A PROJECT FOR THE DEVELOPMENT of the WOODS CREEK RAVINE, WASHINGTON and LEE UNIVERSITY CAMPUS, Lexington, Virginia.

Thesis Presented for the Degree of

Bachelor of Science

in

CIVIL ENGINEERING

by

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C O N T E N T S.

C O N T E N T S. (Continued)

BIBLIOGRAPHY.

Williams;	Design of Masonry Structures and Foundations
Allen;	Railroad Curves and Earth-work
Babbitt and Doland;	Water Supply Engineering
Carnegic Steel Company;	Pocket Companion
Schoder and Dawson;	Hydraulics
Fitz Water Wheel Co.;	Bulletin 60 Catalog C

DRAWING	NUMBER

INTRODUCTION

LOCATION OF PROPERTY:: The improvements contemplated under the plan of this thesis are for that part of the Woods Creek ravine which is included within the boundaries of the Washington and Lee University campus.

PURPOSE: The plan under consideration of the authors is one to investigate and show the feasibility of developing a natural resource of the campus. Advantages presented by such a development are distinctly three-fold in nature: aesthetical, recreational, and educational.

ADAPTABILITY: The general topographical, hydrographical, and geological conditions prevailing in the Woods Creek ravine are highly favorable for development. The topography of the area traversed and drained by the creekpresents a suitable site for the construction of a dam near where the northeastern boundary of the campus intersects the ravine. A dam at this location would serve several purposes; first, it would make available the hydraulic power of the creek; second, the pondage created would serve as an artifical lake for beautification of the campus and at the same time fill the want of long desired outdoor aquatic sports.

PRELIMINARY INVESTIGATION.

General Considerations.

Since the problem is not one of the commercial exploitation of power, a height of dam could be chosen which would give a selected area of pondage. No provisions would be needed for storage, as the minimum discharge of the creek is sufficient for the purposes of the project. Also, a dependence upon storage for increased power would involve a sacrifice of beauty,as a lowering of the water level during the time of dry periods would result in an exposure of unsightly areas. For expmple, a drop of water level of one foot, which is an estimated head of storage, would cause an exposure of many square feet of the flatter region surroundingthe upper reaches of the stream. In order to provide for the increased flow during the time of a freshet, the dam crest may be designed for overflow for a maximum discharge.

The engineering department of the university has long lacked sufficient room for a practical laying out of laboratory equipment. This is especially true of the Civil Engineering Department. From an examination of existing conditions, it is seen that many possibilities present themselves for expansion in connection with the proposed project.

A power plant designed to house an adaptable hydroelectric unit, with sufficient space for additionalequipment, would serve excellently as a hydraulics laboratory. In this connection, the dam could be utilized as a weir by notching the crest for varying stages of overflow. At such times when the plant proper was not in operation, and when normal dischargewas had, the overflow could be confined to a specially designed notch for weir purposes. By means of imbedding steel plates in the dam crest, the necessary sharp-edge could be obtained to eliminate the frictional coefficient of discharge. Accurate field measurements of water discharge could thus be made for laboratory work.

Modifying Factors:

No peculiarities of the site necessitate any design out of the ordinary. Excavation and embankment, construction of the dam, and clearing of the proposed flooded area from trees and underbrush would be such as is ordinarly encountered in work of this nature. Location of the power plant on the downstream side of the dam would require some provision being made to prevent flooding at times of maximum overflow. A foundation designed as a retaining wall and founded on bed rock would prevent flooding of the plant.

Economy:

Since, as has been stated before, the development contemplated isn't one involving commercial considerations, the controling factors of economy are those dealing with a selection of materials and the execution of necessary construction work to carry out the plans of the project.

It has been decided that a concrete masonry dam would be the most practical and economical one to construct, since some type of masonry dam is required for overflow.

In the clearing of the flooded area, economy may be effected by contracting this work in consideration for the timber obtainable from the land.

Beauty:

Masonry structures are especially well adapted to aesthetic treatment in their design. Good architectural treatment is entirely compatible with strength and economy of construction and can be obtained by giving attention to the matter in the course of design, without appreciable increase in the total cost. While there are no fixed canons of taste and beauty in works of engineering, those designs are generally most pleasing that are in harmony with nature's outlines. For this reason, the completed dam, together with the sight of the overflowing water, would present a very pleasing appearance.

The beauty of the lake created by construction of the dam is obvious. The development of a lake park could be made a feature of the campus. Since it is here applicable, it might be stated that sufficient power would be generated for lighting requirements of the park.

LOOKING ACROSS THE RAVINE FROM A POINT
ON THE B. & O. R. R., SHOWING PART OF
SITE OF PROPOSED LAKE

DETAILED INVESTIGATION.

The purpose of a hydrographical investigation for this project is:

(1) To determine the quantity of water available for hydraulic power.

(2) To determine flood conditions in consideration of their effect upon the design of the dam.

(3) To determine the back-water curve, in its effect upon the amount of flooded area.

Records Available:

Efforts were made to obtain data upon the flow of Woods Creek but none were available. Testimony of persons familiar with the creek tended to show that no previous gauging was ever undertaken. It was therefore decided that personal observations of freshet flow and of daily variation would be made.

Discharge Measurement:

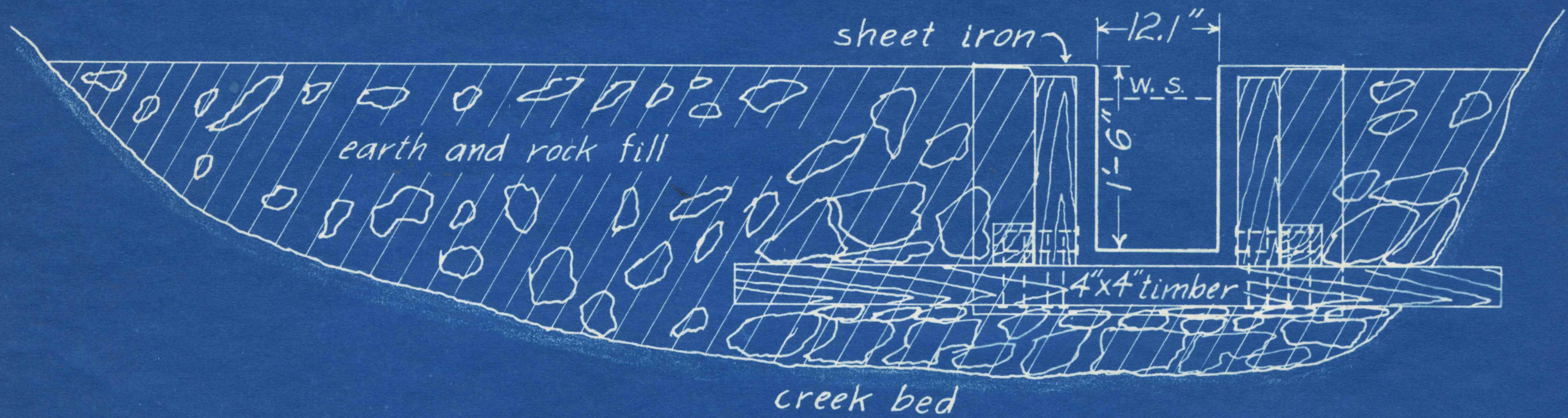
Personal observations were first made of the stream with a view to obtainingsome knowledge of the limits of discharge. It was found that during times of freshets the flow increased enormously, the creek overflowing its banks and spreading to the extent that its maximumwidth was approximately four times its normal width. Therefore, a weir large enough to measure flood flow would not measure with any accuracy the normal flow, since the head on a weir must be greater than three-tenths of a foot in order to apply the weir formula. However, since actual measurement of flood flow was un-necessary, a weir damwas constructed to measure normal flow.

The first step taken was to find a suitable location. After making an examination of the entire length of the stream bed bounded by the campus, a site was found where the stream was restricted to a comparatively narrow channel by the banks. All preparations for construction of the weir dam were made so that it could be placed with no undue loss of time immediately after the occurrence of a freshet. This was done with the expectation that sufficient gauge readings could be obtained to find an average value of the normal discharge before another freshet occurred which might possibly wash out the dam.

Rock was obtained from the bed of the stream above and below the site selected, and earth from the banks of the stream above the site. The latter served also to increase the area of confinement of the water immediately back of the dam, which decreased the turbulence of the water. The size of timbers used and methods of construction of the weir are shown by the accompanying sketch. Heavy galvanized tin was used to face the weir. This was required in order to obtain the necessary thin edge and accurate cross-sectional area of opening. The size of opening needed was determined from an approximate calculation of the discharge. This calculation was made by measuring the height of water flowing over a sewer pipe at a point 300 feet above the site of the dam. The sewer pipe is 24 inches in diameter and partly submerged in the stream bed, crossing it at right angles and its crest being very nearly parallel to the surface of the water. The average height of water flowing over it was found to be 1 inch. The width of the stream at this point is 15 feet. Thus, the approximate normal cross-sectional area of discharge is

1/12 of 15, which equals 1.25 sq. feet.

After the construction of the weir dam was completed, a vertical gauge, consisting of a standard yard stick, was secured to the side of a tree trunk at the edge of the bank. This tree was conveniently located at a point 10 feet upstream from



WOODS CREEK PROJECT
WEIR

Scale: $\frac{3}{4}$" = 1'

by J.T. Mosch and D.B. Cook

VIEW OF WEIR DAM

the weir, and made un-necessary the driving of a hub. Zero reading of the gauge was obtained by differential leveling. An arbitrary bench-mark (assumed elevation=100 feet) was first established. The elevation of the crest of the weir was then found and this same elevation used to calibrate the gauge. A check was made on the gauge elevation by running a level back to the bench-mark. No error was found.

The stage of the creek surfacewas noted daily from Dedember 12, 1929, to December 18, 1929 at approximately 5:00 P. M. The following table gives the gauge readings and quantites of discharge.

Date	Head (ft.)	Quantity (c.f.s.)
Dec. 12	0.755	2.19
Dec. 13	0.805	2.40
Dec. 14	0.856	2.68
Dec. 15	0.817	2.46
Dec. 17	0.750	2.16
Dec. 18	0.854	2.63
	Average =	2.40 c. f. s.

The discharges given above were taken from "Weir Head and Discharge Scales, Francis Formula".#

The limited number of gauge readings obtained

#Schoder and Dawson--"Hydraulics", P. 153

resulted from a freshet flow which destroyed the weir. Sufficient readings were deemed to have been obtained though for purposes of the project.

TOPOGRAPHICAL SURVEY

The purpose of a topographical survey for this project is:

(1) To determine a suitable location for the dam.

(2) To determine the extent of the area flooded by the back-water of the dam.

Maps Available:

The only map available of the Woods Creek Ravine was one prepared by the university for bulletin purposes. This map included the entire campus and had a contour interval of 20 feet. The large contour interval, and small scale to which it was drawn, inhibited its use for a working map. It was therefore decided that a survey would be necessary to secure an accurate and practical map of the ravine.

Details of Survey:

A bench mark was taken upon a stone bound at the north east corner of the B. & O. R. R. culvert. The mark was indicated by a cross cut with a cold chisel. The assumed elevation of 100 feet was also

VIEW OF CULVERT SHOWING LOCATION OF
BENCH MARK AS INDICATED

cut on the stone adjacent to the bench-mark. A line of levels was first run to establish bench-marks at frequent intervals and to determine the hydraulic gradient of the creek. The extent of this leveling was such as to embrace the region contemplated for flooding. The railroad culvert was chosen as the upper extremity of the survey as flooding beyond this point would involve a right-of-way of the railroad. The lower extremity of the survey was chosen as the property line of the university, since a superficial examination of the ravine showed the probable location of the dam to be nearthis line. A check in the elevations recorded was obtained by closing the traverse. The elevation of the original bench-mark found in closing was exactly 100 feet.

A transit survey was then made by first establishing a backbone line as a basis for the survey. This line was made to approximate the creek bed and stations were established at intervals of 100 feet, except where crossing of the creek necessitated the establishing of lesser intervals. Distances were measured by means of a 100 ft. steel tape, and the total length of the line run was 1584.2 ft. Deflections made were doubled for greater accuracy.

The next step in the transit survey was the establishing of perpendiculars to the backbone line at each station. This was done by use of the transit, and the erecting of stakes to the right or left of the backbone line was determined by the visibility in each case. The stakes were also located at convenient points along the perpendiculars, depending upon the topography of the ground, and distances to them paced from the stations in order to record their location. Contour points of one foot interval were then located on the perpendiculars by use of a Dumpy Level and leveling rod. The distances of these points from the stations were accurately taped.

Map:

The backbone line was first plotted to a scale of 1 inch = 50 feet. Perpendiculars were next drawn at each station point and then the contour points plotted by scaling along the perpendiculars. The map is contained in the accompanying portfolio.

GEOLOGICAL SURVEY

Purpose:

Of primary importance in any dam construction is a study of the geological conditions to be en - countered in work of the foundation. Masonry dams especially are dependent upon the quality of the foundation for stability. When not resting on solid rock, the section of the dam must be designed with sufficient allowance for the uplight of the water beneath the dam. Therefore, the geology of the dam site should provide, preferably near to the ground surface, a bed-rock foundation of solid, impervious rock.

Extent of Survey:

Due to the limited time available for this thesis, and the extent of the work already done in connection with the hydrographical and topograpbhical surveys, no extensive geological survey of the region could be made. However, after a preliminary investigation for the location of the dam was made, a survey restricted to the proposed site was undertaken. By meaas of a 1 inch steel pipe, 5 feet in length and sharpened at one end, tests were made to determine the depth of solid rock below the surface of the ground. A line was established across the creek to serve as location for the dam, and by use of a sledge the pipe was driven at frequent intervals along the line until solid rock was encountered. At some points the top soil and mantle rock was of such depth as to exceed the depth to which the pipe could be driven. It was therefore decided that calculations of earthwork for excavation of the foundation would be based on a profile as is shown by the drawing. Contracting of th is work can be let with provisions for a sliding scale for excatation either in excess of, or short of, the amount upon which the calculations herein are based.

SELECTION OF DAM SITE

Factors Considered:

Selection of the dam site was made from a consideration of the greatest topographical, hydrographical, and geological advantages as became apparent in the detailed investigation. For purposes of the lake, the dam should be located as near to the property line as practical, so that a maximum area is had for flooding. Economically, the dam should be so located as to have a minimum length of crest. This latter statement is of course applicable only to the dam of this particular project, since spillway dams frequently require a maximum length of crest for discharge purposes. The geological significance of a dam location has already been discussed.

Site Selected:

In consideration of the above factors, and from a careful study of the topographical map, the dam site was selected as is shown by the included map.

SPECIFICATIONS.

Specifications for Design.

In consideration of the availability of standard specifications for design such as would be applicable to the project of this thesis, the authors deem it an unnecessary refinement to copy and include herein the details of such specifications. Recommendations instead are therefore made that all requirements for specifications be provided for by the Engineer in charge, and subject to the approval of the Engineering Department of the University.

Materials and Workmanship.

Only first class materials conformable to the best engineering practice shall be used in the work, and in such a manner as to produce completed construction as directed by the Engineer. All construction shall be workmanlike and acceptable in every detail to the Engineering Department.

DESIGN.

Design of the Dam.

Type:

A large portion of the dam must be of the overflow type to facilitate the discharge of the flood flow of the creek, with a minimum head on the crest.

Elevation of Crest:

The elevation of the crest of the dam is determined by the desirable extent of the back-water. With reference to the accompanying map, "Proposed Lake", it is seen that elevation 100 crosses the creek at the downstream edge of the railroad culvert, which point was chosed as the limit of the back-water curve.

Method of Design:

In the calculations of the design which follow, only the investigations of final safe and economical sections are shown, various sections having been tried until investigation showed both safety and economy. Reference should first be made to the accompanying drawings of the "Downstream Profile", and "Dam Sections".

INVESTIGATIONS OF DAM SECTIONS.

Unit Stresses

Concrete

Compression	500 lbs. per sq. inch
Sheer	200 lbs. per sq. inch
Tension	0

Steel

Tension	16,000 lbs. per sq. inch

Weight of Concrete

145-150 lbs. per cu. foot

I. Investigations of 18 Foot Section.

OVERTURNING

Let P equal the water pressure.

Let W equal the total weight of the stage considered plus the weight of all above stages.
Let X equal distance from gravity line to point of pressure.

Stage I.

P = 1123
W = 1740

1123 x 2 = 1740 X

X = 1.29'

Width of base equals 4.091'

Kern equals 1.364'

Stage II.

P = 3780
W = 5930

3780 x 3.66 = 5930 X

X = 2.33'

Width of base equal 7.5'

Kern equal 2.5'

Stage III.

P = 8000
W = 13072

8000 x 5.33 = 13072 X

X = 3.26'

Width of base equals 13.6'

Kern equals 4.53'

Stage IV.

P = 11260
W = 20715

$$11260 = \frac{20715\ X}{6.33}$$

X = 3.44

Width of base equals 21.85

Kern equals 7.283

CRUSHING AT TOE AND HEEL

For Stages I, II, and III assume pressures to fall on the third points. This is on the side of safety since the pressures actually fall inside the third points.

Let P equal pressure at the toe reservoir full, or, pressure at heel reservoir empty.

Let W equal verticle component.

Let b equal width of base.

P = 2W/b (whenpressure is at third point)

Stage I.

P = 2x1740/4.091 = 850 lbs. per sq. ft.

Stage II.

P = 2 x 5930/7.5 = 1580 lbs. per sq. ft.

Stage III.

P = 2 x 13072/13.6 = 1920 lbs.per sq. ft.

Stage IV.

For maximum pressure at heel assume pressure at third point.

P = 2 x 20715/21.85 = 1890 lbs. per sq. ft. pressure at heel.

For maximum pressure at toe--

Let e equal eccentricity, or distance from center of base to resultant. The value of e is .015. However, for convenience and safety assume e equal .02.

P = W/b (1 plus 6e/b)

P = 20715/21.85 (1 plus 6 x .02/21.85 = 955 lbs per sq. ft.

HORIZONTAL SHEAR

Shear equals water pressure/b

Stage I.

Shear = 1123/4.091 = 275 lbs. per sq. ft.

Stage II.

Shear = 3780/7.5 = 505 lbs. per sq. ft.

Stage III.

Shear = 8000/13.6 = 587.5 lbs. per sq. ft.

Stage IV.

Shear = 11260/21.85 = 515 lbs. per sq. ft.

VERTICLE SHEAR AT TOE TREATED AS A CANTILEVER
(At Bottom of Dam)

Shear equals upward force/area of verticle section.

Maximum pressure at toe equals 955 lbs. per sq. ft. as found in investigation for crushing. Assume this pressure uniform throughout the base of the dam.

Verticle Section 1 Ft. from Toe

Shear = 955/1.1 = 870 lbs. per sq. ft.

Verticle Section 2 Ft. from Toe

Shear = 2 x 955/1.2 = 1590 lbs. per sq. ft.

Verticle Section 4 Ft. from Toe

Shear = 4 x 955/1.6 = 2390 lbs. per sq. ft.

Verticle Section 6 Ft. from Toe

Shear = 6 x 955/2.4 = 2390 lbs. per sq. ft.

Verticle Section 8 Ft. from Toe

Shear = 8 x 955/6.7 = 1140 lbs. per sq. ft.

It is obvious that further investigation for verticle shear is unnecessary.

FLEXURE IN THE TOE TREATED AS A CANTILEVER

Again assume uniform upward pressure of 955 lbs.per sq.ft. equalling 6.65 lbs. per sq. in.

Verticle Section 3 Ft. from Toe

Let M. = moment

Let S. = maximum stress

Let I. = moment of inertia

Let C. = distance from neutral axis to surface

M = 955 x 3 x 36/2 = 51500 in. lbs.

I/C = 565

S = M divided by I/C = 51500/565 = 91.2 lbs. per sq. in.

Verticle Section 7 ft. from Toe

M = 955 x 7 x 3.5 x 12 = 281000 in. lbs.

I/C = 2600

S = M divided by I/C = 281000/2600 = 108 lbs. per sq. in.

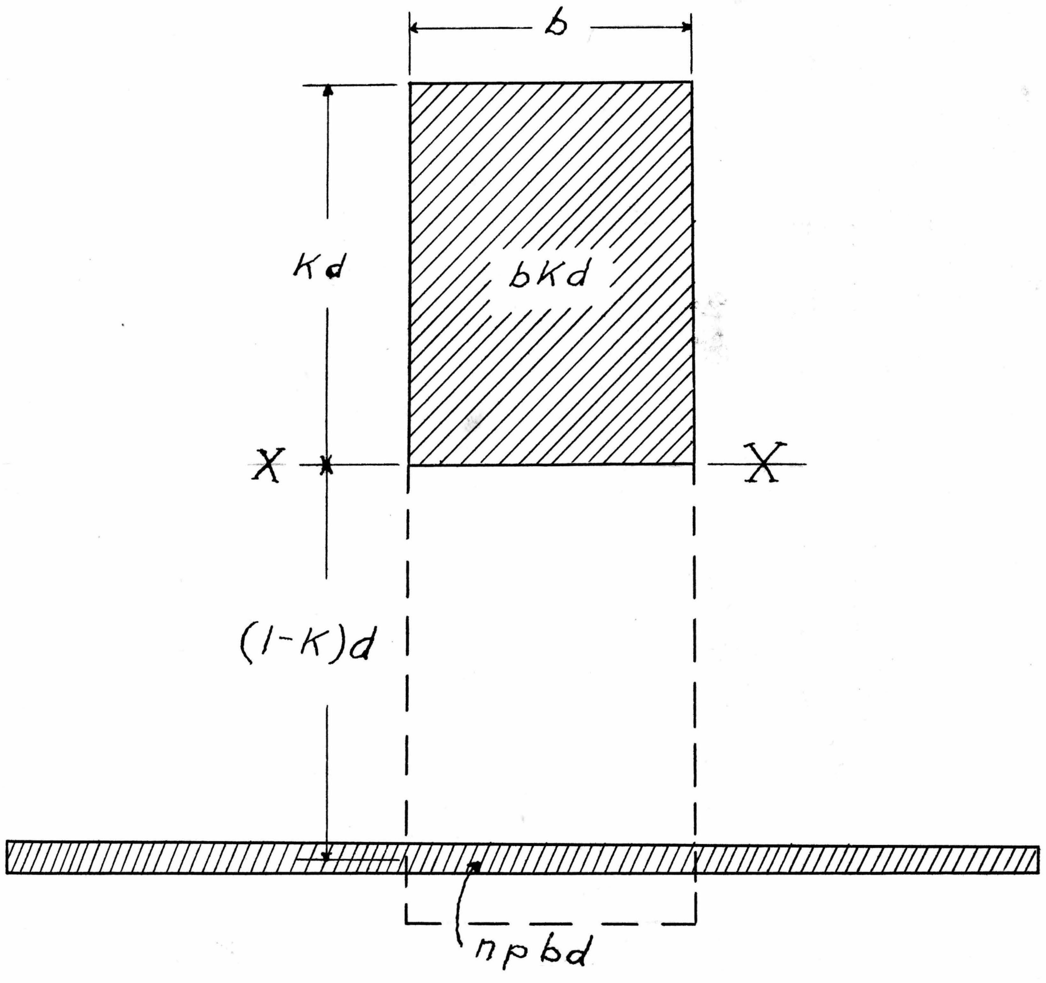
Verticle Section 5 ft. from Toe

M = 955 x 5 x 30 = 143000 in. lbs.

I/C = 1150

S = M divided by I/C = 143000/1150 = 124

Thus it is seen that the greatest stress due to Flexure occurs at about 5 ft. from the toe and it may be assumed to be 150 lbs. per sq. in. Therefore, a little re-inforcement should be used to care for the tension. This steel shall be placed two (2) inches from the bottom.



Let S_c = stress in concrete

Let S_s = stress in steel

P = area of steel/area of concrete

b = 12"

d = 22"

$n = E_s/E_c = 29000000/2000000 = 14.5$

$K = \sqrt{2 Pn \text{ plus } (Pn \times Pn)} - Pn$

I = K x K x bK x d x d x d/3 plus npbd x d x d(1-K) x (1 - K)

$S_c = MKd/I$

$S_s = nM(1 - K) d/I$

Assume p equals .002

$K = \sqrt{2 \times .002 \times 14.5 \text{ plus } (.002 \times 14.5)\times(.002\times14.5)} - .002 \times 14.5$

K = .213

I = 12 x .0097 x 10648/3 plus 14.5 x .002 x 12 x 106480 (.787) x (.787)

I = 2708.6

S_c = 143000 x .213 x 22/2708.6 = 248 lbs. per sq. in.

S_s = 14.5 x 143000 (.787) 22/2708.6 = 13254 lbs.per sq. in.

Therefore, .002 is a correct value for P.

Amount of steel per linear ft. = pbd = .002 x 12 x 24 = .576 sq. in.

Therefore, 7/8" reinforcing bars shall be used, placed 1ft. apart giving an area of steel of .6013 sq. in. per linear foot.

II. Investigations of 14.5 Foot Section.

OVERTURNING

Let W equal the total weight of the stage considered plus the weight of all above stages.

Let X equal distance from gravity line to point of pressure.

Stage I.

W = 1353

1353 X = 31.2 x 25 x 5/3

X = 10.4 x 125/1353 = .96'

Width of base equals 3.3

Kern equals 1.1

Stage II.

W = 5120

5120 X = 31.2 x 100 x 10/3

X = 10.4 x 1000/5120 = 2.03'

Width of base equals 7.1

Kern equals 2.367

Stage III.

W = 10870

10870 X = 31.2 x 14.5 x 14.5 x 14.5/3

X = 10.4 x 14.5 x 14.5 x 14.5/10870 = 2.92

Width of base equals 10.25

Kern equals 3.416

CRUSHING AT TOE AND HEEL

Assume pressures to fall on the third points. This is on the side of safety since pressures are inside third points.

Let P equal pressure at toe reservoir full, or, pressure at heel reservoir empty.

Let W equal verticle component.

Let b equal width of base.

P = 2W/b (when pressure is at third point)

Stage I.

P = 2 x 1353/3.3 = 820 lbs. per sq. ft.

Stage II.

P = 2 x 5120/7.1 = 1440 lbs. per sq. ft.

Stage III.

P = 2 x 10870/10.25 = 2120 lbs. per sq. ft.

HORIZONTAL SHEAR

Shear equals water pressure/b

Stage I.

Shear = 31.2 x 25/3.3 = 236 lbs. per sq.ft.

Stage II.

Shear = 31.2 x 100/7.1 = 440 lbs. per sq.ft.

Stage III.

Shear = 31.2 x 14.5 x 14.5/10.25 = 640 lbs. per sq. ft.

VERTICLE SHEAR AT TOE TREATED AS A CANTILEVER
(At Bottom of Dam)

Shear equals upward force/area of verticle section

Maximum pressure at toe equals 2120 lbs. per sq. ft. as found in investigation for crushing. Assume this pressure uniform throughout the base of the dam.

<u>Verticle Section 1 ft. from Toe</u>

Shear = 2120/1.7 = 1250 lbs. per sq. ft.

Obviously, investigation of other verticle sections is unnecessary. Also investigation at the heel or at other stages is unnecessary.

III. Investigations of 9.5 Foot Section.

OVERTURNING

Let W equal the total weight of the stage considered plus the weight of all above stages.

Let X equal distance from gravity line to point of pressure.

Stage I.

Same as Stage I. of 14.5 ft. Section.

Stage II.

W = 4625

4625 X = 31.2 x 9.5 x 9.5 x 9.5/3

X = 1.925

Width of base equals 6.46

Kern equals 2.15

HORIZONTAL SHEAR

Stage I.

Same as Stage I. for 14.5 ft. Section.

Stage II.

Shear = 31.2 x 9.5 x 9.5/6.46 = 436 lbs. per sq. ft.

CRUSHING AT TOE AND HEEL

Assumptions and notations as used for 14.5 ft. Section.

Stage I.

Same as Stage I. of 14.5 ft. Section.

Stage II.

P= 2 x 31.95 x 145/6.46 = 1435 lbs.

VERTICLE SHEAR AT TOE TREATED AS A CANTILEVER
(At Bottom of Dam)

Vertical Section 1 ft. fromToe

Shear = 1435/1.7 = 845 lbs.per sq. ft.

Obviously further investigation for vertical shear is unnecessary.

POWER PLANT.

Power Unit:

The power unit shall be that recommended by the Fitz Water Wheel Company as follows: One 9 inch diameter standard Fitz-Burnham horizontal turbine, mounted in a horizontal cast case on a structural steel frame designed to carry the generator on the same base; this water wheel to be direct coupled to a 3 K. W. capacity, 110 volt, D. C., compound wound Robbins and Myers generator; and provided also with a Fitz automatic water wheel governor to regulate the speed and power of the water wheel in accordance with the load on the plant.

Power Obtainable:

The above unit, when operating with normal flow (2.4 cu. feet per second), will generate 2½ K. W. However, since the generator has a capacity of 3 K. W., it would be possible to consume this amount of power during flood, or in case of emergency the generator could be run at full capacity for a time, lowering the lake. At full capacity, the unit requires 200 cu. ft. per minute, which is 56 cu. ft. per minute more than normal flow. At this rate it would require 4½ days to lower the lake 2 feet.

During a part of the year, floods occur more often than weekly, so that it would be possible to operate nearly at capacity during this time. Fortunately, this period of frequent floods is during the winter months when the days are shortest and the most electric light is required. Furthermore, at this time of year it would not be objectional to lower the lake, as its beauty is not so apparent.

It is thus evident that the power would be of same value for lighting purposes of the university. Also, since the generator is of the direct current type, it could be used to advantage in charging the storage batteries in the Electrical Engineering Department of the university.

Evaporation:

The area of the water surface which will be subject to evaporation was determined from the contour map by means of a planimeter. The area enclosed within the back-water curve (100 ft. contour), was found to be 84.57 sq.inches on the map. Since the scale of the map is 1 inch=50 feet, the above figure multiplied by 2500, or 211,425 sq.feet represents the exposed area.

From a study of the table of evaporation rates, as given on page 82 of Babbitt's and Doland's "Water

Supply Engineering", it is seen that the maximum rates of evaporation occur during the months of July and August. This is because the vapor tension at the dew point is a direct function of the air temperature, and because the difference in temperature between the water surface and the atmosphere is usually greater in warm weather than in cold weather.

Assuming therefore the maximum rate of evaporation, and interpolating for local conditions of temperature, there is obtained from the table 7.2 inches as the monthly rate.

$$\frac{7.2}{12} \times 211425 = 126,855 \text{ cu. ft. per month}$$

$$\frac{126855}{30 \times 24 \times 60 \times 60} = 0.049 \text{ cu. ft. per second}$$

Since the normal discharge is 2.4 cu. ft. per sec., and 0.049 cu. ft. per sec. is the absolute maximum loss due to evaporation, the loss can be considered as negligible in its effect upon the discharge.

Time of Filling:

Using the normal discharge of the creek, 6 days were computed as being the time of filling of the proposed lake region. Volumes were computed by means of the contour map and use of a planimeter.

Building:

The building might well be fitted up as a hydraulic laboratory for the use of the engineering departments. The size of the building would therefore depend upon the amount of equipment installed. This matter is better left to the department heads since it depends upon the amount of funds available. However, a brick building, 15 ft. x 18 ft., and two stories high, is recommended. The floor, at least of the lower story, should be of concrete, and the foundation should be constructed so that it would stand a possible flood.

The power unit should be bolted to the floor with bolts imbedded in the concrete in order to prevent any movement or vibration of the machine.

The feed water pipe shall be laid in a straight line as nearly as is possible to minimize friction loss. It shall be laid under ground in accordance with the best practice to prevent freezing. Riveted steel pipe manufactured by the Fitz Water Wheel Co. shall be used since it will stand maximum pressures, and also since it is a copper alloy steel superior to ordinary steel in resisting corrosion.

A small switch-board will be necessary with switches to direct the power to the university or to the park lighting system. For regulation of voltage, a field rheostat will also be necessary. This equipment shall be placed near the wall toward the dam, adjacent to the power unit so that the remainder of the floor space may be utilized for the hydraulic laboratory.

All wires leading from the generator to the switch-board shall be in a conduit in the floor covered by removable steel plates.

Location:

The power plant shall be located so that the upstream wall of the building is immediately below the face of the dam. It shall be on the southeast side of the stream and the floor of the power story shall be at an elevation of 90 feet with respect to the datum plane used in this design. The shorter dimension shall be parallel to the dam.

It is necessary that the building be at the above elevation to prevent flooding and the tail water from backing up into the turbine.

COST

Detailed Cost of Materials, Equipment, and Construction.

I. Dam.

A. 796.8 cu.yds. of concrete at $12.00 per cu. yd. in place---------------$ 9560.00

B. 710 cu. yds. of earthwork at $1.00 per cu. yd.-------------------------- 710.00

C. Gate valve, 12 in.,----------------- 55.00

D. Plate for weir notch, 40.8 lbs. at $.05 per lb.------------------------ 2.00

E. Reinforcing bars, 2080 lbs. at $.04 per lbs.----------------------- 85.00

II. Clearing.

A. 5 acres at $25.00 per acre------- 125.00

III. Power Plant.

A. Building------------------------- 2000.00

B. 85.5 cu. yds. of earth work (tail race, building, feed pipe) at $1.50 per cu. yd.------------------------ 130.00

IV. Electrical Equipment.

A. Switch board (including accessories) 250.00

V. Power Unit.

A. Complete unit as specified (f.o.b. Hanover, Pa.)--------------------- 1512.00

COST (Continued)

B. Steel Pipe

1. 22 ft. of 14½ in. at $3.35 per ft.$ 75.00

2. 38 ft. of 18 in. at $3.60 per ft.- 135.00

3. 5 ft.6in. length of draft tube---- 30.00

Total-----$14669.00

VI. Plus 2% of Total for Miscellaneous Items 294.00

FINAL COST---------$14963.00