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JAMES RIVER BASIN

Name Of Dam: CLIFTON FORGE Dam

Location: ALLEGHANY COUNTY, VIRGINIA

Inventory Number: VA 00503

LEVEL I

# PHASE I INSPECTION REPORT

## NATIONAL DAM SAFETY PROGRAM

Clifton Forge Dam (Inventory Number VA 00503). James River Basin. Alleghany County, Virginia. Phase I Inspection Report.

AD A063604

Final rpt.

66 p.

Sep 78

Thomas Roberts

DACW 65-78-D-0014



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PREPARED FOR

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BY

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SEPTEMBER, 1978

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER VA 00503	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Phase I Inspection Report National Dam Safety Program Clifton Forge Alleghany County, Virginia		5. TYPE OF REPORT & PERIOD COVERED Final	
		6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s) Gilbert Associates- Thomas Roberts		8. CONTRACT OR GRANT NUMBER(s) DACW 65-78-D-0014	
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineering District, Norfolk 803 Front Street Norfolk, VA 23510		12. REPORT DATE September 1978	
		13. NUMBER OF PAGES 51	
14. MONITORING AGENCY NAME & ADDRESS (If different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified	
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report)  Approved for public release; distribution unlimited.			
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
18. SUPPLEMENTARY NOTES  Copies are obtainable from National Technical Information Service, Springfield, Virginia 22151			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)  Dams - VA National Dam Safety Program Phase I Dam Safety Dam Inspection			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)  (See reverse side)			

## 20. Abstract

Pursuant to Public Law 92-367, Phase I Inspection Reports are prepared under guidance contained in the recommended guidelines for safety inspection of dams, published by the Office of Chief of Engineers, Washington, D. C. 20314. The purpose of a Phase I investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general conditions of the dam is based upon available data and visual inspections. Detailed investigation and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

Based upon the field conditions at the time of the field inspection and all available engineering data, the Phase I report addresses the hydraulic, hydrologic, geologic, geotechnic, and structural aspects of the dam. The engineering techniques employed give a reasonably accurate assessment of the conditions of the dam. It should be realized that certain engineering aspects cannot be fully analyzed during a Phase I inspection. Assessment and remedial measures in the report include the requirements of additional indepth study when necessary.

Phase I reports include project information of the dam and appurtenances, all existing engineering data, operational procedures, hydraulic/hydrologic data of the watershed, dam stability, visual inspection report and an assessment including required remedial measures.



PHASE I INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM

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PHASE I INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM

Name of Dam: Clifton Forge  
State: Virginia  
County: Alleghany  
USGS Quadrangle Sheet: Clifton Forge, Virginia  
Stream: Smith Creek

The Clifton Forge Dam is a concrete gravity dam approximately 52 feet high and 265 feet long. The dam serves to retain the water supply storage for the city of Clifton Forge. The reservoir volume at the level of the spillway crest is 160 acre-feet.

Based on the visual inspection, the dam did not appear to be in an imminently dangerous condition; however, there are seepage conditions which could become hazardous. Calculations indicate that the dam has inadequate factors of safety with respect to structural stability. A seepage condition at the left abutment requires monitoring to detect increases in flow rate. The spillway can only pass up to 50 percent of the probable maximum flood (PMF) before overtopping occurs. (See Appendix VII, Conditions.)

An analysis of the spillway capacity found that the PMF will overtop the dam by 4.8 feet for 4.5 hours. The design flood for the dam is the PMF; thus, the spillway is rated as "inadequate" but not "seriously inadequate" based on the U.S. Corps of Engineers' inspection guidelines described in paragraph 5.8.

The stability of the dam was analyzed for an extreme combination of loading and was found to have inadequate factors of safety against sliding and overturning. A summary of the stability analysis is in Appendix V.

The recommendations provided in this Report pertain to the structural stability and also to the general management of the dam. Except for the additional stability studies and the establishment of a warning system, they are not of an urgent nature. Briefly, the recommendations call for additional stability studies, the establishment of a warning system, a semiannual inspection program, and the maintenance of a file of all design documents and related materials. Minor maintenance, such as removing the

concrete debris from the old 12-inch downstream pipeline and repair of the scaling concrete, should be done. It is also suggested that future consideration be given to increasing the spillway capacity.

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Date: SEP 22 1978



August 1978

OVERVIEW - CLIFTON FORGE DAM

PHASE I INSPECTION REPORT  
NATIONAL DAM SAFETY PROGRAM  
NAME OF DAM: Clifton Forge I.D. #: VA 00503

SECTION 1 - PROJECT INFORMATION

1.1 General

1.1.1 Authority: Public Law 92-367, 8 August 1972, authorized the Secretary of the Army, through the U.S. Corps of Engineers to initiate a national program of safety inspections of non-Federal dams throughout the United States. The Norfolk District of the U.S. Corps of Engineers has been assigned the responsibility of the inspection of dams in the Commonwealth of Virginia. Gilbert Associates, Inc. has entered into a contract with the Norfolk District to inspect this dam, Gilbert Work Order 06-7250-005.

1.1.2 Purpose of Inspection: The purpose is to conduct a Phase I inspection according to the Recommended Guidelines for Safety Inspection of Dams (Reference 1 of Appendix VI) and contract requirements between Gilbert Associates, Inc. and the Corps of Engineers. The objectives are to expeditiously identify whether this dam apparently poses an immediate threat to human life or property, and to recommend future studies and/or any obvious remedial actions that may be indicated by the inspection.

1.2 Project Description

The Clifton Forge Dam is a concrete gravity dam approximately 52 feet high and 265 feet long. According to the drawings, the structure is founded on rock throughout and is keyed into the rock along the upstream face or heel of the dam. The top width is 8 feet, except through the spillway piers and gatehouse where it measures 16 feet and 14 feet, respectively. The base width through a central cross section of the dam is 37 feet. The structure is composed of six concrete monoliths, three of which form the central spillway section. The spillway is to the right of the center of the dam and consists of seven bays, formed by six 3-foot wide piers at the crest. The piers were originally designed to support radial gates that were initially installed but removed soon after the dam was completed. The total clear opening width of the spillway is 112 feet. At the base of the spillway, a concrete apron with a 25-foot radius flip bucket dissipates the energy of the flow. The lip of the apron is at elevation 1357.3 feet m.s.l.

The Clifton Forge reservoir is used for water supply and recreation. An intake tower and control house are located on the left end of the spillway. The intake tower provides the inlet for the water supply to a nearby treatment plant and also houses the control valve for the 30-inch reservoir outlet. The reservoir intake system incorporates a portion of an upstream water supply system that is still in use. A small reservoir 2000 feet upstream supplies water to a 16-inch pipeline which runs under the Clifton Forge



reservoir and, prior to 1950, continued down Smith Creek to Clifton Forge. The pipeline now runs through the dam and is diverted to the water treatment plant. The water supply can be withdrawn from either reservoir. A valve housed at the toe of the dam on the left end of the spillway is used to select from which reservoir the water supply will be taken. The upstream reservoir is used most often. The supply line from the Clifton Forge reservoir is 24 inches in diameter.

1.2.2 Location: The Clifton Forge dam is located on Smith Creek, a tributary of the Jackson River. The dam is 2.5 miles northwest of the city of Clifton Forge.

1.2.3 Size Classification: Based upon the height of 52 feet and a maximum storage volume of 318 acre-feet, the dam is classified as intermediate size in accordance with Section 2.1.1 of Reference 1 of Appendix VI.

1.2.4 Hazard Classification: Based upon the requirements of Section 2.1.2 of Reference 1 of Appendix VI, a dam should be classified as having "high" hazard potential if a failure of the dam will result in extensive economic loss or the loss of more than a few lives. The location of the city of Clifton Forge on Smith Creek, a short distance below the dam, requires that the hazard potential be rated as high. The hazard classification used to categorize dams is a function of location only, and unrelated to the stability or probability of failure.

1.2.5 Ownership: The dam is owned by the city of Clifton Forge.

1.2.6 Purpose: The dam and reservoir are used for water supply and for fishing.

1.2.7 Design and Construction History: The dam was designed by J. C. Remington, Jr. and John S. Hale of Staunton, Virginia, in May 1946. It was constructed in 1949, but the name of the contractor is not known.

1.2.8 Normal Operating Procedure: Under normal conditions the water treatment plant uses water from the upstream reservoir. The outlet gates on the Clifton Forge Dam are kept closed and all excess inflows are passed over the ungated spillway.

### 1.3 Pertinent Data

1.3.1 Drainage Area: 12.6 square miles

1.3.2 Discharge at Dam Site: The maximum discharge of the dam site occurred in August 1969 as a result of Hurricane Camille. (Reference 8 of Appendix VI.) The estimated discharge was 1500 c.f.s. The calculated flows through the spillway and outlet works are presented below.

Spillway Capacity:

Pool level at the top of the dam . . . . .17,600 c.f.s.

Outlet Works:

Pool level at the spillway crest . . . . .124 c.f.s.

1.3.3 Dam and Reservoir Data: Pertinent data is summarized in Table 1.1.

Table 1.1 RESERVOIR PERFORMANCE

<u>Item</u>	<u>Elevation ft, m.s.l.</u>	<u>Surface Area acres</u>	<u>Reservoir Capacity</u>		<u>Length miles</u>
			<u>Acre- feet</u>	<u>Watershed inches</u>	
Top of Dam	1408.0	15.1	318	0.47	0.45
Spillway Crest	1396.0	11.4	160	0.24	0.38
Streambed at Dam	1356.0	0	0	0	0

## SECTION 2.0 ENGINEERING DATA

2.1 Design: One set (9 sheets) of design drawings is available for the dam and includes plan views and sections, core drilling and topography, and some details on the spillway and outlet tower gates. These drawings are included in this report as Appendix I. Specific details on outlet tower, gates, and piping are not available.

It was reported by the owner's representative that soon after the completion of the dam, during a sudden large storm, the spillway gates did not operate correctly. The Mayor of Clifton Forge, feeling that the town was threatened, ordered the gates blown off the dam. No attempt has been made to replace the gates. Prior to the removal of the gates, the normal reservoir pool elevation was 1406.0 feet m.s.l. The present pool level is at the spillway crest elevation of 1396 feet m.s.l.

Two spillway portals on the right end of the dam do not discharge directly downstream. The flows over the spillway are intercepted by a training wall which guides the flow to the left toward the center of the concrete apron at the base of the dam. Reportedly, when discharging at high rates, the flows overtop the training wall and impact against a rock outcrop on the right abutment.

Because it was felt that the impacting waters would eventually erode the rock, an attempt was made to change the flow pattern over the crest. Notches were cut into the spillway floor just below the crest. The notches formed a flat ledge about 4 feet wide and 2 feet deep and were constructed by drilling closely spaced holes and then breaking out the concrete. The notch in the spillway portal furthest to the right was completed. In the next portal the procedure was discontinued when about one-half complete. A photograph of a notch is included in Appendix II.

What effect these notches have had on the spillway hydraulics is difficult to evaluate. There did not appear to be any spalled concrete near the broken concrete giving evidence of cavitation damage, and there did not appear to be any excessive erosion on the abutment below the spillway. The notches have little effect on the structural integrity of the dam.

A large discharge over the dam in 1950 caused the existing scour at the end of the spillway. The old 12-inch pipeline, in existence prior to the construction of the dam, was washed out and the streambed was heavily scoured. However, there was no evidence of a deep scour pool at the end of the spillway. Another large flood was produced by Hurricane Camille in 1969. A damage survey of Smith Creek was performed by the Corps of Engineers in 1971 after the flood and no serious damage to the dam was noted in their report. A portion of the report is included in Appendix IV.

The foundation design and geological data, including key trenches and concrete corewall cutoff, are described in paragraph 6.2.

2.2 Construction: No construction information was available.

2.3 Operation: No operating records are kept. The water treatment plant normally uses a smaller upstream reservoir for its water supply and allows the Clifton Forge reservoir to remain full. The reservoir was drained three years ago (1975); reportedly, it took about six hours to drain. This time is much shorter than the time calculated in paragraph 5.7 (22 hours), but this latter time is based upon an estimated equipment configuration and an estimated valve hydraulic head loss. In either case, the time to drain the reservoir can be considered short.

2.4 Evaluation: The design data presented in the drawings provide adequate information to determine the size and operating characteristics of the dam. The dam appears to conform closely to the drawings, and the only deviations from the plans appear to be the elimination of intake gates at intermediate levels of the reservoir. The only questionable condition from an operational standpoint is the concrete notches cut in the spillway; however, there was no evidence of any detrimental effects resulting from this modification.



### SECTION 3 - VISUAL INSPECTION

3.1 Findings: The dam was inspected in the afternoon on a clear, warm day. The reservoir was full at the time with only a slight flow over the spillway.

There were no conditions observed which indicated that the dam needed immediate repair. The concrete was scaling in some areas, particularly at the top of the spillway gate piers. For the most part, this scaling appeared to be a mortar-cemented surface which was beginning to separate from the mass concrete beneath. More severe scaling is occurring on the face of the dam near the left abutment. The scaling is occurring at a horizontal joint at the top surface of a lift of concrete.

The cause of the scaling is unknown but it could be due to "freeze-thaw" action on the surface, brought about by seepage through the construction joint. The scaling concrete is several inches deep and runs along the entire length of the bulkhead section of the dam, 23 feet below the top. The scaling does not appear to represent a condition which would affect the safety of the dam, but the owner should consider repairing it as part of a general maintenance procedure.

Two areas of seepage were observed on the left abutment near the base of the dam. The flow was coming from the horizontal construction joint referred to above and also from the ground surface nearby. The rate of seepage was low, about 10 g.p.m. The operator of the nearby treatment plant, who also monitors the conditions at the dam, reported that he believes the seepage has been in existence for several years.

The rock outcrops at the right abutment and the streambed indicate that the foundation rock is grey siliceous shale interbedded with grey fine-grained sandstone. The rock strata at the dam site strike approximately N35°E nearly parallel to the dam axis and dips at about 35°SE toward the downstream.

The spillway crest was notched in the right two portals in what was reported to be an attempt to prevent the discharge through these two openings from impacting against an abutment outcropping and causing erosion of the rock. No one present was able to inform us as to the success of this modification to the spillway, but erosion of the rock below the spillway did not appear to be a problem.

The gate in the outlet tower was reported to be in good operating condition but it was not opened during the inspection.

3.2 Evaluation: None of the conditions observed at the dam gave indication that the dam presents an imminent hazard to the people and property below it. The scaled concrete is the only significant sign of wear and it does not appear to present any hazard to the structure. The seepage observed could be significant if it shows signs of increasing. Therefore, monitoring of the seepage is recommended as part of an inspection program.



## SECTION 4 - OPERATIONAL PROCEDURES

4.1 Procedures and Maintenance: There is very little operation involved in running the dam. The reservoir is maintained in a full condition and excess inflows are passed over the spillway. During dry conditions when inflows do not meet treatment plant demands, a minimum flow is passed through the outlet works.

Maintenance is performed by the Public Works Department of the city of Clifton Forge. There is no regular maintenance procedure and, although none of the conditions at the dam appeared hazardous, the general condition of the dam and auxiliary structures could be described as very worn.

4.2 Warning System: There is no warning system maintained by the city of Clifton Forge, but an around-the-clock treatment plant operator is nearby.

4.3 Evaluation: The dam appears to be operating satisfactorily, but there is very little procedure involved in operating the dam. The only apparent serious deficiency is the lack of a warning system to notify downstream residents of a hazardous situation at the dam. The maintenance procedures at the dam could be upgraded somewhat, but most of the resulting improvement would be to the general appearance of the dam. From a performance standpoint, the maintenance procedures have been adequate.

## SECTION 5 - HYDRAULIC/HYDROLOGIC DESIGN

5.1 Design: The most interesting feature of the hydraulic design of the dam was the automatic radial gates. The gates were removed soon after the dam was constructed because they failed to open when a large storm produced a high reservoir level. No explanation for the gate failure was determined. The spillway now operates as a simple overflow spillway. Notches were cut into the two spillway portals below the crest at the right end of the dam as described in paragraph 2.1. The purpose of the notches was to change the flow pattern below the crest. There is no information as to who instituted the change or as to how effective it was. The change should not have any significant effect on the spillway capacity.

Details on the design of the outlet works are not available except as shown on the drawings (Appendix I). From discussions with the dam operators, the following details have been determined. Water enters the gate tower through an entrance at the bottom of the reservoir. Within the tower are two outlets: a 30-inch steel pipeline, which, after reducing to 16-inches, carries raw water to the treatment plant; and a 30-inch pipeline, which discharges into the pool at the base of the spillway.

The flow through the pipeline to the treatment plant is controlled either at the treatment plant or at a valve house located at the toe of the dam. The 30-inch discharge pipe is controlled by a gate within the gate tower from an operating mechanism at the top of the dam. The capacities of the spillway and the 30-inch outlet pipe are given in paragraph 1.3.2.

5.2 Hydrologic Records: A stream gage was in place 0.8 miles upstream of the Clifton Forge Dam at another older dam. The gage, "Smith Creek above old dam," near Clifton Forge, Virginia, was in operation from 1947 through 1956. A maximum discharge of 1200 c.f.s. was observed on December 7, 1950, and the average flow for the nine years was 18.3 c.f.s. The drainage area of the gage was 12.4 square miles. From 1944 until 1947 another gage known as "Smith Creek near Clifton Forge" was in place below the old dam.

5.3 Flood Experience: The largest known flood at the dam site was a result of the runoff from Hurricane Camille on August 19, 1969. The storm delivered 10.12 inches of precipitation in 13 hours. A flood damage survey conducted by the Corps of Engineers on the Smith Creek drainage area (Reference 4 of Appendix VI) found little damage in the dam site area. The flow, estimated from information in the damage survey, was 1500 c.f.s., with the reservoir level at 1398.5 feet, 9.5 feet below the top of the dam, and 2.5 feet above the spillway crest.

5.4 Flood Potential: The flood potential was evaluated using generalized rainfall information with the flood hydrographs and reservoir routing computed using the HEC-1 computer program. Based upon the hazard

classification of the dam, the design flood is the PMF. The results of this analysis are presented in paragraph 5.6. These analyses pertain to present hydrologic conditions and do not consider future conditions, such as urbanization or other changes in the watershed.

5.5 Reservoir Regulation: The reservoir is used only for the purpose of water supply. While streamflows are adequate to provide downstream needs, the reservoir is maintained at or near the spillway crest level. The pool is lowered only when downstream demands exceed the upstream inflows.

5.6 Overtopping Potential: The PMF, one-half the PMF, and the 100-year flood hydrographs were developed for the Clifton Forge dam drainage basin and routed through the reservoir.

The hydrographs were developed and routed using the HEC-1 computer program (Reference 2 of Appendix VI) and appropriate precipitation, losses, unit hydrograph, and storage volume versus outflow data as input. Probable maximum precipitation (PMP) and 100-year precipitation data were obtained from U.S. Weather Bureau publications (References 3 and 4 of Appendix VI). A reduction factor of 19 percent was applied to the PMP as recommended for a drainage basin with an area of 12.6 square miles (Reference 5 of Appendix VI). Losses were estimated at an initial loss of 1.0 inch and a constant loss rate of 0.3 inch/hour. The triangular unit hydrograph was developed from the drainage area and an estimated time to peak of 2.5 hours (Reference 5 of Appendix VI). Information from record drawings and field observations was used to compute the storage-outflow relation.

Table 5.1 summarizes the results:

Table 5.1 RESERVOIR PERFORMANCE

Item	Hydrograph		
	One Percent Flood (a)	1/2 PMF	PMF (b)
Peak Flow, c.f.s.			
Inflow	7370	17,740	35,500
Outflow	7230	17,660	35,400
Peak Elevation, feet m.s.l.	1402.8	1408.0	1412.8
Ungated Spillway			
Depth of Flow, feet	5.1	9.2	13.3
Average Velocity, f.p.s.	12.7	17.1	20.7
Non-overflow Section			
Depth of Flow, feet (c)	-	0	2.9
Average Velocity, f.p.s.	-	0	9.7
Duration, hours	-	0	4.5

Notes:

(a) The 1 percent exceedence frequency flood has one chance in 100 of being exceeded in any given year.

(b) The PMF is an estimate of flood discharges that may be expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region.

(c) Critical depth.

5.7 Reservoir Emptying Potential: The time required to drain the reservoir from a full condition with the reservoir at the spillway crest elevation was calculated at approximately 22 hours. The calculation required several assumptions concerning gate losses and assumed an inflow to the reservoir of 1.3 cubic feet per second per square mile (c.f.s.m.) or 16.4 c.f.s. The reservoir was drained in 1975 and the operator of the dam estimated that it took about six hours to drain.

5.8 Evaluation: Three spillway capacity ratings are possible under the U.S. Corps of Engineers' inspection guidelines: Adequate; Inadequate; and Seriously Inadequate. (Reference 1 and the U.S. Corps of Engineers' Engineer Technical Letter No. 1110-2-234). The screening criteria for assessing the adequacy of the spillway allow essentially no risk of loss of life from dam failure by overtopping. Experience indicates that very few existing non-Federal dams were designed with such conservative criteria. Therefore, the Phase I inspection findings will indicate that most non-Federal dams will have an inadequate spillway.

A spillway is "considered inadequate" if it cannot pass the PMF without overtopping the dam. It is "seriously inadequate" if it is overtopped by less than a one-half PMF that could lead to a failure of the dam, resulting in an increased hazard to loss of life downstream from that which would exist just before overtopping failure.

The results of the flood analysis indicate that the spillway can pass up to 50 percent of the PMF before the dam is overtopped. The PMF will overtop the dam by 4.8 feet. Based upon the Corps of Engineers' inspection guidelines, the spillway is classified as "inadequate," but not "seriously inadequate."



## SECTION 6 - DAM STABILITY

6.1 Stability Analysis: A record of the stability calculations was not available, so in accordance with the Corps of Engineers' guidelines, a brief analysis was made to determine if further studies should be required. Assumptions were made of the foundation parameters used in the analysis on the basis of the field observations and the typical values of the particular rock. The assumed loadings were for extreme conditions, and the analysis was carried out for a narrow strip of the structure at the most critical location in the structure; thus, a more refined analysis may improve the findings that are presented in this Report.

The Clifton Forge Dam has two main sections: the spillway section which makes up the right end of the structure, and a bulkhead section which forms the left end. A separate analysis was provided for each. The spillway section was found to be slightly better with respect to stability than the bulkhead section under all loading conditions, but neither section meets the required factors of safety as set out in Reference 1 of Appendix VI. Basically, the factor of safety against sliding should be greater than 3 and the resultant foundation pressure force should fall within the middle third of the base of the structure.

These conditions were only satisfied for the spillway section for the loading conditions with the reservoir at the level of the spillway crest. The bulkhead section had a factor of safety of 2.8 for this condition, only slightly below the criteria. For the loading conditions presented by the PMF and one-half PMF, the factors of safety were generally between 1 and 2 for sliding, with the resultant foundation pressure force outside the middle one-third section of the base. A summary of the results of the stability calculations are presented in Appendix V.

6.2 Foundation and Abutments: The rock outcrops at the right abutment and the streambed indicate that the foundation rock is chiefly grey siliceous shale interbedded with grey fine-grained sandstone of the Brallier Formation, Devonian in age (Figure 10 of Appendix I and References 6 and 7 of Appendix VI). The rock strata at the dam site strike approximately N35°E nearly parallel to the dam axis and dip at about 35°SE toward the downstream. The dam was designed to be founded on "hard rock." The foundation design of the dam consists of a key trench at the heel, a stepped key trench below the "hard rock" line on the right abutment, and a stepped key trench below the "hard rock" line with concrete corewall on the left abutment. The junction of the right abutment rock and the dam appears to be in good condition, whereas the condition of the contact between left abutment and the concrete corewall and the dam was not observable because of the thick fill cover. A seepage, estimated at 10 to 15 g.p.m., was occurring at the junction of the left abutment fill and the dam, about 23 feet below the dam crest.

6.3 Evaluation: The dam appears to have been stable under the past operating conditions. There is no structural cracking or sign of movement at the base of the dam, the type of foundation rock indicated is generally medium hard and durable, and possesses adequate bearing capacity when in a sound state for supporting the structure.

Our structural stability analysis, based on the PMF and one-half the PMF loading conditions (see paragraph 6.1), indicates the static stability of the dam is unsatisfactory.

The dam is located within Zone 2 on the Algermissen Seismic Risk Map of the United States (1969 edition) and there are uncertainties with respect to the static stability of the dam, as set forth in paragraph 6.1. Therefore, in accordance with paragraph 3.6.4 of Reference 1 of Appendix VI, additional assessments with respect to the seismic stability of the dam should be considered based on the results of studies outlined in paragraph 7.2.1.

Seepage at the left abutment might develop into a safety hazard in the future and should be monitored to detect a change in conditions.

## SECTION 7 - ASSESSMENT, RECOMMENDATIONS/REMEDIAL MEASURES

The assessment, recommendations, and remedial measures contained in this Report are based on the provisions of Appendix VII, Conditions.

7.1 Assessment: The dam shows many indications of wear on the concrete and appurtenant structures, but apparently all the equipment works adequately for daily operations.

The spillway is capable of passing 50 percent of the PMF before the dam is overtopped and thus is classified as "inadequate" but not "seriously inadequate."

The static stability of the structure did not meet the Corps of Engineers' inspection guidelines and further studies are required.

Some seepage was detected at the base of the bulkhead section on the left abutment. The seepage rate was low but it should be monitored in the future for any significant increase.

7.2 Recommendations/Remedial Measures: The following actions are recommended for the owner's consideration:

7.2.1 Structural Stability: The owner should obtain the services of a qualified consultant to evaluate the structural stability of the dam and make recommendations for remedial action to be carried out by the owner. The analysis should follow the guidelines recommended in Reference 1 of Appendix VI and should be completed within 120 days of receipt of this Report.

7.2.2 Warning System: A detailed emergency warning system should be developed as soon as possible to notify the downstream inhabitants when a rising reservoir level threatens to overtop the dam or when any other dangerous condition exists. In order for the warning system to be effectively applied, a study of the downstream area should be made so that the areas subject to flooding as a result of a dam break can be identified.

7.2.3 Inspection and Maintenance Program: It is recommended that the owner establish a semiannual inspection program to monitor the conditions at the dam. Particular attention should be given to monitoring the seepage on the left abutment.

The monitoring program should initially include monthly measurements of the flow rate, and measurements of flow rate whenever the reservoir is at peak levels. The monthly measurements should continue until a pattern of variation in the flow is established, and it can be determined that the flow is not increasing. Measurements can then be performed semiannually. If the seepage shows steadily increasing rates of flow, corrective action should be considered. The unstable slope area on the right bank downstream should be stabilized and protected from excessive scouring and erosion in the future.

7.2.4 Design Documents: A complete set of all available design documents should be maintained by the owner. These files should include available design drawings, calculations, pertinent correspondence, and maintenance records. In addition, an attempt should be made to obtain all available information on past design changes and repairs to the dam and the reasons for the changes.

7.2.5 Spillway Capacity: Future consideration should be given to increasing the capacity of the spillway.

APPENDIX I  
MAPS AND DRAWINGS



# IMPROVEMENTS TO WA

FOR THE CITY OF

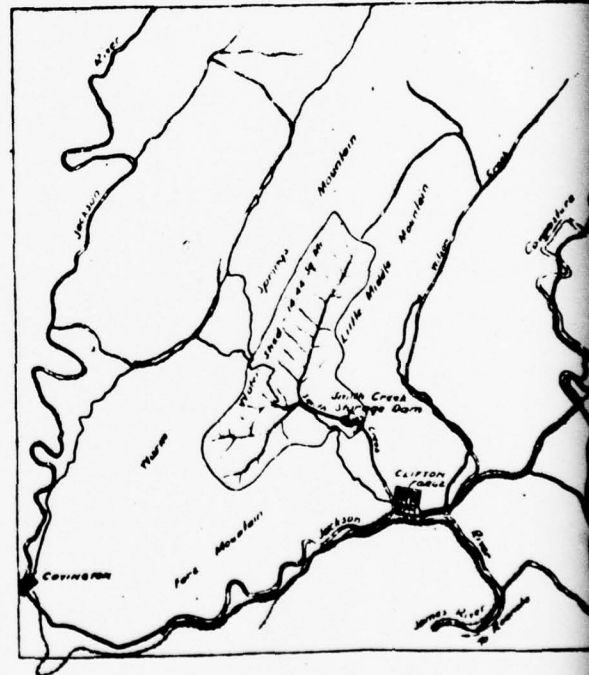
## CLIFTON FORGE, VIR

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J.C. Remington, Jr. & John S. Hale  
Consulting Engineers  
Camden, N.J.      Staunton, Va.

### INDEX:

SHEET NO.	TITLE
1	SITUATION MAP
2	LAND ACQUISITION MAP
3	TOPOGRAPHY & CORE DRILLING
4	PLAN
5	ELEVATIONS
6	SECTIONS
7	DETAILS



Scale 1 inch = 2 miles



MAY, 1948

# S TO WATER SYSTEM

THE CITY OF

## FORGE, VIRGINIA

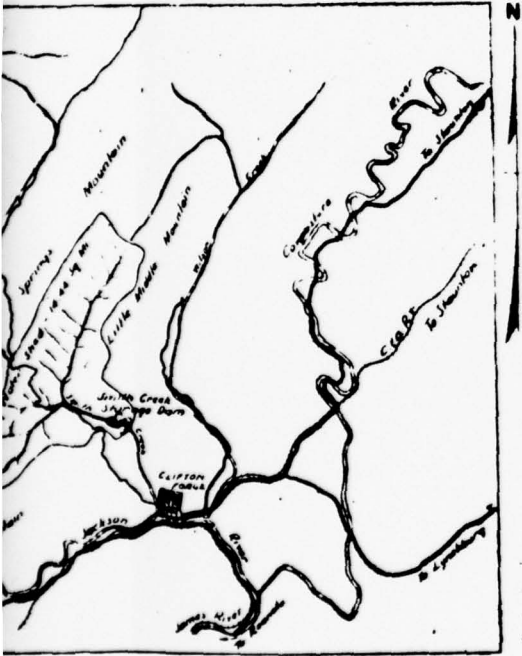
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ington, Jr. & John S. Hale  
onsulting Engineers  
en, N.J. Staunton, Va.

### CITY COUNCIL:

- W.J. ENOS, Mayor
- M.B. WHITING, Vice-Mayor
- L.P. CAMPBELL
- Dr. G.S. HARTLEY
- H.C. WOOD

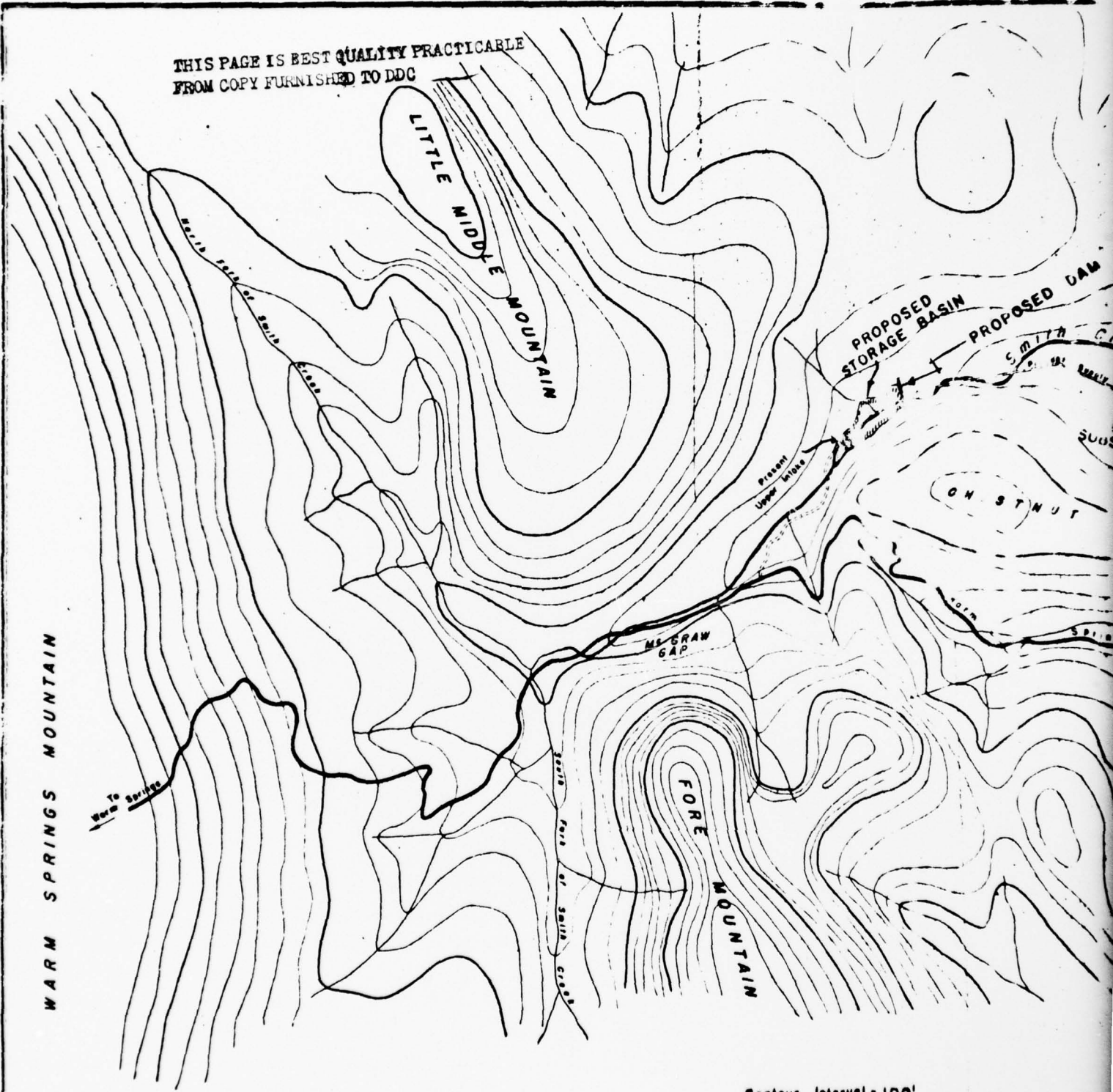
W.C. DRAGER, City Manager



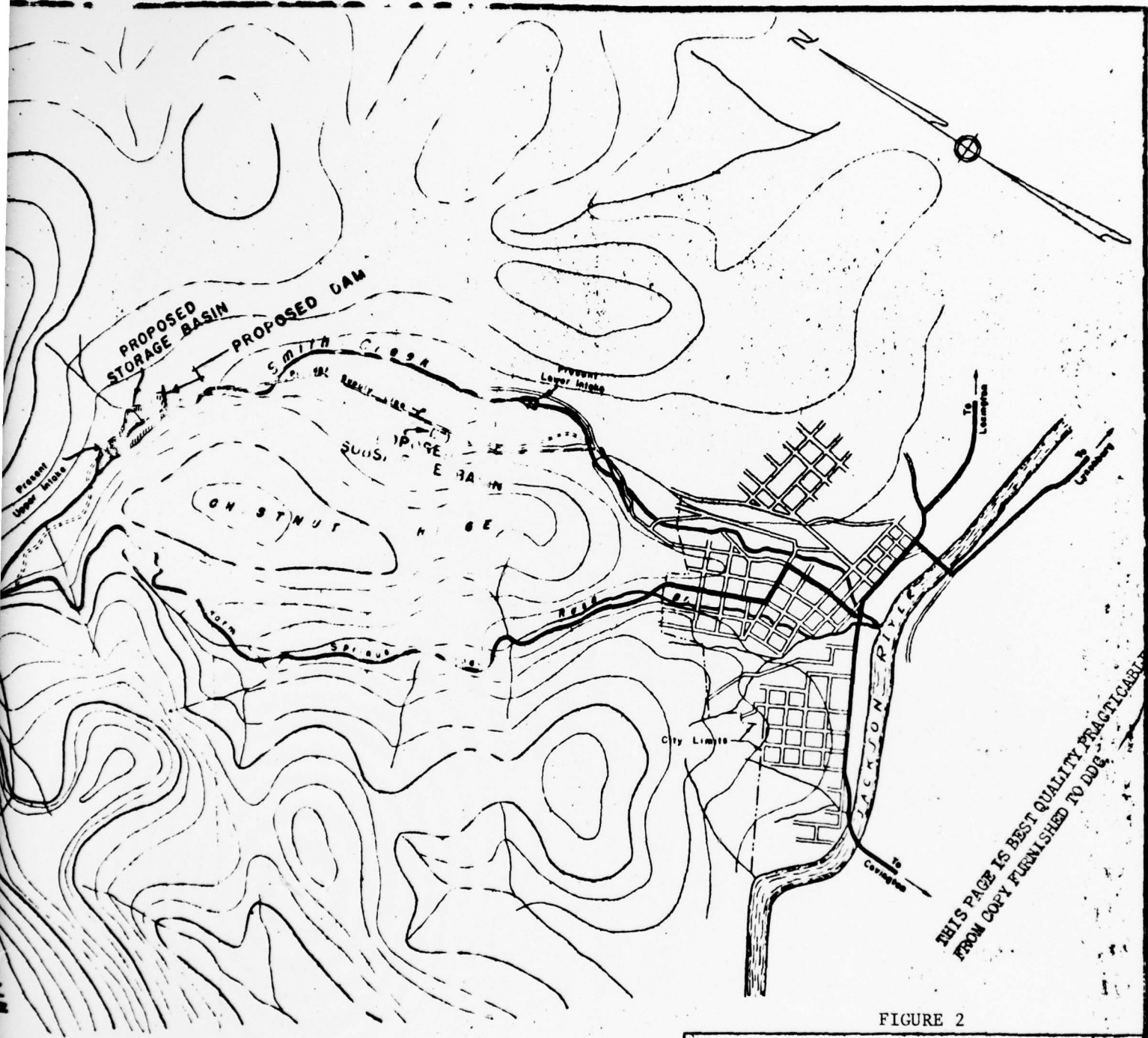
MAY, 1948

FIGURE 1

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Contour Interval = 100'



Contour Interval = 100'

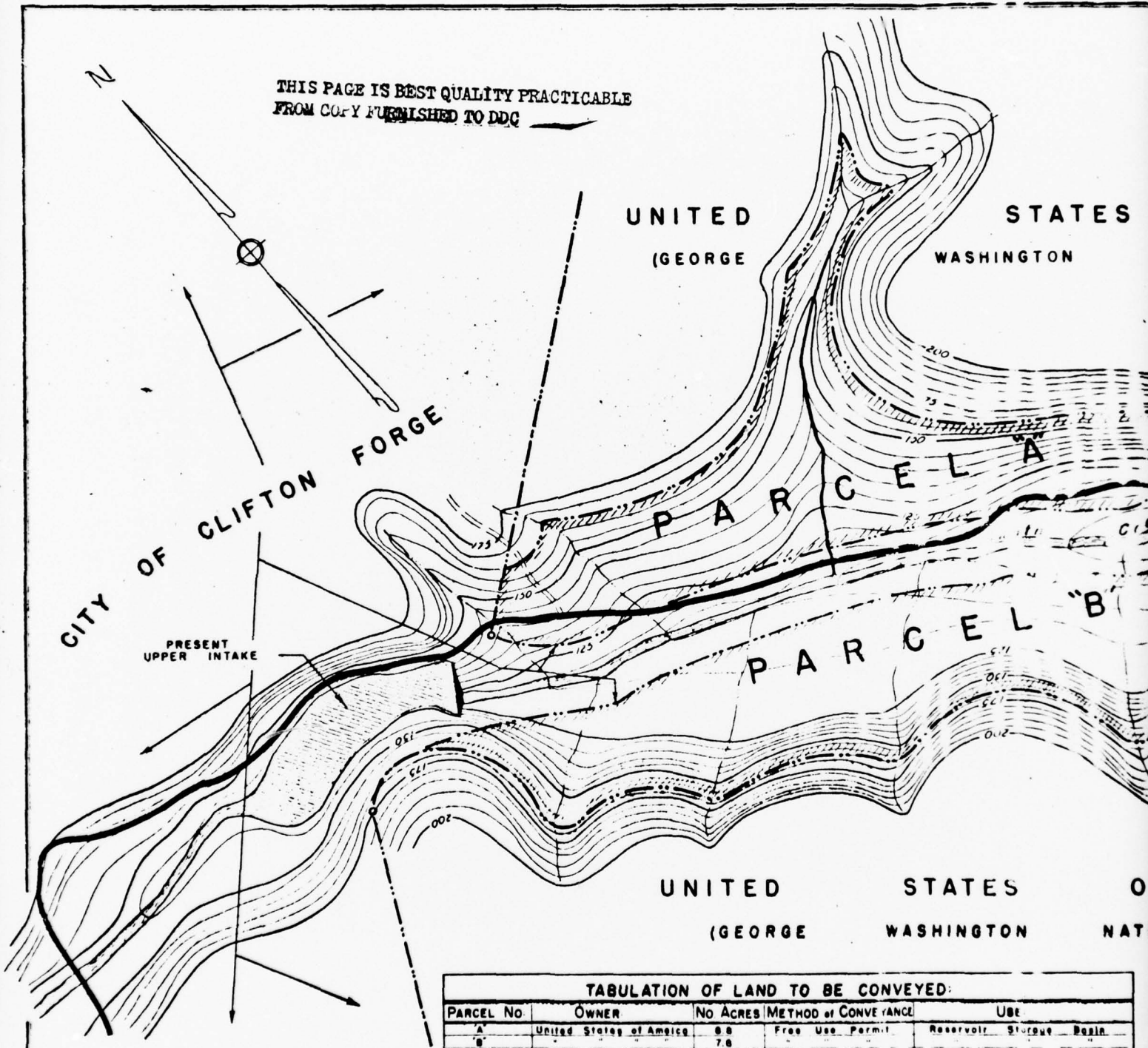
FIGURE 2

<b>IMPROVEMENTS TO WATER SYSTEM FOR THE CITY OF CLIFTON FORGE, VA.</b>		
<b>SITUATION MAP</b>		
Scale 1"=1000'	J.C. Remington, Jr. & John S. Hale	Approved By
Drawn By: J.C.H.	Consulting Engineers	Date
Checked By: J.J.H.	Camden, N.J.      Staunton, Va.	
Sheet No.		

21



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UNITED STATES  
(GEORGE WASHINGTON

UNITED STATES OF AMERICA  
(GEORGE WASHINGTON NATIONAL

**TABULATION OF LAND TO BE CONVEYED:**

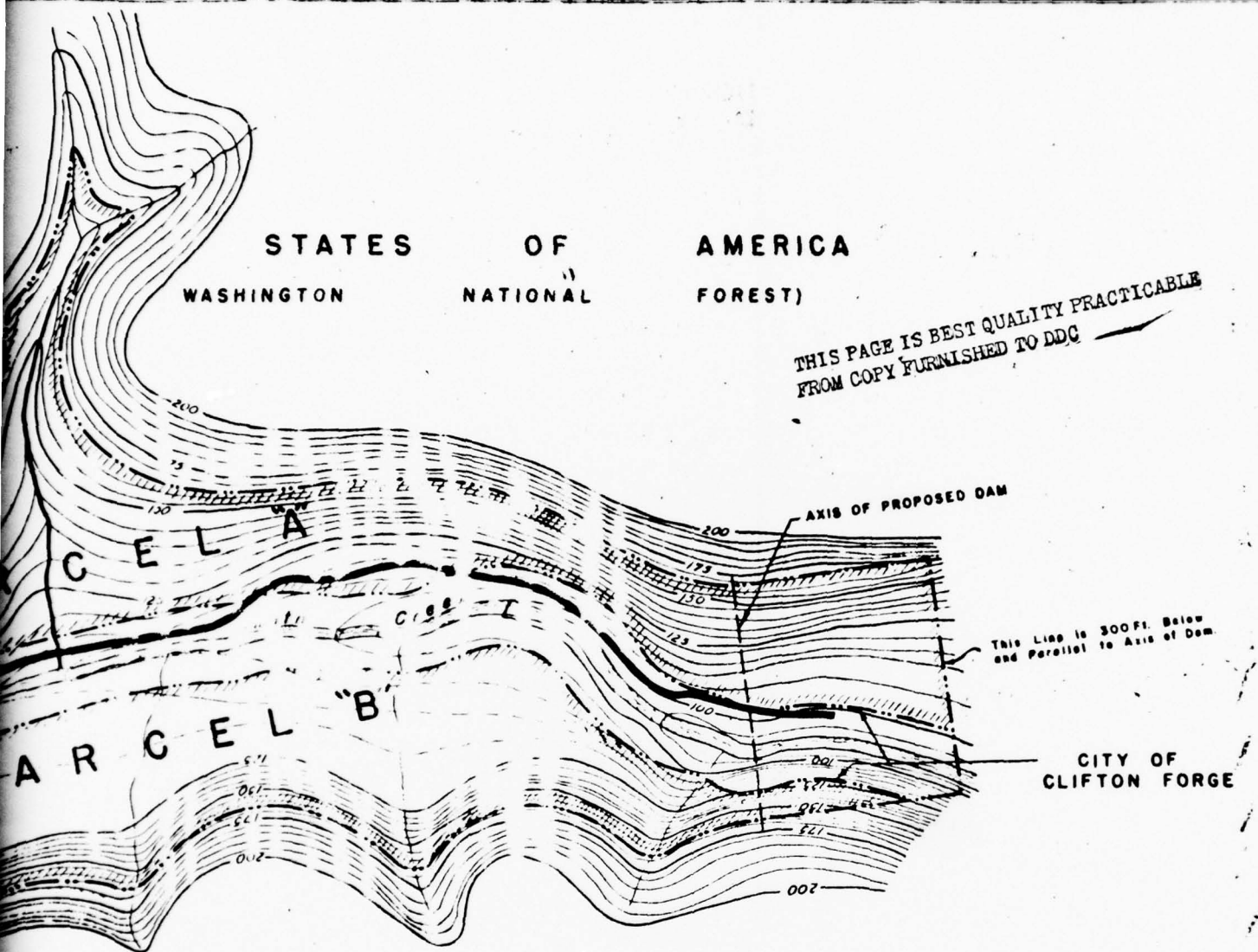
PARCEL NO	OWNER	NO ACRES	METHOD of CONVEYANCE	USE
A	United States of America	8.8	Free Use Permit	Reservoir Storage Basin
B	"	7.8	"	"
C	"	"	"	Temporary Site for Const. Camp
D	"	"	"	Quarry Opn.

**GENERAL NOTES**  
All elevations are referenced to  
Site Datum, on which 00+1364.5'  
Contour Interval = 5'



STATES OF AMERICA  
WASHINGTON NATIONAL FOREST)

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STATES OF AMERICA  
WASHINGTON NATIONAL FOREST)

FIGURE 3

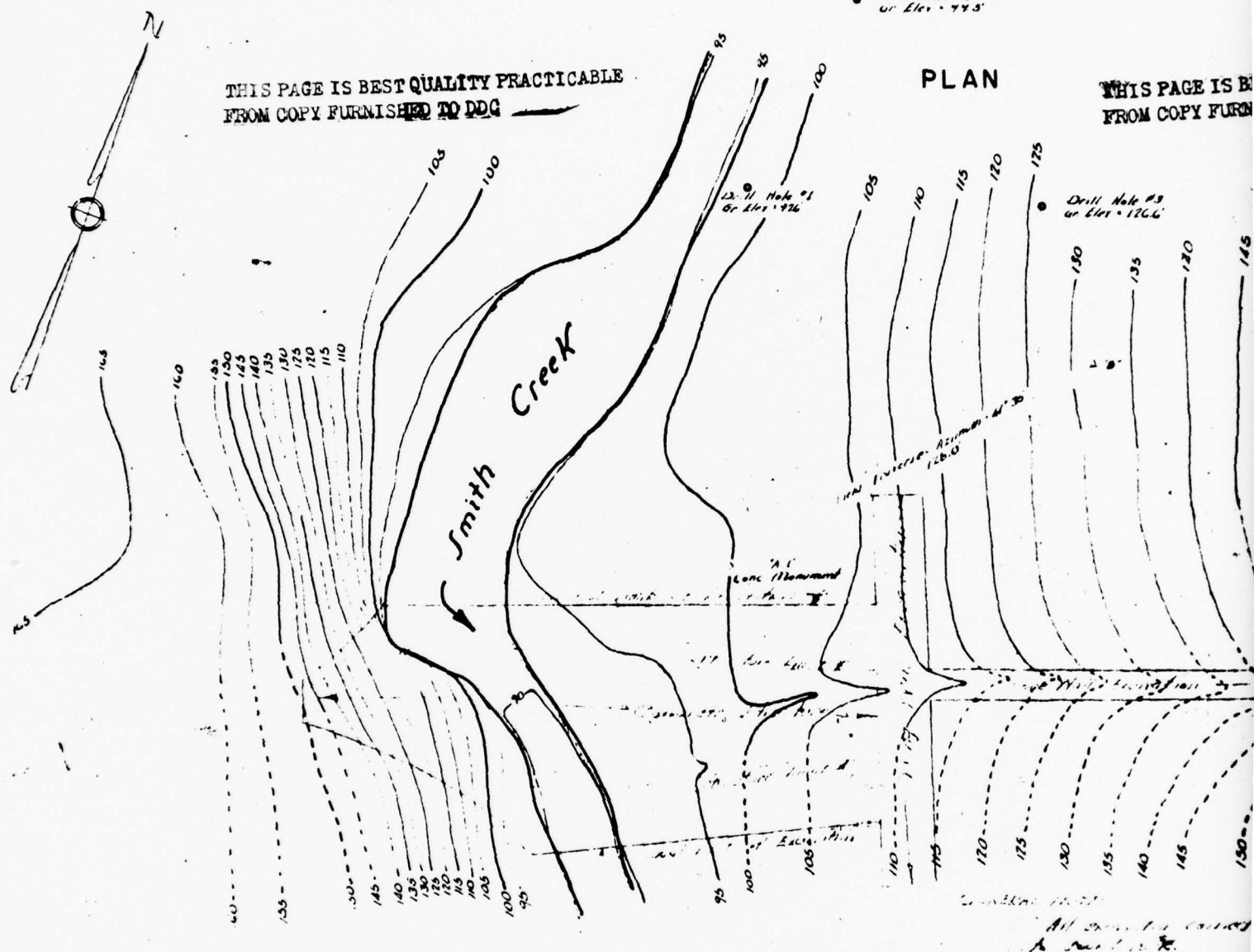
TO BE CONVEYED:	
METHOD of CONVEYANCE	Use
Res. Use Permit	Reservoir, Storage Basin
	Temporary Site for Const. Camp
	Quarry Open

IMPROVEMENTS TO WATER SYSTEM FOR THE CITY OF CLIFTON FORGE, VA.		
LAND ACQUISITION MAP		
Scale 1"=100'	J.C. Remington, Jr. & John S. Hale Consulting Engineers Camden, N.J. Staunton, Va.	Approved By: Date
Drawn By: [unclear]	Checked By: [unclear]	
Sheet No. [unclear]		

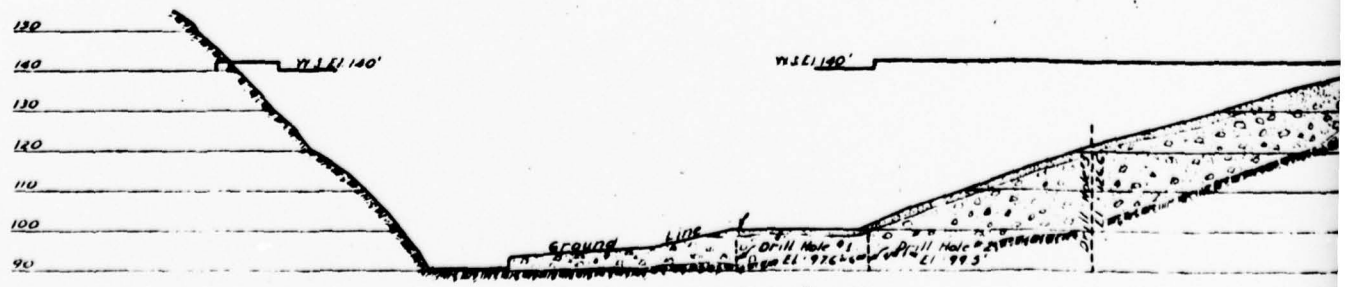
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PLAN

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ELEVATION

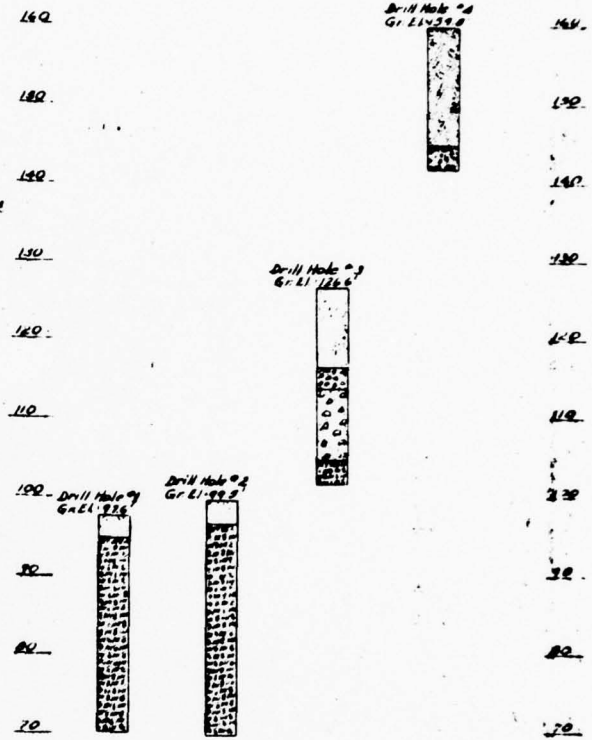
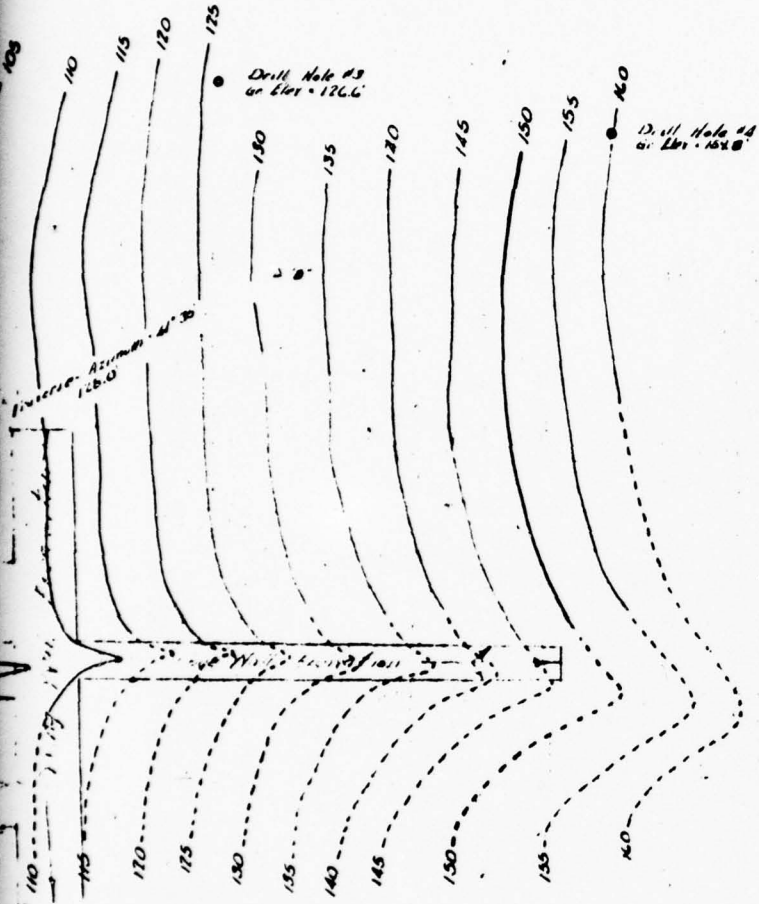


Drill Hole #2  
at Elev. 99.5'

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PLAN

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LOG OF CORE DRILLING  
SCALE 1" = 10'

LEGEND

- Soil Overburden
- Boulders & Sand
- Broken Weathered Shale
- Rock

CONTOUR 125.0  
All shown for contour  
to match 125.0

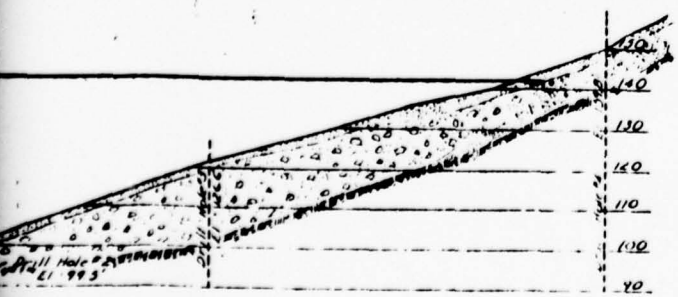
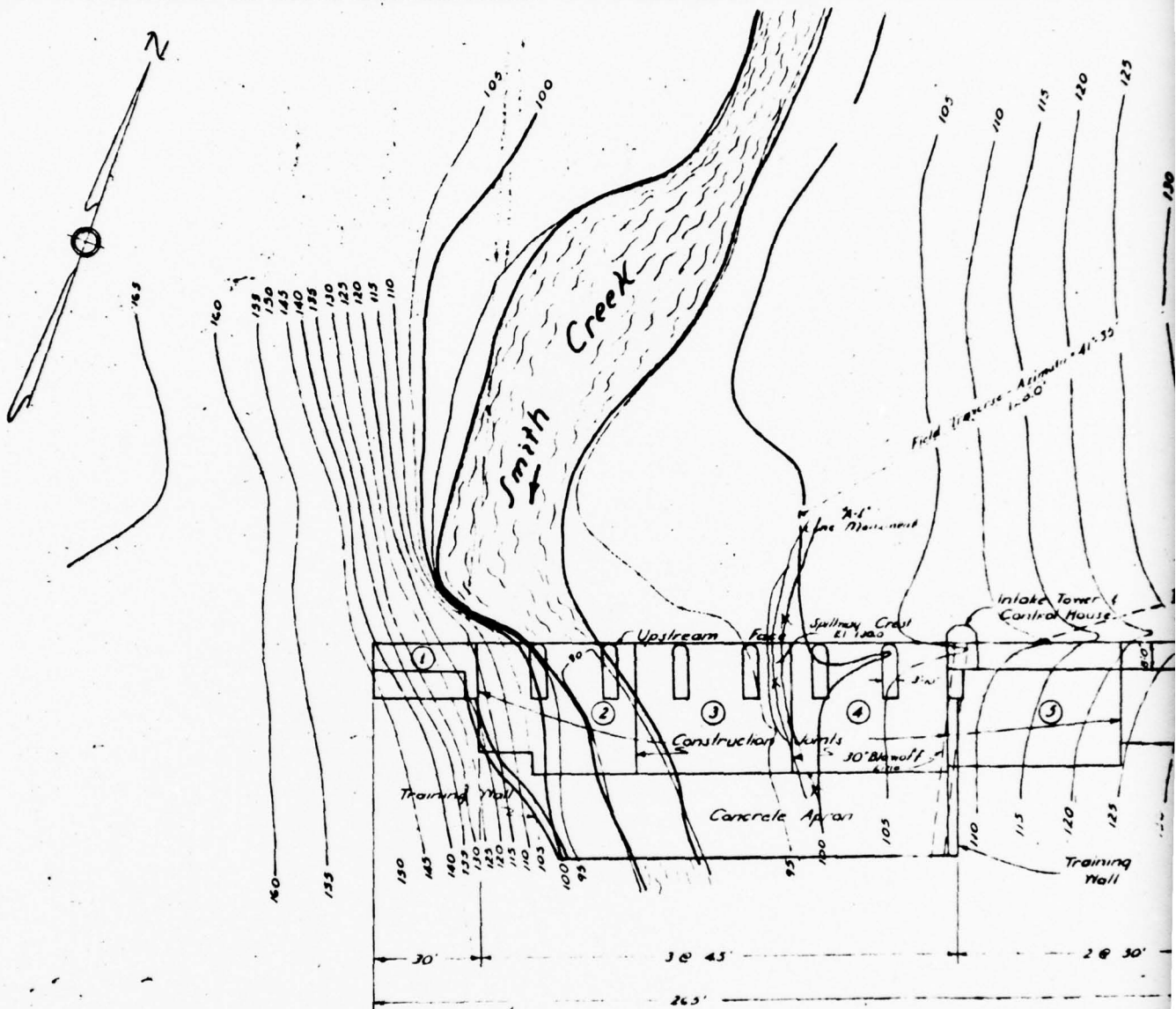


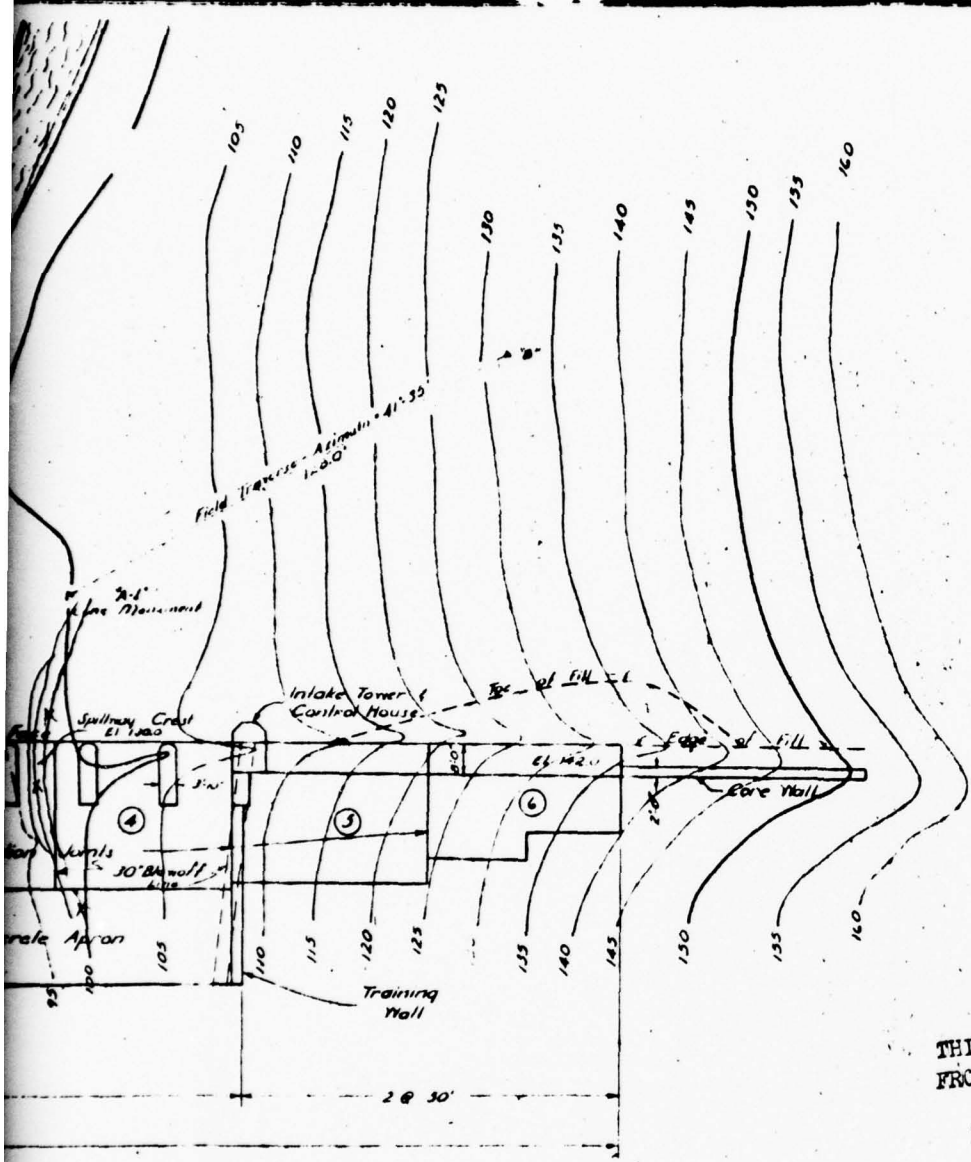
FIGURE 4

<b>IMPROVEMENTS TO WATER SYSTEM FOR THE CITY OF CLIFTON FORGE, VA.</b>		
<b>TOPOGRAPHIC MAP OF DAM SITE</b>		
Scale Drawn By Checked By Sheet No	J.C. Remington, Jr. & John S. Hale Consulting Engineers Camden, N.J.    Staunton, Va.	Approved By Date



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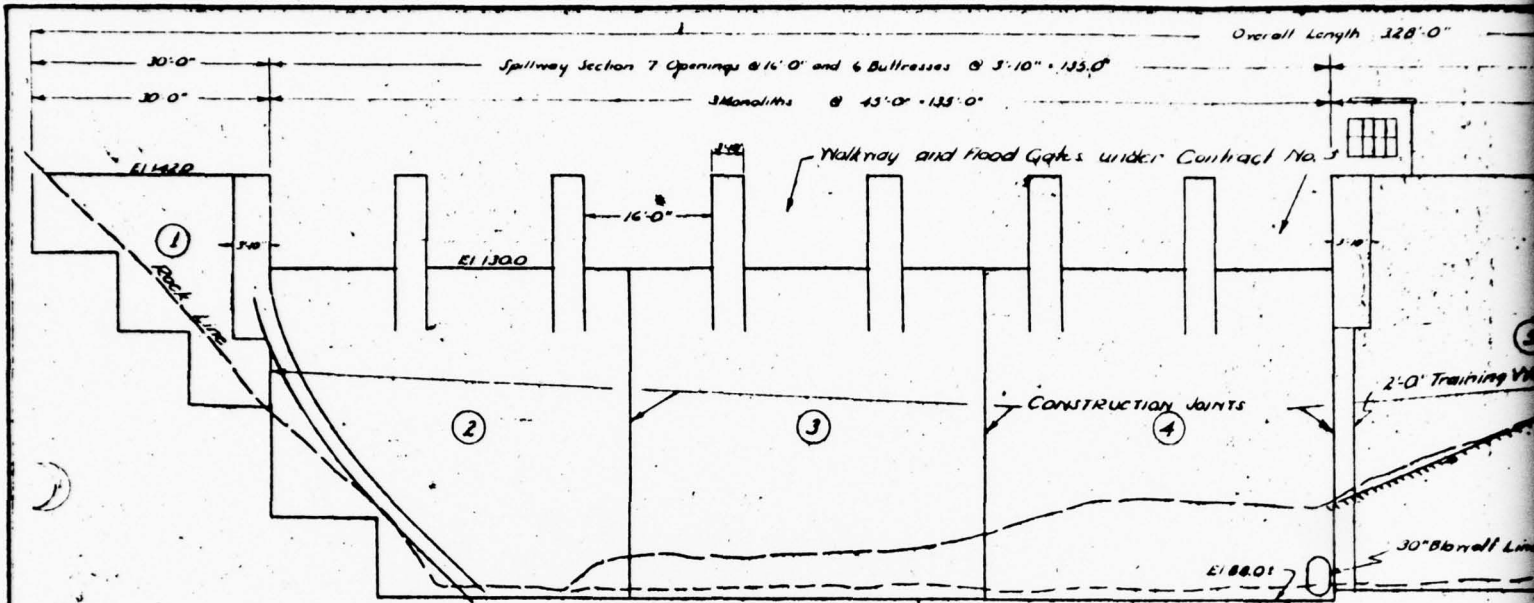
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FIGURE 5

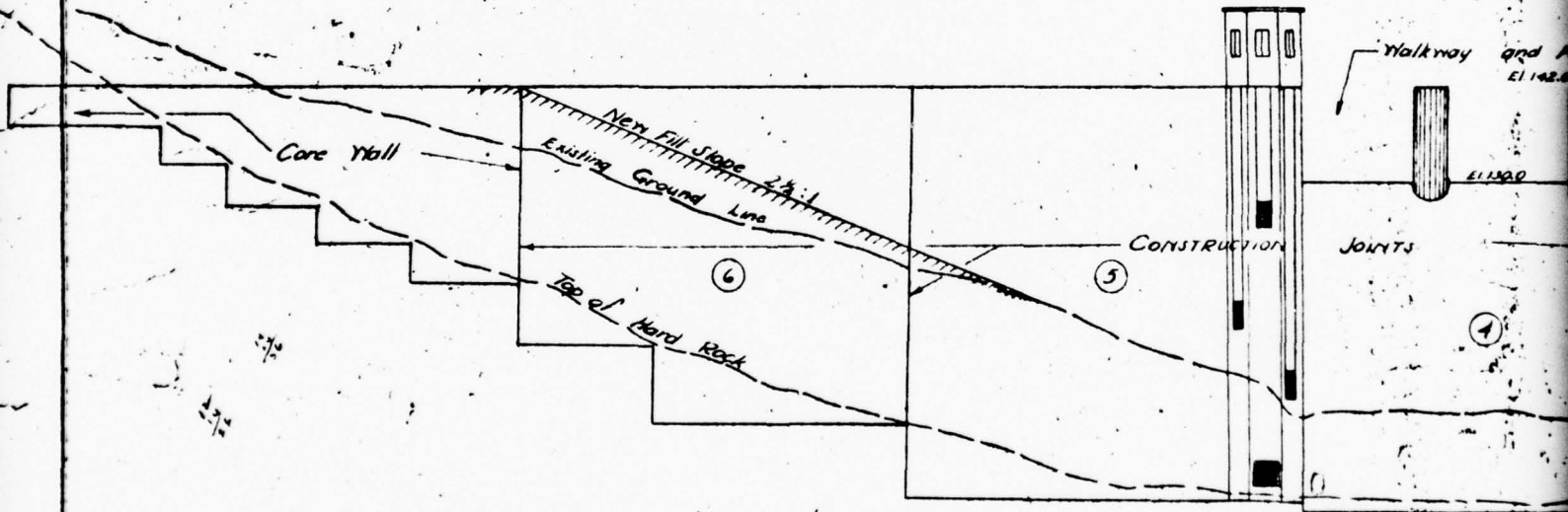
<b>IMPROVEMENTS TO WATER SYSTEM</b> FOR THE CITY OF <b>CLIFTON FORGE, VA.</b>		
<b>PLAN</b>		
Scale 1" = 20' Drawn By Checked By Sheet No.	<b>J.C. Remington, Jr. &amp; John S. Hale</b> Consulting Engineers Camden, N.J.    Staunton, Va.	Approved By  Date

21





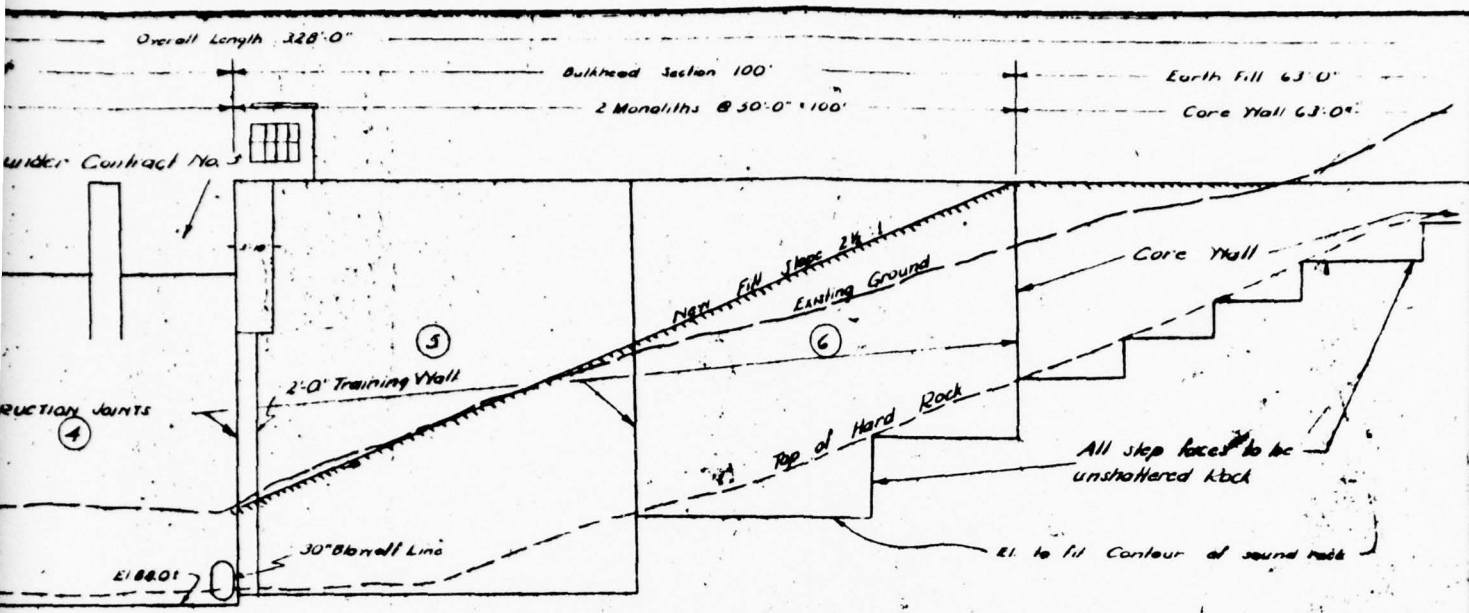
DOWN STREAM ELEVATION



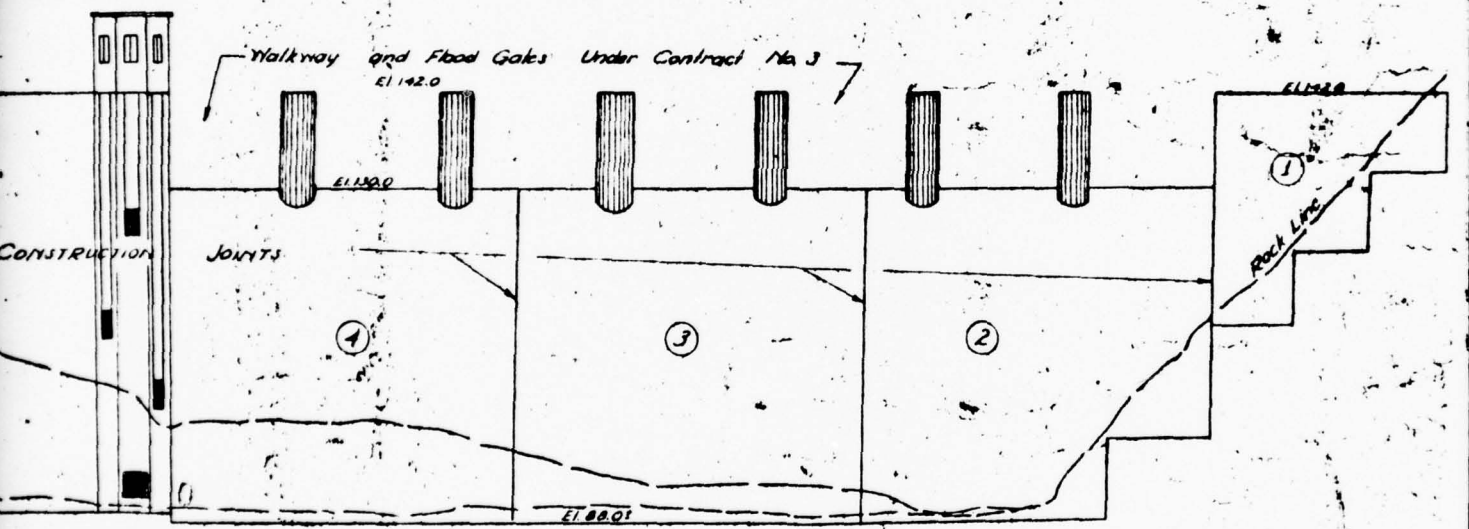
UPSTREAM ELEVATION

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GENERAL NOTE:  
For details of Reinforcement  
Intake structure - See Sheet #7



ELEVATION



ELEVATION

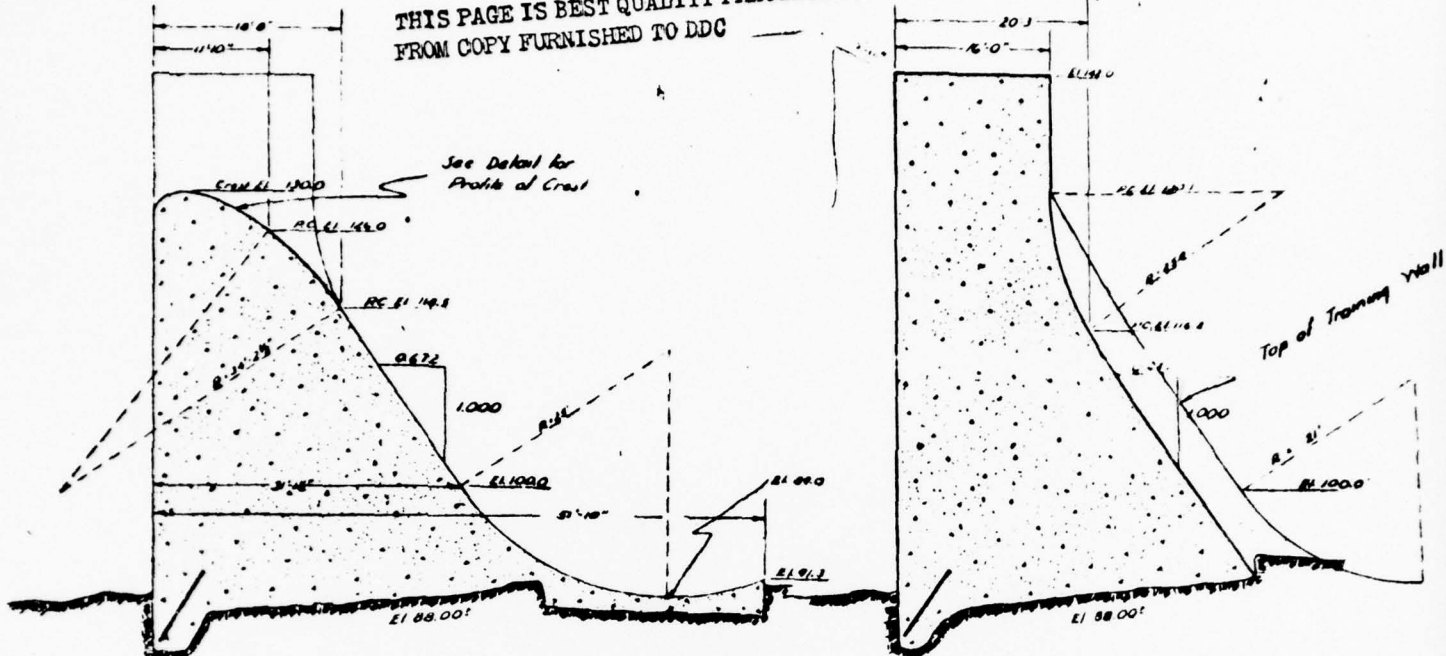
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GENERAL NOTE:  
For details of Reinforcement and  
Intake structure - See Sheet #7

FIGURE 6

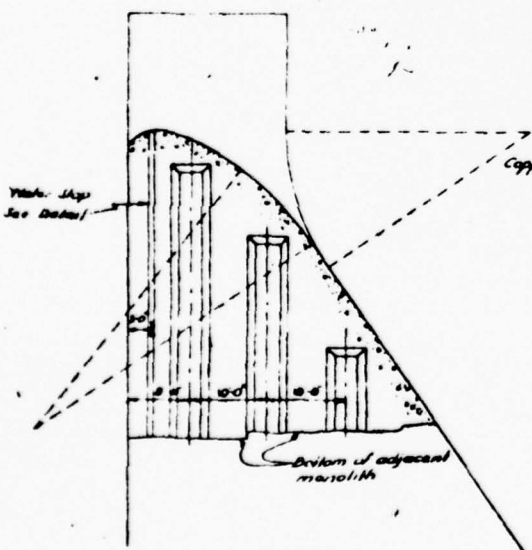
<b>IMPROVEMENTS TO WATER SYSTEM FOR THE CITY OF CLIFTON FORGE, VA.</b>		
<b>ELEVATIONS OF DAM</b>		
Scale 1"=10'	J.C. Remington, Jr. & John S. Hale Consulting Engineers Camden, N.J.    Staunton, Va.	Approved By:  Date
Drawn By		
Checked By		
Sheet No		

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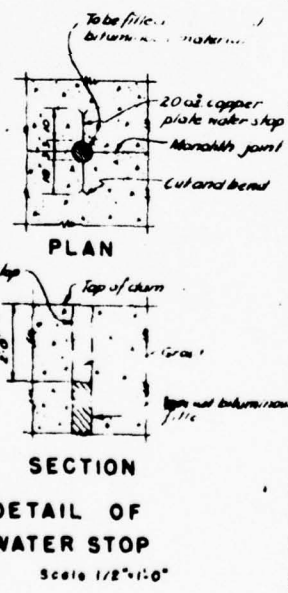


**SPILLWAY SECTION**  
Scale 1/8" = 1'-0"

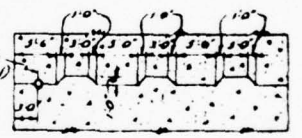
**BUTTRISS SECTION**  
Scale 1/8" = 1'-0"



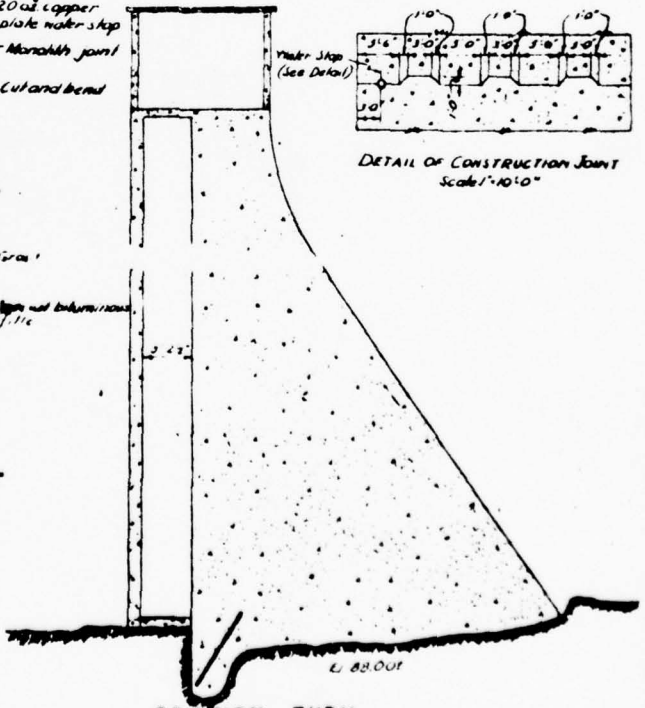
**TYPICAL DETAIL OF CONSTRUCTION JOINT**  
Scale 1/8" = 1'-0"



**SECTION  
DETAIL OF WATER STOP**  
Scale 1/2" = 1'-0"

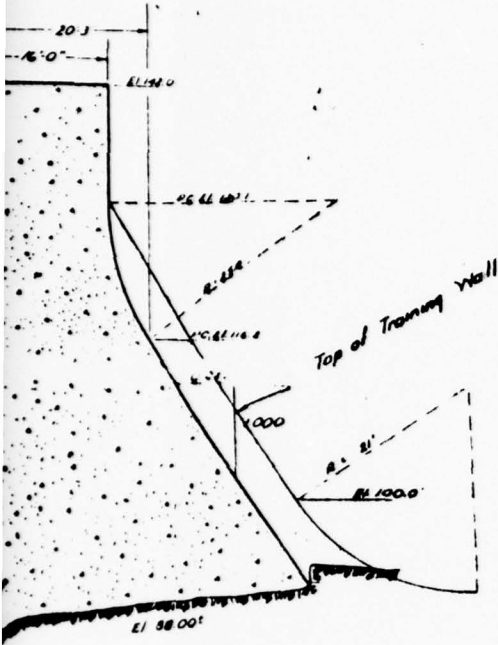


**DETAIL OF CONSTRUCTION JOINT**  
Scale 1/4" = 1'-0"

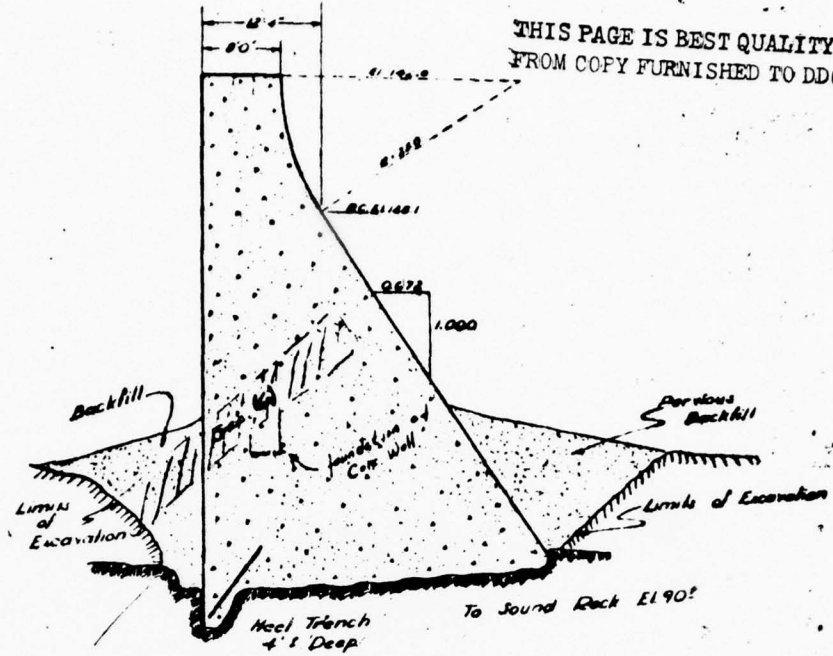


**SECTION THRU INTAKE TOWER**  
Scale 1/8" = 1'-0"

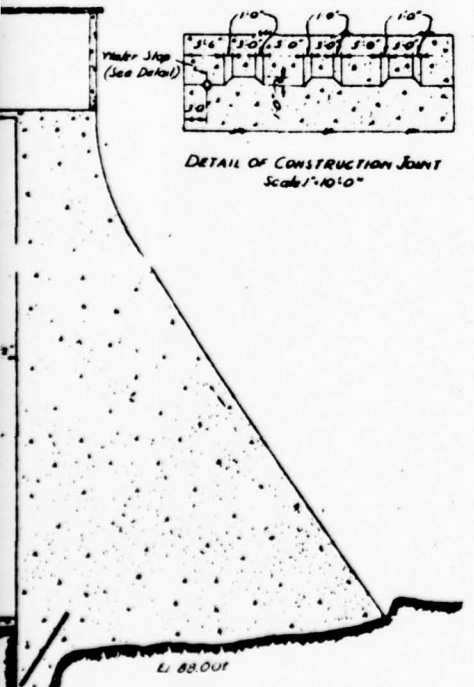
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**BUTTRESS SECTION**  
Scale 1/8" = 1'-0"



**BULKHEAD SECTION**  
Scale 1/8" = 1'-0"



**SECTION THRU INTAKE TOWER**  
Scale 1/8" = 1'-0"



**DETAIL OF CONSTRUCTION JOINT**  
Scale 1/10" = 1'-0"



**PROFILE OF CREST OF SPILLWAY**  
Scale 1/8" = 1'-0"

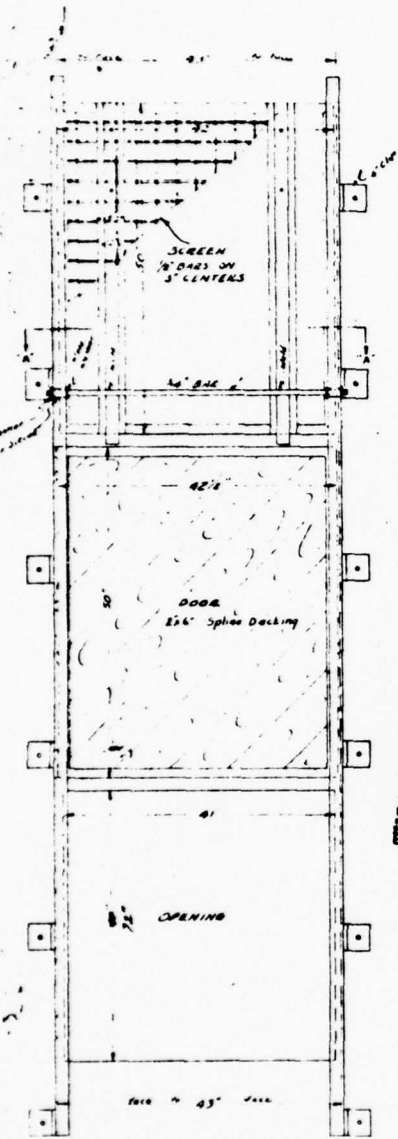
FIGURE 7

**IMPROVEMENTS TO WATER SYSTEM  
FOR THE CITY OF  
CLIFTON FORGE, VA.**

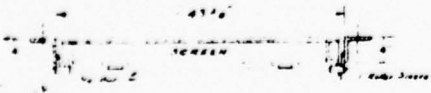
**SECTIONS**

Scale: 1/8" = 1'-0"	J.C. Remington, Jr. & John S. Hale	Approved By:
Drawn By:	Consulting Engineers	
Checked By:	Camden, N.J. Staunton, Va.	Date:
Sheet No.:		



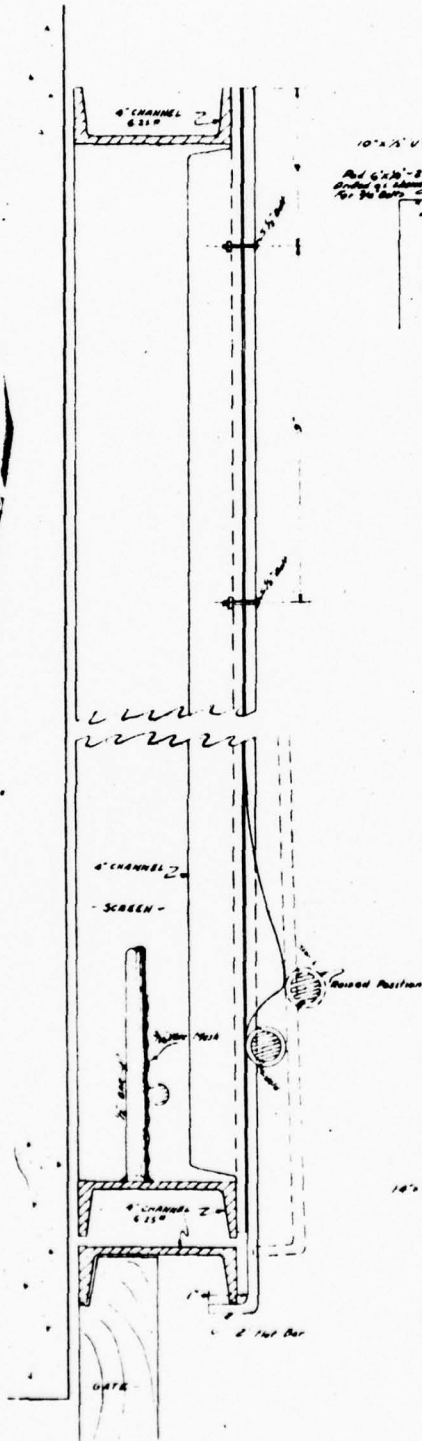


TYPICAL ELEV.  
WATERHOUSE GATE & SCREEN  
Scale 1" = 1'

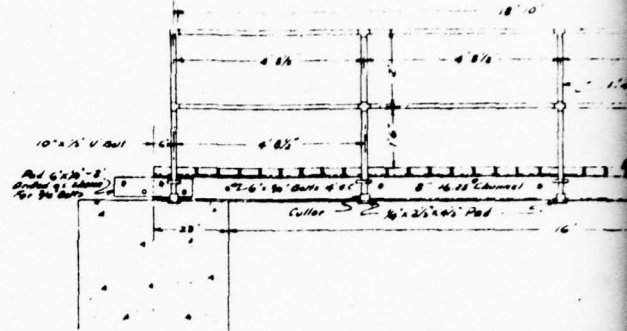


SECTION 'A-A'  
Scale 1" = 1'

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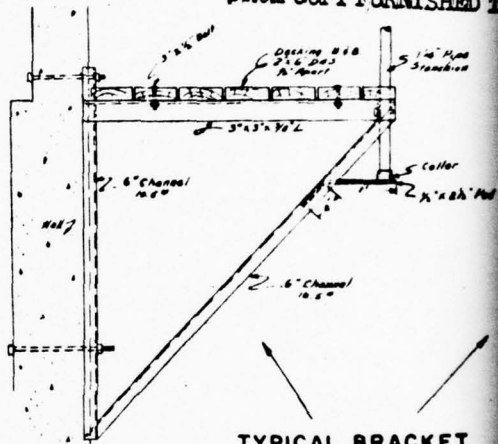


SCREEN & LATCH DETAIL  
Scale 1/2" = 1"

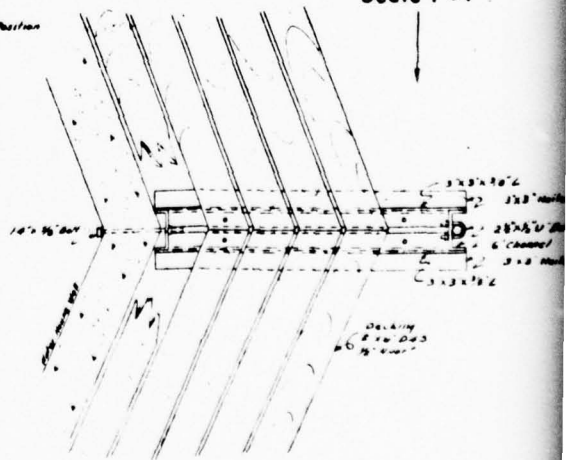


TYPICAL SECTION  
BRIDGE FOR DAM  
Scale 1/2" = 1'

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TYPICAL BRACKET  
CATWALK AROUND WATER  
Scale 1" = 1'



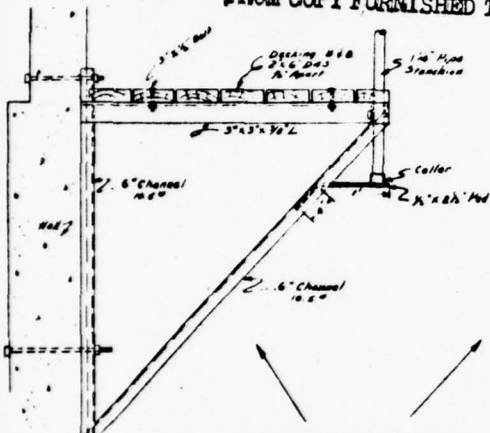


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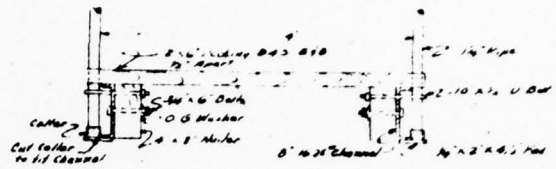


TYPICAL SECTION BRIDGE FOR DAM Scale 1/2" = 1'

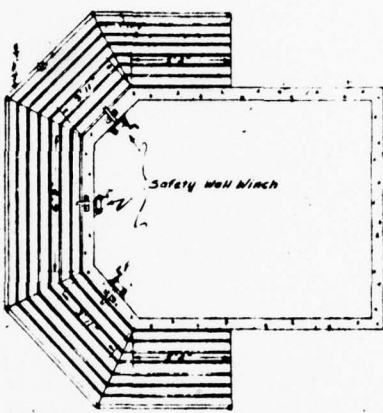
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TYPICAL BRACKET CATWALK AROUND WATERHOUSE Scale 1" = 1'

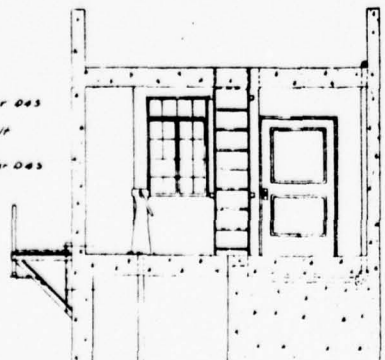


CROSS SECTION BRIDGE FOR DAM Scale: 1" = 1'



WATERHOUSE-HORIZONTAL SECTION Scale: 1/4" = 1'

NO.	SIZE	ITEM	AMT.
14	8" x 19.0	10.25" Channel	1
12	1/2" x 2"	Flat Bar	10
14	4.4" x 10.0	Rolling-Stranchon Panels	14
70	6" x 3.5"	Bolts, Machine	70
36	1/2" x 2 1/2"	Bolts	36
40	1/2" x 2 1/2"	Flat Bar	40
84	10" x 1/2"	U Bolts	84
14	4" x 8" - 20	Nailers (D45 848)	14
250	2" x 4"	Decking (D45 848)	250
2	6" x 4.5"	10.5" Channel	2
2	6" x 5.5"	10.5" Channel	2
4	6" x 4.11"	10.5" Channel	4
4	6" x 6.5"	10.5" Channel	4
4	3.5" x 7.5"	4" Angle	4
8	3.5" x 7.5"	4" Angle	8
10	1/2" x 2 1/2"	Flat Bar	10
12	10" x 5/8"	Bolts, Machine	12
6	2 1/2" x 1/2"	U Bolts	6
250	2" x 6"	Decking (D45 848)	250
30	2" x 4"	Nailers & Decking	30
120	1 1/2"	Pipe for Railing	120
15	2"	Pipe	15
120	1/2"	Flat Bar	120
12	10" x 5/8"	Bolts, Machine	12
12	3/4"	U Bolts	12
150	2" x 6"	Spine Decking	150
110	8" x 10.5"	10.5" Channel	110
		W. Bolt	
3	14"	Sheave	3
160	5/16" 6213	Wire Rope	160
3	Draw 627	Safety Wall Winch (Takes up 160' of rope)	3



WATERHOUSE-VERTICAL SECTION Scale: 1/4" = 1'

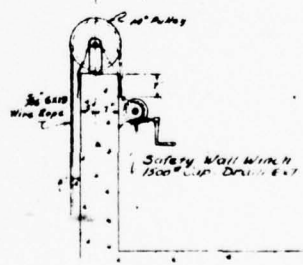
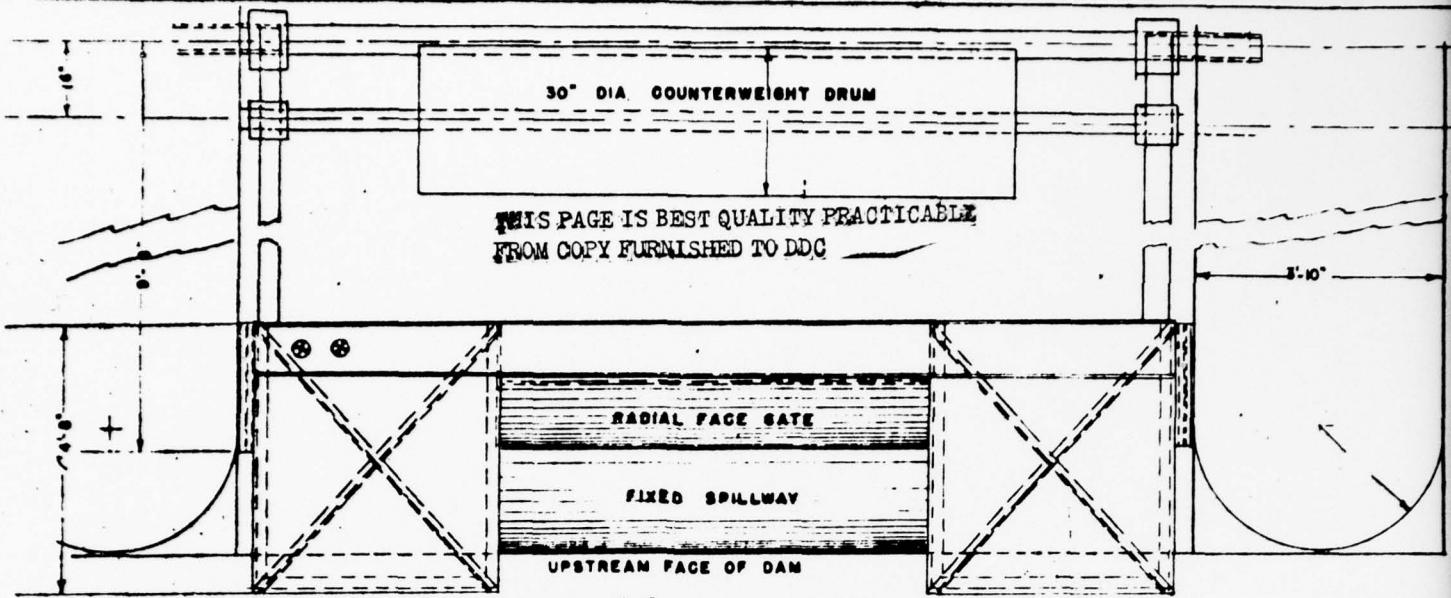


FIGURE 8 ELEVATION - WATERHOUSE GATE WINCH 1/2" = 1'

IMPROVEMENTS TO WATER SYSTEM FOR THE CITY OF CLIFTON FORGE, VA.

DETAILS OF WATERHOUSE GATES & WALKWAYS		
Scale	J.C. Remington, Jr & John S. Hale	Approved By
Drawn By	Consulting Engineers	
Checked By	Camden, N.J. Staunton, Va.	Date
Sheet No.		



19'-10"

PLAN

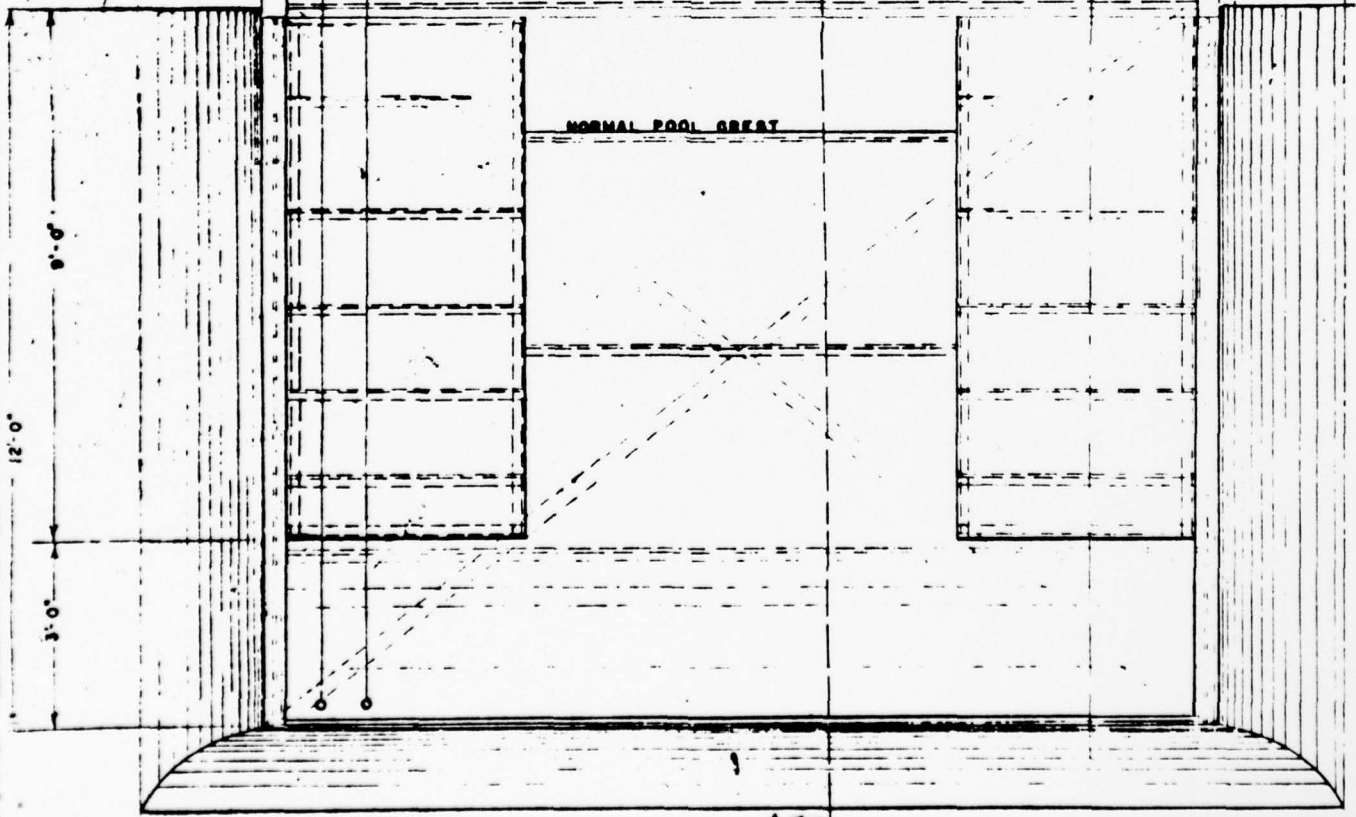
16'-0"

15'-3"

7'-3"

A

NORMAL POOL GREST



ELEVATION LOOKING DOWNSTREAM

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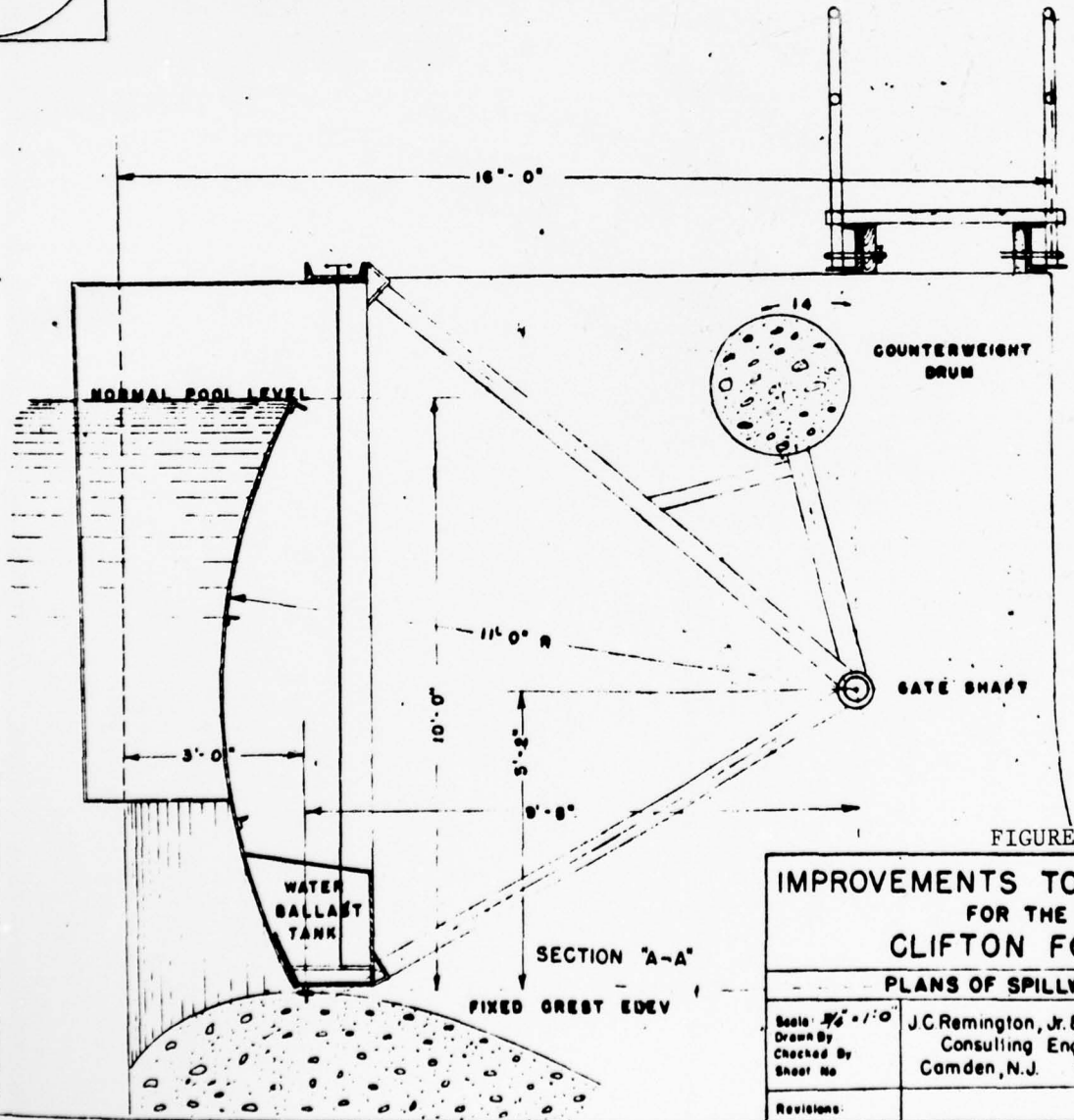
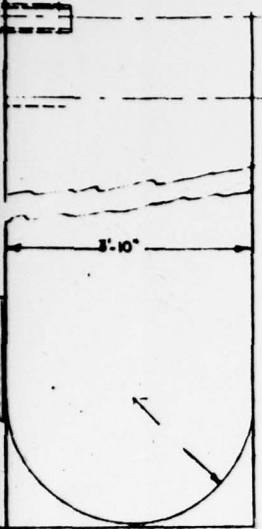
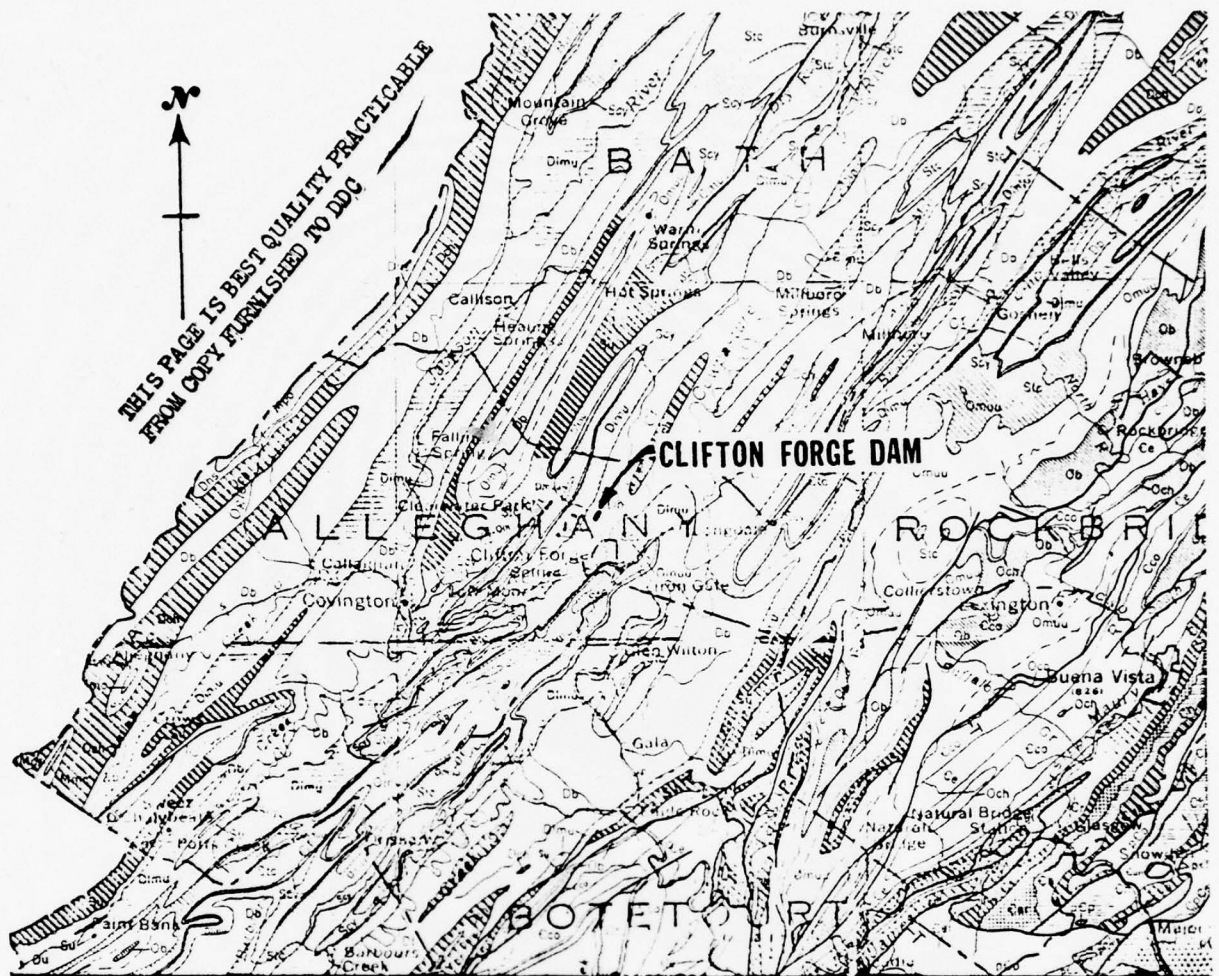


FIGURE 9

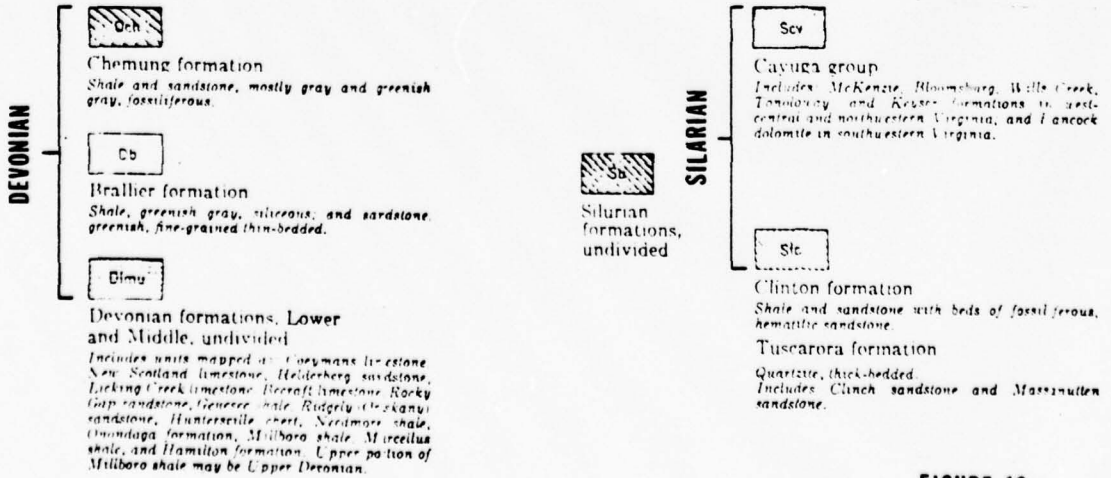
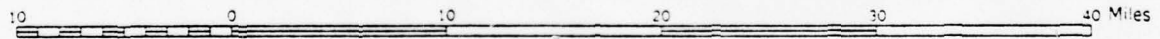
<b>IMPROVEMENTS TO WATER SYSTEM FOR THE CITY OF CLIFTON FORGE, VA.</b>		
<b>PLANS OF SPILLWAY GATES</b>		
Scale: $\frac{3}{8}'' = 1'-0''$	J.C. Remington, Jr. & John S. Hale Consulting Engineers Camden, N.J. Staunton, Va.	Approved By:
Drawn By		Date
Checked By		
Sheet No		
Revisions:		





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Scale 1:500,000  
1 inch equals approximately 8 miles



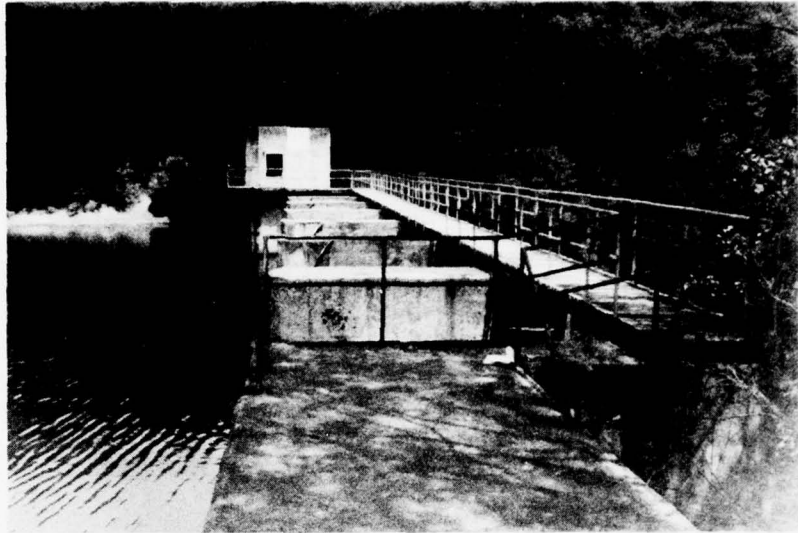
SOURCE: GEOLOGIC MAP OF VIRGINIA, 1963

FIGURE 10  
REGIONAL GEOLOGIC MAP  
SHOWING DAM LOCATION

APPENDIX II

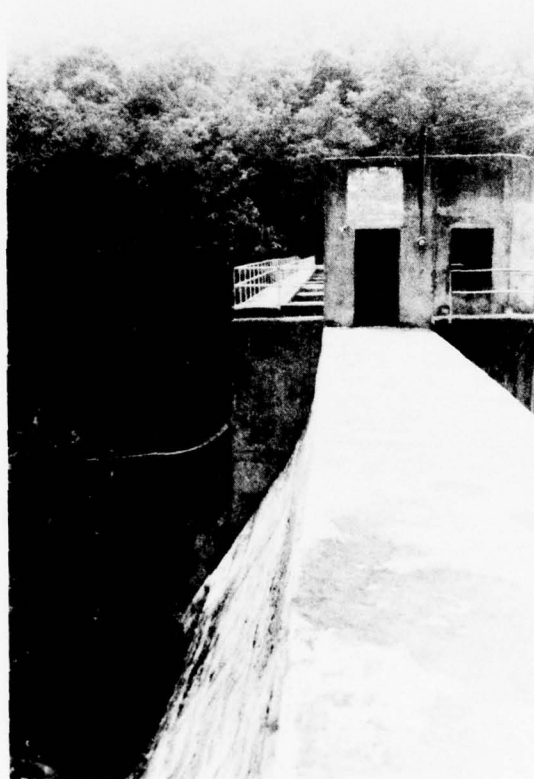
PHOTOGRAPHS





August 1978

VIEW OF DAM FROM RIGHT ABUTMENT



VIEW OF DAM FROM LEFT  
ABUTMENT

August 1978

SPILLWAY GATE PIERS

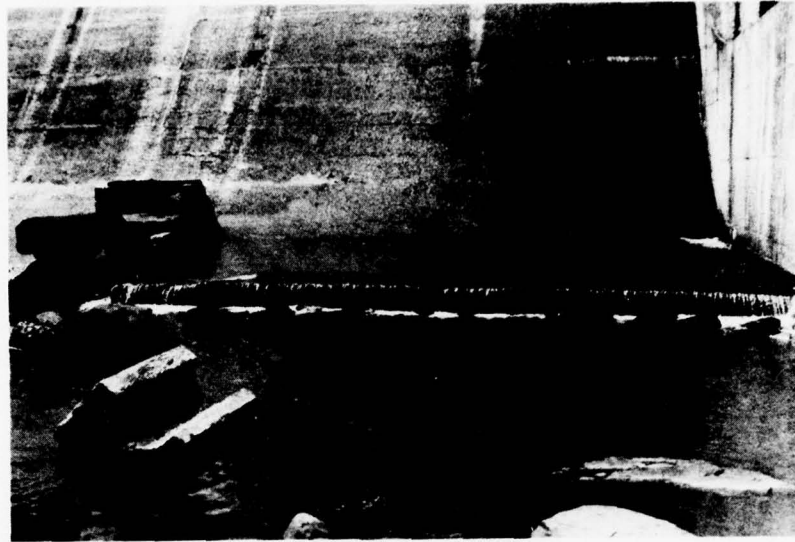


August 1978



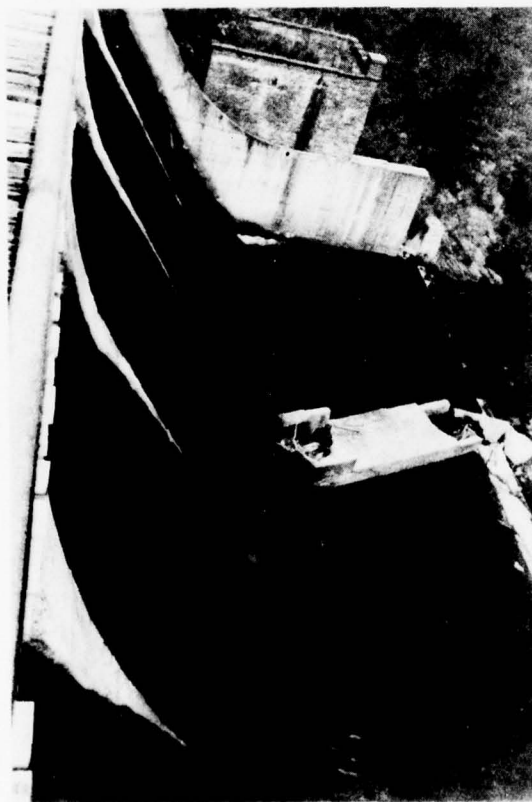
SCALING CONCRETE ON THE TOP  
OF THE SPILLWAY PIERS

August 1978



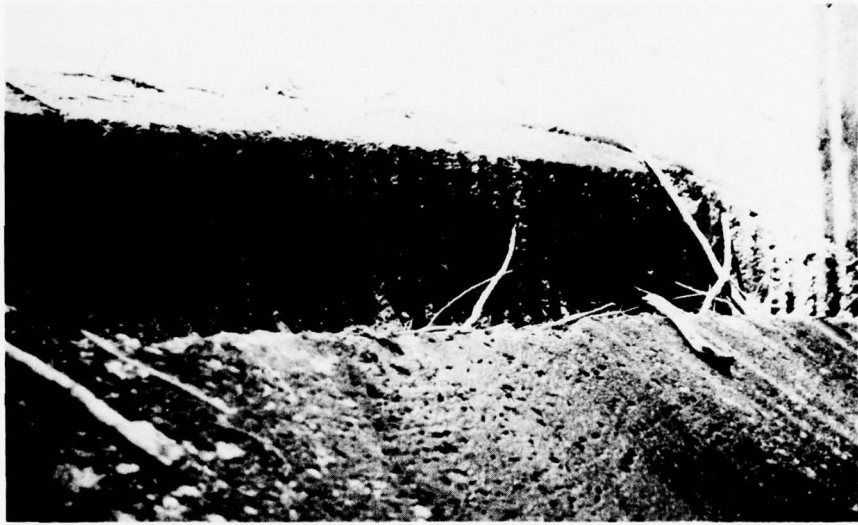
August 1978

BASE OF SPILLWAY CHUTE - RESERVOIR OUTLET IS ON  
RIGHT, SOME DAMAGE RESULTING FROM HURRICANE CAMILLE ON LEFT?



SPILLWAY CHUTE FROM TOP  
OF DAM

August 1978



August 1978

NOTCH CUT INTO SPILLWAY FLOOR VIEWED  
FROM RIGHT ABUTMENT BELOW SPILLWAY



APPENDIX III

FIELD OBSERVATIONS

Check List  
Visual Inspection  
Phase 1

Name Dam: Clifton Forge (lower dam) County: Alleghany State: Virginia Coordinators: Norfolk District  
Corps of Engineers

Date(s) Inspection: August 10, 1978 Weather: Clear and warm Temperature: 75°F

Pool Elevation at Time of Inspection: 1396 feet m.s.l. Tailwater at Time of Inspection: 1357± m.s.l.

Gilbert Associates, Inc.  
Inspection Personnel:

Thomas E. Roberts

Thomas W. Schreffler

Fine T. Hsu

Also Present:

"Pee Wee" Higgins - City of Clifton Forge

Gary Elander - City of Clifton Forge

Dave Lucado - Virginia State Water Control Board

Thomas W. Schreffler - Recorder

CONCRETE/MASONRY DAMS

Sheet 1

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SEEPAGE OR LEAKAGE	<p>A seepage, estimated at 10 to 15 g.p.m. was occurring at the junction of the left abutment fill and the dam about 23 feet below the crest of the dam at approximately 38 feet from the north end of the bulkhead section. Strong iron oxide stains below the discharge point were observed.</p> <p>Minor seepages coming from the horizontal construction joints were also seen on the left downstream face of the dam below elevation 1385 feet.</p>	<p>Regular monitoring of all seepages for any change in flow should be instituted.</p>
STRUCTURE TO ABUTMENT/EMBANKMENT JUNCTIONS	<p>Several wet spots were observed in the lower portion of the north valley slope, about 50 feet beyond the toe of the dam.</p> <p>Minor seepage paths along the base of the right downstream concrete wall were noticed, the total quantity was estimated on the order of 1 to 2 g.p.m.</p> <p>The contact of right abutment rock and the dam appears to be in good condition. The concrete corewall extending into the left abutment was not exposed for examination.</p>	<p>These wet spots may indicate the existence of seepage through the left abutment.</p>

CONCRETE/MASONRY DAMS

Sheet 2

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
DRAINS	None were observed.	
WATER PASSAGES	A 30-inch outlet pipe runs through the bulkhead section of the dam and discharges into the left end of the spillway chute. A 12-inch and 24-inch pipeline runs through the spillway section of the dam and then runs to the water treatment plant.	
FOUNDATION	No excessive erosion at the downstream toe area was observed; the foundation area was not affected by the scouring and erosion that was observed.	
SURFACE CRACKS CONCRETE SURFACES	A portion of the concrete surface of the bulkhead section of the dam was severely scaled at a horizontal construction joint about 23 feet below the top of the dam. Occasional scaling and spalling was observed at other locations, particularly the tops of the spillway piers, but none of it appeared serious.	The deteriorated concrete may be the result of long term exposure to the seepage at the construction joint.
STRUCTURAL CRACKING	None were observed.	
VERTICAL AND HORIZONTAL ALIGNMENT	Both vertical and horizontal alignments were good.	



CONCRETE/MASONRY DAMS

Sheet 3

REMARKS OR RECOMMENDATIONS

OBSERVATIONS

VISUAL EXAMINATION OF

MONOLITH JOINTS

No seepage or cracking was observed at the joints.

CONSTRUCTION JOINTS

The horizontal joint of the buttress section at elevation 1385 feet has been subject to seepage and deterioration. At some points, the scaling is several inches deep.

OUTLET WORKS

Sheet 1

REMARKS OR RECOMMENDATIONS

OBSERVATIONS

VISUAL EXAMINATION OF

**CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT**  
The location of the 30-inch outlet prevented a close examination. The two smaller pipelines leading to the treatment plant were in good condition but the concrete housing for the pipelines had been destroyed during a 1969 flood.

**INTAKE STRUCTURE**  
The only features visible were the operating deck and the gate operator. The windows of the enclosure were broken, giving the structure a rundown appearance, but structurally it appeared to be in sound condition.

**OUTLET STRUCTURE**  
None.

**OUTLET CHANNEL**  
The downstream channel was rocky and fairly steep. It appears to have withstood erosion very well.

**EMERGENCY GATE**  
None.

UNGATED SPILLWAY

Sheet 1

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	The concrete surface is worn and pitted but no cracks were observed. The two rightmost portals were modified by drilling and chipping out the concrete below the crest forming a horizontal ledge. The modification does not appear to have increased the wear of the adjacent concrete surfaces.	The modification was made to change the flow pattern below the spillway. It is not known if the results were successful.
APPROACH CHANNEL	None.	
DISCHARGE CHANNEL	The concrete spillway section appeared to be in serviceable condition. The right channel sidewall may be overtopped when high discharges occur, causing scour of the abutment rock. Some modifications were made to the spillway crest (see Concrete Weir above) to alleviate this situation. No excessive scour was observed on the abutment.	
BRIDGE AND PIERS	The footbridge over the spillway is in good condition and will not restrict the flood discharge.	

INSTRUMENTATION

Sheet 1

REMARKS OR RECOMMENDATIONS

OBSERVATIONS

VISUAL EXAMINATION OF

MONUMENTATION/SURVEYS      None observed.

OBSERVATION WELLS      None observed.

WEIRS      None observed.

PIEZOMETERS      None observed.

OTHER



RESERVOIR

Sheet 1

REMARKS OR RECOMMENDATIONS

OBSERVATIONS

VISUAL EXAMINATION OF

SLOPES

Moderately steep slopes around the reservoir rim were observed at the dam site. Surface sloughing along some steep colluvial and rock slopes were seen, but none on a large scale. Vegetation is generally dense except in some upstream barren areas as shown in the USGS topographic sheet. Because the bedding of the strata dips 30°-40° toward the downstream at the dam site, large scale deep-seated landslides are not to be expected.

SEDIMENTATION

No sedimentation was observed.

DOWNSTREAM CHANNEL

Sheet 1

REMARKS OR RECOMMENDATIONS

OBSERVATIONS

VISUAL EXAMINATION OF

CONDITIONS

(OBSTRUCTIONS,  
DEBRIS, ETC.)

There are erosion and scouring scars such as unstable side slopes and broken concrete slabs along the immediate downstream channel, which were left from the 1950 flood.

SLOPES

Active sloughing was located on the right bank about 100 feet downstream from the dam. The unstable area involved is about 40 feet long and 25 feet high along the slope.

The unstable slope area should be stabilized and then protected from excessive scouring and erosion.

APPROXIMATE NUMBER OF  
HOMES AND POPULATION

The business district of Clifton Forge is located about two miles downstream. There are about a dozen homes scattered along this 2-mile long flood plain area. (Base: USGS 7-1/2 minute Clifton Forge quadrangle, photorevised 1969).

APPENDIX IV  
INSPECTION REPORTS

EXCERPT FROM U.S. ARMY CORPS OF ENGINEERS'  
FLOOD PLAIN INFORMATION  
SMITH CREEK  
CLIFTON FORGE AND ALLEGHANY COUNTY, VIRGINIA  
JANUARY 1971

"Located on Smith Creek about 3.4 miles above the mouth of the stream, this dam is the source of raw water for Clifton Forge's water treatment plant. Built in 1949, the dam is a concrete gravity type structure.

"Originally it had a gated spillway. However, the gates have since been removed to prevent overtopping of the non-overflow section of the dam during freshets. The dam is 52 feet high and 267 feet long. Referred to sea level datum, the top of the dam is at elevation 1407.8 and the spillway crest is at elevation 1396. The spillway section is comprised of seven 16-foot wide bays separated by concrete piers, each 11.8 feet high and 4 feet wide. These piers served originally as supports for the spillway gates. The reservoir receives runoff from 12.6 square miles of drainage area and can store about 57 million gallons below the spillway crest. However, the amount of water that can be stored in back of the dam is small compared to the total volume of runoff which would occur during a large flood. Therefore, the reservoir has no significant effect on floods at Clifton Forge. Figure 5 is a photograph of the dam.\*

"The dam is apparently founded on massive rock which underlies the entire area. An inspection indicated no evidence of damage or pitting or spalling of the surface concrete and it is concluded that the overall condition of the dam is sound. The dam suffered little or no damage during the passage of the recent August 1969 flood. Prior to the removal of the spillway gates, the non-overflow section of the dam was overtopped on at least one occasion by a flood which occurred while the spillway gates were in a closed position. The dam was in no apparent danger of failure during either the 1969 or earlier flood.

"The water supply dam spillway is capable of passing floods up to the size of the Standard Project Flood. Floods larger than this would overtop the non-overflow section of the dam. Although failure is not likely, consideration should be given to the consequences of such an occurrence.

\*Figure 5 is a reference used in the Corps' report and should not be confused with Figure 5 of this Report.



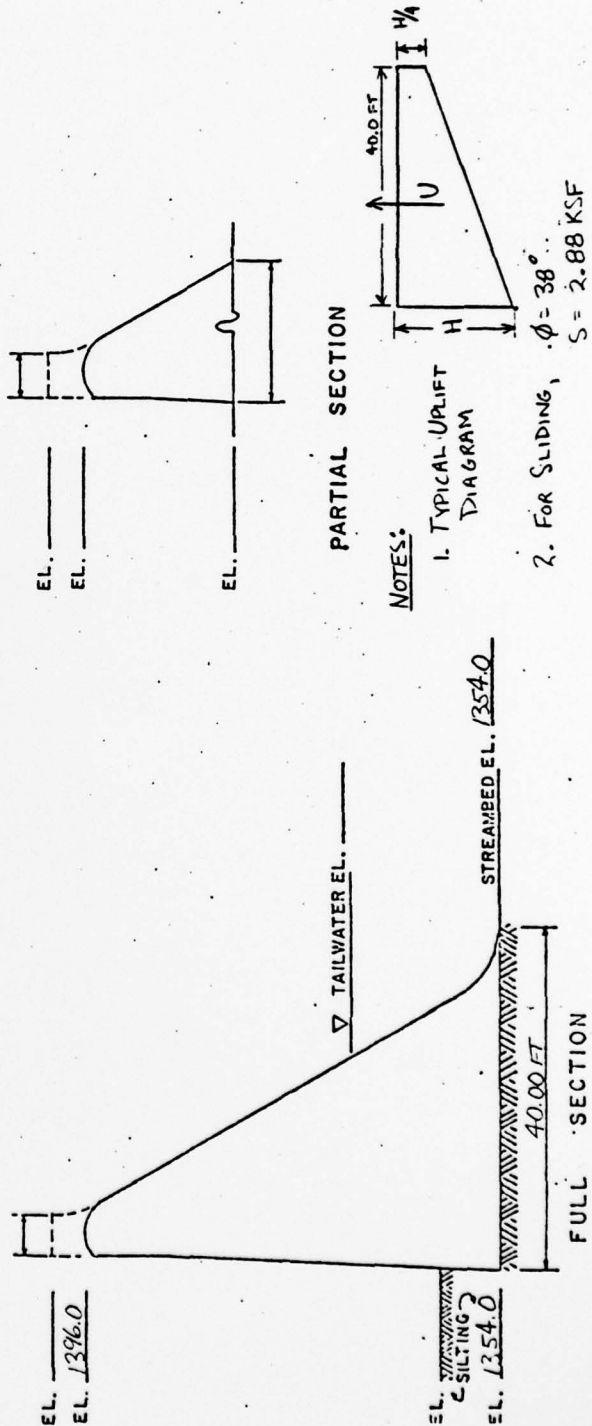
"The total volume of water stored below the spillway crest of a dam provides a means of estimating the possible effects on downstream conditions in the event of failure. This amount is about 175 acre-feet for Clifton Forge's water supply dam and represents only about .25 inch of runoff over the watershed. Failure, if it should occur, would probably take place gradually and not result in an instantaneous release of all the water stored in back of the dam. The volume of water that can be stored by the water supply dam is small compared to that which would be associated with a large flood. Should all or a part of the stored water be released by reason of the dam failing, some diminishing of the resulting flood wave would take place in the two mile reach between the dam and the major damage center at Clifton Forge. Accordingly, failure of the water supply dam would probably not add drastically to the already high downstream flood stages which would no doubt be associated with such an event."

APPENDIX V  
STABILITY ANALYSIS

# GRAVITY DAM DESIGN STABILITY ANALYSIS

ANALYSIS DONE ON X FULL SECTION PARTIAL SECTION  
 LOCATION OF SECTION CLIFTON FORGE SPILLWAY  
 ANALYSIS PREPARED BY D.C. RECHWARD

LOADING CASE	ELEV. HEAD WATER	ELEV. TAIL WATER	ΣV	ΣH	ΣH / ΣV	LOCATION RESULTANT FROM TOE	% BASE COMPRESSION IN	FACTOR SAFETY SLIDING	FOUNDATION PRESSURE	
									TOE	HEEL
PMF	1412.8		68.9 K/FT	99.1 K/FT	1.44	3.53 FT	26%	1.71	13.01 KSF	0. KSF
1/2 PMF	1408.0		76.5	86.5	1.13	9.01	68%	2.02	5.66	0.
NORMAL WATER LEVEL + ICE	1396.0		95.1	60.0	0.63	16.73	100%	3.16	3.54	1.21

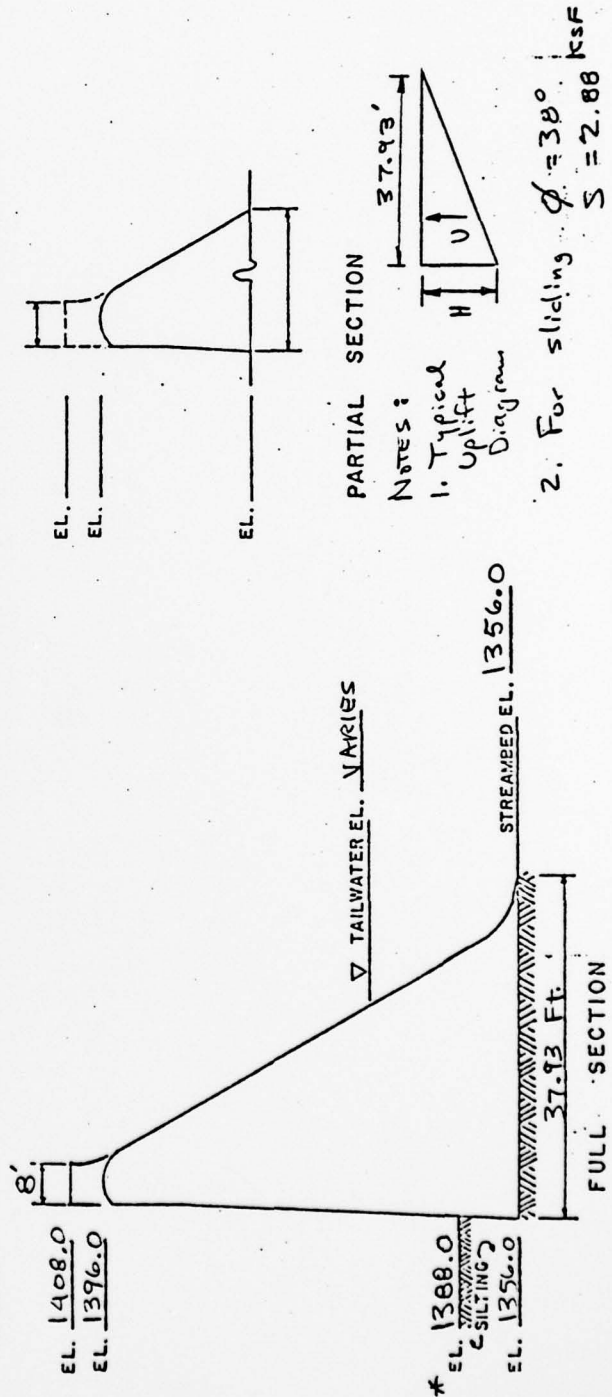


26/27

# GRAVITY DAM DESIGN STABILITY ANALYSIS

ANALYSIS DONE ON  $\sqrt{\text{FULL SECTION}} - \text{PARTIAL SECTION}$   
 LOCATION OF SECTION CLIFTON FORGE BULKHEAD  
 ANALYSIS PREPARED BY T. SCHNEFFELT

LOADING CASE	ELEV. (FT)		$\Sigma V$ (K/FT.)	$\Sigma H$ (K/FT.)	$\frac{\Sigma H}{\Sigma V}$	LOCATION RESULTANT FROM TOE (FT)	% BASE COMPRESSION IN	FACTOR SAFETY SLIDING	FOUNDATION PRESSURE	
	HEAD WATER	TAIL WATER							TOE (KSF)	HEEL (KSF)
PMF	1412.8	1368.0	84.3	117.3	1.39	2.99	24%	1.49	18.8	0
1/2 PMF	1408.0	0	104.2	101.0	0.97	9.78	77%	1.89	7.10	0
Normal Water Level + ICE	1396.0	0	118.3	71.64	.61	16.69	100%	2.82	4.24	2.00



\* From design drawings

APPENDIX VI

REFERENCES



APPENDIX VI

REFERENCES

1. Recommended Guidelines for Safety Inspection of Dams, Washington, D.C., Department of Army, Office of the Chief of Engineers.
2. HEC-1 Flood Hydrograph Package, Hydrologic Engineering Center, U.S. Army Corps of Engineers, January 1973.
3. "Seasonal Variation of the Probable Maximum Precipitation East of the 105th Meridian," Hydrometeorological Report No. 33, U.S. Weather Bureau, April 1956.
4. "Rainfall Frequency Atlas of the United States," Technical Paper 40, U.S. Weather Bureau, May 1961.
5. Design of Small Dams, U.S. Department of the Interior, Bureau of Reclamation, Second Edition, 1973.
6. Shale in Appalachian Geology, Byron N. Cooper, Department of Geological Sciences, Virginia Polytechnic Institute, Blacksburg, Virginia.
7. Geology of the Appalachian Valley in Virginia, Charles Butts, Bulletin 52, Virginia Division of Mineral Resources.
8. Flood Plain Information, Smith Creek, Clifton Forge and Alleghany County, Virginia, U.S. Army Corps of Engineers, January 1971.

APPENDIX VII

CONDITIONS

APPENDIX VII

CONDITIONS

This Report is based on a visual inspection of the dam, a review of available engineering data, and a hydrologic analysis performed during a Phase I Investigation as set forth in the U.S. Corps of Engineers' Recommended Guidelines for Safety Inspection of Dams and the contract between the U.S. Corps of Engineers and Gilbert Associates, Inc.

The foregoing inspection, review, and analysis are by their nature limited in scope. It is possible that conditions exist which are hazardous, or which might in time develop into safety hazards, that are not detectable by this inspection, review and analysis. Accordingly, Gilbert Associates, Inc. cannot and does not warrant or represent that conditions which are hazardous, or which may in time develop into safety hazards, do not exist.