0 mg/l	N/A
BOD	42.0 mg/l	N/A
COD	21.7 mg/l	N/A
TP	0.34 mg/l	N/A
SP	----	N/A
TKN	0.56 mg/l	N/A
NO_x	9.22 mg/l	N/A
TCu	< 0.05	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 2 : Monument Creek - North.
Date - 19 June 92, Time - 0835
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 21
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ______
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 19 June, 0938 Hours
24 Hour Flow 915.2 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	12.0 mg/l	N/A
BOD	36.0 mg/l	N/A
COD	21.7 mg/l	N/A
TP	0.57 mg/l	N/A
SP	----	N/A
TKN	0.13 mg/l	N/A
NO_x	6.41 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 2 : Monument Creek - North.
Date - 23 June 92, Time - 0937
Sample Type - Baseline __X__ Rainstorm _____
Number of Bottles Filled In Sampler - 11
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ____
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 23 June, 1056 Hours
24 Hour Flow 509.29 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	Results unavailable at publishing.	
BOD		
COD		
TP		
SP		
TKN		
NO_x		
TCu		
TPb		
TZn		

Sample Location # 3 : Smith Creek.
Date - 15 June 92, Time - 0725
Sample Type - Baseline __X__ Rainstorm _____
Number of Bottles Filled In Sampler - 23
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 15 June, 0910 Hours
24 Hour Flow 21.6 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	10.0 mg/l	N/A
BOD	28.0 mg/l	N/A
COD	21.4 mg/l	N/A
TP	< 0.05 mg/l	N/A
SP	----	N/A
TKN	0.50 mg/l	N/A
NO_x	7.01 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 3 : Smith Creek.
Date - 16 June 92, Time - 0740
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 24
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__ (at 1600)
Sample Cooled With Ice __X__
Batteries Changed - YES
Date/Time Delivered to Laboratory - 16 June, 1007 Hours
24 Hour Flow 15.56 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	6.0 mg/l	N/A
BOD	56.0 mg/l	N/A
COD	24.5 mg/l	N/A
TP	0.24 mg/l	N/A
SP	----	N/A
TKN	4.1 mg/l	N/A
NO_x	5.20 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 3 : Smith Creek.
Date - 17 June 92, Time - 0857
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 17
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 17 June, 1025 Hours
24 Hour Flow 14.69 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	13.0 mg/l	N/A
BOD	45.0 mg/l	N/A
COD	25.5 mg/l	N/A
TP	0.44 mg/l	N/A
SP	----	N/A
TKN	1.35 mg/l	N/A
NO_x	4.90 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 3 : Smith Creek.
Date - 18 June 92, Time - 0753
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 23
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 18 June, 0935 Hours
24 Hour Flow 8.81 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	8.0 mg/l	N/A
BOD	39.0 mg/l	N/A
COD	26.0 mg/l	N/A
TP	0.07 mg/l	N/A
SP	----	N/A
TKN	0.30 mg/l	N/A
NO_x	9.01 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 3 : Smith Creek.
Date - 19 June 92, Time - 0710
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 24
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 19 June, 0938 Hours
24 Hour Flow 7.68 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	24.0 mg/l	N/A
BOD	31.0 mg/l	N/A
COD	26.8 mg/l	N/A
TP	0.11 mg/l	N/A
SP	----	N/A
TKN	0.63 mg/l	N/A
NO_x	6.40 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 3 : Smith Creek.
Date - 23 June 92, Time - 0917
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - __
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - YES, Identification - # 6
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 23 June, 1056 Hours
24 Hour Flow 20.74 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	Results unavailable at publishing.	
BOD		
COD		
TP		
SP		
TKN		
NO_x		
TCu		
TPb		
TZn		

Sample Location # 4 : Black Squirrel Creek.
Date - 13 June 92, Time - 0925
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - N/A
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 13 June, 1010 Hours
24 Hour Flow 51.84 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	33.0 mg/l	N/A
BOD	31.0 mg/l	N/A
COD	13.0 mg/l	N/A
TP	0.65 mg/l	N/A
SP	----	N/A
TKN	1.4 mg/l	N/A
NO_x	9.51 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 4 : Black Squirrel Creek.
Date - 14 June 92, Time - 0815
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - N/A
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 14 June, 0900 Hours
24 Hour Flow 49.25 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	27.0 mg/l	N/A
BOD	29.0 mg/l	N/A
COD	13.0 mg/l	N/A
TP	< 0.05 mg/l	N/A
SP	----	N/A
TKN	0.8 mg/l	N/A
NO_x	16.11 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 4 : Black Squirrel Creek.
Date - 16 June 92, Time - 0725
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - N/A
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 16 June, 1007 Hours
24 Hour Flow 43.20 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	4.0 mg/l	N/A
BOD	43.0 mg/l	N/A
COD	18.0 mg/l	N/A
TP	0.25 mg/l	N/A
SP	----	N/A
TKN	2.0 mg/l	N/A
NO_x	3.80 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 4 : Black Squirrel Creek.
Date - 17 June 92, Time - 0833
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - N/A
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - YES
Date/Time Delivered to Laboratory - 17 June, 1025 Hours
24 Hour Flow 45.79 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	27.0 mg/l	N/A
BOD	48.0 mg/l	N/A
COD	22.0 mg/l	N/A
TP	0.06 mg/l	N/A
SP	----	N/A
TKN	1.13 mg/l	N/A
NO_x	5.6 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 4 : Black Squirrel Creek.
Date - 18 June 92, Time - 0731
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - N/A
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - YES (original battery recharged)
Date/Time Delivered to Laboratory - 18 June, 0935 Hours
24 Hour Flow 58.41 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	43.0 mg/l	N/A
BOD	30.0 mg/l	N/A
COD	22.5 mg/l	N/A
TP	0.05 mg/l	N/A
SP	----	N/A
TKN	2.5 mg/l	N/A
NO_x	9.51 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 4 : Black Squirrel Creek.
Date - 19 June 92, Time - 0731
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - N/A
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - YES, Identification - # 6
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 19 June, 0938 Hours
24 Hour Flow 91.58 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	46.0 mg/l	22.0 mg/l
BOD	30.0 mg/l	3.0 mg/l
COD	17.2 mg/l	17.8 mg/l
TP	0.16 mg/l	< 0.05 mg/l
SP	----	N/A
TKN	0.22 mg/l	1.06 mg/l
NO_x	6.21 mg/l	5.51 mg/l
TCu	< 0.05 mg/l	< 0.05 mg/l
TPb	< 0.10 mg/l	< 0.10 mg/l
TZn	< 0.05 mg/l	< 0.05 mg/l

Sample Location # 4 : Black Squirrel Creek.
Date - 23 June 92, Time - 0845
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - ____
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - YES
Date/Time Delivered to Laboratory - 23 June, 1056 Hours
24 Hour Flow 95.58 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	Results Unavailable at publishing.	
BOD		
COD		
TP		
SP		
TKN		
NO_x		
TCu		
TPb		
TZn		

Sample Location # 5 : West Monument Creek.
Date - 15 June 92, Time - 0815
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 18
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 15 June, 0910 Hours
24 Hour Flow 254.64 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	14.0 mg/l	N/A
BOD	26.0 mg/l	N/A
COD	0.0 mg/l	N/A
TP	< 0.05 mg/l	N/A
SP	----	N/A
TKN	0.8 mg/l	N/A
NO_x	9.0 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 5 : West Monument Creek.
Date - 16 June 92, Time - 0830
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 18
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - YES, Identification - # 6
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 16 June, 1007 Hours
24 Hour Flow 245.78 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	6.0 mg/l	11.0 mg/l
BOD	46.0 mg/l	42.0 mg/l
COD	4.0 mg/l	6.6 mg/l
TP	0.22 mg/l	0.79 mg/l
SP	----	N/A
TKN	2.0 mg/l	0.64 mg/l
NO_x	4.2 mg/l	3.9 mg/l
TCu	< 0.05 mg/l	< 0.05 mg/l
TPb	< 0.10 mg/l	< 0.10 mg/l
TZn	< 0.05 mg/l	< 0.05 mg/l

Sample Location # 5 : West Monument Creek.
Date - 17 June 92, Time - 0945
Sample Type - Baseline X Rainstorm ______
Number of Bottles Filled In Sampler - 16
Mixing Bucket Cleaned X
Sample Bottles Cleaned X
Sample Container Identified X
Split Sample Taken - NO, Identification - ____
Ice Added To Sampler X
Sampler Reset X
Sample Cooled With Ice X
Batteries Changed - NO
Date/Time Delivered to Laboratory - 17 June, 1025 Hours
24 Hour Flow 233.02 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	20.0 mg/l	N/A
BOD	47.0 mg/l	N/A
COD	2.8 mg/l	N/A
TP	0.05 mg/l	N/A
SP	----	N/A
TKN	0.41 mg/l	N/A
NO_x	5.6 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 5 : West Monument Creek.
Date - 18 June 92, Time - 0832
Sample Type - Baseline X Rainstorm ______
Number of Bottles Filled In Sampler - 14
Mixing Bucket Cleaned X
Sample Bottles Cleaned X
Sample Container Identified X
Split Sample Taken - NO, Identification - ____
Ice Added To Sampler X
Sampler Reset X
Sample Cooled With Ice X
Batteries Changed - NO
Date/Time Delivered to Laboratory - 18 June, 0935 Hours
24 Hour Flow 222.87 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	19.0 mg/l	N/A
BOD	32.0 mg/l	N/A
COD	1.5 mg/l	N/A
TP	< 0.05 mg/l	N/A
SP	----	N/A
TKN	< 0.3 mg/l	N/A
NO_x	9.1 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 5 : West Monument Creek.
Date - 19 June 92, Time - 0853
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 15
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ___
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - YES
Date/Time Delivered to Laboratory - 19 June, 0938 Hours
24 Hour Flow 220.69 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	12.0 mg/l	N/A
BOD	3.0 mg/l	N/A
COD	2.5 mg/l	N/A
TP	< 0.05 mg/l	N/A
SP	----	N/A
TKN	< 0.3 mg/l	N/A
NO_x	6.4 mg/l	N/A
TCu	< 0.05 mg/l	N/A
TPb	< 0.10 mg/l	N/A
TZn	< 0.05 mg/l	N/A

Sample Location # 5 : West Monument Creek.
Date - 23 June 92, Time - 1008
Sample Type - Baseline __X__ Rainstorm ______
Number of Bottles Filled In Sampler - 16
Mixing Bucket Cleaned __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Split Sample Taken - NO, Identification - ____
Ice Added To Sampler __X__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - NO
Date/Time Delivered to Laboratory - 23 June, 1056 Hours
24 Hour Flow 232.43 x 10^3 ft^3

Laboratory Results

Constituent	Concentration	Split Sample
TSS	Results unavailable at publishing.	
BOD		
COD		
TP		
SP		
TKN		
NO_x		
TCu		
TPb		
TZn		

Rain Event Samples

Sample Location # 1 : Monument Creek - South.
Date - 20 June 92, Time - 1807
Sample Type - Baseline ___ Rainstorm _X_
Sample Bottles Cleaned _X_
Sample Container Identified _X_
Ice Added To Sampler _YES_
Sampler Reset _X_
Sample Cooled With Ice _X_
Batteries Changed - _NO_
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.23 inches

Container #1
Flow - 90,000 ft^3
Time interval - 1 hr 6 minutes
Time sample was taken - 1906 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	40.0
BOD	2.0
COD	10.9
TP	< 0.05
SP	N/A
TKN	0.63
NO_x	0.41
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #2
Flow - 90,000 ft^3
Time interval - 1 hr 6 minutes
Time sample was taken - 2012 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	48.0
BOD	2.0
COD	9.7
TP	0.11
SP	N/A
TKN	0.79
NO_x	0.41
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #3
Flow - 90,000 ft^3
Time interval - 1 hr 7 minutes
Time sample was taken - 2119 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	44.0
BOD	2.0
COD	15.1
TP	< 0.05
SP	N/A
TKN	0.64
NO_x	0.61
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #4
Flow - 90,000 ft^3
Time interval - 1 hr 7 minutes
Time sample was taken - 2225 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	40.0
BOD	< 1.0
COD	13.6
TP	< 0.05
SP	N/A
TKN	0.68
NO_x	0.41
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 1 : Monument Creek - South.
Date - 20 June 92, Time - 1807
Sample Type - Baseline ____ Rainstorm __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Ice Added To Sampler __YES__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - __NO__
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.30 inches

Container #19
Flow - 90,000 ft^3
Time interval - 1 hr 5 minutes
Time sample was taken - 1502 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	12.0
BOD	2.0
COD	7.4
TP	0.42
SP	N/A
TKN	1.41
NO_x	1.1
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #20
Flow - 90,000 ft^3
Time interval - 1 hr 7 minutes
Time sample was taken - 1609 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	80.0
BOD	3.0
COD	13.5
TP	0.58
SP	N/A
TKN	0.67
NO_x	0.52
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #21
Flow - 90,000 ft^3
Time interval - 1 hr 1 minutes
Time sample was taken - 1710 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	184.0
BOD	3.0
COD	20.8
TP	0.42
SP	N/A
TKN	0.33
NO_x	Insufficient Sample
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #22
Flow - 90,000 ft^3
Time interval - 1 hr 4 minutes
Time sample was taken - 1814 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	200.0
BOD	3.0
COD	10.0
TP	0.36
SP	N/A
TKN	0.22
NO_x	0.71
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 1 : Monument Creek - South.
Date - 21 June 92, Time - 1205
Sample Type - Baseline ____ Rainstorm __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Ice Added To Sampler __YES__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - __NO__
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.07 inches

Container #1
Flow - 90,000 ft^3
Time interval - 1 hr 3 minutes
Time sample was taken - 1924 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	28.0
BOD	10.0
COD	7.4
TP	0.52
SP	N/A
TKN	0.11
NO_x	6.01
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #2
Flow - 90,000 ft^3
Time interval - 1 hr 2 minutes
Time sample was taken - 2026 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	144.0
BOD	6.0
COD	15.2
TP	0.32
SP	N/A
TKN	0.18
NO_x	0.41
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #3
Flow - 90,000 ft^3
Time interval - 1 hr 2 minutes
Time sample was taken - 2128 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	120.0
BOD	8.0
COD	15.6
TP	0.79
SP	N/A
TKN	0.16
NO_x	1.01
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #4
Flow - 90,000 ft^3
Time interval - 1 hr 2 minutes
Time sample was taken - 2230 hours, 20 June.

Laboratory Results

Constituent	Concentration (mg/l)
TSS	70.0
BOD	9.0
COD	13.1
TP	0.48
SP	N/A
TKN	< 0.01
NO_x	7.01
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 1 : Monument Creek - South.
Date - 22 June 92, Time - 0955
Sample Type - Baseline ___ Rainstorm _X_
Sample Bottles Cleaned _X_
Sample Container Identified _X_
Ice Added To Sampler _YES_
Sampler Reset _X_
Sample Cooled With Ice _X_
Batteries Changed - _NO_
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.07 inches

Container #7
Flow - 90,000 ft^3
Time interval - 1 hr 4 minutes
Time sample was taken - 1938 hours, 21 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	56.0
BOD	2.0
COD	9.3
TP	0.42
SP	N/A
TKN	0.32
NO_x	0.50
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #8
Flow - 90,000 ft^3
Time interval - 1 hr 5 minutes
Time sample was taken - 2043 hours, 21 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	80.0
BOD	2.0
COD	15.4
TP	0.36
SP	N/A
TKN	1.12
NO_x	0.51
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #9
Flow - 90,000 ft^3
Time interval - 1 hr 2 minutes
Time sample was taken - 2146 hours, 21 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	39.0
BOD	3.0
COD	7.4
TP	0.50
SP	N/A
TKN	1.22
NO_x	0.50
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #10
Flow - 90,000 ft^3
Time interval - 1 hr 0 minutes
Time sample was taken - 2246 hours, 21 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	40.0
BOD	3.0
COD	9.7
TP	0.54
SP	N/A
TKN	0.33
NO_x	0.61
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #11
Flow - 90,000 ft^3
Time interval - 1 hr 1 minutes
Time sample was taken - 2347 hours, 21 June.

Laboratory Results

Constituent	Concentration (mg/l)
TSS	40.0
BOD	3.0
COD	10.6
TP	0.53
SP	N/A
TKN	0.62
NO_x	0.61
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #12
Flow - 90,000 ft^3
Time interval - 1 hr 0 minutes
Time sample was taken - 0047 hours, 22 June.

Laboratory Results

Constituent	Concentration (mg/l)
TSS	80.0
BOD	3.0
COD	10.1
TP	0.11
SP	N/A
TKN	0.64
NO_x	0.41
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 2 : Monument Creek - North.
Date - 20 June 92, Time - 1650
Sample Type - Baseline ____ Rainstorm __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Ice Added To Sampler __YES__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - __NO__
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.23 inches

Container #1
Flow - 43,000 ft^3
Time interval - 1 hr 2 minutes
Time sample was taken - 1900 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	64.0
BOD	3.0
COD	14.5
TP	0.37
SP	N/A
TKN	0.32
NO_x	0.43
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #2
Flow - 43,000 ft^3
Time interval - 1 hr 4 minutes
Time sample was taken - 2004 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	50.0
BOD	2.0
COD	13.2
TP	0.69
SP	N/A
TKN	0.63
NO_x	0.43
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #3
Flow - 43,000 ft^3
Time interval - 1 hr 5 minutes
Time sample was taken - 2109 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	50.0
BOD	3.0
COD	13.9
TP	0.69
SP	N/A
TKN	0.29
NO_x	0.33
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #4
Flow - 43,000 ft^3
Time interval - 1 hr 3 minutes
Time sample was taken - 2212 hours, 19 June.

Laboratory Results

Constituent	Concentration (mg/l)
TSS	40.0
BOD	2.0
COD	15.5
TP	0.56
SP	N/A
TKN	0.19
NO_x	0.33
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 2 : Monument Creek - North.
Date - 21 June 92, Time - 1032
Sample Type - Baseline ____ Rainstorm __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Ice Added To Sampler __YES__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - __NO__
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.30 inches

Container #1
Flow - 43,000 ft^3
Time interval - 1 hr 2 minutes
Time sample was taken - 1822 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	24.0
BOD	5.0
COD	17.0
TP	< 0.05
SP	N/A
TKN	0.26
NO_x	19.62
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #2
Flow - 43,000 ft^3
Time interval - 1 hr 1 minutes
Time sample was taken - 1923 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	48.0
BOD	7.0
COD	15.2
TP	0.06
SP	N/A
TKN	0.42
NO_x	11.52
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #3
Flow - 43,000 ft^3
Time interval - 1 hr 2 minutes
Time sample was taken - 2025 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	18.0
BOD	2.0
COD	16.0
TP	< 0.05
SP	N/A
TKN	0.18
NO_x	16.82
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #4
Flow - 43,000 ft^3
Time interval - 1 hr 1 minutes
Time sample was taken - 2126 hours, 20 June.

Laboratory Results

Constituent	Concentration (mg/l)
TSS	28.0
BOD	7.0
COD	7.0
TP	< 0.05
SP	N/A
TKN	0.10
NO_x	18.21
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 3 : Smith Creek.
Date - 20 June 92, Time - 1632
Sample Type - Baseline ____ Rainstorm __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Ice Added To Sampler __YES__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - __NO__
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.23 inches

This was a 24 hour composite sample. 24 hour flow - 15.29×10^3 Ft^3

Laboratory Results

Constituent	Concentration (mg/l)
TSS	12.0
BOD	2.0
COD	16.6
TP	0.15
SP	N/A
TKN	0.66
NO_x	0.21
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 3 : Smith Creek.
Date - 21 June 92, Time - 1015
Sample Type - Baseline ____ Rainstorm __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Ice Added To Sampler __YES__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - __NO__
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.30 inches

This was a 24 hour composite sample. 24 hour flow - 22.90×10^3 Ft^3

Laboratory Results

Constituent	Concentration (mg/l)
TSS	40.0
BOD	7.0
COD	21.7
TP	0.16
SP	N/A
TKN	0.66
NO_x	0.31
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 3 : Smith Creek.
Date - 22 June 92, Time - 0835
Sample Type - Baseline ____ Rainstorm __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Ice Added To Sampler __YES__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - __NO__
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.07 inches

This was a 24 hour composite sample. 24 hour flow - 34.82 x 10^3 Ft^3

Laboratory Results

Constituent	Concentration (mg/l)
TSS	16.0
BOD	3.5
COD	22.0
TP	0.18
SP	N/A
TKN	0.79
NO_x	0.31
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 4 : Black Squirrel Creek.
Date - 20 June 92, Time - 1600
Sample Type - Baseline ____ Rainstorm __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Ice Added To Sampler __YES__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - __NO__
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.23 inches

Container #1
Flow - 7,000 ft^3
Time interval - 1 hr 7 minutes
Time sample was taken - 1906 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	20.0
BOD	1.0
COD	14.7
TP	0.35
SP	N/A
TKN	0.89
NO_x	0.02
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #2
Flow - 7,000 ft^3
Time interval - 1 hr 11 minutes
Time sample was taken - 2017 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	40.0
BOD	2.0
COD	18.1
TP	0.10
SP	N/A
TKN	0.50
NO_x	0.02
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #3
Flow - 7,000 ft^3
Time interval - 1 hr 14 minutes
Time sample was taken - 2131 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	24.0
BOD	1.0
COD	24.6
TP	0.06
SP	N/A
TKN	0.20
NO_x	0.12
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #4
Flow - 7,000 ft^3
Time interval - 1 hr 17 minutes
Time sample was taken - 2248 hours, 19 June.

Laboratory Results

Constituent	Concentration (mg/l)
TSS	12.0
BOD	1.0
COD	17.4
TP	0.18
SP	N/A
TKN	0.20
NO_x	0.12
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 4 : Black Squirrel Creek.
Date - 21 June 92, Time - 0936
Sample Type - Baseline ____ Rainstorm _X_
Sample Bottles Cleaned _X_
Sample Container Identified _X_
Ice Added To Sampler _YES_
Sampler Reset _X_
Sample Cooled With Ice _X_
Batteries Changed - _NO_
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.30 inches

Container #1
Flow - 7,000 ft^3
Time interval - 1 hr 20 minutes
Time sample was taken - 1757 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	62.0
BOD	2.0
COD	21.3
TP	< 0.05
SP	N/A
TKN	0.80
NO_x	13.42
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #2
Flow - 7,000 ft^3
Time interval - 1 hr 14 minutes
Time sample was taken - 1911 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	26.0
BOD	2.0
COD	19.8
TP	0.12
SP	N/A
TKN	0.32
NO_x	8.11
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #3
Flow - 7,000 ft^3
Time interval - 1 hr 17 minutes
Time sample was taken - 2028 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	32.0
BOD	2.0
COD	23.7
TP	0.14
SP	N/A
TKN	0.13
NO_x	0.01
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #4
Flow - 7,000 ft^3
Time interval - 1 hr 21 minutes
Time sample was taken - 2129 hours, 20 June.

Laboratory Results

Constituent	Concentration (mg/l)
TSS	24.0
BOD	2.0
COD	22.0
TP	< 0.05
SP	N/A
TKN	< 0.01
NO_x	10.91
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 4 : Black Squirrel Creek.
Date - 22 June 92, Time - 0835
Sample Type - Baseline ____ Rainstorm __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Ice Added To Sampler __YES__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - __NO__
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.07 inches

Container #3
Flow - 7,000 ft^3
Time interval - 1 hr 28 minutes
Time sample was taken - 1409 hours, 21 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	40.0
BOD	7.0
COD	30.4
TP	0.14
SP	N/A
TKN	0.25
NO_x	0.12
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #4
Flow - 7,000 ft^3
Time interval - 1 hr 26 minutes
Time sample was taken - 1535 hours, 21 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	16.0
BOD	9.3
COD	25.0
TP	0.05
SP	N/A
TKN	0.32
NO_x	0.91
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #5
Flow - 7,000 ft^3
Time interval - 1 hr 25 minutes
Time sample was taken - 1700 hours, 21 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	24.0
BOD	2.0
COD	13.7
TP	0.10
SP	N/A
TKN	0.16
NO_x	0.51
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #6
Flow - 7,000 ft^3
Time interval - 1 hr 26 minutes
Time sample was taken - 1826 hours, 21 June.

Laboratory Results

Constituent	Concentration (mg/l)
TSS	Sample not analyzed by laboratory.
BOD	
COD	
TP	
SP	
TKN	
NO_x	
TCu	
TPb	
TZn	

Sample Location # 5 : West Monument Creek.
Date - 20 June 92, Time - 1650
Sample Type - Baseline ____ Rainstorm X
Sample Bottles Cleaned X
Sample Container Identified X
Ice Added To Sampler YES
Sampler Reset X
Sample Cooled With Ice X
Batteries Changed - NO
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.23 inches

Container #1
Flow - 14,400 ft^3
Time interval - 1 hr 23 minutes
Time sample was taken - 1920 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	24.0
BOD	2.0
COD	16.0
TP	0.07
SP	N/A
TKN	0.40
NO_x	0.12
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #2
Flow - 14,400 ft^3
Time interval - 1 hr 27 minutes
Time sample was taken - 2047 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	42.0
BOD	1.0
COD	5.7
TP	0.11
SP	N/A
TKN	3.6
NO_x	0.12
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #3
Flow - 14,400 ft^3
Time interval - 1 hr 28 minutes
Time sample was taken - 2215 hours, 19 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	16.0
BOD	1.0
COD	8.5
TP	0.33
SP	N/A
TKN	0.10
NO_x	0.13
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #4
Flow - 14,400 ft^3
Time interval - 1 hr 28 minutes
Time sample was taken - 2343 hours, 19 June.

Laboratory Results

Constituent	Concentration (mg/l)
TSS	40.0
BOD	2.0
COD	5.7
TP	0.16
SP	N/A
TKN	0.20
NO_x	0.11
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 5 : West Monument Creek.
Date - 21 June 92, Time - 1132
Sample Type - Baseline ____ Rainstorm __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Ice Added To Sampler __YES__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - __NO__
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.30 inches

Container #1
Flow - 14,400 ft^3
Time interval - 1 hr 27 minutes
Time sample was taken - 1918 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	12.0
BOD	2.0
COD	6.2
TP	< 0.05
SP	N/A
TKN	< 0.01
NO_x	14.0
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #2
Flow - 14,400 ft^3
Time interval - 1 hr 25 minutes
Time sample was taken - 2043 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	12.0
BOD	2.0
COD	7.1
TP	0.05
SP	N/A
TKN	0.08
NO_x	< 0.10
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #3
Flow - 14,400 ft^3
Time interval - 1 hr 25 minutes
Time sample was taken - 2208 hours, 20 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	14.0
BOD	2.0
COD	9.6
TP	Insufficient Sample Quantity
SP	N/A
TKN	0.32
NO_x	< 0.10
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #4
Flow - 14,400 ft^3
Time interval - 1 hr 24 minutes
Time sample was taken - 2332 hours, 20 June.

Laboratory Results

Constituent	Concentration (mg/l)
TSS	12.0
BOD	< 1.0
COD	5.4
TP	0.09
SP	N/A
TKN	0.41
NO_x	< 0.10
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Sample Location # 5 : West Monument Creek.
Date - 22 June 92, Time - 0939
Sample Type - Baseline ____ Rainstorm __X__
Sample Bottles Cleaned __X__
Sample Container Identified __X__
Ice Added To Sampler __YES__
Sampler Reset __X__
Sample Cooled With Ice __X__
Batteries Changed - __NO__
Date/Time Delivered to Laboratory - 22 June, 1113 Hours
Rainfall - 0.07 inches

Container #2
Flow - 14,400 ft^3
Time interval - 1 hr 23 minutes
Time sample was taken - 1429 hours, 21 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	6.0
BOD	8.0
COD	14.4
TP	< 0.05
SP	N/A
TKN	0.78
NO_x	22.4
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #3
Flow - 14,400 ft^3
Time interval - 1 hr 25 minutes
Time sample was taken - 1554 hours, 21 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	16.0
BOD	6.0
COD	7.0
TP	< 0.05
SP	N/A
TKN	0.32
NO_x	17.5
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #4
Flow - 14,400 ft^3
Time interval - 1 hr 25 minutes
Time sample was taken - 1719 hours, 21 June

Laboratory Results

Constituent	Concentration (mg/l)
TSS	12.0
BOD	5.0
COD	3.5
TP	< 0.05
SP	N/A
TKN	0.13
NO_x	15.7
TCu	< 0.05
TPb	< 0.10
TZn	< 0.05

Container #5
Flow - 14,400 ft^3
Time interval - 1 hr 27 minutes
Time sample was taken - 1846 hours, 21 June.

Laboratory Results

Constituent	Concentration
TSS	Sample was not analyzed by laboratory.
BOD	
COD	
TP	
SP	
TKN	
NO_x	
TCu	
TPb	
TZn	

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13. ABSTRACT *(Maximum 200 words)*

The purpose of this research was development of a methodology for characterization and management of Nonpoint Source (NPS) water pollution. Section 319 of the 1987 Water Quality Act requires states to develop management programs for reduction of NPS pollution via Best Management Practices (BMPs). Air Force installations are expected to abide by federal, state, and local environmental regulations. Currently, the Air Force does not have a methodology to identify and quantify NPS pollution, or a succinct catalog of BMPs. Air Force installation managers need a package to assist them in meeting legislative and regulatory requirements associated with NPS pollution. Ten constituents characteristic of urban runoff were identified in the Nationwide Urban Runoff Program (NURP) and selected as those constituents of concern for modeling and sampling. Two models were used and compared with the results of a sampling and analysis program. Additionally, a compendium of BMPs was developed.

14. SUBJECT TERMS

Nonpoint Source Pollution (NPS), Best Management Practices (BMPs), Water Pollution, Water Sampling and Analysis, Stormwater Runoff Modeling, NPDES.

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