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NATIONAL DAM INSPECTION PROGRAM. CRYSTAL LAKE DAM (NDS ID NUMBE--ETC(U)
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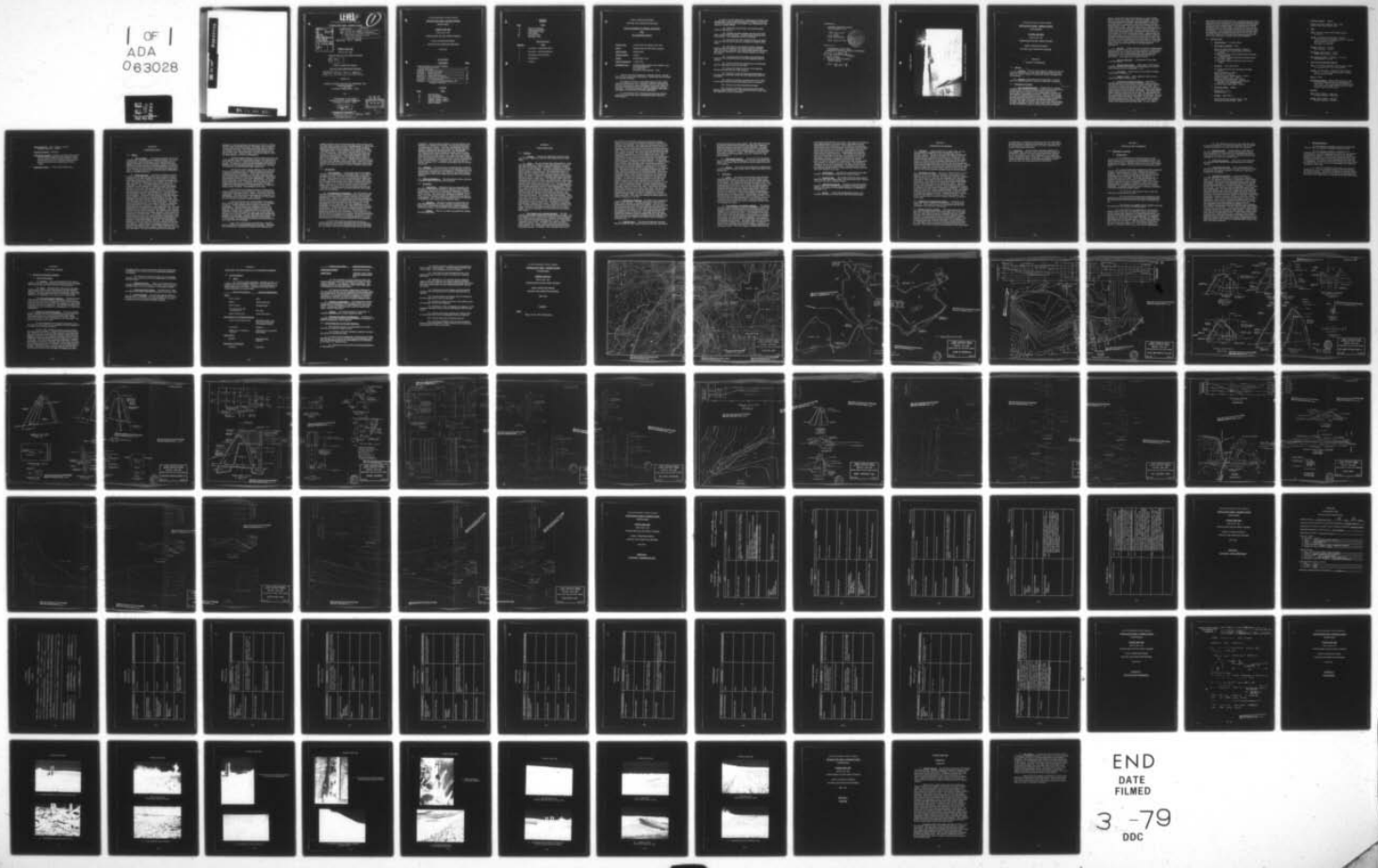

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SUSQUEHANNA RIVER BASIN

WAPWALLOPEN CREEK, LUZERNE COUNTY

PENNSYLVANIA

(6) National Dam Inspection Program. Crystal Lake Dam (NDS ID#562), Susquehanna River Basin, Wapwallopen Creek, Luzerne County, Pennsylvania. Phase I Inspection Report. (Number)

DACW31-78-C-0046

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CRYSTAL LAKE DAM

NDS ID No. 562

PENNSYLVANIA GAS AND WATER COMPANY

(12) 89 p.

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

(15) DACW31-78-C-0046

Prepared by

GANNETT FLEMING CORDDRY AND CARPENTER, INC.
Consulting Engineers
P.O. Box 1963
Harrisburg, Pennsylvania 17105

For

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

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SUSQUEHANNA RIVER BASIN

WAPWALLOPEN CREEK, LUZERNE COUNTY

PENNSYLVANIA

CRYSTAL LAKE DAM

NDS ID No. 562

PENNSYLVANIA GAS AND WATER COMPANY

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

MAY 1978

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PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

BRIEF ASSESSMENT OF GENERAL CONDITION

AND

RECOMMENDED ACTION

Name of Dam:	Crystal Lake Dam (NDS ID No. 562)
Owner:	Pennsylvania Gas and Water Company
State Located:	Pennsylvania
County Located:	Luzerne
Stream:	Wapwallopen Creek
Date of Inspection:	27 April 1978
Inspection Team:	Gannett Fleming Corddry and Carpenter, Inc. Consulting Engineers P.O. Box 1963 Harrisburg, Pennsylvania 17105

Based on the visual inspection, available records, calculations and past operational performance, Crystal Lake Dam is judged to be in good condition.

The spillway will pass the Probable Maximum Flood (PMF) without overtopping the dam. Therefore, based on criteria established for these studies by the Department of the Army, Office of the Chief of Engineers (OCE), the spillway capacity is rated as adequate. The existing spillway can accommodate a flood with a peak inflow of 186 percent of the PMF peak inflow.

It is recommended that a detailed emergency and warning system for Crystal Lake Dam be developed by the Owner in a timely manner.

In order to correct operational, maintenance and repair deficiencies and to more accurately assess the condition of the dam, the following measures are recommended to be undertaken by the Owner in a timely manner:

(1) Repair top of rutted dikes and provide impediments to trail bike use.

(2) Monitor wet areas visually and with observation wells or other instrumentation. Provide positive drainage from toes of dikes. Take appropriate action as required.

(3) Ensure that the right abutment dike has an impervious fill zone and that it acts as a cutoff up to maximum pool level.

(4) Although it is not believed that the shrinkage cracks in the main spillway and auxiliary spillway presently effect the safety of the dam, the Owner should monitor the cracks and study the possibility of some remedial program for sealing the cracks.

(5) Visually monitor the seepage and deteriorating concrete at the contraction joints and take remedial action as required.

(6) Visually monitor the seepage from the foundation and take appropriate action as necessary.

(7) Remove the bridge at the end of the spillway channel and widen the end of the channel.

(8) Undertake a study to determine the adequacy of the emergency drawdown system and take appropriate action as necessary.

(9) Inspect and monitor concrete and steel for signs of acid deterioration and take appropriate action as required.

(10) Remove brush from downstream channel.

(11) Study the suitability of the access road during periods of high precipitation, study alternate access routes, and take appropriate action as necessary.

Submitted by:

GANNETT FLEMING CORDDRY
AND CARPENTER, INC.

A. C. HOOKE
Head, Dam Section

Date: June 16, 1978

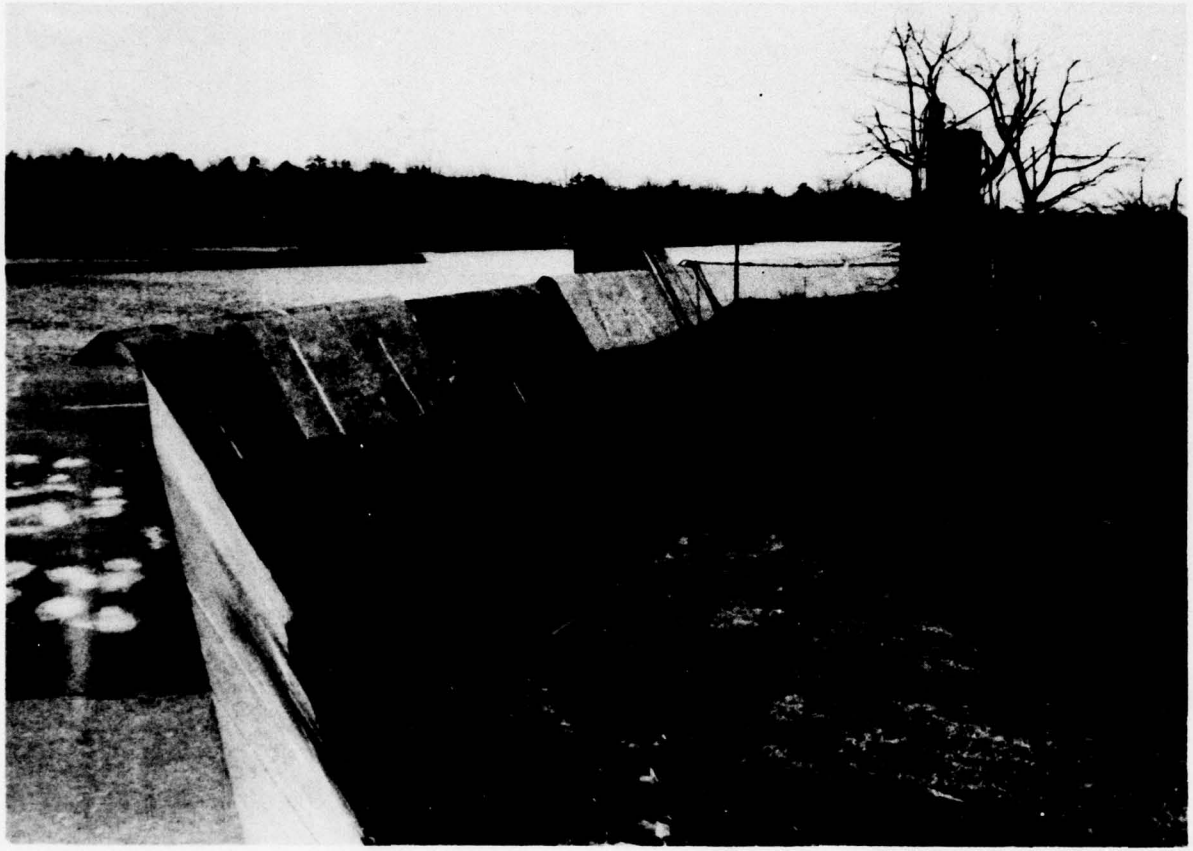
Approved by:

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS

G. K. WITHERS
Colonel, Corps of Engineers
District Engineer

Date: 29 Jun 78

CRYSTAL LAKE DAM



Crystal Lake Dam — View from Right Abutment

SUSQUEHANNA RIVER BASIN

WAPWALLOPEN CREEK, LUZERNE COUNTY

PENNSYLVANIA

CRYSTAL LAKE DAM

NDS ID No. 562

PENNSYLVANIA GAS AND WATER COMPANY

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

ABSTRACT

SECTION 1

PROJECT INFORMATION

1.1 General.

a. 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.

b. Purpose. The purpose of the inspection is to determine if the dam constitutes a hazard to human life or property.

1.2 Description of Project.

ABSTRACT

a. Dam and Appurtenances. Crystal Lake is a natural spring-fed lake whose water surface has been raised about 25 feet by construction of a dam across its natural outlet channel. Crystal Lake Dam consists of a main impoundment structure and three auxiliary impoundment structures. The main dam consists of a main and auxiliary spillway, both of which are ogee-shaped concrete structures with short nonoverflow sections on each end. The combined length of the main and auxiliary spillways is 700 feet. The right nonoverflow section is 65 feet long and abuts a rockfill embankment, 330 feet long, which leads to high ground. The left nonoverflow section is 100 feet long and abuts natural

ground. To the left of this natural ground is a zoned earthfill dike, 500 feet long, which runs to the left abutment. The three auxiliary impoundment structures are zoned earthfill dikes having a total length of 4,225 feet. The three dikes are situated around the lake to prevent the reservoir from flowing into the adjacent drainage areas. The main outlet works is located in the center of the auxiliary spillway of the main dam and consists of two 20-inch diameter cast-iron pipes running, under pressure, to valves on the downstream side. An abandoned gate structure is in the middle of the left nonoverflow section. Separate from the main outlet works is an uncontrolled 18-inch diameter reinforced-concrete pipe that extends under one of the dikes to a pond near the lake. A 30-inch diameter cast-iron force main, used to pump water from an adjacent drainage area to the reservoir, enters near one of the dikes. Various features of the dam are shown on the plates at the end of the report and on the photographs in Appendix D.

b. Location. Crystal Lake Dam is located on Wapwallopen Creek in Luzerne County about 6 miles southeast of Wilkes-Barre, Pennsylvania, and one mile east of Mountain Top, Pennsylvania. The lake is shown on USGS Quandrangle, Wilkes-Barre East, Pennsylvania. The main dam has coordinates N41° 10'10" - E75°50'40". The location map is shown on Plate 1.

c. Size Classification. Intermediate (32 feet high, 9,337 acre-feet).

d. Hazard Classification. High hazard. Downstream conditions indicate that a high hazard classification is warranted for Crystal Lake Dam (Paragraph 5.1.e.).

e. Ownership. Pennsylvania Gas and Water Company, Wilkes-Barre, Pennsylvania.

f. Purpose of Dam. Water supply for areas in and around Wilkes-Barre, Pennsylvania.

g. Design and Construction History. The natural Crystal Lake was first dammed in 1861 with a timber structure. The Crystal Springs Water Company removed the timber dam and constructed a concrete gravity dam at the site in 1888. This structure was designed by Charles Brush, Engineer, of New York, and constructed by John Schmitt, Contractor. The Crystal Springs Water Company raised the dam 5 feet in 1893. The Spring Brook Water Company acquired the site in 1896. An experimental raising, accomplished with sheet metal plates and A-frames, was constructed in 1898 and removed a year later. At that time, the dam was permanently raised 6 feet. In 1914, the dam was studied by the Pennsylvania Water Supply Commission. No recommendations were forthcoming from their report. In 1951, after a

long history of deteriorating concrete, a concrete liner was placed along a part of the upstream face. The dam was completely reconstructed in 1964 in conjunction with the building of an experimental floating water treatment plant. The treatment plant, whose abandoned frames are still afloat in the lake, did not prove successful and not all of the proposed modifications to the dam were accomplished. The modifications that were accomplished included raising the then existing concrete dam by 6 to 6.5 feet, adding dikes at both ends of the dam and at reaches along the lake shore, and modifying and adding outlet works facilities.

1.3 Pertinent Data.

a. Drainage Area - 2.5 square miles.

b. Discharge at Damsite. (cfs).

Maximum known flood at damsite - unknown.
Water supply line at maximum pool elevation - unknown.
Emergency drawdown line at maximum pool elevation - 2 (approximate).
Main spillway capacity with pool at auxiliary spillway crest - 280.
Total spillway capacity with pool at top of dam - 12,060.

c. Elevation. (Feet above msl.)

Top of dam (breached area assumed top of dam) 1946.8.
Top of embankment - 1947.5.
Maximum pool - 1946.8.
Normal pool (main spillway crest) - 1943.0.
Auxiliary spillway crest - 1944.0.
Upstream invert outlet works - 1918.7.
Downstream invert emergency discharge line (blowoff)- 1918 (approximate).
Streambed near outlet works - 1915.0.

d. Reservoir Length. (Miles.)

Normal pool - 1.5.
Maximum pool - 1.5.

e. Storage. (Acre-feet.)

Normal pool (main spillway crest) - 7442.
Maximum pool (top of dam) - 9337.

f. Reservoir Surface. (Acres.)

Normal pool (main spillway crest) - 494.
Maximum pool (top of dam) - 503.

g. Dam.

Type - Concrete gravity with earthfill dikes at abutments.

Length - Earthfill abutment dikes - 830 feet.
Concrete gravity nonoverflow sections - 165 feet.
Auxiliary spillway - 620 feet.
Main spillway - 80 feet.
Total dam - 1,695 feet.

Height - Main dam - 32 feet.
Main spillway - 28 feet.

Top Width - Embankment - 10 feet.
Nonoverflow section - 4 feet.

Side Slopes of Dikes - Upstream - 1V on 3H.
Downstream - 1V on 2H.

h. Diversion and Regulating Tunnels.

Type - Two 20-inch diameter cast-iron pipes. (Also four abandoned 48" x 60" sluice gates.)

Length - Indeterminate, connected to water supply system. A 6-inch diameter blowoff is interconnected with the system.

Access - None.

Regulating Facilities - Valves with riser pipes. The two 20-inch diameter pipes are interconnected with valves. The 6-inch diameter blowoff is tapped off the water supply system and has a valve with riser pipe near the outlet.

i. Spillway.

Type - Main spillway - ogee weir.
Auxiliary spillway - ogee weir.

Length - Main spillway - 80 feet.
Auxiliary spillway - 620 feet.

Crest Elevations - Main spillway - 1943.0.
Auxiliary spillway - 1944.0.

Upstream Channel - Reservoir.

Downstream Channel - Irregular rock-lined basin downstream of main spillway leading through a narrow and low bridge to the steep and overgrown stream downstream of the dam. Auxiliary spillway discharge would flow over natural ground to the stream.

j. Regulating Outlets. None except outlet works.

SECTION 2

ENGINEERING DATA

2.1 Design.

a. Data Available. Very little engineering data for the structure as it now exists was available for review. The structure had been studied previously by the Pennsylvania Water Supply Commission for their 1914 report. Except for the description of the watershed and downstream channel, the description of the geologic conditions, and the description of the concrete structure as it then existed, the report is no longer applicable. Engineering data on the subsequent major modifications were not available for review.

b. Design Features. A plan of the reservoir is shown on Plate 1A and a plan and profile of dam is shown on Plate 2. Starting from the right abutment, the dam consists of a rockfill embankment which runs 330 feet to a concrete nonoverflow section. The rockfill embankment is also referred to as right abutment dike (Plate 7). The right abutment dike is shown on Photograph C. The nonoverflow section is a concrete gravity structure, 65 feet long with a 4.0-foot top width, downstream batter of 1.73V on 1H, and upstream batter of 3.08V on 1H. The wall is keyed into rock and has anchor bars, 2 feet apart and 6 feet into rock, near the upstream face. The top elevation of the section is 1948.5, which is about 11.5 feet above the rock foundation. To the left of this section is the main and auxiliary spillways that have a combined length of 700 feet. The spillways are concrete gravity structures keyed into rock, with post-tensioned rods on 4-foot centers anchored 12 feet into rock, near the upstream face for 173.5 feet of the length. The ogee crest and downstream face were added in 1964 as a modification to the existing dam, and have a 1.73V on 1H batter from the downstream toe to approximately 2 feet below the crest. The ogee shape varies for the main and auxiliary spillways. Both are segments of circular curves in section. The upstream face, between the crest and just above the original structure, slopes toward the reservoir at a 45 degree angle. The original structure has an upstream batter of 3.2V on 1H. Some sections of the original structure are wider than others because there was a modification constructed in 1951 which added a 2-foot thick concrete liner upstream to a reach of the original structure. The modifications performed in 1964 are keyed into rock and dowelled into the original structure. Reinforcing bars are placed in areas of the concrete that were added in 1964. The auxiliary spillway crest is at Elevation 1944, with the main spillway, which is 80 feet long, being 1 foot lower. The dam has three angles in the horizontal

alignment. The main spillway, the right end of which is 168 feet from the right nonoverflow section, discharges into an irregularly shaped outlet channel whose bottom and 4-foot high side slopes are covered with stone. The spillway discharge passes under a small bridge at the downstream end of the channel and then into the existing creek. Spillway details are shown on Plates 3 and 4. The main spillway is shown on Photograph F.

An intake chamber with two 20-inch diameter cast-iron pipes is 325 feet left of the right nonoverflow section. The intake chamber is shown on Plate 5. Valves for these pipes are downstream of the dam. The pipes are interconnected downstream of the dam and extend to a 6-inch diameter emergency or blowoff line, and both a 14-inch and a 20-inch diameter water supply line.

The left end of the auxiliary spillway abuts a 100-foot long left nonoverflow section, of identical section and elevation to the right nonoverflow section. In the center of the left nonoverflow section is a gatehouse, 22 feet wide, with four rising stem, 48-inch high by 60-inch wide, unseating head sluice gates. The gatehouse is shown on Plate 6 and Photograph L. Two of the gates have inverts at Elevation 1930, with the other two inverts being at Elevation 1936. A trashrack slot is provided in the upstream most section of the gatehouse. At present, the downstream side of the gatehouse is backfilled with rock, which completely covers the gates. The gatehouse is not used.

Left of the left nonoverflow section is a reach of natural ground without any structure thereon. The lowest elevation in this reach is Elevation 1946.8, which is lower than top of the embankment. This area has been excavated and is referred to as the breached area by the Owner. This elevation has been assumed as top of dam for spillway capacity purposes.

Left of this reach is the zoned earthfill left abutment dike, which is about 500 feet long and which has a top elevation of 1951.0. The left abutment dike is shown on Plate 8 and Photograph K. The dike follows the alignment of the dam for about 150 feet, then turns 95 degrees upstream to tie into the abutment. The dike has a cutoff trench with a 12-foot bottom width which extends into impervious soil. An 18-inch thick riprap layer on an 18-inch thick, two-stage filter layer protects the upstream 1V on 3H slope. A three-stage filter drain covered with cobbles is provided below Elevation 1940 on the downstream 1V on 2H slope. The downstream slope above this elevation and the 10-foot wide toe are seeded.

Also a part of this project are three dikes, identical in cross section to the left abutment dike at the dam. The south dike, 545 feet long, prevents the reservoir from flowing into a

swamp and thence into the Little Nescopeck Creek drainage area. The south dike is shown on Plate 9 and Photograph M. An 18-inch diameter reinforced-concrete pipe, without closure facilities, leads from Crystal Lake to Nescopeck Pond, which is normally at Elevation 1943.3. The southeast and northeast dikes, 1,325 and 2,355 feet long, respectively, prevent the lake from flowing into a swamp and from there into the Geneceda Creek and Tenmile Run drainage areas. The southeast dike is shown on Plate 10 and Photograph N and the northeast dike is shown on Plate 11 and Photographs P and Q. Tenmile Run eventually flows into Bear Creek upstream of Bear Creek Lake. There is a 30-inch diameter cast-iron force main from Bear Creek Lake which enters Crystal Lake directly adjacent to the east abutment of the south dike.

2.2 Construction.

a. Data Available. Construction data for the original structure or for modifications accomplished prior to 1914 that is available for review, consists of the information contained in the 1914 report prepared by the Pennsylvania Water Supply Commission. Information in the 1914 report is limited. Some data for the modifications constructed in 1951 is available for review from the files of the Pennsylvania Office of Dams and Encroachments. Although no "as-built" drawings exist for the 1964 modification, the Owner did provide an informal interview with a construction engineer who was present when the 1964 modification was constructed.

b. Construction Considerations. The 1914 report by the Pennsylvania Water Supply Commission raised several concerns about the construction of the original structure and the earlier modifications. Most of the concerns were about the bonding of concrete placed during the modifications to the structure beneath. Details of construction methods and practices for the original dam apparently were not available to the Commission, as the information was not definitive. The 1951 modification was accomplished, according to the files, without any special construction problems. It was noted that the concrete placed on the upstream face of the dam was keyed 4 to 5 feet into the rock, which was reported as a hard sandstone. It was noted in an inspection report that drilling and grouting of the old concrete structure and the rock foundation was proposed. As drilling and grouting work was not mentioned in the permit application or on the construction plans, it is uncertain whether it was accomplished.

As was noted under the construction history for Crystal Lake Dam, the 1964 modification was to be implemented with a floating treatment plant experiment that proved unsuccessful. As a result, not all of the features shown on the plans were

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completed. Other than these omissions, the only change to the drawings, as reported by the Owner, was concrete paving placed downstream of the dam. Fractured, disintegrated rock that permitted seepage through it was removed to varying depth and replaced with anchored concrete paving. The flip buckets that were indicated on the drawings as being at the toe of the main spillway were never constructed. The Owner is uncertain about the reason for this change. The Owner did report trouble with concrete placement during construction of the 1964 modification. Honeycombing of the concrete was a constant problem when the forms were removed. Attempts by the Owner and the Contractor, Glasgow, Inc., to resolve this problem were not entirely successful.

2.3 Operation. No formal records of operation were reviewed. Based on information from the Owner and the caretaker of the dam, all structures have performed satisfactorily. The highest flow recalled by the caretaker was water almost at the crest of the auxiliary spillway, with waves lapping over the top of the auxiliary spillway.

2.4 Other Investigations. The Owner does not have any plans to further modify Crystal Lake Dam at present.

2.5 Evaluation.

a. Availability. Engineering data was provided by the Division of Dams and Encroachments, Bureau of Water Quality Management, Department of Environmental Resources, Commonwealth of Pennsylvania and by the Owner, Pennsylvania Gas and Water Company. The Owner made available an engineer, caretaker, and a construction engineer for information during the visual inspection. The Owner also researched his files for additional information upon request of the inspection team.

b. Adequacy. The type and amount of design data and other engineering data is limited, and the assessment must be based on the combination of available data, visual inspection, performance history, and hydrologic and hydraulic assumptions.

c. Validity. There is no reason to question the validity of the available data.

SECTION 3

VISUAL INSPECTION

3.1 Findings.

a. General. The general appearance of Crystal Lake Dam is good. However, there are some deficiencies as noted below.

b. Dikes. The left abutment dike (Photograph K), south dike (Photograph M), southeast dike (Photograph N), and northeast dike (Photographs P and Q) appear in excellent condition. The sod is in good condition. No cracks, movement, or sloughing were noted on the dikes. The top of the south dike was rutted to a depth of about 8 inches. The Owner reports that, although the area is posted, trail bikes use the top of dike as a road. The riprap is in excellent condition with no signs of weathering or erosion. There is a noticeable difference in the gradation of the riprap in some areas. The stones in these areas are segregated into clusters of larger and smaller sizes. These clusters are neither large in area nor extreme in size of stone. Standing water was noted at the toes of the dikes. The left abutment dike had water standing at the downstream toe and extending from it for 15 feet downstream towards a gully (Photograph J). A wet area, about 100 square feet in size, was observed 40 feet downstream of the toe of the left abutment dike. This wet area was at the base of the hill that forms the abutment of the dike. The boots of inspectors walking over the wet area penetrated about 1 inch into the surface. No standing water was observed. There was no flow from the wet area nor from the pools of standing water at the toes of the dikes. Water was standing in many low areas of the unpaved roads in the vicinity. The right abutment dike (Photograph C) does not appear to be constructed in accordance with the plans supplied by the Owner. The dike is covered with rock, and the top of the dike is 2.5 feet lower than the plans indicate. Adjacent to the right overflow section, for a 15-foot length, the top of embankment is 1 foot lower than the nonoverflow section.

c. Main Spillway and Auxiliary Spillway. The main spillway and auxiliary spillway are similar in cross section. The main spillway crest is 1 foot lower and shaped slightly differently than the auxiliary spillway crest. There are many shrinkage cracks along the spillways (Photographs F and H). These cracks extend from crest to toe. Generally, the cracks are in the center of monoliths. Many of these cracks were painted with white material. The Owner reports that those cracks have been chemically grouted. In addition, there are three cracks just a

few inches from contraction joints in the auxiliary spillway. These cracks are adjacent to monoliths where the centerline of spillway crest deflects. The cracks near contraction joints start near the crest and make a 45° angle with the vertical for about 6 inches. The two longest cracks then extend vertically downward. The largest crack of the three is 5.5 feet long and about 1/2 inch wide. There is seepage from weep holes near the toe of the main and auxiliary spillways. The Owner reports that these holes extend to the interface of the concrete placed prior to the 1964 modification and the concrete placed during the 1964 modification. There is also seepage from the contraction joints starting about 3 feet above toe of main and auxiliary spillways. At the joints, there is evidence of leaching as white deposits or "efflorescence" was observed. Many of these joints are spalling, typically to about a 1-inch depth (Photograph G). There is water at the toes of the main and auxiliary spillways (Photograph I). The Owner is of the belief that the water is seeping through the rock foundation. The Owner stated that the foundation seepage had been noted during construction of the 1964 modification. Some of the water was coming through the weep holes and some through the contraction joints. The combined seepage from all causes was estimated at 1 gallon per minute for the area to the right of the spillway. The toe of the auxiliary spillway to the left of the spillway and most of the main spillway toe are covered with stone. Flowing water in this area could not be observed. In all, there was not sufficient seepage to create a watercourse from toe of dam to the existing creek. The main spillway channel is irregularly shaped and lined with stone. The channel is 80 feet wide at the upstream end and about 4 feet deep. The channel funnels under a bridge about 100 feet downstream of the dam. The bridge is in very poor condition, estimated as unable to support vehicular traffic, and has a waterway under it which is about 5 feet wide. The clearance between the bridge beams and bottom of channel is 3.67 feet.

d. Appurtenant Structures. No defects were noted in the active intake structure. The abandoned gate structure (Photograph L) also appeared in excellent condition. The Owner reported that the area immediately downstream of the gate structure was backfilled with rock. He also stated that the gates had a protective coating applied to them before the backfill was placed. The operating of the valve on the 6-inch diameter blowoff line (Photograph B) was not observed. The Owner stated that this blowoff was intended to remove sediment from the water supply lines and would be incapable of drawing down the reservoir. He stated that the water supply lines could be used as emergency drawdown lines.

e. Reservoir Area. The reservoir slopes are wooded. About one-half the area, located away from the lake, has mature

trees with some low but steep slopes. The other half is very flat ground with small trees and shrubs and there was evidence of much fire damage on this portion of the watershed. The areas immediately beyond the dikes, although not in the watershed proper, were observed to be extensive swamps. The lake itself has a fetch of almost 1.5 miles. The Owner stated that the pH of the lake usually varies from 4.2 to 5.0. A low of 3.5 has been recorded.

f. Downstream Channel. On the day of the inspection, the downstream channel (Photograph D) was dry and heavily overgrown. The Owner reports that there is rarely discharge over the main spillway.

g. Access. The access road to the dam is unpaved and passes through a heavily wooded area for over a mile before reaching the dam.

3.2 Evaluation.

a. Dikes. The rutting along the top of the south dike could lead to low spots in the top. As the top of dike is substantially above top of dam elevation, this is of slight concern at the moment. The segregation of riprap stone size on the dike is not sufficiently extreme to be more than of slight concern. The standing water at the toe of dikes and the wet area downstream of the left abutment could be related to the standing water remaining in the undrained areas of the nearby roads. The water at the toe of dikes could also indicate normal functioning of the drains in the dikes. It would be desirable to have positive drainage paths from these drains. The wet area and standing water could have a potential to be a more serious problem. It is not certain that the right abutment dike, as it exists, acts as a cutoff for surface or subsurface flow. It did not appear to be constructed according to plan and its construction details were not available for review.

b. Main Spillway and Auxiliary Spillway. The shrinkage cracks were probably caused by a combination of excessive monolith length and shallow thickness of concrete placed. The lengths of the concrete monoliths constructed during the 1964 modification are generally 27 feet. It is uncertain if the monoliths coincide with the monoliths of the structure as it existed before 1964. No monolith lengths or contraction joint locations are shown on the 1964 modification drawings. It is uncertain if the length and location of the monolith joints were given any consideration during design. The three cracks near the contraction joints are probably also shrinkage cracks. A review of Plates 3 and 4 indicates that there is a shear key present at the contraction joints. The cracks appear to deflect approximately

at the point where the shear key starts. The longest crack extends down approximately to the level of top of dam before the 1964 modifications were constructed. Crack control in the planning of the concrete work does not appear to have been a prime criteria during either design or construction. The deteriorating concrete at the contraction joints could be the disintegration of mortar placed over honeycombed areas. Honeycombing was reported a major problem during construction. The seepage from the joints could be caused solely by the lack of waterstop in the contraction joints. However, Crystal Lake Dam has had a history of disintegrating concrete, probably due to the acid, low pH water, as noted in the periodic inspections by the Commonwealth. The condition is, therefore, of some concern. The quantity of seepage at the toe of the spillways is of slight concern as long as it does not increase significantly. The bridge at the end of the spillway channel serves no useful purpose at present and can only raise tailwater at the dam.

c. Outlet Works. The Owner's assessment of the capabilities of the emergency drawdown line appears correct.

d. Reservoir Area. The acidity of the lake water and its effect upon the water supply pipes, the steel anchor bars, and the concrete in the dam is of some concern.

e. Downstream Channel. The growth in the downstream channel could raise tailwater during spillway discharge periods. Additional discussion on downstream conditions is presented in Paragraph 5.1.e.

f. Access. During high precipitation storms, it is uncertain that the access road to the dam would be passable.

SECTION 4

OPERATIONAL PROCEDURES

4.1 Procedure. During periods of very high runoff, the reservoir level is maintained by the main spillway crest at Elevation 1943.0, with any excess reservoir inflow passing over the main spillway. Normally, however, the reservoir level is maintained below spillway crest and there is no spillage. Two 20-inch diameter lines at the intake structure of the dam release water to a treatment plant immediately downstream of the dam. Water then passes through both a 14-inch and a 20-inch diameter gravity transmission line that extends toward Wilkes-Barre. In addition to normal runoff, water enters the reservoir from the 30-inch diameter supply line from Bear Creek Lake at the south dike. The valve on the 6-inch diameter emergency line is normally closed.

4.2 Maintenance of Dam. The dam is visited daily by a caretaker who checks the treatment equipment, and if water is not flowing over the main spillway, he checks the reservoir elevation. When the reservoir is below the main spillway crest, the caretaker reports the reservoir elevation to the Owner's Engineering Department. This information is used by the Engineering Department for regulating flows in the distribution system. The caretaker is also responsible for observing the general condition of the dam and appurtenant structures, and for reporting any changes or deficiencies to the Owner's Engineering Department. A Pennsylvania Gas and Water Company engineer makes a formal inspection of the dam each year, and the records are kept on file and used for determining priority of repairs. Informal inspections are also made when the engineer is on the site for other reasons. The seeded embankments are mowed at regular intervals and brush is cut annually.

4.3 Maintenance of Operating Facilities. According to the Owner, the valves attached to the water lines are permanently lubricated. Operating facilities are maintained when they are considered to be in need of maintenance.

4.4 Warning Systems in Effect. The Owner furnished the inspection team with a chain of command diagram for Crystal Lake Dam and a generalized emergency notification list that is applicable for all the Pennsylvania Gas and Water Company dams. The Owner said that during periods of heavy rainfall, available personnel are dispatched to the dams to observe conditions. All company vehicles are equipped with radios, and the personnel can communicate with each other and with a central control facility. Evaluation of risk is made by the Owner's Engineering Department. The Owner's Engineering Department is also responsible

for notification of emergency conditions to the local authorities. Detailed emergency operational procedures have not been formally established for Crystal Lake Dam, but are as directed by the Owner's Engineering Department.

4.5 Evaluation. The operational procedure appears to be satisfactory. The procedures used by the Owner for inspecting the dam are adequate, but some needed repairs have not been made. As observed in the visual inspection, the maintenance for the operating facilities is adequate. In general, the warning system is adequate, but is not in sufficient detail for Crystal Lake Dam when its overall importance is considered.

SECTION 5

HYDROLOGY AND HYDRAULICS

5.1 Evaluation of Features.

a. Design Data.

(1) No hydrologic and hydraulic analysis for the existing Crystal Lake Dam design was available for review. Previous analyses are not applicable to the dam after its final modification was complete. Spillway capacity, as used in this Section, represents the combined capacity of the main and auxiliary spillways.

(2) In the recommended guidelines for safety inspection of dams, the Department of the Army, Office of the Chief of Engineers (OCE) established criteria for rating the capacity of spillways. The recommended spillway design flood for the size (intermediate) and hazard potential (high) classification of Crystal Lake Dam is the PMF. If the dam and spillway are not capable of passing the PMF without overtopping failure, the spillway capacity is rated as inadequate. If the dam and spillway are capable of passing one-half of the PMF without overtopping failure, the spillway capacity is not rated as seriously inadequate. A spillway capacity is rated as seriously inadequate if all of the following conditions exist:

(a) There is a high hazard to loss of life from large flows downstream of the dam.

(b) Dam failure resulting from overtopping would significantly increase the hazard to loss of life downstream from the dam from that which would exist just before overtopping failure.

(c) The dam and spillway are not capable of passing one-half of the PMF without overtopping failure.

(3) In the report on the application by the Owner to modify Crystal Lake Dam, the Division of Dams and Encroachments, Pennsylvania Department of Environmental Resources, indicated that the main spillway and auxiliary spillway could pass the curve "C" with 3 feet of freeboard remaining. No spillway capacity was mentioned in this report. The elevation of the low spot between the left abutment dike and the left nonoverflow section at top of dam is 1946.8. With the reservoir at this level, the head on the main spillway is 3.8 feet and the spillway capacity, as computed for this study, is 12,060 cfs (Appendix C).

(4) The hydrologic analysis for this study was based on existing conditions of Crystal Lake watershed and the effects of future development of the watershed were not considered.

b. Experience Data. For this study, a PMF peak derived from generalized data supplied by the Baltimore District, Corps of Engineers for this area of the Susquehanna River Basin was adapted to Crystal Lake watershed. The PMF peak flow was estimated to be 6,500 cfs at Crystal Lake.

c. Visual Observations. On the date of the inspection, no conditions were observed that might decrease the spillway capacity.

d. Overtopping Potential. For an occurrence of the Crystal Lake PMF, the peak inflow of 6,500 cfs into Crystal Lake is less than the spillway capacity of 12,060 cfs. There is no potential for overtopping.

e. Downstream Conditions. Crystal Lake Dam is 1.2 miles upstream of Penobscot, Pennsylvania as shown on Plate 1. Just upstream of Penobscot, Wapwallopen Creek passes under the old Lehigh Valley Railroad embankment, which is about 40 feet high. The creek has no habitations between the dam and this railroad embankment. The creek then flows for 0.2 mile to the old Central of New Jersey Railroad embankment, which is about 20 feet high. This reach has some structures less than 20 feet above streamgrade. The creek passes under this embankment and then under Pennsylvania Route 309. Within this reach, there are numerous houses which would be flooded by the failure of Crystal Lake Dam. The stream then flows through an extensive swamp which could have a significant mitigating effect on flood flows further downstream. There is extensive new development about 1.6 miles downstream of this swamp. Although the Lehigh Valley Railroad embankment would initially impede flood flows from Crystal Lake Dam, the embankment would probably overtop and extensive floodflows would pass through an inhabited area. Therefore, the conditions downstream of the main dam of Crystal Lake warrant a high hazard classification. Failure of the auxiliary impoundment structures would lead to flooding of other streams. Failure of the south dike would cause flooding of Little Nescopeck Creek, which flows towards the Susquehanna River. Failure of the northeast or southeast dike would cause flooding of Geneceda Creek, which eventually flows into Bear Creek Lake in the Delaware River Basin. Extensive swamps downstream of the auxiliary impoundment structures would have a very significant mitigating effect on peak flood flows from these structures.

f. Spillway Adequacy.

(1) The spillway is capable of passing the PMF peak inflow of 6,500 cfs without overtopping Crystal Lake Dam.

(2) The maximum tailwater is estimated to be Elevation 1934.7 at the PMF discharge of 6,500 cfs. At maximum pool elevation, there is a difference of about 11 feet between headwater and tailwater. If Crystal Lake should fail due to overtopping, the hazard to loss of life downstream from the dam will be significantly increased from that which would exist just prior to overtopping. The amount of storage in Crystal Lake that is from the original natural lake could not be determined from information available for this study.

(3) Based on established OCE criteria as outlined in Paragraph 5.1.a.(2), the spillway capacity of Crystal Lake Dam is rated as adequate. Neglecting the effects of surcharge storage, the spillway discharge capacity of 12,060 cfs can accommodate a flood with a peak inflow that is 186 percent of the PMF peak inflow.

SECTION 6

STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability.

a. Visual Observations.

(1) General. The visual inspection of the dam resulted in a number of observations relevant to structural stability. These observations are listed herein for various features.

(2) Dikes. Standing water at the toes of the dikes, standing water and wet areas downstream of the left abutment dike, and the rutted surface of the top of south dike, have been observed. The detailed description and evaluation of these conditions are in Paragraphs 3.1.b. and 3.2.a., respectively.

(3) Main and Auxiliary Spillways. Shrinkage cracks along the surface of the spillways and structural cracks at its crest have been observed. Seepage from some of the contraction joints and flow from the weep holes was observed, as was standing water at the toes of spillways. The detailed description and evaluation of these conditions are in Paragraph 3.1.c, and 3.2.b., respectively.

b. Design and Construction Data. No record of design data or stability analysis for the original dam was available for review. However, in 1914 the Pennsylvania Water Supply Commission performed a stability study on the dam. At that time, the maximum section considered was 18.0 feet high. The result of the analysis is on file.

The dam dimensions have changed significantly after the 1951 and 1964 modifications, therefore, the 1914 analysis is not valid for the existing conditions.

For this study, additional analyses were performed. Two cases were considered. The first case included the following: reservoir level at one-half PMF elevation, full hydrostatic pressure on upstream face and uplift varying uniformly from full tailwater at the toe to full tailwater at the heel, plus 2/3 of the difference between the headwater and the tailwater also applied at the heel. The second case included the following: the lake covered by an ice layer at Elevation 1944, force due to ice equal to 8.0 KIPS per linear foot, no tailwater, and the uplift pressure varying uniformly from zero at the toe to 2/3 of the headwater at the heel. The results of the analyses indicated that for both cases toe pressure and factor of safety for sliding were within

acceptable limits and the resultant was within the middle third. Consequently, the results meet OCE recommended guidelines for stability.

The concrete nonoverflow section was not analyzed because it was judged that, due to its dimensions, the section would be stable.

c. Operating Records. There is no evidence that any stability problems have occurred for the dikes, the concrete nonoverflow section, the main spillway or the auxiliary spillway.

d. Post-Construction Change. As noted herein, there is adequate information concerning the changes made after 1899.

e. Seismic Stability. Crystal Lake Dam is located in Seismic Zone 1. Normally, it can be considered that if a dam in this zone is stable under static loading conditions, it can be assumed safe for any expected earthquake loading.

SECTION 7

ASSESSMENT, RECOMMENDATIONS, AND REMEDIAL MEASURES

7.1 Dam Assessment.

a. Safety.

(1) Based on visual inspection, available records, calculations and past operational performance, Crystal Lake Dam is judged to be in good condition. However, some maintenance and repair deficiencies were noted. A summary of features and observed deficiencies are listed below:

Feature and Location	Observed Deficiencies
Dikes:	
Tops of dikes	Ruts.
Riprap	Uneven gradation.
Toes of dikes	Standing water.
Left abutment of left abutment dike	Wet area.
Right abutment dike	Varies from plans.
Main Spillway and Auxiliary Spillway:	
Crest and downstream face	Shrinkage cracks, seepage and deterioration of concrete at joints.
Foundation	Seepage.
Bridge at end of spillway channel	Deteriorated and hydraulically small.
Outlet Works:	
Blowoff	Small discharge capacity.
Reservoir and Watershed:	
Reservoir	Acid water.

Feature and Location	Observed Deficiencies
Downstream Channel:	Constricted by brush.
Access Road:	Uncertain access during periods of high precipation.

(2) The overtopping potential analysis shows that Crystal Lake Dam will not be overtopped by the PMF occurring over its watershed. The spillway is rated as adequate. The existing spillway can accommodate a flood with a peak inflow of 186 percent of the PMF peak inflow.

(3) Review of stability computations performed for this study indicate that the main spillway and the auxiliary spillway are apparently structurally adequate for the pool conditions considered. For the pool conditions considered, computations show that the resultants are inside the middle third, and that sliding factors and toe pressures are within acceptable limits.

b. Adequacy of Information. The information available is such that an assessment of the condition of the dam can be inferred from the combination of visual inspection, past performance, computations performed prior to and as a part of this study, and other information.

c. Urgency. The recommendations in Paragraph 7.2 should be implemented in a timely manner as noted.

d. Necessity for Further Investigations. In order to accomplish some of the remedial measures outlined in Paragraph 7.2, further investigations will be required.

7.2 Recommendations and Remedial Measures.

a. The following measure is recommended to be undertaken by the Owner in a timely manner:

(1) Develop a detailed emergency operation and warning system for Crystal Lake Dam.

b. In order to correct operational, maintenance and repair deficiencies, and to more accurately assess the condition of the dam, the following measures are recommended to be undertaken by the Owner in a timely manner:

(1) Repair top of rutted dikes and provide impediments to trail bike use.

(2) Monitor wet areas visually and with observation wells or other instrumentation. Provide positive drainage from toes of dikes. Take appropriate action as required.

(3) Insure that the right abutment dike has an impervious fill zone and that it acts as a cutoff up to maximum pool level.

(4) Although it is not believed that the shrinkage cracks in the main spillway and auxiliary spillway presently affect the safety of the dam, the Owner should monitor the cracks and study the possibility of some remedial program for sealing the cracks.

(5) Visually monitor the seepage and deteriorating concrete at the contraction joints and take remedial action as required.

(6) Visually monitor the seepage from the foundation and take appropriate action as necessary.

(7) Remove the bridge at the end of the spillway channel and widen the end of the channel.

(8) Undertake a study to determine the adequacy of the emergency drawdown system and take appropriate action as necessary.

(9) Inspect and monitor concrete and steel for signs of acid deterioration and take appropriate action as required.

(10) Remove brush from downstream channel.

(11) Study the suitability of the access road during periods of high precipitation, study alternate access routes and take appropriate action as necessary.

SUSQUEHANNA RIVER BASIN

WAPWALLOPEN CREEK, LUZERNE COUNTY

PENNSYLVANIA

CRYSTAL LAKE DAM

NDS ID No. 562

PENNSYLVANIA GAS AND WATER COMPANY

PHASE I INSPECTION REPORT

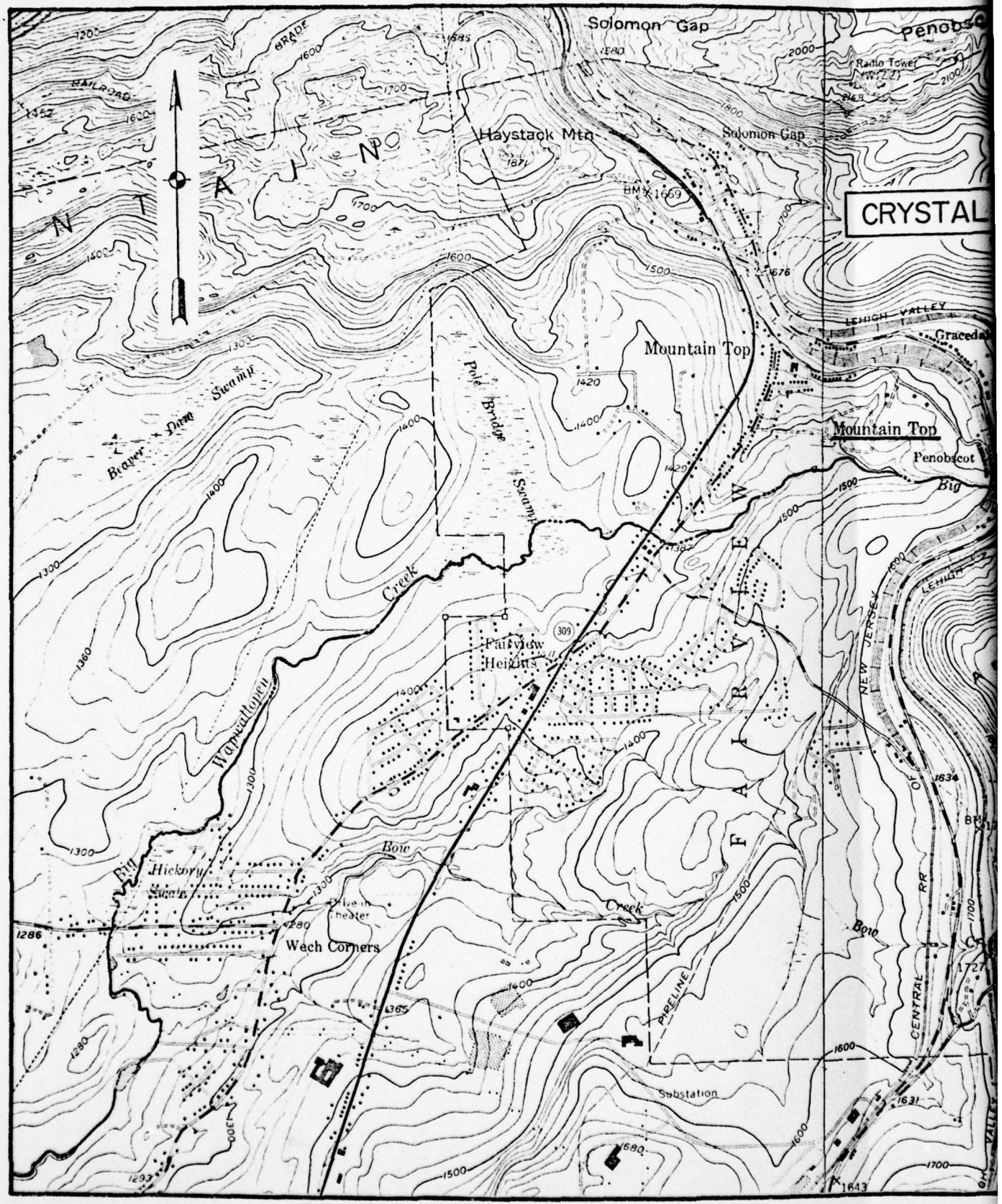
NATIONAL DAM INSPECTION PROGRAM

MAY 1978

PLATES

NOTE:

Plates are for 1964 modifications.



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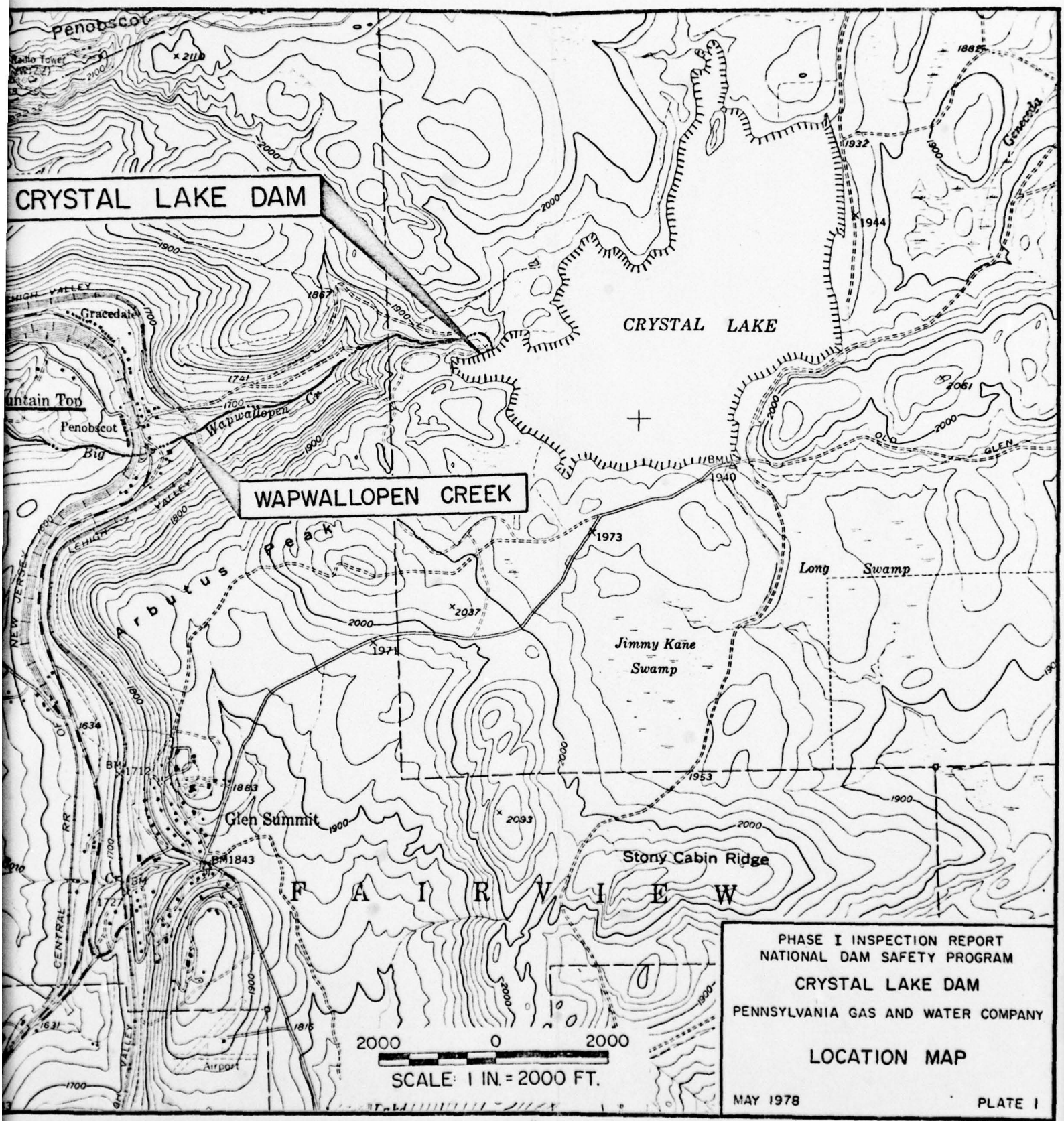

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NATIONAL DAM SAFETY PROGRAM

CRYSTAL LAKE DAM

PENNSYLVANIA GAS AND WATER COMPANY

LOCATION MAP

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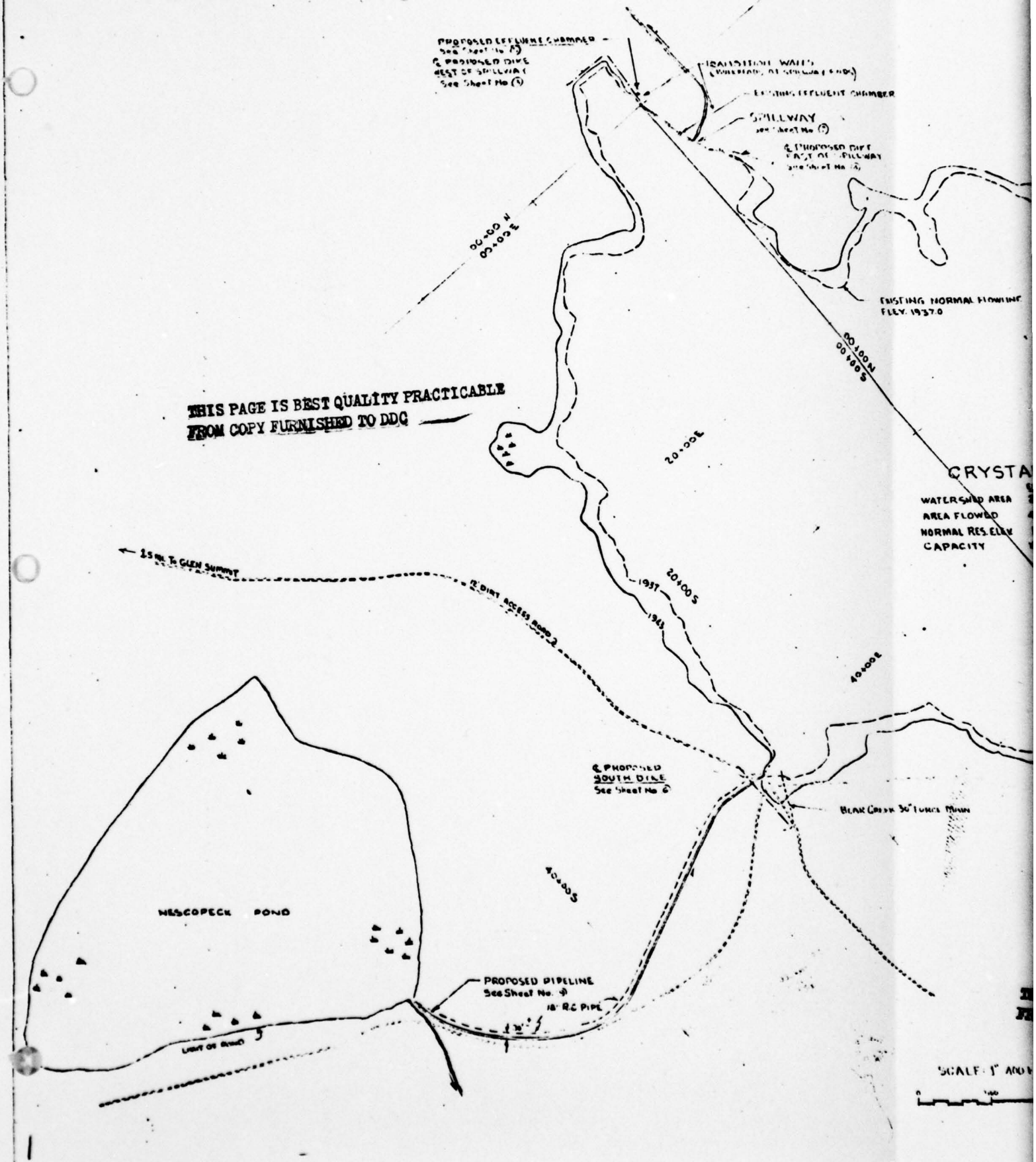

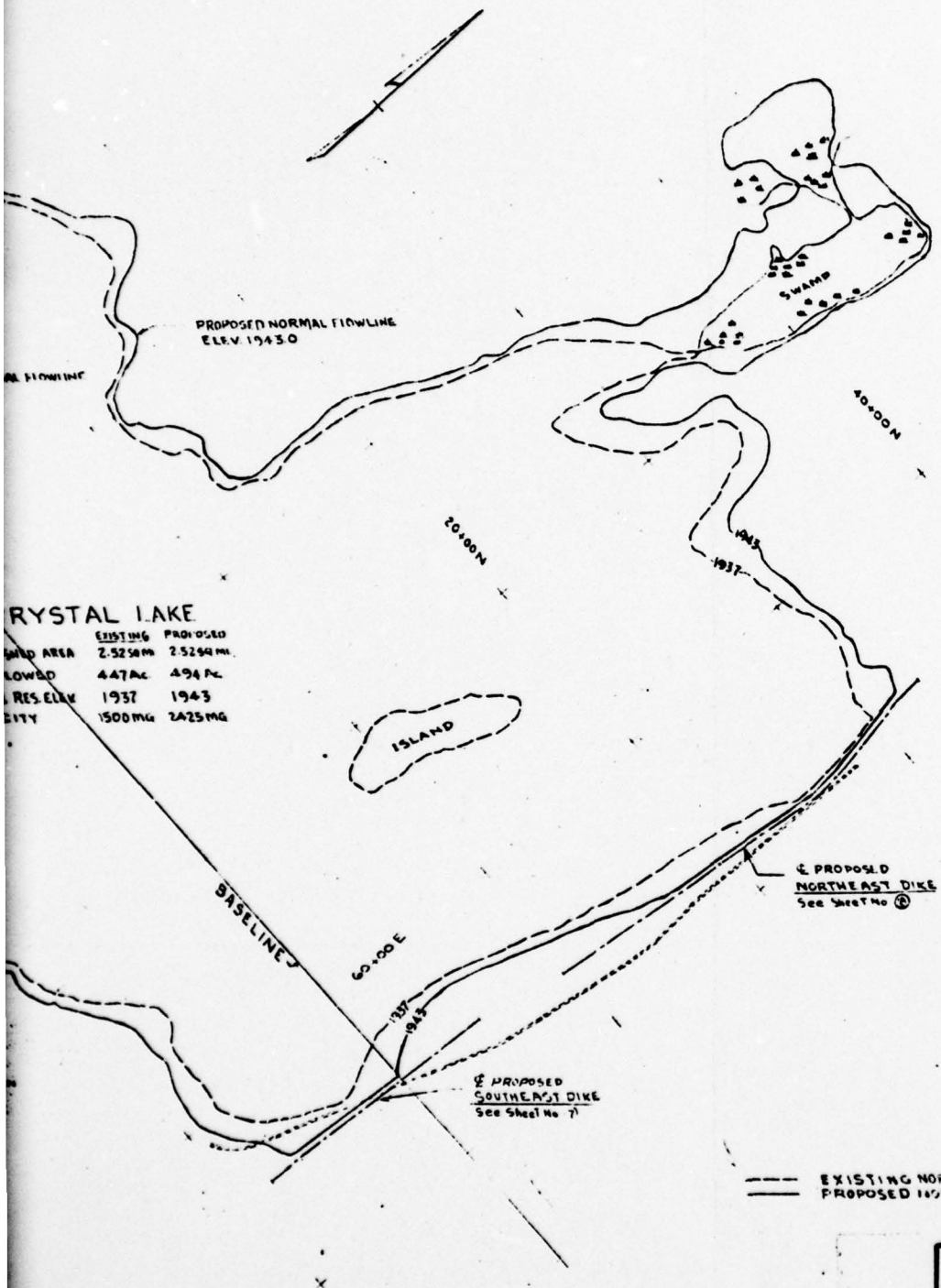

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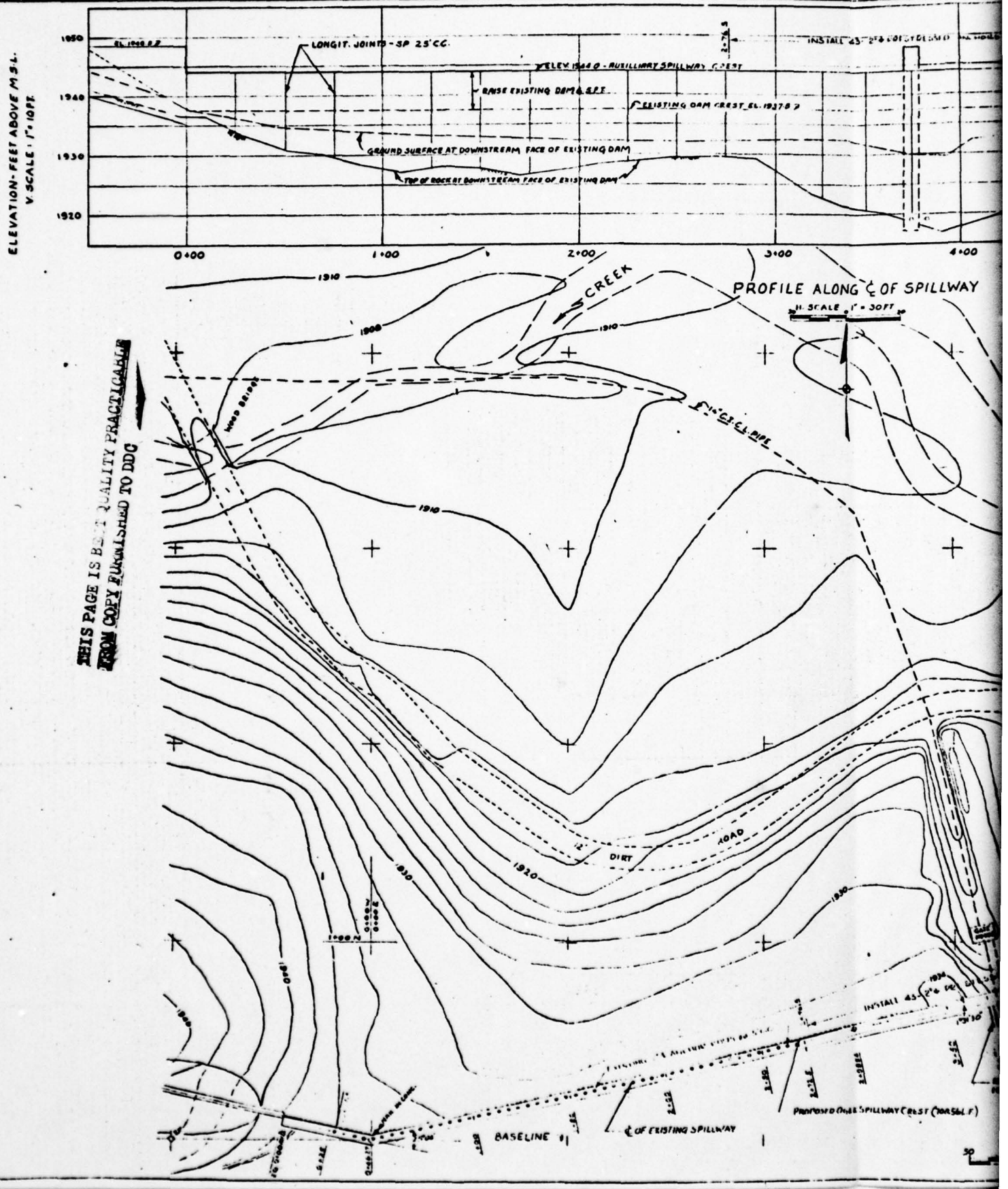
CRYSTAL LAKE DAM

PENNSYLVANIA GAS AND WATER COMPANY

PLAN OF RESERVOIR

MAY 1978 PLATE IA

2



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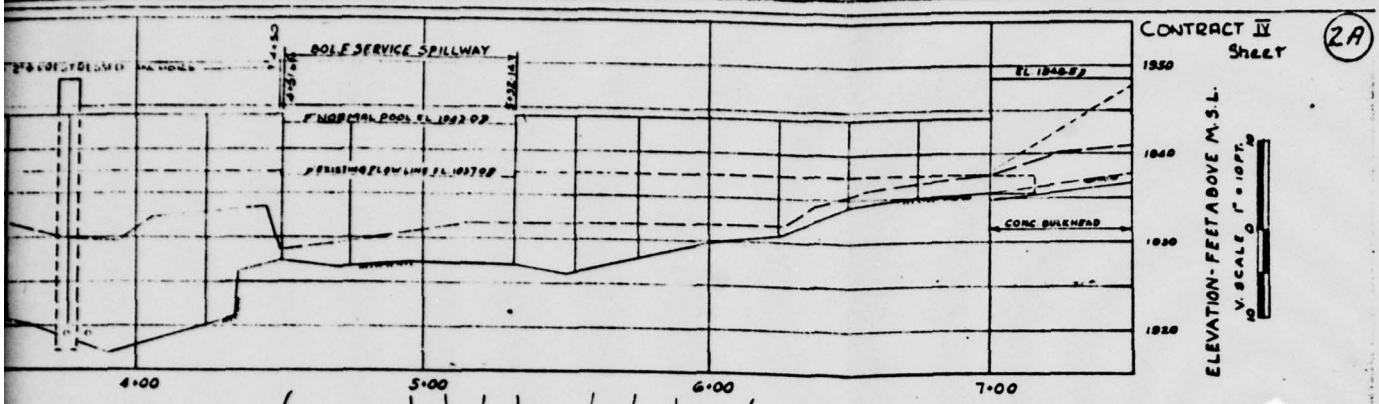

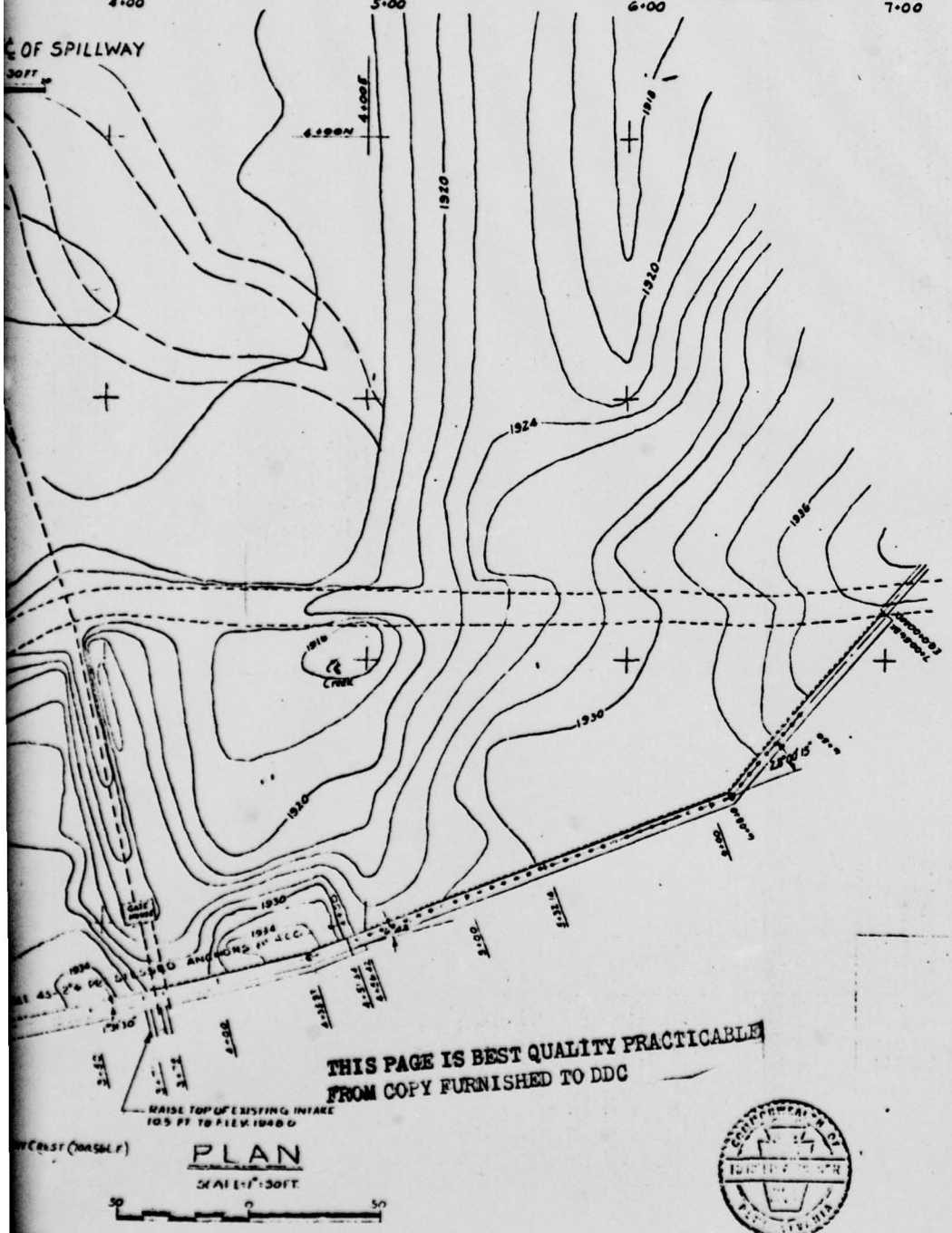

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NATIONAL DAM SAFETY PROGRAM

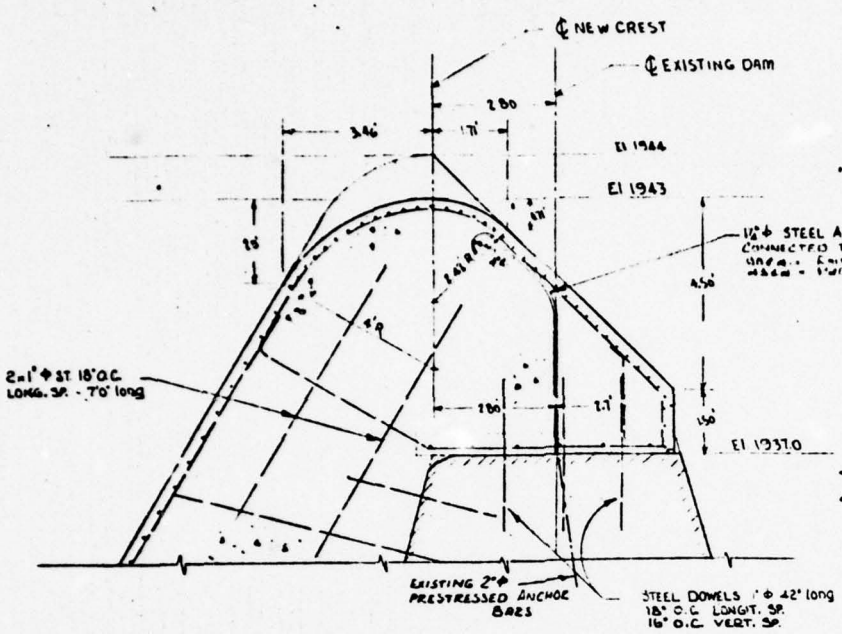
CRYSTAL LAKE DAM

PENNSYLVANIA GAS AND WATER COMPANY

PLAN AND PROFILE OF DAM

MAY 1978 PLATE 2

2



CREST DETAIL
SERVICE SPILLWAY
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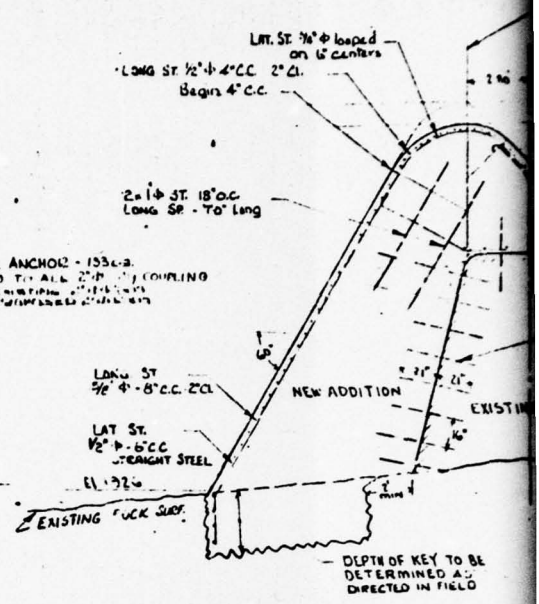
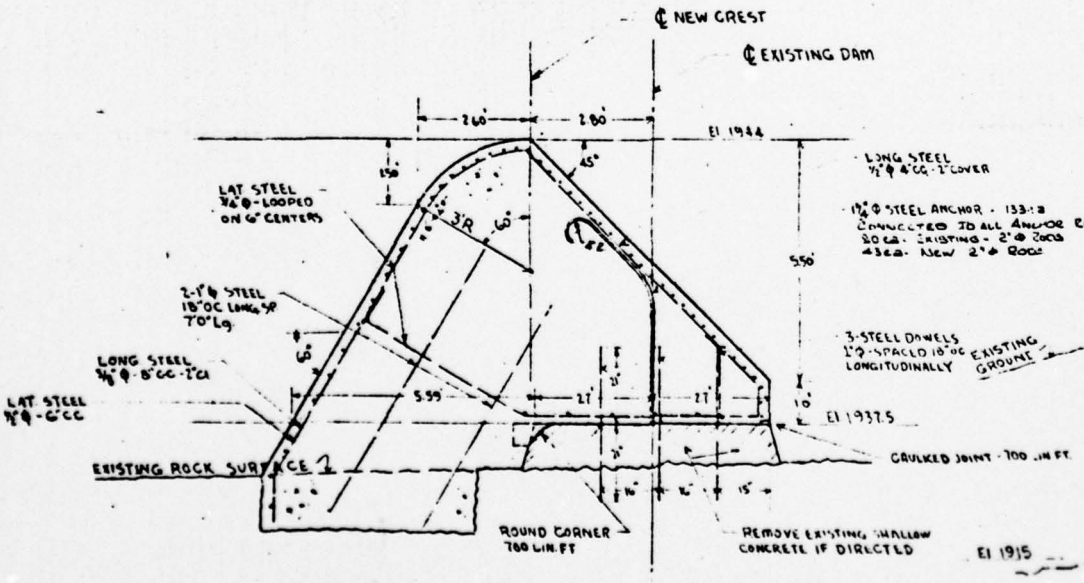
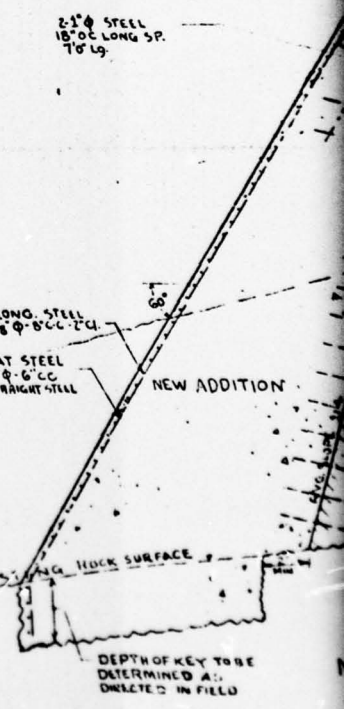


SERVICE SP
SECTION STA
SCALE 1"=





TYPICAL CREST DETAIL
STA 0+10
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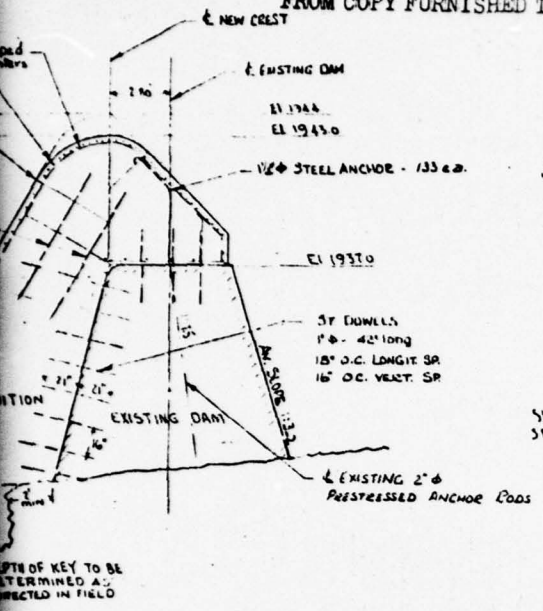

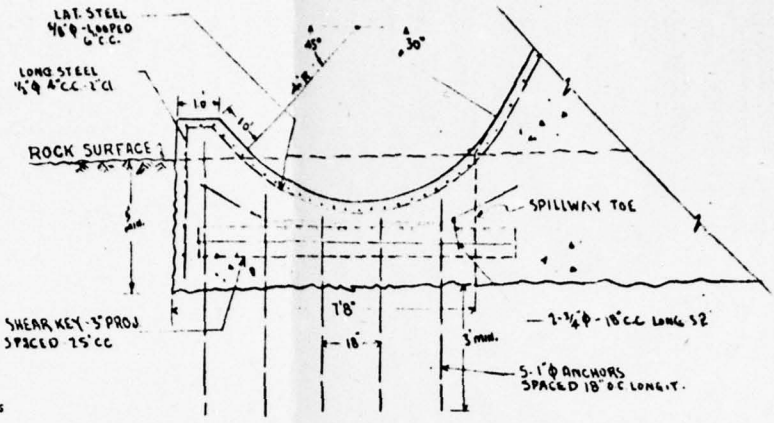

BUCKET DETAIL - ALTERNATIVE

SERVICE SPILLWAY ONLY

Scale: 1 in = 2 ft

SERVICE SPILLWAY
SECTION STA 5+00
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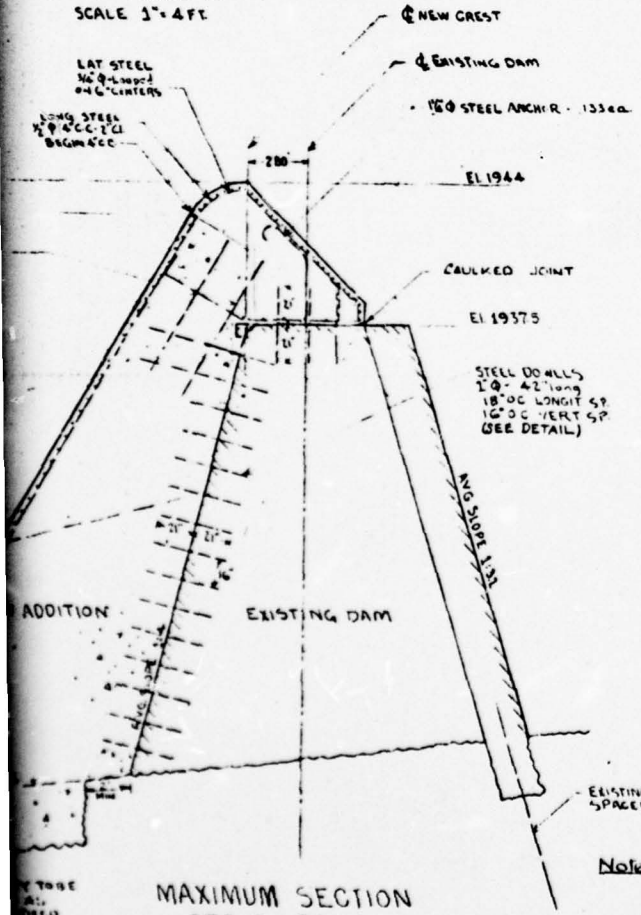

MAXIMUM SECTION
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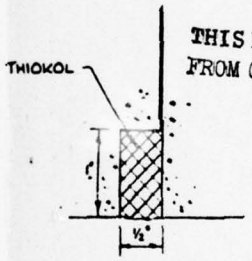
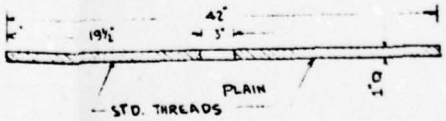


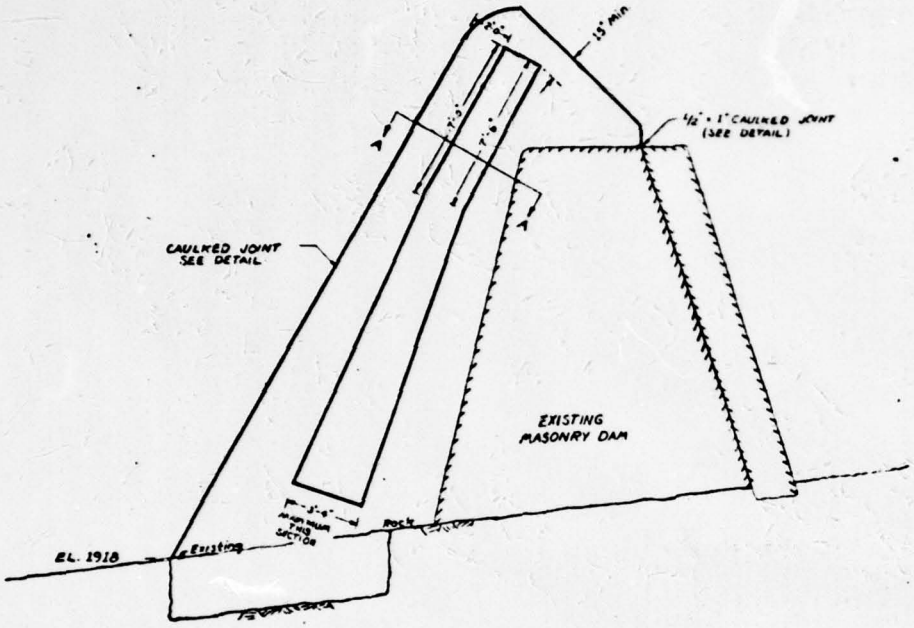
CAULKED JOINT
DETAIL
Scale - Full Size



1ℓ DOWEL DETAIL
SCALE ⅛" = 1'0"

Note:-
Remove bituminous layer from existing dam and steel shall bear surfaces

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
CRYSTAL LAKE DAM
PENNSYLVANIA GAS AND WATER COMPANY
SPILLWAY DETAILS SHEET I
MAY 1978 PLATE 3



CONTRACTION JOINT DETAIL
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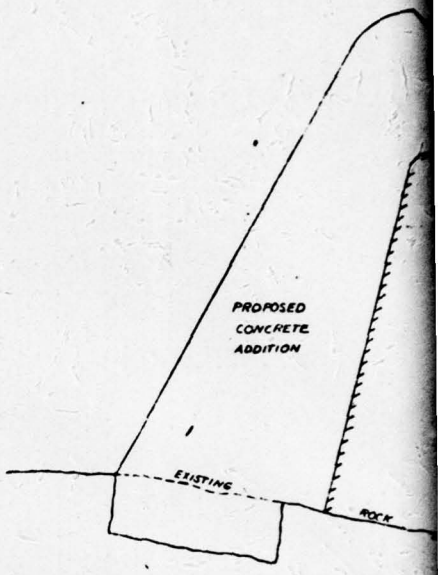
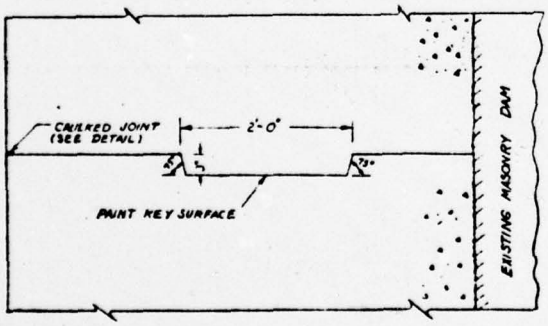


STA.

TYPICAL SECTION

SCALE



SHEAR KEY DETAIL - SECT. AA
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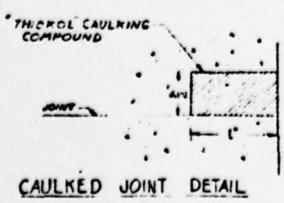

CAULKED JOINT DETAIL
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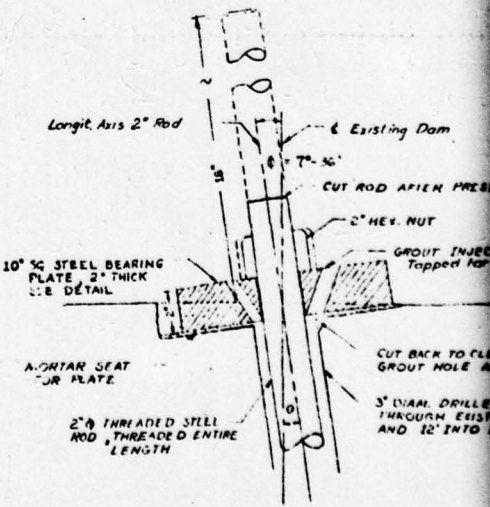

SECTION DETAIL OF PRESTRESS ROD ANCHORAGE
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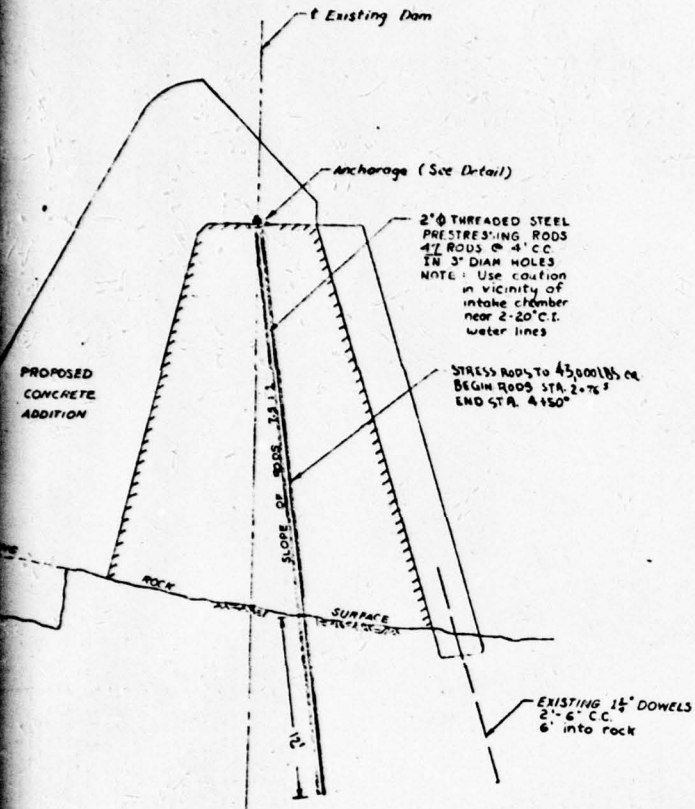

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STA. 3+22.5

YPICAL SECTION THROUGH PRESTRESS ROD

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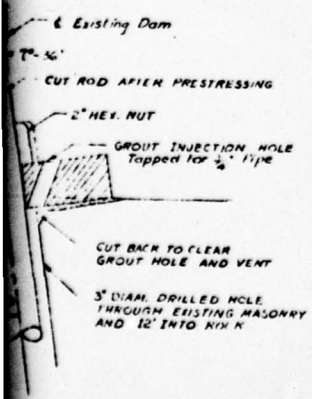

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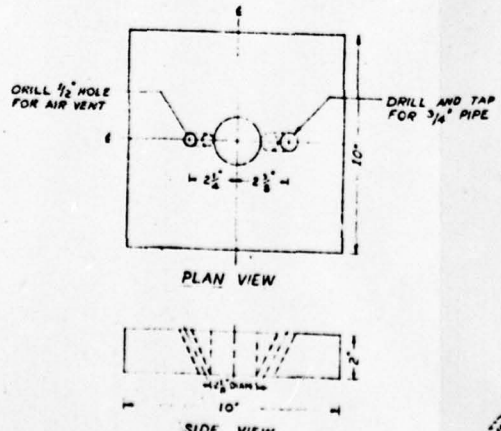


DETAIL OF BEARING PLATE

SCALE: ½" = 1"

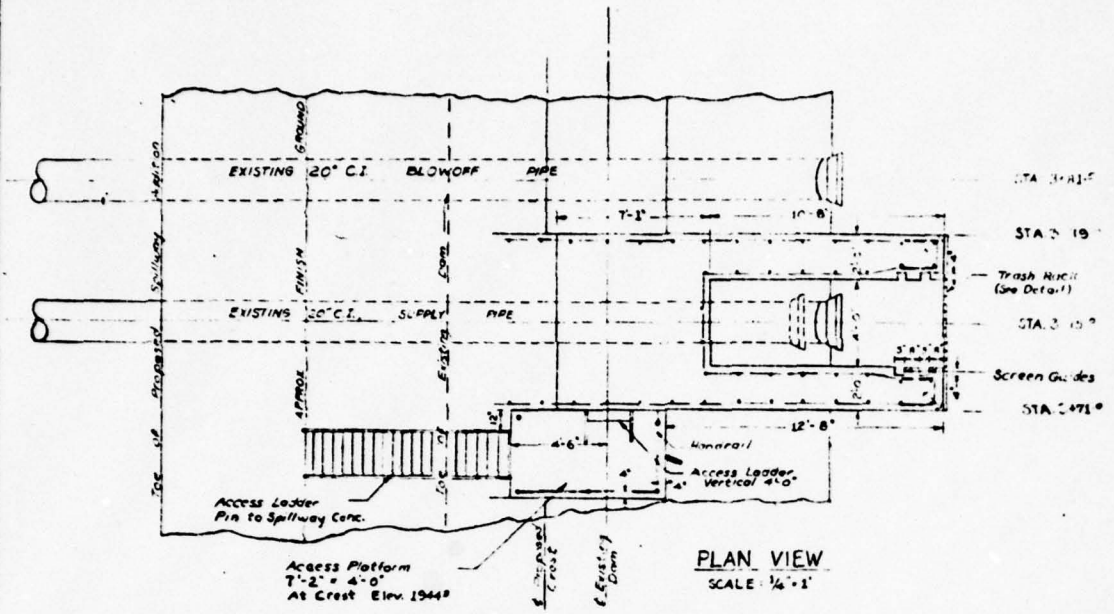
PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

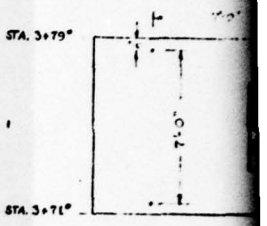
CRYSTAL LAKE DAM

PENNSYLVANIA GAS AND WATER COMPANY

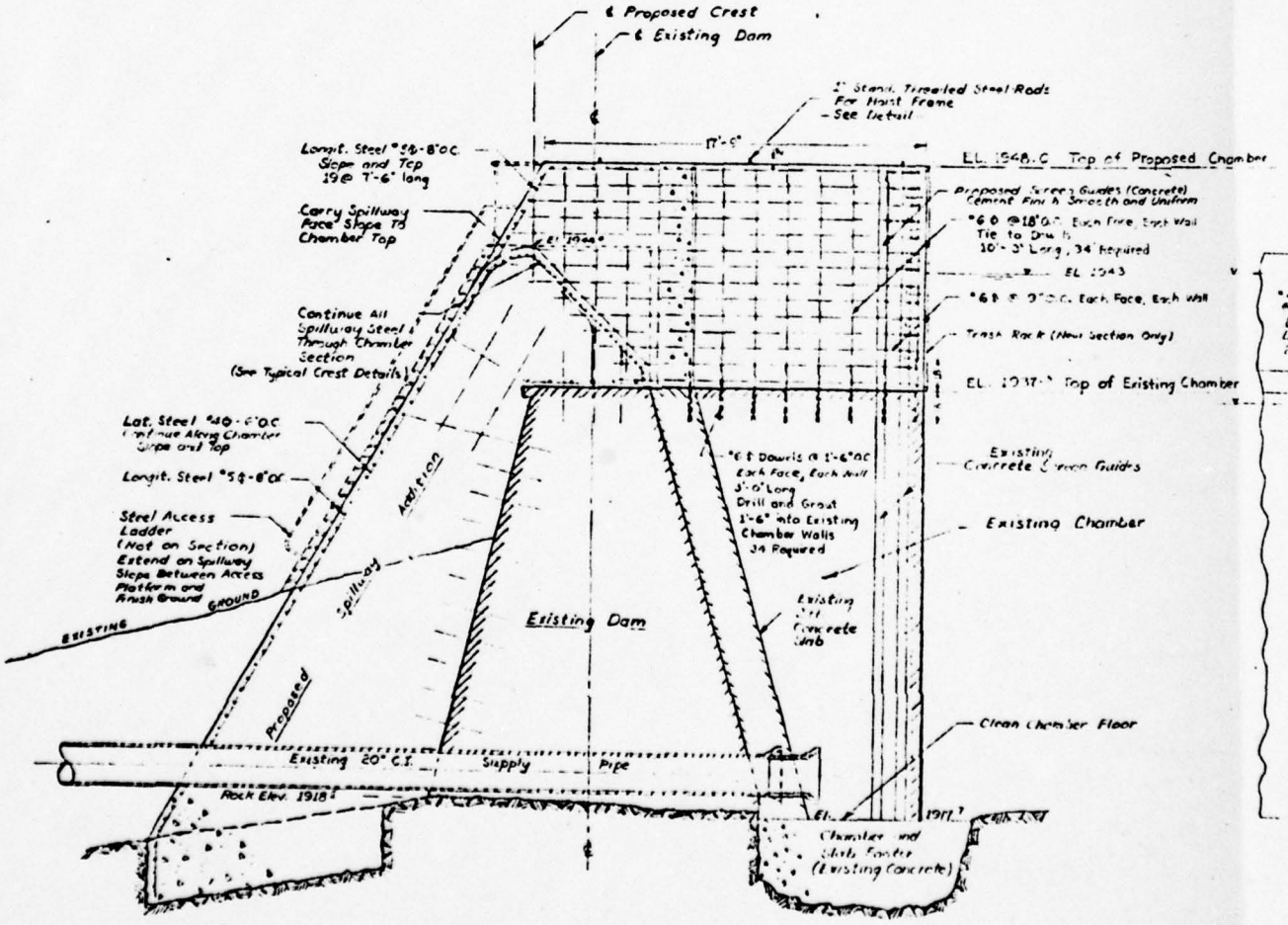
SPILLWAY DETAILS SHEET 2

MAY 1978 PLATE 4





DETAIL
FRAME



SECTION THROUGH CHAMBER
AT STATION 3+75.0
SCALE: 1/4" = 1'

(VIEWING

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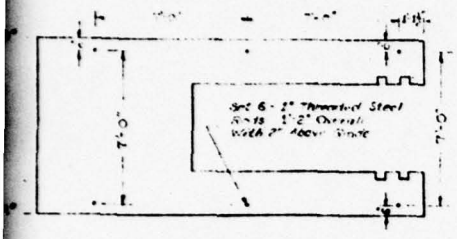
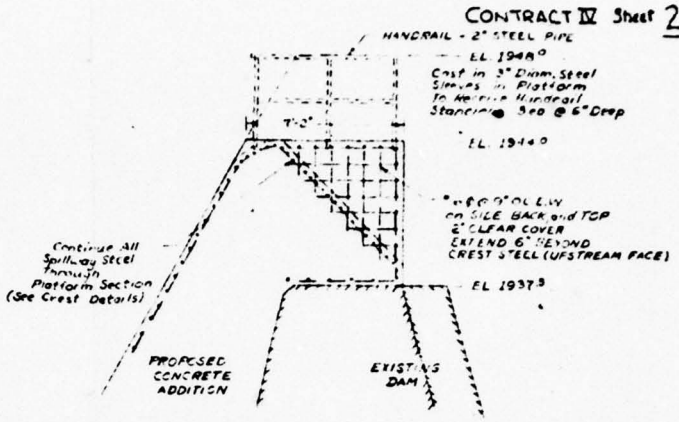


DETAIL OF HOISTING
FRAME HOLD-DOWN PINS
PLAN VIEW
SCALE - 4/4" - 1'



SECTION THROUGH CHAMBER
ACCESS PLATFORM
SCALE - 1/4" - 1'

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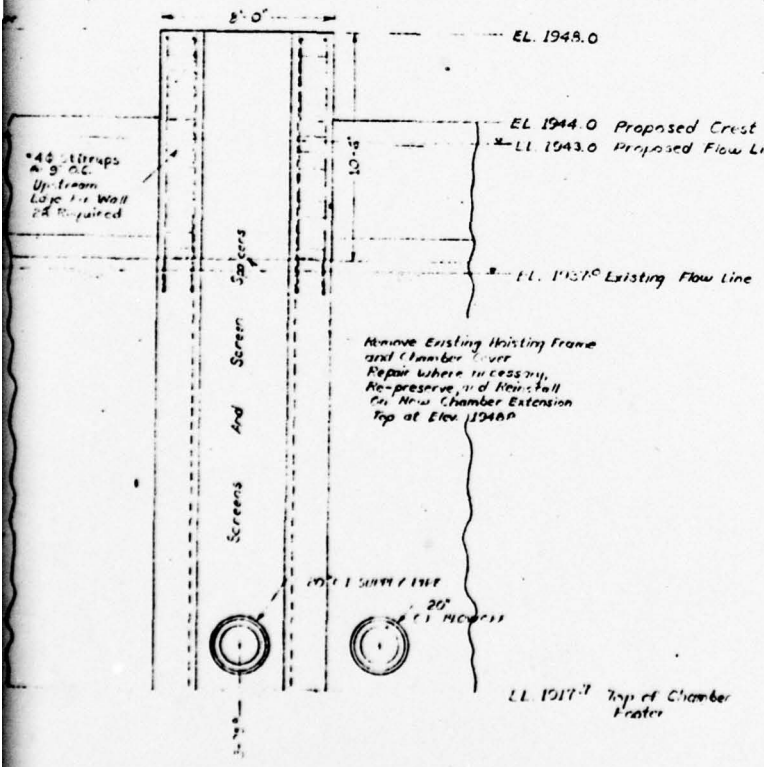
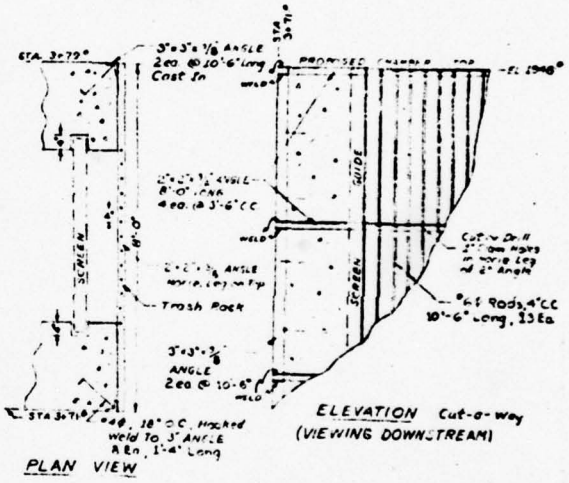


ELEVATION
(VIEWING DOWNSTREAM)
SCALE - 1/4" - 1'



TRASH RACK DETAIL - Scale - 1/2" - 1'

NOTES:

1) Chamber Extension to be poured monolithicly with spillway section
2) Verify Hoisting Frame dimensions in field prior setting hold-down pins
3) Minimum Concrete Cover Over Reinforcing Steel - 2"
4) Provide 1" Chamfer on all concrete edges and intersections.
5) Remove Existing Hoisting Frame, Repair As Necessary, Re-preserve, And Reinstall On Raised Chamber. Do Same with Existing Chamber Cover

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

CRYSTAL LAKE DAM

PENNSYLVANIA GAS AND WATER COMPANY

INTAKE CHAMBER

MAY 1978 PLATE 5

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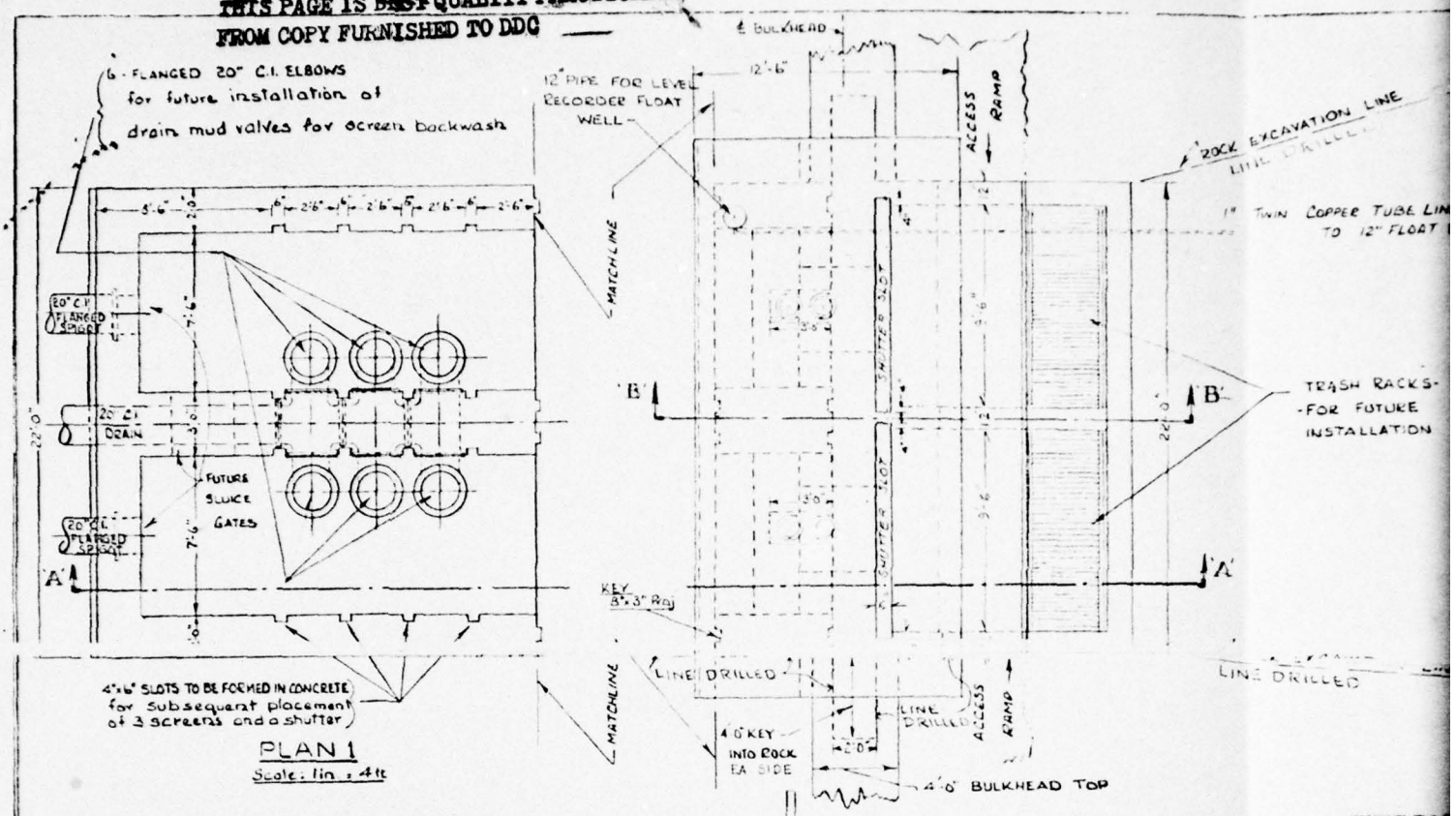

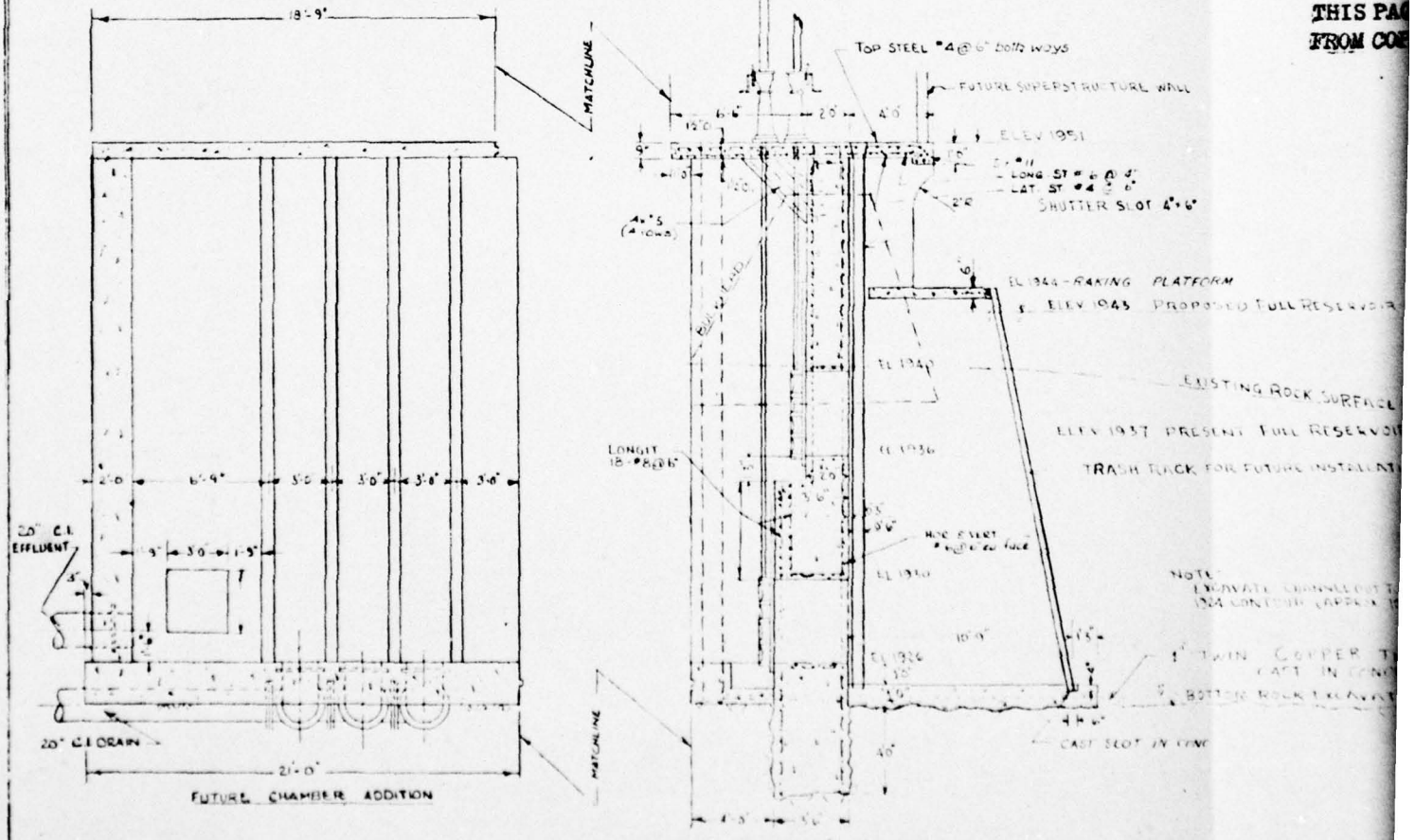

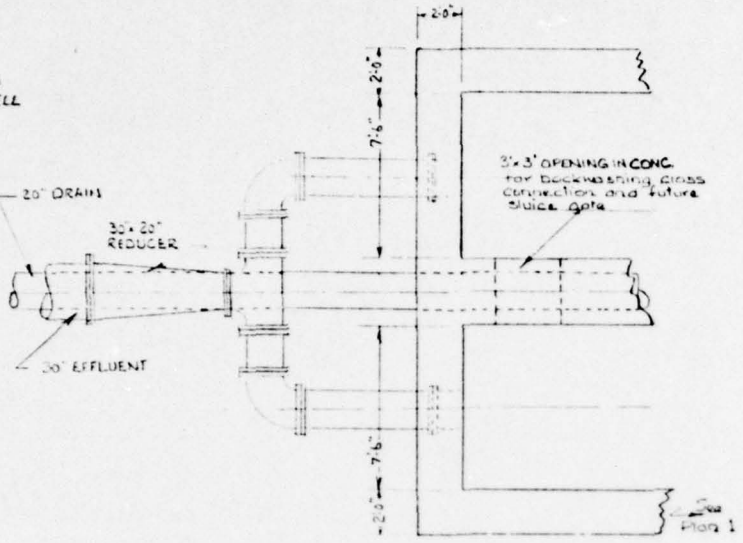

PLAN 2
Scale 1 in. = 4 ft.

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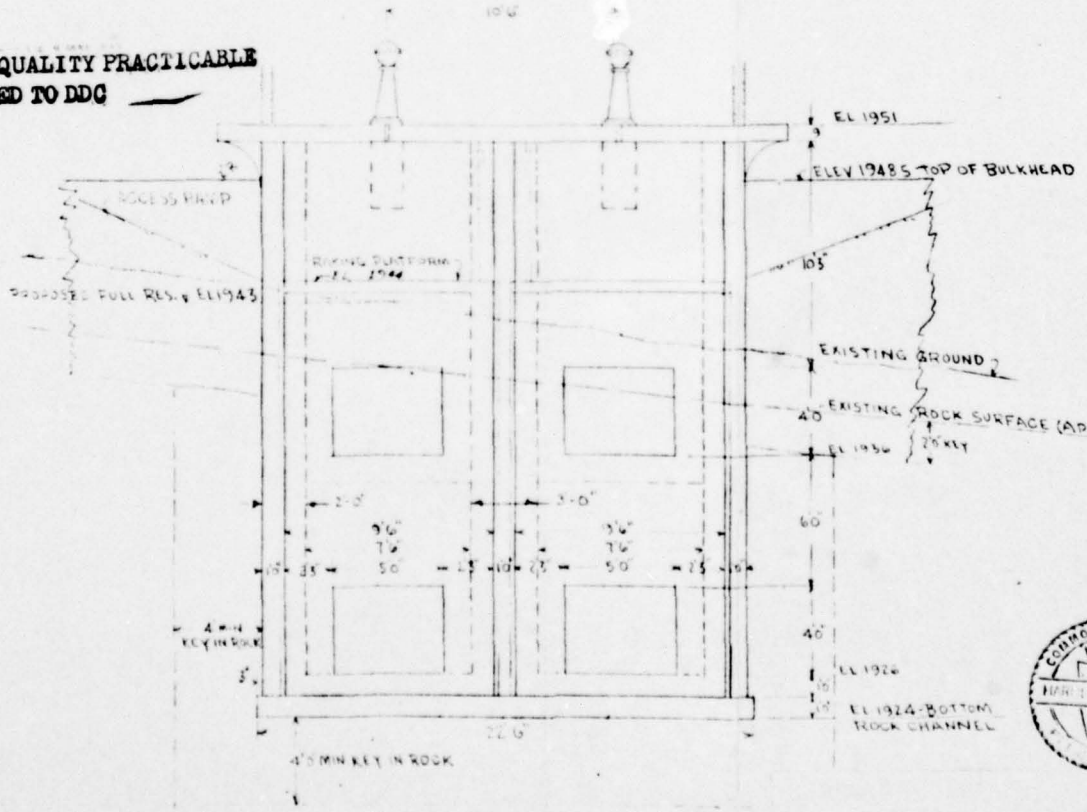

LAKE SIDE ELEVATION
SCALE 1/4" = 1'0"

COMMONWEALTH OF PENNSYLVANIA

PHAS
NATION
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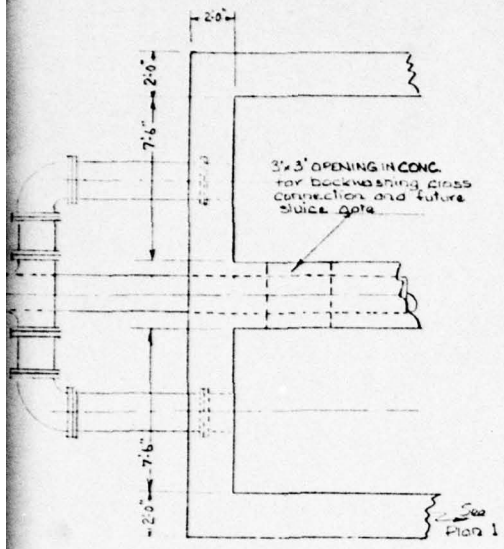
PENNSYLVA
EFF
MAY 1978

CONTRACT IV Sheet 5A



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n. = 44.

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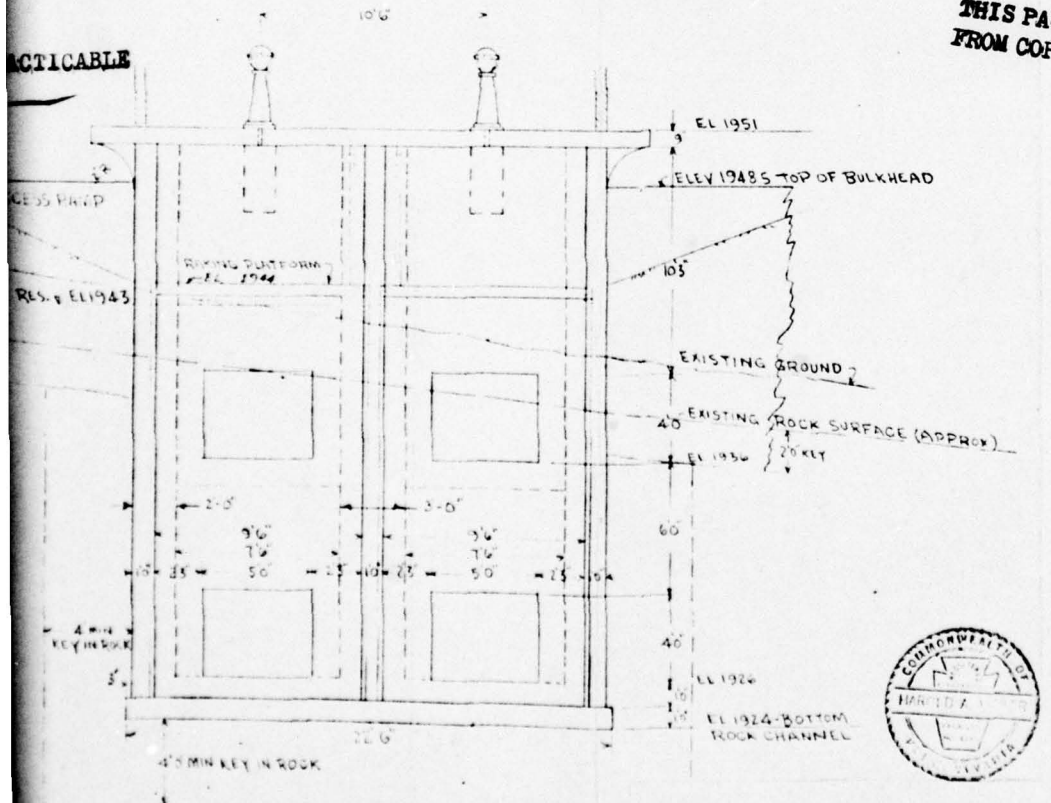


LAKE SIDE ELEVATION
SCALE 1/4" = 1'0"

COMMONWEALTH OF PENNSYLVANIA
HARRISBURG

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

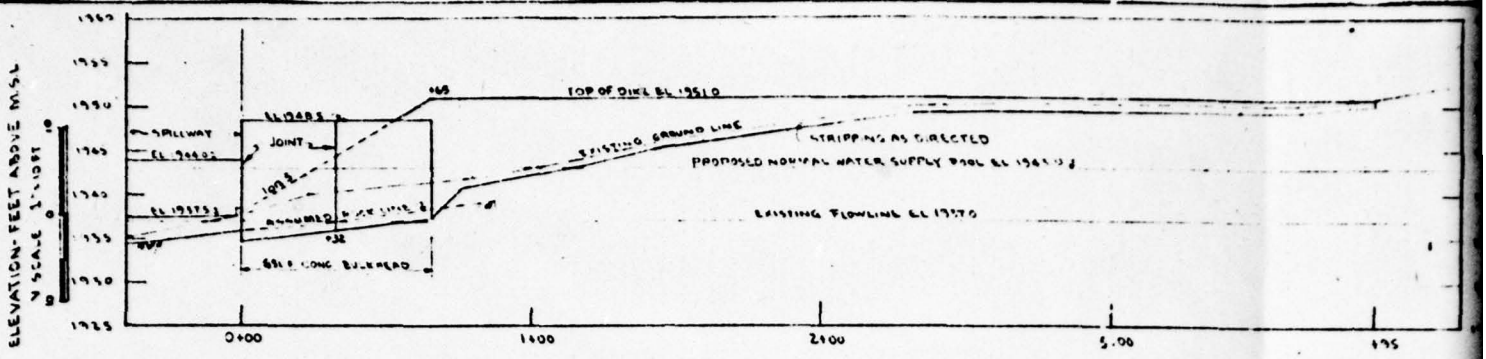
CRYSTAL LAKE DAM

PENNSYLVANIA GAS AND WATER COMPANY

EFFLUENT GATEHOUSE

MAY 1978 PLATE 6

3



PROFILE ALONG ℄ OF DIKE

SCALE 1" = 50FT

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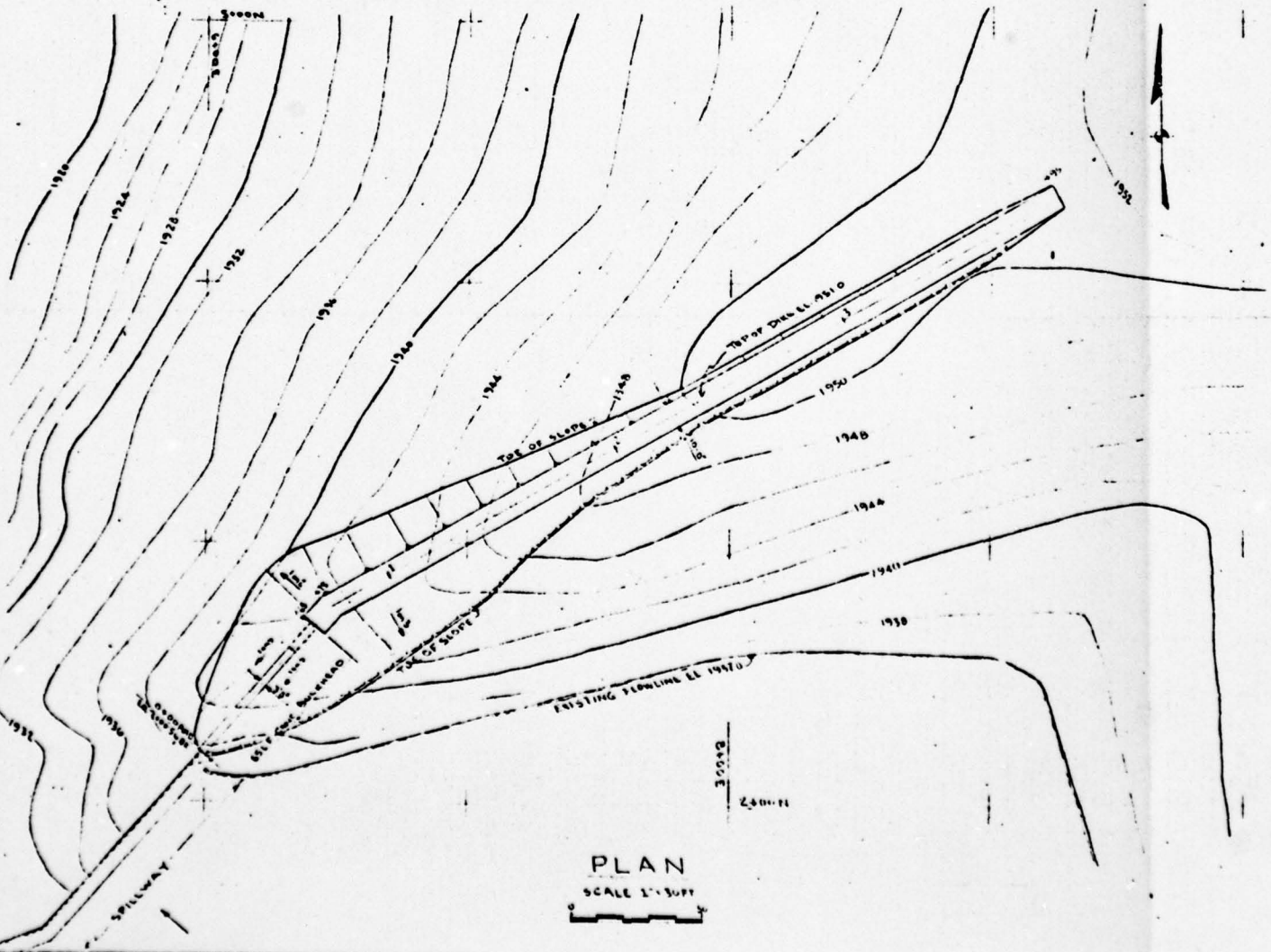

PLAN

SCALE 1" = 50FT

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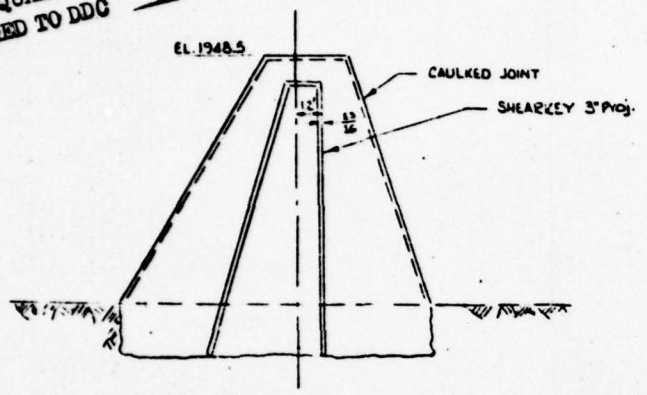
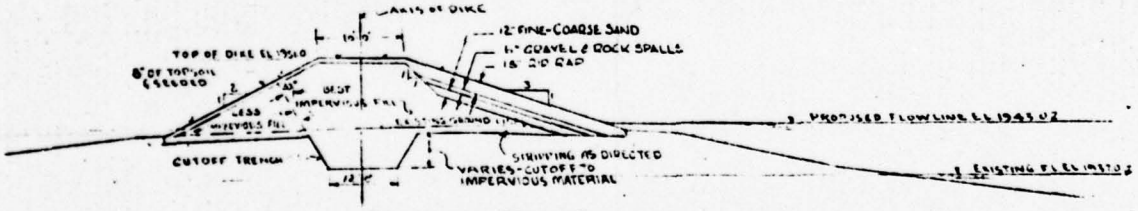
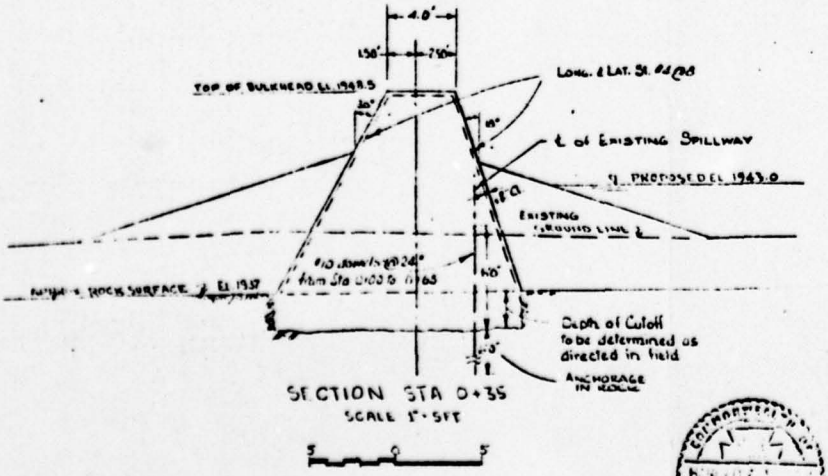


BULKHEAD
LATERAL JOINT DETAIL
(TYPICAL)
Scale: 1" = 4 ft



SECTION STA 1+00
SCALE 1" = 10 FT



SECTION STA 0+35
SCALE 1" = 5FT

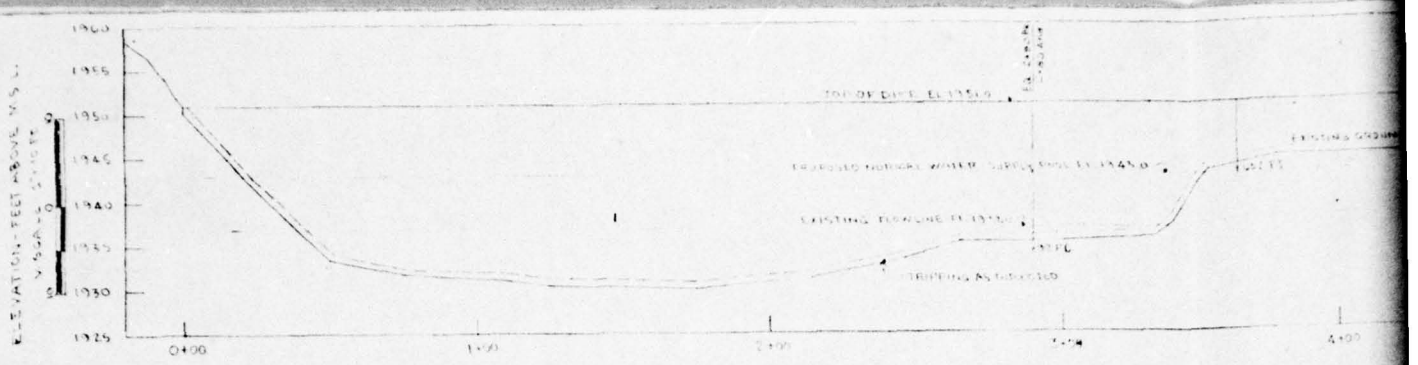
PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

CRYSTAL LAKE DAM

PENNSYLVANIA GAS AND WATER COMPANY

RIGHT ABUTMENT DIKE

MAY 1978 PLATE 7



PROFILE ALONG ℄ DIKE

H SCALE 1" = 30FT

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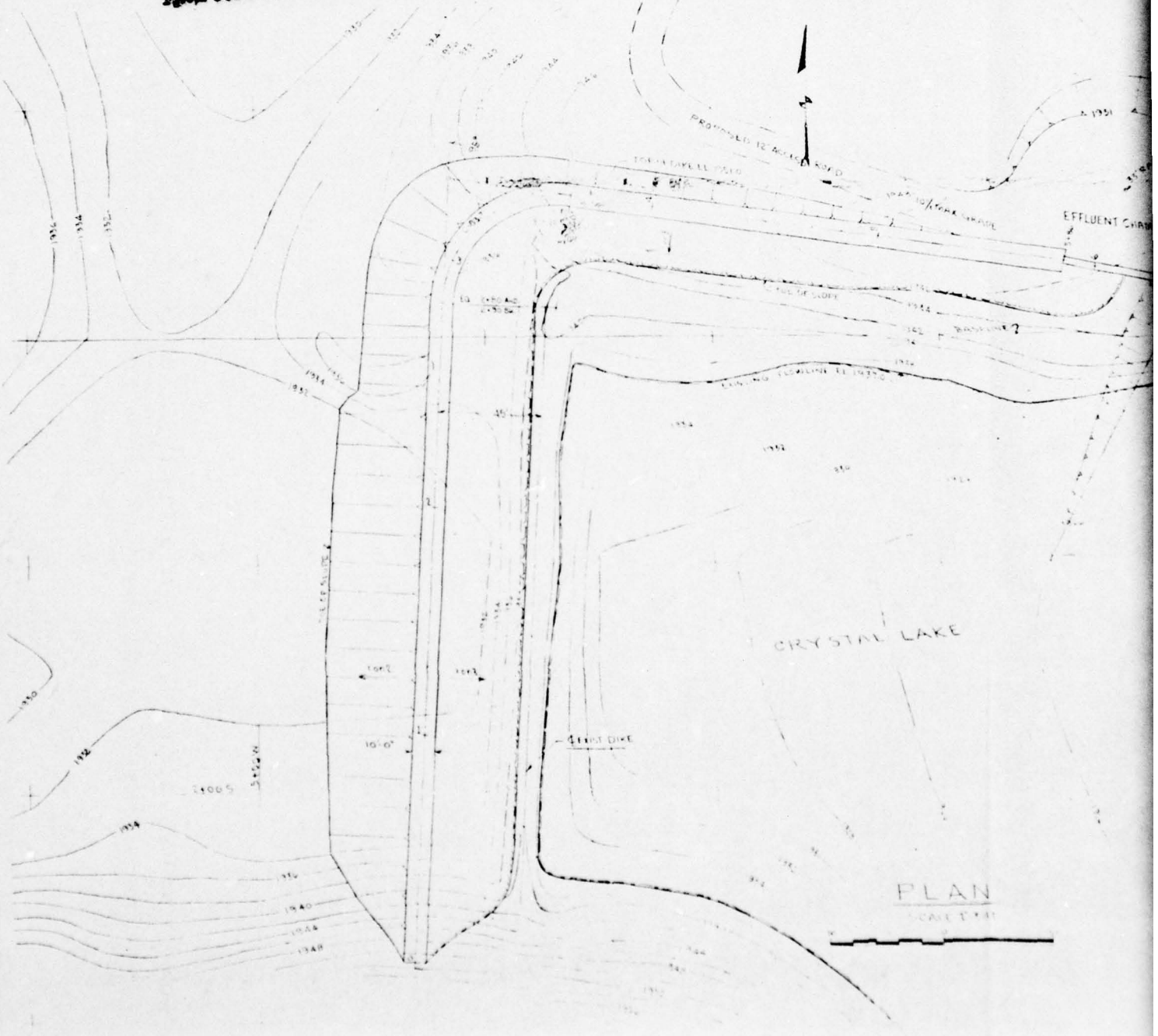

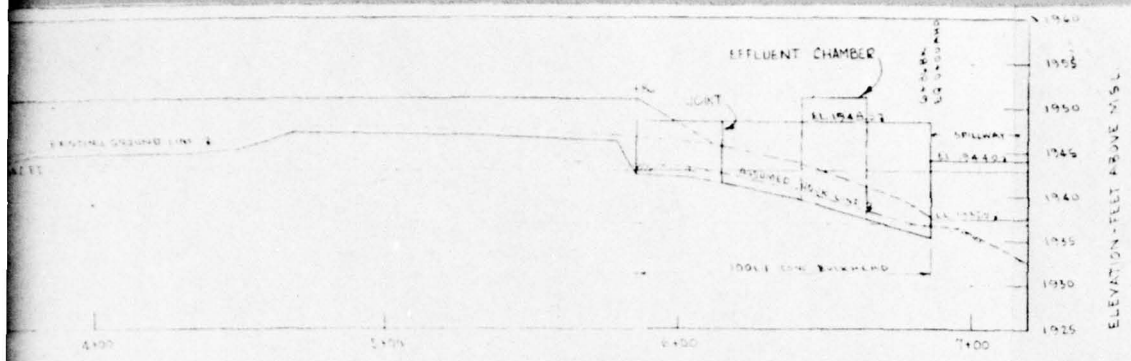

DIKE

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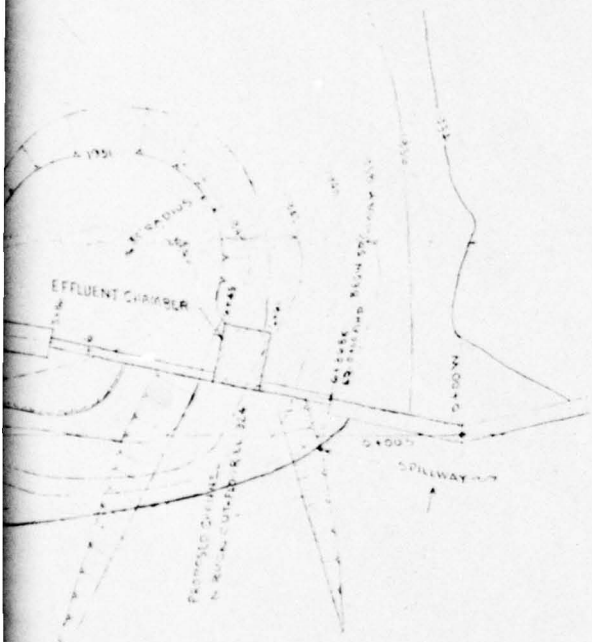

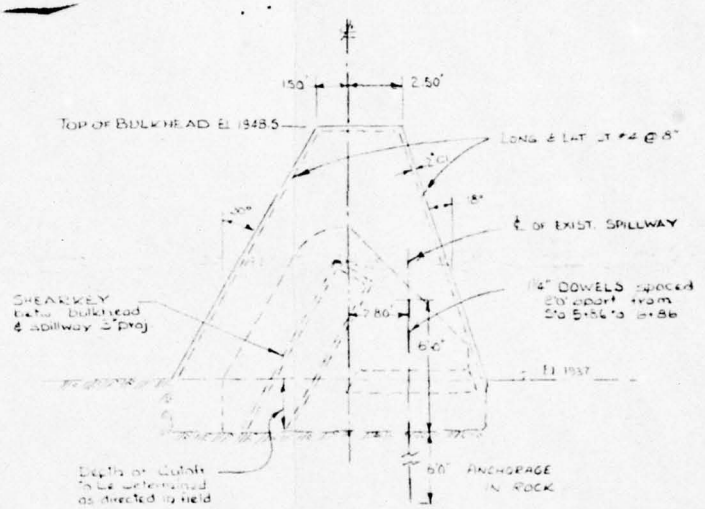

BULKHEAD SECTION
STA 6+86
Scale 1" = 5 FEET

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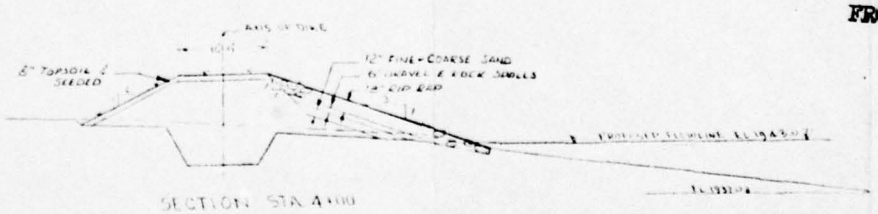
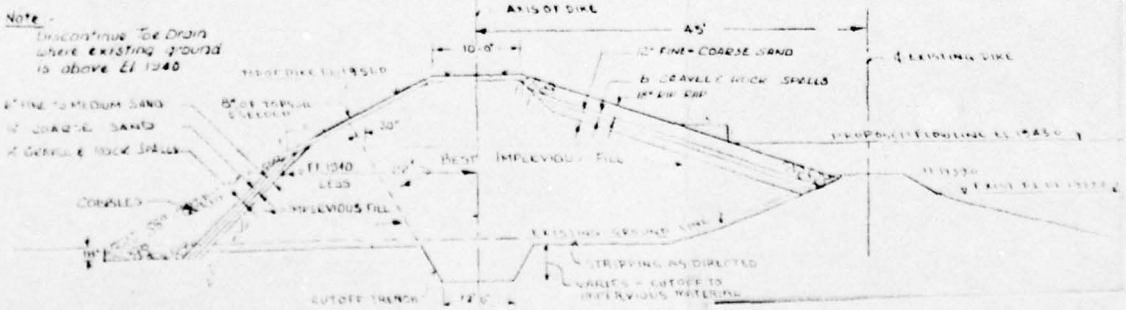


SECTION STA 4+00
SCALE 1" = 10 FT



SECTION STA 1+00
SCALE 1" = 10 FT

PHAS
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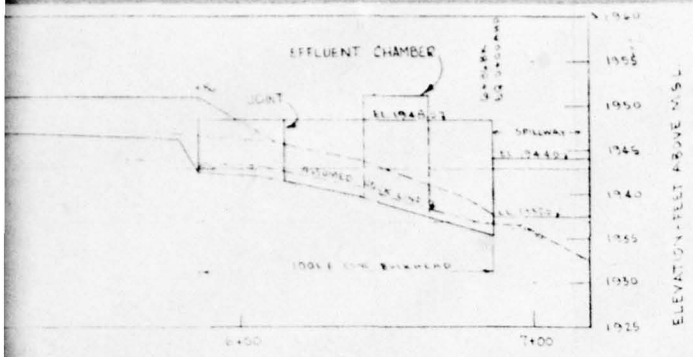
MAY 1978

CONTRACT IV Sheet (3)



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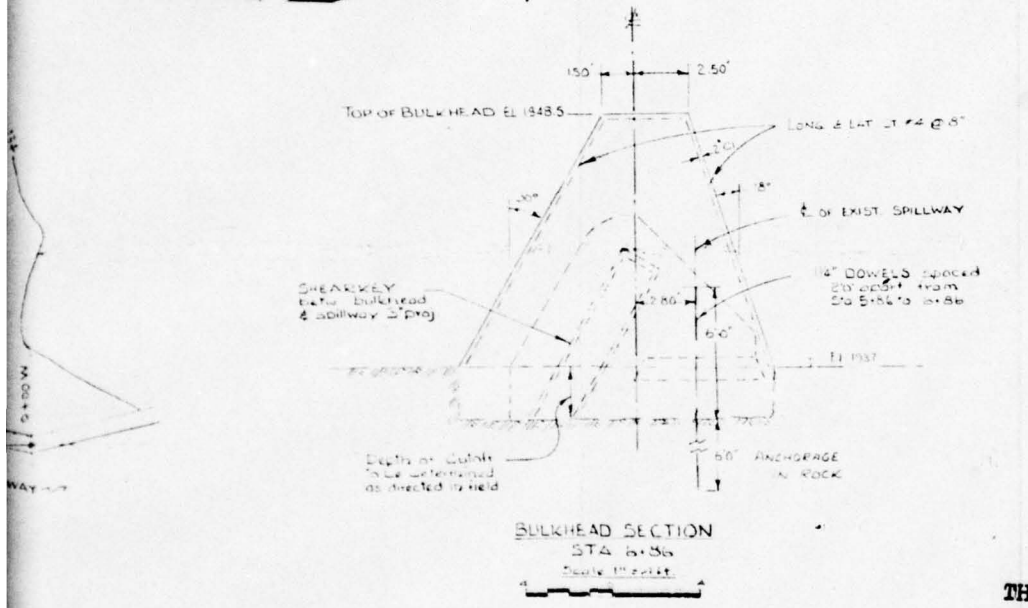

BULKHEAD SECTION
STA 6+86
Scale 1"=5'-0"

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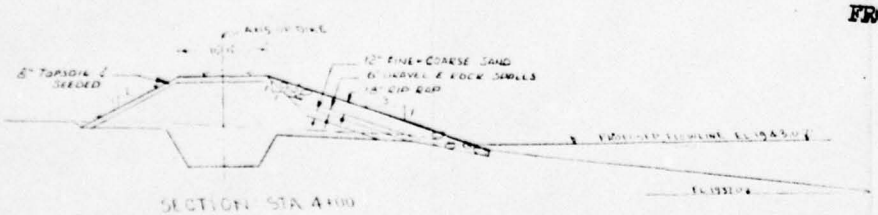
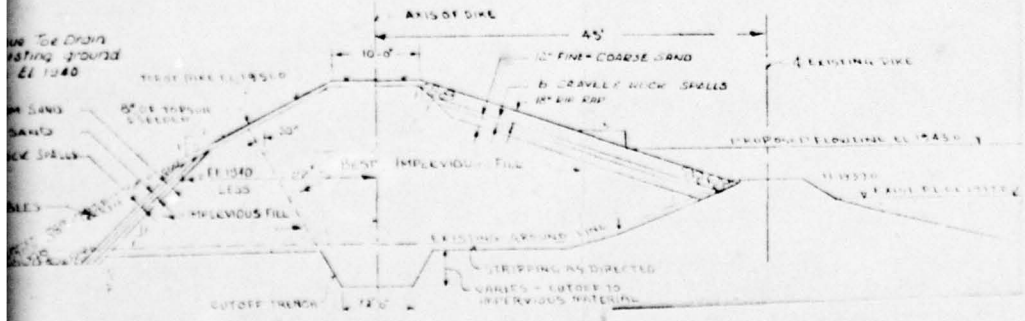


SECTION STA 4+00
SCALE 1"=10'-0"



SECTION STA 1+00
SCALE 1"=10'-0"

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

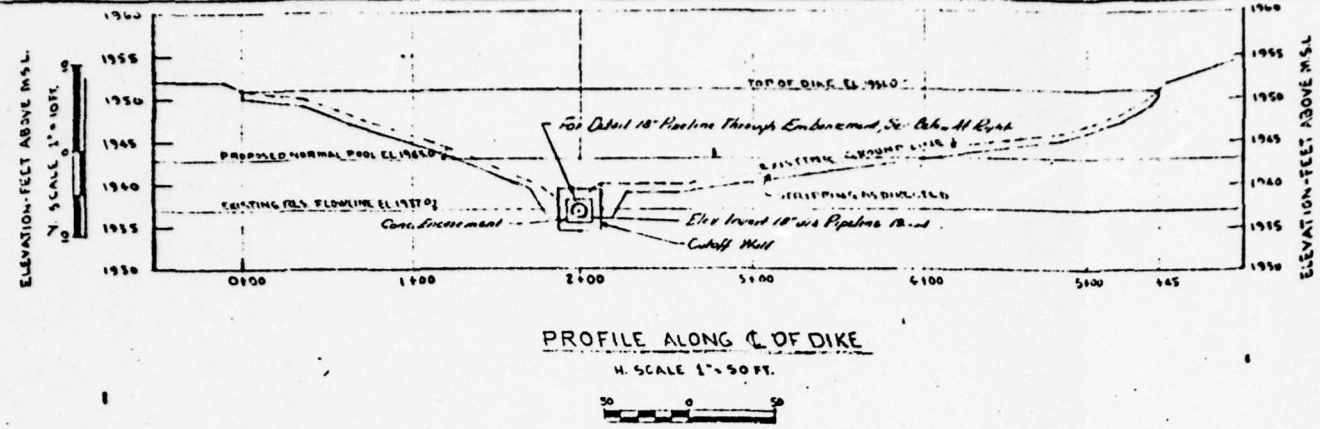
CRYSTAL LAKE DAM

PENNSYLVANIA GAS AND WATER COMPANY

LEFT ABUTMENT DIKE

MAY 1978 PLATE 8

3



PROFILE ALONG ℄ OF DIKE

H. SCALE 1" = 50 FT.

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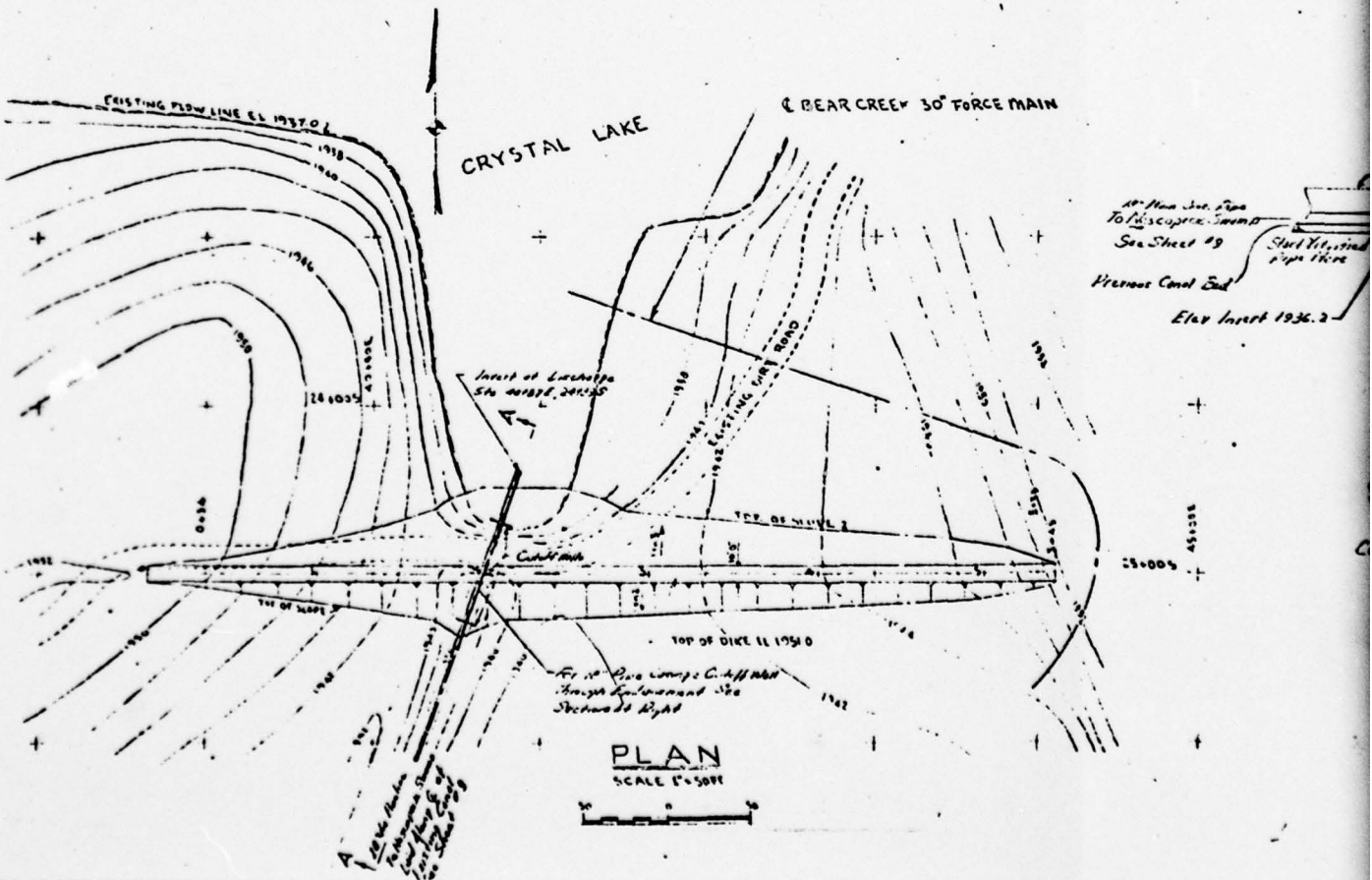

PLAN

SCALE 1" = 50 FT.

CONTRACT IV Sheet (6)

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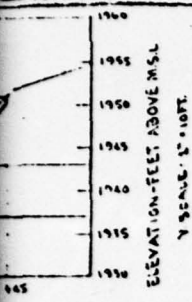
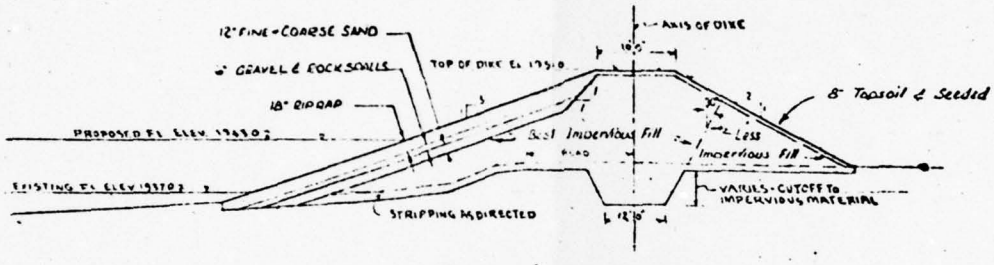
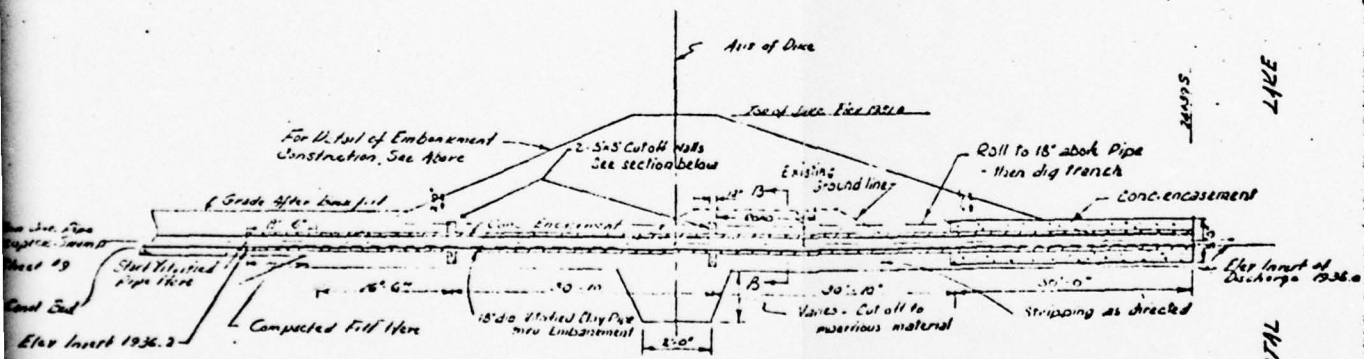
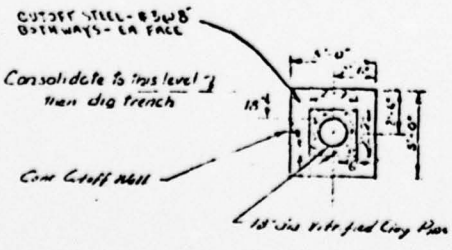




SECTION STA 2+40
0 SCALE 1"=10FT. 20



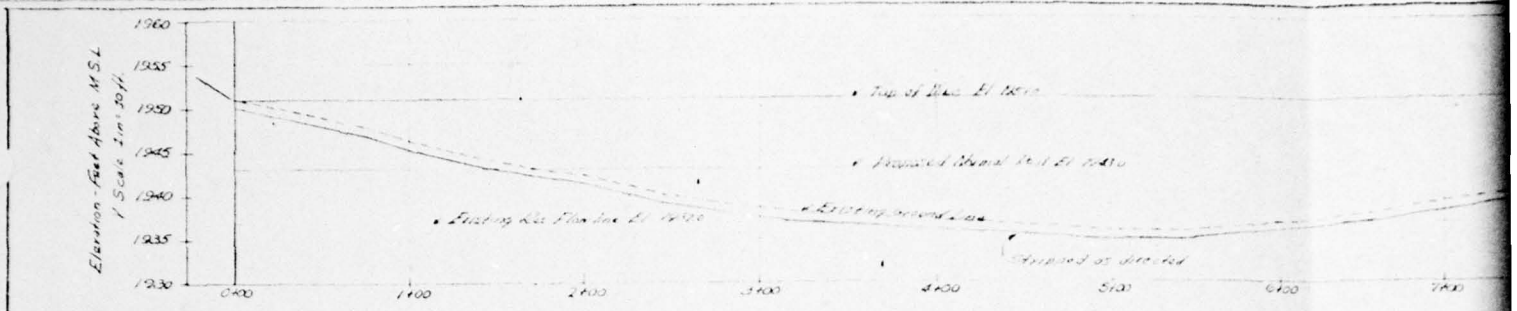
PROFILE OF PIPELINE THROUGH EMBANKMENT
SECTION A-A
0 Scale 1"=10' 20



SECTION B-B
Scale 1"=5' 10

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM
CRYSTAL LAKE DAM
PENNSYLVANIA GAS AND WATER COMPANY
SOUTH DIKE
MAY 1978 PLATE 9

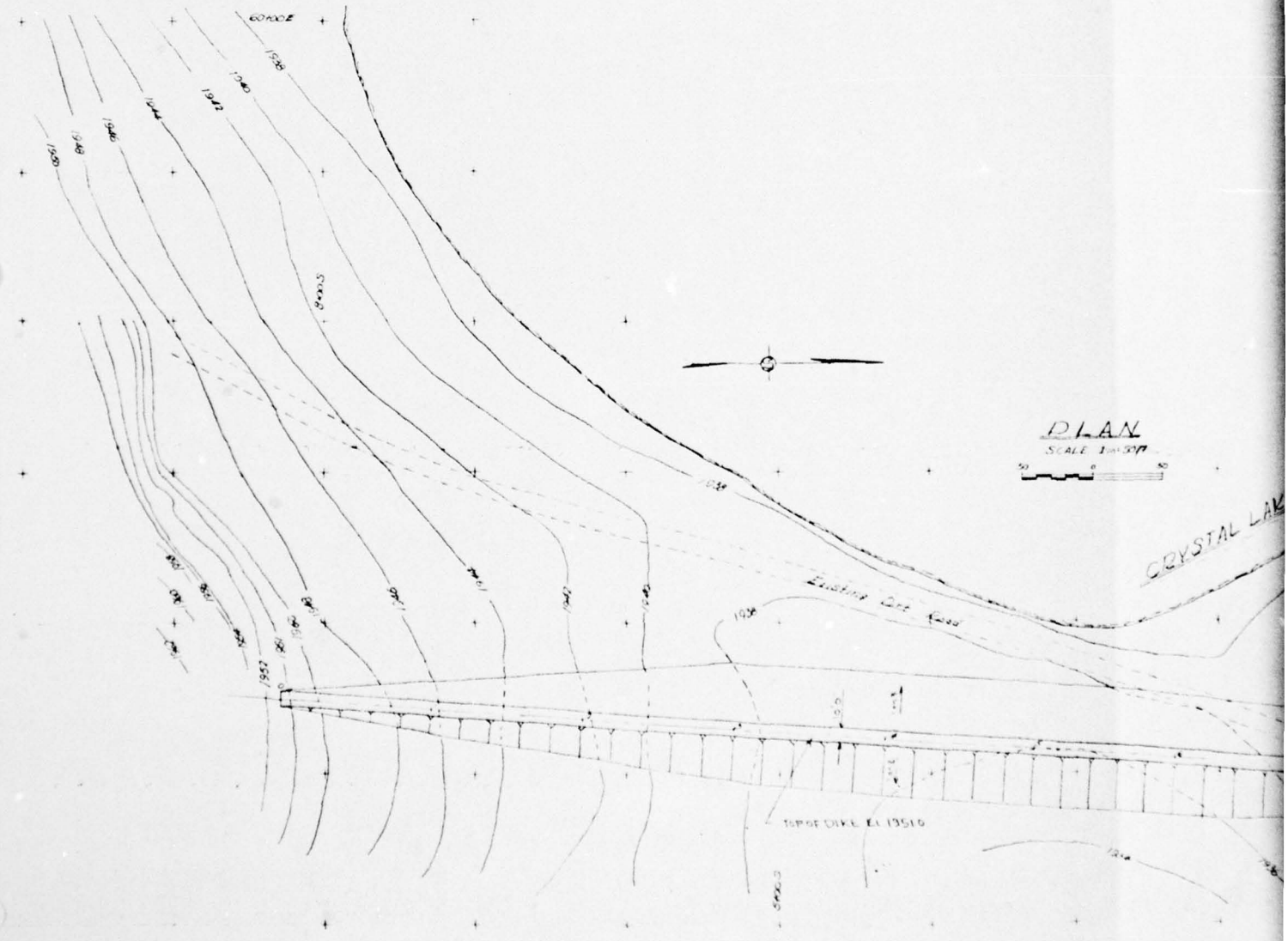
2

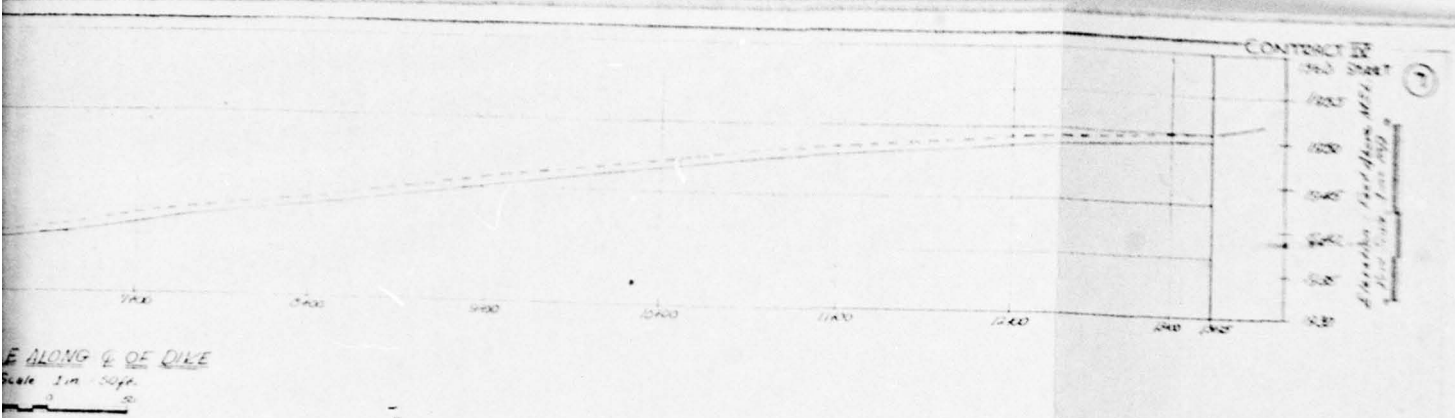


PROFILE ALONG ℄ OF DIKE

H Scale 1 in 50 ft.

50 0 50





E ALONG ℄ OF DIKE
Scale 1 in = 50 ft.

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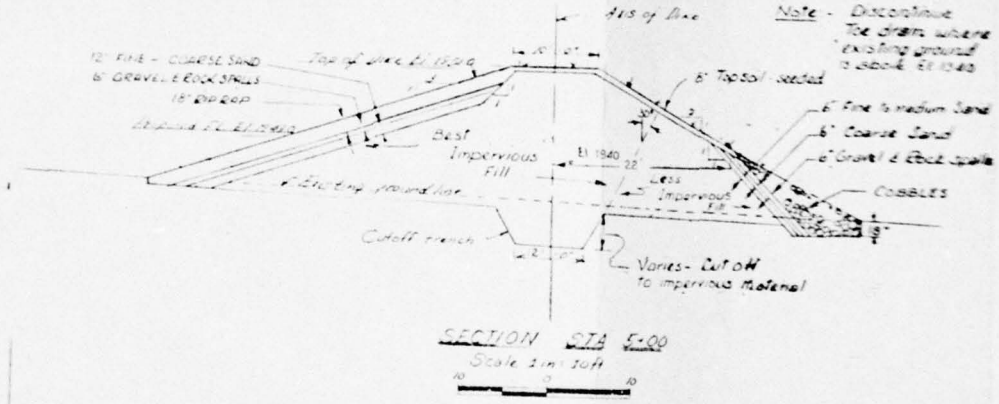
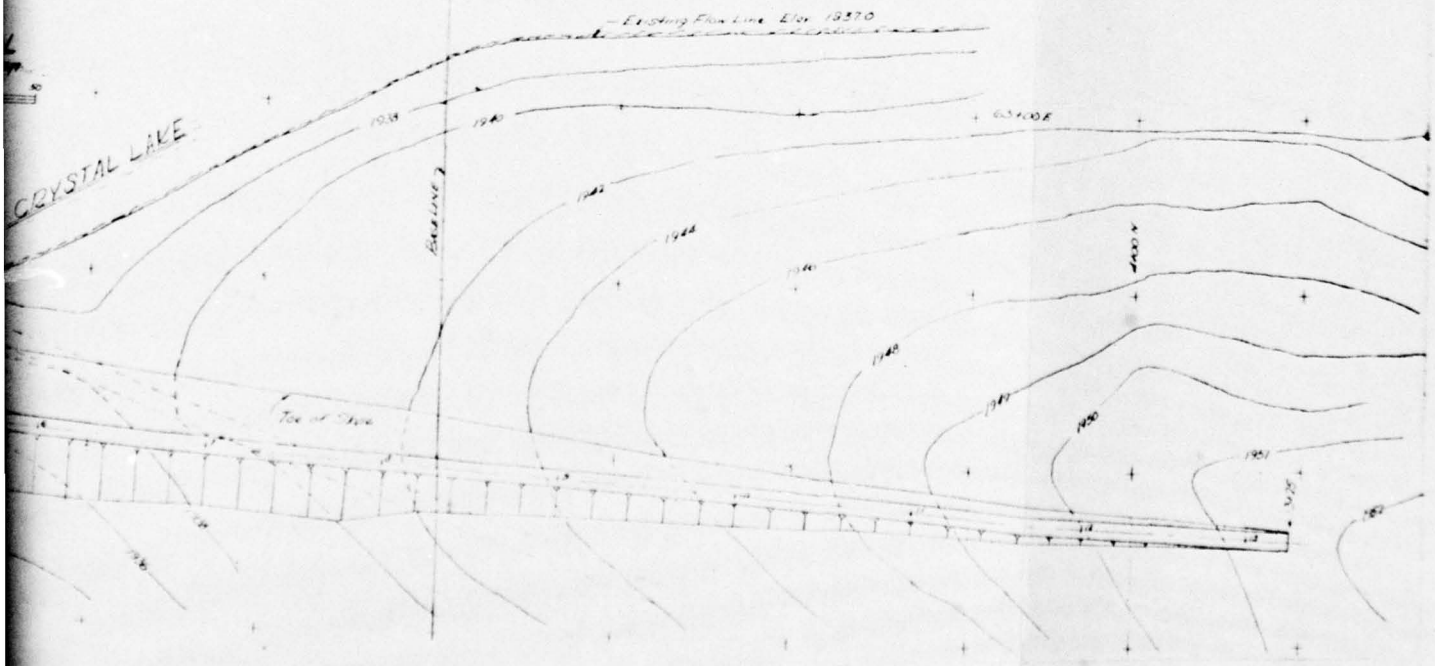


SECTION STA 5+00
Scale 1 in = 10 ft
10 0 10



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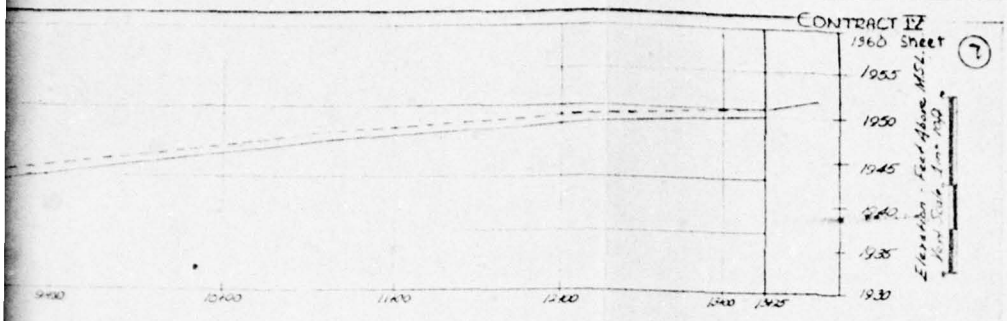

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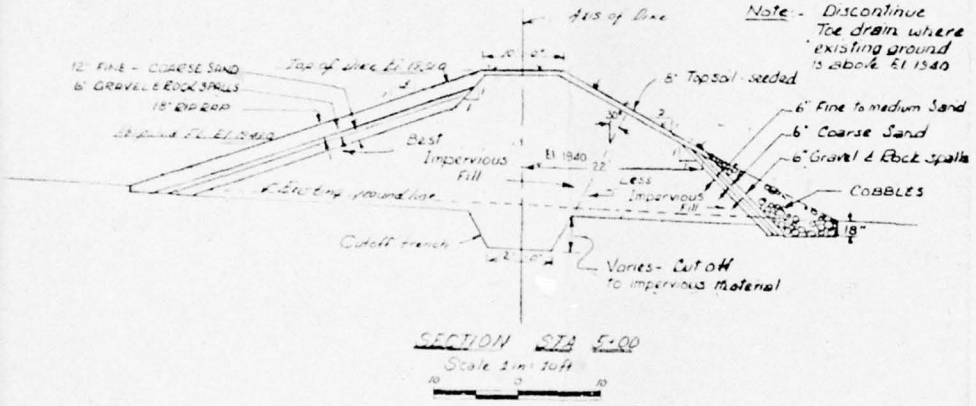

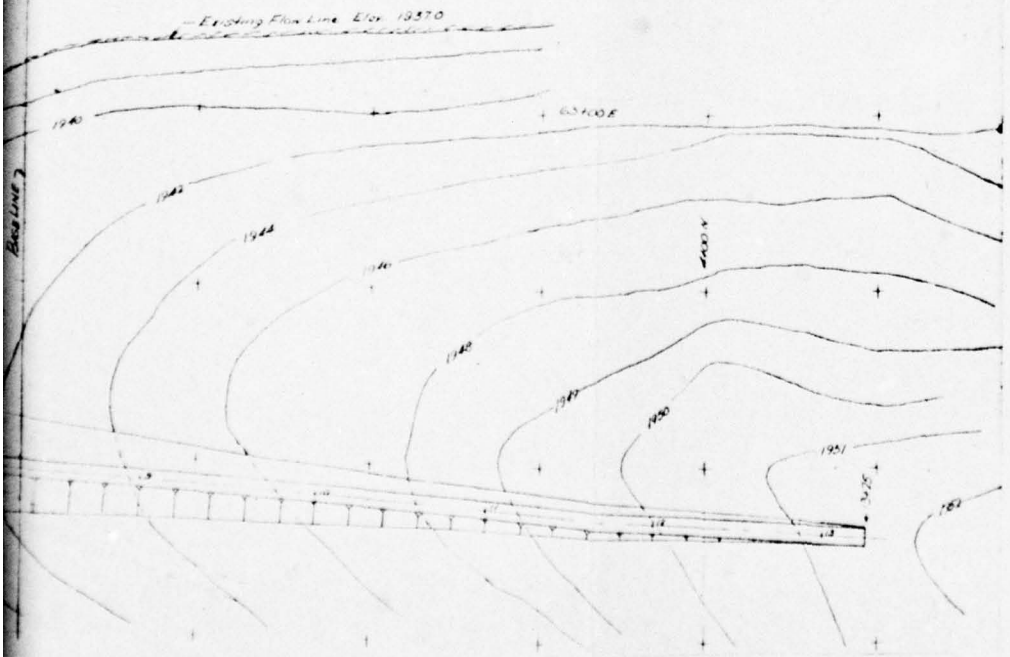

PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

CRYSTAL LAKE DAM

PENNSYLVANIA GAS AND WATER COMPANY

SOUTH-EAST DIKE

MAY 1978 PLATE 10

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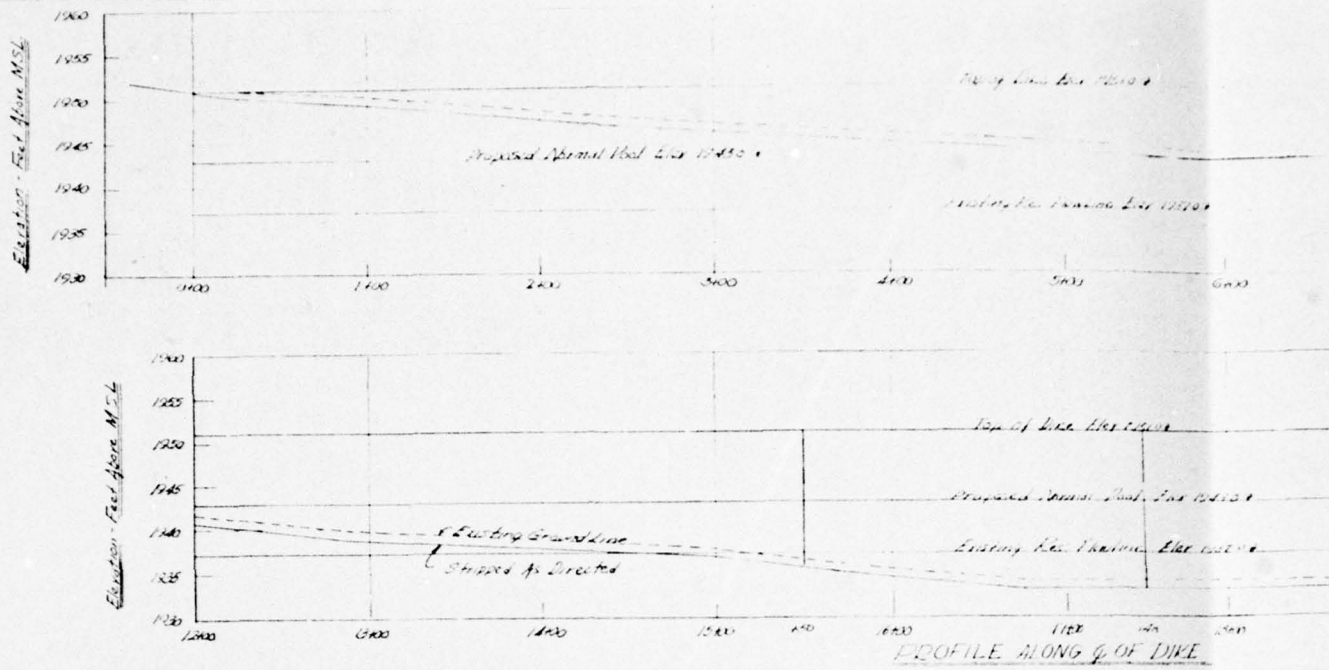

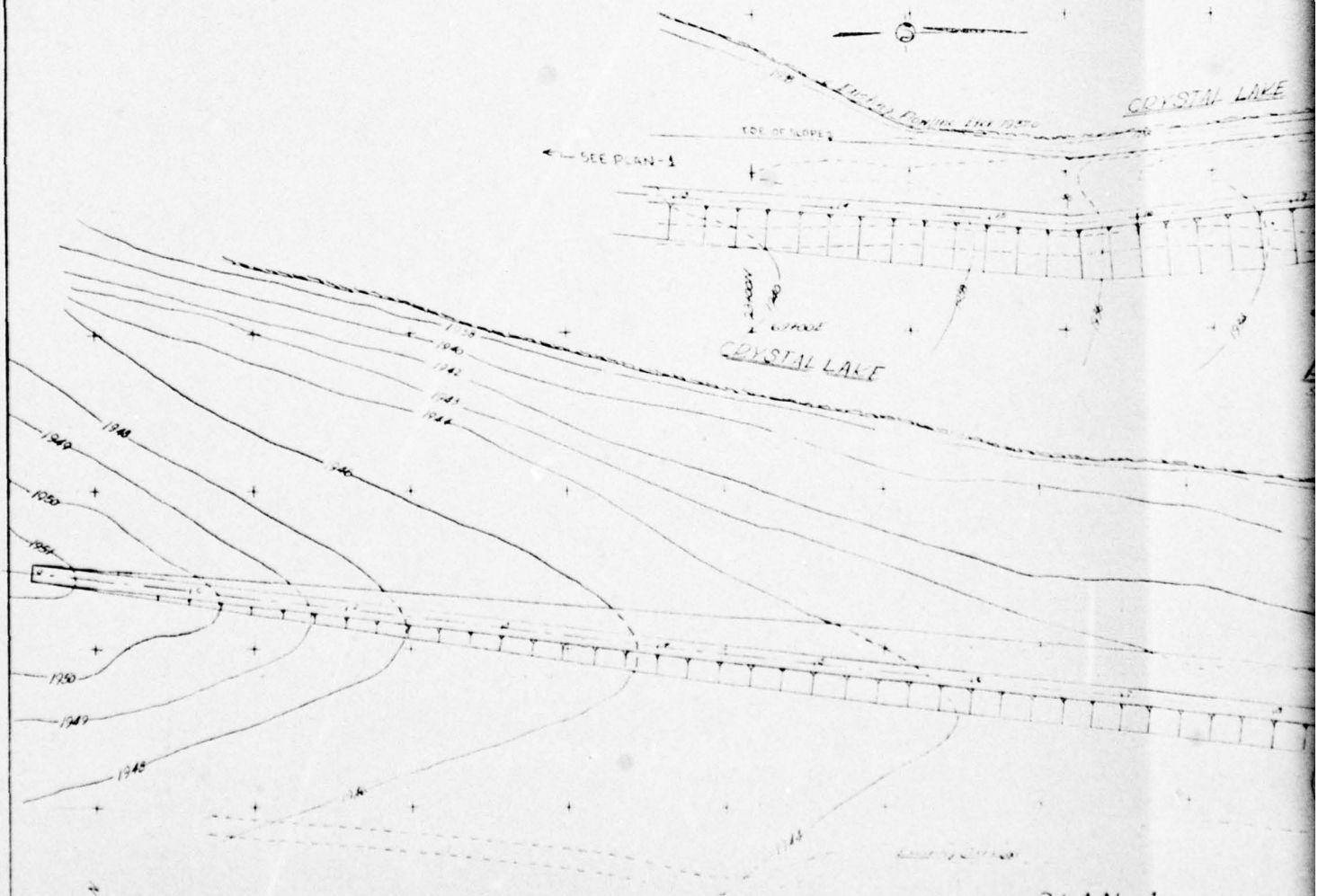

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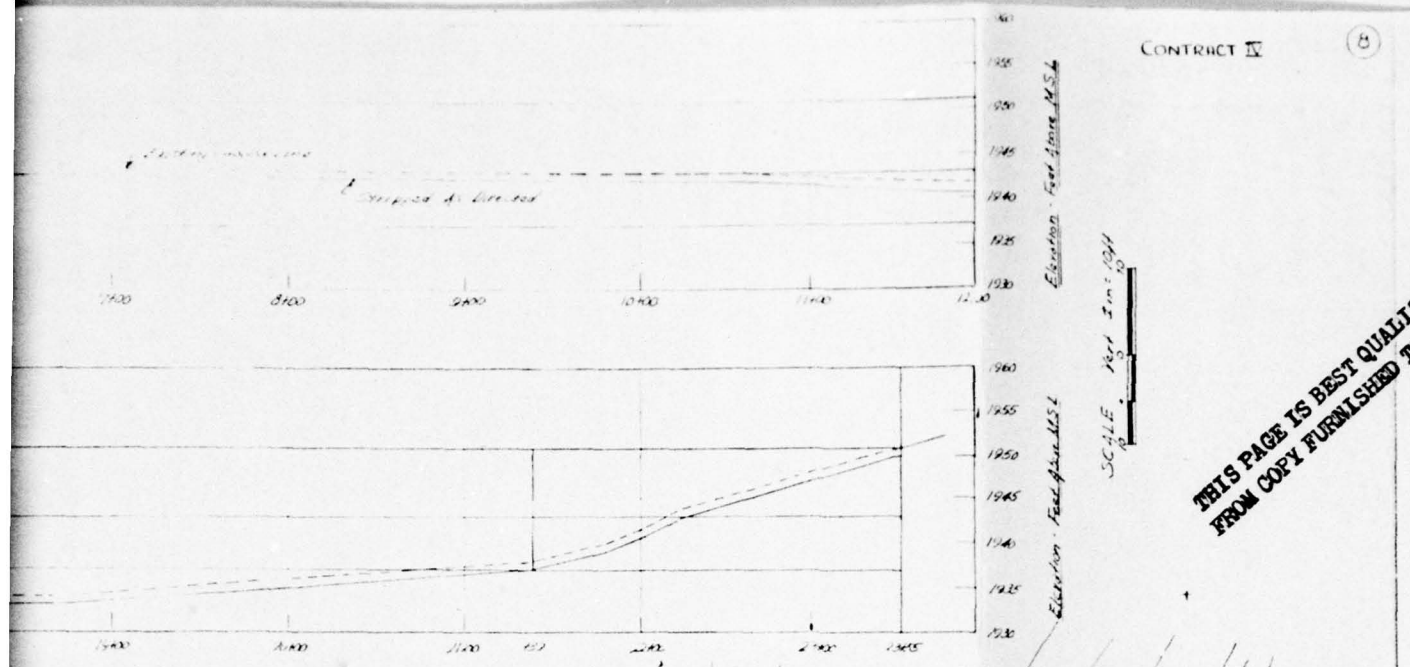
CONTRACT IV (8)



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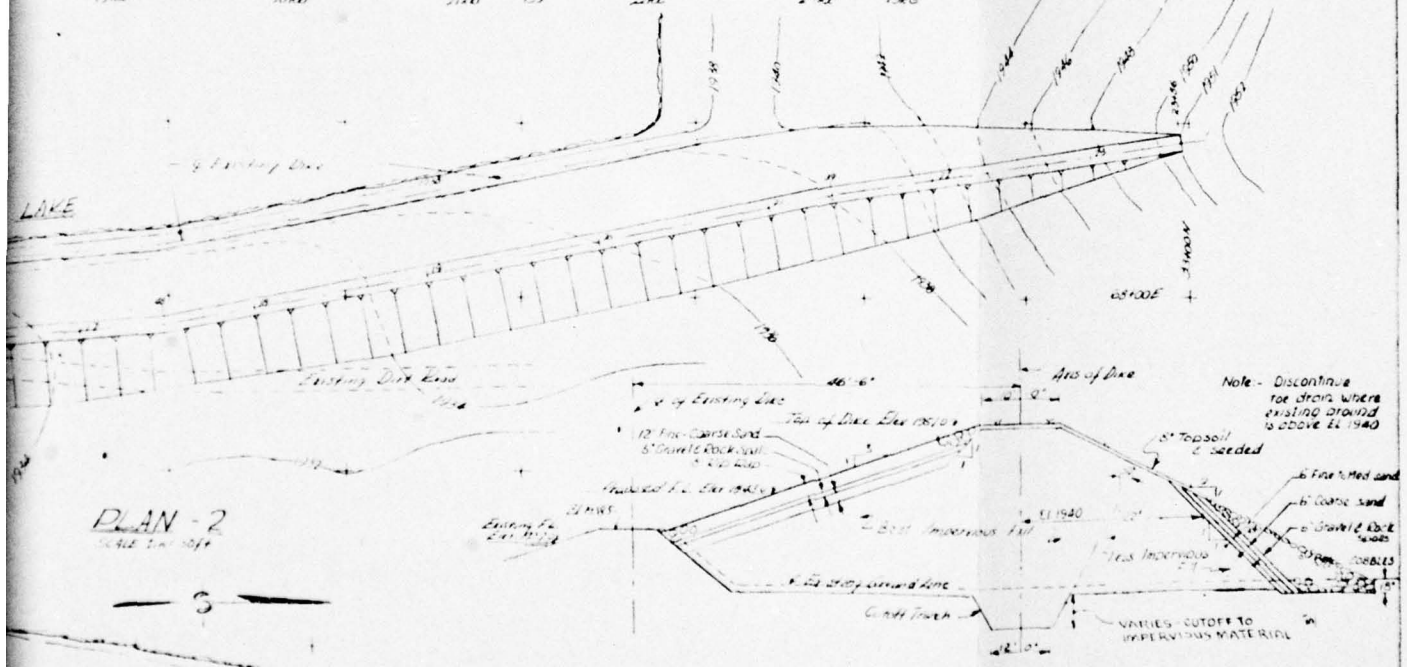

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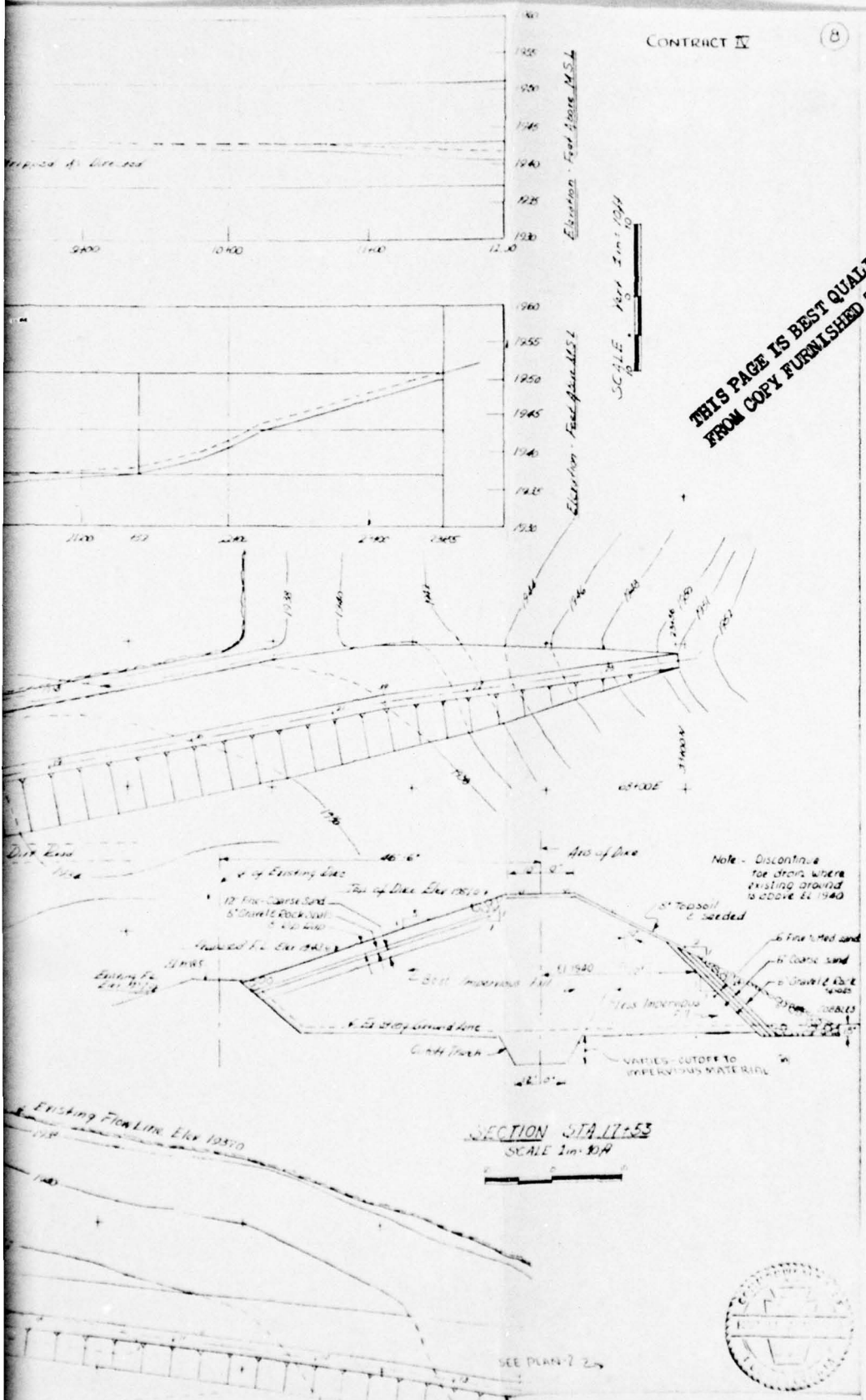

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PHASE I INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

CRYSTAL LAKE DAM

PENNSYLVANIA GAS AND WATER COMPANY

NORTHEAST DIKE

MAY 1978 PLATE II

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SUSQUEHANNA RIVER BASIN

WAPWALLOPEN CREEK, LUZERNE COUNTY

PENNSYLVANIA

CRYSTAL LAKE DAM

NDS ID No. 562

PENNSYLVANIA GAS AND WATER COMPANY

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

MAY 1978

APPENDIX A

CHECKLIST - ENGINEERING DATA

CHECKLIST

ENGINEERING DATA

DESIGN, CONSTRUCTION, AND OPERATION
PHASE I

NAME OF DAM: Crystal Lake

NDS ID NO.: 562 DER ID NO.: 40-22

Sheet 1 of 4

ITEM	REMARKS
AS-BUILT DRAWINGS	None available.
REGIONAL VICINITY MAP	Project is shown on Wilkes-Barre East, Pennsylvania, Quadrangle N4107.5 - W7545/7.5, 1947, Photo Revised 1969.
CONSTRUCTION HISTORY	1861-Timber dam. 1881-Concrete dam (core of present structure). 1893-Dam raised 3 feet. 1898-Dam raised 4 feet by "A" frames w/metal plates. 1899-1898 modification removed. 1951-Liner wall placed on upstream face. 1964-Complete reconstruction and raising.
TYPICAL SECTIONS OF DAM	Plans, sections, and details are available.
OUTLETS: Plan Details Constraints Discharge Ratings	Plans are available. Discharge ratings not available.

ENGINEERING DATA

ITEM	REMARKS
RAINFALL/RESERVOIR RECORDS	None available.
DESIGN REPORTS	None available.
GEOLOGY REPORTS	1914 report describes geologic conditions.
DESIGN COMPUTATIONS: Hydrology and Hydraulics Dam Stability Seepage Studies	None available for present structure.
MATERIALS INVESTIGATIONS: Boring Records Laboratory Field	None available.
POSTCONSTRUCTION SURVEYS OF DAM	1914 report. None for structure after 1964 modifications.

ENGINEERING DATA

ITEM	REMARKS
BORROW SOURCES	No records available.
MONITORING SYSTEMS	Caretaker visits dam daily.
MODIFICATIONS	See "Construction History".
HIGH POOL RECORDS	No formal records for structure after 1964 modification. Caretaker reports only waves lapping over auxiliary spillway.
POSTCONSTRUCTION ENGINEERING STUDIES AND REPORTS	None available.
PRIOR ACCIDENTS OR FAILURE OF DAM: Description Reports	1919 inspection noted that waves overtopped structure and scour resulted. - Structure has been modified since.

ENGINEERING DATA

ITEM	REMARKS
MAINTENANCE AND OPERATION RECORDS	None available.
SPILLWAY: Plan Sections Details	Plans, sections, and details are available.
OPERATING EQUIPMENT: Plans Details	Plans are available.
PREVIOUS INSPECTIONS Dates Deficiencies	1919-Waves overtopped crest with resulting scour. 1924-Concrete deteriorating downstream left of spillway, some seepage on downstream face. 1928-Some seepage below earth embankment on left end. Brush on embankment. Concrete of main dam disintegrating to left of spillway and on upstream edge and near left end. Cracks through dam. Wells built on construction joints are full of water with slight seepage and also seepage at a horizontal joint left of spillway.

ENGINEERING DATA

ITEM	REMARKS
PREVIOUS INSPECTIONS (Continued)	1932: From 12 to 112 feet left of spillway downstream face badly disintegrated with leakage at places. Also seepage along toe at various places. 1933: Much disintegrated concrete left of spillway and beyond buttresses left of spillway and also along
(Continued)	toe. A small stream flows at toe of structure with seepage over disintegrated concrete and along toe further to left. Some remedial grouting done after last inspection. Swampy area near toe of "Dike". 1934: Crest disintegrated in places. Serious erosion of downstream face in several places. Seepage at
(Continued)	various places along toe and in downstream face. Brush on "Dike". 1941: Considerable disintegration of concrete at extreme left of dam and some disintegration at cracks. Brush on auxiliary spillway. Vertical cracks on downstream face. Disintegration of concrete on
	downstream face between blowoff and spillway and also at left end of dam. Slight leakage and general seepage at vertical cracks in downstream face and between blowoff and spillway. Two cracks and some disintegration on spillway crest. Brush in outlet channels.
	1943: Disintegrated concrete on left end of crest. Considerable amount of brush on upstream, crest and downstream slope of auxiliary embankment. Vertical and horizontal cracks, badly disintegrated, on downstream face. Leakage and seepage throughout entire structure at cracks. Seepage at left end auxiliary embankment.

SUSQUEHANNA RIVER BASIN

WAPWALLOPEN CREEK, LUZERNE COUNTY

PENNSYLVANIA

CRYSTAL LAKE DAM

NDS ID No. 562

PENNSYLVANIA GAS AND WATER COMPANY

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

MAY 1978

APPENDIX B

CHECKLIST - VISUAL INSPECTION

CHECKLIST

ENGINEERING DATA

HYDROLOGY AND HYDRAULICS

NAME OF DAM: Crystal Lake Dam NDS ID NO.: 562 DER ID NO.: 40-22

ELEVATION TOP NORMAL POOL (STORAGE CAPACITY): Elevation 1943.0

ELEVATION TOP FLOOD CONTROL POOL (STORAGE CAPACITY): Elevation 1946.8

ELEVATION MAXIMUM DESIGN POOL: Not Available.

ELEVATION TOP DAM: Elevation 1946.8

SPILLWAY CREST:
- a. Elevation 1943.0
- b. Type Ogee-concrete gravity section.
- c. Width Not Applicable.
- d. Length 80.0 Feet
- e. Location Spillover Right of center of auxiliary spillway.
- f. Number and Type of Gates None

OUTLET WORKS:
- a. Type Two 20-inch diameter cast-iron pipes.
- b. Location Auxiliary spillway left of spillway.
- c. Entrance Inverts 1918.7 (approximate)
- d. Exit Inverts Not applicable - water supply line.
- e. Emergency Draindown Facilities 6-inch diameter blowoff.

HYDROMETEOROLOGICAL GAGES:
- a. Type None
- b. Location None
- c. Records None

MAXIMUM NONDAMAGING DISCHARGE: 12,060 cfs

CHECKLIST

VISUAL INSPECTION

PHASE I

Name of Dam: Crystal Lake Dam County: Luzerne State: Pennsylvania

NDS ID No.: 562 DER ID No.: 40-22

Type of Dam: Concrete Gravity with Earthfill Ends Hazard Category: High

Date(s) Inspection: April 27 and April 28, 1978 Weather: Clear-breezy Temperature: 60° F

Soil moist - much puddled water in low spots on adjacent roads although no reported precipitation for week previously.

Pool Elevation at Time of Inspection: 1941.45 msl/Tailwater at Time of Inspection: Dry msl

Inspection Personnel:

F. Mansour (GFCC)	D. Kauffman (PG&W)	J. Good (PG&W)
P. van der Goes (GFCC)	J. Skoritowski (PG&W)	P. Swerdon (DER)
D. Ebersole (GFCC)	E. Morris (PG&W)	

A. Whitman (GFCC) Recorder

EMBANKMENT

Sheet 1 of 2

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	No defects.	
UNUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	No defects.	
SLOUGHING OR EROSION: Embankment Slopes Abutment Slopes	No defects.	Rutting - 8-inch deep-in South Dike-from trail bikes.
CREST ALIGNMENT: Vertical Horizontal	No defects.	
RIPRAP FAILURES	Areas of clustered sizes. Large stones in some areas, smaller stones in others.	Riprap is in excellent condition.

EMBANKMENT

Sheet 2 of 2

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
JUNCTION OF EMBANKMENT WITH: Abutment Spillway Other Features	Left dam abutment dike - see below. Right dam abutment dike - for a short reach adjacent to nonoverflow section, dike is 1-foot lower.	
ANY NOTICEABLE SEEPAGE	At toe of Left End Dike, South Dike, Northeast Dike, Southeast Dike - standing water, no seepage.	At left abutment of dam downstream 40 feet, wet spot 10' x 10', boots sink 1" - No flow.
STAFF GAGE AND RECORDER	None.	
DRAINS	Left Dam Abutment Dike - drain with ponded water at toe.	

CONCRETE/MASONRY DAMS

Sheet 1 of 2

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
ANY NOTICEABLE SEEPAGE	Standing water in rock (riprap) at toe of dam. Water is seeping through bottom 2 feet of almost all joints. See Last Sheet.	Reported by Owner's construction superintendent as seepage through rock foundation.
JUNCTION OF STRUCTURE WITH: Abutment Embankment Other Features	See "Embankment".	
DRAINS	Weep holes near main spillway section weeping.	
WATER PASSAGES	Not observable.	
FOUNDATION	No observed defects.	

CONCRETE/MASONRY DAMS

Sheet 2 of 2

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SURFACES: Surface Cracks Spalling	Many surface cracks, vertical and near vertical, 80% painted white.	Owner reports white painted joints have been chemically grouted.
STRUCTURAL CRACKING	See last sheet.	
ALIGNMENT: Vertical Horizontal	Agrees with plans.	
MONOLITH JOINTS	Concrete is deteriorating along lower half of many of the joints, typically 1-2 inches each side of joint.	Hard encrusted material on many of the joints where seepage occurs.
CONSTRUCTION JOINTS	No defects.	
STAFF GAGE OR RECORDER	None	

OUTLET WORKS

Sheet 1 of 1

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT	Conduits are cast-iron.	
INTAKE STRUCTURE	No defects.	
OUTLET STRUCTURE	None.	
OUTLET CHANNEL	None for outlet works.	
EMERGENCY GATE	None.	

UNGATED SPILLWAY

Sheet 1 of 1

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	No defects on weir - see "Concrete/masonry" dam.	
APPROACH CHANNEL	None.	
DISCHARGE CHANNEL	Dry, with boulders at side slopes and in bottom. Irregularly shaped.	
BRIDGE AND PIERS	Bridge at end of spillway discharge channel 4.75' wide by 3.67' high- in very poor condition.	Bridge would not support vehicles. It is not needed for access to main features.

INSTRUMENTATION

Sheet 1 of 1

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	None.	
OBSERVATION WELLS	None.	
WEIRS	None.	
PIEZOMETERS	None.	
OTHER	None.	

RESERVOIR AND WATERSHED

Sheet 1 of 1

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	Lake covers 30 percent of drainage area. Some steep but relatively low slopes observed. These are far back from lake.	Most of watershed is quite flat.
SEDIMENTATION	No observed or reported problems.	
WATERSHED DESCRIPTION	Mostly softwoods evident. Evidence of large amount fire damage. Areas are swampy.	Owner reports pH of lake usually 4.2 to 5.0-record low of 3.5 pH reported.
ADDITIONAL SOURCES	Water from Bear Creek Lake is pumped into lake.	

DOWNSTREAM CHANNEL

Sheet 1 of 1

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION: Obstructions Debris Other	Heavily overgrown. The channel is dry directly below the dam.	Spillway discharges are rare, according to Owner.
SLOPES	Flat, near dam.	
APPROXIMATE NUMBER OF HOMES AND POPULATION	None observable.	

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
ANY NOTICEABLE SEEPAGE (Continued)	Seepage from all causes estimated at 1gpm from right of spillway. Seepage from left of spillway unable to be estimated. It flows one-half way across road before being absorbed.	Owner reported "As Built" change. A footing, concrete with anchor bars into rock, was extended over exposed rock from toe of dam.
STRUCTURAL CRACKING	Where the centerline of the concrete dam angles, at the adjacent construction joints, structural cracking has started near the top of dam. The largest crack is about 1/2" wide, 5.5' long, vertical.	
(Continued)	It appears that there is a differential movement of about 1/4" at this joint. Near the other angle point, starting at the top, is the beginning of another crack. Horizontal movement is estimated at 1/16" between monoliths.	

SUSQUEHANNA RIVER BASIN

WAPWALLOPEN CREEK, LUZERNE COUNTY

PENNSYLVANIA

CRYSTAL LAKE DAM

NDS ID No. 562

PENNSYLVANIA GAS AND WATER COMPANY

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

MAY 1978

APPENDIX C

HYDROLOGY AND HYDRAULICS

GANNETT FLEMING CORDDRY AND CARPENTER, INC.
HARRISBURG, PA.

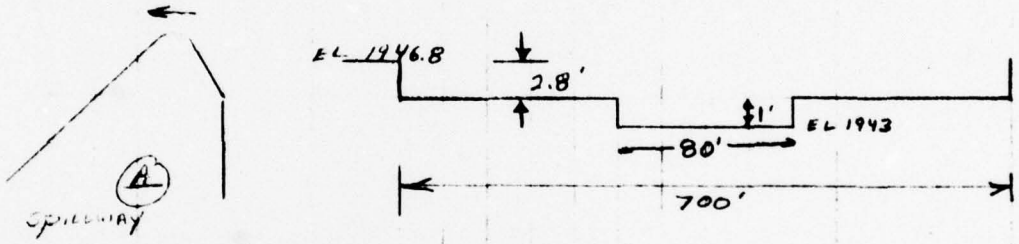
SUBJECT HYDRAULICS AND HYDROLOGY FILE NO.
SHEET NO. 1 OF 1 SHEETS
FOR CRYSTAL LAKE
COMPUTED BY AHW DATE 5/19/78 CHECKED BY FFM DATE 5-22-78

NAB INSTRUCTIONS: USE CURVE

DRAINAGE AREA 2.5 mi²

FROM CURVE (SUSQUEHANNA REGION 2)
Q_{PEAK/MI^2} = 2600 CFS

$Q_{PEAK-PMF} = 2600 \times 2.5 = 6500$ CFS



AND AUXILIARY SPILLWAY

C VALUES FROM "KINGS HANDBOOK OF HYDRAULICS"
C = 3.43 H=3' C = 3.53 H=4'

$Q = 3.43 \times 620 \times (H-1)^{3/2} + 3.53 \times 80 \times H^{3/2}$

H = 3.8 FT.

Q = 9964 CFS + 2092 CFS = 12,056 CFS. SPILLWAY CAPACITY

USE 12,060 CFS

THE SPILLWAY CAPACITY IS GREATER THAN THE PMF PEAK INFLOW

THE SPILLWAY CAN PASS 186% OF THE PMF PEAK FLOW

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SUSQUEHANNA RIVER BASIN

WAPWALLOPEN CREEK, LUZERNE COUNTY

PENNSYLVANIA

CRYSTAL LAKE DAM

NDS ID No. 562

PENNSYLVANIA GAS AND WATER COMPANY

PHASE I INSPECTION REPORT

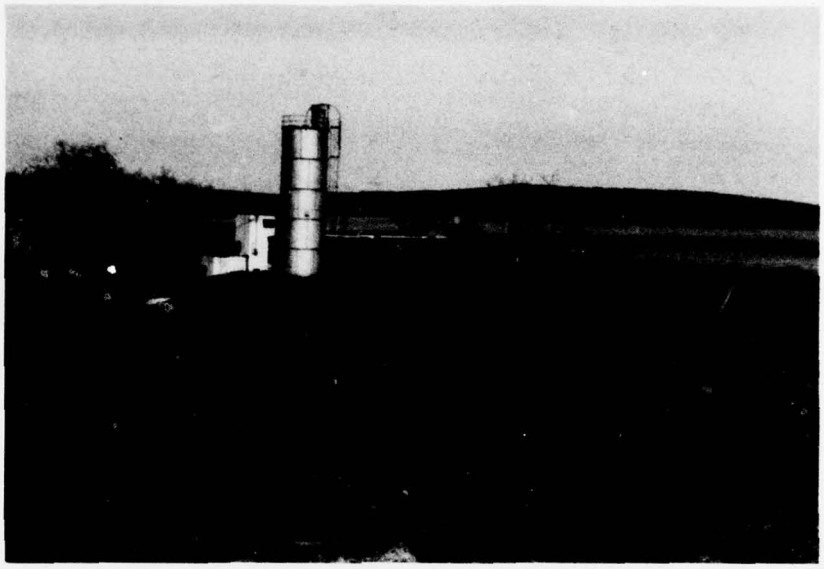
NATIONAL DAM INSPECTION PROGRAM

MAY 1978

APPENDIX D

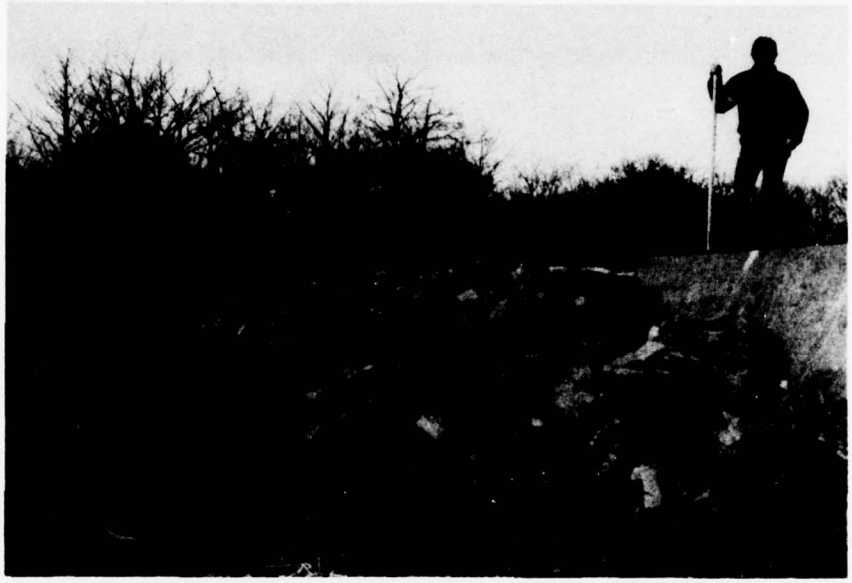
PHOTOGRAPHS

CRYSTAL LAKE DAM



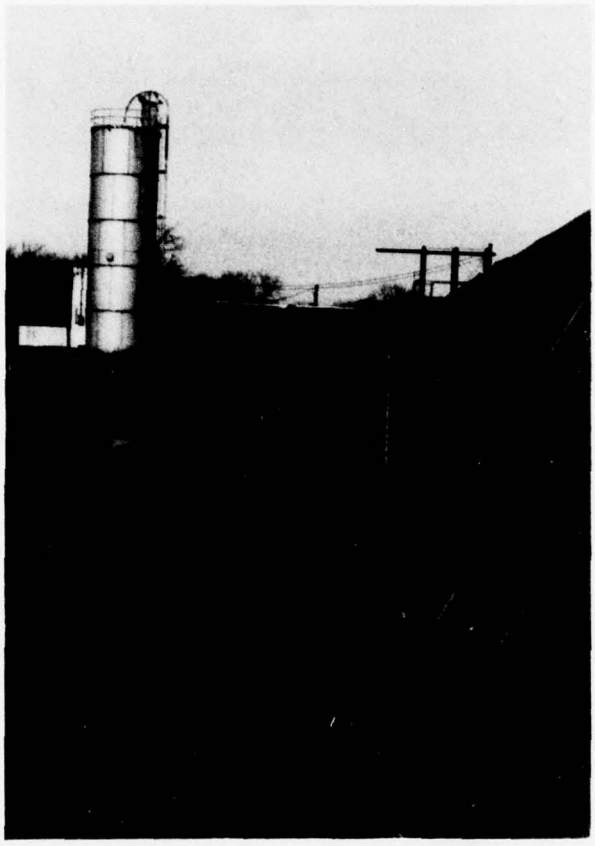
A. Auxiliary Spillway and Water Treatment Plant

B. Blowoff Pipe and Riser Pipe for Valve

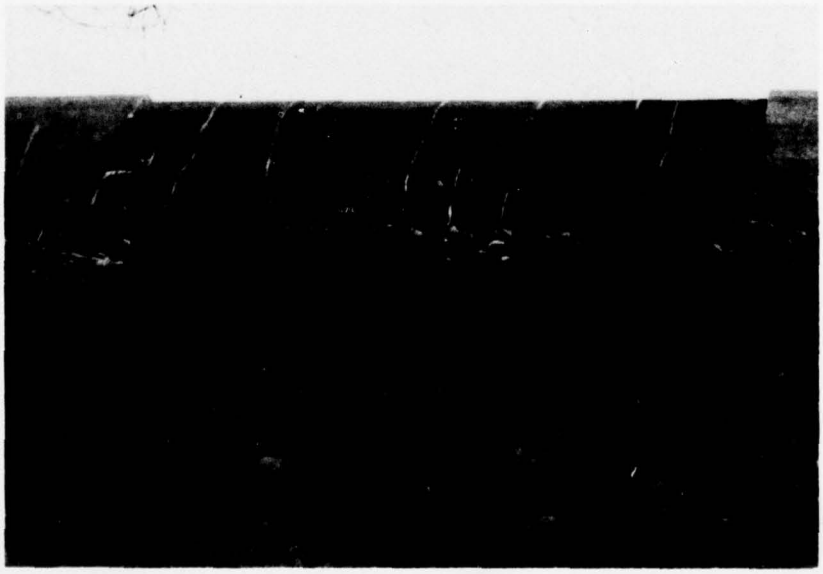


C. Right Abutment Dike
Nonoverflow Section at Right

D. Main Spillway Outlet Channel



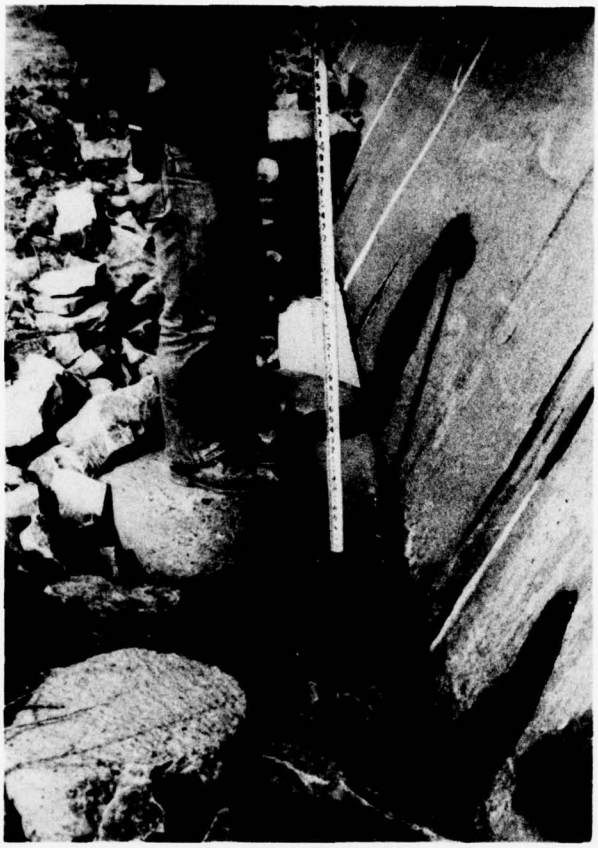
E. Downstream Face of Auxiliary Spillway and Water Treatment Plant



F. Main Spillway Looking Upstream

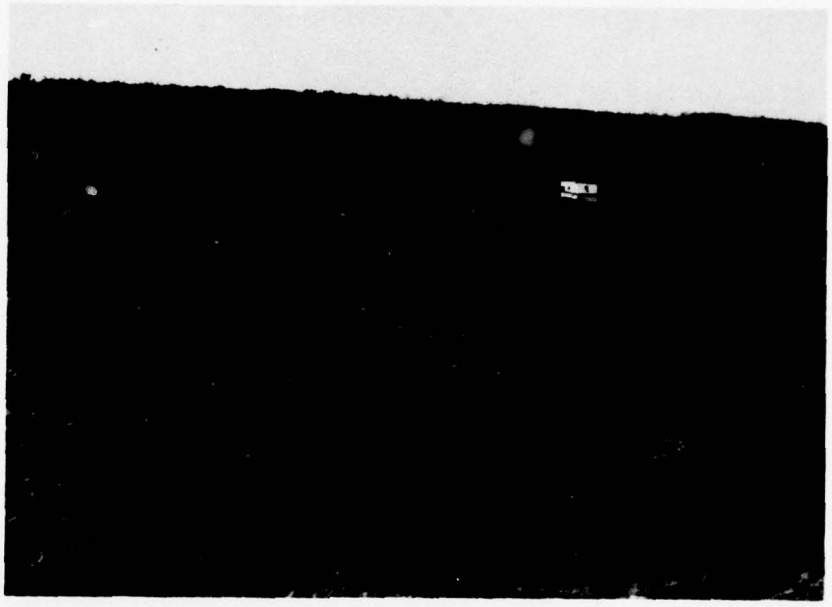
G. Downstream Face of Main Spillway Showing Deteriorating Concrete

H. Downstream Face of Auxiliary Spillway Showing Crack



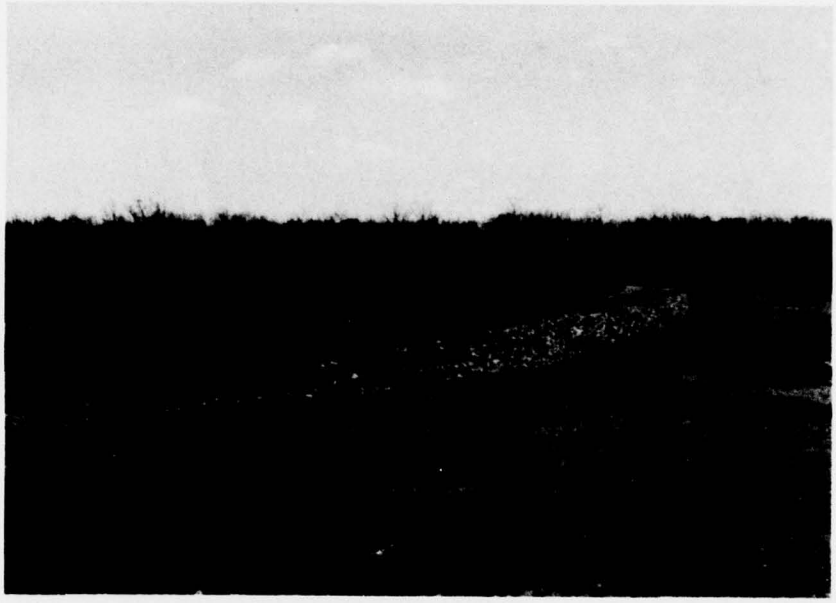
I. Water at the Toe
of the Main Spillway

J. Wet Area at the Toe
of the Left Abutment Dike

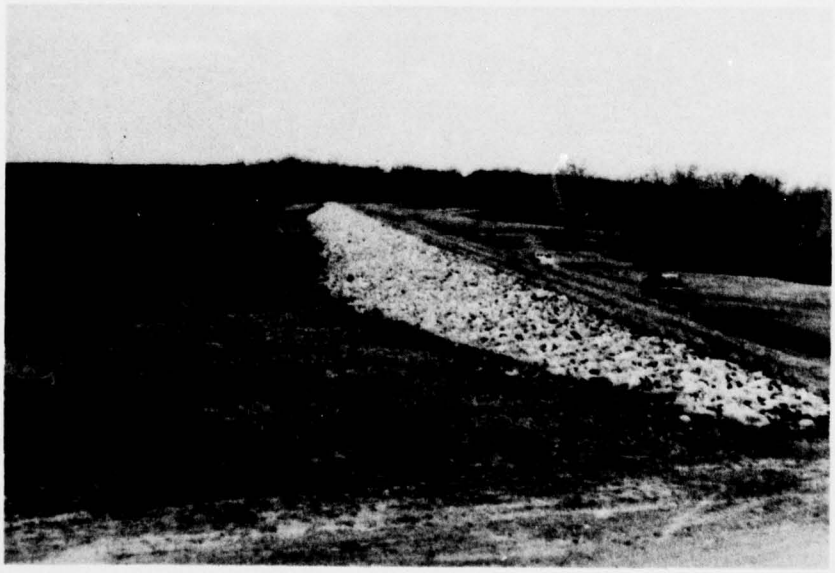


K. Left Abutment Dike
Showing Breached Area at Upper Right

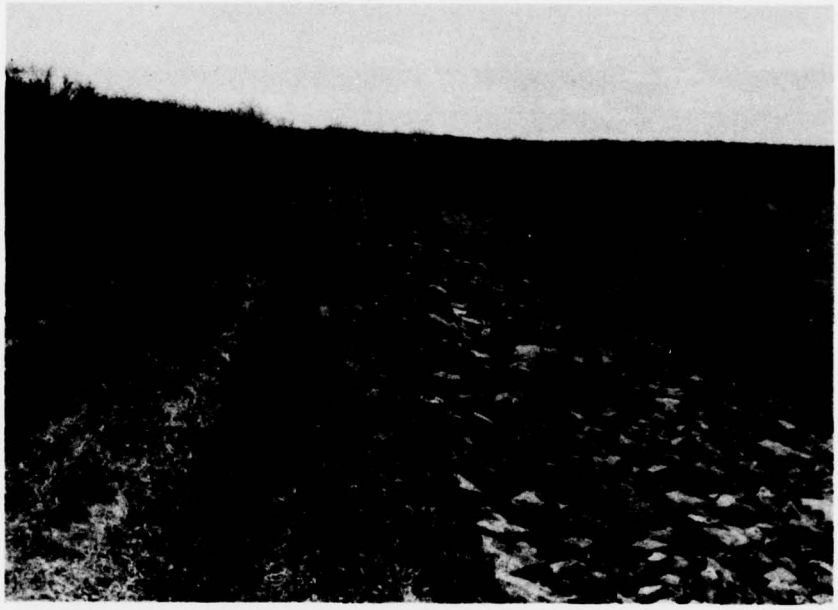
L. Abandoned Water Supply Gate Structure
and Nonoverflow Section at Right



M. South Dike
Crystal Lake Shown at Right



N. Southeast Dike
Crystal Lake Shown at Left



P. Northeast Dike
Crystal Lake Shown at Right

Q. Downstream Face of Northeast Dike

SUSQUEHANNA RIVER BASIN

WAPWALLOPEN CREEK, LUZERNE COUNTY

PENNSYLVANIA

CRYSTAL LAKE DAM

NDS ID No. 562

PENNSYLVANIA GAS AND WATER COMPANY

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

MAY 1978

APPENDIX E

GEOLOGY

CRYSTAL LAKE DAM

APPENDIX E

GEOLOGY

1. General Geology. The damsite and reservoir are located in Luzerne County. The rock formations exposed in Luzerne County range from the post-Pottsville formations, of Pennsylvanian Age, down to the Onondaga formation, of Middle Devonian Age. The Wisconsin terminal moraine crosses the southern part of the County, and the greater part of the County is covered by glacial drift. Extensive deposits of glacial outwash occur along the Susquehanna River and less extensive deposits along the smaller streams.

Nearly all of Luzerne County lies in the Valley and Ridge Province in which nearly all the rocks have been strongly folded. In going from north to south across the County, five major folds are encountered, all of which trend northeast. The first of these is a shallow syncline on the crest of North Mountain, forming the Mehoopany coal basin. The second is the Milton Anticline, which exposes the Portage group in the northwestern part of the County and gradually flattens out toward the northeast. The third and most pronounced is the Lackawanna Syncline, which originates in Lackawanna County to the north, and has preserved the post-Pottsville formations throughout the Wyoming Valley. The maximum depth of this syncline is reached in the vicinity of Wilkes-Barre and Plymouth. The double rim of this syncline is formed by the resistant Pottsville formations and Pocono sandstone, separated by the less resistant Mauch Chunk shale. The fourth fold is the Berwick (Montour) Anticline, which exposes a few feet of the Onondaga formation in the vicinity of Beach Haven. This fold reaches its maximum development farther west and only the eastern portion reaches Luzerne County. The fifth major fold comprises a series of anticlines and synclines forming the Eastern Middle Anthracite Field in the vicinity of Hazleton. The synclinal basins in this region are relatively shallow and there are large areas from which all coalbeds have been eroded.

The general dips of the region vary from 0° to 40°, and the maximum dips are found on the rims and within the synclinal coal basins. The relatively soft post-Pottsville beds in their cores are severely folded and contorted with numerous minor faults. The northern and easternmost parts of the County border the Appalachian Plateau Province and are characterized by horizontal, or nearly horizontal strata. The Catskill continental group of rocks underlies those parts of Luzerne County that are outside of the five major folds.

2. Site Geology. Crystal Lake Dam is founded on hard, horizontally stratified sandstones and shales of the Catskill group in a plateau area that is near the eastern limit of the Berwick Anticline. The original lake was formed in a natural depression created by the overlapping effects of three of the five major folds in the County. The lake is located a few miles east of the limits of the Berwick Anticline, a few miles south of the limits of the Lackawanna Syncline and a few miles north of the folds of the Middle Eastern Anthracite Fields. The natural lake area is the origin of Big Wapwallopen Creek which flows in a westward direction, parallel to the axis of the Berwick Anticline, to a confluence with the Susquehanna River at Wapwallopen.

Records from the original construction, and later modifications, indicate that all structures were founded upon either hard, sound sandstone or hard sound shale. All accounts agree that it was never necessary to excavate more than 2 to 3 feet in order to secure a sound rock foundation.