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NATIONAL DAM INSPECTION PROGRAM. WIGWAM LAKE DAM (NDI ID NUMBER--ETC(U)
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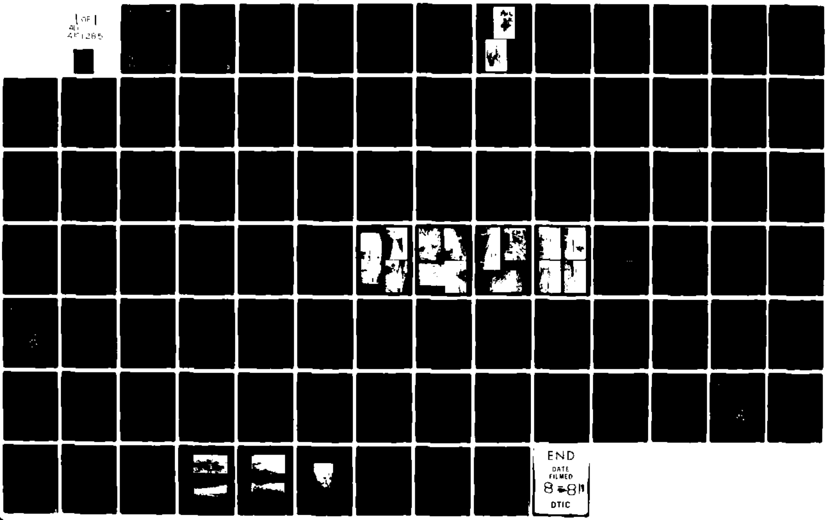

LEVEL II

DELAWARE RIVER BASIN
WIGWAM RUN, MONROE COUNTY

PENNSYLVANIA

WIGWAM LAKE DAM

NDI ID NO. PA-00990
DER ID NO. 45-124

HARRY SNOW

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

Prepared by
Geo-Technical Services, Inc.
CONSULTING ENGINEERS & GEOLOGISTS
851 S. 19th Street
Harrisburg, Pennsylvania 17104

For
DEPARTMENT OF THE ARMY
Baltimore District, Corps of Engineers
Baltimore, Maryland 21203

MAY 1981

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DELAWARE RIVER BASIN

WIGWAM RUN, MONROE COUNTY, PENNSYLVANIA

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National Dam Inspection Program. Wigwam Lake Dam (NDI ID Number PA-00990, DER ID Number 45-124), Delaware River Basin, Wigwam Run, Monroe County, Pennsylvania. Phase I Inspection Report,

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BALTIMORE DISTRICT, CORPS OF ENGINEERS

Baltimore, Maryland 21203

MAY 1981

PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I investigation is to identify expediously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected and only through continued care and maintenance can these conditions be prevented or corrected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the spillway design flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonable possible storm runoff), or fractions thereof. The spillway design flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

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PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

BRIEF ASSESSMENT OF GENERAL CONDITION

AND

RECOMMENDED ACTION

Name of Dam:	Wigwam Lake Dam NDI ID No. PA-00990 DER ID No. 45-124
Size:	Small (14 feet high; 50 acre-feet)
Hazard Classification:	High
Owner:	Harry Snow R.D. #3 Stroudsburg, Pa. 18760
State Located:	Pennsylvania
County Located:	Monroe
Stream:	Wigwam Run
Date of Inspection:	November 26, 1980

Based on visual inspection, the Wigwam Lake Dam is judged to be in poor condition. Based on the size and hazard classification of the dam, the recommended Spillway Design Flood (SDF) varies from ½PMF (Probable Maximum Flood) to the full PMF. Because of the small storage capacity of the reservoir,the ½PMF is selected as the SDF for the dam. Under the present conditions, the spillway will pass approximately 15 percent of the PMF without overtopping the dam. Overtopping depth of 1.2 feet was calculated for a flood magnitude of ½PMF; whereas, it was judged that the dam will begin to fail under the overtopping depth of one foot. Because failure of the dam would increase the downstream high hazard conditions, the spillway is seriously inadequate. Therefore, according to the guidelines for Safety Inspection of Dams, the dam is rated as unsafe, non-emergency.

Considering the steepness of the embankment slopes, the marshy conditions at the toe of the dam could, in time, affect the stability of the embankment.

The observed inclination of the spillway endwall from the vertical, away from the retained embankment earthfill, could, if further movement occurs, affect the integrity of the embankment.

The unknown condition and location of the valve mechanism, regulating flow through the outlet pipe, precluded assessment of the prevailing conditions of the outlet works. Ready access to an operable valve, or other method of drawing down the reservoir level during emergencies, is required. Such requirement may arise should excessive seepage or piping develop.

WIGWAM LAKE DAM

The present condition of the dam and appurtenances indicate that maintenance of the dam is unsuitable. There is no warning system and evacuation plan in effect at the present time.

The following investigations and remedial measures are recommended for immediate implementation by the owner:

(1) Engage a professional engineer experienced in the design and construction of dams to perform additional hydrologic and hydraulic analyses to more accurately ascertain the spillway capacity of the facility. As a result of the analyses, implement the necessary remedial measures to upgrade the present spillway capacity to the required Spillway Design Flood.

(2) Locate the valve mechanism for the outlet works, if required, and provide means to operate the valve; or develop another method of emergency drawdown in the event such action becomes necessary.

(3) Remove trees and brush from the crest and slopes of the embankment under the supervision of a professional engineer.

(4) Institute a monitoring program to detect any significant change in the conditions of the dam and appurtenant structures. As a minimum, this program shall include provision for detecting any additional movement in the spillway endwall and the rate and clarity of seepage at the toe of the dam.

In addition, it is recommended that the owner take the following precautionary operational and maintenance measures:

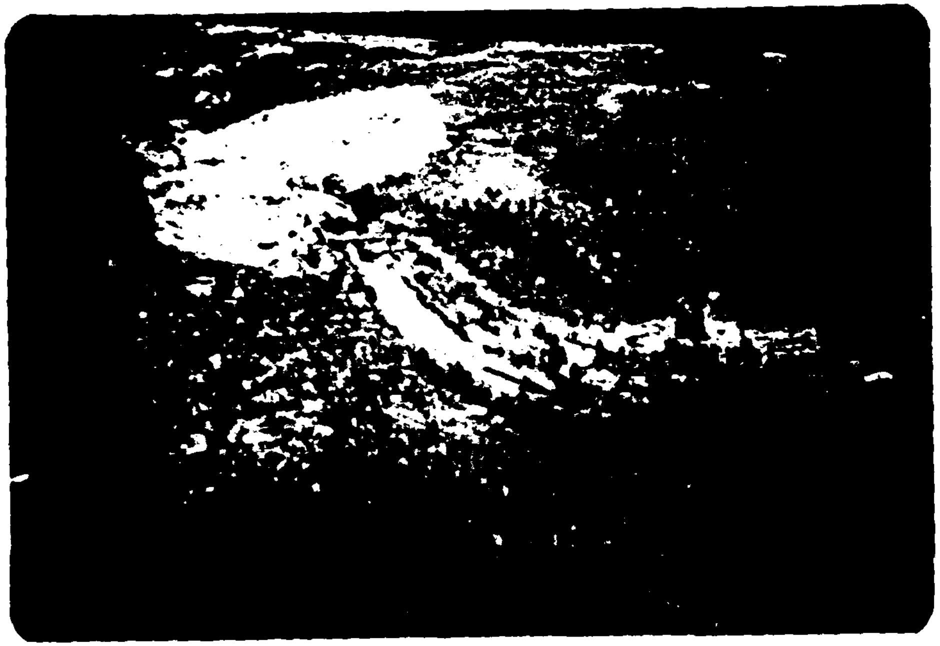
(1) Develop a detailed emergency operation procedure and warning system to facilitate timely and orderly evacuation of the downstream population due to hazardous conditions at the dam.

(2) When warnings of a storm of major proportions are given by the National Weather Service, activate the emergency operation and warning system procedures.

(3) After satisfactory implementation of the remedial measures resulting from the recommended additional investigations, institute a formal inspection and maintenance program for the dam. As presently required by the Bureau of Dams and Waterway Management of PENNDER, the program shall include an annual inspection of the dam by a professional engineer, experienced in the design and construction of dams. Deficiencies found during annual inspections should be remedied as necessary.

Submitted by:	Approved:
GEO-TE[illegible]RVICES, INC.	DEPARTMENT OF THE ARMY BALTIMORE DISTRICT, CORPS OF ENGINEERS
Gideon Yachin	*James W. Peck*
GIDEON YACHIN, P.E.	JAMES W. PECK Colonel, Corps of Engineers Commander and District Engineer
Date: May [illegible], 1981	Date: 3 June 1981

COMMONWEALTH OF PENNSYLVANIA
REGISTERED PROFESSIONAL ENGINEER
GIDEON YACHIN
No. 4934-E



LAKE AREA

DAM AREA

OVERVIEW OF WIGWAM LAKE (PA. 00990)

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

WIGWAM LAKE DAM

NDI# PA-00990, PENNDER # 45-124

SECTION 1

GENERAL INFORMATION

1.1 Authority

The Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of inspection of dams throughout the United States.

1.2 Purpose.

The purpose is to determine if the dam constitutes a hazard to life or property.

1.3 Description of Project.

a. Dam and Appurtenances. Wigwam Lake Dam is an earthfill dam with a maximum height of 14 feet and 253 feet long, including the spillway. The spillway is located at the left abutment and consists of a concrete weir with a vertical downstream face and short rock paved apron. The spillway crest is a 57-foot long, sharp crested weir that intersects the slope of the left abutment and terminates at a vertical endwall on the earthfill dam embankment. The outlet works consist of a 16-inch diameter cast iron pipe with no visible upstream or downstream controls.

b. Location. Wigwam Lake Dam is located on Wigwam Run in Stroud Township, Monroe County, one mile east of Bartonsville, Pennsylvania. The dam and reservoir are contained within the Mount Pocono, Pennsylvania 7.5 minute series USGS Quadrangle Map at Latitude N 41°00'11" and Longitude W 75°15'36". A Location Map is shown in Exhibit E-1.

c. Size Classification. Small (14 feet high, 50 acre-feet storage capacity at top of dam).

d. Hazard Classification. High (see paragraph 3.1e).

e. Ownership. Harry Snow, R.D. #3, Stroudsburg, Pennsylvania 18760.

f. Purpose of Dam. The original purpose of the impounded water was for ice making and recreation. Presently, the lake is being used for recreation.

g. Design and Construction History. Wigwam Lake Dam was designed by John L. Westbrook, Civil Engineer and Surveyor of Stroudsburg, Pennsylvania. Exhibits E-2 and E-3 indicate the final revised plans for which a construction permit was issued to John J. Fredericks (the original owner) by the Pennsylvania Water and Power Resources Board on August 17th, 1927. Construction started in the summer of 1927 and completed in the Spring of 1928 by Caratti (Contractor). Although "as-built" drawings are not available, construction history is documented in inspection reports, correspondence and photographs obtained from the Pennsylvania Department of Environmental Resources (PENNDER) files.

h. Normal Operational Procedure. The pool is maintained at the spillway crest elevation with excess inflow discharging over the spillway into Wigwam Run, a tributary of Pocono Creek. The outlet works was not discharging on the day of the inspection and appeared to be permanently closed. The location of regulating mechanism for the outlet works was not visible and could not be verified.

1.4 Pertinent Data

a. Drainage Area (square miles).	1.5
b. Discharge at Damsite (cfs).	
Maximum known flood at damsite	Unknown
Outlet works at maximum pool elevation	
Design	Unavailable
Computed, assuming "downstream control"	30
Spillway capacity, prior to overtopping	
Design	965
Existing condition	475
c. Elevation (feet above msl).	
Top of Dam	
Design conditions (top of dam)	711
Existing conditions (lowest point)	709.8
Maximum pool	
Design conditions	711.0
Existing conditions	709.8
Normal Pool (spillway crest)	708
Upstream Invert Outlet Works (design)	696.5, Approx.
Downstream Invert Outlet Works	696
Streambed at toe of dam	696
Maximum tailwater	702.5
d. Reservoir Length (feet).	
Normal Pool	1500
Maximum Pool	1800
e. Storage (acre-feet).	
Normal Pool	32
Maximum Pool	
Design conditions	58
Existing conditions	50

f. Reservoir Surface (acres).

Normal Pool	8
Maximum Pool	
Design conditions	Unknown
Existing conditions	8.3

g. Dam.

Type	Earthfill
Length, excluding spillway (feet)	196
Maximum Height (feet)	
Design conditions	16
Existing conditions	14
Top Width (feet)	
Design conditions	8
Existing conditions	varies 7 to 14
Side Slopes	
Upstream	
Design	2H:1V
Existing conditions	vary (3.6H:1V to 1.3H:1V)
Downstream	
Design	2H:1V
Existing conditions	vary (2.6H:1V to 1.35H:1V)
Zoning	
Upstream	Earthfill
Downstream	Earth and rock fill
Cut-off	Concrete Core Wall
Impervious Core	Concrete Core Wall
Grout Curtain	None

h. Diversion and Regulating Tunnel. None

i. Spillway.

Type	Uncontrolled, sharp crested, concrete weir with vertical drop on paved apron.
Length of Weir (feet)	57
Crest Elevation	708
Upstream Channel (stone paved), Length (feet)	15
Downstream Channel	Swale to streambed.

j. Outlet Works.

Type	16" dia. CIP
Length (feet)	64 (design)
Closure and Regulating Facilities	Unknown
Access	Unknown

SECTION 2
ENGINEERING DATA

2.1 Design.

a. Data Available. Design data available for review consist of the 1927 drawings, specifications, inspection reports, and photographs obtained from PENNDER files. Construction drawings are presented in Appendix E.

b. Design Features.

(1) Embankment. The dam was designed as a zoned embankment with an earth fill upstream section and an earth and rock fill downstream section. The dam has a crest width of 8 feet and side slopes of 1 vertical to 2 horizontal on both upstream and downstream faces. The upstream slope protection was to consist of 8-inch thick stone paving throughout the face of the dam. Foundation treatment was to be a 6-foot wide cut-off trench along the dam axis between both abutments, including the spillway. Trench excavation was to extend to bedrock, or terminate in impervious overburden material. A concrete core wall was to be founded on a 3-foot wide concrete footing at the bottom of the cut-off trench. The 12-inch (top width) concrete core wall was to terminate one foot below the dam crest, extending from the right abutment, throughout the length of the earth embankment, to the spillway endwall.

(2) Appurtenant Structures.

(a) Spillway. The spillway was to consist of a two-foot wide weir, 60 feet long, tapered on top to provide a sharper crest. The crest elevation was to be three feet below the top of the dam. An earthfill blanket was to be placed against the upstream vertical face of the weir, forming an adverse slope toward the natural ground in the reservoir. The short approach channel, formed by the earth blanket, was to be stone paved. The downstream face of the weir was to drop five feet into a sloping concrete apron in five one-foot steps. The weir was to terminate at each abutment with 18-inch thick concrete endwalls. The right endwall was to conform to the top width and side slopes of the retained earth embankment. The apron was to terminate with a concrete cut-off wall that was to extend to the depth of the endwall foundations, 4 feet below the original ground surface.

(b) Outlet Works. The outlet works was to consist of 16-inch diameter cast iron pipe, approximately 64 feet long, and its lower half was to be embedded in a 24-inch wide concrete encasement. Two anti-seep concrete collars were to be provided along the upstream end of the pipe. Although details of the intake structure and controls for flow in the pipe are not shown on the drawings, the existence of an upstream gate valve is referenced in correspondence, available in PENNDER files.

(c) Specific Design Data and Criteria. The spillway capacity was designed to meet the Pennsylvania Department of Forests and Waters criteria of 700 cubic feet per second per square mile of drainage area above the dam. The embankment was to be constructed on clay and sand or gravel from borrow areas adjoining the damsite. Fill material was to be placed in successive 6 or 8-inch layers, compacted by tamping and driven over continuously by teams and wagons after sprinkling.

2.2 Construction Records.

Review of inspection reports and correspondence indicates that the bottom of the cut-off trench did not extend to bedrock, or to impervious overburden material, under the entire length of the dam. Large loose boulders, rather than bedrock were encountered in the cut-off trench on the right abutment; whereas, the bottom of the trench was terminated in coarse gravel approximately 6 feet below ground surface on the left abutment and under the spillway.

2.3 Operational Records.

Review of correspondence between 1928 and 1965 indicates considerable water losses at the initial filling of the reservoir. Water level could not be maintained at spillway crest, although water released through the outlet works was but a fraction of the inflow into the reservoir. The downstream half of the right spillway endwall settled (observed in 1933), causing a large horizontal crack in the wall, 8 inches above the spillway crest elevation. A one inch wall separation in the vertical construction joint of the wall at the dam axis was also attributed to the settlement of the wall. Seepage and swampy conditions at the downstream toe of the maximum section were observed since the first filling of the reservoir. A six inch embankment settlement along the entire length of the dam was reported in 1941. Available records also indicate that applications were filed with the Fish Commission for a permit to draw down the reservoir for repairs in 1946 and in 1953. The 1946 repairs were attempted to reduce leakage from the dam. Repairs to the upstream gate valve were made in 1953.

2.4 Other Investigations.

After completion of construction (December 1928), available reports indicate that on-site inspections were made in June 1929, May 1931, June 1933, June 1934, May 1935, June 1938, May 1941, May 1950, and in January 1957. These inspections were made as part of the Pennsylvania State mandated inspection program. Additionally, inspections were made by engineers from the Pennsylvania Department of Forests and Waters (presently PENNDER) to investigate property owners' complaints. The complaints were related to reduction in the flow of Wigwam Run, downstream of the constructed dam, during periods of low flow.

2.5 Evaluation.

(a) Availability of Data. Although "as built" plans for Wigwam Lake Dam are not available, data obtained from PENNDER files provide information relative to the chronology of construction, operation and repairs of the dam and appurtenant structures.

(b) Adequacy. The available data is limited and the assessment must be based primarily on the visual inspection and hydrologic and hydraulic analysis, presented in Section 5.

(c) Validity. With the exceptions noted on Exhibit E-3, there is no reason to question the validity of the available data.

SECTION 3
VISUAL INSPECTION

3.1 Observations.

(a) General. The overall appearance of the dam and its appurtenant structures is considered to be poor. The locations of observed deficiencies are shown on the Sketch Plan, presented in Exhibit A-1, Appendix A. The profile and typical sections of the dam are presented in Exhibits A-2, A-3, and A-4 and are based on field survey made on the day of inspection. The survey datum for this inspection was an approximate elevation obtained for the spillway crest from a USGS map. The construction drawings for the dam and appurtenant structures are shown in Exhibits E-2 and E-3, Appendix E. The elevations shown on the construction drawings are based on a different datum than that of the USGS map. Therefore, to convert the elevations shown on the appended construction drawings to the elevations used in this report, it is necessary to add 609 feet to the elevations shown on the appended drawings. On the inspection date (11/26/80), the lake level was 0.1 foot above the spillway crest (elevation 708 above mean sea level). Deficiencies observed during the field inspection are described below, and further illustrated in Exhibits A-1, Appendix A. Visible features of the dam are depicted in photographs, presented in Appendix C.

b. Embankment. Observations made during inspection indicate that the embankment is in poor condition. The upstream slope, above the lake level varies from 1V:3.6H (1 vertical to 3.6 horizontal) near the left abutment to 1V:1.3H near the maximum section (see Exhibits A-3 and A-4). The 8-inch thick stone pavement on the upstream face of the embankment, shown on the construction drawing (Appendix E), does not exist above the lake level (see photographs 1 and 2, Appendix C). The top width of the dam varies from 7 feet at the left abutment to 14 feet at the maximum dam section, as shown on Exhibits A-1, A-3, and A-4. The crest of the dam, upstream of the core wall, settled approximately 4 inches, exposing the upstream face of the core wall (see Section B, Exhibit A-4, and photographs 5 and 6, Appendix C). The crest of the dam at the junction with the spillway endwall on the left abutment is 0.6 foot lower than the top of the wall (see photograph 10, Appendix C). The top of the dam elevations vary as indicated in Exhibit A-2. The lowest point on the top of the dam is at elevation 709.8', which is 1.3 feet lower than the design elevation for the top of the dam. The abundance of brush and trees on the top of the embankment slopes and at the toe of the dam are illustrated in photographs 1, 2, 5, 6, and 8, Appendix C. The downstream slope of the embankment varies from 1V:2.6H on the left abutment to 1V:1.35H at the maximum section, near the right abutment (see Exhibits A-3 and A-4). Clear seepage at a total estimated rate of 2 gallons per minute (GPM) was observed immediately to the right of the outlet pipe and at a point

50-feet left of the outlet works. The entire downstream area near the toe of the maximum section is marshy. Approximate limits of the marshy area are shown in Exhibit A-1. The right abutment of the dam is at the toe of a near-vertical cliff, as shown on photographs 4 and 6, Appendix C, and further discussed in Appendix F, Geology. A gully shaped depression begins downstream of the right abutment of the dam and extends to the toe of the dam, as shown in Exhibit A-1 and photograph 7, Appendix C. The top of the dam near the right abutment and the beginning of the depression is at elevation 709.9, which is 1.1 feet lower than the design elevation for the top of the dam.

(c) Appurtenant Structures.

(1) Spillway. The overall appearance of the spillway is poor. The left spillway endwall and the stepped drops, shown in Exhibit E-3, do not exist. The concrete weir intersects the present slope of the left abutment; and the downstream face of the concrete weir is vertical, as shown in Exhibits A-2 and A-3. The present spillway length is 57 feet, or 3 feet shorter than the design length. The top 4 inches of the weir near the right endwall of the spillway has been lifted by about 2 inches for a distance of approximately three feet, resulting in a near-horizontal joint (see photographs 1, 2, and 10, Appendix C). Flow of water through this joint is illustrated by the icicle formation in photograph 10. The spillway endwall is leaning slightly away from the retained earth embankment. A vertical crack at the center of the wall terminates above the top of the weir, where patching with mortar was previously attempted. The bottom of the spillway outlet channel between the weir and the toe of the endwall has an accumulation of debris, as shown on photograph 10, Appendix C. The spillway concrete apron, shown on the construction drawing (Exhibit E-3), was not visible on the day of inspection. Verification of its existence was hampered by the frozen ground conditions on the day of inspection. The spillway discharge channel, shown in Exhibit E-2, is eroded at the downstream end of the spillway endwall. The present alignment of spillway channel, downstream of the dam, is illustrated in Exhibit A-1.

(2) Outlet Works. The outlet of the 16-inch diameter cast iron pipe appears to be in good condition. The invert of the outlet pipe is located at the maximum section of the dam and is at stream level (see photograph 8, Appendix C). The end of the concrete cradle shown in Exhibit E-2 was not visible. There was no flow through the outlet pipe on the day of the inspection. The upstream gate valve (see Engineering Data, Section 2) was not visible and its location or existence could not be verified.

(d) Reservoir Area. The watershed is predominantly wooded, rising from elevation 708 to elevation 1020 feet above mean sea level. The immediate area along the left bank of the lake is flat to moderately sloped (less than 5%). The right bank of the lake rises from elevation 708 feet to elevation 800 feet, sloping from 20% along the shore line to near-vertical cliff at the right abutment of the dam. There was no evidence of slide activity on the steep slopes that can endanger the safety of the dam.

Both permanent and seasonal homes are located along the entire eastern shore of the lake, as well as on the upstream half of the western shore. A residential developement is located on the lower part of the watershed, approximately 1000 feet west of Wigwam Lake and above elevation 820 feet. The drainage pattern from this development is in southeasterly direction toward the lake. The northern half of the watershed is characterized by wider valleys and milder slopes. Pertinent watershed features are presented in Exhibit E-1, Appendix E. Geologic features of the area are described in Appendix F.

(e) Downstream Channel. The average slope of the stream channel between the dam and State RTE 611 is 0.007 foot per foot (0.7%). Computer printouts of typical sections, located 800 feet and 2100 feet downstream of the dam, are presented in Appendix D. Each section represents the downstream end of the stream reach where existing residences may be subject to inundation, should Wigwam Lake Dam fail. Present stream encroachments within the aforementioned reaches consist of a box culvert and a bridge, a distance of 500 to 1900 feet from the dam, respectively. The 3-foot high by 5-foot wide box culvert is shown in photographs 11 and 12; and the 4-foot high bridge, spanning 18 feet across the stream, is shown in photographs 13 and 14, Appendix C. Development within the first reach of the stream and below the top of dam elevation consists of five permanent and seasonal dwellings that are located on the east side of Wigwam Run. Development within the second stream reach consists of five permanent dwellings, residential garages, a trailer court, a grocery store, and a restaurant (see photographs 11, 12, 13, and 14, Appendix C). The survey indicates that more than a few lives can be lost and a significant amount of property damage incurred should the dam fail when the cited structures are occupied. Consequently, the Wigwam Lake Dam is classified as a high hazard structure.

SECTION 4
OPERATIONAL PROCEDURES

4.1 Normal Operating Procedure.

The reservoir is maintained at normal pool level with the excess inflow discharging over the spillway into the downstream channel. The upstream control for the outlet pipe was not visible and does not appear operational.

4.2 Maintenance of Dam.

Maintenance activities by the present owner could not be verified during the inspection and appear to be minimal. Past history of the dam indicates that maintenance was infrequent and consisted of brush and tree removal from the top and downstream toe of the dam. The removal of trees by the previous owners was ordered by the Pennsylvania Department of Forests and Waters, following inspection by the Department's personnel (see paragraph 2.4, Section 2). In 1966, the Department instructed the present owner to remove trees and brush growing on the dam embankment as well as the removal of debris from the wasteway channel. The conditions on the top of the dam on 11/26/80 are shown in photographs 1, 2, and 5. The debris downstream of the spillway weir on the day of the inspection is shown in photograph 10, Appendix C.

4.3 Maintenance of Operating Facilities.

The condition of the upstream operating facilities for the outlet pipe could not be verified during the site inspection. Past history of the dam indicates that valve repair work in 1953 necessitated a permit to draw down the reservoir for an estimated depth of 10 to 15 feet.

4.4 Warning System in Effect.

There is no emergency operation and warning system in effect at the present time.

4.5 Evaluation.

The maintenance of the outlet pipe control facilities is inadequate. The owner should institute regularly scheduled maintenance inspections. Operational control facilities to lower the water level in the reservoir may be required for emergency repairs at the downstream toe of the dam. Institution of a surveillance and warning system and plan of evacuation for the downstream population is necessary to detect adverse conditions at the dam and to prevent loss of life should the dam fail.

SECTION 5
HYDROLOGY AND HYDRAULICS

5.1 Design Data.

The permit given by the Pennsylvania Water and Power Resources Board stipulates that the spillway design meets the criteria to pass 700 cfs per square mile of the drainage area above the dam. Consequently, the spillway design capacity for the 1.5-square mile drainage area above the dam was 1050 cfs. To obtain this capacity for the design head and spillway length shown in Appendix E, it appears that a spillway discharge coefficient of 3.37 was adopted for spillway design. Hydraulic analysis presented in Appendix D employed a discharge coefficient of 3.1, which better represents the conditions of the constructed spillway. The drainage area above the dam was verified to be 1.5 square miles.

5.2 Experience Data.

The probable flood of record in Wigwam Run is the August 1955 flood. Flood stages or flow records at the damsite or above the mouth of the stream are not available. No records are available on the maximum stage of the reservoir nor to indicate past overtopping of the Wigwam Lake Dam.

5.3 Visual Observations.

Based on the visual inspection and field survey, described in Section 3 of this report, the observations relevant to hydrology and hydraulics are evaluated below:

a. Embankment. The present low point on top of the dam is at 709.8, or 1.2 feet below the design elevation for the top of the dam. The low top of dam elevation on the right abutment, the existing gully between that abutment and the toe of the dam, and the steep downstream embankment slope of the maximum dam section suggests that the Wigwam Lake Dam may have been overtopped at least one time since 1928.

b. Spillway. The spillway crest is at elevation 708.0 feet and the top of the spillway endwall at the left end of the dam is at elevation 711.1. The length of the spillway crest is 57 feet, or 3 feet shorter than the design length. In the absence of the left spillway endwall shown in Appendix E, the present spillway has a trapezoidal cross-sectional area with the top width of overflowing water surface varying from 57 feet at elevation 708 feet to approximately 78 feet at elevation 711. Should the top of the dam be restored to elevation 711 throughout its entire length, the maximum capacity of spillway discharge will increase from the present 475 cfs to approximately 965 cfs.

c. Reservoir Area. There are no upstream structures of significant influence on the rate and time of flood inflow into Wigwam Lake. Land use changes within the watershed, resulting from residential development since the construction of the dam, are described in Paragraph 3.1d, Section 3. Although this residential development increases the runoff from the watershed, the extent of this development is not expected to alter significantly the rate of reservoir inflow during extreme floods.

d. Downstream Conditions. The present and the design spillway capacity are not affected by tailwater conditions. Two stream stretches were selected for the determination of flood stage elevations resulting from Dam Break analysis. The location of the selected stretches are shown on Exhibit E-1. Computer printouts of typical channel sections for each stream reach are presented in Appendix D. Each section was selected with due consideration given to the backwater effect from bridges or other stream encroachments. Hazard to life and property, resulting from dam failure, is limited to the flood plain of Wigwam Run along the first 2100 feet of the stream below the dam.

5.4 Method of Analysis.

Hydrologic and hydraulic evaluation was made in accordance with the procedures and guidelines established by the U.S. Army, Corps of Engineers, Baltimore District, Phase I Safety Inspection of Dams. The analysis has been performed utilizing the HEC-1DB program developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, California. A brief description of program capabilities, as well as the input and output data used specifically for this analysis, is presented in Appendix D.

5.5 Summary of Analysis.

a. Spillway Design Flood (SDF). According to criteria established by the office of the Chief of Engineers (OCE), the Spillway Design Flood (SDF) for the size (small) and hazard potential (high) of the Wigwam Lake Dam is between the one-half Probable Maximum Flood (½PMF) and the full PMF. Because of the small storage capacity of the reservoir, the ½PMF is selected as the SDF for the Wigwam Lake Dam.

b. Results of Analysis. Pertinent results are tabulated in Appendix D. The analysis reveals that under the prevailing top of dam elevations, the spillway discharge is 475 cfs when the water surface in the reservoir reaches the low point on the dam crest. This condition is equivalent to a flood magnitude of approximately 15 percent of the PMF. The insignificant difference between Peak Inflow and Peak Outflow from the reservoir indicates that the effect of reservoir storage on flood reduction is minimal. Should the top of the dam be restored to its design elevation, the spillway could pass approximately 30 percent of the PMF without overtopping the dam. The maximum rates of inflow and outflow from the reservoir, corresponding to a flood magnitude of PMF, are 3340 cfs and 3320 cfs, respectively. For a flood magnitude of ½PMF, the derived inflow and outflow peak rates are 1670 cfs and 1660 cfs, respectively. The dam is overtopped by 0.3 foot, 1.2 feet and 2.2 feet during peak outflow resulting from flood magnitudes of 20%, 50% and 100% of the PMF. The duration of overtopping that corresponds to the aforementioned floods is 3.25, 7.75 and 10.75 hours, respectively.

5.6 Spillway Adequacy.

It was judged that Wigwam Lake Dam would begin to fail during the ½PMF when the pool level reaches elevation 710.8, which is one-foot above the low point on the dam. Because the selected SDF of ½PMF would result in overtopping and probable failure of the dam, a dam breach analysis was performed. Reservoir outflow resulting from the breach was routed through the downstream reaches represented by channel sections 3 and 4, described in Appendix D. Failure of the dam at ½PMF would raise water levels by 3.9 feet and 3.6 feet over the levels that existed just prior to the dam failure at stations 3 and 4, respectively. This would increase the downstream hazard to property and to loss of life. As a result of the hydrologic and hydraulic analysis and the downstream hazard, the present spillway capacity is rated as seriously inadequate.

SECTION 6
EVALUATION OF STRUCTURAL STABILITY

6.1 Visual Observations.

The visual inspection of Wigwam Lake Dam is described in Section 3. Observations that are relevant to structural stability of the dam and the appurtenant structures are evaluated below:

(a) Embankment. Field surveys indicate that both upstream and downstream slopes of the dam at its maximum section are steeper than the design slopes. The upstream slope of the dam above the normal level of the reservoir is 1V:1.3H. Rock pavement over the upstream face is shown on the Construction Drawings, Appendix E, and in a 1928 post-construction photograph of the dam. No rock pavement was visible on the upstream face of the embankment on the day of the inspection. Small seeps and marshy areas at the downstream toe of the dam are shown in Exhibit A-1. The steepness of the embankment slopes at the maximum section of the dam, the absence of upstream slope protection against wave action and the marshy conditions at the toe of the dam are of some concern; but there is no evidence of instability of the dam.

(b) Spillway. Additional investigations and analysis are required to assess the stability of the inclined endwall. This wall should be closely monitored and any additional movement recorded. If further movement of the wall toward the spillway should occur, internal cracking can develop in the earth embankment, as well as in the concrete core wall. Extensive cracking could cause concentration of seepage from the reservoir toward the downstream toe and could possibly cause internal erosion of the earth embankment (piping) and potential failure of the dam. An opening in the vertical joint on the top of the spillway endwall was first observed in 1933. This opening was reported to cause a one-inch separation of the joint and was attributed in the 1933 inspection to settlement of the downstream part of the wall. The present elevations on the downstream top of wall are approximately ½-inch lower than those on the upstream edge, thus supporting the previous observations. However, no significant wall settlement has taken place since 1933 which would affect the structural stability of the wall beyond that previously mentioned. The separation of the top portion of the concrete weir along approximately 3 feet near the endwall does not appear to affect the structural stability of the weir. Frequent inspection of the spillway weir will be necessary to insure that the present condition has not worsened and remedial measures should be taken as required.

(c) Outlet Works. The 16-inch cast iron pipe was constructed in 1928, indicating a period of service for more than fifty years. This length of service approaches the normal expected useful life of cast iron pipe. There was no flow at the pipe outlet on the day of the inspection, indicating that the pipe was not subjected to hydrostatic pressure. Since the reported upstream gate valve could not be located and operated, the effect of pressure flow on the pipe and on the rate of seepage at the toe of the dam could not be verified. Therefore, it is necessary to locate and operate the reported gate valve to evaluate the condition of the outlet works.

6.2 Design and Construction Data.

Available design and construction data are inadequate to assess the present stability of the dam; thus, the evaluation is based on visual inspection.

6.3 Past Performance.

With the exception of the settlement observed in the spillway endwall in 1933 (see Paragraph 6.1b), the available data does not indicate any previous occurrences of structural problems in the dam and appurtenances.

6.4 Seismic Stability.

The dam is located in Seismic Zone 1 and may be subject to minor dynamic forces induced by earthquakes. Normally, it can be considered that if a dam is stable under static loading conditions, it can be assumed safe for minor earthquake loading. However, no computations were made to evaluate this condition.

SECTION 7
ASSESSMENT AND RECOMMENDATIONS FOR REMEDIAL MEASURES

7.1 Dam Assessment.

a. Safety.

(1) Based on visual inspection, the Wigwam Lake Dam is judged to be in poor condition. Based on the size and hazard classification of the dam, the recommended Spillway Design Flood (SDF) varies from ½PMF (Probable Maximum Flood) to the full PMF. In view of the relatively small reservoir storage, it was judged that the SDF of ½PMF is appropriate for this class of structure. Under the present conditions, the spillway will pass approximately 15 percent of the PMF without overtopping the dam. Overtopping depth of 1.2 feet was calculated for a flood magnitude of ½PMF; whereas, it was judged that the dam will begin to fail under an overtopping depth of one foot. Because failure of the dam would increase the downstream high hazard condition, the spillway is seriously inadequate, and the dam is rated as unsafe, non-emergency.

(2) Considering the steepness of the embankment slopes and marshy conditions at the toe of the dam, the stability of the embankment could, in time, be affected.

(3) The observed cracks and inclination of the spillway endwall away from the retained embankment earthfill, could, if further movement occurs, affect the integrity of the embankment.

(4) The unknown condition and location of the valve mechanism, regulating flow through the outlet pipe, precluded assessment of the prevailing conditions of the outlet works. Ready access to an operable valve, or other method of drawing down the reservoir level during emergencies, is required. Such requirement may arise should excessive seepage or piping develop.

(5) The present condition of the dam and appurtenances indicates that maintenance of the dam is inadequate.

(6) There is no warning system and evacuation plan in effect at the present time.

b. Adequacy of Information. The data collected from previously cited dam inspection reports, past performance, visual inspection and computations performed as part of this study are sufficient for Phase I dam safety assessment.

c. Urgency. The recommendations in Paragraph 7.2 should be implemented immediately.

d. Necessity for Further Investigations. In order to accomplish some of the remedial measures outlined in Paragraph 7.2, further investigations by a professional engineer, experienced in the design and construction of dams, will be necessary.

7.2 Recommendations and Remedial Measures.

a. The following investigations and remedial measures are recommended for immediate implementation by the owner:

(1) Engage a professional engineer experienced in the design and construction of dams to perform additional hydrologic and hydraulic analysis to more accurately ascertain the present spillway capacity. As a result of the analysis, implement the necessary remedial measures to upgrade the present spillway capacity to the required Spillway Design Flood.

(2) Locate the valve mechanism for the outlet works facilities and provide means to operate the valve; or develop another method of emergency drawdown, in the event such action becomes necessary.

(3) Remove trees and brush from the crest and slopes of the embankment, under the supervision of a professional engineer.

(4) Institute a monitoring program to detect any significant change in the conditions of the dam and appurtenant structures. As a minimum, this program shall include provision for detecting any additional movement in the spillway endwall and the rate and clarity of seepage at the toe of the dam.

b. In addition, it is recommended that the owner take the following precautionary operational and maintenance measures:

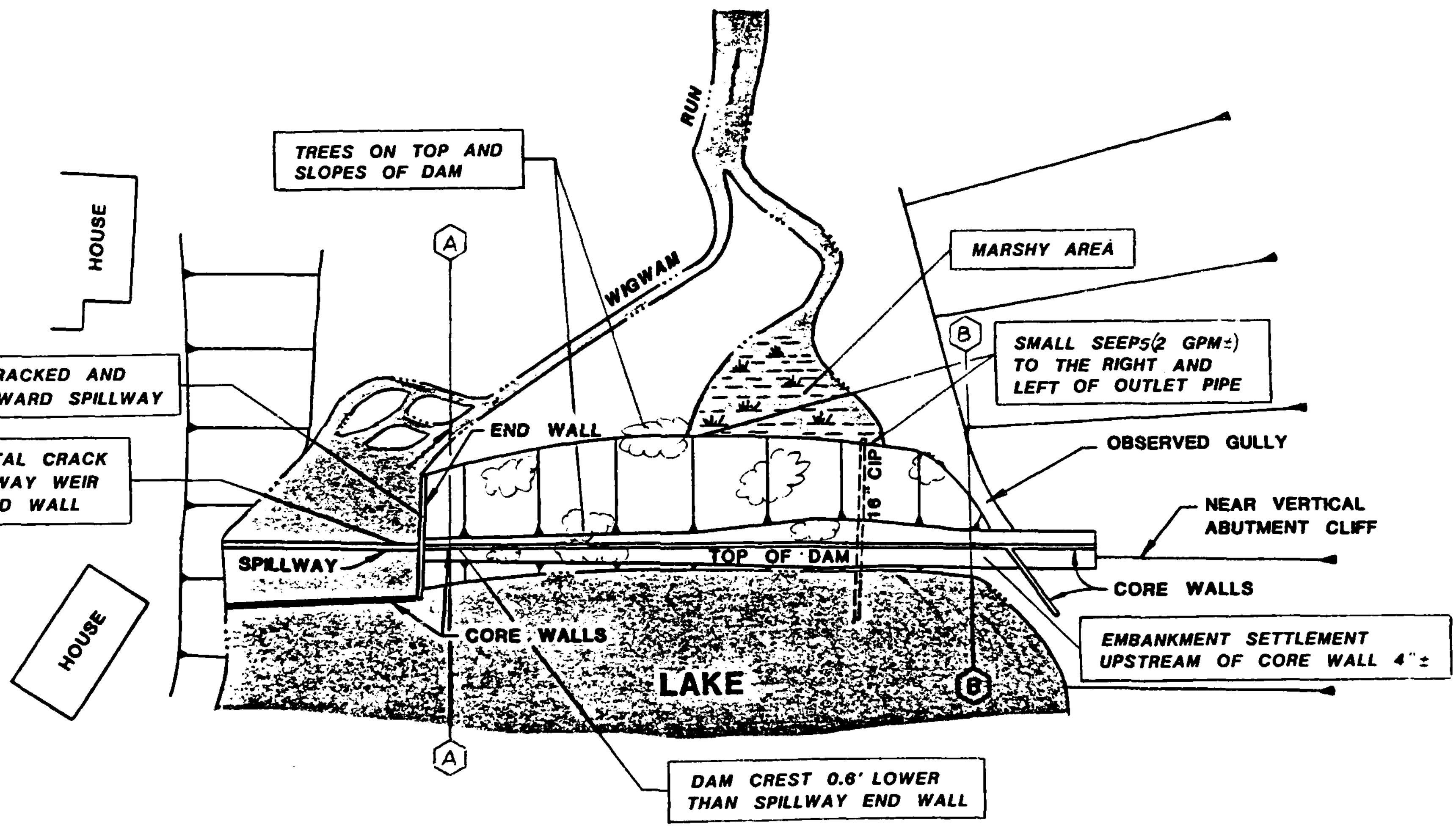
(1) Develop a detailed emergency operation procedure and warning system to facilitate timely and orderly evacuation of the downstream population if any hazardous conditions at the dam are observed.

(2) When warnings of a storm of major proportions are given by the National Weather Service, activate the emergency operation and warning system procedures.

(3) After satisfactory implementation of the remedial measures resulting from the recommended additional investigations, institute a formal inspection and maintenance program for the dam. As presently required by the Bureau of Dams and Waterway Management of PENNDER, the program shall include an annual inspection of the dam by a professional engineer, experienced in the design and construction of dams. Deficiencies found during annual inspections should be remedied as necessary.

APPENDIX A

VISUAL INSPECTION - CHECKLIST AND FIELD SKETCHES



WIGWAM LAKE DAM
GENERAL PLAN - FIELD INSPECTION NOTES

EXHIBIT A-1

GEO-TECHNICAL SERVICES
Consulting Engineers & Geologists

JOB WIGWAM LAKE DER 45-124

SHEET NO.

CALCULATED BY RJM DATE 1-5-81

CHECKED BY DATE

SCALE HORZ. 1" = 50' VERT. 1" = 4'

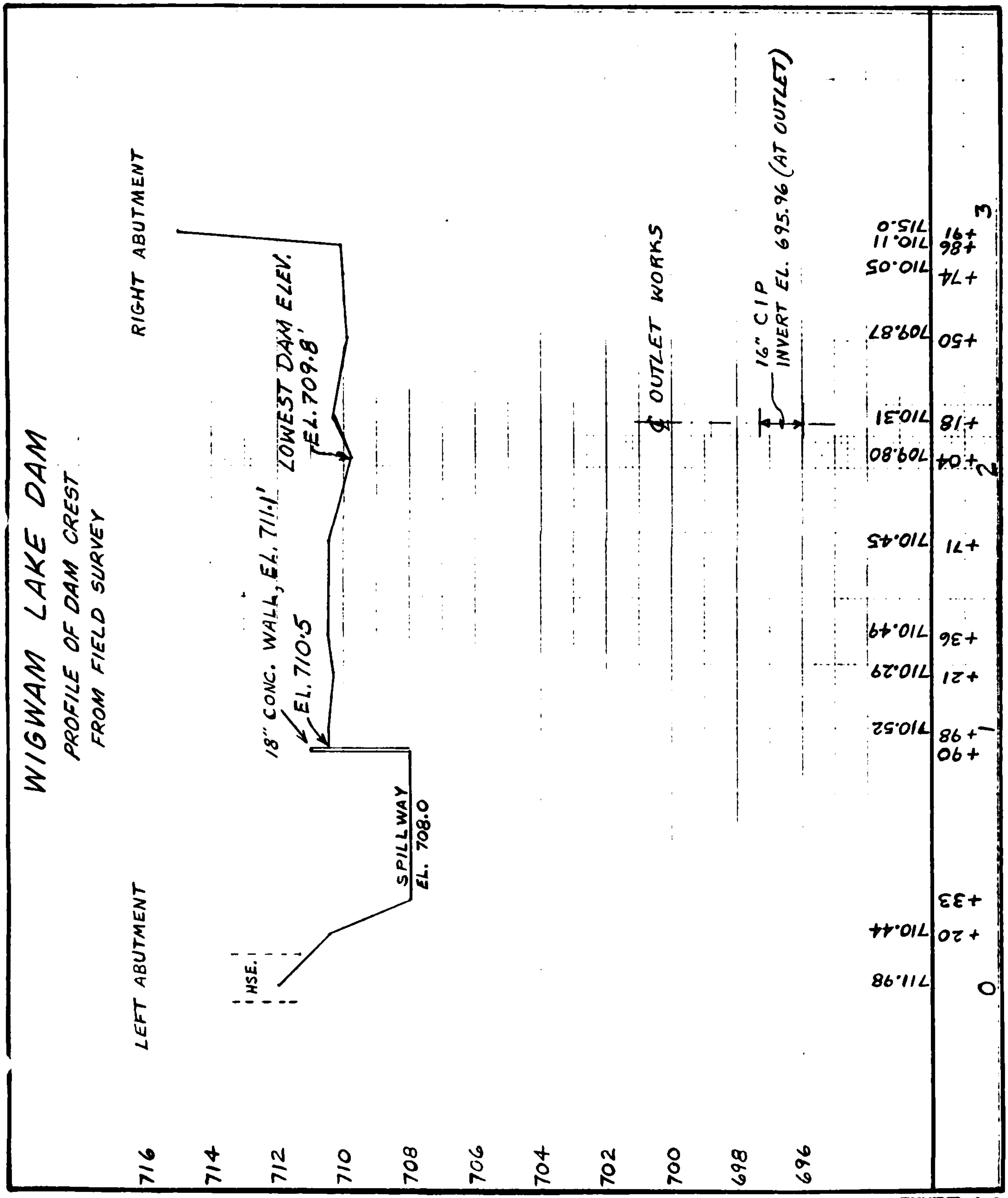
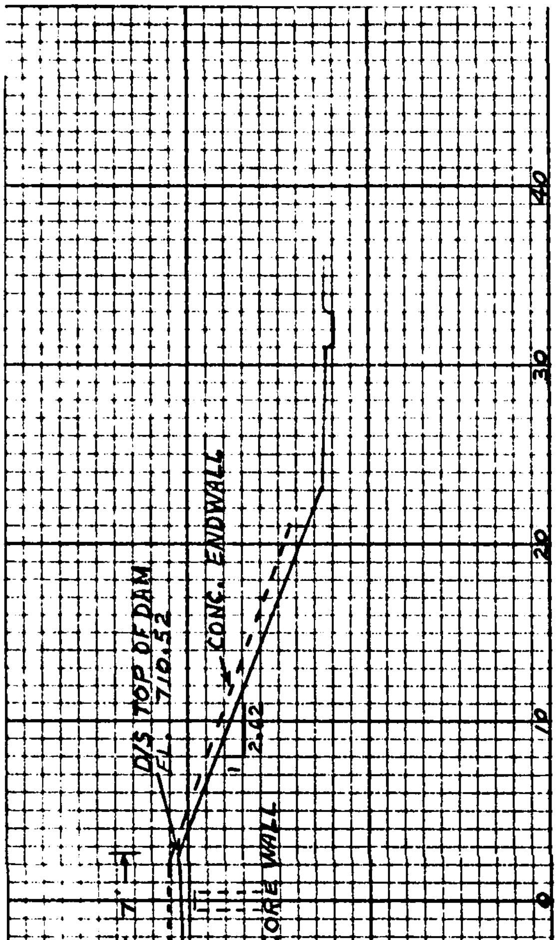
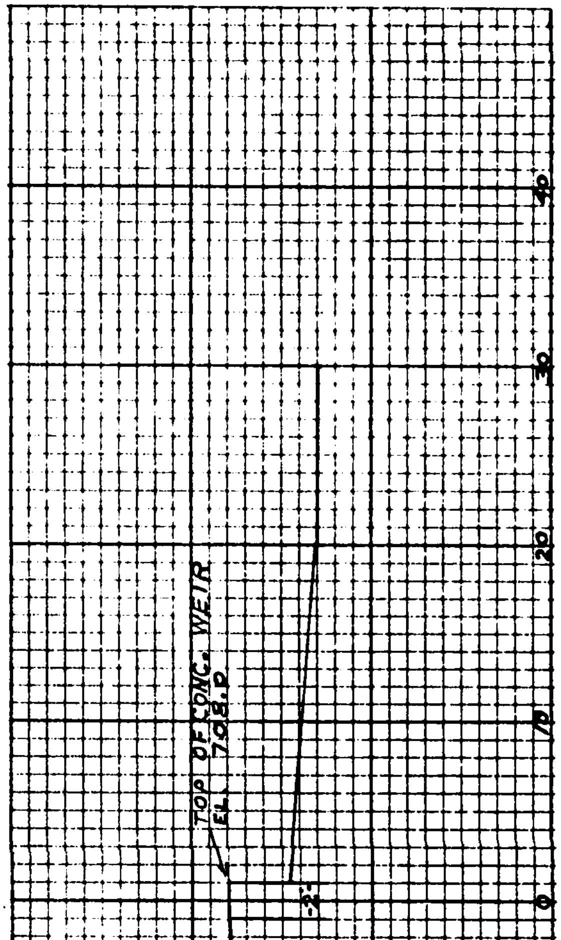


EXHIBIT A-2



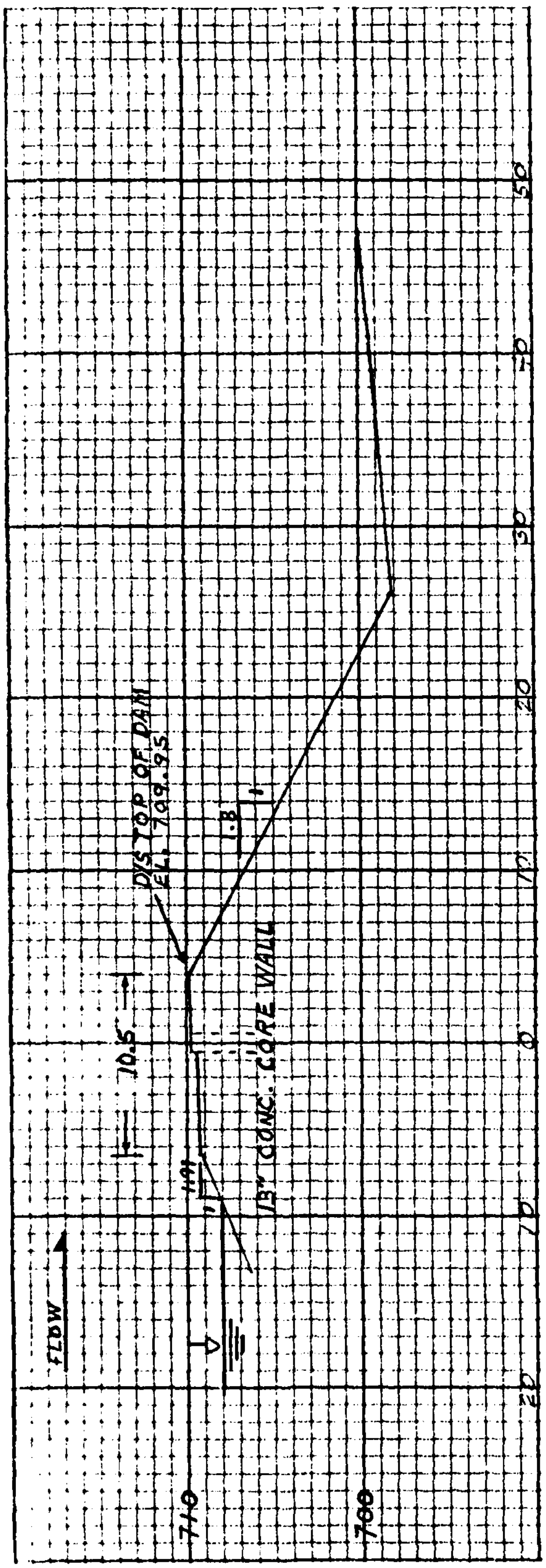
SECTION A



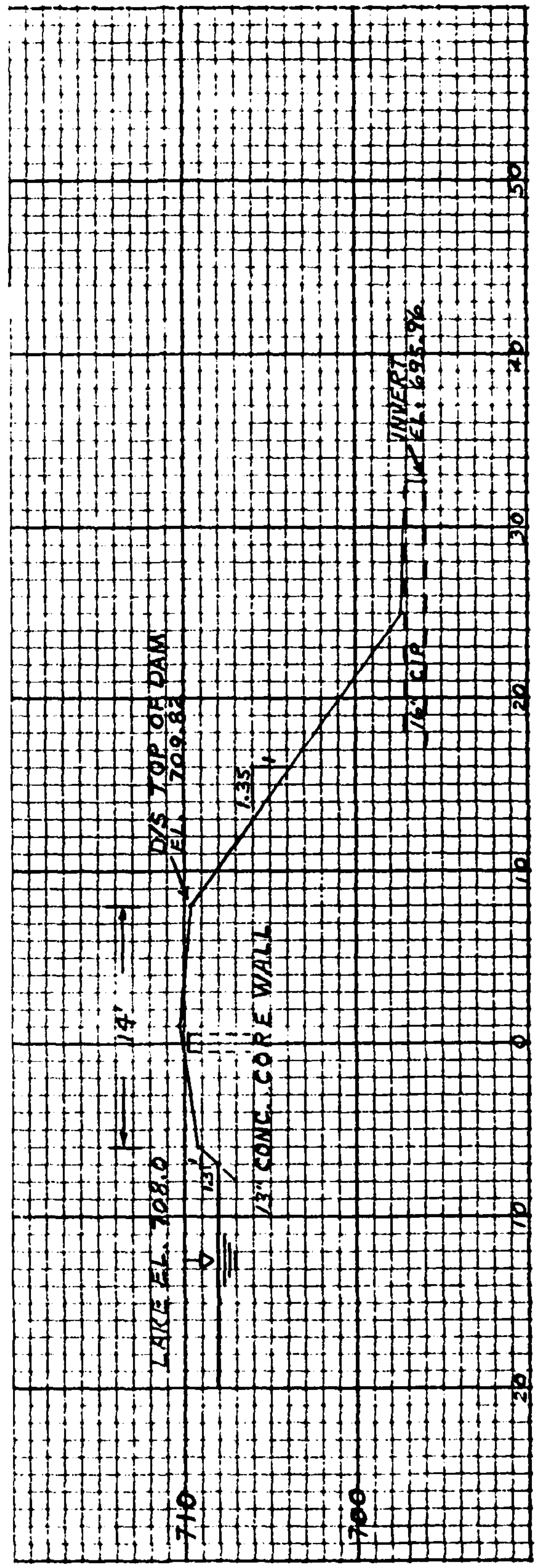
SPILLWAY SECTION

TYPICAL DAM SECTIONS

EXHIBIT A-6



SECTION B



OUTLET WORKS

TYPICAL DAM SECTIONS

CHECK LIST
VISUAL INSPECTION
PHASE 1

NAME OF DAM Wigwam Lake Dam STATE Pennsylvania COUNTY Monroe

NDI # PA — 990 PENNDER # 45-124

TYPE OF DAM Earth (concrete core) SIZE Small HAZARD CATEGORY High

DATE(S) INSPECTION November 26, 1980 WEATHER Clear/cold TEMPERATURE 41^{o}F @ 11:00 A.M.

POOL ELEVATION AT TIME OF INSPECTION 708.1 M.S.L.

TAILWATER AT TIME OF INSPECTION 696.0 M.S.L.

INSPECTION PERSONNEL	OWNER REPRESENTATIVES	OTHERS
Gideon Yachin - Engineer	None (three attempts to contact	
Gerald Branthoover - Geologist	Mr. Harry Snow; reported to be	
Ronald Mather - Surveyor	on leave in Florida)	
Wayne Himes - Surveyor		

RECORDED BY Gideon Yachin, P.E.

EMBANKMENT

ITEM	OBSERVATIONS/REMARKS/RECOMMENDATIONS NDI# PA - 990
SURFACE CRACKS	None Observed
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	None Observed
SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	Evidence of over-topping at right abutment on natural ground. The downstream slope of the maximum dam section near the right abutment is much steeper than the downstream slope of the balance of the dam. (see Exhibit A-4).
VERTICAL AND HORIZONTAL ALIGNMENT OF THE CREST	Horizontal - good Vertical - settlement of embankment upstream of concrete core wall (4"±) on right end of dam. Top of dam elevations vary along the crest of the dam. For top of dam profile, see Exhibit A-2.
RIPRAP FAILURES	None Observed (Thin rock riprap on downstream slope of embankment). No upstream riprap above the water surface in the reservoir.
JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM	Top of dam lower than spillway endwall (6"±) on left dam abutment. Top of dam at right abutment is 1' lower than the design elevation..

EMBANKMENT

ITEM	OBSERVATIONS/REMARKS/RECOMMENDATIONS NDI# PA- 990
DAMP AREAS IRREGULAR VEGETATION (LUSH OR DEAD PLANTS)	Marshy area along toe of dam.
ANY NOTICEABLE SEEPAGE	Seepage (estimated 2$\pm$ GPM) on right side of outlet conduit (16" dia. C.I.P.) and approximately 50 feet to the left of the outlet pipe near the toe of the dam. (see Exhibit A-1).
STAFF GAGE AND RECORDER	None
DRAINS	None Observed
ROCK OUTCROPS	Metamorphic Siltstone, Dark Gray exposed on right abutment. Highly jointed; cleavage pronounced; bedding undefined.
DAM FOUNDATION TREES, OTHER	Trees (4" dia.) on top of dam and at the toe (+8" dia.). Small break in natural spillway channel diverting flow to main stream near the right abutment (away from the toe of the dam).

OUTLET WORKS

ITEM	OBSERVATIONS/REMARKS/RECOMMENDATIONS NDI# PA - 990
INTAKE STRUCTURE	Intake submerged. Method and type of upstream control could not be verified.
OUTLET CONDUIT (CRACKING AND SPALLING OF CONCRETE SURFACES)	16" diameter CIP. No evidence of concrete cradle or encasement.
OUTLET STRUCTURE	None
OUTLET CHANNEL	None Visible. Apparent original stream channel is to the right of outlet pipe
GATE(S) AND OPERATIONAL EQUIPMENT	No downstream gate. Apparent control at inlet to the pipe, or on the upstream section of the conduit.
CONCRETE SURFACES CRACKS, SPALLING JOINTS	Not Applicable

EMERGENCY SPILLWAY

ITEM	OBSERVATIONS/REMARKS/RECOMMENDATIONS NDI# PA- 990
TYPE AND CONDITION	Concrete Weir (slight adverse slope toward upstream; 2' horizontal width) in fair condition with noted exception.
APPROACH CHANNEL	Earth fill with stone paving between upstream cutoff wall and spillway weir.
SPILLWAY CHANNEL AND SIDEWALLS	No evidence of left spillway wall. Right spillway wall cracked with slight lean to the left (off vertical). Evidence of patched concrete along vertical wingwall strip, adjacent to the weir.
STILLING BASIN PLUNGE POOL	None
DISCHARGE CHANNEL	Channel flows perpendicular to the weir to the end of the apron, overflows and runs downslope to the right to join the main stream.
BRIDGE AND PIERS EMERGENCY GATES	None

SERVICE SPILLWAY

ITEM	OBSERVATIONS/REMARKS/RECOMMENDATIONS NDI# PA - 990
TYPE AND CONDITION	NA
APPROACH CHANNEL	NA
OUTLET STRUCTURE	NA
DISCHARGE CHANNEL	NA

INSTRUMENTATION

ITEM	OBSERVATIONS/REMARKS/RECOMMENDATIONS NDI# PA - 990
MONUMENTATION SURVEYS	None
OBSERVATION WELLS	None
WEIRS	None
PIEZOMETERS	None
OTHERS	None
OPERATION AND MAINTENANCE DATA	None available

RESERVOIR AREA AND DOWNSTREAM CHANNEL

ITEM	OBSERVATIONS/REMARKS/RECOMMENDATIONS NDI# PA- 990
SLOPES: RESERVOIR	Steep, from vertical to 1V on 3H slopes along and upstream of right dam abutment; mild to flat slope along and upstream of left abutment.
SEDIMENTATION	Glacial outwash; swampy valley. No evidence of sedimentation.
DOWNSTREAM CHANNEL (OBSTRUCTIONS, DEBRIS, ETC.)	No obstructions until 0.25 mile downstream of dam. Box culvert under township road. Small bridge on Route 611 between grocery store and restaurant.
SLOPES: CHANNEL VALLEY	Channel - swampy, braided stream - flat, 100 yard wide valley - steep slopes 1:1.
APPROXIMATE NUMBER OF HOMES AND POPULATION	10 homes, trailer court, restaurant and a grocery store. Population 50 to 100.
WATERSHED DESCRIPTION	Mostly wooded. Steep slopes in lower half. Wider valleys and moderate slopes in upper half. Strip development along lake and above right abutment of dam.

APPENDIX B

ENGINEERING DATA - CHECKLIST

CHECK LIST
ENGINEERING DATA
PHASE I

NAME OF DAM Wigwam Lake Dam

NDI# PA - 990

ITEM	REMARKS
PERSONS INTERVIEWED AND TITLE	None. Owner in Florida. No response from residents immediately downstream of the dam.
REGIONAL VICINITY MAP	See Exhibit E-1, Appendix E
CONSTRUCTION HISTORY	Construction design by John L. Westbrook, Civil Engineer and Surveyor. Constructed in 1927 - 1928 by Caratti (Contracter), Pennsylvania
AVAILABLE DRAWINGS	Original and revised (two sheets) drawings and specifications on file with PennDER.
TYPICAL DAM SECTIONS	For typical Design Section, see Exhibit E-3, Appendix E. Present condition is depicted in Exhibits A-3 and A-4, Appendix A.
OUTLETS PLAN DETAILS DISCHARGE RATINGS	See Exhibit E-2 Not available

CHECK LIST
ENGINEERING DATA
PHASE I
(CONTINUED)

NDI# PA - 990

ITEM	REMARKS
SPILLWAY PLAN SECTION DETAILS	See Exhibit E-2, Appendix E See Exhibit E-3, Appendix E
OPERATING EQUIPMENT PLANS AND DETAILS	Not shown on origianl drawings (Appendix E)
DESIGN REPORTS	None available
GEOLOGY REPORTS	None available
DESIGN COMPUTATIONS HYDROLOGY AND HYDRAULICS STABILITY ANALYSES SEEPAGE ANALYSES	None available
MATERIAL INVESTIGATIONS BORING RECORDS LABORATORY TESTING FIELD TESTING	Description not available Description of depth to rock available for cutoff trench on file with PennDER; see also Exhibit E-4, Appendix E. None Not known

CHECK LIST
ENGINEERING DATA
PHASE I
(CONTINUED)

NDI# PA - 990

ITEM	REMARKS
BORROW SOURCES	Adjacent to construction site (from construction specifications, PennDER files)
POST CONSTRUCTION DAM SURVEYS	None available prior to 1980. For conditions on 11/26/80, see top of dam profile and typical sections, Appendix A
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	Inspection Reports (1929, 1931, 1933, 1934, 1935, 1938, 1941, 1950 and 1957) on file with PennDER.
HIGH POOL RECORDS	No formal records are available.
MONITORING SYSTEMS	None
MODIFICATIONS	None

CHECK LIST
ENGINEERING DATA
PHASE I
(CONTINUED)

NDI# PA - 990

ITEM	REMARKS
PRIOR ACCIDENTS OR FAILURES	Not reported
MAINTENANCE RECORDS MANUAL	Not available
OPERATION RECORDS MANUAL	Not available
OPERATIONAL PROCEDURES	Self-regulating.
WARNING SYSTEM AND/OR COMMUNICATION FACILITIES	Not available
MISCELLANEOUS	

CHECK LIST
HYDROLOGIC AND HYDRAULIC
ENGINEERING DATA

NDI ID # 00990
PENNDER ID # 45-124

SIZE OF DRAINAGE AREA: 1.5 square miles

ELEVATION TOP NORMAL POOL: 708.0 STORAGE CAPACITY: 32 Acre-feet

ELEVATION TOP FLOOD CONTROL POOL: NA STORAGE CAPACITY: NA

ELEVATION MAXIMUM DESIGN POOL: 711 STORAGE CAPACITY: 47 Acre-feet (exist.) 56 Acre-feet (Design)

ELEVATION TOP DAM: 711 (Design) 709.8 (Exist.) STORAGE CAPACITY: 56 Acre-feet (Design) 47 Acre-feet (Exist.)

SPILLWAY DATA

CREST ELEVATION: 708.0 Feet

TYPE: Uncontrolled, rectangular concrete weir (Design)

CREST LENGTH: 60 feet (Design) 57 feet (Exist.)

CHANNEL LENGTH: 15 feet (Design apron)

SPILLOVER LOCATION: Left abutment

NUMBER AND TYPE OF GATES: None

OUTLET WORKS

TYPE: 16" diameter C.I.P.

LOCATION: At maximum dam section near right abutment

ENTRANCE INVERTS: Elevation 696.5, approximately (Design)

EXIT INVERTS: Elevation 696.0

EMERGENCY DRAWDOWN FACILITIES: None visible (reported upstream valve)

HYDROMETEOROLOGICAL GAGES

TYPE: None

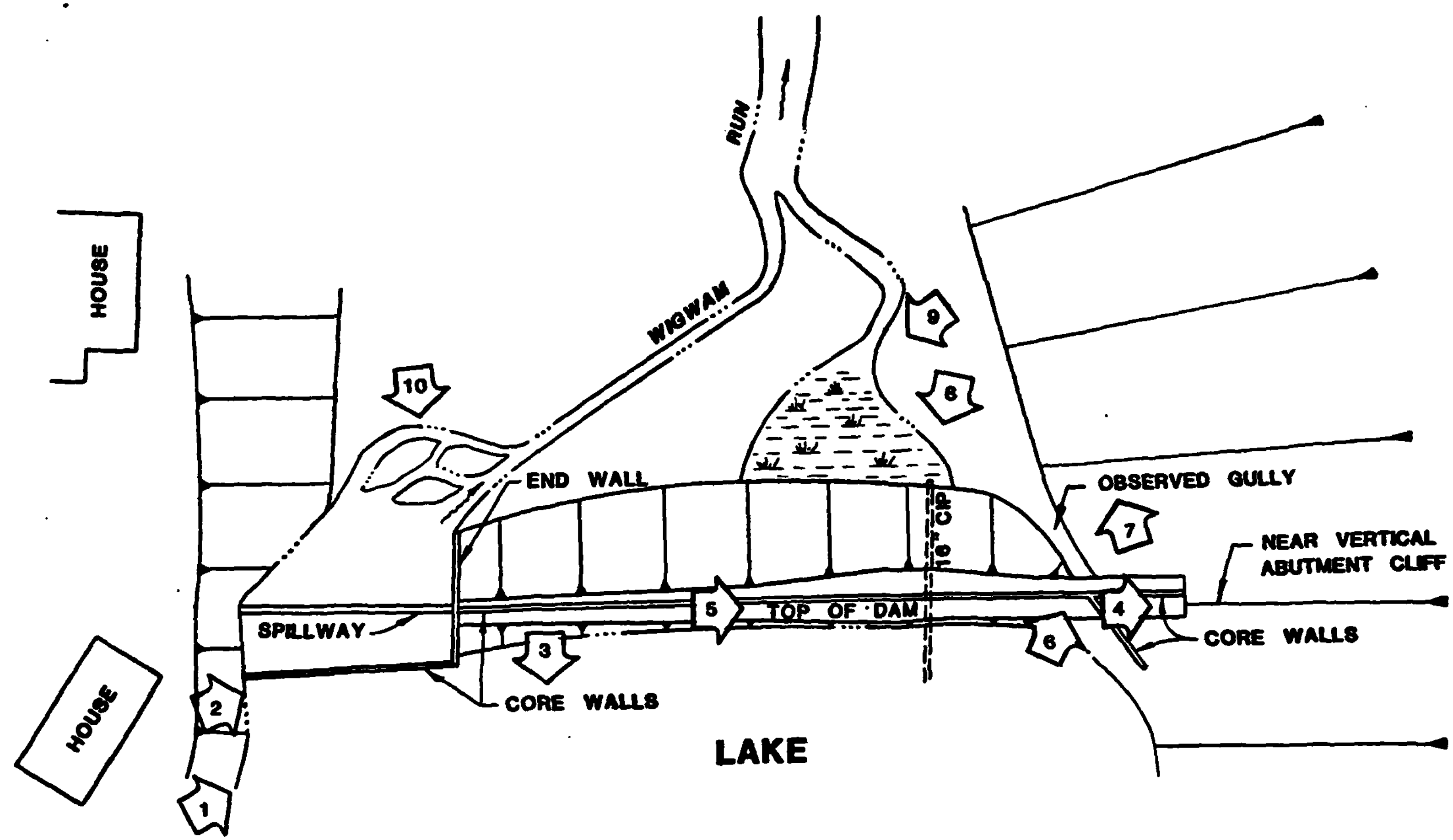
LOCATION: None

RECORDS: None

MAXIMUM NON-DAMAGING DISCHARGE: 500 cfs

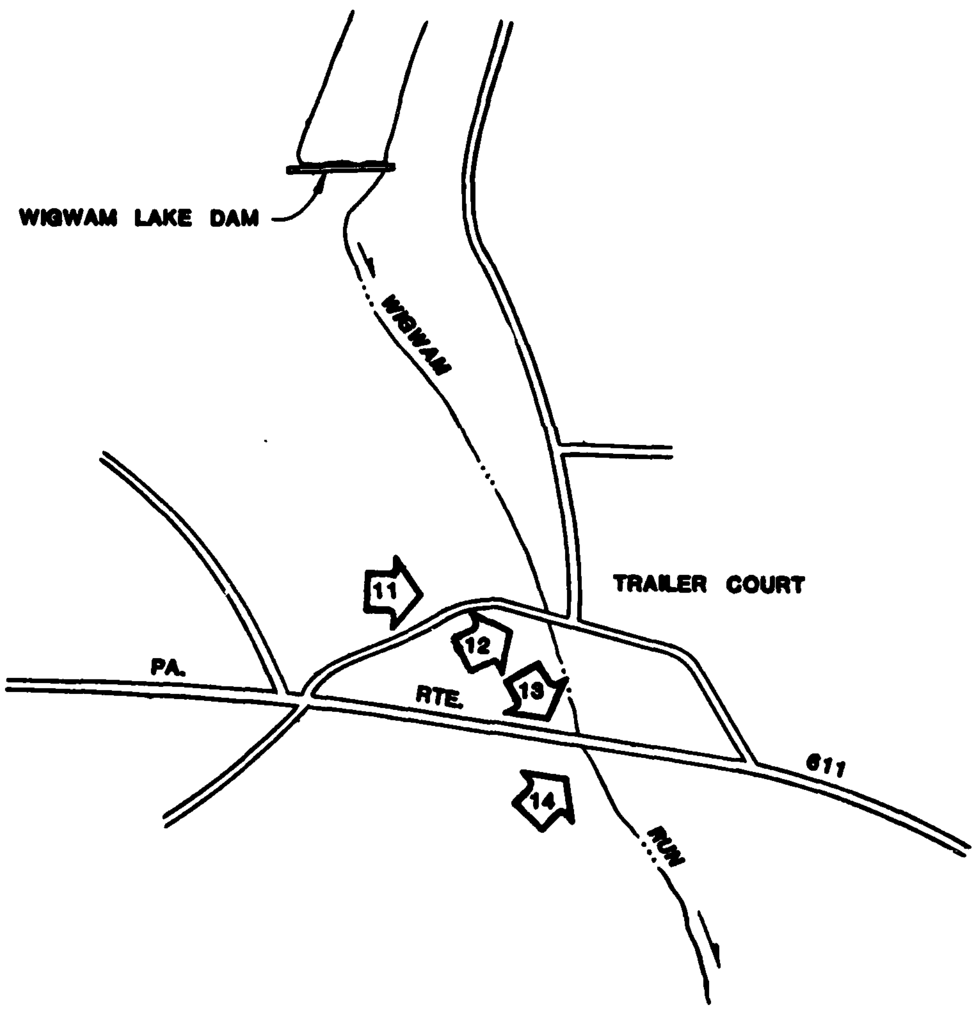
APPENDIX C

PHOTOGRAPHS



WIGWAM LAKE DAM
PHOTOGRAPHS LOCATION MAP

EXHIBIT C-1



WIGWAM LAKE DAM

DOWNSTREAM PHOTOGRAPHS LOCATION MAP

EXHIBIT C-2

1. UPSTREAM FACE OF DAM (FROM LEFT BANK)

2. RIGHT SPILLWAY WALL

3. UPSTREAM VIEW OF WIGWAM LAKE

4.

6. CUTOFF WALL , RIGHT ABUTMENT

5. TOP OF DAN (LOOKING TOWARD RIGHT ABUTMENT)

CLOSE - UP VIEW OF RIGHT ABUTMENT (INSERT 4 , ABOVE)

7. POSSIBLE WASHOUT , DOWNSTREAM OF RT. ABUTM

8. OUTLET PIPE (16" DIA. CIP.)

9. DOWNSTREAM SLOPE , LOOKING TOWARD LEFT ABUTMENT

10. DOWNSTREAM SLOPE AT SPILLWAY WALL

11. TRAILER COURT AT WIGWAM RD. BOX CULVERT

12. LOOKING UPSTREAM AT CULVERT

13. LOOKING DOWNSTREAM OF RTE. 611 BRIDGE

14. LOOKING UPSTREAM OF RTE. 611 ON RESTAURANT

APPENDIX D

HYDROLOGY AND HYDRAULICS

SUMMARY DESCRIPTION
OF
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY INVESTIGATIONS

The hydrologic and hydraulic evaluation for this inspection report has employed computer techniques using the Corps of Engineers computer program identified as the Flood Hydrograph Package (HEC-1) Dam Safety Version.

The program has been designed to enable the user to perform two basic types of hydrologic analyses: (1) the evaluation of the over-topping potential of the dam, and (2) estimate the downstream hydrologic-hydraulic consequences resulting from assumed structural failures of the dam. A brief summary of the computation procedures typically used in the dam overtopping analysis is shown below.

- Development of an inflow hydrograph to the reservoir.

- Routing of the inflow hydrograph(s) through the reservoir to determine if the event(s) analyzed would overtop the dam.

- Routing of the outflow hydrograph(s) of the reservoir to desired downstream locations. The results provide the peak discharge, time of the peak discharge and maximum stage of each routed hydrograph at the outlet of the reach.

The output data provided by this program permits the comparison of downstream conditions just prior to a breach failure with that after a breach failure and the determination as to whether or not there is a significant increase in the hazard to loss of life as a result of such a failure.

The results of the studies conducted for this report are presented in Section 5.

For detailed information regarding this program, refer to the Users Manual for the Flood Hydrograph Package (HEC-1), Dam Safety Investigations prepared by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, Davis, California.

JOB WIGWAM DAM PA 0990

SHEET NO OF

GEO-TECHNICAL SERVICES
Consulting Engineers & Geologists

CALCULATED BY WEH DATE

CHECKED BY DATE

SCALE

METHODOLOGY

1.) MULTI-RATIO OVERTOPPING ANALYSIS

2.) ROUTE TO DOWNSTREAM SECTIONS

3.) DUE TO DOWNSTREAM HAZARD CONDITIONS & OVERTOPPING ANALYSIS A DAM BREACH ANALYSIS WAS PERFORMED.

GEO-TECHNICAL SERVICES
Consulting Engineers & Geologists

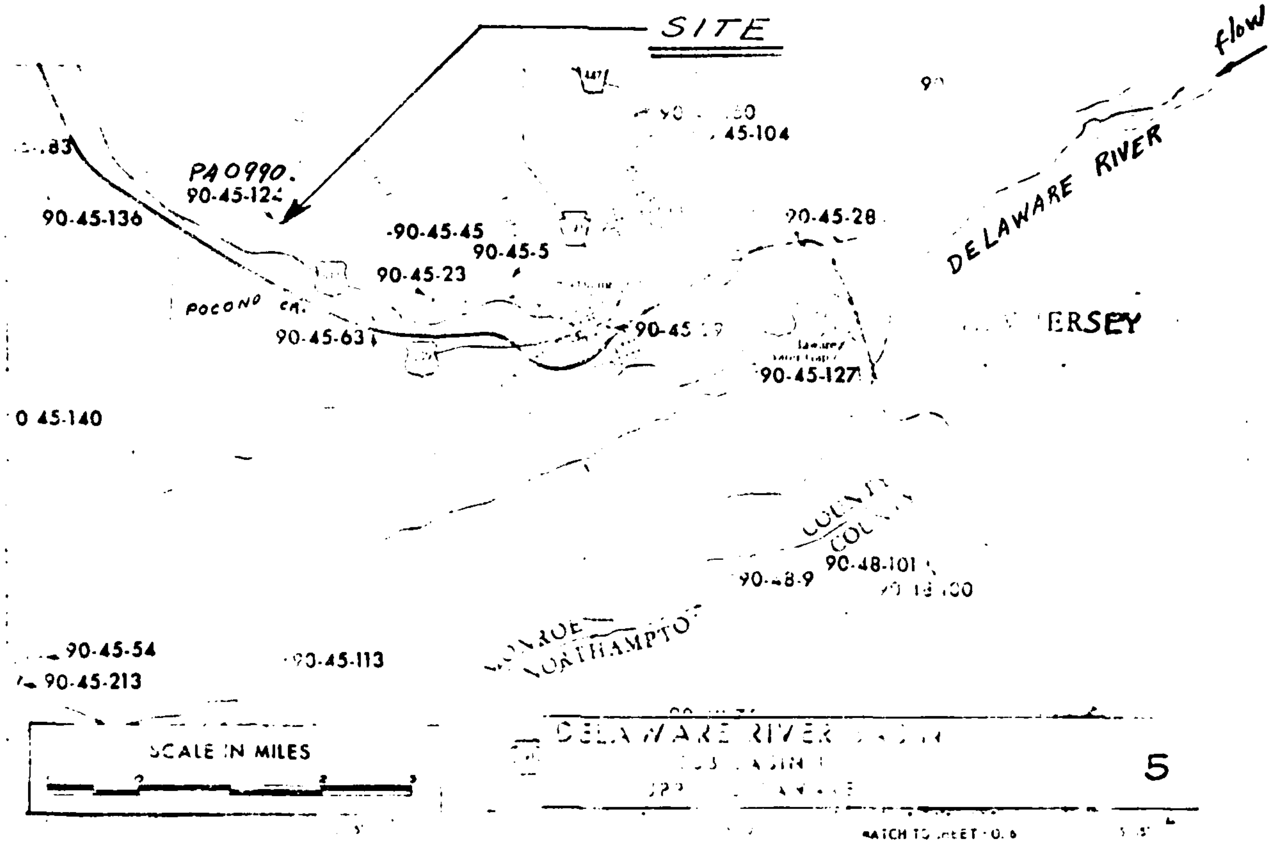
JOB: WIGWAM DAM; PA 0990
CALCULATED BY: G.Y. DATE: 1/19/1981
CHECKED BY:
SCALE:

DELAWARE RIVER BASIN (PENNDER SUB BASIN 1); DER # 45-124

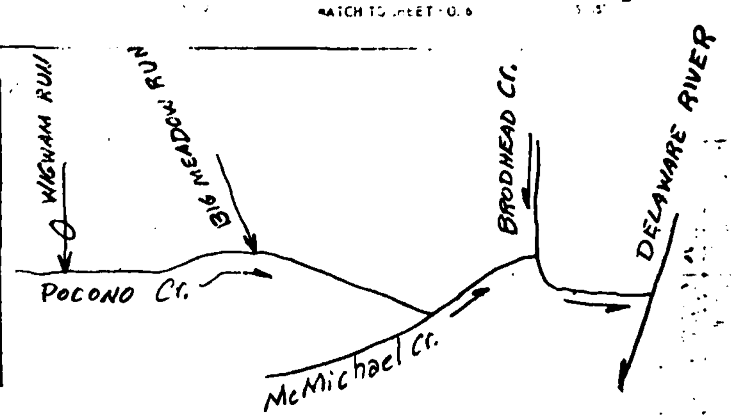
WIGWAM LAKE DAM

STROUD TWP., MONROE CO., PA.

Latitude: N 41° 00' 11" Longitude: W 75° 15' 36" HYDROLOGIC ZONE 1



NAME OF STREAM	DRAINAGE AREA MI² AT MOUTH
Wigwam Run	1.71
Pocono Creek	45.9
McMichael Cr.	113.
Brodhead Cr.	287



TRIBUTARY SCHEMATICS

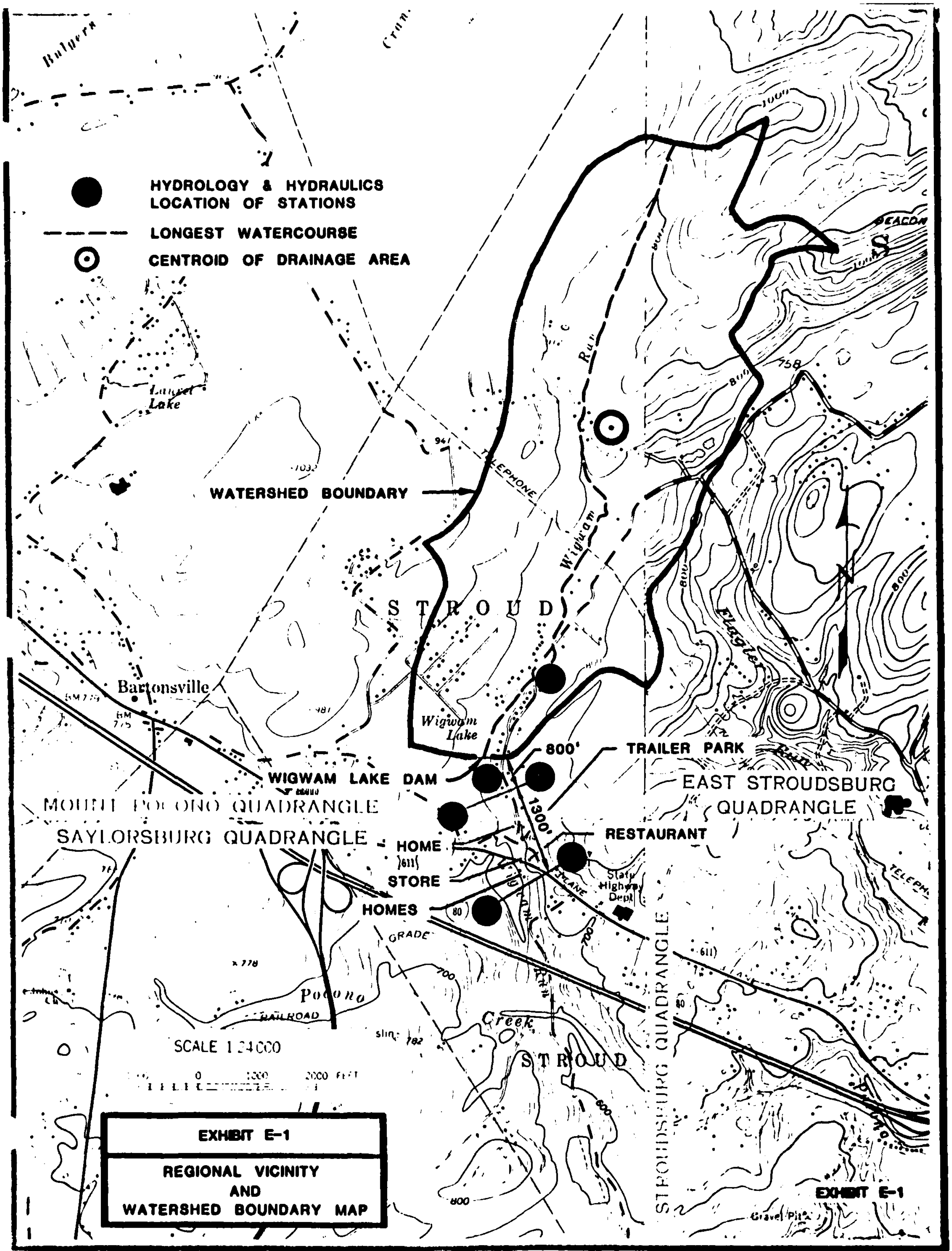


EXHIBIT E-1

REGIONAL VICINITY AND WATERSHED BOUNDARY MAP

UPSTREAM DAMS: None   DOWNSTREAM DAMS: Not applicable

NOTE: Downstream dams (DER # 45-63; 45-29 & 45-28) are located on Pocono Cr, McMichael Cr. and Brodhead Creek, respectively (see Sheet 1). These are non-qualifying dams for Phase 1 inspection program and are located a great distance downstream from Wigwam Lake Dam.

SNYDER'S UNIT HYDROGRAPH PARAMETERS

SUB-AREA	DRAINAGE AREA SQ. MI	Cp (1)	Ct (2)	L MILES (3)	Lca MILES (4)	L' MILES (5)	Tp HOURS (6)	REFERENCE
ABOVE DAM	1.50	0.45	1.23	2.12	1.14	NA	1.60	

(1) & (2) Snyder's Unit Hydrograph Coefficients; Supplied by the Baltimore District, U.S. Army Corps of Engineers: Delaware River Basin Zone Map (Zone 1) and Tabulated Values

(3) & (4) Length of Main watercourse from outflow point to the drainage divide and to the Centroid of the drainage area, respectively.

(6) $T_p = C_t \times (L \times L_{ca})^{0.3}$

RAINFALL DATA (REF. - HYDROMETEROLOGICAL REPORT #33)

PMP Rainfall Index 21.8 inches (24-hour duration over 200 mi² drainage area); Zone 1. Adjustment for drainage area above dam (Hop Brook reduction factor 0.8) is included in HEC 1 DB computer program

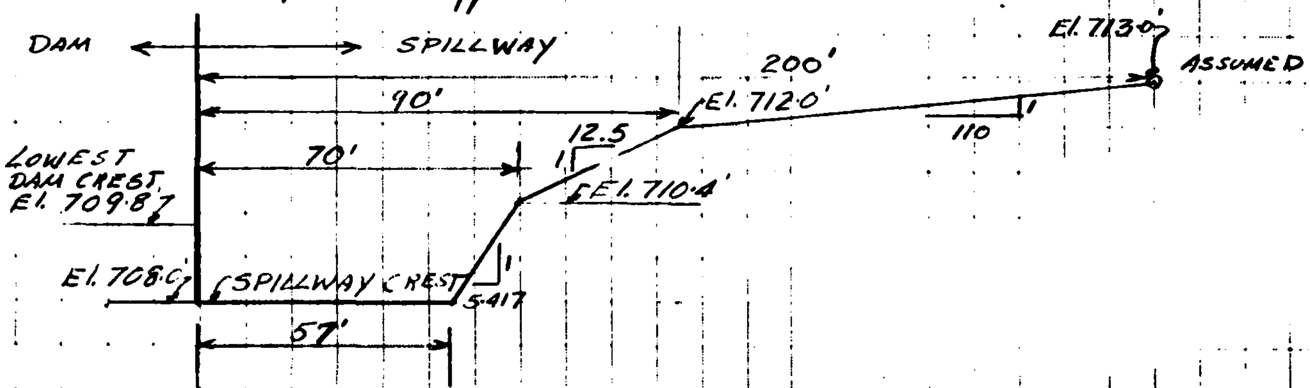
RAINFALL DISTRIBUTION

DURATION	6-HOUR	12-HOUR	24-HOUR	48-HOUR
PERCENT	111	123	133	142

RATING CURVES

A. SPILLWAY

Negligible length of approach channel, resulting in insignificant approach velocities



Use general equation for flow at critical depth (REF. - KING'S HANDBOOK OF HYDRAULICS - SECTION 8)

$\frac{Q^2}{g} = \frac{a^3}{T}$; Substituting $Dm = \frac{a}{T}$

$Q = a \times \sqrt{g\,Dm}$ where Q = Discharge in cfs
g = 32.2 ft/sec²
a = Cross sectional area of flow (ft²)
T = Top width of flow (ft)

Head over crest $Hm = Dc + \frac{Dm}{2}$ where Dc = Critical depth (ft)

At El. 708.5' $Dc = 0.5$; $T = 57 + \frac{0.5\,(70-57)}{(710.4-708)} = 59.71$

$a = \frac{57 + 59.71}{2} \times 0.5 = 29.18\ ft^2$; $Dm = \frac{29.18}{59.71} = 0.49'$

$Q = 29.18 \times \sqrt{32.2 \times 0.49} = 116\ cfs$; $Hm = 0.5 + \frac{0.49}{2} = 0.75'$

RATING CURVES (CONTINUED)

Above El. 710.4' $T = 70' + \Delta Dc \times 12.5$ (see sketch, sheet...)

$$a = 152 ft^2 + \frac{70' + T}{2} \times \Delta Dc$$

Where ΔDc is the incremental critical depth above El. 710.4'

Similarly, above El. 712.0' $T = 90' + \Delta Dc' \times 110'$

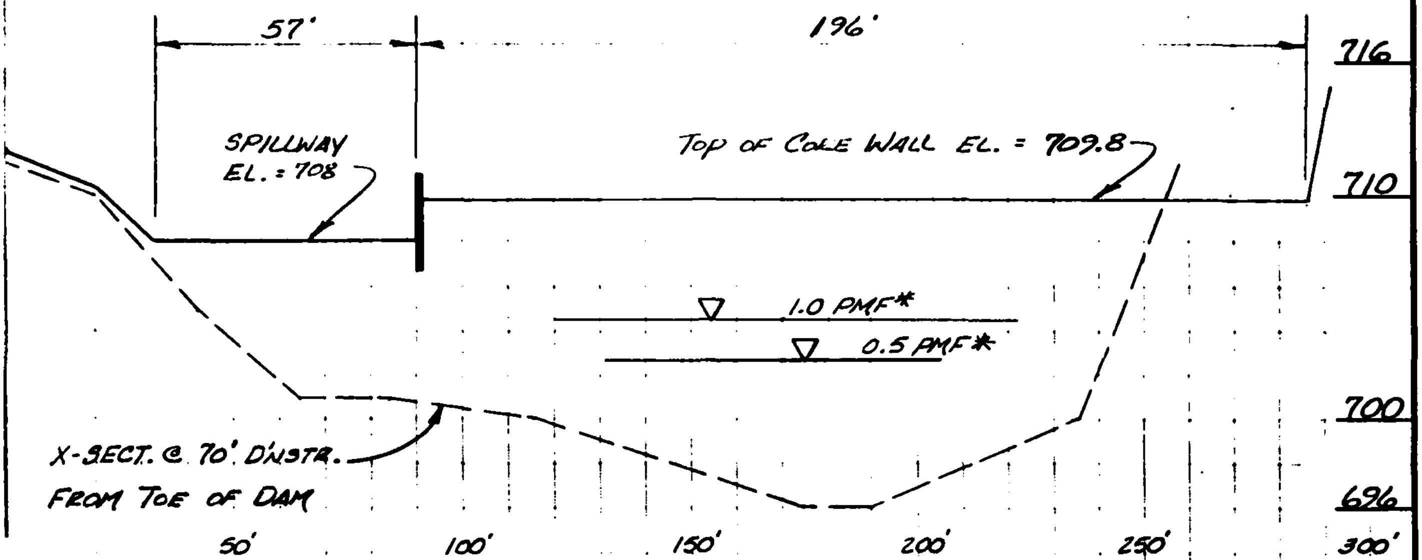
$$a = 280 ft^2 + \frac{90' + T}{2} \times \Delta Dc'$$

Where $\Delta Dc'$ is the incremental critical depth above El. 712.0'

ΔDc	Dc ft	T ft	a ft^2	Dm ft	Q cfs	Hm ft	W. S. ELEV
	0.5	59.71	29.18	0.49	116	0.75	708.75
	1.0	62.42	59.71		331	1.48	709.48
	1.3	64.04	78.68		495	1.91	709.91
	1.5	65.13	91.59		616	2.20	710.20
	1.6	65.67	98.13		680	2.35	710.35
	1.7	66.21	104.73		747	2.49	710.49
	2.0	67.83	124.83		961	2.92	710.92
	2.4	70.00	152.40		1276	3.49	711.49
0.6	3.0	77.50	196.65	2.54	1778	4.27	712.27
1.2	3.6	85.00	245.40	2.89	2366	5.04	713.04
1.6	4.0	90.00	280.40		2808	5.56	713.56
0.5	4.5	145	339.15	2.34	2943	5.67	713.67
1.0	5.0	200	425.40	2.13	3521	6.06	714.06

GEO-TECHNICAL SERVICES Consulting Engineers & Geologists	JOB WIGWAM DAM PA 0990 SHEET NO ____ OF ____ CALCULATED BY WEH DATE 1/24/81 CHECKED BY ____ DATE ____ SCALE ____

COMPUTE TAILWATER @ DOWNSTR. FACE OF DAM



INPUT CRITERIA

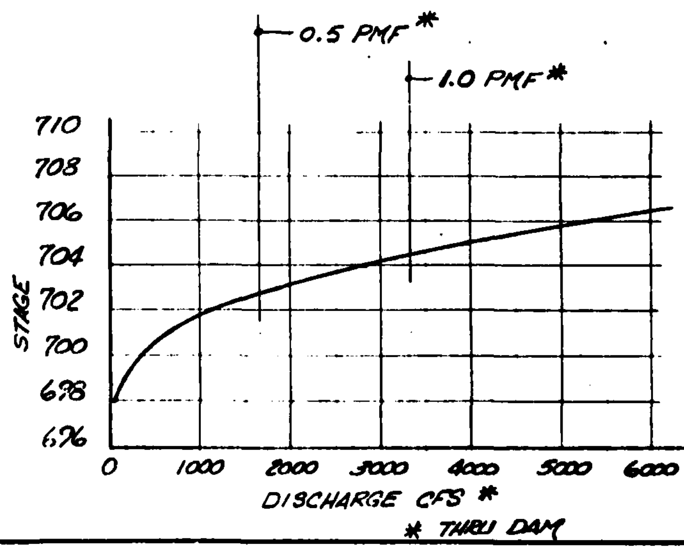
n = 0.09 FOR TOTAL SECTION

SLOPE = .0.0075%

DIST. FROM FACE OF DAM = 70'

WIGWAM DAM PA0990
NORMAL DEPTH RATING CURVE AT DAM FACE

ELEV.	CFS
698.0	31
699.0	135
700.0	337
701.0	662
702.0	1111
703.0	1824
704.0	2808
705.0	3975
706.0	5321
707.0	6792



GEO-TECHNICAL SERVICES
Consulting Engineers & Geologists

JOB WIGWAM LAKE DAM; PA 0990
SHEET NO ____ OF ____
CALCULATED BY GY DATE ____
CHECKED BY ____ DATE ____
SCALE ____

RESERVOIR AREA-CAPACITY DATA

Use Storage Per Bulletin 5 of 24.5 acre-feet (8MG) @ Elev. 708.0 and surface area = 8 acres

Applying the Conic Method for Reservoir Volume,

h = 3 × 24.5/8 = 9.2' ∴ Elev. @ 0 Area = 708.0 − 9.2 = 698.8

Since the derived elevation is above the streambed elevation 696 and in order to comply with the dam break analysis criteria (see D-11), Elev. 696.0 was selected for the zero area and storage capacity.

ELEVATION	AREA (Acres)*
696.0	0
708.0	8
709.8	8.3
711.1	8.5
720.0	28.7

* Planimetered Areas From 7.5' USGS Map

JOB Wigwam Lake Dam; PA0990

SHEET NO ______ OF ______

GEO-TECHNICAL SERVICES
Consulting Engineers & Geologists

CALCULATED BY G.Y. DATE 1/21/1981

CHECKED BY ______ DATE ______

SCALE ______

ESTIMATED OUTLET WORK DISCHARGE

Invert of outlet end, 16"ϕ CIP, El. 696.0'

Normal pool at spillway crest El. 708.0'
High pool at low point on dam El. 709.8'

Head at normal pool in orifice
formula $Q = Ca\sqrt{2gh}$ 708-(696-0.67) 12.67'
$a = \pi D^2/4 = \pi * 1.33^2/4 = 1.39 ft^2$; $C = 0.7$
$Q = 0.7 * 1.39 * \sqrt{64.4 * 12.67} =$ 28 cfs

Q at low point on dam = 30 cfs

GEO-TECHNICAL SERVICES
Consulting Engineers & Geologists

JOB WIGWAM DAM PA 0990
SHEET NO — OF —
CALCULATED BY WEH DATE 3/21/81
CHECKED BY DATE
SCALE

DUE TO THE DOWNSTREAM HAZARD CONDITIONS & THE RESULTS OF THE OVERTOPPING ANALYSIS, A BREACH ANALYSIS WAS MADE.

THE DAM WAS CONSTRUCTED WITH A FULL DEPTH, 13" THICK CONCRETE CORE WALL AT THE ℄ OF THE EMBANKMENT. FOR A BREACH TO OCCUR, A PART OF THIS WALL MUST FAIL, WHICH WOULD HAPPEN IF THE DOWNSTREAM EARTH TOE WAS ERODED. THE WALL WOULD PROBABLY FAIL IN SECTIONS BETWEEN JOINTS. ASSUMING A MONOLITHIC LENGTH OF 30', ANALYZE THE DAM FOR BREACH WIDTHS OF 30', 60' & 90'. SINCE 1' OF OVERTOPPING MAY BE ENOUGH TO ERODE THE EARTH TOE, BEGIN BREACH FAILURE WHEN THE WATER SURFACE REACHES 1' OVER THE WALL = ELEV. 710.8. ASSUME THE BREACH WOULD BE FULL DEPTH TO STREAM BED = ELEV. 696.0, HAVE VERTICAL SIDE SLOPES, & OCCUR QUICKLY ≈ 15 MIN.

THE SPILLWAY DESIGN FLOOD SELECTED FOR THIS DAM IS 0.5 PMF WHICH CAUSES AN OVERTOPPING DEPTH OF 1.2'±

GEO-TECHNICAL SERVICES
Consulting Engineers & Geologists

JOB WIGWAM LAKE

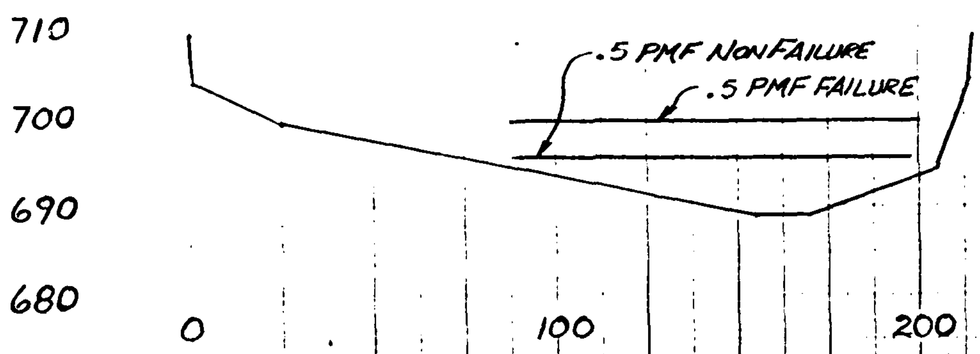
SHEET NO. ______ OF ______

CALCULATED BY ______ DATE ______

CHECKED BY ______ DATE ______

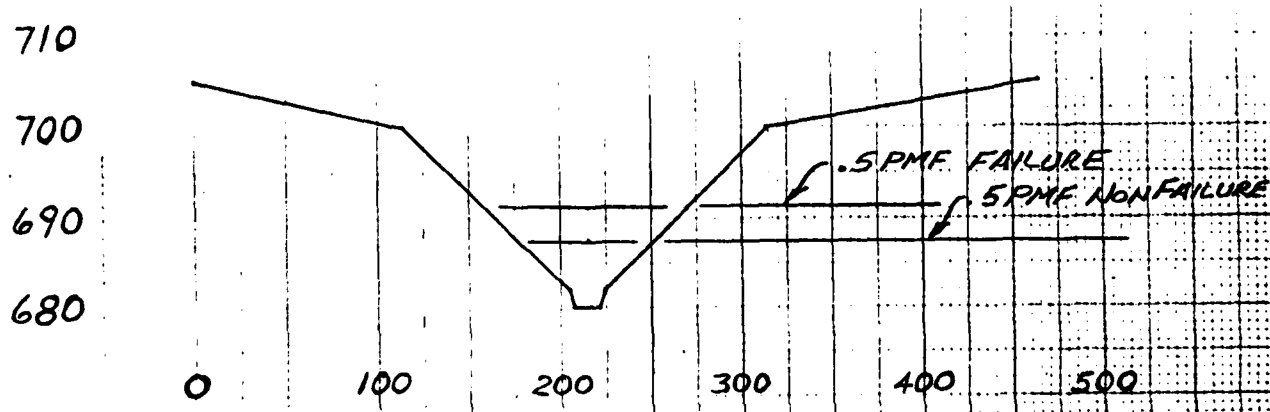
SCALE ______

TYPICAL CHANNEL SECTION 3 800' DOWN STREAM



7 HOUSES & 2 COMMERCIAL BLDGS.
3' TO 7' ABOVE STREAM BED

TYPICAL CHANNEL SECTION 4 2100' DOWN STREAM



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**********      *******************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
 LAST MODIFICATION  01 APR 80
**********************************
A1      NATIONAL DAM INSPECTION PROGRAM
A2      WIGWAM DAM--PA0990 (OVERTOPPING ANALYSIS)
A3      STROUD TWP, MONROE CO, PA
B     150       0      15       0       0       0       0       0      -4       0
B1      5       0       0       0       0       0       0       0       0       0
J       1       7       1       0       0       0       0       0       0       0
J1     .1      .2      .3      .4      .5     .75       1       0       0       0
K       0       1       0       0       0       0       1       0       0       0
K1      INFLOW TO RESERVOIR
M       1       1     1.5       0       0       0       0       0       1       0
P       0    21.8     111     123     133     142       0       0       0       0
T       0       0       0       0       0       0       1     .05       0       0
W     1.6     .45       0       0       0       0       0       0       0       0
X    -1.5    -.05       2       0       0       0       0       0       0       0
K       1       2       0       0       0       0       1       0       0       0
K1      ROUTE THRU RESERVOIR
Y       0       0       0       1       1       0       0       0       0       0
Y1      1       0       0       0       0       0    -706      -1       0       0
Y4    708  708.75  709.48  709.91  710.20  710.35  710.49  710.92  711.49  712.27
Y4713.04   713.56  713.67  714.06       0       0       0       0       0       0
Y5      0     116     331     495     616     680     747     961    1276    1778
Y5   2366    2808    2943    3521       0       0       0       0       0       0
SA      0       8     8.3     8.5    28.7       0       0       0       0       0
SE    696     708   709.8   711.1     720       0       0       0       0       0
SS    708       0       0       0       0       0       0       0       0       0
SD  709.8     2.7     1.5     196       0       0       0       0       0       0
K       1       3       0       0       0       0       1       0       0       0
K1      ROUTE TO STREAM SECTION AT STA 3
Y       0       0       0       1       1       0       0       0       0       0
Y1      1       0       0       0       0       0       0       0       0       0
Y6    .09     .09     .09     689     709     800   .0075       0       0       0
Y7      0     709       1     704      25     699     155     689     170     689
Y7    205     694     214     704     215     709       0       0       0       0
K       1       4       0       0       0       0       1       0       0       0
K1      ROUTE TO STREAM SECTION AT STA 4
Y       0       0       0       1       1       0       0       0       0       0
Y1      1       0       0       0       0       0       0       0       0       0
Y6    .06     .06     .06     680     705    1300   .0069       0       0       0
Y7      0     705     113     700     205     682     207     680     222     680
Y7    224     682     314     700     464     705       0       0       0       0
K      99       0       0       0       0       0       0       0       0       0
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*********** *******************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  01 APR 80
**********************************

RUN  DATE* 81/03/19.
     TIME* 09.07.33.

                         NATIONAL DAM INSPECTION PROGRAM
                         WIGWAM DAM--PA0990 (OVERTOPPING ANALYSIS)
                         STROUD TWP. MONROE CO. PA

                                         JOB SPECIFICATION
          NQ     NHR    NMIN    IDAY     IHR    IMIN  METRC    IPLT    IPRT   NSTAN
         150       0      15       0       0       0      0       0      -4       0
                                JOPER     NWT   LROPT  TRACE
                                    5       0       0      0

                               MULTI-PLAN ANALYSES TO BE PERFORMED
                                  NPLAN= 1 NRTIO= 7 LPTIO= 1
          RTIOS=     .10     .20     .30     .40     .50     .75    1.00

        **********        **********        **********        **********        **********

                                  SUB-AREA RUNOFF COMPUTATION

                    INFLOW TO RESERVOIR

                          ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                              1       0       0       0       0       0       1       0       0

                                         HYDROGRAPH DATA
          IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
              1       1    1.50    0.00    1.50    0.00   0.000       0       1       0

                                           PRECIP DATA
                     SPFE     PMS      R6     R12     R24     R48     R72     R96
                     0.00   21.80  111.00  123.00  133.00  142.00    0.00    0.00
TRSPC COMPUTED BY THE PROGRAM IS  .800

                                            LOSS DATA
       LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
           0    0.00    0.00    1.00    0.00    0.00    1.00    1.00     .05    0.00    0.00

                                      UNIT HYDROGRAPH DATA
                                  TP=  1.60     CP= .45     NTA=  0
```

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```
                                       RECESSION DATA
                        STRTQ=   -1.50    QRCSN=    -.05    RTIOR= 2.00

            UNIT HYDROGRAPH 58 END-OF-PERIOD ORDINATES, LAG=   1.59 HOURS, CP=  .45  VOL= 1.00
         15.       54.      110.      173.      228.      264.      274.      256.      234.      212.
        192.      174.      158.      143.      130.      117.      106.       96.       87.       79.
         72.       65.       59.       53.       46.       44.       40.       36.       33.       30.

         27.       24.       22.       20.       18.                 15.       13.       12.       11.
         10.        9.        8.        7.        7.         .        6.        5.        5.        4.
          4.        3.        3.        3.        3.        2.        2.        2.

      0                                        END-OF-PERIOD FLOW
  MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS   COMP Q      MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS    COMP Q

                                                                      SUM  24.76  22.38   2.39   81560.
                                                                         ( 629.)( 568.)(  61.)( 2309.52)

          **********        **********        **********        **********        **********

                                           HYDROGRAPH ROUTING

                    ROUTE THRU RESERVOIR

                          ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                              2       1       0       0       0       0       1       0       0
                                                   ROUTING DATA
                    QLOSS   CLOSS     AVG    IRES   ISAME    IOPT    IPMP            LSTR
                      0.0   0.000    0.00       1       1       0       0               0

                          NSTPS   NSTDL     LAG   AMSKK       X     TSK   STORA  ISPRAT
                              1       0       0   0.000   0.000   0.000   -708.      -1

    STAGE       708.00     708.75     709.48     709.91     710.20     710.35     710.49     710.92     711.49     712.27
                713.04     713.56     713.67     714.06

     FLOW         0.00     116.00     331.00     495.00     616.00     680.00     747.00     961.00    1276.00    1778.00
               2366.00    2808.00    2943.00    3521.00

  SURFACE AREA=      0.        8.        8.        9.       29.

      CAPACITY=      0.       32.       47.       58.      214.

     ELEVATION=    696.      708.      710.      711.      720.

                      CREL   SPWID    COQW    EXPW   ELEVL    COQL   CAREA    EXPL
                     708.0     0.0     0.0     0.0     0.0     0.0     0.0     0.0
```

DAM DATA

TOPEL	COQD	EXPD	DAMWID
709.8	2.7	1.5	196.

PEAK OUTFLOW IS 324. AT TIME 41.75 HOURS

PEAK OUTFLOW IS 664. AT TIME 41.50 HOURS

PEAK OUTFLOW IS 996. AT TIME 41.50 HOURS

PEAK OUTFLOW IS 1328. AT TIME 41.50 HOURS

PEAK OUTFLOW IS 1661. AT TIME 41.25 HOURS

PEAK OUTFLOW IS 2492. AT TIME 41.25 HOURS

PEAK OUTFLOW IS 3323. AT TIME 41.25 HOURS

********** ********** ********** ********** **********

HYDROGRAPH ROUTING

ROUTE TO STREAM SECTION AT STA 3

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
3	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
0.0	0.000	0.00	1	1	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.000	0.000	0.000	0.	0

NORMAL DEPTH CHANNEL ROUTING

QN(1)	QN(2)	QN(3)	ELNVT	ELMAX	RLNTH	SEL
.0900	.0900	.0900	689.0	709.0	800.	.00750

CROSS SECTION COORDINATES--STA,ELEV,STA,ELEV--ETC

0.00	709.00	1.00	704.00	25.00	699.00	155.00	689.00	170.00	689.00		
205.00	694.00	214.00	704.00	215.00	709.00						

STORAGE	0.00	.49	1.39	2.70	4.42	6.53	8.97	11.69	14.69	17.97
	21.52	25.20	29.00	32.91	36.94	41.06	45.19	49.33	53.47	57.62
OUTFLOW	0.00	31.60	131.20	320.52	620.08	1058.44	1665.13	2416.78	3321.63	4398.15
	5751.12	7420.43	9271.39	11303.43	13516.22	15921.58	18497.66	21231.64	24117.34	27149.60
STAGE	689.00	690.05	691.11	692.16	693.21	694.26	695.32	696.37	697.42	698.47
	699.53	700.58	701.63	702.68	703.74	704.79	705.84	706.89	707.95	709.00
FLOW	0.00	31.60	131.20	320.52	620.08	1058.44	1665.13	2416.78	3321.63	4398.15
	5751.12	7420.43	9271.39	11303.43	13516.22	15921.58	18497.66	21231.64	24117.34	27149.60

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MAXIMUM STAGE IS 692.2

MAXIMUM STAGE IS 693.3

MAXIMUM STAGE IS 694.1

MAXIMUM STAGE IS 694.7

MAXIMUM ST. IS 695.[illegible]

MAXIMUM STAGE IS 696.5

MAXIMUM STAGE IS 697.4

********** ********** ********** ********** **********

HYDROGRAPH ROUTING

ROUTE TO STREAM SECTION AT STA 4

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
4	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
0.0	0.000	0.00	1	1	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.000	0.000	0.000	0.	0

NORMAL DEPTH CHANNEL ROUTING

QN(1)	QN(2)	QN(3)	ELNVT	ELMAX	RLNTH	SEL
.0600	.0600	.0600	680.0	705.0	1300.	.00690

CROSS SECTION COORDINATES--STA,ELEV,STA,ELEV--ETC
0.00 705.00 113.00 700.00 205.00 682.00 207.00 680.00 222.00 680.00
224.00 682.00 314.00 700.00 464.00 705.00

STORAGE	0.00	.64	1.43	2.69	4.47	6.77	9.60	12.95	16.62	21.21
	26.13	31.56	37.52	44.01	51.01	58.54	67.29	78.72	92.86	109.72
OUTFLOW	0.00	48.52	163.72	371.92	703.43	1186.07	1844.64	2702.11	3780.04	5098.95
	6678.48	8537.53	10694.38	13166.74	15971.82	19126.40	20829.87	23467.42	27337.89	32384.81
STAGE	680.00	681.32	682.63	683.95	685.26	686.58	687.89	689.21	690.53	691.84
	693.16	694.47	695.79	697.11	698.42	699.74	701.05	702.37	703.68	705.00
FLOW	0.00	48.52	163.72	371.92	703.43	1186.07	1844.64	2702.11	3780.04	5098.95
	6678.48	8537.53	10694.38	13166.74	15971.82	19126.40	20829.87	23467.42	27337.89	32384.81

MAXIMUM STAGE IS 683.6

MAXIMUM STAGE IS 685.1

MAXIMUM STAGE IS 686.1

MAXIMUM STAGE IS 686.9

MAXIMUM STAGE IS 687.5

MAXIMUM ST IS 688.9

MAXIMUM STAGE IS 690.0

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIO 1 .10	RATIO 2 .20	RATIO 3 .30	RATIO 4 .40	RATIO 5 .50	RATIO 6 .75	RATIO 7 1.00
HYDROGRAPH AT	1	1.50	1	334.	667.	1001.	1335.	1668.	2503.	3337.
	(	3.88)	(	9.45)(	18.90)(	28.35)(	37.79)(	47.24)(	70.87)(	94.49)(
ROUTED TO	2	1.50	1	324.	664.	996.	1328.	1661.	2492.	3323.
	(	3.88)	(	9.18)(	18.80)(	28.21)(	37.62)(	47.02)(	70.57)(	94.09)(
ROUTED TO	3	1.50	1	325.	664.	998.	1331.	1664.	2495.	3327.
	(	3.88)	(	9.19)(	18.80)(	28.26)(	37.69)(	47.12)(	70.65)(	94.21)(
ROUTED TO	4	1.50	1	324.	663.	998.	1332.	1665.	2498.	3331.
	(	3.88)	(	9.16)(	18.78)(	28.25)(	37.71)(	47.15)(	70.74)(	94.33)(

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SUMMARY OF DAM [illegible]TY ANALYSIS

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	708.00	708.00	709.80
STORAGE	32.	32.	47.
OUTFLOW	0.	0.	453.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.10	709.46	0.00	44.	324.	0.00	41.75	0.00
.20	710.10	.30	49.	664.	3.25	41.50	0.00
.30	710.44	.64	52.	996.	5.25	41.50	0.00
.40	710.72	.92	54.	1328.	6.75	41.50	0.00
.50	710.97	1.17	56.	1661.	7.75	41.25	0.00
.75	711.52	1.72	61.	2492.	9.75	41.25	0.00
1.00	712.00	2.20	66.	3323.	10.75	41.25	0.00

PLAN 1 STATION 3

RATIO	MAXIMUM FLOW,CFS	MAXIMUM STAGE,FT	TIME HOURS
.10	325.	692.2	41.75
.20	664.	693.3	41.50
.30	998.	694.1	41.50
.40	1331.	694.7	41.50
.50	1664.	695.3	41.50
.75	2495.	696.5	41.50
1.00	3327.	697.4	41.50

PLAN 1 STATION 4

RATIO	MAXIMUM FLOW,CFS	MAXIMUM STAGE,FT	TIME HOURS
.10	324.	683.6	41.75
.20	663.	685.1	41.50
.30	998.	686.1	41.50
.40	1332.	686.9	41.50
.50	1665.	687.5	41.50
.75	2498.	688.9	41.50
1.00	3331.	690.0	41.50

```
**********************************
A1      NATIONAL DAM INSPECTION ' 'GRAM
A2      WIGWAM DAM--PA0990 (BREA   ANALYSIS)
A3      STROUD TWP, MONROE CO, PA
B     150       0      15       0       0       0       0       0      -4       0
B1      5       0       0       0       0       0       0       0       0       0
J       3       1       1       0       0       0       0       0       0       0
J1     .5       0       0       0       0       0       0       0       0       0
K       0       1       0       0       0       0       1       0       0       0
K1      INFLOW TO RESERVOIR
M       1       1     1.5       0       0       0       0       0       1       0
P       0    21.8     111     123     133     142       0       0       0       0
T       0       0       0       0       0       0       1     .05       0       0
W     1.6     .45       0       0       0       0       0       0       0       0
X    -1.5    -.05       2       0       0       0       0       0       0       0
K       1       2       0       0       0       0       1       0       0       0
K1      ROUTE THRU RESERVOIR
Y       0       0       0       1       1       0       0       0       0       0
Y1      1       0       0       0       0       0    -708      -1       0       0
Y4    708  708.75  709.48  709.91  710.20  710.35  710.49  710.92  711.49  712.27
Y4713.04   713.56  713.67  714.06       0       0       0       0       0       0
Y5      0     116     331     495     616     680     747     961    1276    1778
Y5   2366    2808    2943    3521       0       0       0       0       0       0
$A      0       8     8.3     8.5    28.7       0       0       0       0       0
$E    696     708   709.8   711.1     720       0       0       0       0       0
$$    708       0       0       0       0       0       0       0       0       0
$D 709.8      2.7     1.5     196       0       0       0       0       0       0
$B     30       0     696     .25     708   710.8       0       0       0       0
$B     60       0     696     .25     708   710.8       0       0       0       0
$B     90       0     696     .25     708   710.8       0       0       0       0
K       1       3       0       0       0       0       1       0       0       0
K1      ROUTE TO STREAM SECTION AT STA 3
Y       0       0       0       1       1       0       0       0       0       0
Y1      1       0       0       0       0       0       0       0       0       0
Y6    .09     .09     .09     689     709     800   .0075       0       0       0
Y7      0     709       1     704      25     699     155     689     170     689
Y7    205     694     214     704     215     709       0       0       0       0
K       1       4       0       0       0       0       1       0       0       0
K1      ROUTE TO STREAM SECTION AT STA 4
Y       0       0       0       1       1       0       0       0       0       0
Y1      1       0       0       0       0       0       0       0       0       0
Y6    .06     .06     .06     680     705    1300   .0069       0       0       0
Y7      0     705     113     700     205     682     207     680     222     680
Y7    224     682     314     700     464     705       0       0       0       0
K      99       0       0       0       0       0       0       0       0       0
1              PREVIEW OF SEQUENCE OF STREAM NETWORK CALCULATIONS

                    RUNOFF HYDROGRAPH AT          1
                    ROUTE HYDROGRAPH TO           2
                    ROUTE HYDROGRAPH TO           3
                    ROUTE HYDROGRAPH TO           4
                    END OF NETWORK
```

D-20

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1***********************************
 FLOOD HYDROGRAPH PACKAGE (HEC-1)
 DAM SAFETY VERSION      JULY 1978
   LAST MODIFICATION  01 APR 80
 ***********************************

 RUN  DATE* 81/04/08.
      TIME* 11 11 58

                          NATIONAL DAM INSPECTION PR   AM
                          WIGWAM DAM--PA0990 (BREACH ANALYSIS)
                          STROUD TWP, MONROE CO, PA

                                  JOB SPECIFICATION
          NQ     NHR    NMIN    IDAY    IHR    IMIN   METRC    IPLT    IPRT   NSTAN
         150       0      15       0      0       0       0       0      -4       0
                                JOPER    NWT   LROPT   TRACE
                                    5      0       0       0

                               MULTI-PLAN ANALYSES TO BE PERFORMED
                                  NPLAN= 3 NRTIO= 1 LRTIO= 1
          RTIOS=    .50

     **********       **********       **********       **********       **********

                               SUB-AREA RUNOFF COMPUTATION

          INFLOW TO RESERVOIR

                  ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                      1       0       0       0       0       0       1       0       0

                                     HYDROGRAPH DATA
          IHYDG    IUHG   TAREA    SNAP   TRSDA   TRSPC   RATIO   ISNOW   ISAME   LOCAL
              1       1    1.50    0.00    1.50    0.00   0.000       0       1       0

                                       PRECIP DATA
                  SPFE     PMS      R6     R12     R24     R48     R72     R96
                  0.00   21.80  111.00  123.00  133.00  142.00    0.00    0.00
 TRSPC COMPUTED BY THE PROGRAM IS  .800

                                        LOSS DATA
      LROPT   STRKR   DLTKR   RTIOL   ERAIN   STRKS   RTIOK   STRTL   CNSTL   ALSMX   RTIMP
          0    0.00    0.00    1.00    0.00    0.00    1.00    1.00     .05    0.00    0.00

                                   UNIT HYDROGRAPH DATA
                             TP=  1.60     CP= .45     NTA=  0

                                      RECESSION DATA
                    STRTQ=    -1.50     QRCSN=    -.05    RTIOR= 2.00

       UNIT HYDROGRAPH 58 END-OF-PERIOD ORDINATES, LAG=   1.59 HOURS, CP=  .45  VOL= 1.00
     15.       54.      110.      173.      228.      264.      274.      258.      234.      212.
    192.      174.      158.      143.      130.      117.      106.       96.       87.       79.
     72.       65.       59.       53.       48.       44.       40.       36.       33.       30.
     27.       24.       22.       20.       18.       16.       15.       13.       12.       11.
     10.        9.        8.        7.        7.        6.        6.        5.        5.        4.
      4.        3.        3.        3.        3.        2.        2.        2.

                               END-OF-PERIOD FLOW
 MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS   COMP Q     MO.DA  HR.MN  PERIOD   RAIN   EXCS   LOSS    COMP Q

                                                                    SUM  24.76  22.38   2.39    81560.
                                                                       ( 629.)( 568.)(  61.)( 2309.52)
```

********** ********** ********** ********** **********

HYDROGRAPH ROUTING

ROUTE THRU RESERVOIR

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
2	1	0	0	0	0	1	0	0

ALL PLANS HAVE SAME
ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP		LSTR
0.0	0.000	0.00	1	1	0	0		0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.000	0.000	0.000	-708.	-1

STAGE	708.00	708.75	709.48	709.91	710.20	710.35	710.49	710.92	711.49	712.27
	713.04	713.56	713.67	714.06						
FLOW	0.00	116.00	331.00	495.00	616.00	680.00	747.00	961.00	1276.00	1778.00
	2366.00	2808.00	2943.00	3521.00						

SURFACE AREA=	0.	8.	8.	9.	29.
CAPACITY=	0.	32.	47.	58.	214.
ELEVATION=	696.	708.	710.	711.	720.

CREL	SPWID	COQW	EXPW	ELEVL	COQL	CAREA	EXPL
708.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAM DATA

TOPEL	COQD	EXPD	DAMWID
709.8	2.7	1.5	196.

DAM BREACH DATA

BRWID	Z	ELBM	TFAIL	WSEL	FAILEL
30.	0.00	696.00	.25	708.00	710.80

BEGIN DAM FAILURE AT 40.75 HOURS

PEAK OUTFLOW IS 4331. AT TIME 41.00 HOURS

DAM BREACH DATA

BRWID	Z	ELBM	TFAIL	WSEL	FAILEL
60.	0.00	696.00	.25	708.00	710.80

BEGIN DAM FAILURE AT 40.75 HOURS

PEAK OUTFLOW IS 6325. AT TIME 41.00 HOURS

```
                                          DAM BREACH DATA
                          BRWID      Z     ELBM    TFAIL    WSEL   FAILEL
                            90.    0.00  696.00     .25   708.00   710.80

BEGIN DAM FAILURE AT 40.75 HOURS

PEAK OUTFLOW IS     6734. AT TIME  40.99 HOURS

          **********        **********        *********        **********        **********

                                    HYDROGRAPH ROUTING

               ROUTE TO STREAM SECTION AT STA 3

                   ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                       3       1       0       0       0       0       1       0       0

                                    ALL PLANS HAVE SAME
                                       ROUTING DATA
           QLOSS   CLOSS     AVG    IRES   ISAME    IOPT    IPMP            LSTR
             0.0   0.000    0.00       1       1       0       0               0

                   NSTPS   NSTDL     LAG   AMSKK       X     TSK   STORA  ISPRAT
                       1       0       0   0.000   0.000   0.000      0.       0

NORMAL DEPTH CHANNEL ROUTING
----------------------------

          QN(1)   QN(2)   QN(3)   ELNVT   ELMAX   RLNTH     SEL
          .0900   .0900   .0900   689.0   709.0    800.  .00750

          CROSS SECTION COORDINATES--STA,ELEV,STA,ELEV--ETC
            0.00  709.00    1.00  704.00   25.00  699.00  155.00  689.00  170.00  689.00
          205.00  694.00  214.00  704.00  215.00  709.00

STORAGE       0.00      0.49      1.39      2.70      4.42      6.53      8.97     11.69     14.69     17.97
             21.52     25.20     29.00     32.91     36.94     41.06     45.19     49.33     53.47     57.62

OUTFLOW       0.00     31.60    131.20    320.52    620.08   1058.44   1665.13   2416.78   3321.63   4388.15
           5751.12   7420.43   9271.39  11303.43  13516.22  15921.58  18497.66  21231.64  24117.34  27149.60

 STAGE      689.00    690.05    691.11    692.16    693.21    694.26    695.32    696.37    697.42    698.47
            699.53    700.58    701.63    702.68    703.74    704.79    705.84    706.89    707.95    709.00

  FLOW        0.00     31.60    131.20    320.52    620.08   1058.44   1665.13   2416.78   3321.63   4388.15
           5751.12   7420.43   9271.39  11303.43  13516.22  15921.58  18497.66  21231.64  24117.34  27149.60

MAXIMUM STAGE IS     697.7

MAXIMUM STAGE IS     699.1

MAXIMUM STAGE IS     699.2

          **********        **********        **********
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**********          **********          **********          **********          **********

                                 HYDROGRAPH ROUTING

                 ROUTE TO STREAM SECTION AT STA 4
                       ISTAQ   ICOMP   IECON   ITAPE    JPLT    JPRT   INAME  ISTAGE   IAUTO
                           4       1       0       0       0       0       1       0       0

                                 ALL PLANS HAVE SAME
                                     ROUTING DATA
                 QLOSS   CLOSS     AVG    IRES   ISAME    IOPT    IPMP            LSTR
                   0.0   0.000    0.00       1       1       0       0               0

                       NSTPS   NSTDL     LAG   AMSKK       X     TSK   STORA  ISPRAT
                           1       0       0   0.000   0.000   0.000      0.       0


NORMAL DEPTH CHANNEL ROUTING
----------------------------

          QN(1)   QN(2)   QN(3)   ELNVT   ELMAX   RLNTH     SEL
          .0600   .0600   .0600   680.0   705.0   1300.  .00690

           CROSS SECTION COORDINATES--STA,ELEV,STA,EL--ETC
               0.00  705.00  113.00  700.00  205.00     .00  207.00  680.00  222.00  680.00
             224.00  682.00  314.00  700.00  464.00  705.00


STORAGE       0.00       .64      1.43      2.69      4.47      6.77      9.60     12.95     16.82     21.21
             26.13     31.56     37.52     44.01     51.01     58.54     67.29     78.72     92.86    109.72

OUTFLOW       0.00     48.52    163.72    371.92    703.43   1186.07   1844.64   2703.11   3780.04   5098.95
           6678.48   8537.53  10694.38  13166.74  15971.82  19126.40  20829.87  23467.42  27337.89  32384.81

  STAGE     680.00    681.32    682.63    683.95    685.26    686.58    687.89    689.21    690.53    691.84
            693.16    694.47    695.79    697.11    698.42    699.74    701.05    702.37    703.68    705.00

   FLOW       0.00     48.52    163.72    371.92    703.43   1186.07   1844.64   2702.11   3780.04   5098.95
           6678.48   8537.53  10694.38  13166.74  15971.82  19126.40  20829.87  23467.42  27337.89  32384.81

  MAXIMUM STAGE IS      690.1

  MAXIMUM STAGE IS      691.0

  MAXIMUM STAGE IS      691.1

          **********          **********          **********          **********          **********
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****

1

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

RATIOS APPLIED TO FLOWS

OPERATION	STATION	AREA	PLAN	RATIO 1 .50
HYDROGRAPH AT	1	1.50	1	1668.
	(	3.88)	(	47.24)(
			2	1668.
			(	47.24)(
			3	1668.
			(	47.24)(
ROUTED TO	2	1.50	1	4331.
	(	3.88)	(	122.63)(
			2	6325.
			(	179.10)(
			3	6449.
			(	182.62)(
ROUTED TO	3	1.50	1	3631.
	(	3.88)	(	102.82)(
			2	5196.
			(	147.14)(
			3	5295.
			(	149.95)(
ROUTED TO	4	1.50	1	3469.
	(	3.88)	(	98.22)(
			2	4280.
			(	121.19)(
			3	4346.
			(	123.07)(

1

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	708.00	708.00	709.80
STORAGE	32.	32.	47.
OUTFLOW	0.	0.	453.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.50	710.84	1.04	55.	4331.	2.70	41.00	40.75

PLAN 2 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	708.00	708.00	709.80
STORAGE	32.	32.	47.
OUTFLOW	0.	0.	453.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.50	710.84	1.04	55.	6325.	2.66	41.00	40.75

PLAN 3 ....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	708.00	708.00	709.80
STORAGE	32.	32.	47.
OUTFLOW	0.	0.	453.

RATIO OF PMF	MAXIMUM RESERVOIR W.S.ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
.50	710.84	1.04	55.	6734.	2.64	40.99	40.75

PLAN 1 STATION 3

RATIO	MAXIMUM FLOW,CFS	MAXIMUM STAGE,FT	TIME HOURS
.50	3631.	697.7	41.00

PLAN 2 STATION 3

RATIO	MAXIMUM FLOW,CFS	MAXIMUM STAGE,FT	TIME HOURS
.50	5196.	699.1	41.00

PLAN 3 STATION 3

RATIO	MAXIMUM FLOW,CFS	MAXIMUM STAGE,FT	TIME HOURS
.50	5295.	699.2	41.00

PLAN 1 STATION 4

RATIO	MAXIMUM FLOW,CFS	MAXIMUM STAGE,FT	TIMF HOURS
.50	3469.	690.1	41.25

PLAN 2 STATION 4

RATIO	MAXIMUM FLOW,CFS	MAXIMUM STAGE,FT	TIME HOURS
.50	4280.	691.0	41.25

PLAN 3 STATION 4

RATIO	MAXIMUM FLOW,CFS	MAXIMUM STAGE,FT	TIME HOURS
.50	4346.	691.1	41.25

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1***********************************
 FLOOD HYDROGRAPH PACKAGE (HEC-1)
 DAM SAFETY VERSION      JULY 1978
   LAST MODIFICATION  01 APR 80
 ***********************************
 EOI ENCOUNTERED.
N]
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APPENDIX E

EXHIBITS

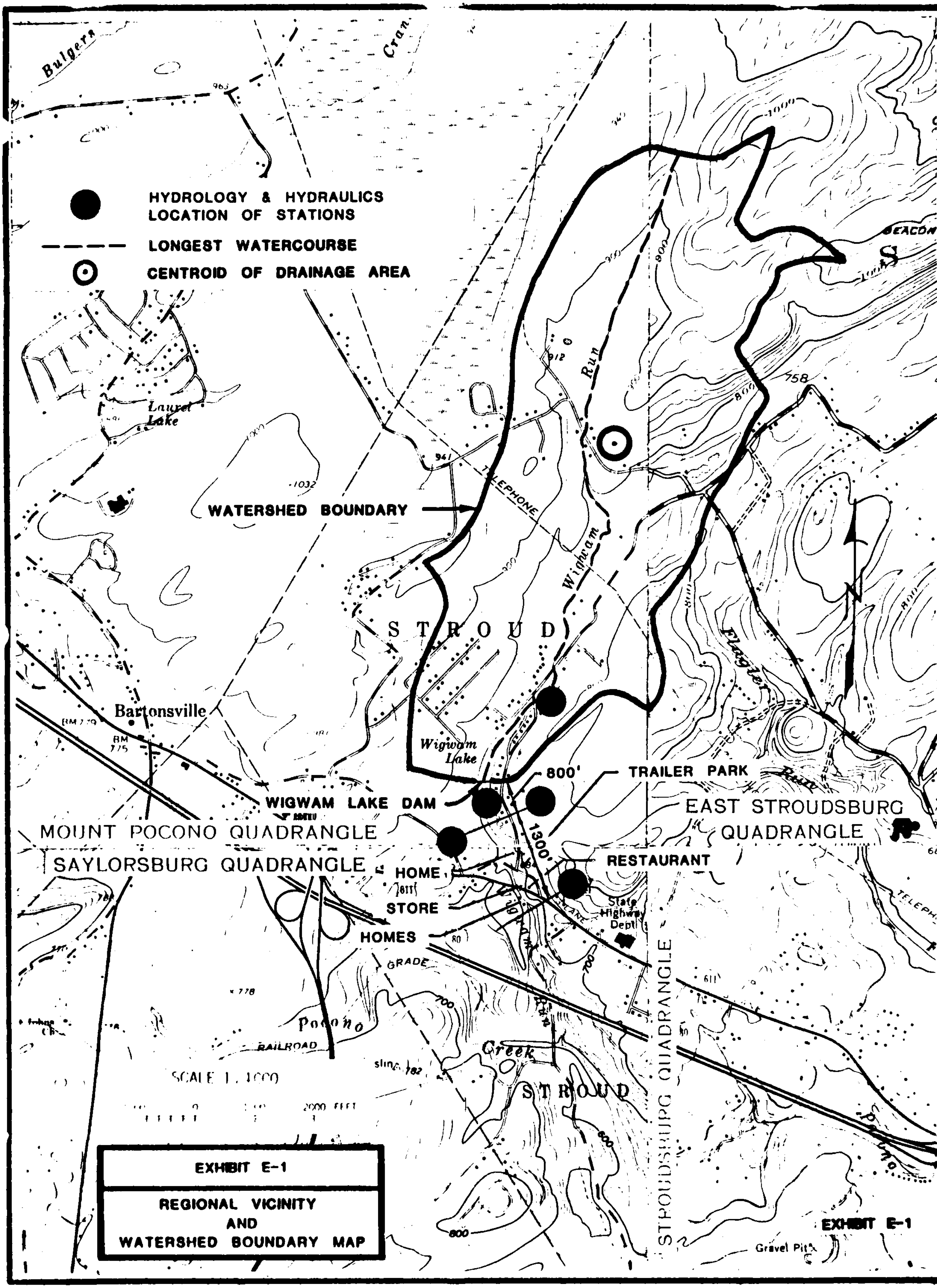
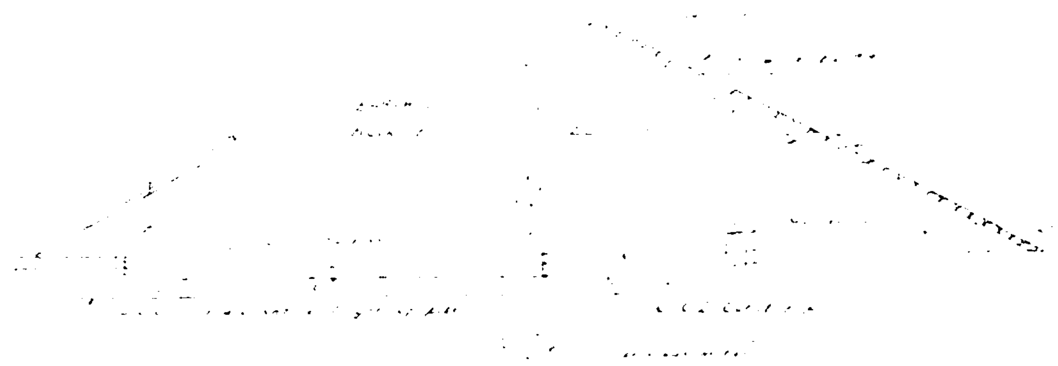
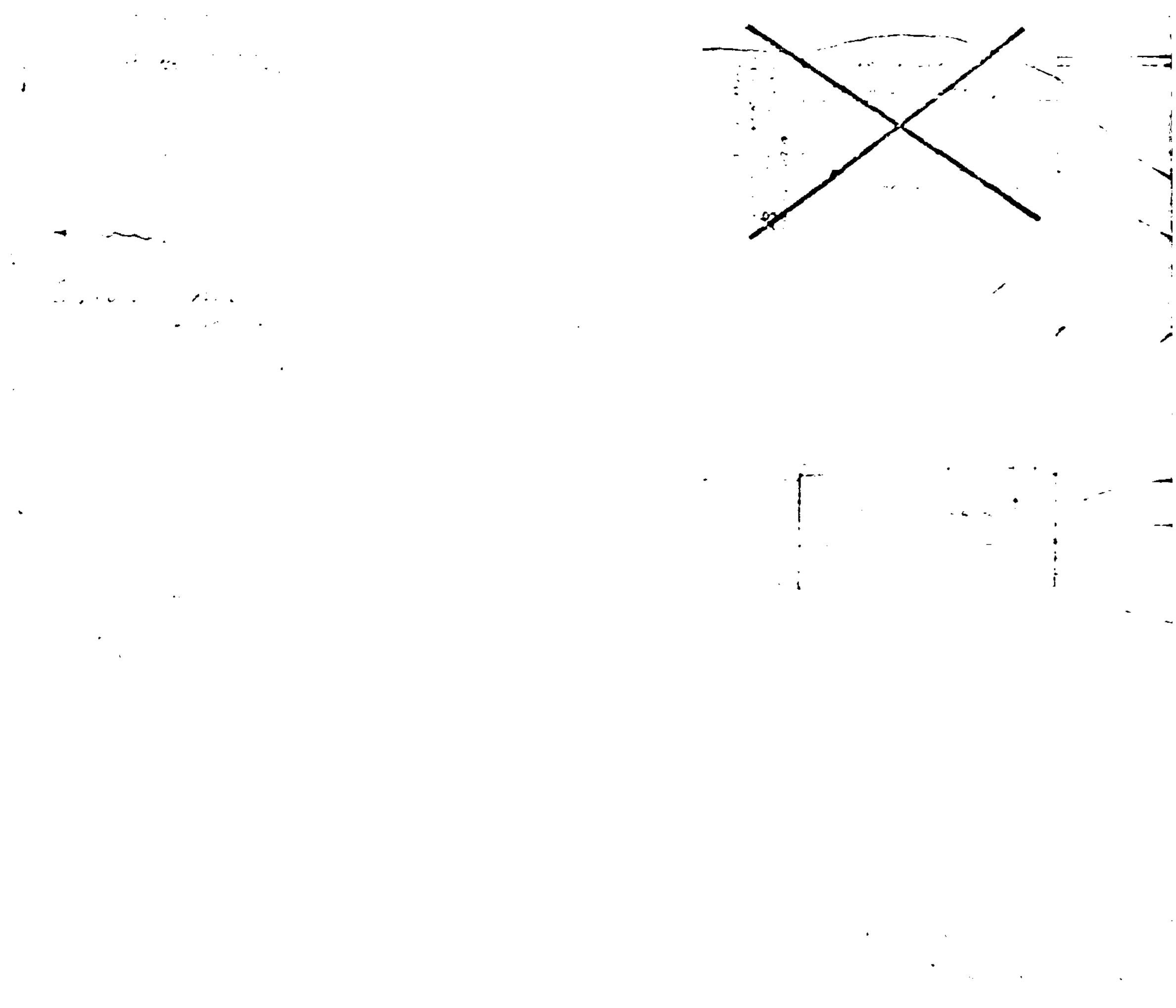


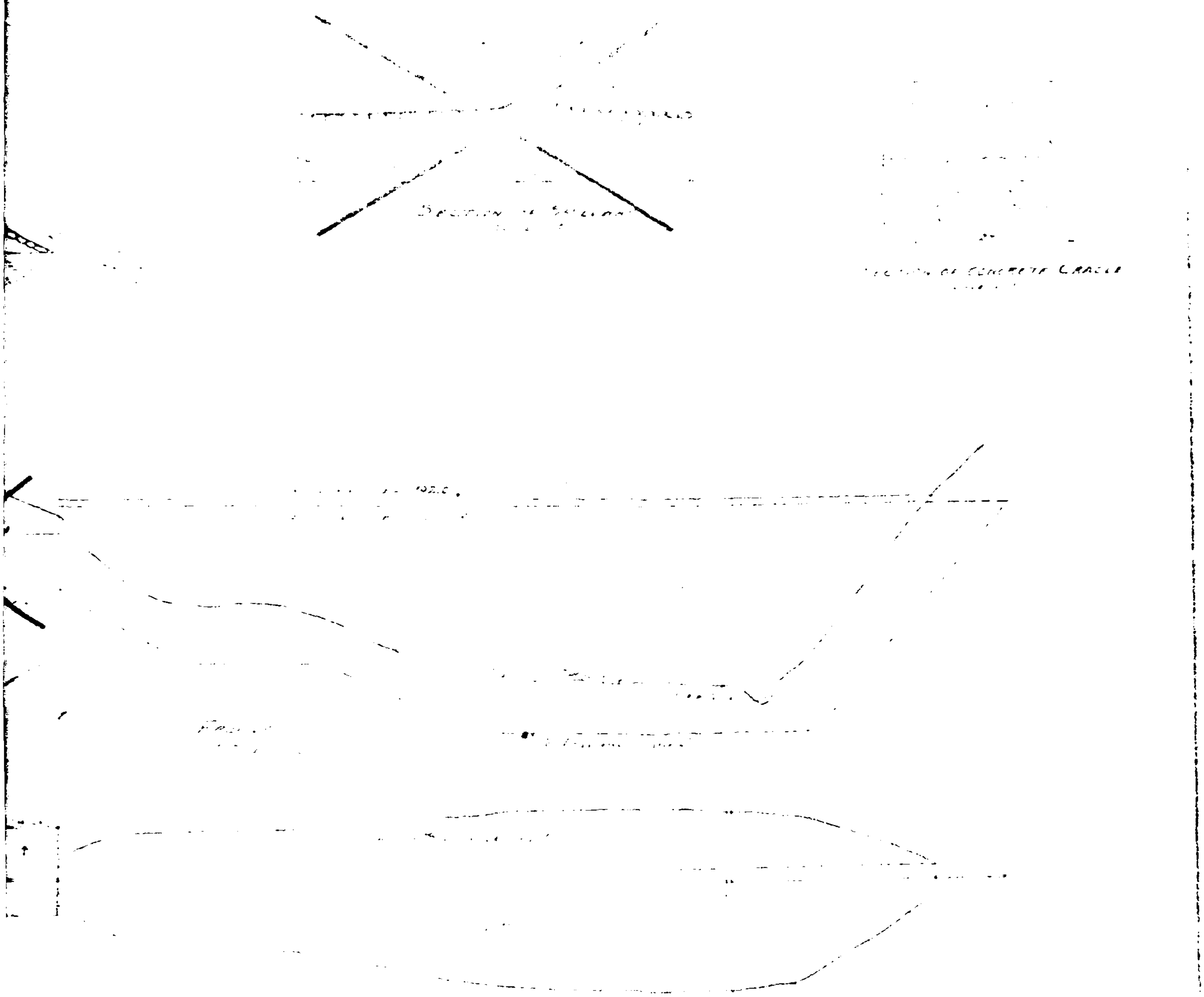
EXHIBIT E-1

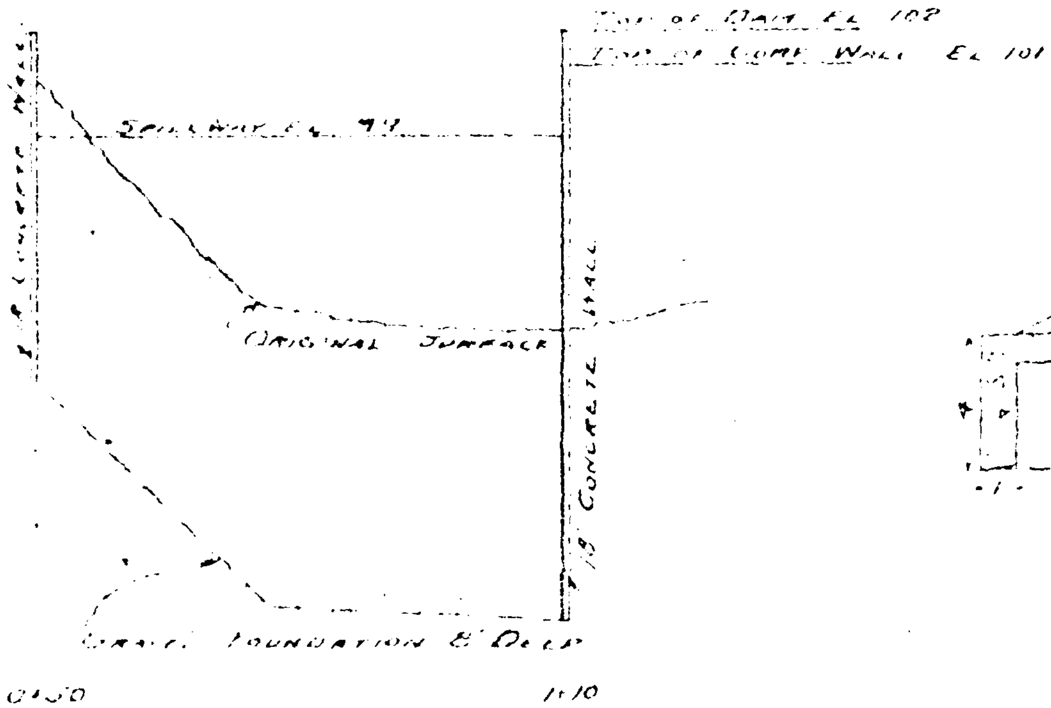
REGIONAL VICINITY AND WATERSHED BOUNDARY MAP



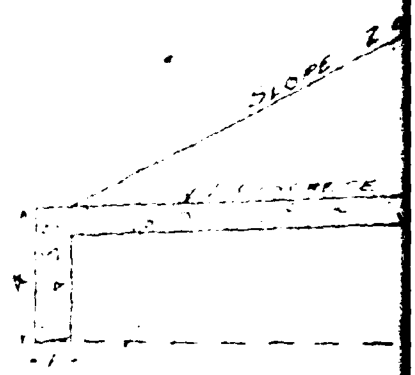
MAXIMUM SECTION



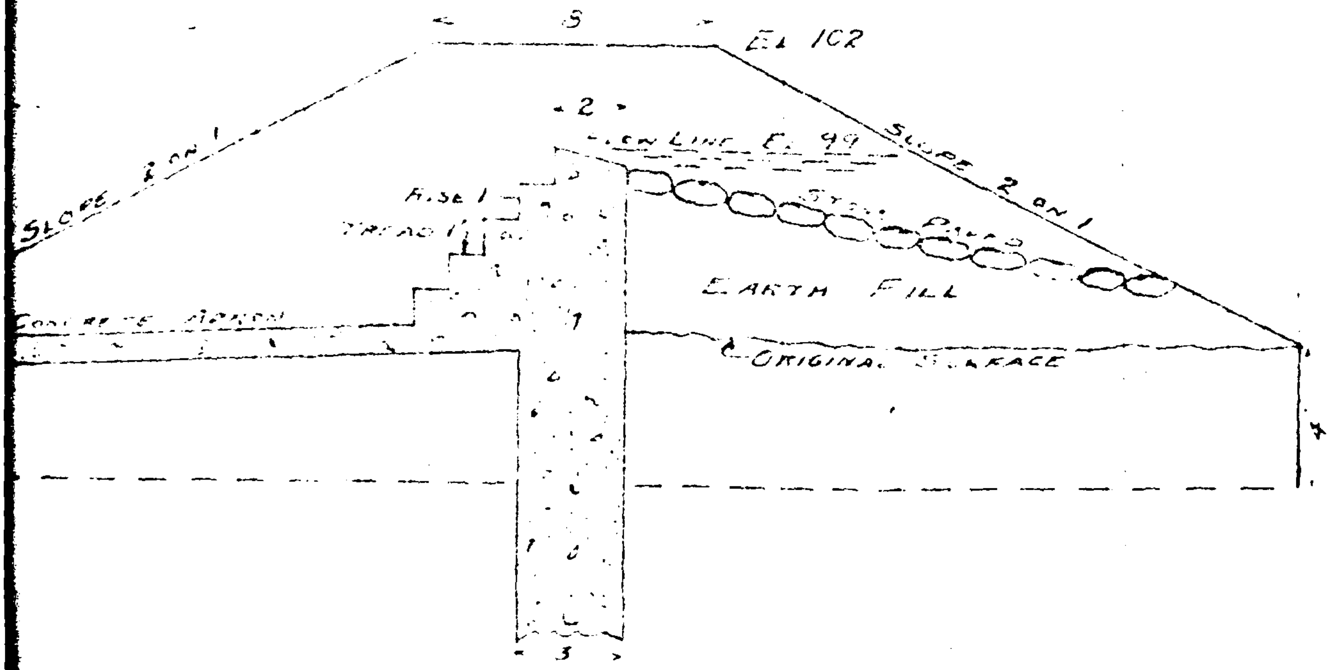

CONCRETE CRADLE



PROFILE OF SPILLWAY
Scale H 1 20
V 1 5



SE



SECTION OF SPILLWAY

REVISED PLAN OF SPILLWAY

[illegible] DAM OF

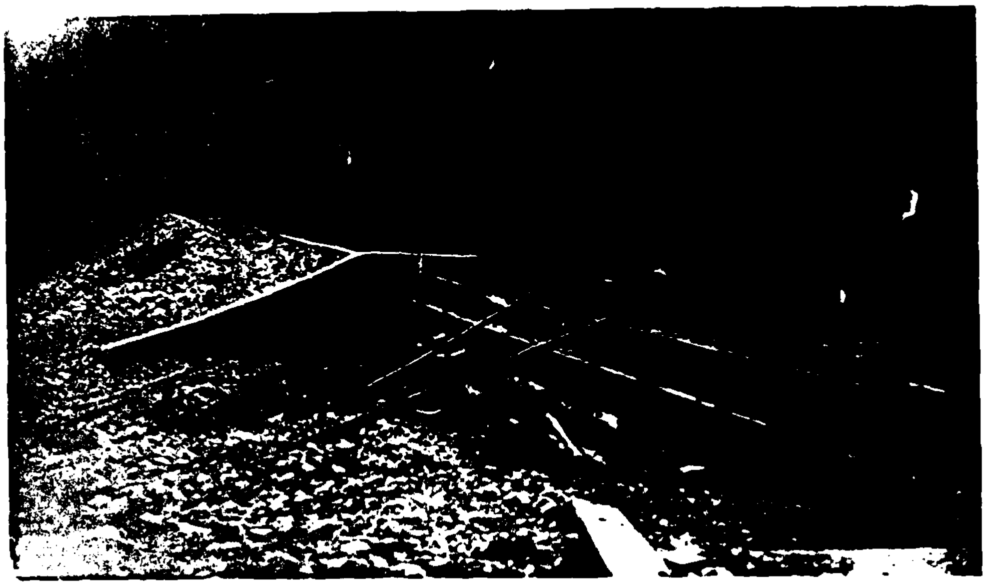
JOHN [illegible]

[illegible] STROUD TOWNSHIP

MONROE COUNTY, PA

EXCAVATION OF CUTOFF TRENCH (6/24/1927)

VIEW OF UPSTREAM FACE, DURING CONSTRUCTION (7/26/1927)

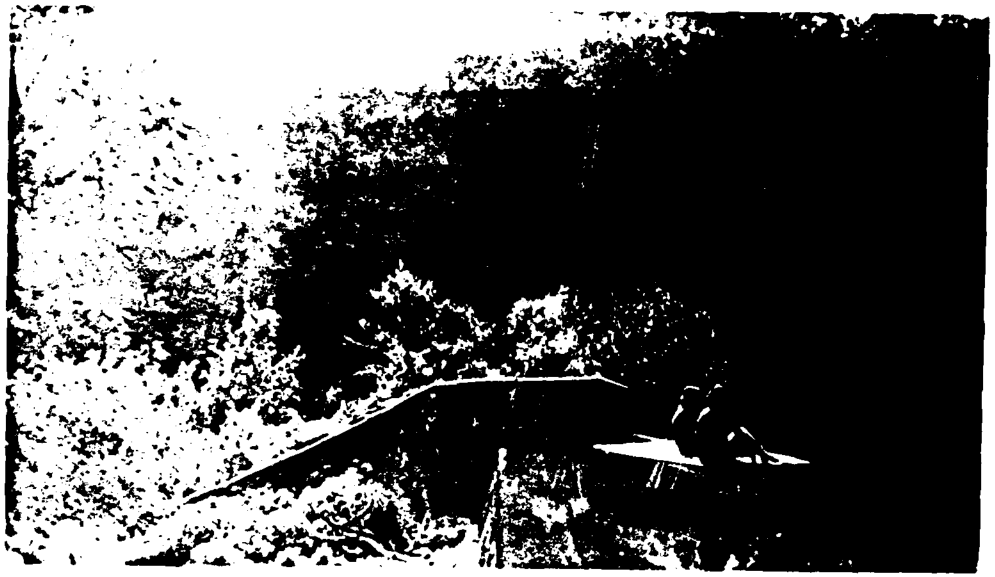


DOWNSTREAM FACE OF DAM AND SPILLWAY (3/29/1928)

(NOTE FLASHBOARDS IN SPILLWAY AND THAT CREST OF DAM LOWER THAN TOP OF ENDWALL)

SPILLWAY ENDWALL AND UPSTREAM FACE OF DAM LOOKING TOWARD RIGHT ABUTMENT (12/13/1928)

(NOTE ROCK PROTECTION ON UPSTREAM FACE)



LOOKING TOWARD RIGHT ABUTMENT

CONDITION ON 6/20/1938

APPENDIX F

GEOLOGY

WIGWAM LAKE DAM

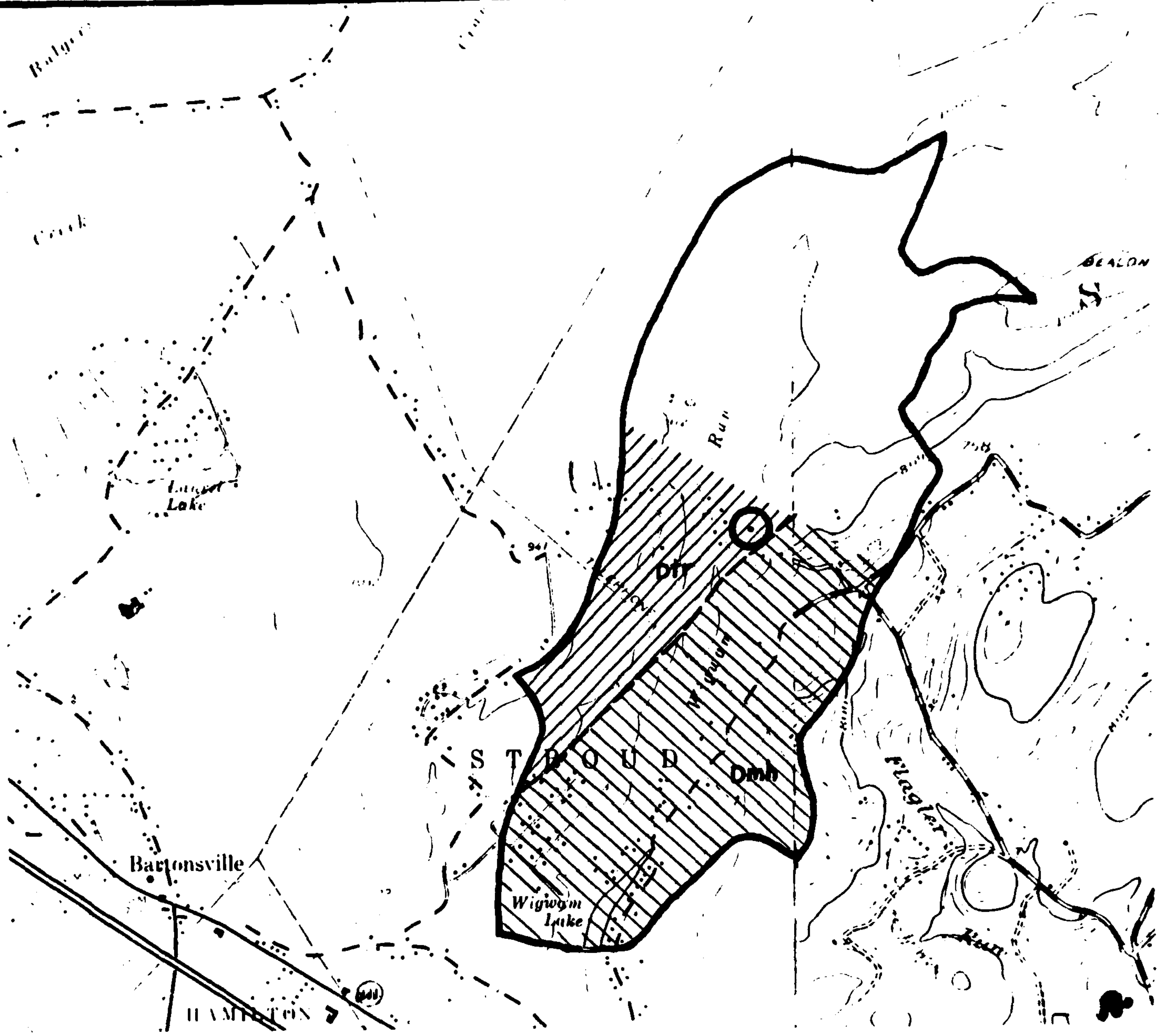
APPENDIX F

GEOLOGY

The Wigwam Lake Dam is located within the glacial low plateaus section of the Appalachian Plateaus Province of east-central Monroe County, Pennsylvania. The bedrock unit present at the dam site is the Mahantango Formation of Middle Devonian age. The soils present downstream and on the eastern side of the reservoir are derived from alluvium and ice contact, stratified drift. The bulk of this stratified material was originally deposited during the stagnation and melting phase of the Woodfordian Glacier in contact with a melting ice lobe south of Camelback Mountain.

The Mahantango Formation is present along the stream valley west of the dam and reservoir. The bedrock outcrops on the right abutment and is comprised of a dark-gray siltstone and silty shale. It displays a well-developed cleavage which has a near-vertical dip striking parallel to the dam centerline. Bedding dips to the northwest at 18^{o} to 20^{o}.

The alluvian and woodfordian ice contact stratified drift are undifferentiated and take the form of subtle sheetlike deposits and terrace filled valley deposits, such as in the Wigwam Run Valley. This material is stratified, unconsolidated sand and gravel with some boulders. The thickness of this material is measured to be 17 feet in a water well along the Wigwam Valley. This material surrounds the reservoir upstream, downstream, on the eastern shore dam abutment and the reservoir bottom.



LEGEND

MIDDLE DEVONIAN

Dtr — Trimmers Formation

Dmh — Mahantango Formation

NOTE:

GEOLOGIC MAP AND LEGEND OBTAINED FROM OPEN FILE MAP OF PENNSYLVANIA BY PA. TOPOGRAPHIC AND GEOLOGIC SURVEY, DATED 1980

PHASE 1 INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

WIGWAM LAKE DAM
GEOLOGIC MAP

GEO - Technical Services, Inc.
HARRISBURG, PA

FEBRUARY 1981

EXHIBIT F

LME