DAM-BREAK FLOOD ANALYSIS

PINE GROVE LAKE DAM AT
VILLAGE OF SLOATSBURG, NEW YORK

FINAL REPORT

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U.S. ARMY CORPS OF ENGINEERS
NEW YORK DISTRICT

DuBois & King inc.

Pine Grove Lake Dam
Dam-Breach Flood Analysis

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EXECUTIVE SUMMARY

The primary purpose of this study is to determine the downstream hazard classification of Pine Grove Lake Dam for the Dam Safety Section under the jurisdiction of the State of New York, Department of Environmental Conservation, Bureau of Flood Protection. The secondary purpose of the study is to provide supporting information for the dam owner to develop an Emergency Action Plan (EAP) in the event of an impending dam failure.

Dam-break conditions are evaluated for both "sunny-day" and "storm-day" failures. The hypothetical flood analyzed were the 100-year, and four ratios of the Probable Maximum Flood (PMF): ¼, ½, ¾, and full PMF.

Inflow hydrographs and spillway hydraulic capacity are developed as a basis upon which to model the breach discharge. Peak flows are routed through the reservoir using the National Weather DAMBRK flood-forecasting model. Breach discharge hydrographs for a sunny-day and a ½ PMF storm-day are routed through the downstream channel for a distance of approximately 1.0 miles below the dam. Limits of inundation are delineated in plan and profile view.

On the basis of U.S. Army Corps of Engineers guidelines for safety inspection (ER-1110-2-106), the Pine Grove Lake Dam size classification is "small". On the basis of the potential of the dam to cause downstream damage in the event of failure, in terms of either loss of life or economic loss, Pine Grove Lake Dam is rated as a Class C, High Hazard Category.

Pine Grove Lake Dam

Dam-Breach Flood Analysis

1. INTRODUCTION

a. Purpose. The purpose of this study is to determine the downstream hazard classification of the Pine Grove Lake Dam located in the Village of Sloatsburg, County of Rockland, New York. The hazard classification is based on a system developed by the U.S. Army Corps of Engineers and used by the State of New York, Dam Safety Section. Hazard classifications are used as the basis for evaluating the hydraulic capacity of the dam and the frequency of inspections of the structure. A second purpose is to provide information for use by the dam owner in developing an Emergency Action Plan (EAP) for use in the event of an impending dam failure. This study was performed for the State of New York, Department of Environmental Conservation, Bureau of Flood Protection, Dam Safety Section.

The study presents the findings for various dam-break flood conditions for Pine Grove Lake Dam with resulting downstream effects. These findings include mechanisms, which trigger failure of the dam, resulting breach discharges, delineation of downstream flood limits (inundation mapping) and determination of downstream hazard classification. This study was performed to investigate results of a hypothetical dam-breach at the Pine Grove Lake Dam and not because of an expected failure of the dam.

b. Authority. In September 1999, the U.S. Army Corps of Engineers, New York District, authorized DuBois & King, Inc., to conduct this dam-break flood analysis. This analysis is the Corps of Engineers' response to a request from the New York Department of Environmental Conservation for assistance in their Dam Safety program. Appreciation is given to Mr. - Michael R. Stankiewicz, P.E. of the Dam Safety Section of the Flood Protection Bureau, who provided valuable information regarding this project.

c. Downstream Hazard Classifications. The State of New York classifies dams according to the potential for loss of life and property damage in the area downstream of the dam if it were to fail. The hazard classification as stated in Part 673.3 of the Dam Safety Regulations[1] is as follows:

> The Department may assign a hazard classification to dams according to the potential impacts of a dam failure.
>
> (1) Class A (LOW hazard) dams are located in areas where failure will damage nothing more than isolated buildings, undeveloped lands, or town or county roads and/or will cause no significant economic loss or serious environmental damage.

(2) Class B (SIGNIFICANT hazard) dams are located in areas where failure may damage isolated homes, main highways, minor railroads, interrupt the use of relatively important public utilities and/or will cause significant economic loss or serious environmental damage.

(3) Class C (HIGH hazard) dams are located in areas where failure may cause loss of human life, serious damage to homes, industrial or commercial buildings, important public utilities, main highways or railroads and/or will cause extensive economic loss.

The factors used to assess a hazard classification are:

(1) the height of the dam and the maximum impoundment capacity;

(2) the potential for loss of human life;

(3) the physical characteristics of the dam site and the location of developed areas, occupied buildings or other land improvement in the area which would be affected by a failure of the dam;

(4) the economic loss, which could result from failure of the dam;

(5) the environmental damage which could result from a failure of the dam; and

(6) other site-specific characteristics which the Department determines are necessary to consider.

2. PROJECT DESCRIPTION

A. Dam Construction

The Pine Grove Lake Dam is an earth embankment structure that includes a 12-foot concrete spillway. The dam is reportedly to have been built in 1968. The dam is located on an unnamed tributary of the Ramapo River in the Village of Sloatsburg. The study area for this project is shown on the site location map (see Plate 1).

Pine Grove Lake Dam is 335 feet long and approximately 8 to 12 feet high at the maximum section. The spillway is 12 feet long (See Photos 1 and 2).

B. Dam Description

1. Identification

Pine Grove Lake Dam is identified by the New York Department of Environmental Conservation as No. 196-3793. The Village of Sloatsburg presently owns the dam. Additional pertinent data on the dam that is listed below was obtained from the survey performed for this dam-break flood analysis.

2. Physical Characteristics

Dam

Type:	Earth embankment
Length:	335 feet
Height:	8 to 12 feet (at maximum section)
Top Width:	18 to 20 feet
Side Slopes - Upstream:	unknown
Downstream:	2.7H to 1V

3. Elevations

Downstream toe of dam	+/- 546.5 NGVD
Spillway control section (crest)	552.45 NGVD
Top of Dam	554.5 NGVD

4. Impoundment Behind Dam

Surface Area:

Spillway control section:	5.1 acres
Top of Dam:	6.3 acres

Storage Volume:

Spillway control section:	35.6 acre-feet
Top of Dam:	47.5 acre-feet

5. Drainage Area

Size: The drainage area at the Pine Grove Lake Dam is 123.7 acres or 0.19 square miles.

3. DOWNSTREAM STUDY AREA

A. Community Description

Pine Grove Lake Dam is located in the Village of Sloatsburg, in Rockland County, New York. The Village is located in southern New York near the New York - New Jersey state-line, near Interstate 87. The Village of Sloatsburg has a population of approximately 3,120 persons.

The total study area is shown on Plate 1. Pertinent locations and features from the Pine Grove Lake Dam to the dam located on the Ramapo River in the Village of Sloatsburg are described within this report, inundation maps, and profiles, using river mile indicators, such as MM 0.00. For example, river mile indicator for the Pine Grove Lake Dam is MM 0.00, the Mirror Lake Dam is MM 0.50 and the culvert crossing under Interstate 87 is MM 0.77.

B. Downstream Conditions

The study begins at the Pine Grove Lake Dam (MM0.00) (See Photos 1 and 2) and extends downstream along the unnamed tributary of the Ramapo River for approximately 1.0-mile to the dam on the Ramapo River at MM 1.0. The reach from the dam MM 0.00 to the Torne Road culvert (MM 0.26) is a heavily wooded stream valley with a large number of residents located on the edge of the floodplain. There are a number of residential structures located around the perimeter of the Mirror Lake from MM 0.26 to MM 0.50. The reach from MM 0.50 to the Interstate 87 is heavily wooded with no residencies. There are a number of residencies located on the west side of Interstate 87.

The reach from the dam (MM 0.00) to the entrance into Mirror Lake (MM0.32) is characterized as a steep, heavily wooded valley (See Photo 3). The slope of the streambed from Pine Grove Lake Dam to MM 0.32 is 344 feet per mile. There is one road crossing, Torne Road, of this unnamed tributary of Ramapo River between MM 0.00 and MM 0.32. There is a culvert at Torne Road, MM 0.26 (See Photo 4).

The stream valley from Mile 0.00 to MM 0.32 is fairly contained; however at the road crossing MM 0.26, the stream valley flattens and broadens and the culvert at MM 0.26, a 2-foot (height) by 8-foot (wide) box culvert is a restriction in the small channel available for conveying floodwaters at this location.

The reach from MM 0.32 to MM 0.50 is controlled by the Mirror Lake Dam at MM 0.50 (See Photos 6 and 7). There are a number of residential structures located around the perimeter of the Mirror Lake (See Photos 5 and 6).

The reach from the Mirror Lake Dam (MM 0.50) to MM 0.77 is a steep, heavily wooded valley until the unnamed tributary crosses Interstate 87. There is a 48-inch culvert conveying the unnamed tributary under Interstate 87 (See Photo 9). The slope of the streambed from Mirror Lake Dam (MM 0.50) to MM 0.77 is 193 feet per mile.

The reach from MM 0.77 to MM 1.00 is flat and heavily wooded with a few homes located on the west side of Interstate 87. An unnamed concrete dam on the Ramapo River is located at MM 1.00 (See Photo 10).

4. METHOD OF ANALYSIS

A. General

This section of the report examines the methods and assumptions used in the dam-break analysis. The magnitude of a flood resulting from a hypothetical dam-breach depends not only on the size of the dam but also on the conditions of failure including the initial water level in the reservoir, size of the breach, rate of breach formation, as well as hydraulic features and initial flows in the downstream river channels. Two types of hypothetical dam-failures were evaluated in this study; a sunny-day failure and a storm-day failure. The results of the analysis are presented in Section V.

A **sunny-day** failure refers to a dam failure under normal water level usually associated with fair weather or non-flood conditions. This type of failure often results from piping, which is the progressive internal erosion of a soil mass such as an embankment, foundation or abutment of a dam from uncontrolled seepage carrying soil particles to an unprotected exit that over time creates an erosion cavity or pipe. Once this happens, a rapid failure of the dam can occur which releases the contents of the reservoir and forms the breach discharge. Piping is the most common cause of sunny-day failures of earth dams and other dams that are constructed on earth foundations or abutments. A sunny-day failure can also result from other causes, such as a sudden failure of a conduit under pressure or a structural component of the dam. Concrete gravity dams can have a partial breach as one or more monolith sections formed during the construction of the dam can be forced apart by the escaping water.

A **storm-day** failure is associated with major storm events and floods. During periods of significant rainfall and resulting runoff, the reservoir will rise to high levels. If the storm is severe enough, and the inflow exceeds the hydraulic capacity of the spillway and reservoir storage capacity, overtopping of the embankment can occur. As floodwaters flow over the dam, the erosion of the earth embankment or abutments can occur resulting in a failure of the dam and the formation of the breach discharge as the contents of the reservoir are released. High reservoir levels associated with the storm-day type failures can also result in other failure modes, such as piping, sudden structural failure or progressive failure of stone or masonry elements.

A dam-breach analysis for Pine Grove Lake Dam was conducted using Boss Corporation's 1992 release of the National Weather Service Dam-Break Flood Forecasting Computer Model (NWS DAMBRK)[2, 3] developed by D.L. Fread. Input for the computer model consists of storage and discharge characteristics of the reservoir, selected geometry and duration of breach development, selected geometry of the stream valley downstream of the dam and the hydraulic roughness coefficients for the downstream channel. Detailed descriptions of this data are discussed later in this section of the report. The computer model analysis provides output on the attenuation of the dam-break flood hydrograph, and the timing of this flood wave as it progresses downstream. These results are also discussed in detail.

B. Hydrology

In order to perform the dam-breach analysis for the Pine Grove Lake Dam and the effected downstream river valley, the antecedent (prior to the hypothetical dam-breach) water levels at the dam and the river flow conditions must be established for the sunny-day and storm-day failures.

Antecedent Sunny-day Failure Conditions

The antecedent sunny-day failure conditions at the Pine Grove Lake Dam and the downstream river valley were initially developed to be equivalent to the mean annual flow for the contributing drainage area of approximately 1.0 to 3.0 cfs per square mile of drainage area. The flow per square mile was developed from an analysis of U.S.G.S. river gages in the vicinity of the Village. For some dam-breach analysis, the resulting antecedent condition needs to be increased to facilitate the dam-break model convergence at initial conditions. The increase is not an uncommon modeling requirement for small drainage areas and is insignificant when compared to the routed dam breach peak discharge. The antecedent flow condition at Pine Grove Dam of 10 cfs was used in the dam-break model.

Antecedent Storm-day Failure Conditions

The antecedent storm-day failure conditions at Pine Grove Lake Dam were developed utilizing the U.S. Army Corps of Engineers HEC-1 Flood Hydrograph Package Computer Program.[4] The HEC-1 Program was used to calculate the storm inflow hydrographs into the reservoirs for the 100-Year storm, the ¼, ½, ¾, and the full probable maximum flood (PMF) storm events. The method used in the HEC-1 Program to develop the storm inflow hydrographs was the SCS Unit Hydrograph. This procedure determines runoff discharge rates for a given drainage area over a specified duration of time. The parameters required for this method include the drainage area, SCS runoff curve number, lag time and rainfall depth of the storm being analyzed. The results of this analysis are presented in Table 1.

The rainfall values used for the 100-Year storm were obtained from the Northeast Regional Climate Center (NRCC) Atlas of Precipitation Extremes for the Northeastern United States and Southeastern Canada.[5] Within the HEC-1 Program, a triangular precipitation distribution is constructed such that the depth specified for any duration occurs during the central part of the storm. The total 24-hour, 100-Year rainfall for this location is 8.7-inches.

The probable maximum precipitation (PMP) was developed in accordance with the procedure outlined in Hydrometeorological Reports 51 [6] and 52 [7] with the storm centered over the 0.19 square mile watershed. Within the HEC-1 Program, a triangular precipitation distribution is constructed such that the depth specified for any duration occurs during the central part of the storm. The resulting 48-hour full PMP is 37.3-inches. The ½ PMP is approximately 18.7-inches.

The antecedent storm-day flows downstream of Pine Grove Lake Dam on the unnamed tributary of the Ramapo River were developed by approximate methods. Based on consultation with the State of New York, Department of Environmental Conservation, Dam Safety Section, the 100-year flood flows at the major stream were incorporated into the NWS DAMBRK Computer Model. This same process for antecedent storm-day downstream inflows was used on other New York projects being performed during this same time period. The 100-year flood flow for the Ramapo River was incorporated into the NWS DAMBRK Computer Model at MM 0.80. The 100-year flood flow on the Ramapo River was obtained from Village of Sloatsburg's Flood Insurance Study [8]. For some dam-breach analysis, a large change in the flow due to a large inflow from a downstream tributary can create convergence difficulties in the computer model. This was the case for the storm-day model, when the 100-year flood flow of 9,500 cfs was included in the DAMBRK computer model at MM 0.80.

For the final computer model of the storm-day failure, the 100-year downstream inflow from the Ramapo River was not included. Since the hypothetical storm-day dam failure at Pine Grove Lake Dam creates a peak discharge of approximately 1,300 cfs and since this peak discharge is only 14 percent of the 100-year flood flow on the Ramapo River it was concluded that the 100-year inundation depths as calculated in the flood insurance study would be the controlling water level at MM 1.00 and the inundation depths as calculated in the NWS DAMBRK Computer Model at MM 0.77 (upstream side of Interstate I-87) and MM 0.80 (downstream of Interstate I-87) would control inundation depths in these areas.

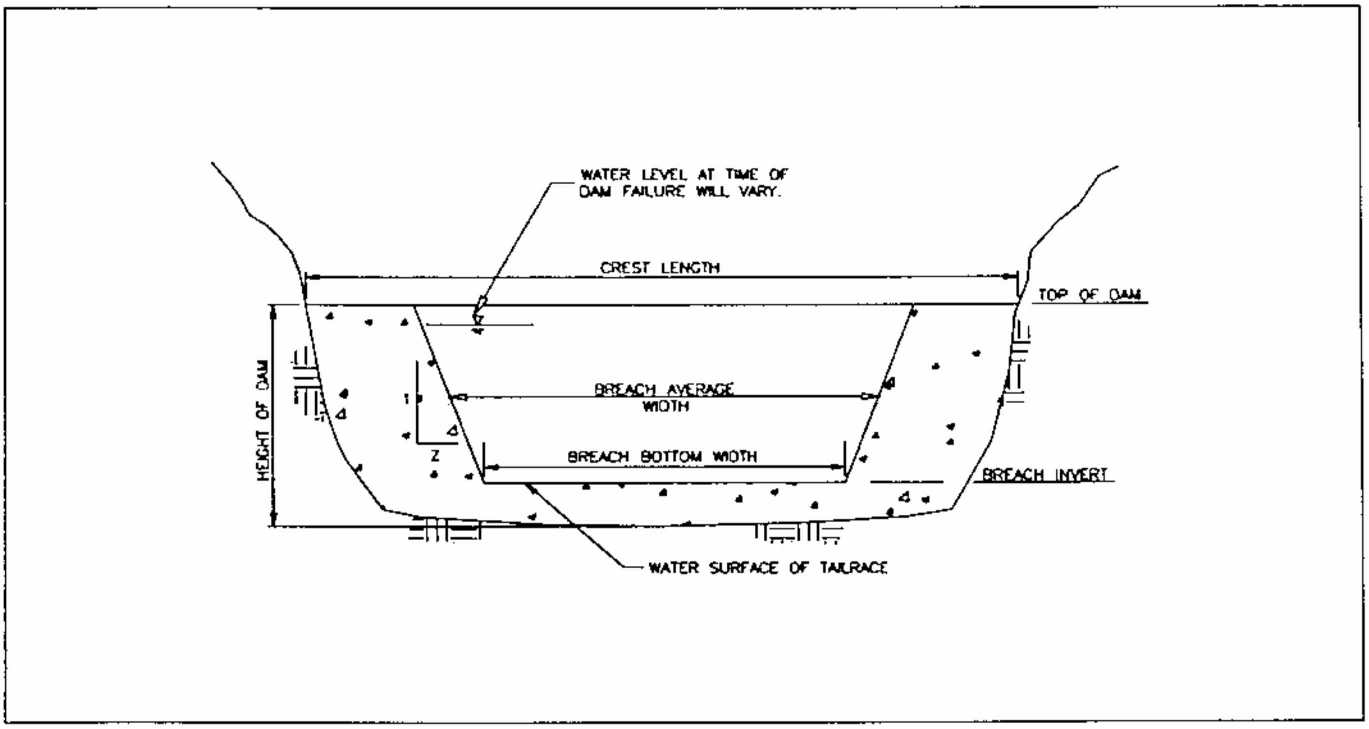
C. Spillway Hydraulic Capacity

The rating curves for the Pine Grove Lake Dam, and Mirror Lake Dam were developed using the weir equation, to describe the capacity of the dam to release floodwaters at different reservoir levels. The rating curve is based on the elevation and geometry of the concrete spillway obtained from field survey. The rating curve also includes the capacity of the dam to release floodwaters over the top of the dam. The rating curve for Pine Grove Lake Dam was used in the HEC-1 Program as well as the NWS DAMBRK Program to route the storm hydrographs through the reservoir.

D. Breach Discharge Hydrograph

The discharge hydrograph from a dam failure, or breach discharge hydrograph, is a function of the routed inflow hydrograph and the breach parameters (time of breach information, size and shape of breach) associated with a hypothetical dam failure. Breach parameters are established based on the Federal Energy Regulatory Commission (FERC) Guidelines [9]. The following sketch illustrates the various dam breach parameters in a typical dam. The total flow from the dam during a dam failure is a combination of flow through the breach opening and flow through the spillways. As the breach in the dam develops, so does the breach discharge. Table 2 provides the assumed breach parameters used for the sunny-day and storm-day dam failures for the Pine Grove Lake Dam.

Definition Sketch of Breach Parameters



E. Downstream Channel Routing

A downstream channel routing analysis using the NWS DAMBRK program, allows the breach discharge to be characterized at points of interest below the dam. A breach hydrograph is attenuated and stored through the downstream channel and flood plain in a manner similar to that of an inflow hydrograph being routed through a reservoir. The degree to which this breach discharge is attenuated is a function of the downstream valley geometry, storage capacity and valley roughness characteristics.

The dynamic wave method of channel routing is used in the NWS DAMBRK model to route the dam breach flood wave downstream. This is a hydraulic routing method that solves the complete unsteady flow equations through a given reach. Results of this method indicate attenuation of the flood wave, resulting flood stages, and the time it takes the wave to reach a section of the river.

To determine the downstream valley geometry and its hydraulic characteristics such as storage, slope and roughness, cross sections of the river valley were obtained from field surveys. Manning's "n" values (hydraulic roughness) were assigned to the channel and overbanks on the basis of field observations and standard reference material.[10] The "n" values for unnamed tributary of Ramapo River channel ranged from

0.035 to 0.0.04. The "n" values for its flood plain ranged from 0.06 to 0.20. The "n" values [11] used in dam-break analysis are typically increased to reflect the additional energy losses associated with the increased turbulence, greater velocities and greater depths of inundation associated with a dam-break floodwave.

There are two stream crossings within the project area. There is one culvert at MM 0.26 (Torne Road) and one culvert at Interstate 87 (MM 0.77). The culvert at MM 0.26 was not modeled due to its size and location. This culvert is small and during larger flood flows that occur during dam-break analysis this culvert would soon be overtopped and the majority of the flow conveyed over the culvert. The Interstate 87 culvert at MM 0.77, was hydraulically modeled in the NWS DAMBRK computer model.

The downstream channel routing procedure is based on the assumption that flow structures such as the spillways at Pine Grove Lake and Mirror Lake and the culvert at Interstate 87 do not become partially or fully blocked with debris. If a structure becomes blocked with debris, then the peak water surface behind them could increase to stages higher than estimated.

The NWS DAMBRK model requires that the water surface elevation at the downstream study limit be established at a known condition. For the sunny-day and storm-day models, the water surface elevations at the downstream study limit, the unnamed dam on Ramapo River (MM 1.00), were established as critical depth.

5. RESULTS OF ANALYSIS

A. <u>Inflow Hydrographs</u>

Table 1 summarizes peak inflow, peak outflow and maximum reservoir water surface elevations for the storm event considered in this dam-breach analysis. Plate 2 depicts the reservoir inflow and routed outflow hydrograph for the ½ PMF storm event. These hydrographs were generated by the HEC-1 computer model.

B. <u>Breach Discharge Hydrograph</u>

The peak breach discharge for the dam based on the previously defined breach parameters is 460 cfs for a sunny-day event and 1,380 cfs for a storm-day event. The breach parameters are based on the FERC guidelines for an earthen dam. The breach location of Pine Grove Lake Dam is assumed to occur at the maximum section (i.e., the section where the dam height is at its greatest dimension).

Tables 3 and 4 summarize the dam peak discharge and the downstream channel routing results under a sunny-day and storm-day failure, respectively. The sunny-day and storm-day failures were assumed to reach the full breach width in 0.5 hours. Downstream breach discharge hydrographs, generated from the dam-break computer model are indicated in Plates 5 and 6.

C. Downstream Channel Routing

As shown in the breach discharge hydrographs generated by the dam-break computer model, flows are attenuated as they are routed downstream (Plates 3 and 4). Plates 5 and 6 show peak water surface profiles (depth of flooding above the streambed) resulting from both the sunny-day and storm-day dam failure scenarios along the unnamed tributary, from MM 0.00 to MM 1.00. Additional information regarding the sunny-day failure scenario is provided in Table 3. Table 3 includes the peak discharge and peak water surface elevation associated with the dam failure, as well as the depth of the flood wave above the streambed and the time to the peak water surface elevation. Table 4 provides identical information for the storm-day failure scenario.

From examination of the Tables and Plates the following conclusions can be reached:

Sunny-Day Results

The peak sunny-day discharge at the dam (MM 0.00) is 460 cfs and is attenuated to 170 cfs at Interstate 87 (MM 0.77).

The peak flow at the Torne Road culvert (MM 0.26) is 435 cfs and overtops the road by approximately 0.5 to 1.0 foot. The existing culvert entrance is 2-foot high by 8 feet wide. The capacity of this culvert is approximately 130 cfs prior to overtopping and flowing onto Torne Road.

The peak discharge at Mirror Lake Dam (MM 0.50) is 175 cfs. At this flow the peak water surface elevation is close to overtopping the Mirror Lake Dam. With the water level in Mirror Lake up 2.5 feet above its normal water surface, the flood water levels will be encroaching upon the two roads that surround the lake. (Greenway and Torne Roads)

The peak flow at Interstate 87 is 175 cfs. At this flow, the floodwaters are close to overtopping the 48-inch culvert and Interstate embankment.

Storm-Day Results

The peak storm-day discharge at the dam (MM 0.00) is 1380 cfs and is attenuated to 1210 cfs at Interstate 87 (MM 0.77).

The peak flow at the Torne Road culvert (MM 0.26) is approximately 1,320 cfs and overtops the road by approximately 2 to 3 feet. There is a residential unit upstream of the entrance to the culvert at Torne Road that will be impacted by the storm-day flood- waters

The peak discharge at Mirror Lake Dam (MM 0.50) is 1,220 cfs. At this flow the peak water surface elevation is overtopping the Mirror Lake Dam by 1.7 feet.

With the water level in Mirror Lake up 4.2 feet above its normal water surface, the flood water levels will be inundating the two roads that surround the lake (Greenway and Torne Roads). There are a number of residential units that border Mirror Lake; these units are not impacted however the roads that provide access to the units will be inundated.

The peak flow at Interstate 87 is 1,210 cfs. At this flow, the floodwaters are overtopping the 48-inch culvert and Interstate embankment by approximately 1 to 2 feet.

D. Inundation Mapping

The limits of inundation were computed by routing the breach discharge hydrograph through the downstream valley cross sections and delineating the resulting maximum stages on the base map. Plate 7 shows the limits of inundation over the 1.0-mile study area. There are numerous structures within these limits, which could be inundated. The structures shown on the inundation maps are those that existed when the orthophoto was taken. A few structures that currently exist may not be shown on the map.

The project mapping was developed from digital orthophotos and digital elevation models (DEM) obtained from the New York State Geographic Information System (GIS) Clearinghouse.

The digital orthophotos are produced by the United States Geological Survey at a scale of 1:12000[12]. The digital elevation models are produced by the United States Geological Survey and are 7.5 minute DEM with 10m by 10m data spacing[13].

The base map has 6-meter (approximately 20-foot) contour interval. Although structures shown within the inundation limits are assumed to be inundated, certain structures may be excluded as a result of local conditions or elevations.

E. Size Classification

Pine Grove Lake Dam is approximately 8 to 12 feet (structural height) at its maximum section. The maximum available storage (at top of dam) is approximately 47.5 acre-feet. According to Article 2.1.1 of the Recommended Guidelines for Safety Inspection of Dams,[14] the dam size is "small."

F. Hazard Classification

On the basis of its potential to cause downstream damage, Pine Grove Lake Dam is given a Class C, HIGH hazard classification. Refer to the Downstream Hazard Classification on page 2 of this document.

The potential economic loss is considered excessive because of the density of residential homes in close proximity to the impacted areas and the area transportation facilities. There are a large number of residential homes located near the dam and in the vicinity of the downstream tributary that conveys the floodwaters released from the Pine Grove Dam. With the large number of residential homes in the area, this suggests that the potential for loss of life from either of the sunny-day dam or storm-day failure scenarios presented herein is more than a few.

From the sunny-day failure of Pine Grove Lake Dam, there is likelihood that only one home would be impacted by a large release of floodwaters from the dam. This home is located immediately upstream of the culvert under Torne Road. In addition to the potential flooding at Torne Road, the water level in Mirror Lake, will rise approximately 2.5 feet, and begin to overtop the Mirror Lake Dam. In addition to the Mirror Lake Dam beginning to overtop, the residential roads (Greenway Road and Torne Road) that border Mirror Lake will be flooded. In addition to the flooding at Mirror Lake during the sunny-day failure, the 48-inch culvert under Interstate 87 will be flowing full with the water levels at the upstream end of the culvert beginning to overtop the Interstate 87 roadway.

From the storm-day failure of Pine Grove Lake Dam, there is likelihood that a few homes would be impacted by a large release of floodwaters from the dam. The homes with a potential for flooding are located immediately upstream of the Torne Road culvert and immediately downstream of the culvert under Interstate 87. The water level in Mirror Lake, will rise approximately 4 feet, and overtop the Mirror Lake Dam by approximately 2 feet. In addition to the Mirror Lake Dam being overtopped, the residential roads (Greenway Road and Torne Road) that border Mirror Lake will be flooded. In addition to the flooding at Mirror Lake during the storm-day failure, the 48-inch culvert under Interstate 87 will be flowing full with the water levels flowing over the Interstate 87 roadway by approximately 1.5 to 2.0 feet.

Additionally, streambank erosion and the possible washout of Torne, Greenway and Interstate 87 roads could be expected.

It is important to understand the following:

1. The terminology HIGH, SIGNIFICANT, and LOW hazard refers to the potential for damage or loss of life and does <u>not</u> refer to the condition of the dam. For example, a HIGH hazard (Class C) dam may be in excellent condition and a LOW hazard (Class A) dam may be in poor condition.

2. A dam's classification may change from what it was when it was built or at the last inspection because of changes in downstream conditions. For example, a Class A (low hazard) dam may become a Class B (significant hazard) or Class C (high hazard) dam if some houses are built downstream that could be impacted by a failure. The classification could also change

(either up or down) if a more detailed breach analysis is carried out that more accurately determines downstream damage potential.

3. It should not be assumed that the failure of a Class A (low hazard) dam would never be a threat to lives. Although direct loss of life (such as by flooding a house) is not expected, the failure could for example, wash out a road and result in a fatal accident.

6. DISCUSSION

The dam-breach analysis for Pine Grove Lake Dam was based on engineering application of certain laws of physics, considering the physical characteristics of the project and downstream channel and conditions of failure. Due to the highly unpredictable nature of a dam-breach and the ensuing sequence of events, the results of this study should not be viewed as exact but only as an appropriate quantification of the dam-breach flood potential.

For purposes of analysis, downstream conditions are assumed to remain constant, and no allowance is made for possible enlargement or relocation of the river channel due to scour or temporary damming effects, all of which could affect, to some extent, the resulting magnitude and timing of flooding.

7. REFERENCES

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13. New York State Geographic Information System (GIS) Clearinghouse, Digital Elevation Model (DEM), United States Geological Survey, 7.5 Minute DEM with 10m x 10m Data Spacing.

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TABLES

TABLE 1

PINE GROVE LAKE DAM
SLOATSBURG, NEW YORK

(DRAINAGE AREA = 0.19 SQUARE MILES)

100-YEAR AND PROBABLE MAXIMUM FLOOD RESERVOIR ROUTING SUMMARY

Flood Frequency	Peak Inflow (CFS)	Peak Outflow* (CFS)	Maximum Lake Water Level (NGVD)	Available Freeboard** (feet)
100-Year	400	210	554.7	Overtopped dam by 0.2 feet
1/4 PMF	650	580	555.1	Overtopped dam by 0.6 feet
1/2 PMF	1300	1270	555.6	Overtopped dam by 1.1 feet
3/4 PMF	1960	1910	556.0	Overtopped dam by 1.5 feet
FULL PMF	2610	2560	556.4	Overtopped dam by 1.9 feet

Values rounded to nearest significant digit.

* Discharge computed by HEC-1; non-failure of Pine Grove Lake Dam assumed.

** Top of dam elevation 554.5.

TABLE 2

PINE GROVE LAKE DAM
VILLAGE OF SLOATSBURG, NEW YORK

ASSUMED DAM-BREACH PARAMETERS

Sunny-Day Failure Condition	
Initial pool level at start of computations	El. 552.0 NGVD
Pool level at dam failure	El. 552.0 NGVD
Breach invert	El. 546.5 NGVD
Breach bottom width	18 feet with side slopes 0.5 H : 1.0V
Time to complete information of breach	0.5 hours
Assumed pre-breach flow immediately downstream of the dam	10 cfs

Storm-Day Failure Condition	
Initial pool level at start of computations	El. 552.0 NGVD
Pool level at dam failure	El. 555.4 NGVD
Breach invert	El. 546.5 NGVD
Breach bottom width	18 feet with side slopes 0.5 H : 1.0V
Time to complete formation of breach	0.5 hours
Assumed pre-breach flow immediately downstream of the dam, prior to dam failure	960 cfs

TABLE 3

PINE GROVE LAKE DAM
VILLAGE OF SLOATSBURG, NEW YORK

DOWNSTREAM CHANNEL ROUTING RESULTS
Sunny-Day Failure

Downstream Location	Peak Discharge (CFS)	Peak Water Surface		Time to Peak* (HOURS)
		Peak Water Surface Elevation (NGVD)	Above Streambed (FEET)	
Pine Grove Lake Dam MM 0.00	460	552.0	10.5	0.0
Cross Section at MM 0.18	435	471.4	2.6	0.5
Torne Road Culvert at MM 0.26	430	449.6	3.1	0.5
Cross Section at MM 0.32	425	434.3	2.9	0.9
Mirror Lake Dam MM 0.50	175	434.3	14.3	0.9
Cross Section at MM 0.68	175	390.1	2.1	0.9
Interstate 87 MM 0.77	175	377.1	9.0	1.0
Dam on Ramapo River MM 1.00	290	347.8	0.4	1.1

*Time to peak measured from start of breach at Pine Grove Lake Dam.

TABLE 4

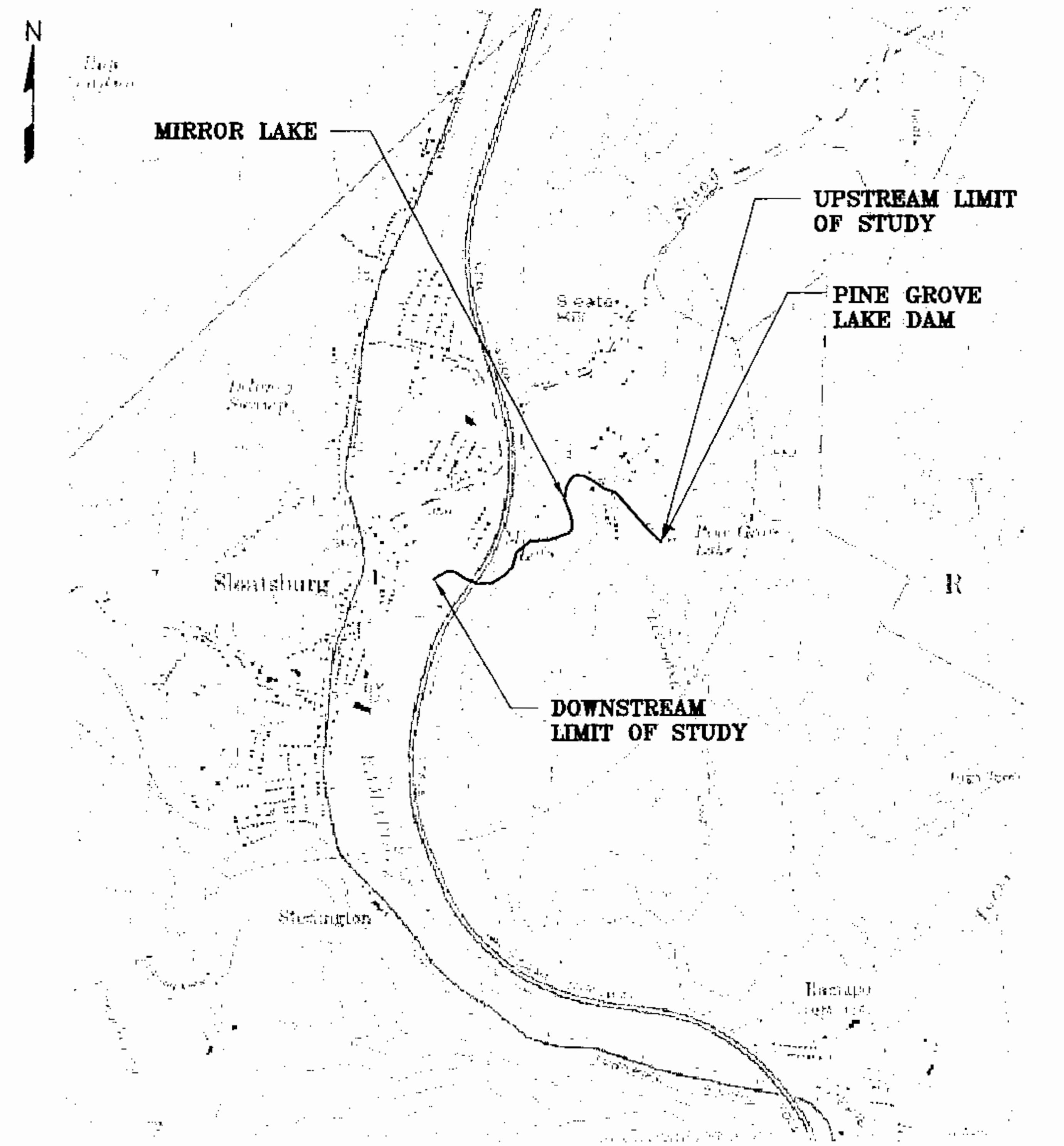
PINE GROVE LAKE DAM
VILLAGE OF SLOATSBURG, NEW YORK

DOWNSTREAM CHANNEL ROUTING RESULTS
Storm-Day Failure

Downstream Location	Peak Discharge (CFS)	Peak Water Surface		Time to Peak [1] (HOURS)
		Peak Water Surface Elevation (NGVD)	Above Streambed (FEET)	
Pine Grove Lake Dam MM 0.00	1380	555.6	14.1	0.0
Cross Section at MM 0.18	1330	475.3	6.5	0.2
Torne Road Culvert at MM 0.26	1320	452.5	5.9	0.3
Cross Section at MM 0.32	1320	436.2	4.8	0.4
Mirror Lake Dam MM 0.50	1220	436.0	16.2	0.4
Cross Section at MM 0.68	1210	391.9	3.9	0.4
Interstate 87 MM 0.77	1210	378.6	10.5	0.4
Dam on Ramapo River MM 1.00	10700 [2]	352.5 [2]	5.1 [4]	N/A [3]

[1] Time to peak measured from start of breach at Pine Grove Lake Dam. Breach begins at hour 0.72.
[2] Peak discharge and peak water surface elevation obtained from the Flood Insurance Study for the Village of Sloatsburg. The inundation level on the Ramapo River controlled by the large flood flow from the Ramapo River not the flow from Pine Grove Lake Dam.
[3] N/A = Not applicable. The inundation level on the Ramapo River controlled by the large flood flow from the Ramapo River not the flow from Pine Grove Lake Dam.
[4] Water level above dam spillway crest elevation 347.4.

PLATES



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MAP FROM U.S.G.S.

SLOATSBURG, N.Y.–N.J.
NW/4 RAMPO 15' QUADRANGLE
N4107.5–W747.5/7.5

1" = 2200'±
SCALE IN FEET

U.S. ARMY ENGINEER DISTRICT
CORPS OF ENGINEERS
NEW YORK DISTRICT

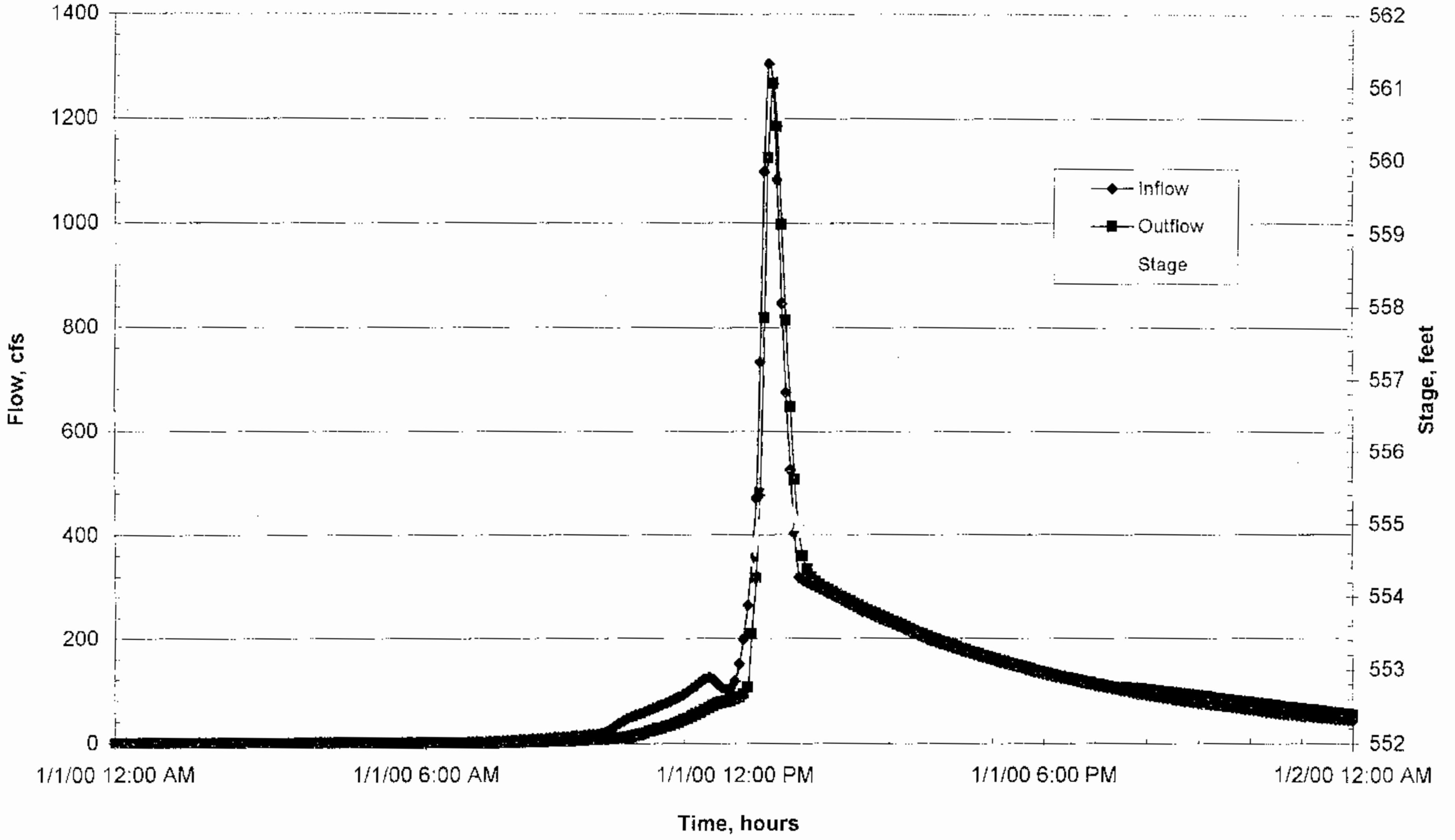
PINE GROVE LAKE DAM
VILLAGE OF SLOATSBURG, ROCKLAND COUNTY, NEW YORK

DAM–BREAK FLOOD ANALYSIS

SITE LOCATION MAP

PLATE 1

Pine Grove Lake Dam
Village of Sloatsburg, New York
1/2 PMP Hydrograph Analysis

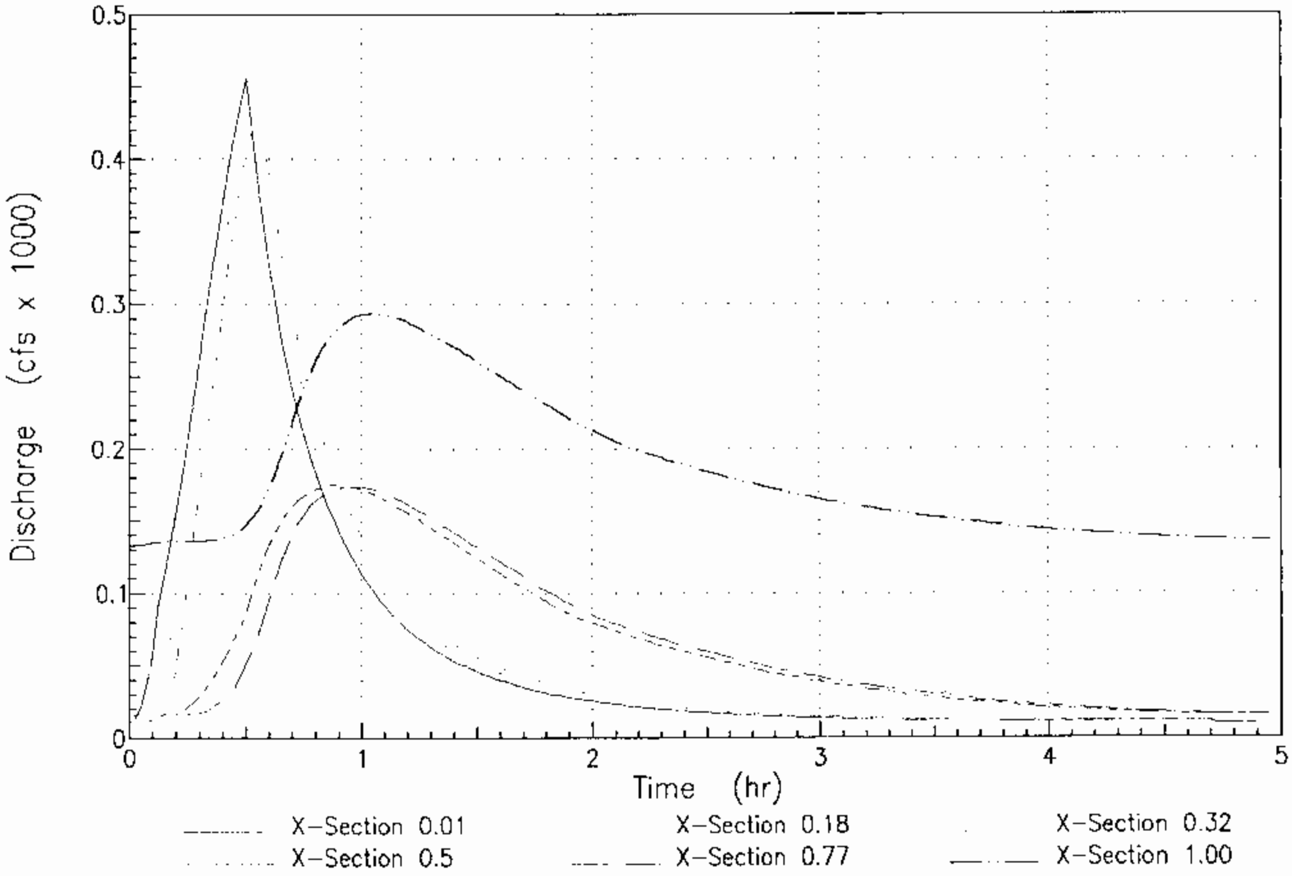


Top of Dam Elev. 554.5
Spillway Crest Elev. 552.45

Pine Grove Lake Dam—Combined Discharge Hydrographs

Sunny—Day Failure

For Unnamed Tributary of Ramapo River in the Village of Sloatsburg, New York



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Note:

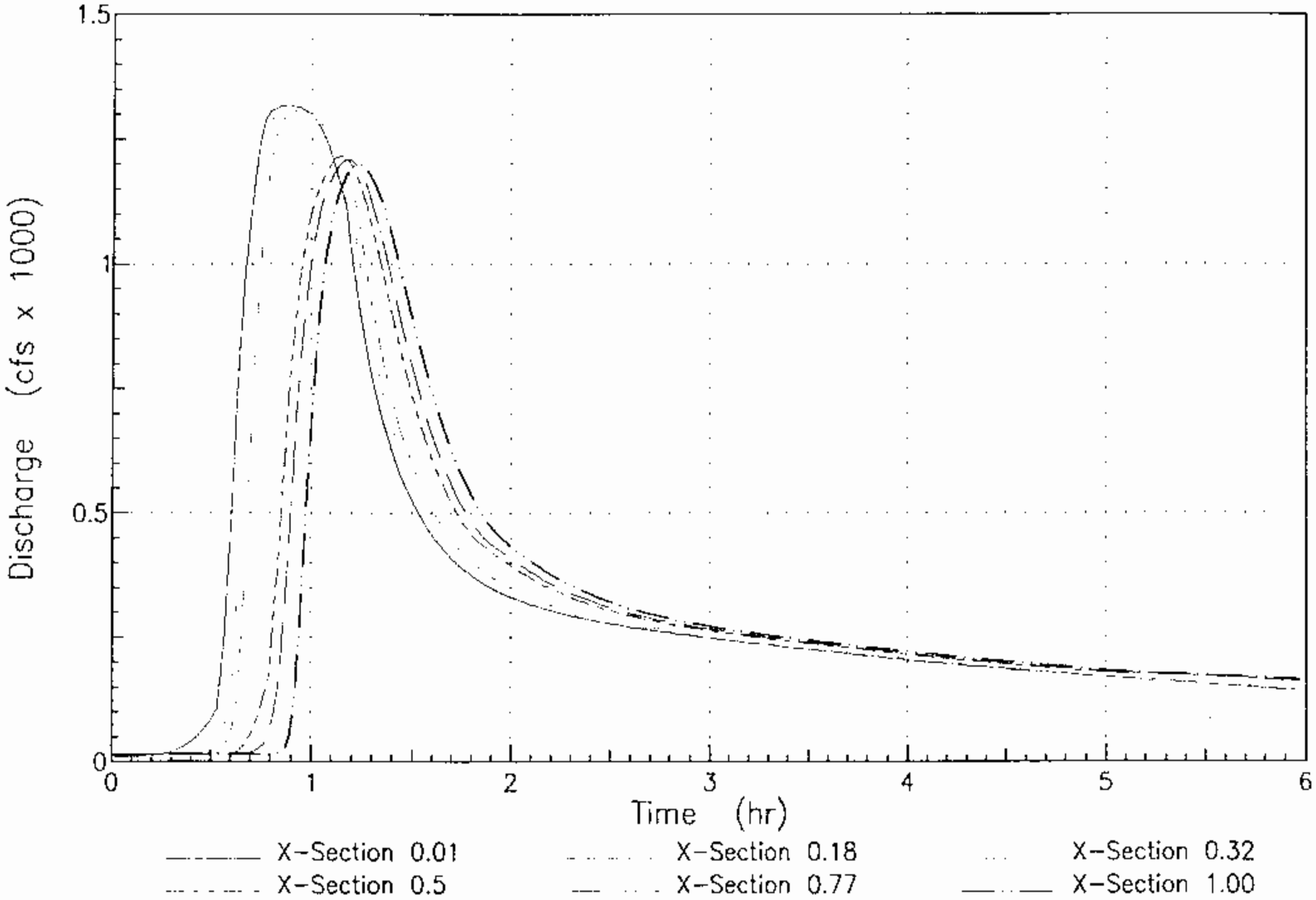
1. The Pine Grove Lake Dam, Sunny—Day breach begins at hour 0.00

PLATE NUMBER 3

Pine Grove Lake Dam—Combined Discharge Hydrographs

Storm—Day Failure

For Unnamed Tributary of Ramapo River in the Village of Sloatsburg, New York



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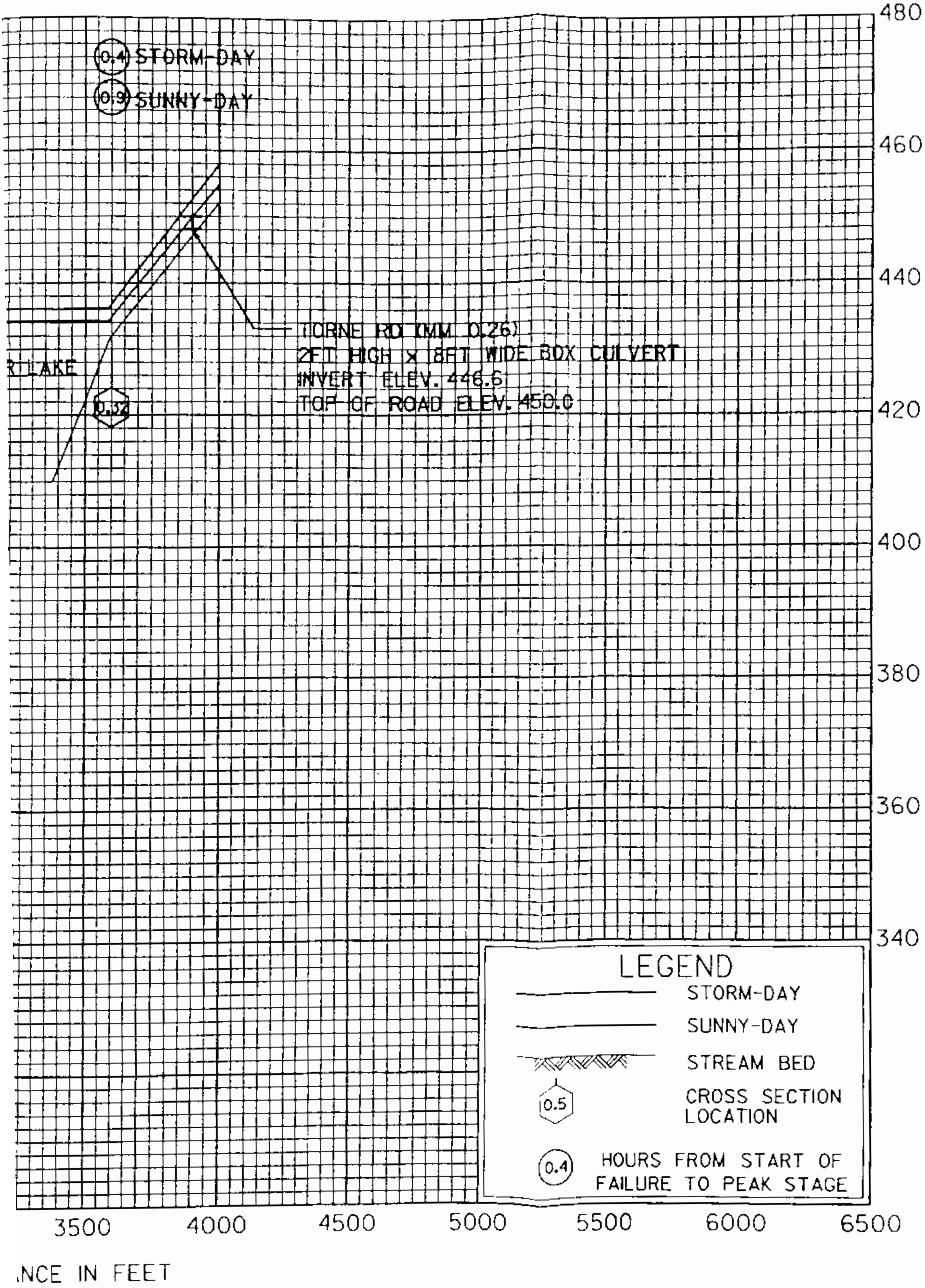
Note:

1. The Pine Grove Lake Dam, Storm—Day breach begins at hour 0.72

PLATE NUMBER 4

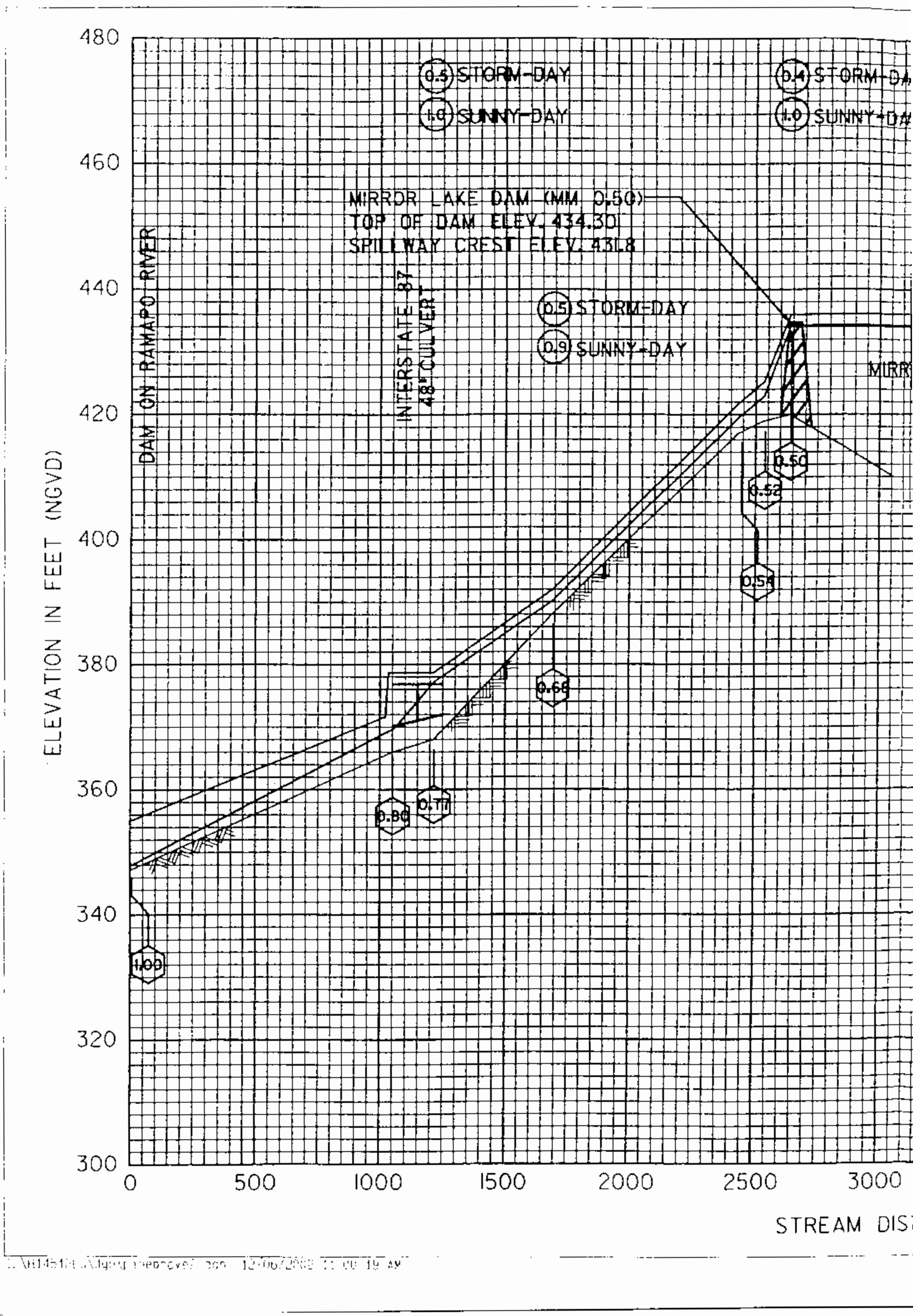


DAM-BREACH FLOOD PROFILES

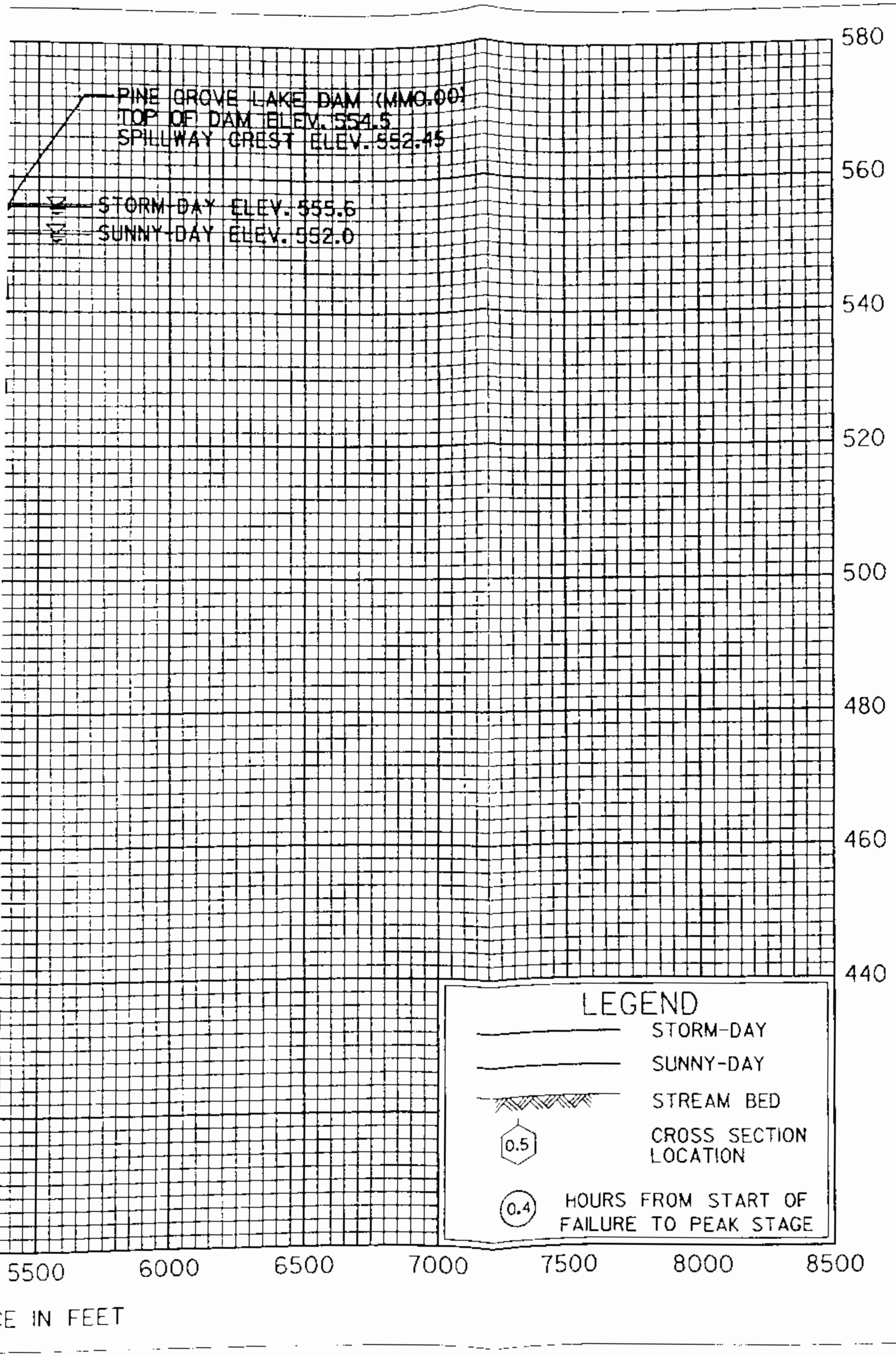
UNAMED TRIBUTARY OF RAMAPO RIVER

PINE GROVE LAKE DAM
SUNNY-DAY AND STORM-DAY
DAM-BREACH FLOOD ANALYSIS

PLATE 5



480
460
440
420
400
380
360
340
320
300
ELEVATION IN FEET (NGVD)
0
500
1000
1500
2000
2500
3000
STREAM DIS
DAM ON RAMAPO RIVER
INTERSTATE 87
48" CULVERT
MIRROR LAKE DAM (MM 0.50)
TOP OF DAM ELEV. 434.30
SPILLWAY CREST ELEV. 431.8
0.5 STORM-DAY
1.0 SUNNY-DAY
0.5 STORM-DAY
0.9 SUNNY-DAY
0.4 STORM-DA
1.0 SUNNY-DA
MIRR
1.00
0.80
0.77
0.68
0.54
0.52
0.50

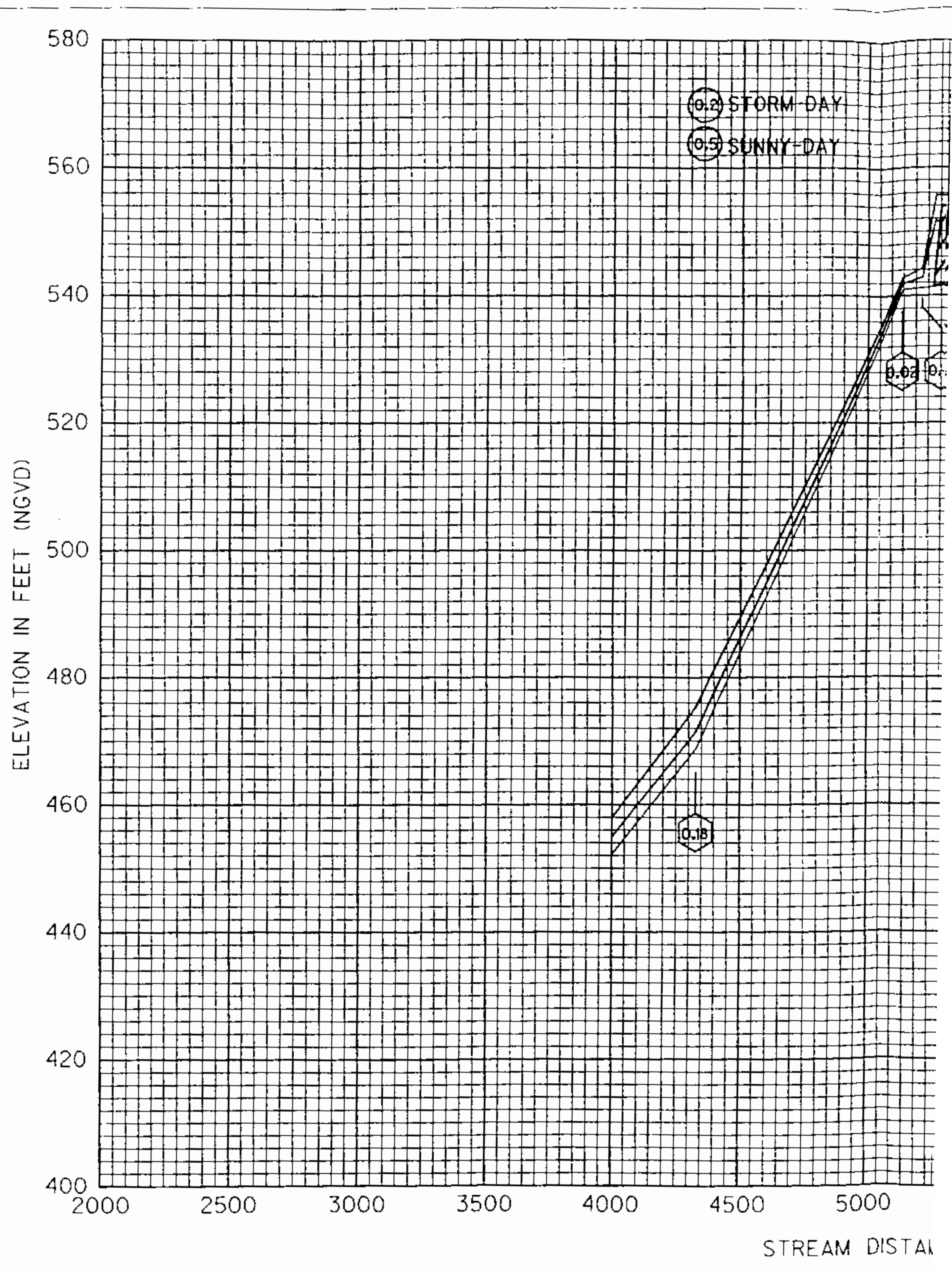


DAM-BREACH FLOOD PROFILES

UNAMED TRIBUTARY OF RAMAPO RIVER

PINE GROVE LAKE DAM
SUNNY-DAY AND STORM-DAY
DAM-BREACH FLOOD ANALYSIS

PLATE 6



0.2 STORM-DAY
0.5 SUNNY-DAY
0.02
0.18
580
560
540
520
500
480
460
440
420
400
2000
2500
3000
3500
4000
4500
5000
ELEVATION IN FEET (NGVD)
STREAM DISTA

PHOTOGRAPHS

Photo 1 – Pine Grove Dam – View of dam crest from northeast abutment. Spillway in foreground (March 2000).

Photo 2 – Pine Grove Dam – View of Dam crest from southwest abutment (June 2002)

Photo 3 – Pine Grove Dam – View from dam crest looking downstream (March 2000).

Photo 4 – Pine Grove Dam – View of culvert entrance at Torne Road near Mirror Lake (March 2000)

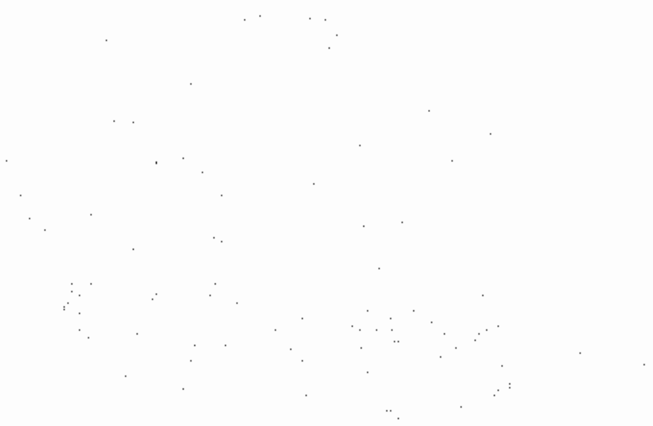


Photo 5 Near Mirror Lake Dam View of Torne Road looking upstream toward the culvert entrance and unnamed tributary conveying water from Pine Grove Dam to Mirror Lake Dam (March 2000)

Photo 6 - Mirror Lake Dam – View of Mirror Lake, looking southwest (March 2000).

Photo 7 - Mirror Lake Dam - Mirror Lake Dam spillway, looking downstream (March 2000).

Photo 8- Mirror Lake Dam - Mirror Lake Dam spillway, view from the northwest abutment looking southeast (March 2000).

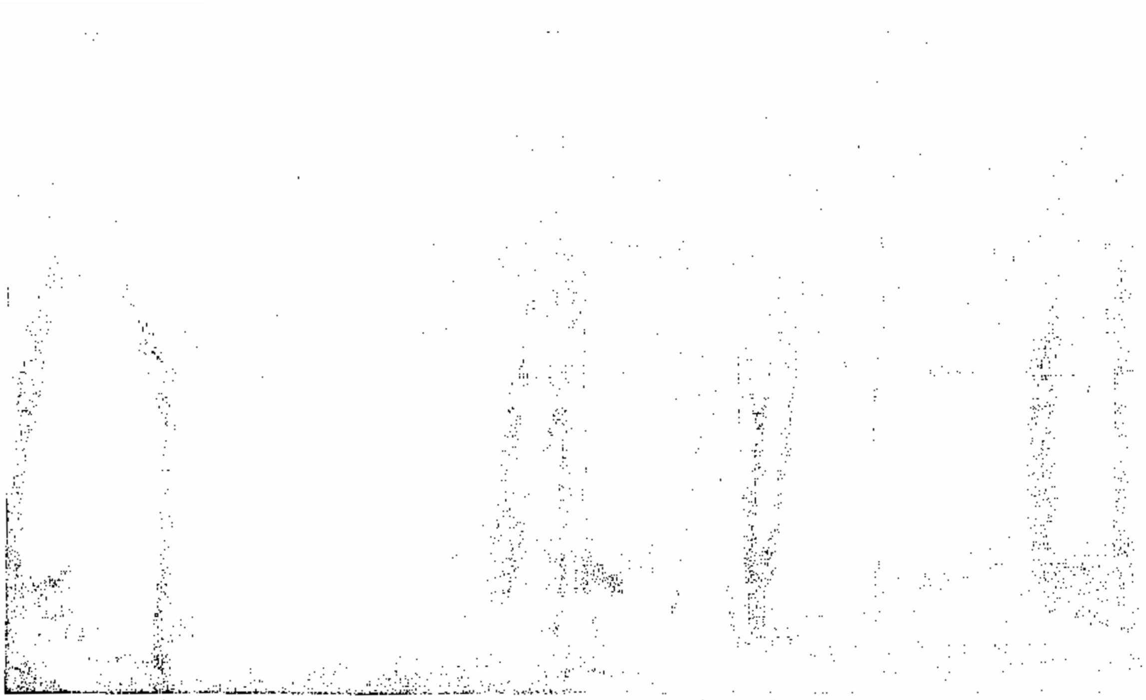


Photo 9 -- 48-inch Culvert Entrance at Interstate I-87– March 2000

Photo 10   Dam on Ramapo River   Downstream limit of study (March 2000).