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# Application of Water Quality Models to a Small Forested Watershed: I. The Nondesignated 208 Area Screening Model

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The natural setting of a small forested watershed, the West Point Study Area, is described. Modeling of the watershed using the nondesignated 208 area screening model is explained. Parameter evaluation and sampling for calibration and verification purposes is detailed. Shortcomings of the model for application to small forested watersheds are identified.

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# APPLICATION OF WATER QUALITY MODELS TO A SMALL FORESTED WATERSHED:
# I. The Nondesignated 208 Area Screening Model

by

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# FOREWORD

As environmental controls become more costly to implement and the penalties of judgment errors become more severe, environmental quality management requires more efficient analytical tools based on greater knowledge of the environmental phenomena to be managed. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Technology Development and Applications Branch develops management or engineering tools to help pollution control officials achieve water quality goals through watershed management.

Basin planning requires a set of analysis procedures that can provide an assessment of the current state of the environment and a means of predicting the effectiveness of alternative pollution control strategies. In 1977, this Laboratory published Water Quality Assessment: A Screening Method for Nondesignated 208 Areas, which contains a set of consistent analysis procedures that accomplish these tasks. The assessment procedure is directed toward local and state government planners who must interpret technical information from many sources and recommend the most prudent course of action that will maximize the environmental benefits to the community and minimize the cost of implementation. An integral part of the development process is the calibration and verification of the screening method on actual watersheds. This report evaluates its use in characterizing wasteloads and water quality in small forested watersheds in New York.

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## ABSTRACT

The natural setting of a small forested watershed, the West Point Study Area, is described. Modeling of the watershed using the nondesignated 208 area screening model is explained. Parameter evaluation and sampling for calibration and verification purposes is detailed. Short-comings of the model for application to small forested watersheds are identified.

This report was submitted in fulfillment of Interagency Agreement No. EPA-IAG-D7-0086 by the U.S. Military Academy under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period July 1976 to September 1979, and work was completed as of 30 September 1979.

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## SECTION 1

## INTRODUCTION

This report presents an evaluation of the application of _Water Quality Assessment: A Screening Method for Nondesignated 208 Areas_ (Zison _et al._, 1977) to a forested watershed on portions of the U.S. Military Academy Reservation and the Harriman Section of The Palisades Interstate Park in Orange County, N.Y. This report is the first of a series produced under an Interagency Agreement with the U.S. Environmental Protection Agency to evaluate the applicability of existing water quality models to a small forested watershed. Future reports will deal with the application of The Nonpoint Source Model (NPS) (Donigian and Crawford, 1976) and The Agricultural Runoff Management (ARM) Model (Donigian _et al._, 1977) to the same watershed.

As part of the calibration and verification process, field data for water quality, hydrologic, and meteorological parameters are being collected. This report details the selection of sampling sites, instruments, techniques, and analytical methods used in the data collection. Parameter selection for model use is explained.

## SECTION 2

## CONCLUSIONS

1. Wasteloading from nonpoint sources on the West Point Study Area or any other steeply sloped area cannot be modeled by the Nondesignated 208 Area Screening Method (Zison *et al.*, 1977) without extension or modification of the algorithm for assigning a value to the topographic factor, LS.

2. Procedures for use of the erosion control practice factor, P, for forested areas need to be clarified in the Nondesignated 208 Area Screening Method (Zison *et al.*, 1977).

3. The formulation for deriving the sediment delivery ratio, $S_d$ in the Nondesignated 208 Area Screening Method (Zison *et al.*, 1977), yields sediment loading values higher than we are comfortable with. The Forest Service (1978) sediment delivery index derived from eight forest parameters seems better suited to forested areas.

4. Lake eutrophication predictions in the Nondesignated 208 Area Screening Method (Zison *et al.*, 1977) only work for phosphorus-limited conditions. The model needs to be extended to other situations.

5. The lake thermal profiles model in the Nondesignated 208 Area Screening Method (Zison *et al.*, 1977) when applied to the West Point Study Area gives a reasonable prediction of actual field conditions.

6. The lake dissolved oxygen prediction in the Nondesignated 208 Area Screening Method (Zison *et al.*, 1977) has been verified for one lake in the West Point Study Area.

7. Application of the Nondesignated 208 Area Screening Method (Zison *et al.*, 1977) to forested watersheds should be done with caution until the methodology is thoroughly tested and verified.

## SECTION 3

## RECOMMENDATIONS

1. That further data collection be conducted on the West Point Study Area to enable verification of the wasteloading prediction from nonpoint sources based on the Nondesignated 208 Area Screening Method (Zison et al., 1977).

2. That model procedures (Zison et al., 1977) be revised to give guidance to the user with forested terrain to model on how to set the erosion control practice factor, P, in the universal soil loss equation.

3. That the procedures from the WRENSS model (Forest Service, 1978) for calculation of the topographic factor, LS, and sediment delivery index, SDI, be added to the Nondesignated 208 Area Screening Method (Zison et al., 1977) as replacements for LS and $S_d$ for steeply sloped forested areas only.

4. That the WRENSS model (Forest Service, 1978) be applied to the West Point Study Area and verified, and that the revised Nondesignated 208 Area Screening Method (see 3 above) be verified on the same watershed to determine which model gives the better prediction of water quality from a forested watershed.

5. That the average annual rainfall factor, R, maps presented in the USDA Agriculture Handbook 537 be substituted for the generalized version presented in Zison et al., 1977.

## SECTION 4

## THE WEST POINT STUDY AREA

### 4.1 GEOGRAPHICAL SETTING

The study area is 46 to 50 miles north of New York City and 3 to 6 miles west of the Hudson River on Popolopen Brook, a tributary to the Hudson in Orange County, New York (Figure 4-1). The area is part of a low mountainous belt known locally as the Hudson Highlands. This name is applied loosely to the portion of the crystalline "Highlands" adjacent to the Hudson River which extend from Reading, Pennsylvania through northern New Jersey and on into Connecticut (Lowe, 1950). These same highlands have been categorized geomorphically as the Reading Prong, a salient of the Upland Section of the New England geomorphic province (Thornbury, 1965; Figure 4-2).

The study area comprises 3,247 acres of watershed draining to the dam on Popolopen Lake (Figure 4-3). The southern portion of the watershed is in the Harriman section of the Palisades Interstate Park. The northern tip is in the Black Rock Forest, an experimental forest belonging to Harvard University. The remainder of the area is part of the U.S. Military Academy Reservation.

Elevations range from 678 ft at Popolopen Lake to 1401 ft along the northwest margin of the basin (Figure 4-4). The Highlands are characterized by escarpments and by 25 to 60 percent slopes which separate the gentle summit terrain from the base slopes of 10 to 25 percent (Engineer Intelligence Division, 1959).

### 4.2 GEOLOGY

The West Point Study Area is underlain by rocks of the Highlands metamorphic-igneous complex. These rocks represent Precambrian sedimentary and perhaps volcanic rocks which have been metamorphosed, folded, and intruded by granite 1.1 billion years ago (Dodd, 1965; Figure 4-5). The topography of the area is controlled by the structure and lithology of the underlying rocks. Ridges and valleys parallel the folds in the metamorphic

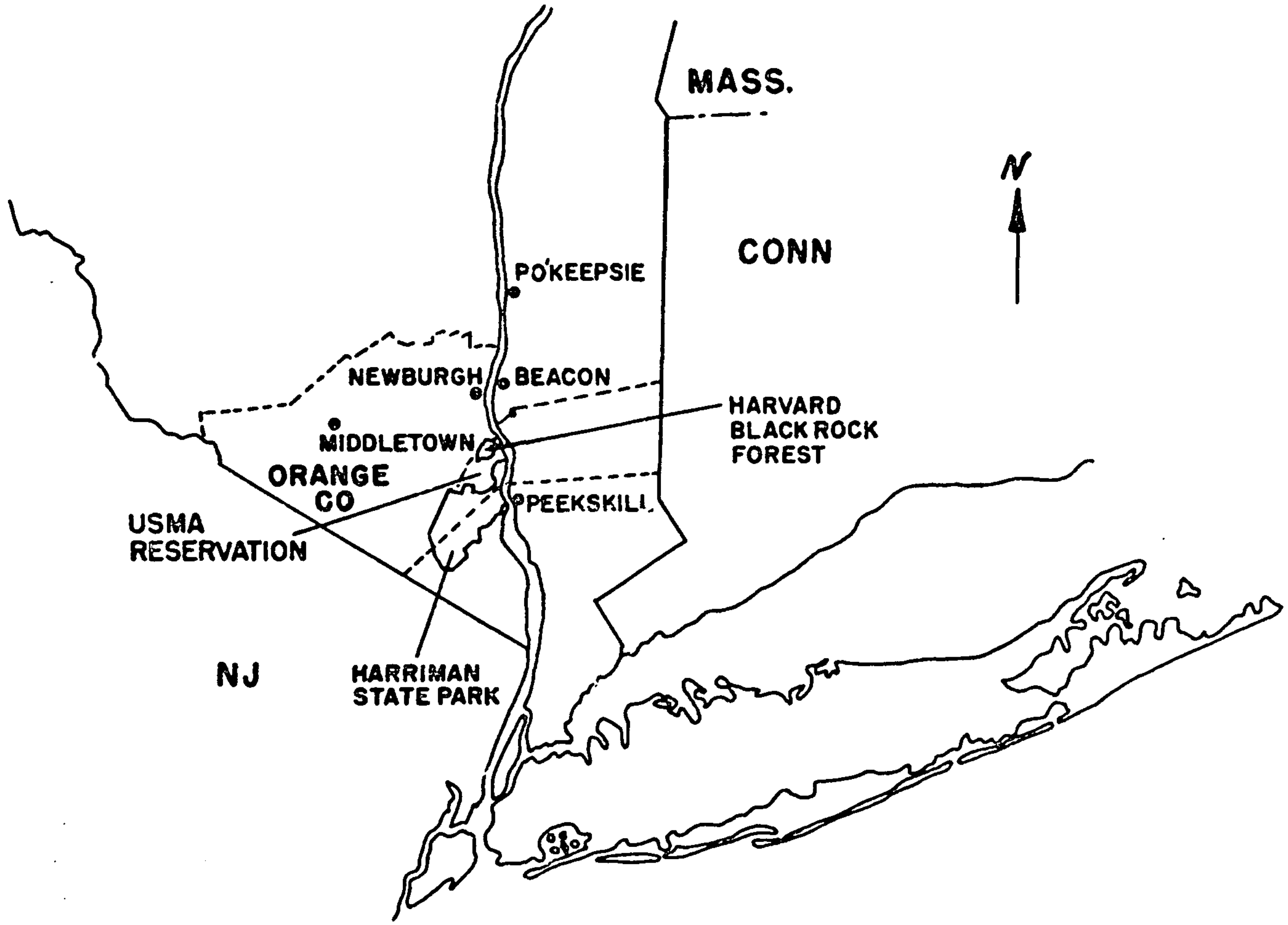


Figure 4-1. Location Map for The West Point Study Area.

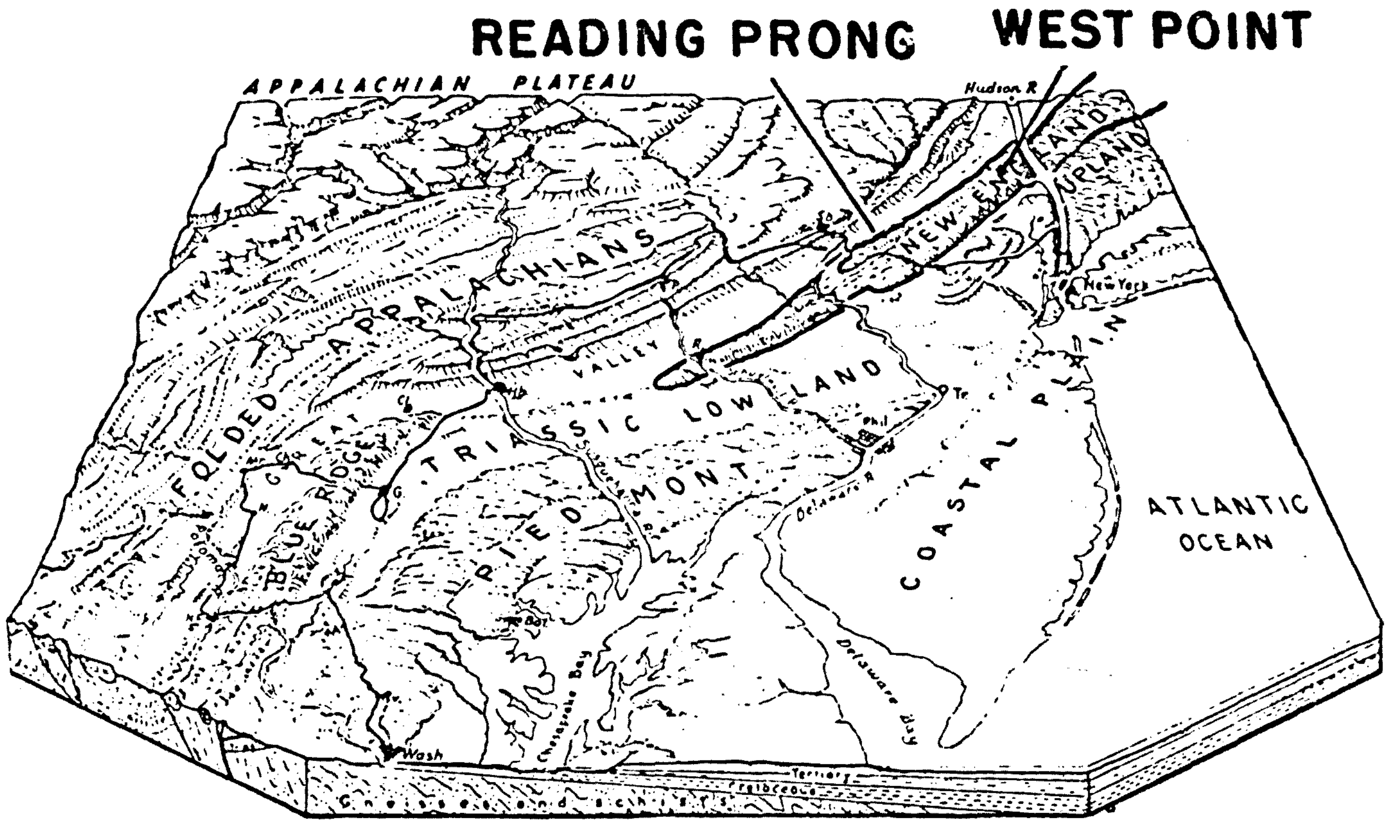


Figure 4-2. Block Diagram Showing The Reading Prong of The New England Province (Johnson, 1932).

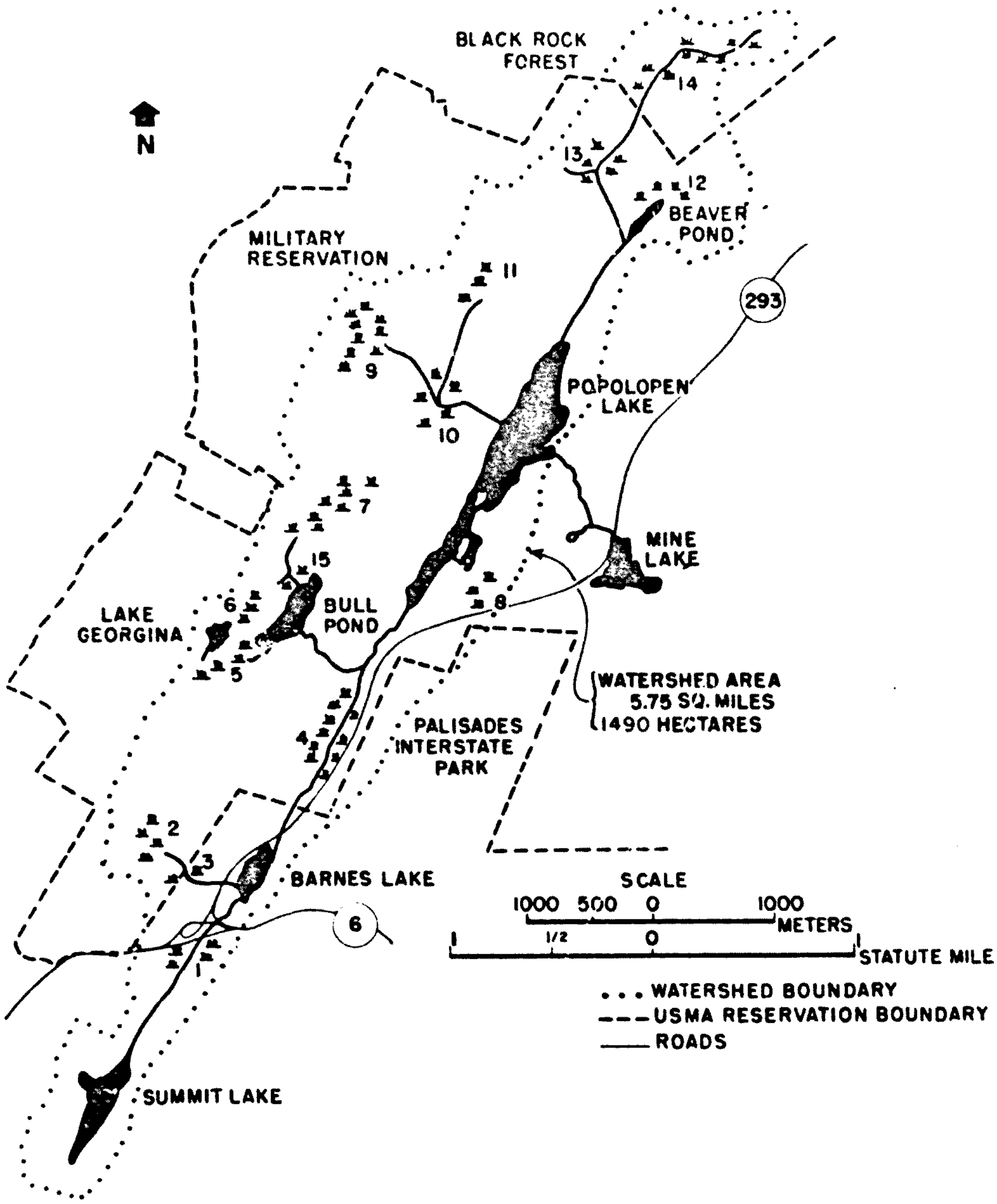


Figure 4-3. The West Point Study Area Showing The Watershed Boundary and Wetland Locations Used in the Text.

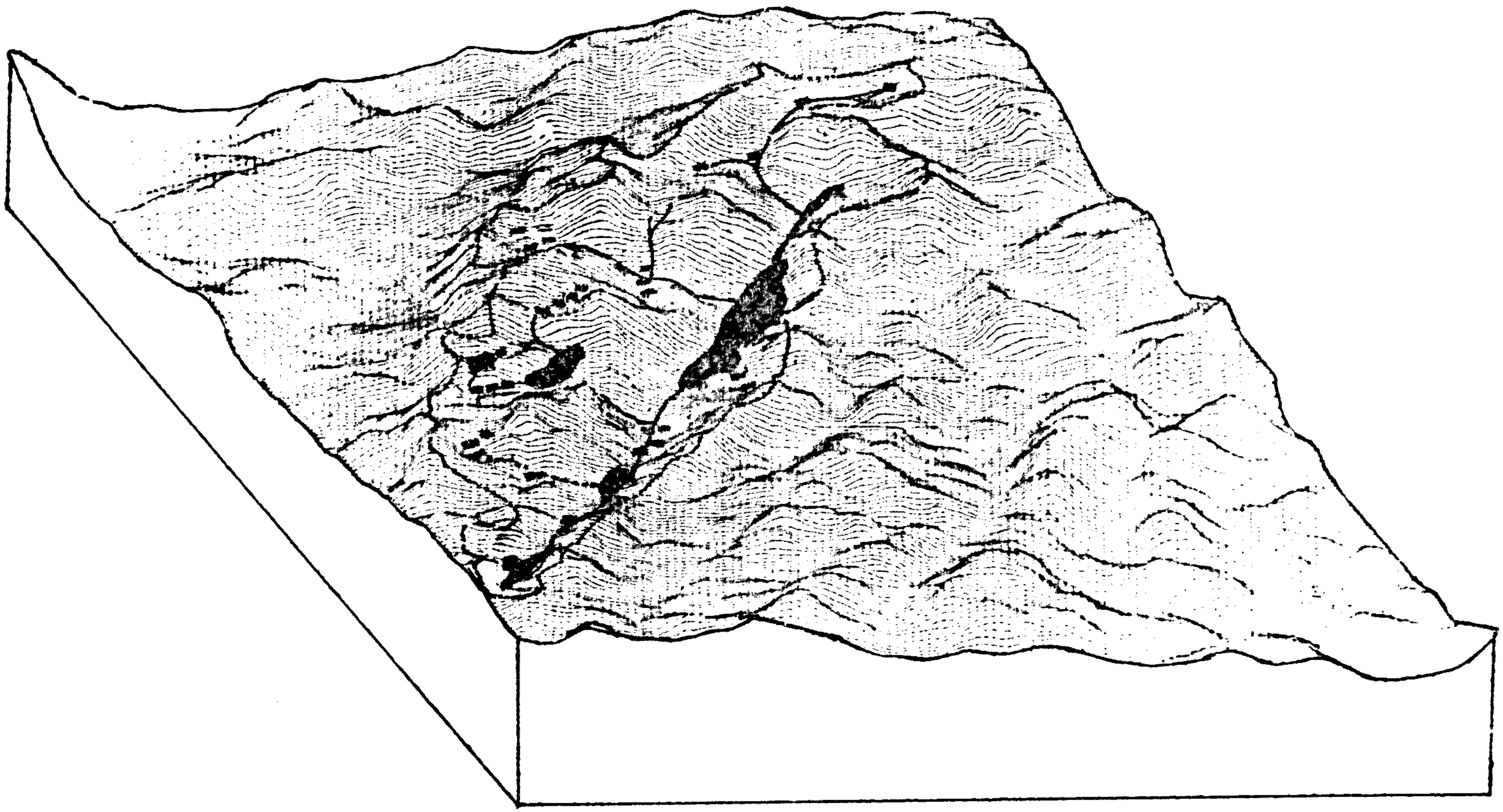

Figure 4-4. Oblique View of The West Point Study Area Generated from a Digitized Data Base by Computer (Charland).

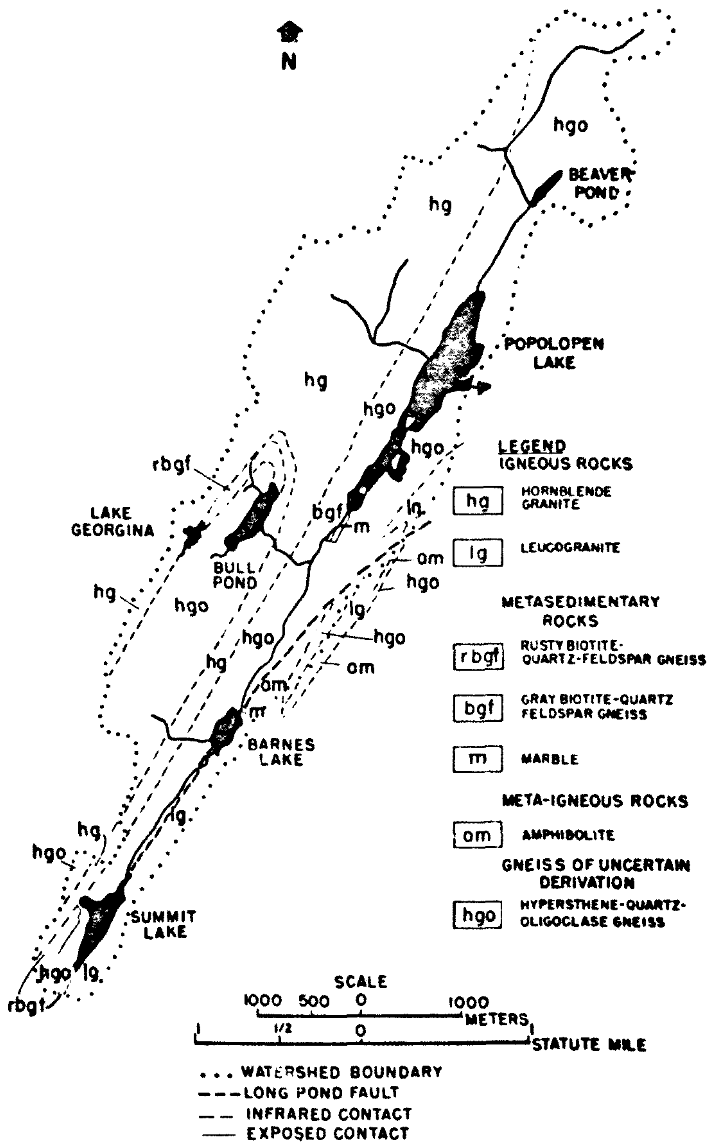


Figure 4-5. Geologic Map of The West Point Study Area (after Dodd, 1965).

rocks and the crystalline lineation of the rocks. High ridges in the area are developed on the intrusive granites. The northeast-southwest trending valley is developed in the southern portion of the basin on the Long Pond Fault (Engineering Intelligence Division, 1959; unnamed by Dodd, 1965). The entire area shows evidence of glaciation from the north. Glacial-erosional features are common (roche moutonees, striations, chatter marks) as are glacial depositional features (filled valleys, kames, and kame terraces). Erratic material, mostly of local derivation, mantles the hills (Dodd, 1965).

## 4.3 SOILS

Soils in Orange County were mapped for the Orange County Soil and Water Conservation District by the Soil Conservation Service of the Department of Agriculture in the early 1970's (Wright and Olsson, 1972). Individual township maps for Cornwall, Highlands, and Woodbury (Orange County Soil and Water Conservation District, 1974) have been pieced together to produce a composite soil map for the West Point Study Area (Figure 4-6). In producing the composite soil map we have eliminated the slope class symbol and grouped soils by the mapping unit code. The mapping unit codes from the original report (Wright and Olsson, 1972) have been retained. The soil descriptions for each of the soil types in the West Point Study Area are reproduced in Appendix A.

Most of the study area is labeled as Hollis Rock Outcrop with "outcrops occupying 90 percent of the area". While there are significant outcrop areas, they are by no means as extensive as classified by the Soil Conservation Service (Wright and Olsson, 1972). Labeling these areas Hollis Rocky Association (070) would be more appropriate. We hope to revise the soil map for the area in conjunction with colleagues from the SUNY-College of Environmental Science and Forestry, Syracuse, New York (SUNY-ESF) over the next several years.

Soils on the hills are shallow with zero to 18-24 inches overlying bedrock. Lowland soils are deeper, up to 6 feet. Detailed mapping of soil depths will be accomplished as part of the SUNY-ESF cooperative project. A detailed soil profile is presented in Appendix B.

## 4.4 CLIMATE

Climatological data for the area are available for WEST POINT, a reporting station in Climatological Data (National Climate Center) and from the Water Plant at Bear Mountain Park. A continous recording station associated with this project has been established at Stilwell Lake (Figure 6-2) to provide hourly,

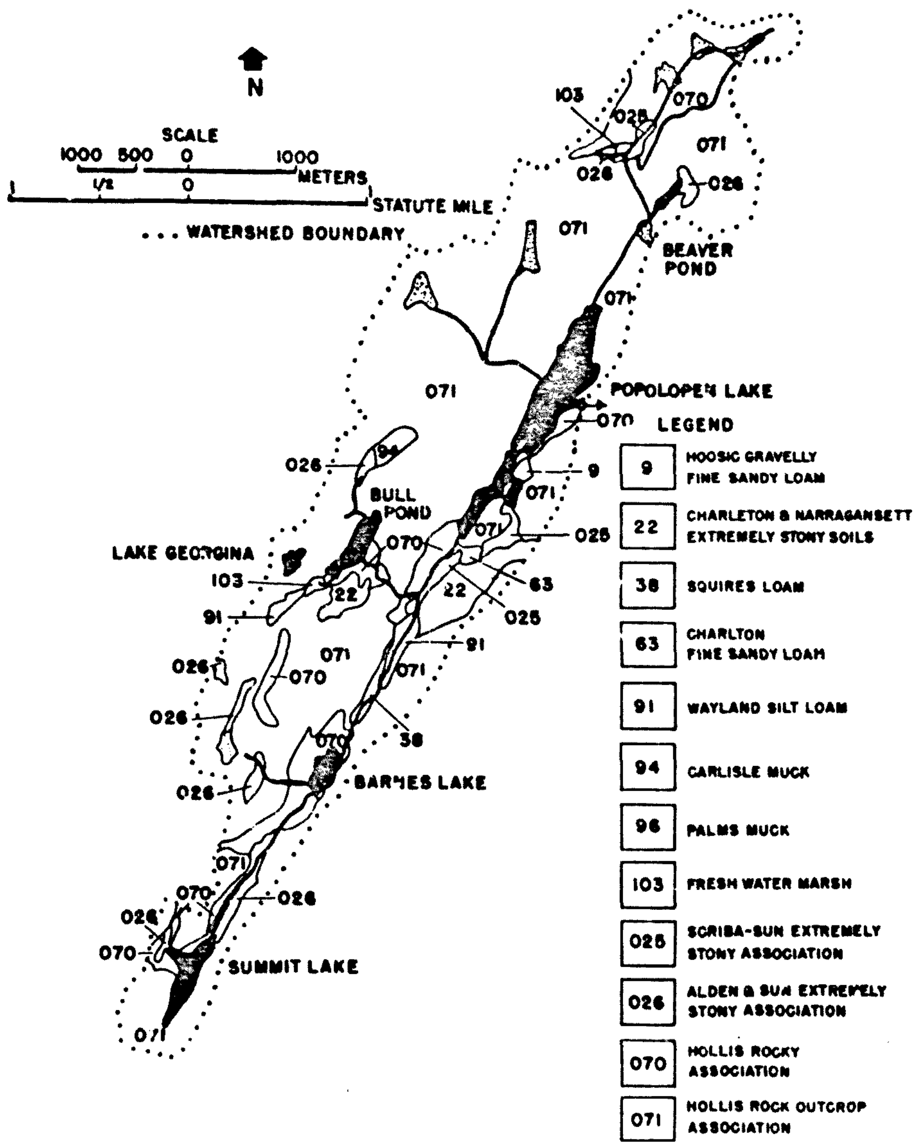


Figure 4-6. Soils Map of The West Point Study Area (after Orange County Soil and Water Conservation District, 1974).

15-minute, and 5-minute rainfalls needed for modeling. Supplemental weighing rain gauges are being sited throughout the watershed (see section 6).

Summer temperatures at West Point average 74 degrees Fahrenheit, but short hot spells in the nineties are common. Winters in the West Point Area are moderately cold, with temperatures averaging just below the freezing point at West Point (The West Point site is located adjacent to the Hudson River and generally stays warmer than locations in the study area). It is not unusual to have rain throughout the winter. Snowpack typically comes and goes throughout the winter. The average number of days with snow on the ground (greater than one inch) are:

| | |
|---|---|
| November | <1 day |
| December | 5 days |
| January | 10.5 days |
| February | 10.5 days |
| March | 6.0 days |
| April | <1 day |

(Engineering Intelligence Division, 1959)

The mean annual precipitation at West Point is 47 inches, distributed evenly through the year. Figure 4-7 shows the average monthly precipitation at Bear Mountain Water Plant, Bear Mountain, N.Y., for the twenty-one year period 1958-1978. In the winter, elevations above 1,000 feet tend to have snow when the lower lying areas are having rain. These areas also keep snow-cover for a longer period.

Wind roses for the study area are not available at this time. Data from the Stilwell Lake station will be prepared in this format in the future.

## 4.5 DRAINAGE

Drainage on the watershed is a modified trellis pattern influenced by the lineation in the underlying rocks and faults. Six lakes (ponds) and fifteen wetland complexes affect the flow of water on the watershed. Five of the six lakes are manmade: Summit, Barnes, Georgina, Popolopen, and Beaver. Bull Pond, the deepest lake, is natural. Three of the five manmade lakes have depths greater than the dam height and thus must have existed as small ponds or wetlands prior to impoundment (Summit, Popolopen, Beaver).

The streams in the area have cut to bedrock in most cases. Channels are strewn with boulders and stones. Streams flash to high flow after storms because of the impervious bedrock material close to the surface. There is little overland flow under the forest canopy. A great deal of interflow takes place at the soil-bedrock interface.

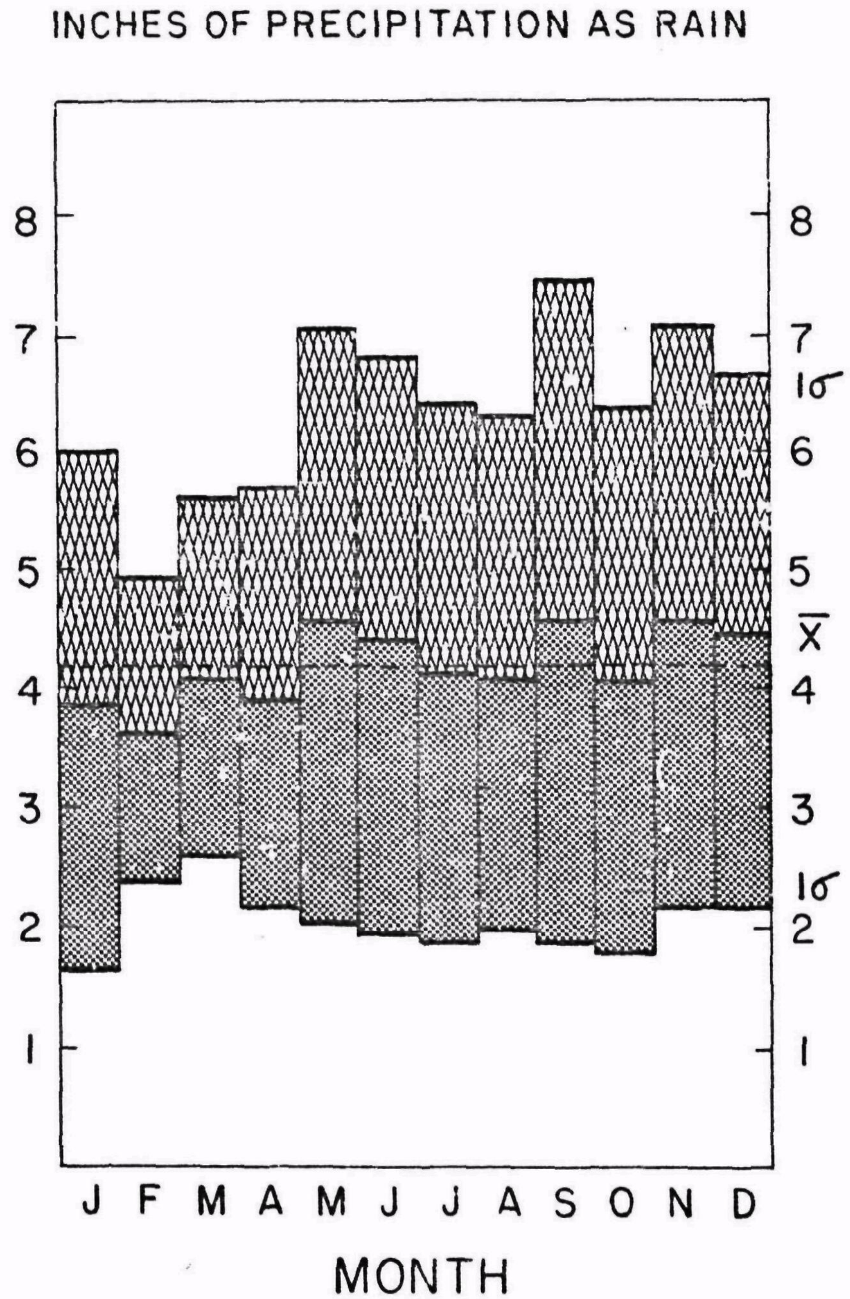


Figure 4-7. Average Monthly Precipitation at Bear Mountain 1958-1978.

## 4.5.1 Lakes

Bathymetric data for ponds on the U.S. Military Academy Reservation were obtained from the USMA forester. The maps were produced in 1975 by an anonymous technician by lowering a weight into the lake, recording the depth, and then contouring by hand the resulting point data. Our spot checks for accuracy using the same technique and with a sonic depth finder have shown these maps to depict the shape of the bottom accurately, but to show depths greater than actual. These lakes will be resurveyed in subsequent winters using the technique described below for the Palisades Lakes.

Bathymetric data for Popolopen Lake are from a 1942 engineering survey (Potter Associates, 1944). Spot checks of these data have shown the survey to be reliable. This lake will be resurveyed last, because data for this lake have proven to be reliable.

Summit Lake and Barnes Lake were surveyed in February 1979 by laying a grid on the surface of the ice and measuring the depth using a Lowrance Fish-Lo-K-Tor ("The Green Box") sonic depth finder. Depths at Barnes Lake were measured through the ice, whereas those at Summit Lake, because of air pockets in the ice, were measured by placing the sensor in a hole dug with an ice auger. In both cases frequent checks were made to confirm the accuracy of the sonic depth finder and our ability to discriminate the lake bottom in areas with soft bottom. Point data from the field were contoured to produce the bathymetric maps.

Lake volumes were calculated from areas within the contour lines using the formula for the volume of a frustrum of a cone (Hutchinson, 1957). Areas were computed using standard planimetric techniques on the maps presented (Lind, 1974).

Beaver Pond (Figure 4-8) is a shallow pond in a depression on the ridge. The dam of glacial materials may have raised the level of the natural pond a foot or two. An extensive wetland complex borders the pond on the north and east sides. Surface area is 8.43 acres and the volume is $1.28 \times 10^6$ $ft^3$. Average depth is 3.5 feet.

Popolopen Lake (Figure 4-9) is a manmade lake with a 16 foot concrete dam. Water levels are regulated in the winter and spring to prevent ice damage to docks and shoreline buildings at Camp Buckner and to control runoff from snow melt in the spring. The two deep basins in the lake exceed the dam height suggesting shallow ponds similar to Beaver Pond existed before damming. Water from the lake is used as water supply at Camps Buckner and Natural Bridge. Treated sewerage from the camps is discharged to Popolopen Brook outside the watershed. Popolopen Lake's surface

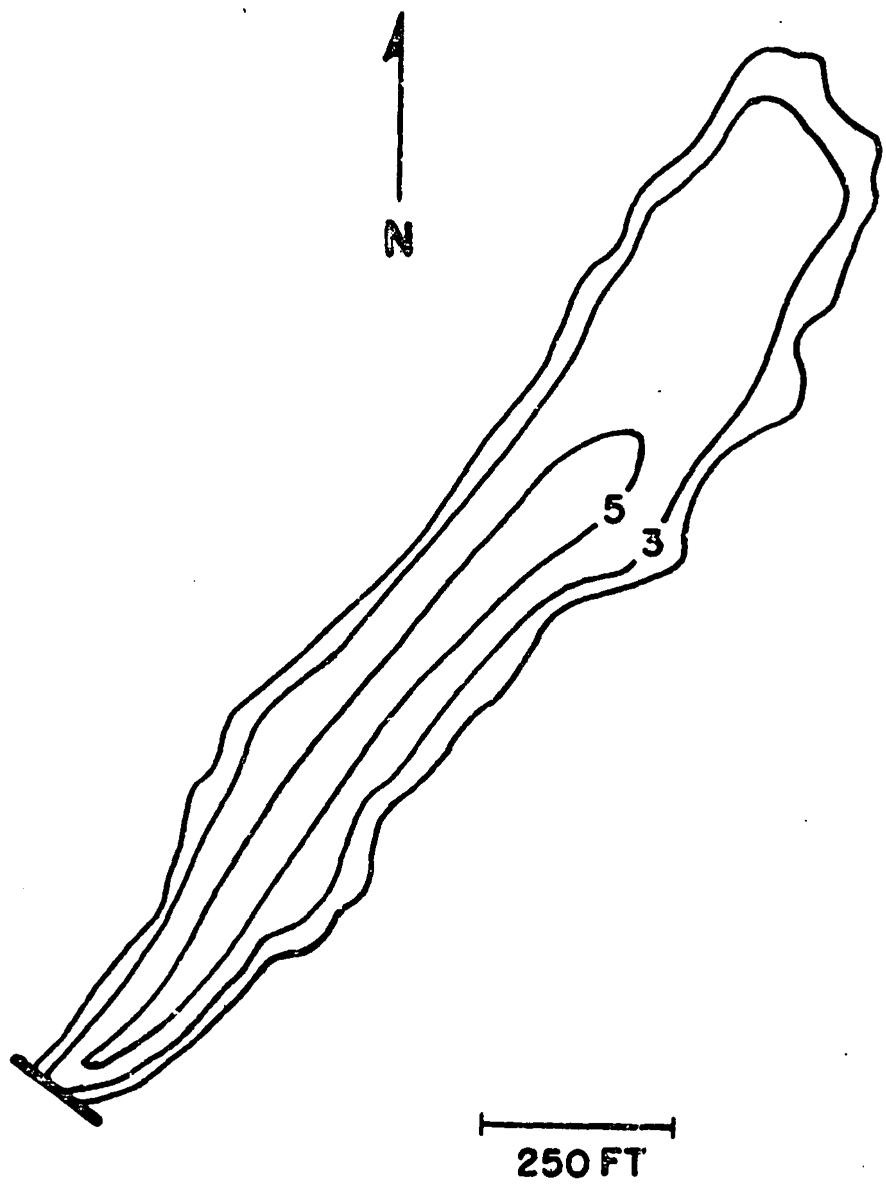


Figure 4-8. Bathymetry of Beaver Pond (source unknown).

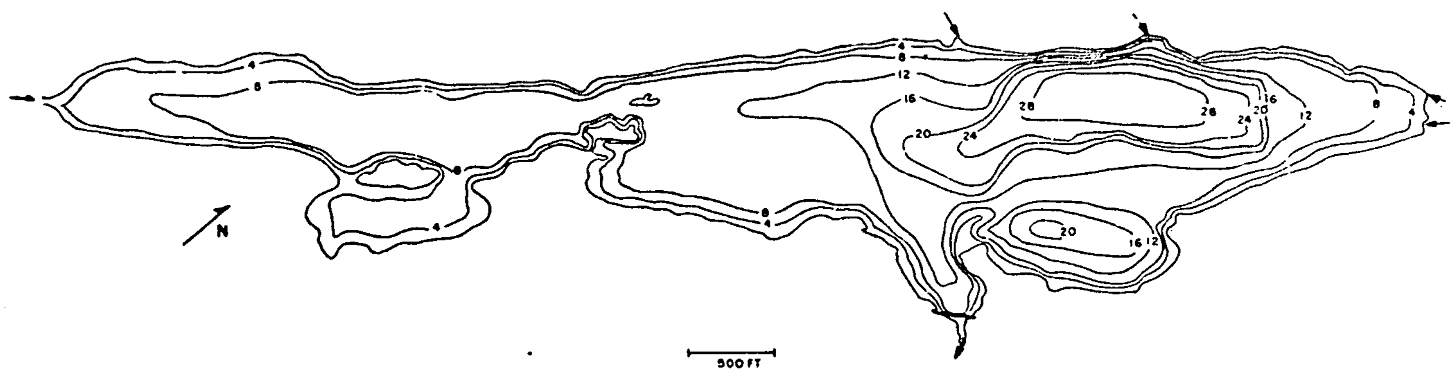


Figure 4-9. Bathymetry of Popolopen Lake (Potter Associates, 1944).

area is 148.8 acres and volume is $7.28 \times 10^7$ $ft^3$. Its average depth is 11.2 feet. Popolopen Lake serves as a recreational area for the two camps.

Bull Pond (Figure 4-10) is a natural pond in a deep depression on the ridge. An extensive lakeside wetland borders it on the southwest end. The deepest point is approximately 64 feet. A silt layer 2 to 3 feet deep covers most of the bottom. Bull Pond has a surface area of 21.6 acres and volume of $2.04 \times 10^7$ $ft^3$. Average depth is 21.6 feet. It is used as a recreational area for West Point. The natural fish population has been supplanted by hatchery trout.

Lake Georgina (Figure 4-11) is a manmade lake on the ridge. Much of its bottom is exposed bedrock. It was built to supply water to a resort at the base of the ridge near Lake Frederick. Today it is used for cadet training in crossing water obstacles and recreational fishing. Its surface area is 4.6 acres, with a volume of $2.38 \times 10^6$ $ft^3$. Its average depth is 11.9 feet.

Barnes Lake (Figure 4-12) in Palisades Interstate Park, is manmade. It provides recreation to two summer camps located on its shores. One of the two camps was abandoned in 1977. It has a surface area of 11.3 acres, and volume of $3.53 \times 10^6$ $ft^3$. Average depth is 7.2 feet.

Summit Lake (Figure 4-13) in Palisades Interstate Park is manmade. It provides recreation for a Girl Scout camp located on its shore from mid-June to late August each year. It is the water source for the camps on Summit, Barnes, Massawippa, and the Twin Lakes. Summit Lake has an extensive growth of watermilfoil (*Myriophyllum brasiliense*), spatterdock (*Nuphar advena*), and white waterlily (*Nymphea odorata*) on its bottom. Summit Lake has a surface area of 31.8 acres, and a volume of $1.30 \times 10^7$ $ft^3$. It has an average depth of 9.4 feet.

Summit Lake is the only lake of the group with extensive plant growth on its bottom. All the lakes have aquatic plants along the edge and in the shallow water, but the growth is sparse. Summit Lake is densely packed with plant growth.

### 4.5.2 Wetlands

Fifteen freshwater wetlands exist in the study area (Figure 4-3). The numbers used to identify the wetlands in Figure 4-3 will be used throughout this report. We are using Golet's (1976) scheme for wetlands in the glaciated northeast to classify these wetlands. This work has just begun. In most cases a preliminary assessment of site type has been made and is presented. The wetland classes present and the dominant wetland class have only been determined in one or two instances and are presented. It is important to keep the presence of the wetlands in mind, since the

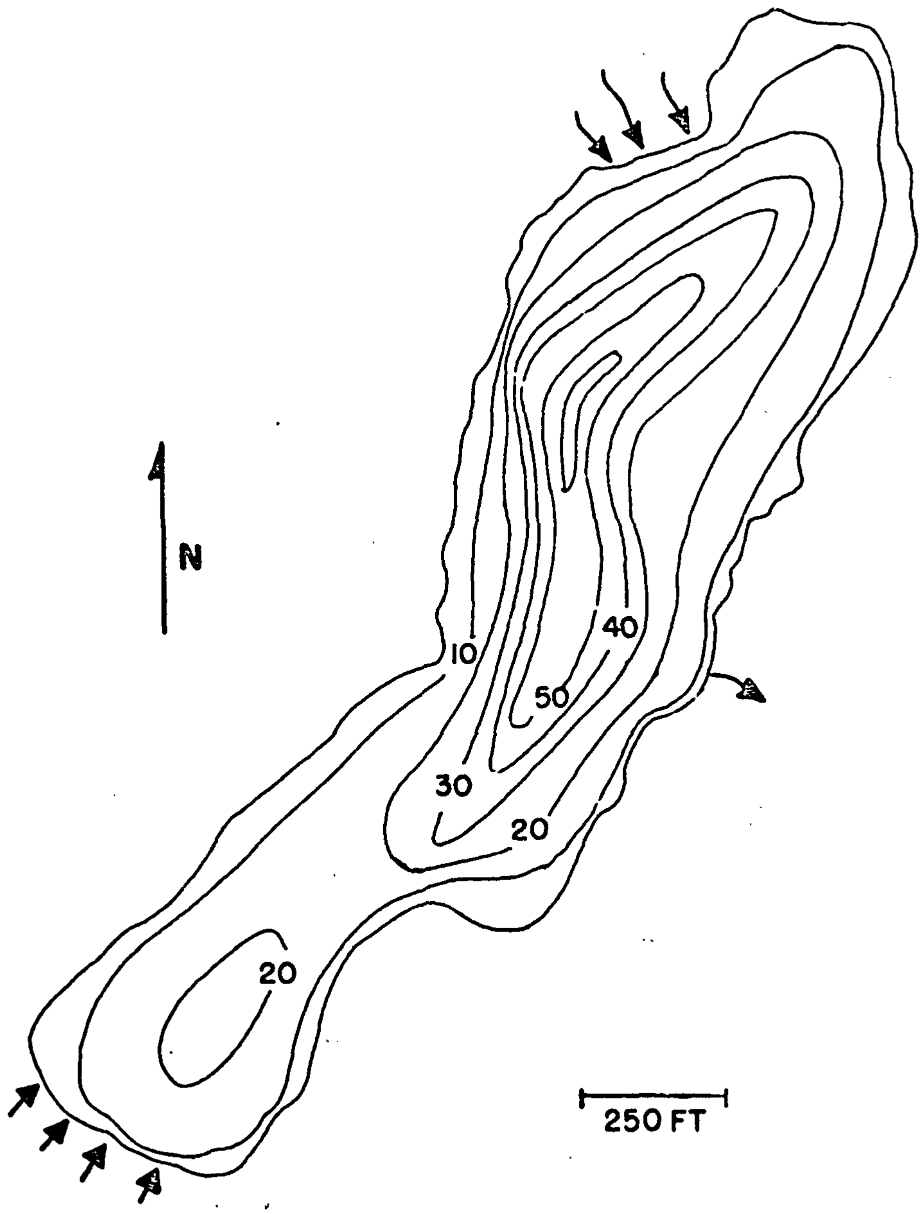


Figure 4-10. Bathymetry of Bull Pond (source unknown).

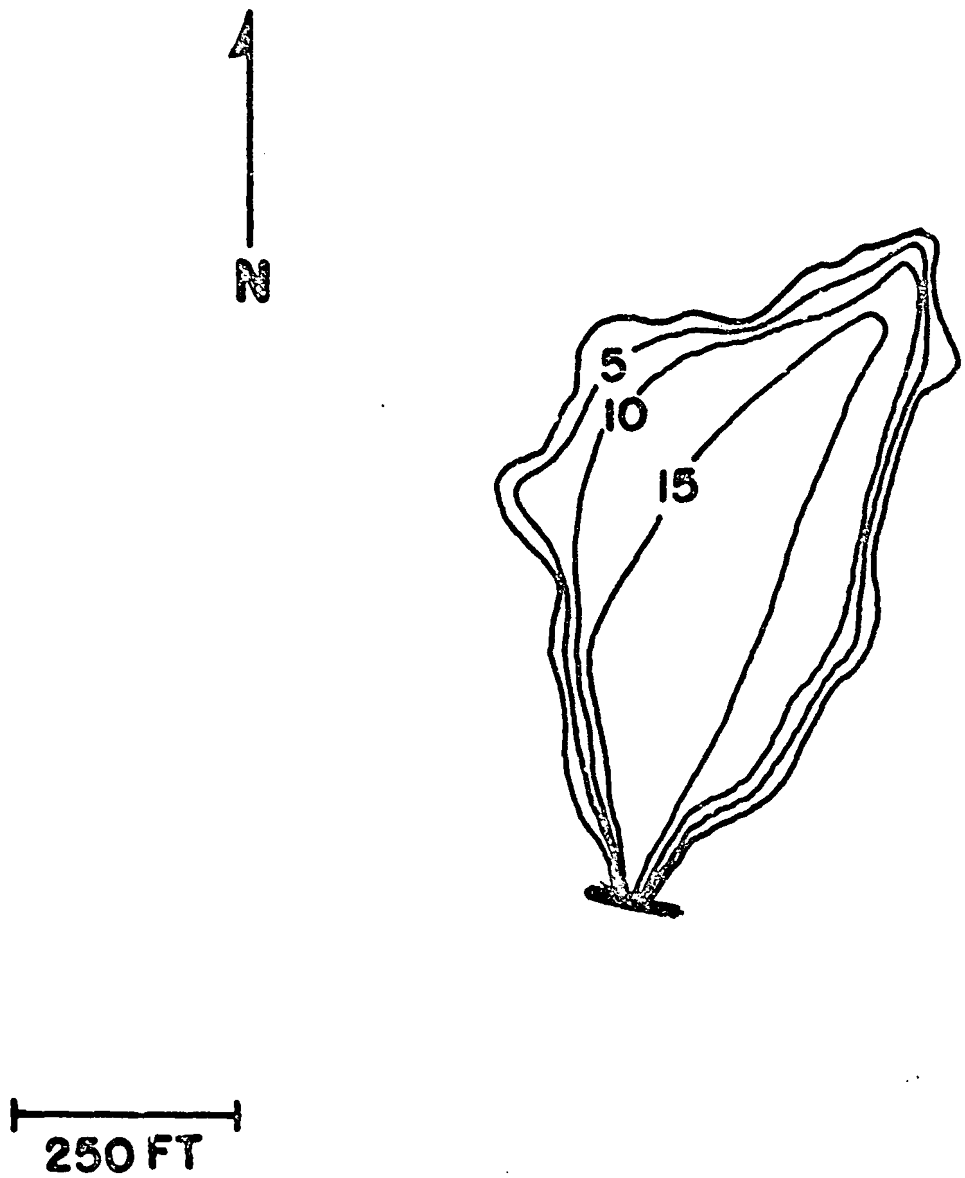


Figure 4-11. Bathymetry of Lake Georgina (source unknown).


Figure 4-12. Bathymetry of Barnes Lake (this report).

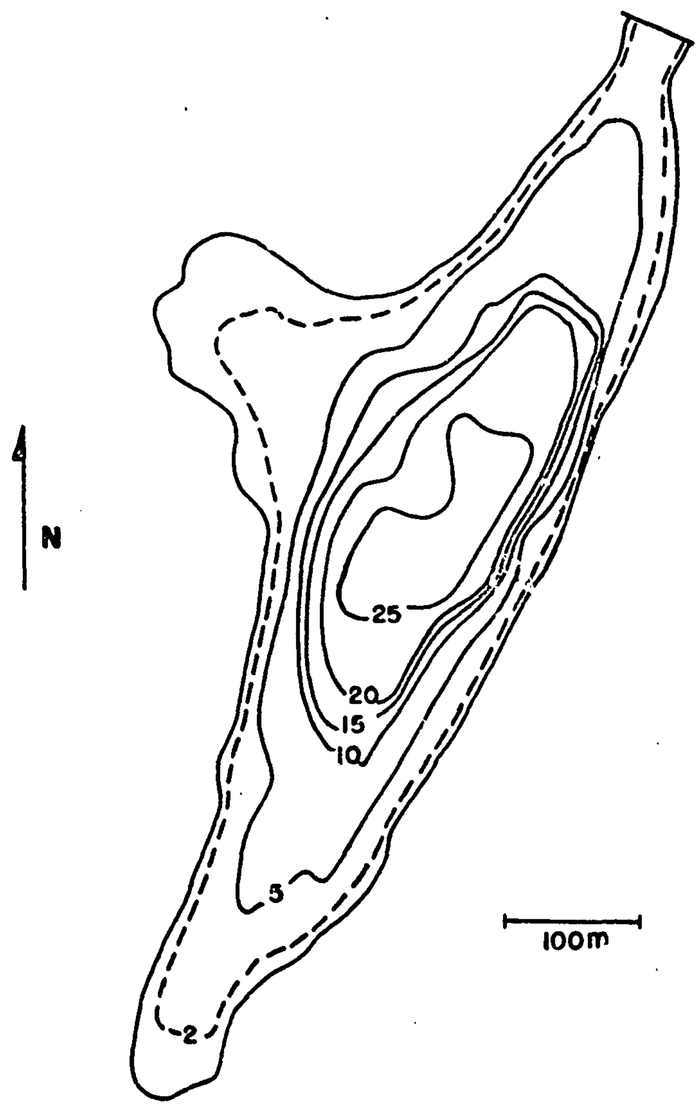


Figure 4-13. Bathmetry of Summit Lake (this report).

screening models treat wetlands as though they were gently sloping fields or meadows.

Wetlands 2, 7, 9, and 11 are upland-isolated wetlands. All were deciduous wood swamp (WS-1) at one time. The old large trees are dying off due to the water level (increased by beavers on occasion). Wetland 9 has lost all its trees, with rotting dead stumps remaining. It is better classified now as a dead woody deep marsh (DM-1). The others (2, 7, and 11) are in transition towards this state, but still should be classified as deciduous wood swamps (WS-1).

Wetlands 5 and 12 are bottomland-lakeside wetlands, although wetland 5 could just as easily be thought of as bottomland-streamside if one worked from Lake Georgina towards Bull Pond. Classes have not been worked out for these two wetlands.

Wetlands 3, 4, 10, and 14 are bottomland-streamside wetlands. Numbers 3 and 10 are deciduous wooded swamps (WS-1). Wetland 14 has not been classified. Wetland 4 has a high wetland class richness, with low vegetative interspersion. Figure 4-14 shows the concentric nature of the wetland. The central portion is floating leaved shallow marsh (SM-4). The surrounding zone is narrow-leaved shallow marsh (SM-2) characterized by the growth of Tussock sedge (Carex stricta). On the western edge of the complex is a narrow zone of sapling shrub swamp (SS-1). The southwestern (upstream) end of the wetland is bushy shrub swamp (SS-2). This zone grades into another zone of sapling shrub swamp (SS-1) and then to deciduous wooded swamp (WS-1).

Wetland 8 is a bottomland-isolated wetland of deciduous wooded swamp (WS-1). Wetland 15 is a bottomland-deltaic wetland with bushy shrub swamp (SS-2) as the dominant class. Wetland 13 appears to be a bog. Detailed plant identification to confirm this has not been completed. Wetlands 1 and 6 have not been worked on.

## 4.6 VEGETATION AND FAUNA

The forest of the study area is in the glaciated section of the oak-chestnut forest region (Braun, 1950). A number of loosely defined forest types are distinguished (Figure 4-15). The predominant community is a Red Oak community (Braun, 1950, p254; Raup, 1938, p56), found at higher elevations on generally poor rocky sites. It consists of red oak (Quercus rubra), chestnut oak (Quercus montana), sugar maple (Acer saccahrum), tulip tree (Liriodendron tulipifera), white ash (Fraxinus americana), and black birch (Betula lental). A second dominant community also found at higher elevations is the Chestnut Oak community consisting of chestnut oak, red oak, black oak (Quercus velutina), hickory (Carya sp.), and red cedar (Juniperus

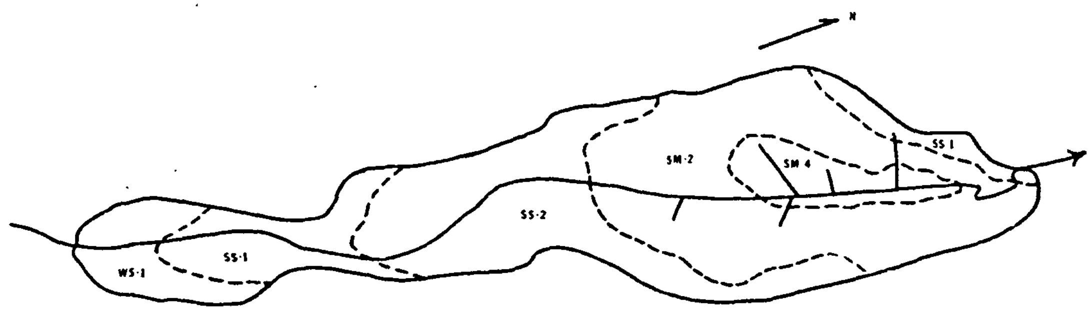


Figure 4-14. Wetland Classes in Wetland 4, West Point Study Area. See Figure 4-3 for location.

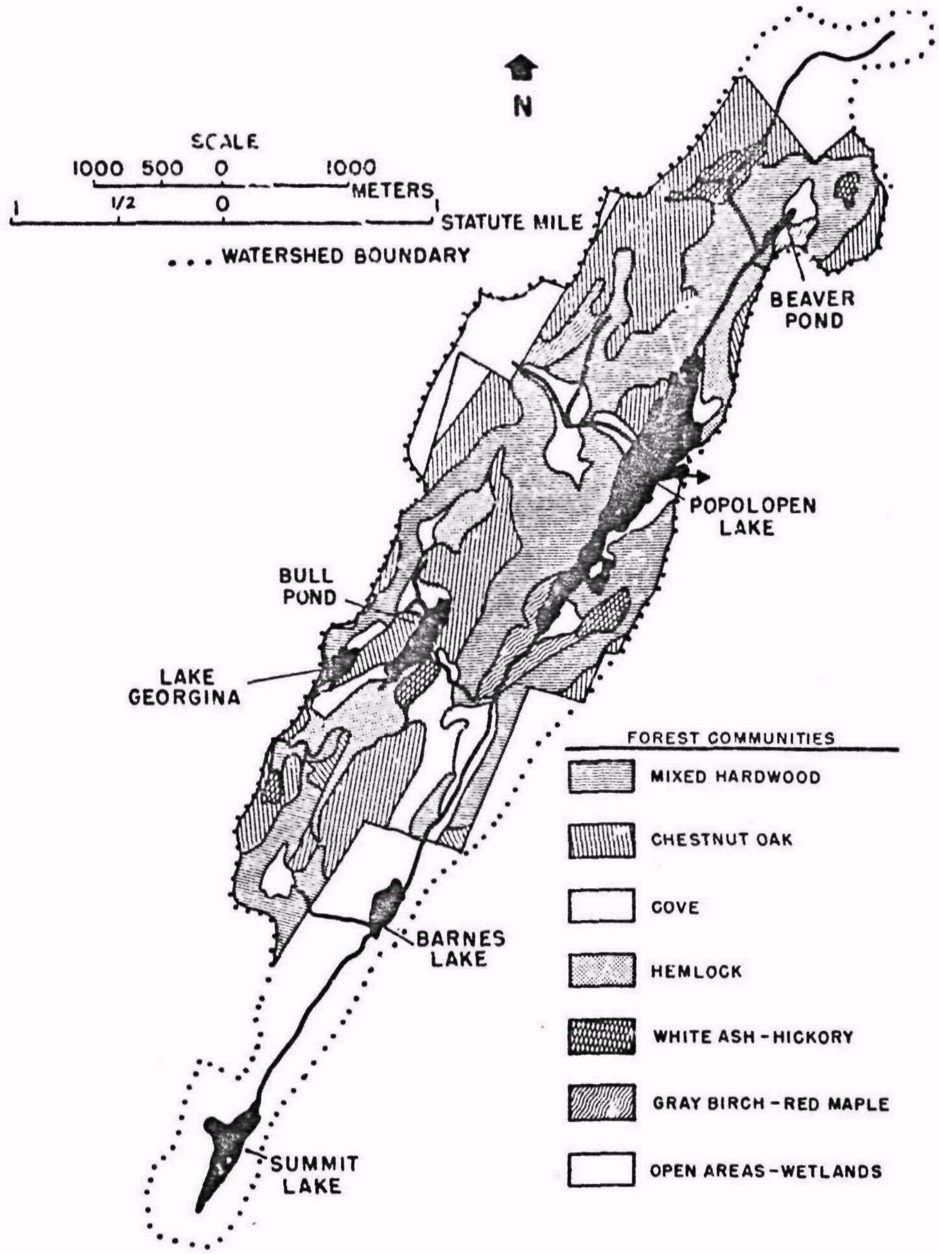


Figure 4-15. Forest Communities, West Point Study Area (after Office of the Engineer, West Point, 1962; Joe Deschenes, personal communication).

virginiana). The third forest community is Cove (Raup, 1938), found in ravines and lower north slopes with tulip tree, basswood (Tilia americana), sugar maple, red oak, white oak (Quercus alba), and white ash predominating. Poorly drained soils supported a Gray Birch-Red Maple community in Raup's time consisting of gray birch (Betula populifolia), red maple (Acer rubrum), elm (Ulmus sp.), black birch, white ash, and alder (Alnus rugosa). The gray birch is a shade-intolerant pioneer species which has almost completely disappeared from the watershed. It has been replaced by sugar maple, ash, hickory, and black birch forming what is now best described as a Red Maple Community (Deschenes, personal communication). A Hemlock community predominates on the northwesterly slopes of the ridges. In some places the stands are relatively pure hemlock (Tsuga canadensis) and in others sugar maple, white ash, yellow birch (Betula alleghaniensis), basswood, and tulip tree, are associated. The last community found is a White Ash-Hickory association not usually found in a normal climax forest. Its presence is thought to be the result of past severe cuttings of a selective nature (Office of the Engineer, West Point, 1962).

Areas within the study area have been subjected to forest fires over the years. Records prior to ownership by West Point (1938-1944) are nonexistent. The forest fire map (Figure 4-16) plots those fires known since 1951. The USMA Woodland Management Plan (Office of the Engineer, West Point, 1962) states that "over a period of years, almost all of the woodlands in this region have been repeatedly burned. The fires were generally surface or ground fires whose apparent damage was then deemed insignificant...." It is possible that additional areas may have been burned for which we have no record.

Fauna common to northern hardwood forests occur within the study area (Appendix C). An over population of white tail deer (Odocoileus viginianus) exists due to restricted hunting on the U.S. Military Academy Reservation, and no hunting or bow-only hunting in the Palisades Interstate Park to the south and north of the study area. Browse damage to tree seedlings has prevented efforts at reforestation.

## 4.7 LAND USE

Much of the land within the study area has always been wooded because the steep terrain precludes agricultural use. Small to moderate sized farms were present prior to West Point's acquisition of the property (1938-1944). Stone walls, building foundations, and overgrown apple orchards exist, mainly on the near-level portions with good soil.

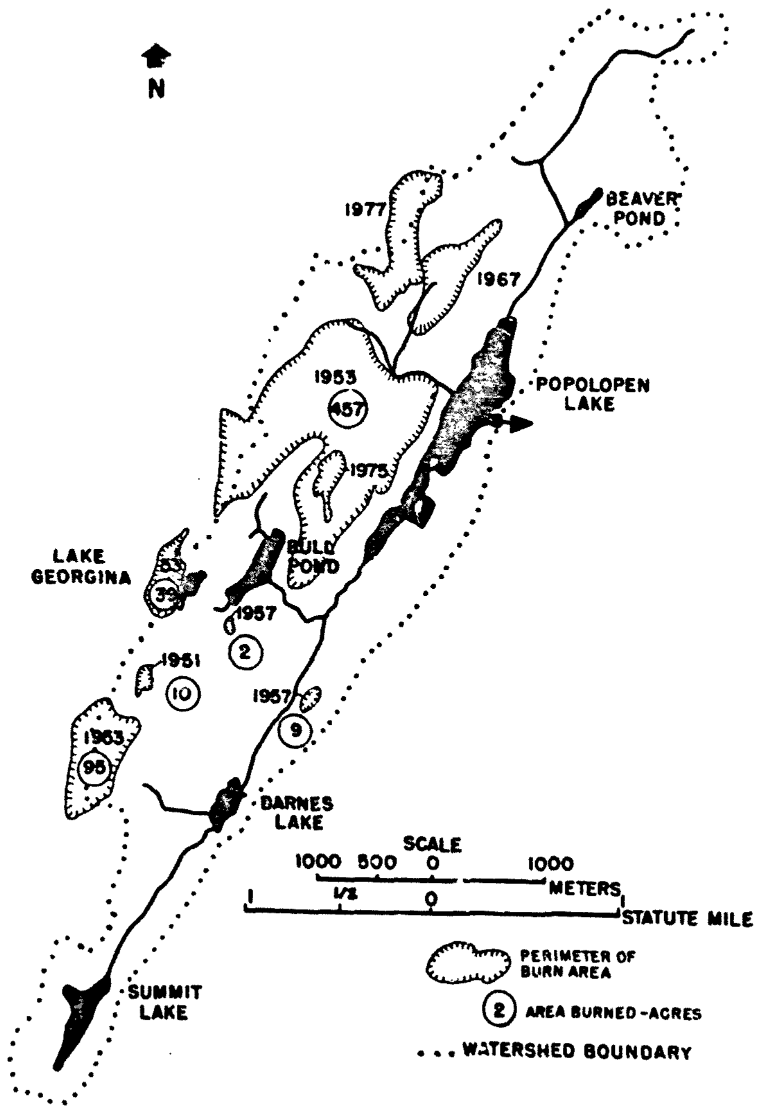


Figure 4-16. Forest Fire History Since 1951 (after Office of the Engineer, West Point, 1962; Joe Deschenes, personal communication).

Forests in the area were cut to supply charcoal to the many brickyards along the Hudson River and charcoal and mine timbers for the iron mining operations centered in the Stilwell Lake area. No detailed record exists of the cutting history for most of the area. The Woodland Management Plan for USMA (Office of the Engineer, West Point, 1962) contains a map of the USMA reservation with cutting histories as known prior to 1942. Information from this map has been abstracted as it applies to the study area (Figure 4-17). In addition recent commercial cuttings have been plotted based on the USMA forester's records (Joe Deschenes, personal communication).

The Palisades Interstate Park area is a nature preserve and, except for the camp areas, has remained wild since acquisition (date unknown). Several foundations and stone walls are in evidence within the Park area indicating some prior occupation.

Today the USMA reservation is primarily used to support summer military training of cadets. Army Reserve and ROTC units use the ranges and training areas in the spring and fall for the same purpose. Areas within the study area are used for small unit tactics, land navigation, etc., with the exception of one small demolition range adjacent to wetland 4 (Figure 4-3). Some use of the area is made by West Point personnel for recreation. Two camps, Natural Bridge and Buckner, are located on the shores of Lake Popolopen. A cabin complex is located adjacent to Bull Pond. Non-potable water is derived from a well. Drinking water is brought in. Sewage is collected in a concrete septic tank.

The portion of the study area in Palisades Interstate Park is used for non-profit group camping during the period from mid June to late August. A Girl Scout camp, Camp Teata, belonging to the Paterson, New Jersey, council is located at Summit Lake. As mentioned previously Summit Lake also serves as the water supply for this camp, and several others outside the study area. Two camps are located on the shores of Barnes Lake. One was abandoned in 1977, and the other is occupied on a family basis by individuals from the Central Valley (N.Y.) Colony Club. All the Palisade camps use pit septic tanks for sewage.

The USMA woodlands are managed by a professional forester. Military training requirements and use of the study area for water supply have precluded clear cutting or strip cutting. A selection system requiring marking of salable timber is currently practiced. Current practice calls for cutting within an area approximately every 16 years to achieve an all-aged crop as opposed to the even-aged crop existing in many areas. Timber is harvested by commercial sawyers under contract to the government (Joe Deschenes, USMA forester, personal communication; Office of the Engineer, West Point, 1962).

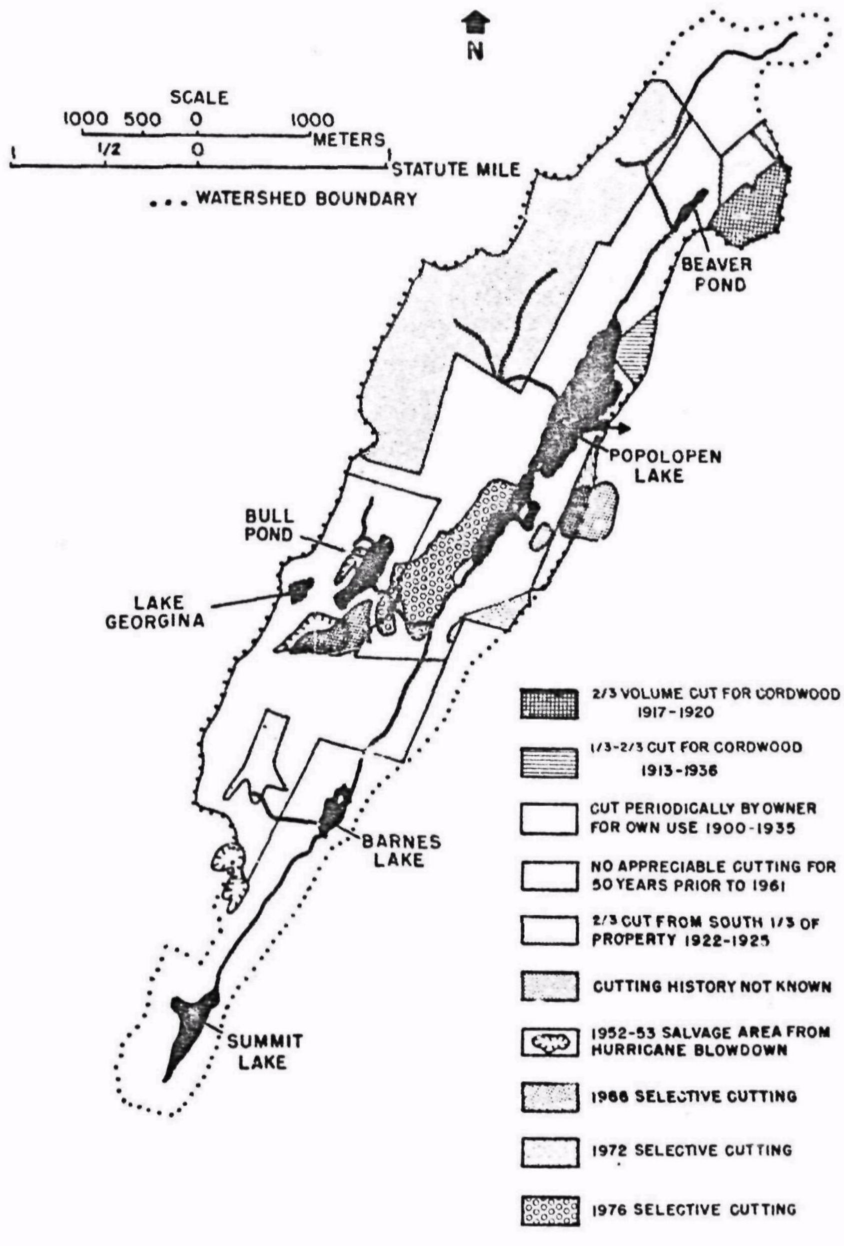


Figure 4-17. Timber Cutting History as Known (after Office of the Engineer, West Point, 1962; Joe Deschenes, personal communication).

## SECTION 5

## NONDESIGNATED 208 AREA SCREENING METHOD MODELS

### 5.1 INTRODUCTION

In 1977 the Environmental Protection Agency published a set of water quality models developed by Tetra Tech, Inc., for screening Nondesignated 208 (Section 208 of the Federal Water Pollution Control Act Amendments of 1972) areas (Zison et al., 1977). These models are intended to provide planners with simplified desk top methods for preliminary assessment of surface water quality with little external data input.

This screening method provides for the assessment of:

1. Wasteloads from point and nonpoint sources.

2. Quality of stream waters.

3. Lake water quality.

4. Estuary quality and classification.

In general terms the screening method models are applied as follows.

1. A rough estimation of wasteloads is made from both point and nonpoint sources. Such pollutants as sediment, nutrients, organic matter, salts, heavy metals, pesticides, coliforms and others are considered.

2. Wasteloads are used as inputs to the stream water quality model. Stream processes are modeled to determine water quality in terms of biochemical oxygen demand (BOD), dissolved oxygen (DO), temperature, nutrients and eutrophication, coliforms, conservative constitutents, and sediments and suspended solids along the length of the receiving stream.

3. Estimated or measured wasteloads are used either directly or as modified by in-stream processes as inputs to either impoundment or estuary models. Lake processes

are modeled to determine thermal stratification, sediment accumulation, eutrophication, and dissolved oxygen conditions. Estuaries are modeled to determine thermal pollution, turbidity and sedimentation, flushing time and pollutant concentrations.

## 5.2 APPLICABILITY TO THE WEST POINT STUDY AREA

The nature of the West Point Study Area, as described earlier, is such that the use of the screening method models is limited.

### 5.2.1 Wasteloading Estimation

Wasteloads from point sources will not be addressed because the study area contains no significant point sources; in fact, only one continuously occupied single family home is present in the study area.

Nonpoint wasteloads are estimated for sediment, nutrients (nitrogen and phosphorus) and organic matter. Due to lack of irrigated farms in the study area, salinity is not modeled.

### 5.2.2 River and Stream Quality

The river and stream quality portion of the screening method models is designed to predict responses of rivers to waste loading schemes and assumes steady-state flow conditions on the order of a week or longer (Zison *et al.*, 1977, page 136). The streams in the West Point Study Area are too small to allow much if any in-stream response. The longest reach is a little more than one mile in length with travel time of water in the stream on the order of one or two hours. We will treat streams as transport mechanisms only and will not model any water quality other than accumulated nonpoint loadings.

### 5.2.3 Lake Water Quality

The West Point Study Area contains several small lakes ranging in depth from 13 to over 60 feet (Section 4.5.1). These lakes will be modeled for thermal stratification, sediment accumulation, eutrophication, and dissolved oxygen based on the estimated nonpoint wasteloads.

### 5.2.4 Estuaries

No attempt will be made to utilize the estuary models, because the study area contains no estuaries.

## 5.3 AREAS MODELED

The entire watershed tributary to Popolopen Lake will be modeled for this study. Individual sub-areas are shown in Figure 5-1. The ground surface of all areas will be modeled individually for nonpoint wasteloads of sediment, nitrogen, phosphorus, and organic matter. In addition composite loads from areas 1 through 4 and for the entire study area will be predicted.

The estimated wasteloads of area 1 will be used as inputs to Summit Lake, which will be modeled for sedimentation, eutrophication, and thermal stratification. Similarly the estimated nonpoint loads of areas 1, 2, and 3 will be used as inputs to Barnes Lake. Barnes Lake will be modeled for the same properties as Summit Lake.

Area 5 will be modeled to determine estimated nonpoint loadings of sediment, nutrients, and organic matter. These will be used as inputs to Bull Pond, which will be modeled for sedimentation, eutrophication, thermal stratification, and hypolimnion dissolved oxygen.

Popolopen Lake will be modeled for the same characteristics as Summit Lake. Inputs will be the nonpoint loads predicted from the entire watershed. Where data exist, actual outflow of lakes will be used rather than predicted nonpoint loadings which do not reflect in-lake processes.

The many wetlands in the study area (Section 4.5.2) will be treated as much as possible as land surface for wasteload estimation. Subsequent studies will allow us to measure the inputs and outputs of some of these wetlands to evaluate this analysis method.

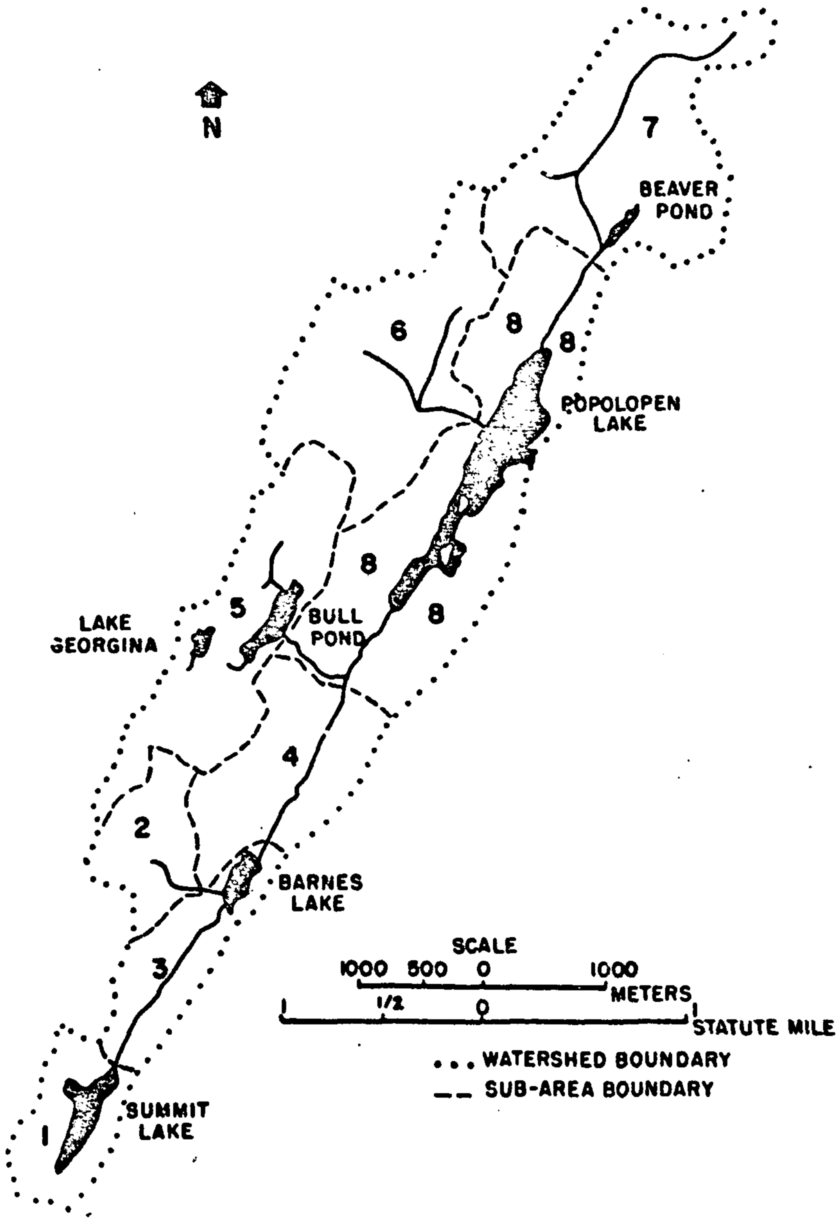


Figure 5-1. Sub-Area Basins Within The West Point Study Area.

SECTION 6

# DATA COLLECTION

## 6.1 INTRODUCTION

This section details the establishment of the data collection network on the West Point Study Area. The network described is designed to gather data for the EPA supported model testing program and to serve as the basis for a future program dealing with the hydrology and nutrient budgets of wetlands. Data gathered will serve four purposes:

1) input to a simulation model on which the algorithm bases its prediction.

2) data against which the model prediction will be compared during the calibration of the model to the West Point Study Area.

3) data against which the prediction from the calibrated model will be compared to verify that the model is providing valid predictions.

4) data to support the wetland studies.

Data needs are in the following areas.

1) Hydrology - stream flow, evaporation, precipitation, etc.

2) Meteorology - temperature, dew point, radiation, wind speed, etc.

3) Physical characteristics of the watershed - area, slope, soil depth, soil types and extent, cover, aspect, etc.

4) Water Quality - both chemical and biological.

5) Rate constants for reactions.

The establishment of a data network and supporting laboratory facilities is a cyclical process that may require several iterations of parameter estimation, equipment specification, parameter measurement, adjustment of equipment specification, etc. until the best configuration for providing reliable data within the budget allowance is found. This is a frustrating process which may take a year or more as one progresses through the seasonal variations and the vagaries of the year to year variations in parameters. Ultimately we have found that compromises must be made or that more than one data sensor may be needed to back up another for conditions encountered.

## 6.2 HYDROLOGIC DATA ACQUISTION

Included here are those parameters needed to define the transport of water through the watershed: precipitation, evaporation, transpiration, interception, infiltration, percolation, storage, and runoff (Gray, 1973). We have chosen to make as much use of prior records for stations in the vicinity of West Point as possible. Our approach to this has been to duplicate the parameter measurement within the study area over a period of time, then to correlate the two stations. Once correlated, the assumption is made that the relationship between the two stations has held over time and the older station data are adjusted to reflect the differences between the two locations. Where possible several stations are correlated for each parameter. As the period of record on the study area increases the correlations are updated.

### 6.2.1 Precipitation

Model requirements for precipitation data vary greatly. The nondesignated 208 area screening model (Zison *et al.*, 1977) requires average annual precipitation (see Section 7), whereas the NPS model (Donigian and Crawford, 1976) requires hourly or 15-minute rainfall data and the updated version of the ARM model (Donigian and Davis, 1978) requires hourly, 15-minute, or 5-minute rainfalls. A new EPA comprehensive watershed model currently in the formulation stage at Hydrocomp, Inc. - Hydrologic Simulation Programming in Fortran (HSPF) - will give the user the choice of 19 precipitation periods starting from 1 minute (Johanson, personal communication).

National Climatic Center precipitation data are available for sites surrounding the study area (Figure 6-1) in hourly and daily formats. Hourly precipitation data for Poughkeepsie, N.Y., Yorktown Heights, N.Y., Carmel, N.Y., and Oakland Valley, N.Y. (see Figure 6-1) are being collected by purchasing tapes of past records from the National Climatic Center and by subscribing to *Hourly Precipitation Data* (National Climatic Center). Daily precipitation data have been collected from the same four stations, plus West Point by purchase from the National Climate Center and subscription to *Climatological Data* (National Climatic Center). In addition, the Palisades Interstate Park Commission

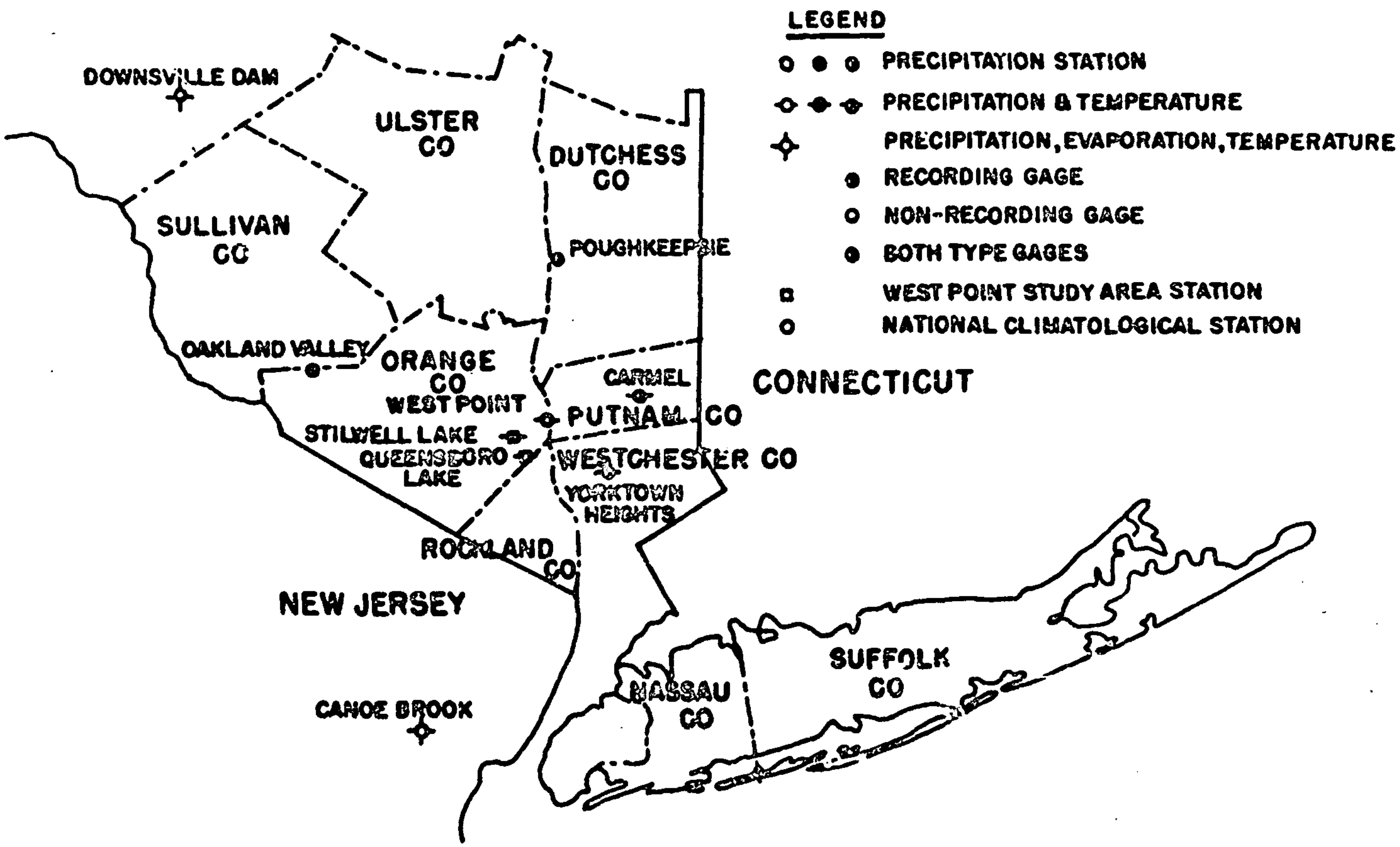


Figure 6-1. Climatogical Stations Used as a Source of Data for Modeling in The West Point Study Area.

has made available daily precipitation data with 22 years of record at Queensboro Lake, Bear Mountain, New York.

To meet the demands of future modeling efforts, recording rain gages were installed in the study area. A Weathermeasure model P511E heated tipping bucket gage was installed at Stilwell Lake (Figure 6-2) in June 1978. In June 1979 a Belfort model 5-780 double traversing weighing rain gage was collocated with the tipping bucket. The tipping bucket records on a 30-day chart with 5-minute time resolution; the weighing gage records on a 7-day chart with 20-minute time resolution. Both will be converted to record on a digital tape recorder in the future for better time resolution and ease of data handling.

The Stilwell Lake site was chosen outside the study area proper (Figure 6-2) to accommodate the radiation meter (see Section 6.3.1). It also afforded us a source of electricity, security, and occupation by West Point personnel on a daily basis, particularly during hunting season. The site was also accessible year round.

As a measure of the heterogeneity of the rain over the study area, supplemental weighing rain gages will be placed at several locations on the watershed. Few open sites exist on the study area that meet gage placement criteria (McKay, 1973). These locations are biased to lowland clearings on fairly level ground, although some upland locations exist that will be difficult to service in winter. Densities for agricultural watersheds recommended by Holtan et al. (1962) will be used as a starting point for determining gage density. For a watershed the size of our study area (3247 acres), 1 gage per square mile is recommended. Because of terrain considerations we will double the density to a minimum of 2 gages per square mile, while trying to balance the number of upland and lowland gages.

### 6.2.2 Evaporation

Evaporation data from the National Climatic Center stations at Downsville Dam, N.Y. and Canoe Brook, N.J. (Figure 6-1) have been obtained on computer tape and through subscription to Climatological Data (National Climatic Center) for New York and New Jersey. The daily service requirements of a standard U.S. Weather Bureau Evaporation Pan have caused us to choose a substitute evaporation sensor which measures evaporation from a wetted filter paper housed in an aspirated shelter. This instrument will be installed at Stilwell Lake when budgetary considerations permit. Evaporation data are required inputs to the NPS and ARM models.

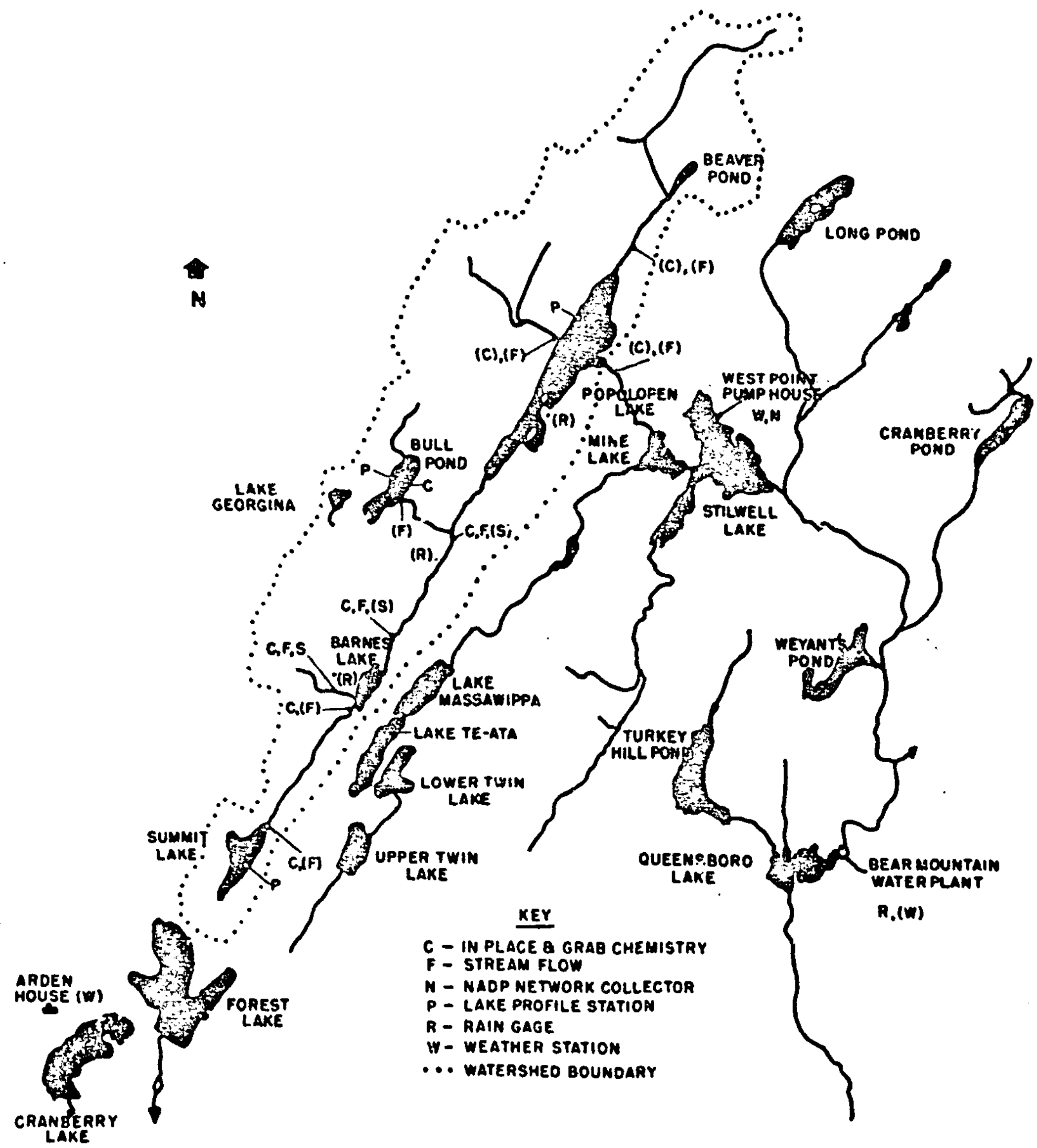


Figure 6-2. Sampling Sites and Instrument Locations, West Point Study Area. Sites in parentheses are projected.

## 6.2.3 Transpiration, Interception, Infiltration, Storage

A number of prepositioned aluminum wells for use with a neutron soil moisture meter are being implaced. They will be used to monitor soil moisture conditions. No attempt will be made to measure transpiration, interception, and infiltration parameters at this time.

## 6.2.4 Streamflow

Streamflow is perhaps the most important parameter in our modeling studies because it is the prime indicator of calibration and verification. It has also been the most difficult to measure. The sections below present our solution to the streamflow measurement problem.

### 6.2.4.1 Site Selection/Sub-basins

Discharge gaging stations were chosen to monitor areas suitable for modeling purposes and to provide input/output data for the wetland study. Site locations are shown on Figure 6-2. At the present time only those stations at the exits of sub-basins 2, 3, and 4 (Figure 5-1) have been constructed. Those at the exits of areas 1, 5, 6, 7, and 8 have been designed and construction sites have been surveyed.

### 6.2.4.2 Discharge Measurement

A number of standard references were consulted to determine the best kind of primary discharge measurement device for the watershed (Kulin and Compton, 1975; Carter and Davidian, 1968; Buchanan and Somers, 1969 a and b; Bureau of Reclamation, 1975). Standard thin plate weirs looked easy to construct, implace, and maintain. The added benefit of readily available calibration tables reinforced this approach. A 45-degree V-notch weir of 1/4-inch aluminum plate reinforced with steel angle was implaced at the exit of sub-area 3 in the fall of 1977. Problems were encountered with sealing the edges of the plate to be sure that all flow went through the weir. Polyethylene sheeting bolted to the weir plate and held in place by water pressure performed well for a year, but became brittle and tore easily after one year in place. The requirements to be met for weir implacement and use (Bureau of Reclamation, 1975, page 12-13) created pool depths for the range of flows encountered such that heavy duty reinforcement was needed to prevent plate bending. During the first winter (1977-78), combined ice and water loads bent a 36-inch high by 1/4-inch thick aluminum plate reinforced with 2-inch angle iron. Under load conditions in the stream, bending was greater than six inches. Another approach was needed. V-notch characteristics at low flow conditions in the summer were desirable, but rectangular notch characteristics were needed at other times. It was decided to compromise and create a compound weir with low flow V-notch and rectangular notch or notches. Standard calibration curves

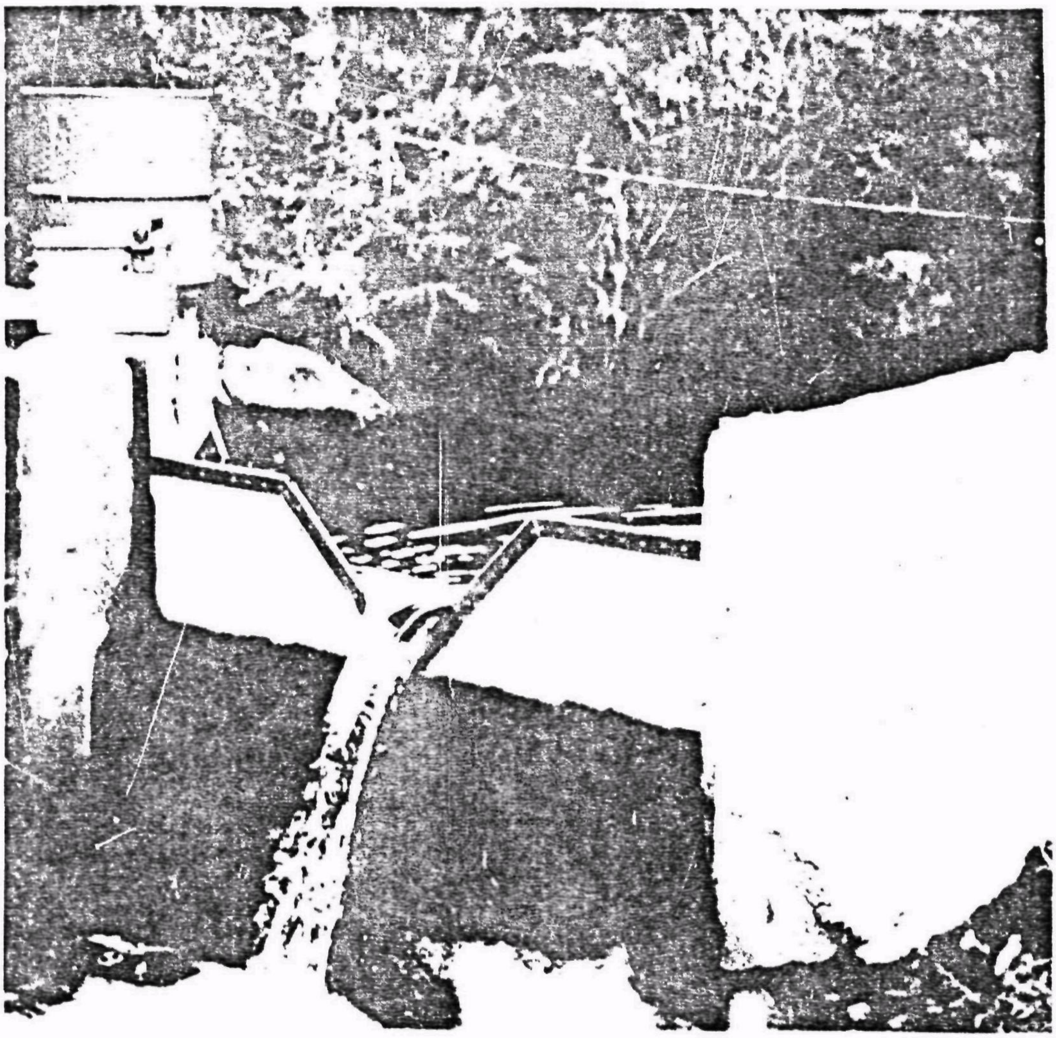

Figure 6-3. Compound Thin Plate Weir at the Exit of Sub-Area 2. V-notch is 15 inches high. Rectangular notch is 5 feet wide. Dipping stage recorder in metal box at left. Dipper dips in pipe cast in the wall.

were available for the lower V-notch portion of the weir but not for the combined weir. Calibration by volumetric methods and current meter (Buchanan and Somers, 1969b) are being used to establish flow ratings in place.

The exit to sub-area 4 presented measurement problems of a different nature. Wetland 4 is within the sub-area and close enough to the exit so as to be permanently influenced by any kind of flow structure which created a pond behind it. Several flumes were looked at and a cutthroat flume (Skogerbee et al., 1972; Bennett, 1972) with 6-foot throat and 9-foot length was chosen. This flume would raise the water level approximately 3-inches under average spring and fall conditions and should have minimum effect on the wetland. The structure was implaced in October 1978.

6.2.4.3 Stage Measurement

A number of recording stage meters for keeping 24-hour or 7-day records behind each weir were examined. Floats were not used because of the added problems in building stilling wells. Bubble type meters were not used because of exposure of the bubbler tube and the battery or canned gas requirements for these instruments. A Manning model 3030 dipping flow meter with linear (height) cam was chosen. These instruments were easy to calibrate and implace. They proved fairly reliable in warm weather, but needed battery changes every two to three days in cold weather. Once the water surface froze, the instruments ceased to operate since ice does not conduct electricity and the instrument can no longer detect the surface. Staff gages are being installed for the winter of 1979-80 and will be read every day to get an approximation to the winter flow. A new radio frequency sensor based instrument which will operate year round will also be tried at the same time.

6.2.4.4 Velocity Measurements

Calibration of each weir site is an ongoing task. In the summer, readings are made with a large plastic garbage can which has 20, 25, and 30 gallon levels marked internally. Water is directed to the can by a chute constructed of aluminum stove pipe. A stop watch is used to time the interval required to fill the can to the level of interest. Ten or more repetitions are made at each calibration point to minimize random errors.

The U.S. Geological Survey (Buchanan and Somers, 1969b) procedures for use of the Price pygmy and Price type AA current meters mounted on a top-setting wading rod have been adopted for calibrations at higher flows. Most stream depths in the area are below 2.5 feet and the six-tenths-depth method has been utilized. Calibration curves are constantly checked as new data points are established to make sure the new point is not significantly different from an old one indicating a change in the stream channel or damage to the current meter.

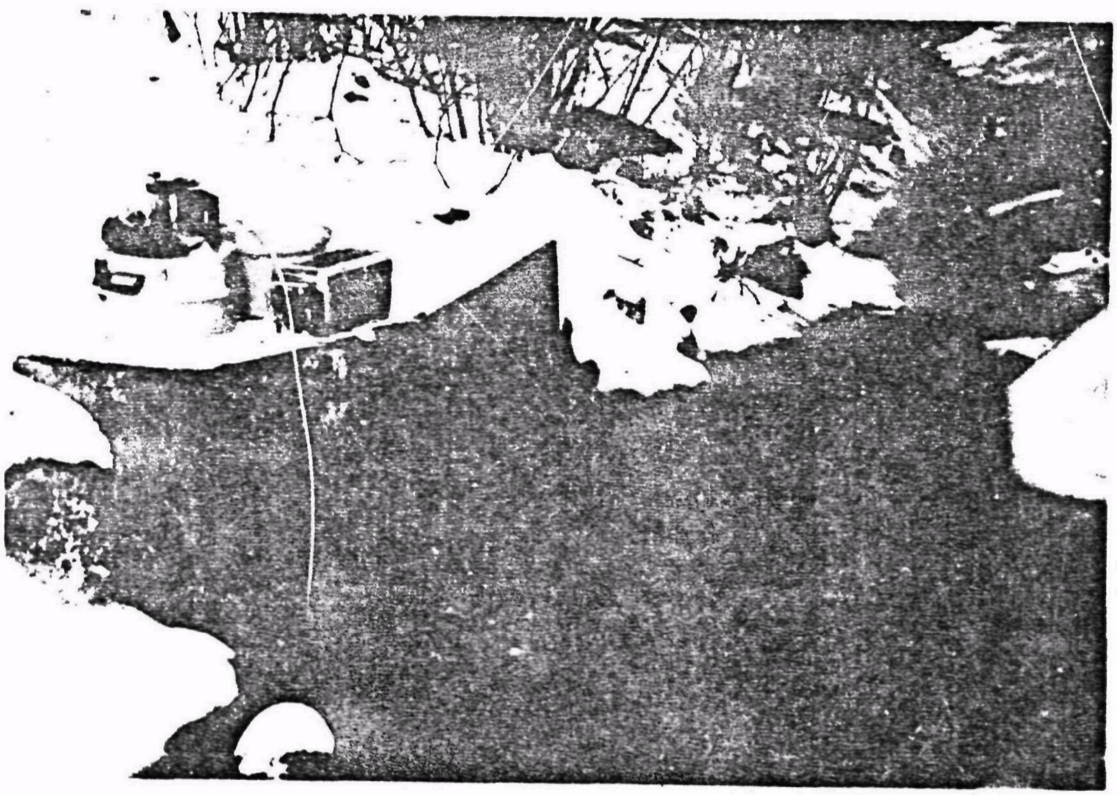

Figure 6-4. Cutthroat Flume at the Exit of Wetland 4 and Sub-Area 4.

## 6.3 METEOROLOGY

Meteorological data requirements vary from model to model. Precipitation and evaporation data requirements have been presented in the hydrology discussion (Section 6.2.1). The Nondesignated 208 Area model has no other meteorological data requirements. The NPS and ARM models require daily maximum and minimum air temperature, and daily solar radiation data for modeling snow accumulation and melt processes.

### 6.3.1 Stilwell Lake Station

In June 1978 a Weathermeasure recording weather station was activated at the pump house at Stilwell Lake (Figure 6-2) on the USMA reservation. Instrumentation at the site measures barometeric pressure, dewpoint temperature, ambient temperature, wind speed, wind direction, and rainfall (tipping bucket rain gage). In July 1979 a weighing rain gage and National Atmospheric Deposition Program wet-dry collector were collocated at the site. In October 1979 incoming, outgoing, and net radiation gages will be added to the station. All sensors (except weighing rain gage) record on a multipoint chart recorder. Each sensor is polled, in turn, once every 30 seconds.

### 6.3.2 Future Expansion

As part of another EPA supported program (Robertson *et al.*, 1979), additional weather stations are planned which will also supply data to this study. The first will be at the Bear Mountain water plant at Queensboro Lake (Figure 6-2). Existing daily precipitation data from this station will be supplemented with recordings of rainfall (tipping bucket rain gage), ambient temperature, wind speed, and wind direction. The second station is proposed for Arden House (Figure 6-2), a retreat house belonging to Columbia University located on the edge of the Reading Prong about 1 mile southwest of Summit Lake. This station will be at least the same as the Queensboro Station, but may have additional sensors similar to the Stilwell Lake site.

## 6.4 WATER QUALITY

Biweekly grab samples are taken in polyethylene bottles at the seven sampling locations shown on Figure 6-2 and returned to the laboratory for further analysis. At the same time, in-situ measurements of temperature, dissolved oxygen, pH, and conductivity are made with a Horiba model U-7 water quality checker. The Horiba instrument has a 10-meter cord and is also used for DO, pH, and conductivity profiles in Bull Pond and Summit Lake. Temperature profiles are made with a Cole Parmer Electronic Thermometer with weighted thermistor sensor which reaches to 65 feet.

### 6.4.1 Chemical

No preservatives are used since samples are returned to the laboratory and analyzed within 3-hours of collection. A Dionex model 14 Ion Chromatograph is now utilized to analyze for $Na^+$, $K^+$, $NH_4^+$, $Ca^{+2}$, $Mg^{+2}$, $F^-$, $Cl^-$, $PO_4^{-3}$, $NO_3^-$, and $SO_4^{-2}$. A Varian model 1280 atomic absorption spectrophotometer equipped with a Varian model 90 carbon rod atomizer and Varian model 53 automatic sampling device is used for heavy metal analyses. Detailed laboratory procedures will be presented with field data in future reports.

### 6.4.2 Biological

Total and fecal coliform analyses are performed during the summer months on specially collected samples using standard methods. BOD readings presented were performed at the U.S. Military Academy Water Plant. Additional readings have been performed in-house using a dissolved oxygen sensor rather than standard techniques.

## SECTION 7

## APPLICATION OF SCREENING METHOD MODELS TO THE WEST POINT STUDY AREA

### 7.1 INTRODUCTION

In this chapter we describe the application of the screening models to arrive at predicted water quality characteristics in the West Point Study Area. All eight sub-areas of the study area will be modeled for nonpoint wasteloads. Predictions will also be made on wasteloads from a composite of area 1 through 4 and of the total study area, areas 1 through 8. Several of the lakes in the study area will be modeled for impoundment water quality characteristics.

### 7.2 NONPOINT WASTELOAD ESTIMATION

The nonpoint wasteloads of sediment, nitrogen, phosphorus, and organic matter will be estimated using the methods described by Tetra Tech, Inc. (Zison et al., 1977, Chapter 3) and taken from a handbook prepared by the Midwest Research Institute (McElroy et al., 1976). The estimated loads of nitrogen, phosphorus, and organic matter are closely related to the sediment loading function which is basically the Universal Soil Loss Equation (Wischmeier and Smith, 1965). This equation was developed to predict average annual sediment yield from surface erosion on agricultural watersheds east of the Rocky Mountains.

Two basic problems may restrict the application of the nonpoint model to the West Point Study Area: 1) the study area is almost totally forested with no agricultural land, 2) the assumption that the majority of the nutrient and organic loads are tied to sediment may not hold for watersheds having relatively low sediment yields. Little work has been done on applying the Universal Soil Loss Equation to forested lands and thus input parameters are less clearly defined. Both of these problems are recognized and presented in the model discussion (Zison et al., 1977, Pages 17-18 and 84-86). It may be, then, that we are applying these loading functions beyond the region for which they were designed or are valid. Subsequent comparison of predicted and actual loading data will allow us to address these issues;

for the present, however, we will assume that the loading functions can be used to predict wasteloads in the West Point Study Area.

### 7.2.1 Sediment Loading Function

The sediment loading function may be stated as:

$$Y(S)_E = \sum_{i=1}^{n} [A_i \cdot (R \cdot K \cdot LS \cdot C \cdot P \cdot S_d)_i] \qquad (7\text{-}1)$$

where:

- $Y(S)_E$ = sediment loading from surface erosion, tons/year
- $n$ = number of sub-areas in the area
- $A_i$ = surface area of sub-area i, in acres
- $R$ = the rainfall factor, expressing the erosion potential of average annual rainfall. The dimensions of the rainfall factor are erosion-index units.
- $K$ = the soil-erodibility factor expressed in tons per acre per R (or erosion-index unit)
- $LS$ = the topographic factor, a dimensionless ratio reflecting the influence of slope length and steepness
- $C$ = the cover factor, a dimensionless ratio reflecting the influence of surface vegetation
- $P$ = the erosion control practice factor, a dimensionless ratio reflecting the influence of measures taken to control surface erosion
- $S_d$ = the sediment delivery ratio, a dimensionless ratio indicating the amount of eroded material that is transported the entire distance from the slope to the receiving waters

7.2.2 Sediment Parameter Estimation

Each of the parameters comprising the sediment loading function are discussed in detail in this section. The meaning of each parameter, the physical characteristics upon which they are based, and the method for estimating or designating values are presented. Parameter values selected for each sub-area are summarized in Table 7-6.

7.2.2.1 Surface Area, A

The Universal Soil Loss Equation predicts the annual sediment load eroded and delivered to a stream or other body of water from each acre of the drainage basin. The entire West Point Study Area basin was delineated by locating the basin drainage divides on a 1:25,000 topographic map (U.S. Army Topographic Command, 1970). Similarly the sub-areas were each defined by the present or proposed location of a stream flow control structure at its downstream limit (Figures 5-1 and 6-2). The area of the entire sub-area was then determined using a planimeter. Surface areas of lakes or ponds in the sub-area were also determined by planimetery and subtracted from the entire area to produce the ground or soil surface area of the sub-area. The surface area of the sub-areas varied from 130 to 772 acres. The composite of sub-areas 1 through 4 is 946 acres, and the entire study area has a surface area of 3247 acres.

7.2.2.2 Rainfall Factor, R

The rainfall factor or erosion index is the term of the sediment loading function that reflects the erosion potential of precipitation. It is determined by summing the products of storm kinetic energy and maximum 30 minute intensity for all significant storms in the local area. For these models the average annual R is used. Maps showing average annual R values for the U.S. are published in many sources (Zison et al., 1977, McElroy, et al., 1976 and Wischmeier and Smith, 1965), however the easiest map to use is that in the Agriculture Handbook 537 (U.S. Department of Agriculture, 1978) because it is of larger scale and shows county boundries. From this map it was determined that the R value over the entire West Point Study Area is 150 erosion index units.

While R is given as an average annual value, its theoretical distribution over the year is expressed on a set of graphs included in the model publication (Zison et al., 1977, Appendix A). By finding the location of the area of interest on the index map and applying the appropriate distribution graph, it is possible to determine the theoretical monthly distribution of R and thus sediment, nutrient, and organic matter loads throughout the year. The West Point Study area fell within area 31 (Zison et al., 1977).

We have some reservations as to the validity of breaking down a long term annual average into short term increments. However, monthly predictions for wasteloads will be presented in addition to annual estimates.

7.2.2.3 Soil-Erodibility Factor, K

The soil-erodibility factor is the term in the sediment loading function that reflects the relative ease with which particles of soil are eroded from plots of specific soil type. It is expressed as the annual rate of erosion (tons of sediment per year) from a unit plot of a specific soil type of standard length, slope, and surface conditions for each unit of erosion index (R above).

Since soils and soil characteristics are localized, the best information on soil K values is obtained from local sources. We obtained soil maps and soil-erodibility values for the local area from the Middletown, N.Y., office of the Soil Conservation Service (K. Vinar, personal communication; Wright and Olsson, 1972) and overlayed the information on the study area map (Figure 4-6).

The K value for each sub-area was determined by taking an area-weighted average of all soil type erodibility factors in that sub-area. Factors for the soils in the study area are shown in Table 7-1. Since most of the soil area of the watershed is classified as one of the Hollis Rocky soils (070 or 071), there is little variation of K values between the sub-areas. The K value was either 0.19, 0.20 or 0.21 for each of the sub-areas (Table 7-6).

7.2.2.4 Topographic Factor, LS

The topographic factor, sometimes referred to as soil-loss ratio, is the term in the sediment loading function that accounts for the length and steepness of the slope over which surface water flows toward receiving waters. Previously the topographic factor has been presented as two separate slope factors, the slope length factor, L, and the slope gradient or steepness factor, S (Zison et al., 1977; McElroy et al., 1976; and Wischmeier and Smith, 1965). However, in usage the slope length and steepness had usually been handled as a combined term.

Zison et al. (1977, page 37) present a figure from which the LS value for irregular slopes may be found when entered with slope length and steepness for segments of the entire irregular slope. This graph covers neither the lengths of slopes nor the slope steepness (up to 60 percent) that are found in the study area. Foster and Wischmeier, (1973) from which the irregular slope determination method was taken, was consulted. Here it was determined that we could find the LS value for irregular slopes by applying the equation:

TABLE 7-1 Soil Erodibility Factors*

| Mapping Unit | Soil Name | "K" Value | Erosion Potential# |
|---|---|---|---|
| 9 | Hoosic Gravelly Fine Sandy Loam | 0.20 | MED |
| 22 | Charlton and Narragansett Extremely Stony Soils | 0.20 | LOW |
| 38 | Squires Loam | 0.24 | MED |
| 63 | Charlton Fine Sandy Loam | 0.20 | MED |
| 91 | Wayland Silt Loam | 0.0 | HIGH-VERY LOW+ |
| 94 | Carlisle Muck | 0.0 | HIGH-VERY LOWx |
| 96 | Palms Muck | 0.0 | HIGH-VERY LOWx |
| 103 | Fresh Water Marsh | 0.0 | HIGH-VERY LOWx |
| 025 | Scriba-Sun Extremely Stony Association | 0.32 | MED |
| 026 | Alden and Sun Extremely Stony Soils | 0.28 | MED |
| 070 | Hollis Rocky Association | 0.20 | LOW |
| 071 | Hollis Rock Outcrop Association | 0.20 | LOW |

Notes: #Erosion Potential LOW, K=0.10-0.20
MED, K=0.24-0.32
HIGH, K=0.37-0.49

+ Very low except where water is running over the soil surface.
x Only erodible by wind, when drained of water.
* Soil Conservation Service, 1976; Wright and Olsson 1972; K. Vinar, personal communication

$$LS = \sum_{j=1}^{n} \frac{(S_j \lambda_j^{1.5} - S_j \lambda_{j-1}^{1.5})}{\lambda_e (72.6)} \qquad (7\text{-}2)$$

where:

$LS$ = topographic factor

$S_j$ = slope factor for slope segment j

$\lambda_j$ = distance, in feet, from the top of the entire irregular slope to the bottom of segment j

$\lambda_e$ = distance, in feet, from the top of the entire irregular slope to the bottom of the last segment

The slope factor S in equation 7-2 is a function of the slope of the segment, shown below:

$$S_j = \frac{0.43 + 0.30S + 0.043S^2}{6.613} \qquad (7\text{-}3)$$

where:

S = percent slope of slope segment j

This assumes an irregular slope of n segments shown below:

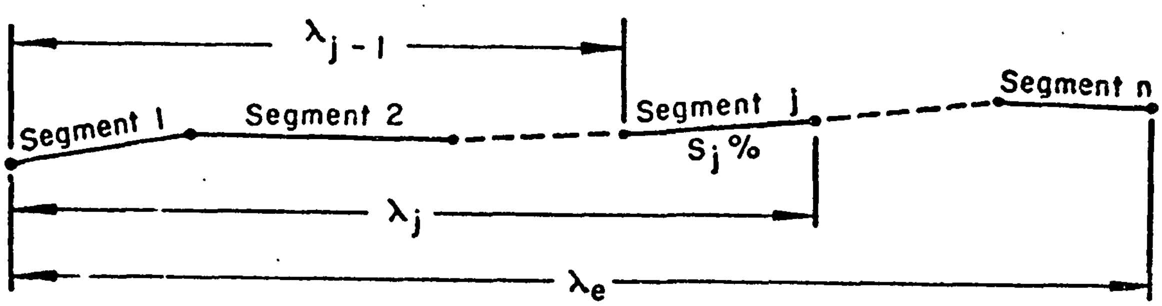


Figure 7-1. Slope Segmenting for Equations 7-2 and 7-3 (Foster and Wischmeier, 1973).

To determine LS, several representative slopes were chosen in each sub-area. These slopes were divided into segments based on percent slope as determined from a 1:25,000 topographic map and equations 7-2 and 7-3 were applied. These LS values were averaged yielding an average topographic factor, LS, for each of the sub-areas. LS values varied from 13.6 to 25.5 for the sub-areas of the West Point Study Area.

The length of slope used to determine LS values is defined as "the distance from the point of origin of overland flow to either of the following, whichever is limiting for the major part of the area under consideration: (1) the point where the slope decreases to the extent that deposition begins, or (2) the point where runoff enters a well-defined channel..." (Wischmeier and Smith, 1965). In this study area we defined slopes as starting at a ridge line or hilltop and ending at a stream, lake or wetland (as shown on the map), or at a steep narrow valley or draw which probably contained a "well-defined channel." We can find no good description of what constitutes a "well-defined channel" especially in a steep rocky area such as our location. This method of slope designation resulted in slope lengths up to almost 4000 feet and in general over 1000 feet. It is possible and even most probable that a "well-defined channel" is encountered well before overland flow has proceeded 1000 feet.

We recalculated LS values, limiting all slopes to 400 feet or less, to determine the effect of overestimating the slope lengths. As was expected LS values generally were lower when slope length was 400 feet or less. However, we found that this limitation did not produce much of a decrease, the average being a 16 percent reduction. The larger values are used in further calculations because we have chosen to overestimate wasteloads as we screen the area for trouble areas.

TABLE 7-2. COMPARISON OF LS VALUES RESULTING FROM RESTRICTIONS ON SLOPE LENGTH. See text for discussion.

| West Point Study sub-area number | LS Values 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| unlimited length | 15.7 | 19.4 | 13.9 | 24.9 | 17.4 | 13.6 | 25.5 | 19.5 |
| limited length (<400') | 13.8 | 23.6 | 10.4 | 19.9 | 12.9 | 8.6 | 19.5 | 17.8 |

An alternate method for determining LS based on the same equations but with slightly different exponents may be found in a handbook for evaluating silviculture nonpoint sources (Forest Service, 1978). This method uses the equation below and Figure

7-2 (reproduced from the above publication).

$$LS = \sum_{j=1}^{n} \frac{\mu_{2j} - \mu_{1j}}{\lambda_e} \qquad (7\text{-}4)$$

where:

$\mu_{1j}$ = value of $\mu$ from Figure 7-2 with $\lambda$ to the top of segment j and the line representing the percent slope of segment j

$\mu_{2j}$ = value of $\mu$ from Figure 7-2 with $\lambda$ to the bottom of segment j and the line representing the percent slope of segment j

$\lambda_e$ = distance, in feet, from the top of the entire irregular slope to the bottom of the last segment

7.2.2.5 Cover Factor, C

The cover or cropping-management factor is the term for the sediment loading function that accounts for the reduction of erosion caused by the presence of a vegetation cover. Much work has been done on the effects of different types and amounts of plant cover (Wischmeier, 1972 and Water Resources Administration, 1973). The West Point Study Area is adequately described as a well stocked woodland, with 100-75 percent tree canopy; 100-90 percent of soil litter covered and unmanaged (i.e. grazing uncontrolled, fires controlled somewhat). Based on these characteristics a C value for the entire study area of 0.003 was chosen (Zison et al., 1977, page 44).

7.2.2.6 Erosion Control Practice Factor, P

The erosion control practice factor (primarily intended for agricultural areas) is the term in the sediment loading function that accounts for the reduction in surface erosion caused by such conservation practices as contouring and terracing. P factors and associated control practices are shown in Table 7-3.

Good conservation practices can reduce erosion up to 75 percent on shallow slopes from that experienced under poor conservation. We are at a loss as to how this applies to a forested watershed. A steep sloped agricultural area could have P values ranging from 0.45 to 1.0. Being unsure whether to apply the higher value because there are no erosion control practices or to apply the lower value because the forested area is undisturbed, we have chosen the higher value of 1.0. This is because, once again, we want to risk overestimation rather than underestimation of sediment yield and because we believe that the very low cover (C) factor above probably accounts for reduced erosion from forested areas.

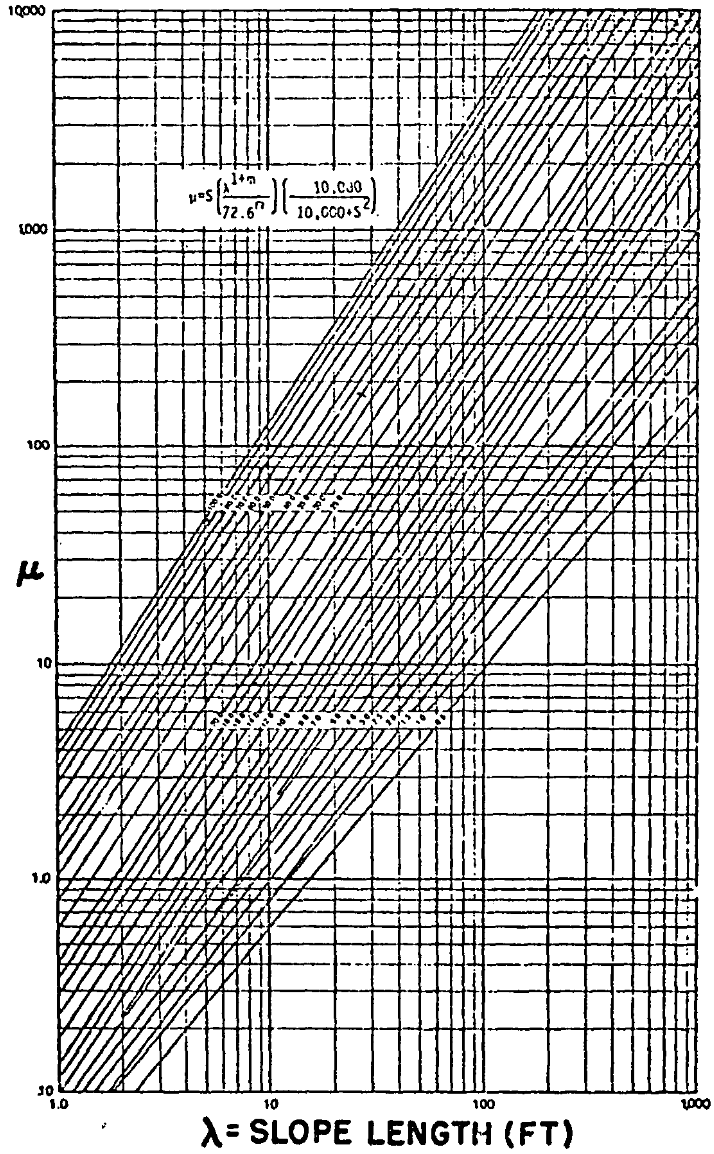


Figure 7-2. Values of μ for Irregular Slopes (after Forest Service, 1978).

TABLE 7-3. "P" VALUES FOR EROSION CONTROL PRACTICES ON CROPLANDS (Zison *et al.*, Table III-6)

| Slope | Up-and-Downhill | Cross-slope Farming Without Strips | Contour Farming | Cross-slope Farming With Strips | Contour Strip-cropping |
|---|---|---|---|---|---|
| 2.0- 7 | 1.0 | 0.75 | 0.50 | 0.37 | 0.25 |
| 7.1-12 | 1.0 | 0.80 | 0.60 | 0.45 | 0.30 |
| 12.1-18 | 1.0 | 0.90 | 0.80 | 0.60 | 0.40 |
| 18.1-24 | 1.0 | 0.95 | 0.90 | 0.67 | 0.45 |

7.2.2.7 Sediment Delivery Ratio, $S_d$

The sediment delivery ratio is the term in the sediment loading function that reflects the amount of sediment delivered to receiving waters by overland flow. It reflects deposition of sediment on the land surface. As such the $S_d$ term is a function of both particle size and the distance that the particles must travel to reach the receiving waters. $S_d$ depends on the soil texture and the area's drainage density. The texture of the study area soil was determined to be "median", (i.e. between sandy and predominantly silt), after consultation with the Soil Conservation Service (Vinar, personal communication).

The drainage density is defined as the total length of all stream channel segments in an area divided by the basin area (Leopold et al., 1964). While the basin areas are easily determined (see section 7.2.2.1 above), the channel length is not easily defined. The problem is in determining what constitutes a channel (Coats, 1958; Hesson, 1977). We have defined a channel as that which is shown as a stream on The West Point and Vicinity, 1:25,000 topographic map (U.S. Army Topographic Command, 1970). The stream segments in each sub-area were measured from the topographic map. To these we added the centerline lengths of lakes, ponds and wetlands to account for these portions of the drainage network. The drainage densities were then determined by dividing the total channel (plus centerline) length by the entire sub-area surface area (lake surfaces included).

To determine the effect of more accurate channel determination, which would presumably result from using a larger scale map or an aerial photograph, a 1:7,500 scale map (U.S. Military Academy Orienteering Club, 1978) was used to determine the drainage density. The comparison of drainage densities shown in Table 7-4 indicates that a larger scale map generally makes little change (note however that on two of the areas there is a two-fold increase when the larger scale map was used).

TABLE 7-4. DRAINAGE DENSITY ($MILE/MILE^2$)

| | Sub-area Number | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Scale | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1:25,000 map | 3.3 | 1.9 | 3.2 | 1.5 | 3.1 | 1.6 | 2.5 | 2.8 |
| 1:7,500 map | nd | 3.1 | nd | nd | 3.8 | 3.5 | 2.7 | 3.0 |

nd = not determined

Entering Zison et al.'s (1977) graph with the reciprocal of drainage density and using the median soil texture yields the $S_d$ values shown in Table 7-5.

TABLE 7-5. SEDIMENT DELIVERY RATIO

| SUB-AREA NUMBER | $S_d$ 1:7,500 | $S_d$ 1:25,000 | SDI |
|---|---|---|---|
| 1 | | 0.41 | O-TRACE |
| 2 | 0.41 | 0.37 | O-TRACE |
| 3 | | 0.41 | O-TRACE |
| 4 | | 0.36 | O-TRACE |
| 5 | 0.43 | 0.40 | O-TRACE |
| 6 | 0.41 | 0.37 | O-TRACE |
| 7 | 0.40 | 0.39 | O-TRACE |
| 8 | 0.40 | 0.40 | O-TRACE |

Also shown in Table 7-5 are sediment delivery values determined by a method that accounts for more physical parameters than the graphical technique above (Forest Service, 1978). As can be seen this more rigorous method yielded an $S_d$ value so low as to be negligible. This method consists of the plotting of values for eight specific evaluation parameters or factors on a Stiff diagram (Figure 7-3). A detailed description of the evaluation factors can be found elsewhere (Forest Service, 1978, page IV.54-IV.58). An example of the application of this method to one of our sub-areas is presented in Figure 7-3. The eight evaluation factors for sub-area 2 were determined and plotted on the Stiff diagram. The plotted points were then connected with straight lines forming a polygon. The area inside the polygon is then measured (in our case by planimetery) and its percentage of the entire Stiff diagram area calculated. The S-shaped curve in Figure 7-4 is used to determine the sediment delivery index (ratio). All the sub-areas in the West Point area produced a polygon with less than 4 percent of the Stiff diagram area. This results in a sediment delivery of very nearly zero.

We have chosen to use the higher $S_d$ values (from the 1:25,000 map). The $S_d$ found using the larger scale map differed little for the areas determined but could not be applied to all sub-areas because the 1:7,500 map covered only a portion of the

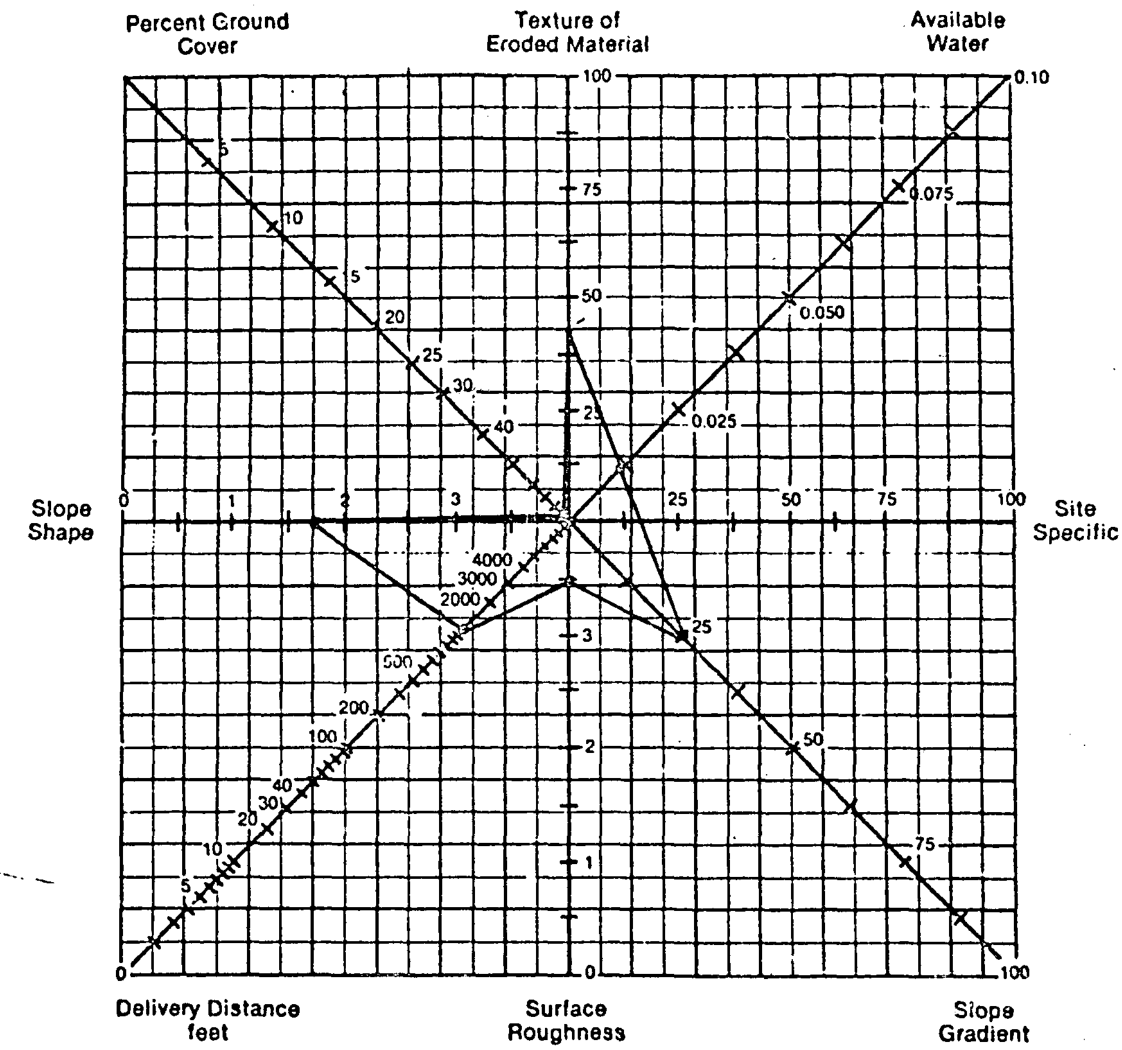


Figure 7-3. Stiff Diagram for Sub-Area 2, West Point Study Area.

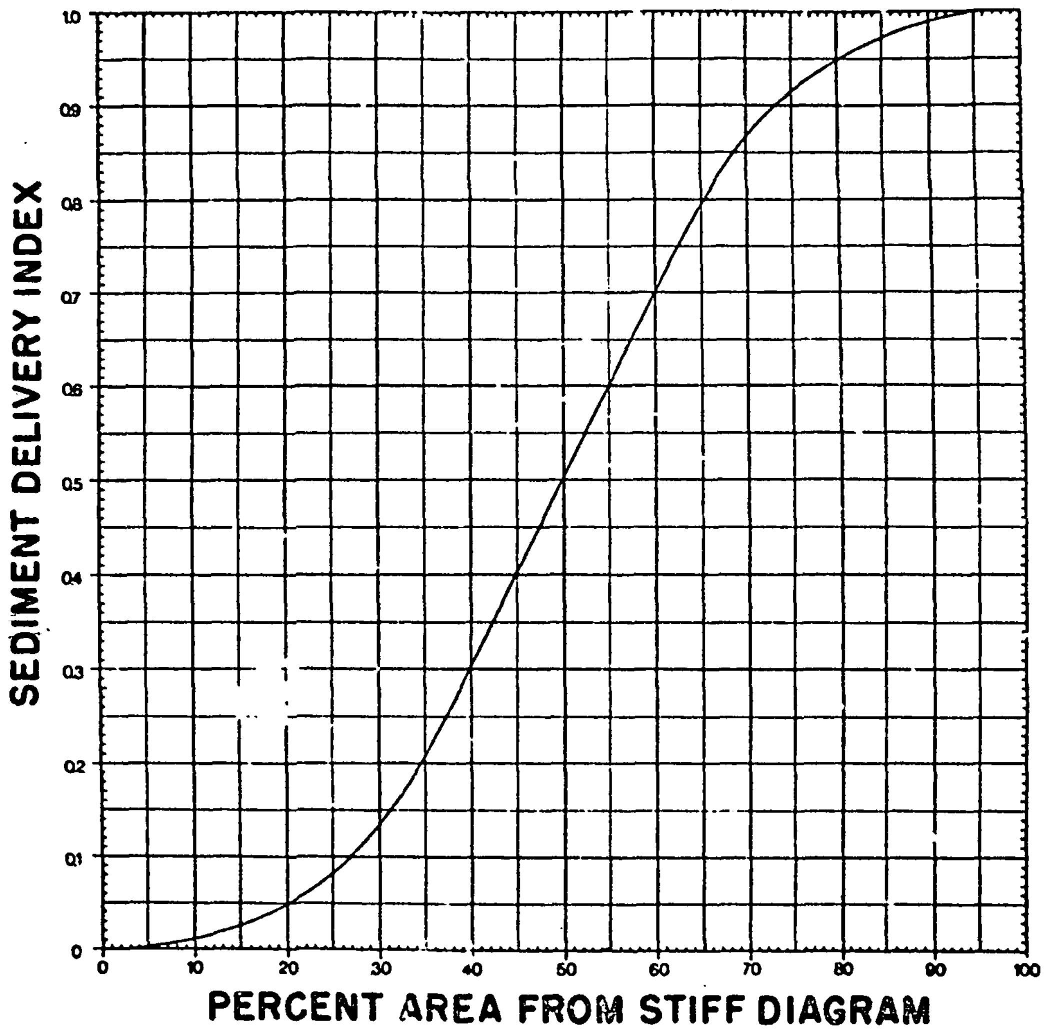


Figure 7-4. Relationship Between Polygon Area on Stiff Diagram and Sediment Delivery Index (Forest Service, 1978).

TABLE 7-6. SEDIMENT LOAD PARAMETERS AND ESTIMATES

| Factors | Sub-areas 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Area, $A_i$, acres | 130 | 186 | 250 | 380 | 409 | 580 | 540 | 772 |
| Rainfall, R, erosion index units | 150 | 150 | 150 | 150 | 150 | 150 | 150 | 150 |
| Erodibility, K, tons/year/R | 0.20 | 0.20 | 0.21 | 0.19 | 0.19 | 0.19 | 0.19 | 0.20 |
| Topographic, LS, dimensionless | 15.7 | 19.4 | 13.9 | 24.9 | 17.4 | 13.6 | 25.5 | 19.5 |
| Cover, C, dimensionless | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| Practice, P, dimensionless | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Sed. Delivery, $S_d$, dimensionless | 0.41 | 0.37 | 0.41 | 0.36 | 0.40 | 0.37 | 0.39 | 0.40 |
| Estimated Sediment Load, tons/year | 75 | 120 | 135 | 291 | 243 | 250 | 459 | 542 |
| Estimated Sediment Load, tons/acre-yr | 0.58 | 0.65 | 0.54 | 0.77 | 0.60 | 0.43 | 0.85 | 0.70 |
| Estimated Sediment Load, Areas 1-4 as a unit | | 621 tons/year | | | 0.66 tons/acre-year | | | |
| Estimated Sediment Load, Areas 1-8 as a unit | | 2,115 tons/year | | | 0.65 tons/acre-year | | | |

USMA reservation. Should actual loads be very low it may indicate that the Stiff diagram produces better values, but for now we are once again chosing parameter values on the high side of their range.

### 7.2.3 Sediment Yield Estimation

Substitution of the parameters discussed above and summarized in Table 7-6 into the Sediment Loading Function (Equation 7-1) results in the estimated average annual sediment yields from each of the study area sub-areas.

These sediment loads are also summarized in Table 7-6.

### 7.2.4 Nitrogen Loading Function

The nitrogen loadings from the eight sub-areas and the composite sub-areas of the study area have been estimated using the sum of erosion and precipitation nitrogen loads shown below. These two loads are presented separately in Zison et al., 1977 (pages 67 & 68) but will be dealt with jointly here.

$$Y(N) = Y(NT)_E + Y(N)_{Pr} \qquad (7\text{-}5)$$

where:

$Y(N)$ = total nitrogen load from the drainage basin (lb/year)

$Y(NT)_E$ = total nitrogen load from erosion (lb/year)

$Y(N)_{Pr}$ = stream nitrogen load from precipitation (lb/year)

The nitrogen load from erosion is expressed as:

$$Y(NT)_E = 20 \cdot Y(S)_E \cdot C_S(NT) \cdot r_N \qquad (7\text{-}6)$$

where:

$Y(NT)_E$ = total nitrogen load from erosion (lb/year)

$Y(S)_E$ = sediment load from surface erosion (tons/year)

$C_S(NT)$ = total nitrogen concentration of the soil (g/100g)

$r_N$ = nitrogen enrichment ratio

The nitrogen load from precipitation is expressed as:

$$Y(N)_{Pr} = A \frac{Q(OR)}{Q(Pr)} N_{Pr} \cdot 0.75 \qquad (7-7)$$

where:

$Y(N)_{Pr}$ = stream nitrogen load from precipitation (lb/year)

$A$ = Basin area (acres)

$Q(OR)$ = overland flow from precipitation (in/year)

$Q(Pr)$ = total precipitation (in/year)

$N_{Pr}$ = nitrogen load in precipitation (lb/acre-year)

Substituting equations 7-6 and 7-7 into equation 7-5 yields the function of total nitrogen load in its most basic terms.

7.2.5 Nitrogen Parameter Estimation

Each of the parameters comprising the nitrogen loading function is evaluated and discussed in this section. Parameter values are summarized in Table 7-7.

7.2.5.1 Sediment Load, $Y(S)_E$

The sediment load in the nitrogen function is simply the value calculated by the sediment loading function (Section 7.2.3) and summarized in Table 7-6.

7.2.5.2 Nitrogen Concentration of the Soil, $C_S(NT)$

The value of the nitrogen concentration of the soil is an expression of the percent by weight of the native soil of an area that is nitrogen. This information was unavailable for the West Point area (Vinar, personal communication). The nitrogen concentration map (Zison *et al.*, 1977, page 70) was utilized instead. The map values are generalized as to location and are based on data more than 30 years old (Hesson, 1977, page 14-15) and are only an approximation. The map value of $C_S(NT)$ used in the study is 0.15 g/100g.

7.2.5.3 Nitrogen Enrichment Ratio, $r_N$

The nitrogen enrichment ratio is the term in the nitrogen loading function that accounts for the tendency of the soil closer to the surface, and thus more susceptible to erosion to have a higher concentration of nitrogen than the total soil column. We were unable to obtain a local value for this parameter. We have chosen $r_N$ to be 3.0 which is midway in the range of reported values (Zison *et al.*, page 68).

7.2.5.4 Basin Area, A

The basin area is used in the nitrogen loading function to multiply by the nitrogen load in precipitation (which is in lb/acre-year) to yield the weight of nitrogen that is spread over the drainage basin by precipitation (lb/year). The total area of each sub-area is used (lake and soil area) and not just the soil surface area.

7.2.5.5 Overland Flow from Precipitation, Q(OR)

The overland flow from precipitation is best found from a series of stream flow recorders where overland flow may be calculated from the recorded hydrographs. Our flow stations are in the earliest stages of operation or in some cases not yet operational. We, therefore, will use a regional average of 14.6 percent of rainfall as direct runoff (Likens et al., 1977) yielding a runoff of 6.86 inches.

7.2.5.6 Total Precipitation, Q(Pr)

The average rainfall in the West Point area is 47 inches per year (Section 4.4). This is used as the annual precipitation for each of the sub-areas in this study. The ratio:

$$\frac{Q(OR)}{Q(Pr)}$$

is then 0.146 for all sub-areas.

7.2.5.7 Nitrogen Load in Precipitation, $N_{Pr}$

The nitrogen load in precipitation is nothing more than the effective contribution of nitrogen from precipitation that is deposited on each acre of the watershed per year. This may be found by locating the study area on a map of annual nitrogen load in precipitation in the U.S. (Zison et al., 1977, page 75) or by applying locally available data. The nitrate concentration in local rain about 0.87 mg/l with little or no other nitrogen species present (Robertson et al., 1979). This is equivalent to a $N_{Pr}$ value of 2.1 lb/acre-year using the average annual precipitation of 47 inches. This corresponds almost exactly with the value 2.0 lb/acre-year taken from Zison et al.'s map (1977, page 75).

## 7.2.6 Nitrogen Yield Estimation

Substitution of the parameters derived above (summarized in Table 7-7) into the Nitrogen Loading Function (Equation 7-5) results in the estimated average annual nitrogen yields for each of the sub-areas. Also presented are those portions of the nitrogen loads attributed to erosion and to precipitation. The contribution to total nitrogen load from precipitation is small compared to that from erosion ($\sim$5% of total load). For a rough approximation to total load the small precipitation input could be ignored.

TABLE 7-7. NITROGEN SUMMARY

| Parameters | Sub-areas | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1-4 | 1-8 |
| Sediment Load, $Y(S)_E$, tons/year | 75 | 120 | 135 | 291 | 243 | 250 | 459 | 542 | | |
| N Conc'n in Soil, $C_S(NT)$, g/100g | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | 0.15 | | |
| N Enrichment Ratio, $r_N$, Dimensionless | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | | |
| Basin Area, A, Acres | 162 | 186 | 265 | 381 | 435 | 580 | 548 | 921 | | |
| Overland Flow From Precip., Q(OR), in/year | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | | |
| Total Precip. Q(Pr), in/year | 47 | 47 | 47 | 47 | 47 | 47 | 47 | 47 | | |
| N Load, Precip. $N_{Pr}$, lb/acre-year | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | 2.1 | | |
| N From Erosion, lb/year | 675 | 1,080 | 1,215 | 2,619 | 2,187 | 2,250 | 4,131 | 4,878 | 5,589 | 19,035 |
| N From Erosion, lb/acre-year | 5.2 | 5.8 | 4.9 | 6.9 | 5.3 | 3.9 | 7.7 | 6.3 | 5.9 | 5.9 |
| N From Precip. lb/year | 37.5 | 43.0 | 61.3 | 88.1 | 100.6 | 134.1 | 126.7 | 213.0 | 230.0 | 804.4 |

TABLE 7-7. Continued

| Parameters | Sub-areas | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1-4 | 1-8 |
| N From Precip. lb/acre-year | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 |
| Total N Load, lb/year | 712 | 1,123 | 1,276 | 2,707 | 2,287 | 2,384 | 4,257 | 5,091 | 5,819 | 19,839 |
| Total N Load, lb/acre-year | 5.5 | 6.0 | 5.1 | 7.1 | 5.6 | 4.1 | 7.9 | 6.6 | 6.2 | 6.1 |

### 7.2.7 Phosphorus Loading Function

The phosphorus loadings from the eight sub-areas and the composite sub-areas of the study area will be estimated using the phosphorus loading function below (Zison *et al.*, 1977, pages 76 and 77):

$$Y(PT) = 20 \cdot Y(S)_E \cdot C_S(PT) \cdot r_p \qquad (7\text{-}9)$$

where:

$Y(PT)$ = total phosphorus loading (lb/year)

$Y(S)_E$ = sediment load from surface erosion (tons/year)

$C_S(PT)$ = total phosphorus concentration of the soil (g/100g)

$r_p$ = phosphorus enrichment ratio

### 7.2.8 Phosphorus Parameter Estimation

Each of the parameters comprising the phosphorus loading function is evaluated and discussed in this section. Parameter values are summarized in Table 7-8.

#### 7.2.8.1 Sediment Load, $Y(S)_E$

Sediment is assumed to be the major vehicle by which phosphorus, as was nitrogen, is carried from the land surface to receiving waters. The sediment load in the phosphorus loading function is that calculated previously (Section 7.2.3) and summarized in Table 7-6.

#### 7.2.8.2 Phosphorus Concentration of the Soil, $C_S(PT)$

The phosphorus concentration of the soil is the percent of soil weight that is phosphorus. These data were unavailable (Vinar, personal communication) and we used a generalized nationwide map (Zison *et al.*, 1977, page 78). From this map it was determined that our study area should have a $P_2O_5$ concentration of about 0.15 g/100g in the top foot of soil. This converts to a phosphorus concentration of 0.07 g/100g (as P) in the soil.

#### 7.2.8.3 Phosphorus Enrichment Ratio, $r_p$

This term, similar to that for nitrogen, is intended to account for the tendency of the soil at the surface to have higher concentrations of phosphorus than the general soil column. The average reported value of 1.5 was used as our enrichment ratio (Zison *et al.*, 1977, page 79).

TABLE 7-8. PHOSPHORUS SUMMARY

| Parameters | Sub-areas 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 1-4 | 1-8 |
|---|---|---|---|---|---|---|---|---|---|---|
| Sediment Load, $Y(S)_E$, tons/year | 73 | 120 | 135 | 291 | 243 | 250 | 459 | 542 | | |
| P Conc'n in Soil $C_S(PT)$, g/100g | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | | |
| P Enrich. Ratio, $r_p$, Dimen'less | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | | |
| Total P Load, lb/year | 158 | 252 | 284 | 611 | 510 | 525 | 964 | 1138 | 1305 | 4442 |
| Total P Load, lb/acre-year | 1.22 | 1.35 | 1.14 | 1.61 | 1.25 | 0.91 | 1.79 | 1.47 | 1.38 | 1.37 |

### 7.2.9 Phosphorus Yield Estimation

Substitution of the parameters discussed above and summarized in Table 7-8 into the Phosphorus Loading Function (Equation 7-9) results in the estimated average annual phosphorus yields from each of the study area sub-areas. These phosphorus loads are summarized in Table 7-8.

### 7.2.10 Organic Matter Loading Function

The organic matter loading from the sub-areas in the study area will be estimated using the loading function published by Tetra Tech, Inc. (Zison et al., 1977, page 80) shown below:

$$Y(OM)_E = 20 \cdot C_S(OM) \cdot Y(S)_E \cdot r_{OM} \qquad (7\text{-}10)$$

where:

$Y(OM)_E$ = organic matter loading (lb/year)

$C_S(OM)$ = organic matter concentration of the soil (g/100g)

$Y(S)_E$ = sediment loading from surface erosion (tons/year)

$r_{OM}$ = organic matter enrichment ratio

### 7.2.11 Organic Matter Parameter Estimation

The parameters of the organic matter loading function will each be evaluated and discussed in this section.

7.2.11.1 Organic Matter Concentration of the Soil, $C_S(OM)$

An approximate value of $20 \cdot C_S(NT)$ is assumed for the organic concentration of the soil (Zison et al., 1977, page 80). $C_S(OM)$ for all areas is then 3.0 g/100g of soil.

7.2.11.2 Sediment Load from Surface Erosion, $Y(S)_E$

This term has been discussed previously and is summarized in Table 7-6.

7.2.11.3 Organic Matter Enrichment Ratio, $r_{OM}$

The organic enrichment ratio, like those for nitrogen and phosphorus, is an indication of organic matter in the top layers of the soil. Values of $r_{OM}$ are reported as ranging from 1 to 5. The median value of 2.5 has been used as an estimate for our study area.

### 7.2.12 Organic Matter Yield Estimation

Substitution of the parameters discussed above into the Organic Matter Loading Function (Equation 7-10) results in the estimated average annual organic matter yields for each of the sub-areas. These loadings are summarized in Table 7-9.

TABLE 7-9. ESTIMATED ORGANIC MATTER LOADS

| Sub-areas | Organic Matter lb/year | Organic Matter lb/acre-year |
|---|---|---|
| 1 | 11,250 | 86.5 |
| 2 | 18,000 | 96.8 |
| 3 | 20,250 | 81.0 |
| 4 | 43,650 | 114.9 |
| 1-4 | 93,150 | 98.5 |
| 5 | 36,450 | 89.1 |
| 6 | 37,500 | 64.7 |
| 7 | 68,850 | 127.5 |
| 8 | 81,300 | 105.3 |
| 1-8 | 317,250 | 97.7 |

### 7.2.13 Nonpoint Load Summary

Based on the published loading functions (Zison *et al.*, 1977) estimates were made of the average annual loads of sediment, nitrogen, phosphorus and organic matter contributed from each of eight sub-areas of the West Point Study Area. These estimated loads have been presented above (Tables 7-6, 7-7, 7-8, and 7-9) and are summarized in Table 7-10 for the entire study area (sub-areas 1 through 8) and for the four southern sub-areas as a whole (sub-areas 1 through 4).

As discussed in Section 7.2.2.2 it is possible to break down these annual loads into monthly values. This has been done for the estimated loads of the entire watershed (sub-areas 1 through 8) and is shown as Figure 7-5. The same breakdown can be made for each of the sub-areas simply by assigning the appropriate percent of annual load to each month; these percentages are constant for all loadings and sub-areas. Little would be gained by presenting these figures here, thus they are omitted.

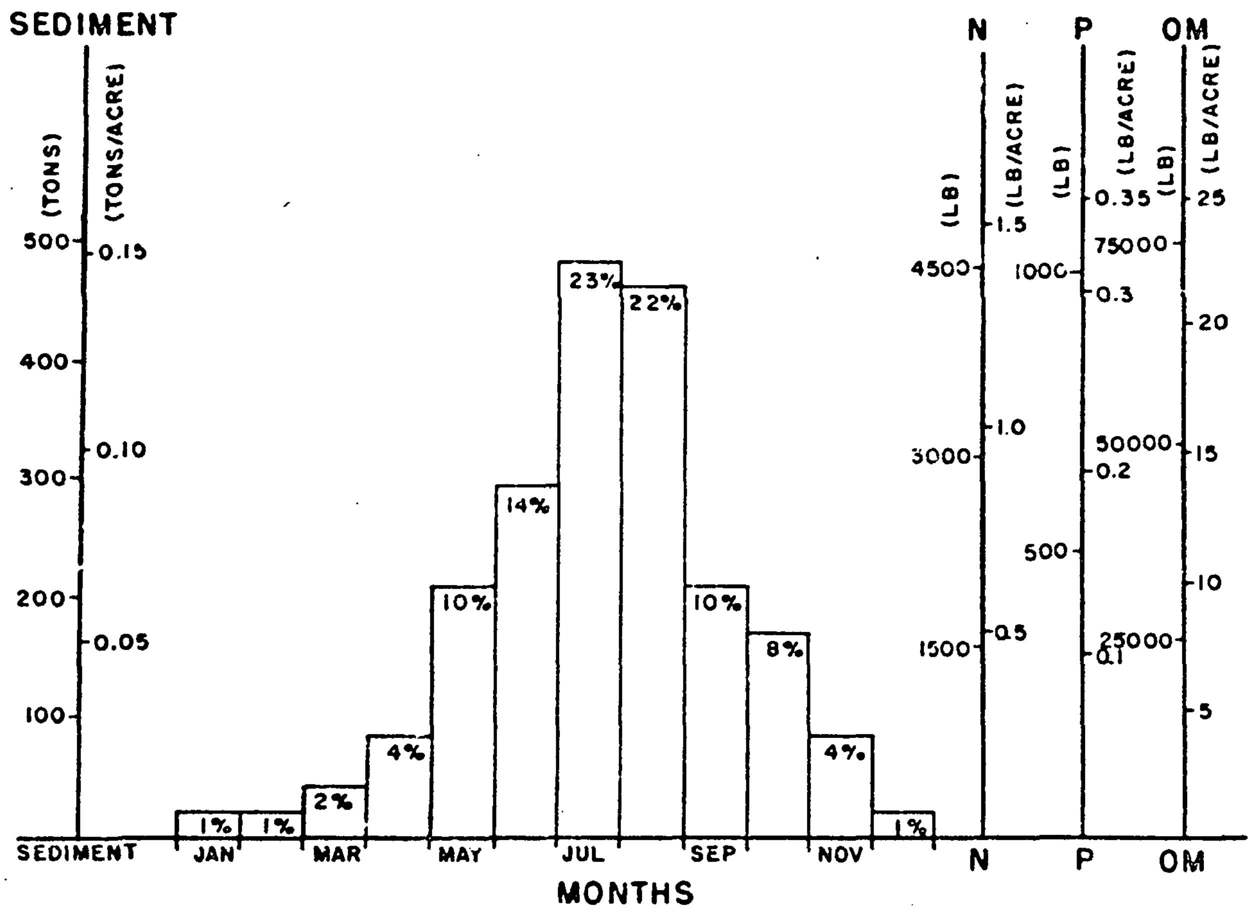


Figure 7-5. Predicted Monthly Nonpoint Loads for the West Point Study Area (Sub-Areas 1-8 as a unit).

TABLE 7-10. SUMMARY OF PREDICTED NONPOINT LOADS FROM THE WEST POINT STUDY AREA USING THE METHOD OF ZISON *et al.*, 1977

| | Southern Area (sub-areas 1-4) | Entire Study Area (sub-areas 1-8) |
|---|---|---|
| Sediment, tons/year | 621 | 2,115 |
| Sediment, tons/acre-year | 0.66 | 0.65 |
| Nitrogen, lb/year | 5,818 | 19,839 |
| Nitrogen, lb/acre-year | 6.1 | 6.1 |
| Phosphorus, lb/year | 1,305 | 4,442 |
| Phosphorus, lb/acre-year | 1.38 | 1.37 |
| Organic Matter, lb/year | 93,150 | 317,250 |
| Organic Matter, lb/acre-year | 98.5 | 97.7 |

## 7.3 LAKE WATER QUALITY PREDICTION

The impoundments models found in the screening method (Zison *et al.*, 1977, chapter 5) will be used to attempt prediction of thermal stratification, sediment accumulation, and eutrophication of the lakes in the study area. Additionally, predictions of dissolved oxygen will be attempted for selected lakes.

### 7.3.1 Thermal Stratification

Plots of theoretical thermal profiles at 10 locations in the United States for various impoundment depths, hydraulic residence times, and degrees of mixing are presented in the model (Zison *et al.*, 1977, Appendix E). The method of predicting lake stratification is to first choose the location which best matches the meteorologic characteristics of the area to be modeled and to then find the set of thermal profiles whose physical parameters most closely approach the lake to be modeled. When no single location or set of profiles matches the lake to be modeled, the prediction takes the form of two or more sets of thermal profiles that become boundaries within which the actual lake profiles should fall.

The West Point Study Area at latitude 41.3°N is bounded in latitude by plots for Salt Lake City, Utah and Burlington, Vermont at 40.8°N and 44.5°N, respectively. A comparison of meteorologic factors such as air temperature, wind speed, and cloud cover indicates that our study area resembles these two locations about equally. Since the purpose of the study is to evaluate the applicability of the model, we will continue with both sets.

The next step is to find the thermal profiles at Salt Lake City and Burlington that most closely approach those of the West Point lakes in the parameters of maximum depth, hydraulic residence time, and degree of mixing. The model thermal profiles have lake depths of 20, 40, 75, 100, and 200 feet. Since we are already bounding lake thermal predictions by two modeled locations, we have chosen a specific set of profiles based on depth, residence time, and mixing. Study area lake parameters are summarized in Table 7-11 along with the depth of model profile chosen for each.

The mean hydraulic residence time ($\tau_w$) is estimated as the total lake volume (V) divided by the mean inflow rate ($\bar{Q}$). Table 7-11 summarizes the volume, flow rate, and residence time of the study area lakes. The model residence times chosen from those in Zison et al., 1977 (10, 30, 75, 250, and infinite days) for the individual study area lakes are also shown. Lake mixing characteristics are primarily determined in the West Point area by the surface winds. The lakes in the study area are not well protected from the wind and thus will be modeled as having maximum mixing.

On the basis of the parameters discussed above, two sets of thermal profiles have been chosen to model each West Point lake. These profiles are shown with actual thermal profiles for Summit Lake, Bull Pond, and Lake Popolopen in Figures 7-6, 7-7, and 7-8.

The thermal profiles for Burlington and Salt Lake City are nearly identical for similar depth, residence time, and degree of mixing. Many of the actual thermal profiles at West Point are closely approximated by the model profiles. In general the actual hypolimnion is closer to the surface than the model hypolimnion predicted and the actual thermocline has a more rapid temperature change with depth. This indicated to us that the real lakes may not be as well mixed as we assumed for modeling purposes. The actual Bull Pond profile and the Burlington profile (assuming maximum mixing) were replotted with a second Burlington profile assuming minimum mixing (Figure 7-9). The actual Bull Pond profile is well bounded in most cases by the two theoretical profiles at Burlington. Where the two model profiles differ, the actual profile tends to be closer to the model profile assuming minimum mixing.

It may be that the West Point lakes should all have been modelled assuming less mixing. A better set of boundaries may result by using the two mixing conditions rather than the two

TABLE 7-11. LAKE MORPHOMETRIC PARAMETERS

| Lake | Actual Depth (feet) | Model Depth (feet) | V Volume ($10^6 ft^3$) | $\bar{Q}$ Mean inflow ($10^4 ft^3$/day) | $\tau_w$ Actual Residence Time (days) | $\tau_w$ Model Residence Time (days) |
|---|---|---|---|---|---|---|
| Summit | 28 | 40 | 13.0 | 3.8 | 339 | 250 |
| Barnes | 13 | 20 | 4.7 | 14.3 | 33 | 30 |
| Bull Pond | 64 | 75 | 20.4 | 10.4 | 196 | 250 |
| Georgina | 17 | 20 | 2.4 | 1.4 | 171 | 250 |
| Popolopen | 32 | 40 | 72.8 | 81.7 | 89 | 75 |
| Beaver Pond | 6 | 20 | 1.3 | 12.9 | 10 | 10 |

a. Based on 50% of annual rainfall becoming runoff. Averaged over the entire year. From U.S.G.S. regional stream flow data in southern New York (Bernard Dunn, personal communication).

b. Based on total lake volume.

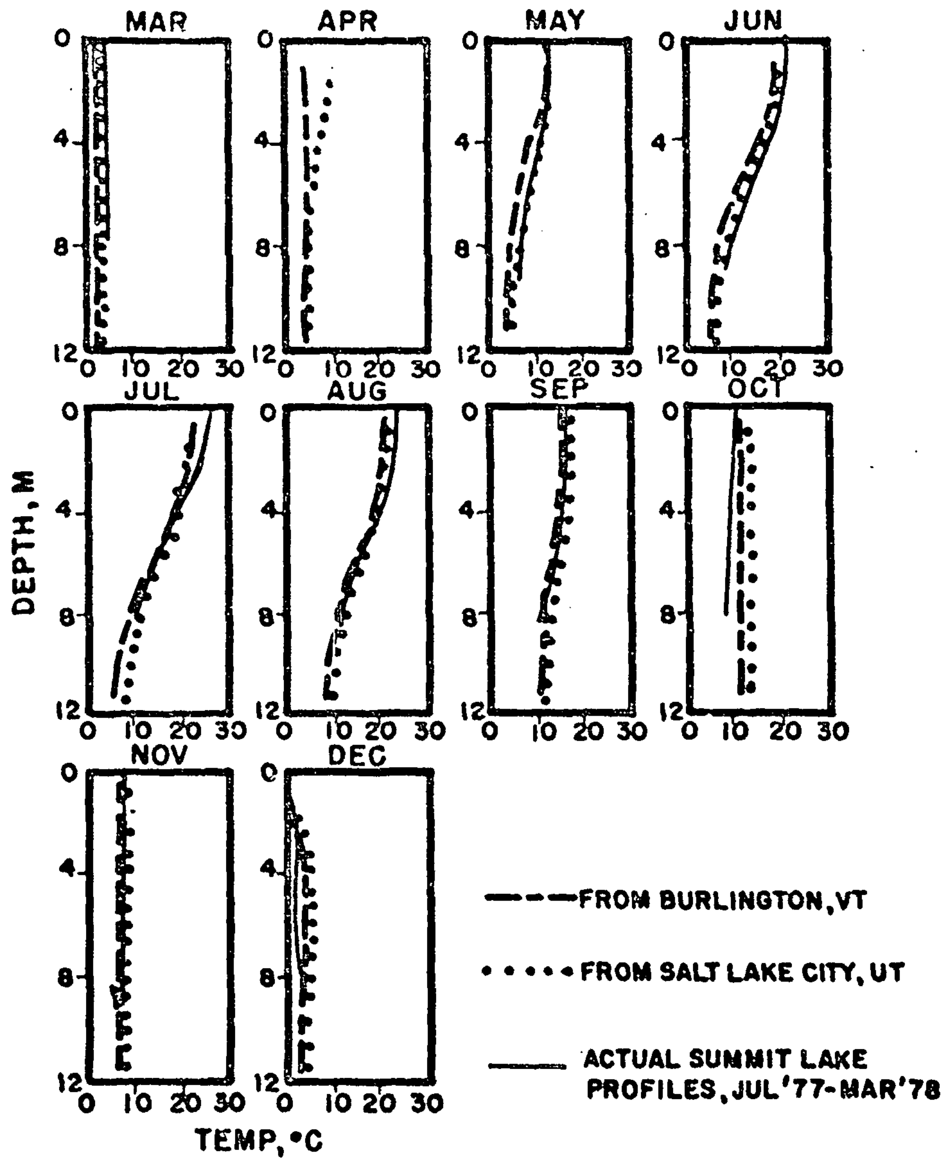


Figure 7-6. Comparison of Summit Lake Thermal Profiles with Model Estimates.

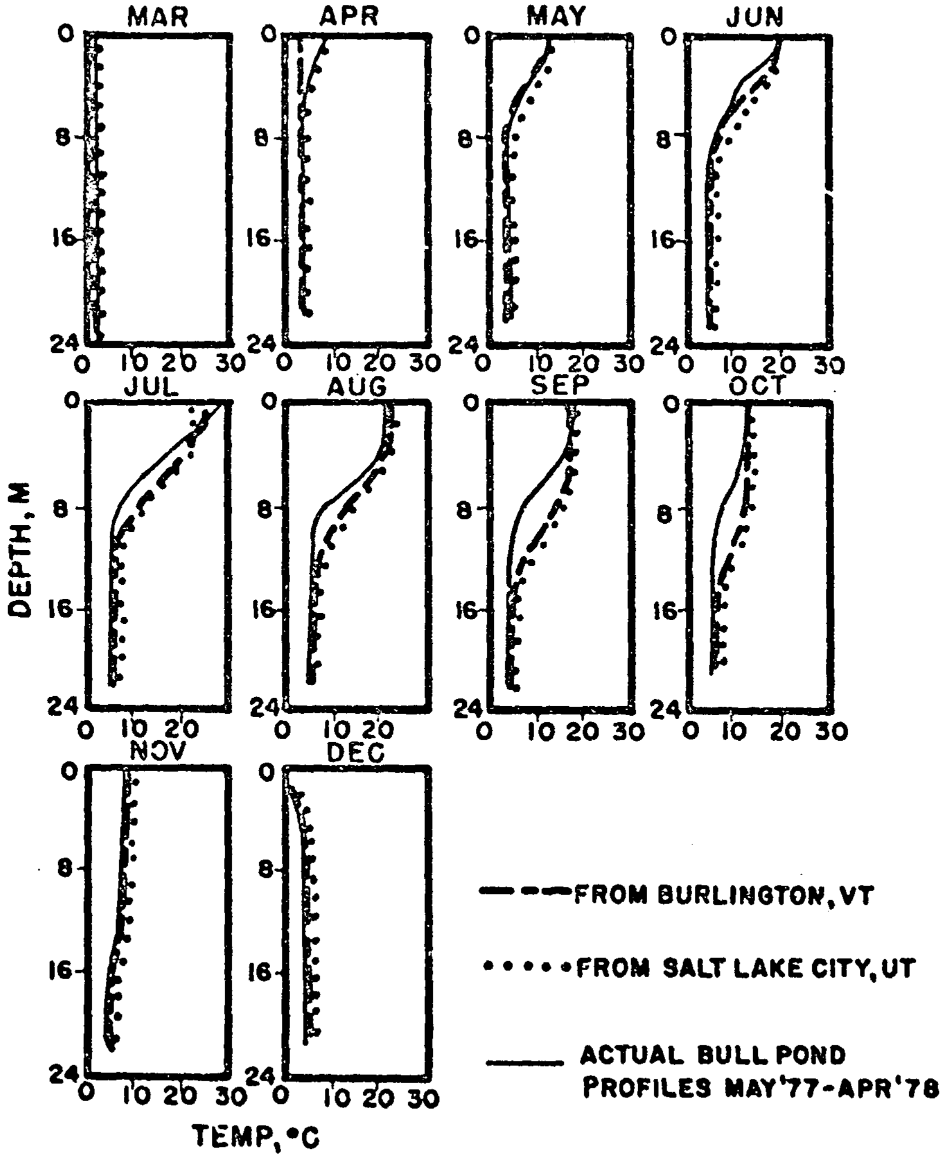


Figure 7-7. Comparison of Bull Pond Thermal Profiles with Model Estimates.

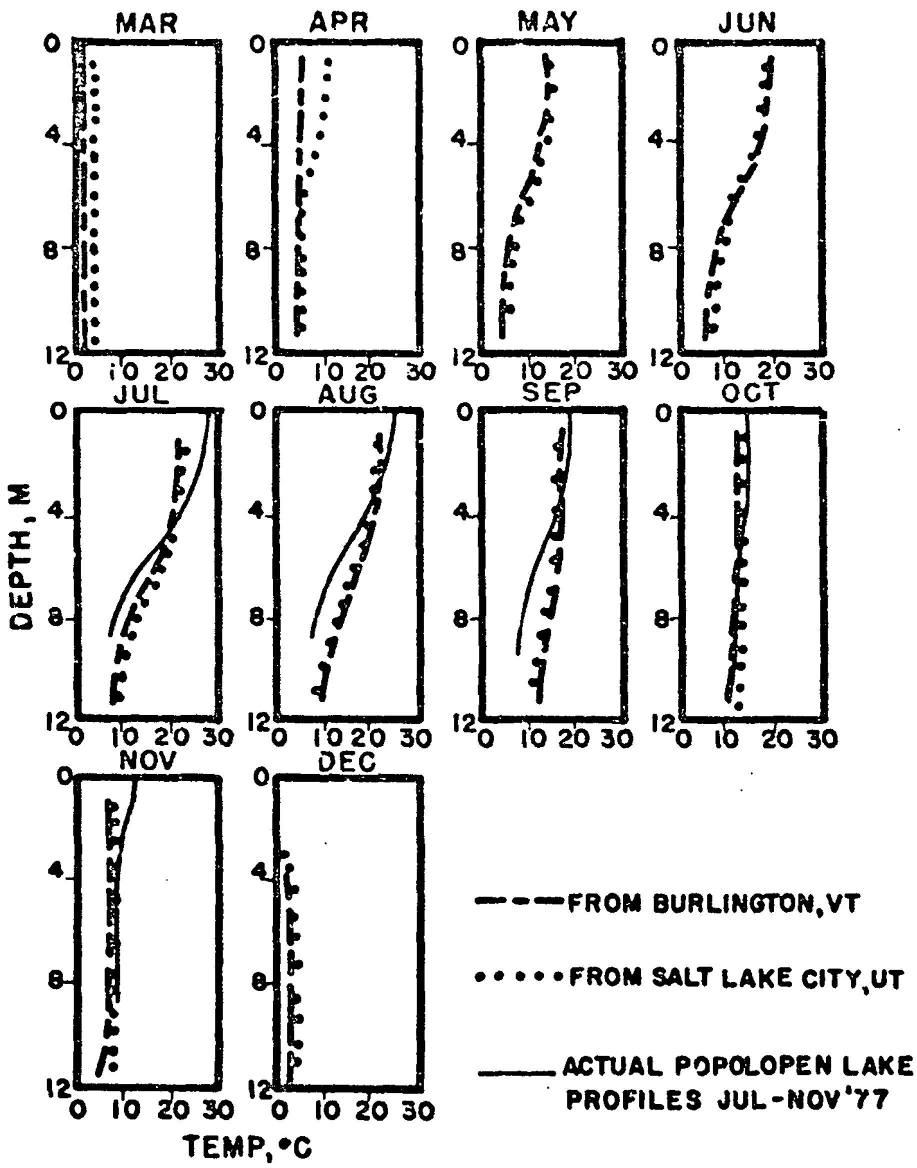


Figure 7-8. Comparison of Popolopen Lake Thermal Profiles with Model Estimates.

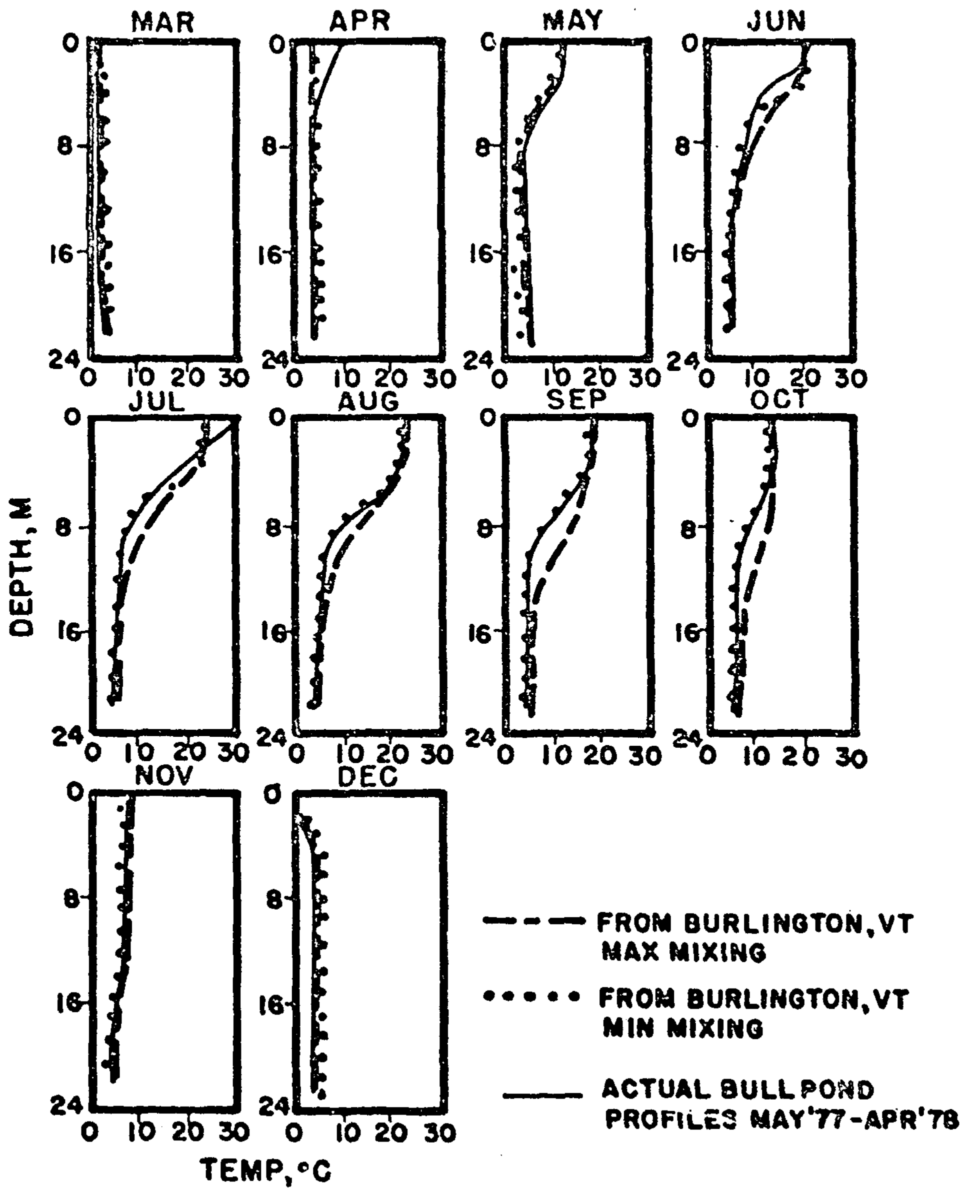


Figure 7-9. Comparison of Bull Pond Thermal Profiles with Model Estimates Assuming Varying Degrees of Mixing.

locations as boundary conditions. A rigorous application of the model would result in an approximation by 12 theoretical profiles, two sets for each of two locations (two for depth, two for mixing, and two for residence time).

### 7.3.2 Sediment Accumulation

Two model methods will be applied to the West Point lakes to model the long term accumulation of sediment. The first of these methods consists of making an impoundment sedimentation estimate based on locally reported data by searching a set of reservoir sedimentation surveys (Appendix F, Zison et al., 1977). The second involves calculating accumulation based on inflow and lake volume.

Six New York reservoirs were found in the surveys. One of these (Wappinger Creek) is physically located less than 20 miles north of West Point. All six New York reservoirs are on streams cutting through areas underlain by sedimentary rock and which primarily support farming. The West Point study area is on crystalline metamorphic and igneous rocks and is primarily forestland. One would expect larger amounts of sediment in the six reported reservoirs than would be found at West Point. However, if our study area were experiencing sedimentation at the same rate as the worst case of the six New York reservoirs (Patterson Creek, 1.09 tons/watershed acre-year), then no lake at West Point would be accumulating sediment at a rate faster than 0.05 feet per year. Such slow rates, if evenly distributed over the lake bottom, would be undetectable to us in the short time we have been investigating them.

The second estimate of sediment accumulation involves application of the following equation.

$$S_t = S_i P \qquad (7\text{-}11)$$

where:

$S_t$ = weight of sediment trapped per time period

$S_i$ = sediment transport rate (weight per time period)

$P$ = trap efficiency (expressed as a decimal)

The sedimentation rate, $S_i$, is derived using either measured or estimated sediment transport (nonpoint Sediment Loading Function, Equation 7-1). The trap efficiency is determined from a graph based on the ratio of lake volume to inflow (Zison et al., 1977; Figure V-7). Substitution into Equation 7-11 yields estimated sedimentation rates for the lakes in the West Point Study Area. Sediment lost to sedimentation in upstream lakes

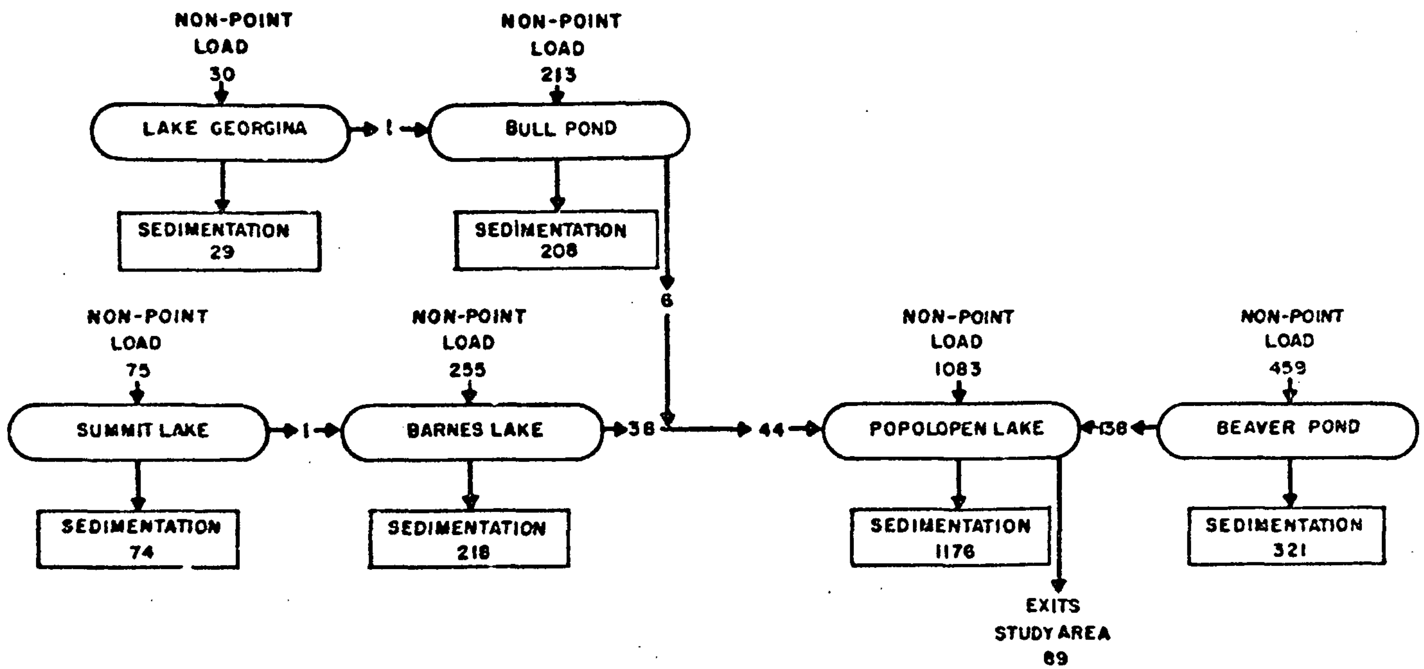


Figure 7-10. Sediment Routing, West Point Study Area.
(units are tons/year)

TABLE 7-12. ESTIMATED SEDIMENTATION RATES

| Lake | Volume ($10^6$ $ft^3$) | Inflow ($10^6$ $ft^3$/yr) | Trap Efficiency[a] | Sedimentation Rates tons/yr | $ft^3$/yr[b] | in/yr[c] |
|---|---|---|---|---|---|---|
| Summit | 13.0 | 14.0 | 0.98 | 74 | 2,960 | 0.03 |
| Barnes | 4.7 | 52.3 | 0.85 | 218 | 8,720 | 0.17 |
| Bull Pond | 20.4 | 38.0 | 0.97 | 208 | 8,320 | 0.11 |
| Georgina | 2.4 | 5.1 | 0.96 | 29 | 1,160 | 0.07 |
| Popolopen | 72.8 | 298.1 | 0.93 | 1,176 | 47,040 | 0.09 |
| Beaver Pond | 1.3 | 47.3 | 0.70 | 321 | 13,840 | 0.42 |

a. From Zison et al., 1977 (Figure V-7)

b. Assumes 50 lb/$ft^3$ (Zison et al., 1977)

c. Assumes uniform distribution on lake bottom must be subtracted as one works successively downstream (Figure 7-10). Estimated sedimentation rates are shown in Table 7-12. Note that the model ignores the effect of swamps and marshes on the sediment load. It is entirely reasonable to assume sedimentation in the swamps.

Such rates of sediment accumulation on the lake bottoms would be undetectable except over a very long time. No identifiable depositional features, such as deltas, have been observed on these lakes. After a heavy storm, lake waters are light brown from suspended sediment. This may indicate that sediment is deposited over the entire lake bottom.

### 7.3.3 Eutrophication

The predicted trophic state of lakes in the West Point area has been attempted using the Vollenweider relationship (Zison et al., 1977, pages 334-342). This model relates the trophic state of a body of water to mean depth, adjusted hydraulic residence time, and phosphorus load.

The model assumes that phosphorus is the nutrient which limits plant growth, rather than nitrogen. The ratio of N to P should be greater than 10, for this to be true. Actual nutrient measurements indicate that the N:P ratio in West Point waters is much less than 5 (often less than 1) through most of the year. On occasion the ratio reaches as high as 40. At the time of spring turn-over, the N:P ratio is too low to indicate phosphorus limitation. No further application of the model was attempted.

### 7.3.4 Dissolved Oxygen

The dissolved oxygen model presented by Zison et al., (1977) may be used to predict the concentration of dissolved oxygen in the hypolimnion of an impoundment at any time from the onset of thermal stratification to overturn in the fall. In general the critical time of least dissolved oxygen is just before overturn, when hypolimnion water has been isolated from surface reaeration longest and the organic load has consumed the greatest amount of the initial dissolved oxygen. The equation for hypolimnion dissolved oxygen at time t is:

$$O_t = O_o - \Delta O_L - \Delta O_c \qquad (7\text{-}12)$$

where:

$O_t$ = dissolved oxygen at time t

$O_o$ = initial dissolved oxygen, t=0

$\Delta O_L$ = dissolved oxygen decrease due to benthic demand

$\Delta O_c$ = dissolved oxygen decrease due to hypolimnion BOD

The benthic demand is expressed as:

$$\Delta O_L = \left(\frac{L_{ss}}{D} + \frac{k_s C_{ss}}{k_s + k_1 - k_4}\right)\left(1 - e^{-k_4 t}\right) - \left(\frac{k_s C_{ss}}{k_s + k_1 - k_4}\right)\left(\frac{k_4}{k_s + k_1}\right)\left(-e^{-(k_s + k_1)t}\right)$$

where:

$L_{ss}$ = steady-state loading of BOD on lake bottom

$D$ = lake depth, meters

$C_{ss}$ = steady-state loading of BOD in hypolimnion

$k_s$ = BOD settling rate onto lake bottom, day

$k_1$ = mean rate of decay of BOD in hypolimnion, day

$k_4$ = benthic decay rate, day

In evaluating these parameters we found that very few water samples had any sediment settle even after several weeks. What sediment was observed was judged to be mineral rather than organic. Based on these observations we concluded that dissolved substances or unsettleable particles were the cause of any BOD. The value of $k_s$ is either zero or so small as to be negligible and

$$\Delta O_L = \left(\frac{L_{ss}}{D}\right)\left(1 - e^{-k_4 t}\right)$$

However:

$$L_{ss} = \frac{k_s C_{ss} D}{k_4} \qquad (7\text{-}13)$$

is used to estimate the benthic BOD load prior to stratification. Since $k_s$ is zero or so very small as to be negligible in our judgement the above estimation of initial benthic demand becomes zero. The effect of this assumption will be explored further after we compare the prediction with actual field data.

Making the above assumptions $O_t$ reduces to:

$$O_t = O_o - \Delta O_c$$

The value of $\Delta O_c$ is:

$$\Delta O_c = \left(\frac{k_1 C_{ss}}{k_1 + k_s}\right) \left(1 - e^{-(k_1 + k_s)t}\right)$$

But since $k_s = 0$, then:

$$\Delta O_c = C_{ss} \ (1 - e^{-k_1 t})$$

and:

$$O_t = O_o - C_{ss} \ (1 - e^{-k_1 t})$$

An examination of study area lake data showed that only one lake, Bull Pond, has a potential problem of DO depletion. All other lakes are too shallow to maintain a hypolimnion through the entire summer. The evaluation of hypolimnion DO in Bull Pond consists of finding values for $O_o$, $C_{ss}$, and $k_1$ for that lake and solving for $O_t$ through the period of interest (May-August). Water samples taken in mid May 1979 (just before stratification) were analysed and yielded the following parameter values:

$$O_o = 10.2 \text{ mg/l}$$

$$C_{ss} = 1.3 \text{ mg/l}$$

$$k_1 \text{ (at } 5^\circ C) = 0.052 \text{ day}$$

The value of $k_1$ was found by applying the relationship below to the laboratory $k_1$ found at 20°C.

$$k_{1,T} = k_{1,20^\circ C} \cdot 1.047^{(T-20)}$$

where:

T = the temperature of the lake water, (5°C).

The laboratory $k_{1,20^\circ C}$ was 0.104. The equation for Bull Pond hypolimnion DO is then:

$$O_t = 10.2 - 1.3 \ (1 - e^{-0.052t})$$

Values for $O_t$ from t=0 to 120 days are shown in Figure 7-11. It may be seen then that essentially all BOD initially in the hypolimnion at stratification is exerted in 90 days. Based on

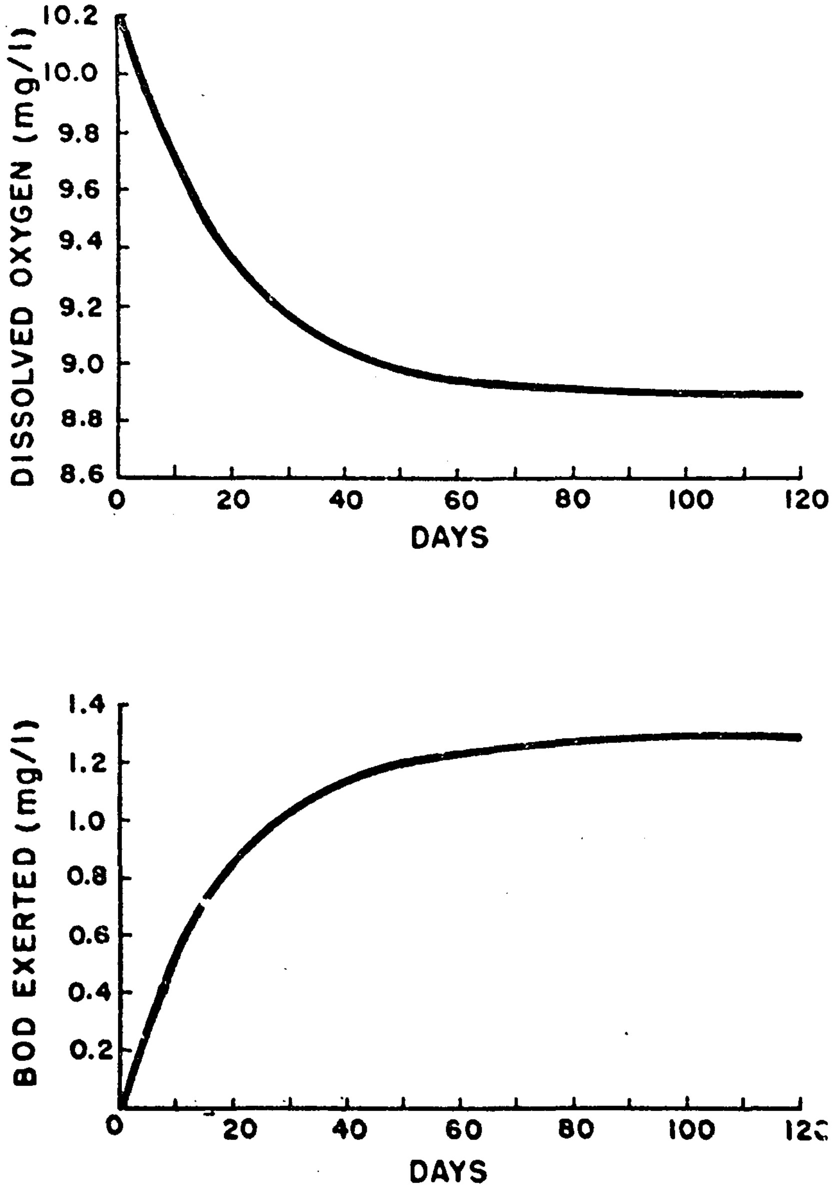


Figure 7-11. Hypolimnion Dissolved Oxygen Prediction for Bull Pond, 1979.

stratification in mid May the lowest DO will be from mid August until turnover. This DO should be just under 9.0 mg/l which cannot be considered low. Actual water samples taken on 30 August 1979 at the same location and depth as the mid-May samples showed dissolved oxygen content of 7.9 mg/l and 8.0 mg/l from replicate amples. These same samples had an average BOD of 0.22 mg/l.

The model formulation (Equation 7-12) ignores settling of organic material from the epilimnion and metalimnion. The lower than predicted DO and higher than expected BOD are consistent with such an input of material. Another possible source of disagreement between the predicted and observed values may be traceable to our assuming that $L_{SS}$, the benthic BOD load prior to stratification was zero. If we had assumed $L_{SS}$ was 100 $g/m^2$ (Table V-10, Zison et al., 1977) and $k_S$ on the order of 0.00166 at 5°C then at 90 days $\Delta O_L$ would be 0.7 mg/l of DO decrease in addition to that already predicted assuming $k_S$=0. This would bring the predicted DO at 90 days to 8.2 mg/l, in better agreement with the observed. We believe the model has predicted DO content satisfactorily and can be considered validated for Bull Pond.

## SECTION 8

## DISCUSSION

### 8.1 INTRODUCTION

In trying to apply the *Non-designated 208 Area Screening* Method models (Zison et al., 1977) to the West Point Study Area several problems were encountered:

1. Portions were just not applicable. In this case, we went back to the source material to determine whether the model could be extended to cover our situation within the limits of the original field studies on which the model was based, or we searched for an alternate procedure.

2. Portions were presented in an unclear manner, requiring clarification before we could proceed.

Except for the lake eutrophication model, we have found methods which allowed the screening methods to be applied to a steeply sloped forested watershed. At this time insufficient data exist on the West Point Study Area to allow comparison between the predictions from the extended Nondesignated 208 Area Screening Method and actual field data. Chemical and hydrological data collection now in progress in sub-areas 1 through 4 should allow this comparison to be made in the next year.

### 8.2 WASTE LOADING PREDICTIONS FROM NONPOINT SOURCES

Parameter estimation for use in the Universal Soil Loss Equation was the biggest problem encountered, although ill-defined procedures for determining slope length and drainage density caused some difficulty. These are discussed below.

#### 8.2.1 Rainfall Factor, R

This average annual quantity is obtainable from maps presented in the model (Zison et al., 1977). When searching for a method whereby local data could be used to calculate R, we found a much clearer map in Agriculture Handbook 537 (U.S. Department of Agriculture, 1978). This map has county boundaries within a state and allows more accurate location of a watershed on the map and therefore more accurate selection of an R value. Replacement of the current map by the Wischmeier and Smith (1965) map is recommended.

### 8.2.2 Topographic Factor, LS

The graph for determination of LS values from Zison et al. (1977) was not applicable to the West Point Study Area. Two replacement procedures were found:

1. Equations for the determination of LS on irregular slopes (Foster and Wischmeier, 1973).

2. Equations supplemented by graphs for determination of LS in Forested Areas (Forest Service, 1978).

It is not clear from the first (Foster and Wischmeier, 1973) whether the range of slopes covers the up to the 60 degree slopes needed for West Point. In use, the method is cumbersome and fraught with possibilities for errors. The second method (Forest Service, 1978) is a slight improvement on the first, reducing the number of calculations because of Figure 7-2. Many calculations are still necessary to obtain an average LS value for an area. Both methods produce comparable LS values for the West Point slopes. It is not clear whether the Forest Service method (1978) is based on new field data for high slopes, or is an extension of the Foster and Wischmeier (1973) work which does not present any limitation to the range of applicability.

Both the Foster and Wischmeier (1973) and Forest Service (1978) methods require a determination of slope length as pointed out in Section 7.2.2.4. The Zison et al. model needs clarification on how this parameter should be determined. As shown in Table 7-2 the slope length picked makes a significant difference in the value of LS computed. Our procedure of defining slope length as the distance from a ridgeline or hilltop downhill to a stream, lake, or wetland as shown on a 1:25,000 topographic map or to a steep narrow valley or draw, also on the map, which probably contained a "well-defined channel" will produce an LS value on the high side of that produced by measurements from aerial photography, larger scale maps, or field measurement. We believe this is adequate since the Nondesignated 208 Area Screening Methods (Zison et al., 1977) are meant to point up possible pollution problem areas for further investigation or modeling by more rigorous methods.

### 8.2.3 Erosion Control Practice Factor, P

The Zison et al., (1977) model needs clarification on the use of this factor. Setting its value to 1.0 as we did in our calculations effectively eliminates the factor from the calculation. Clearly, use could be made of the factor to distinguish between clear cut, strip cut, selective cut, and undisturbed forested areas. Use could also be made to reflect logging road placement, and methods for log removal from a forest. Our lack of experience in this area does not allow us to suggest values for P for these various forest erosion control practices.

### 8.2.4 Sediment Delivery Ratio, $S_d$

As presented in the Nondesignated 208 Screening Method, calculation of sediment delivery ratio is directly dependent on the determination of drainage density. A clarification is needed in the procedures to standardize how drainage density will be calculated. Our work with 1:7,500 and 1:25,000 scale maps shows that a significant difference in drainage density can result by choice of scale (Table 7-4). This difference does not translate to significant differences in sediment delivery ratio, however (Table 7-5). It seems logical to standardize on the use of the more readily available 1:24,000 USGS quadrangles for drainage density and topographic factor (Section 8.2.2).

We are still concerned about the magnitude of the $S_d$ values calculated for a forested watershed area compared to what we see as sediment load in streams, and as deltaic accumulation where streams enter lakes. It may be that we are focusing too closely on $S_d$ when the other factors in the universal soil loss equation will limit sediment production to a very low value which is then multiplied by what we consider a high sediment delivery ratio yielding a low sediment load prediction. Validation of the extended model based on measured sediment loads is definitely needed. The low sediment delivery index produced by the Forest Service model (1978) more closely approximates what we feel is actually occuring on our watershed. Validation of the models with the Forest Service SDI (1978) replacing $S_d$ should be considered.

## 8.3 IS EXTENSION OF ZISON et al., 1977 TO FORESTS NECESSARY?

In several instances to make the Nondesignated 208 Area Screening Method (Zison et al., 1977) work on the West Point Study Area, we have turned to the Forest Service (1978) WRENSS model and borrowed pieces to patch up difficulties in the former model. Which is the better model, the patched up 208 Screening Method or the WRENSS? The WRENSS model was developed for forested areas and probably should be used for large forested watersheds in preference to the 208 Screening Method. The Nondesignated 208 Screening Method was meant to identify problem areas in large regions, portions of which may contain forests. It should contain procedures to allow modeling of forested areas or incorporate the WRENSS procedures for this purpose. A comparison of the ease of use of the two procedures, and comparison with field data are needed to decide whether WRENSS procedures or patched up Nondesignated 208 Area procedures is the better alternative.

## 8.4 THE IMPOUNDMENT MODELS

The impoundment models were applied without modification. The thermal profile predictions for lakes of various depths and residence times can be said to be validated for The West Point Study Area, although we could have used better guidance in the procedures on how to decide whether our lakes were well mixed. These procedures could easily be applied with confidence to other lakes in The Hudson Highlands with confidence. For existing impoundments, the data requirements for their use, however, are such that we think many modelers would be prevented from using the prediction, finding it easier and cheaper to measure a thermal profile than to obtain data necessary to compute lake volume and residence time. For planned impoundments, the designers would know volumes and easily predict residence time.

The sedimentation rate prediction is easily applied but is only as good as the nonpoint source sediment yield predictions discussed above (Section 8.2.4). When the best predictive method for forested areas is determined, then a closer look at the sediment accumulation prediction can be made.

The impoundment eutrophication predictions in the Nondesignated 208 Area Screening Method (Zison et al., 1977) will indicate a eutrophication problem only in phosphorus limited situations. The procedures should be expanded to allow prediction in nitrogen limiting and situations in which neither controls. The stream models in Zison et al., (1977, Section 4.5) have provision for this and perhaps could be expanded to lakes.

The dissolved oxygen model gives a reasonable approximation for DO levels during the mid-summer maximum stress period. Assuming $k_s$=0, yields a DO prediction higher than observed and can lead one to conclude, as we did, that the benthic DO demand prior to stratification is zero. This is not reasonable for any lake, and in our test at Bull Pond yielded a difference between actual and predicted DO levels of almost 1.0 mg/l. In lakes with higher levels of decaying organic matter the difference would be greater. Table V-10 (Zison et al., 1977) should be used in preference to Equation 7-13 for assigning an $L_{ss}$ value. The assumption, based on observations at Bull Pond, that $k_s$=0 appears justified in other parts of the model. Again this works well for Bull Pond, but in other lakes with higher settable BOD rate, it will lead to a prediction error.

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## APPENDIX A

Soil Units in the West Point Study Area
(after Wright and Olsson, 1972)

Mapping Unit

9 Hoosic Gravelly Fine Sandy Loam
Hoosic soils are well to somewhat excessively drained, brownish, strongly to medium acid, medium to moderately coarse textured soils that formed on glacial outwash plains, valley trains and related kames, eskers and water sorted parts of moraines. They occupy nearly level through very steep slopes. Hoosic soils have 1.5 to 2.5 feet of moderately rapidly permeable gravelly loam to gravelly sandy loam over rapidly permeable sorted sands and gravels dominated by slate and shale.

22 Charlton and Narragansett Extremely Stony Soils
Charlton and Narragansett extremely stony soils are deep, well drained, strongly acid, moderately coarse to medium textured soils that formed in glacial till derived mainly from schist and gneiss. Slope ranges from level through very steep and runoff is slow through rapid. The permeability is moderate to moderately rapid. Stones cover approximately 3 to 15 percent of the surface. These soils are mapped together as an undifferentiated soil group because their differences are not significant to the purpose of the survey or to the soil interpretations.

38 Squires Loam
Squires soils are deep, well drained, medium to slightly acid, medium textured soils developed in glacial till with the admixture of local limestone materials. They occupy gently sloping through steep glaciated hills and uplands in limestone areas. Squires soils have about 2.5 feet of moderately permeable brown loam or silt loam over a slowly permeable substratum of light brown silt loam.

63 Charlton Fine Sandy Loam
Charlton soils are deep, well drained, very strongly to

strongly acid, moderately coarse to medium textured soils that formed in glacial till derived mainly from shist and gneiss. The coarse fragment content ranges from 5 to 30 percent and the soils are frequently stony and very stony. These gently sloping through moderately steep soils are on upland till plains. Permeability of this soil is moderate and runoff is medium to rapid.

91 Wayland Silt Loam

Wayland soils are deep, poorly drained, neutral to mildly alkaline, medium textured soils formed in neutral or calcareous recent alluvium. They occupy nearly level areas or depressions on flood plains or streams receiving erosion from uplands that contain some calcareous materials. Wayland soils have 3 to 5 feet of moderately permeable silt loam or coarse silty clay loam over stratified alluvial sediments consisting of layers of sands, silts, clays and gravel. The surface is high in organic matter.

94 Carlisle Muck

Carlisle soils are organic soils developed in well decomposed woody organic deposits more than 51 inches thick. They occupy bogs within lake plains, outwash plains, till plains and moraines. This soil has a substratum of organic material to a depth of 144 inches.

96 Palms Muck

Palms soils are very poorly drained, medium to slightly acid organic soils developed from highly decomposed herbaceous materials over a loamy mineral substratum. They occupy level to nearly level lake and till plains. Palms soils have 1.5 to 4 feet of black organic material underlain by grayish clay loam to fine sandy loam.

025 Scribe-Sun Extremely Stony Association

Scriba-Sun extremely stony association is deep, somewhat poorly through very poorly drained, medium to moderately coarse texture upland soil that formed in glacial till derived from gray and brown quartzite and sandstone. Slope ranges from level to gently sloping and runoff is slow. Permeability is very slow due to a dense hardpan at 12 inches. This unit has approximately 3 to 15 percent of the surface covered with stones larger than ten inches in diameter. This soil complex is separated because of the high percentage of stones. In this unit both Scriba and Sun soils occur in such an intricate pattern that they cannot be mapped separately. The soil profiles of each are similar to that described for their respective series.

026 Alden and Sun Extremely Stony Soils

Alden and Sun extremely stony soils are poorly to very poorly drained soils. They are the same as the Sun (26) soils except for the stony conditions. The limitation ratings for the Sun soils should be used with consideration given to the stony conditions.

070 Hollis Rocky Association

Hollis rocky association is shallow excessively drained to well drained, moderately coarse to medium textured soils formed in low lying glacial till dominated by granite materials. The slope ranges from gently sloping through steep and runoff is moderate to rapid. Bedrock outcroppings generally occupies from 2 to 10 percent of the surface, but there are small areas in which the bedrock is considerably deeper. As this association occurs mainly in heavily wooded and mountainous areas, it is impossible to map in as much detail as regular mapping units.

071 Hollis Rock Outcrop Association

Hollis Rock Outcrop association is shallow, excessively drained, moderately coarse textured soil formed in low lime glacial till dominated by granitic materials. The slope ranges from gently sloping through very steep and runoff is rapid. Bedrock outcropping generally occupies 90 percent or better of the surface. The shallow Hollis soils occupies 10 percent of the area and the rock outcrop occupies 90 percent of the area. As this association occurs mainly in heavily wooded and mountainous areas, it is impossible to map in as much detail as regular mapping units.

## APPENDIX B

### Soil Profile - Hollis Series

Location: Town of Tuxedo, 200 yards south of New York 210, 1/4 of mile east of 1-87, on New York 210.

O2 3 to 0 inches, dark reddish brown (5YR 3/2) loose decomposed roots, sticks, and leaves; strongly acid; clear smooth boundary.

A1 0 to 4 inches, dark brown (10YR 4/3) gravelly loam; moderate medium granular structure; very friable; many roots; few pores; 15 percent gravel; strongly acid; clear wavy boundary.

B2 4 to 14 inches, strong brown (7.5YR 5/6) gravelly loam; moderate medium subangular blocky structure; fiable; many roots; common pores; 20 percent gravel; strongly acid; abrupt smooth boundary.

R 14 inches, hard gray granitic bedrock.

Range in Characteristics:

Solum thickness and depth to bedrock ranges from 10 to 20 inches. Coarse fragments range from 5 to 25 percent. Textures range from sandy loam through loam. Reaction ranges from strongly acid to very strongly acid. The A1 horizon has color of 10YR hue, 2 through 4 value, and 2 or 3 chroma. The B horizon has color of 10YR to 7.5YR hue, 4 or 5 values, and 5 through 8 chroma. Consistency ranges from friable to very friable. Exposed rock outcrop ranges from rocky through rock-outcrop, which ranges in percentage from 2 through 90 percent.

Harrington, 1975

## APPENDIX C

### Wildlife Present on the USMA Reservation

| Common Name | Scientific Name |
|---|---|
| Deer, white-tail | Odocoileus virginianus |
| Skunk | Mephitis mephitis |
| Mink | Mustela vison |
| Muskrat | Ondatra zibethica |
| Fox, gray | Urocyon cinercoargenteus |
| Fox, red | Vulpes fulva |
| Squirrel, gray | Sciurus caroliniensis |
| Squirrel, red | Tamisciurus hudsonicus |
| Beaver | Castor canadensis |
| Squirrel, flying | Galucomys volans |
| Chipmunk | Tamias striatus |
| Woodchuck | Marmota monax |
| Marten | Martes americana |
| Weasel | Mustela frenata |
| Opposum | Didelphis virginiana |
| Raccoon | Procyon lotor |
| Rabbit, cottontail | Sylvilagus floridanus |
| Field mouse | Microtus pennsylvanicus |
| Pine mouse | Microtus sp. |
| Mole | Scapanus latimanus |
| Otter | Lutra canadensis |
| Rabbit, snowshoe | Lepus americanus |
| Black bear (rare) | Ursus americanus |
| Wildcat (rare) | Lynx rufus |

Office of the Engineer, West Point, 1962