HISTORY, CONSTRUCTION AND OPERATION OF

SAFE HARBOR POWER DEVELOPMENT

by

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INITIATION REQUIRMENT FOR MARYLAND BETA CHAPTER OF

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BRIEF SUMMARY OF THESIS

This thesis deals with the formation of hydro-electric power along the Susquehanna River and the Safe Harbor Power Development. It tells of the archaeological research carried on before construction details and of the difficulties and good fortune encountered during the construction of this project. The major tasks such as diverting the river during construction and stretching the transmission cables across the river, etc., are ably discussed. Construction of the Dam and Power House along with provisions for uninterrupted operation are dealt with. The turbines, generating units and transformers are included and the final step of transmitting the power to Baltimore via cables is all discussed.

The author hopes that he has set forth his material in such a manner as to be both pleasing and informative to the reader.

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ADAPTABILITY OF SUSQUEHANNA FOR HYDRO-ELECTRIC POWER

There is probally no other great river in the world with a variability of flow as much as the Susquehanna. During the drought of 1930 this flow dropped to a miserable 2,000 cubic feet per second while during the great flood of 1889 water thundered down the gorge above Port Deposit at the rate of 725,000 cubic feet per second.

But if the Susquehanna is unkind to engineers in it's variability of flow it is most gracious in other respects. One advantage that it lends to the harnessing of it's power is that it drains a vast area of 26,000 square miles stretching southward from Lake Otsego in Central New York, winding through the beautiful counties of southern New York through the dirty anthracite hills of Pennsylvania, once more through the fertile counties of that state, Lancaster and York, and into a gorge just above the basin of the Safe Harbor Dam.

Along the way new streams add their flow until their combined total reaches the Columbia Bridge and the Susquehanna with one exception, the St, Lawrence River, has become the largest stream that empties into the North Atlantic.

EARLY VENTURES ALONG THE SUSQUEHANNA RIVER

The desirability of harnessing all of this power was recognized at an early date and at one of the sites known as McCall's Ferry a quarter of a century ago a group of financiers started the first major project in this section. It was a time when hydro-electric enthusiam was greater than hydro-electric experience for the development at Niagara Falls had overexcited the country and soon this Susquehanns venture, the first big project at a low head as contrasted with the steep plunge at Niagara Falls, encountered unforeseen difficulties so serious that it's financiers became discouraged and went into the hands of receivers.

As receiver J. E. Aldred in 1909 got things in shape so quickly that early the next year the project was taken over by the Pennsylvania Water and Power Company, which he organized, and during 1910 the plant began delivering electrical power to Baltimore. The old name of McCalls Ferry was dropped and was replaced by it's present name of Holtwood. This project produced 150,000 horse power with it's hydro-electric plant and the accompaning steam plant produced 30,000 horse power, an amazing output for that time.

But Aldred soon realized that even this large output in horse power would not long satisfy the industrial needs of Baltimore so fully a decade and a half ago he and his associates began planning for a new developement situated upstream from Holtwood and to be hooked up with the latter to be operated as a single unit.

ARCHAEOLOGICAL RESEARCH OF LAND TO BE FLOODED

Safe Harbor is located in Lancaster County,Pennsylvania, 28 miles from tidewater and 8 miles upstream from Holtwood. Preliminary work on the construction plant and camp was started during November, 1929 and work in the river began in April, 1930. However before any of the land was flooded a thorough archaeological research was made for the purpose of preserving a numerous quantity of picture rocks existing in that territory.

Under the direction of Dr. Cadzow a group of archaeologists went over this ground for over a year revealing important land sites and life story of almost mythical Susquehannocks Indians and the Algonkins. Literally hundreds of earthen pots have been recovered from the burials and kitchens of a tribe that so far as history records are concerned was not noted for its pottery. Implements of war and the tools of peace made of bone, stone or other durable materials were unearthed.to add their bits to the evidence which history failed to provide. Parts of clothing, ornaments and trinkets rescued from the earth reveal facts concerning the habits of dress of tribes along the Susquehanna. Charred remains of corn, beans and other food stuffs tell us how these tribes were provided with food.

Students of Indian life who visted this scene at Safe Harbor declare that Dr. Cadzow and his associates have unearthed material unequaled anywhere in the east; that the records they have obtained from the east is the most important ever contributed to a knowledge of Indian life along the Atlantic seaboard.

This research was financed by the Pennsylvania Water and Power Company and the relics uncovered are on exhibit at the State Museum at Harrisburg.

GOOD FORTUNE ENCOUNTERED DURING CONSTRUCTION

Throughout the entire project the Power Company was smiled upon by good fortune. First by the fact that they raised their funds just before the market slump. Preliminary costs were carried by the parent Company and not until June, 1930 was it necessary to sell and amount of bonds equal to $21,000,000. They were then marketed to yeild nearly their full interest rate of four and a half per cent. The bond market slump came some weeks later too late to affect the sale.

The project in it's entirety cost in the neighborhood of $30,000,000 of which $9,050,000 went out as wages to men --- 4,000 of which were working at the peak of construction. Even the depression was put to a good advantage for at the time when construction was at its height construction materials were available at prices far below the level of 1929. A higher type of labor was available at that time so there was a small loss in labor turnover and a high amount of output per man.

Secondly they were fortunate in accomplishing so much in a year and a half thereby realizing a saving of many dollars. A lot of this speed was due to good luck for in the first summer of construction when there was a need for a minimum amount of water flow there was a decidingly lack of rainfall thus drying up the river to a large extent. Then when there was a need for a maximum amount of water flow there came a numerous quantity of heavy rainfalls filling the dam several months before the most optimistic expectations and the first turbine started revolving in December, 1931.

However much of this speed was due to good management and fortunate selection. There was a total of 500,000 cubic yards of concrete placed and the coarse for this was found to be available only one mile east of the dam where excellent trap rock was available in the form of a dyke. A crusher plant was located adjacent to the quarry and the concrete was made at a mixing plant on Else Island in the middle of the river. Every ingredient used in the concrete was carefully measured by weight, thus assuring a uniform concrete of high quality.

Another factor which aided the progress of the construction was the availability of power at the adjacent power plant downstream at Holtwood and it was used to a high extent.

DIVERTING THE RIVER DURING CONSTRUCTION

The first big task to confront the construction engineers was the diverting of the river from the east channel into the west channel. This was accomplished by means of two rockfill cofferdams connecting the east shore with Else Island in the middle of the river. By doing this the foundations for the east side of the dam, the power house and the skimmer wall were built on dry land. When the west half of the dam was built it was necessary to enclose a 700 foot section of the dam west of the island by a cofferdam, and then construct it on dry ground. The remainder of the dam extending to the York County side was then enclosed by means of another cofferdam and the water partly diverted through the power house and partly through slots left in the first section of the dam in the west channel.

THE BACKBONE OF THE CONSTRUCTION

A temporary construction bridge was located parallel with and downstream of the dam, which formed the backbone of the construction layout. It carried three standard railroad tracks and a forty foot guage track for the construction cranes. The total number of cranes is comprised of two 150 ton and two 50 ton cranes each equipped with a derrick and a concrete chuting tower forplacing the concrete, handling the concrete forms and erecting steel and Power House machinery. Twenty thousand tons of structural steel was erected and 6,300 tons of reinforcing bars were placed. The construction tracks in the yard, quarry, over the cofferdams, etc., had a combined length of twenty miles. Each of the cranes is equipped with an automatic brake for safety purposes and one of the 150 ton cranes is capable of being operated by means of a gasoline engine as well as electrical power in case of an emergency shutdown of the power plant.

PROVISIONS FOR UNINTERRUPTED OPERATION

Provisions have been made to assure uninterrupted operation under any abnormal river conditions such as ice or trash runs. The forebay of the Power House is seperated from the main river by a rockfill dyke at the upstream side and a concrete skimmer wall entending 1500 feet parallel to the river flow between the dyke and the dam. A curtain wall extending 15 feet below the normal surface of the forebay level guides trash and drift to the spillway and prevents it from reaching the Power House intakes and inflicting any damage to the turbines.

CONSTRUCTION OF DAM AND POWER HOUSE

The dam and power house combined have a total length of 5000 feet from shore to shore. The dam is divided into four non-overflow sections and two spillways, the latter being located on the east and west channels of the river. The head of the dam is kept at a constant height by means of 32 huge crest gates placed on top of the concrete spillways. Twenty four of these being in the York County river channel and the remaining eight form the connection between the Power House and the non-overflow dam on the Island.

Each gate is capable of discharging approximately 30,000 cubic feet per second and when all 32 gates are raised there is a discharge rate of about 1,000,000 cubic feet per second or over 30 per cent more than the record flow of the river. The gates are 35 feet high and 48 feet in width and may be raised or lowered by means of the gantry cranes. Should one gate prove defective repairs are readily possible for the gantry picks up one of the emergency gates from a storage, carries it to the proper place and lowers it into an emergency slot nearer the upper side of the dam where it serves as a coffer while repairs are made on the defective gate.

To insure accurate contol of the water level above the dam four of the gates in the east spillway are in horizontal half sections, the top half of which can be raised or lowered,as required, by stationary hoists located in a tunnel within the dam.

The Power House itself is 920 feet long and the intake structure and tailrace provide for an ultimate installation of twelve main generating units. Foundations for the machinery and the generator room have been built for seven main units and two station units. Over the discharge outlet of the turbines a bridge is provided as a runway for a gantry crane which is to raise or lower the gates placed in front of the these outlets during time of inspection or of repairs of the waterways or turbine equipment installed in them.

In order to prevent the water at the gates and along the skimmer wall from freezing in cold weather an air bubbler system is employed. Tubes connected to a supply of compressed air are immersed in the water along the walls and air at a pressure of 100 pounds is blown in to the water thus keeping it from freezing.

THE TURBINES

At the present time there are five main turbines constructed but only four are in operation. Each of these turbines is capable of delivering 42,500 horse power and in physical dimensions are the largest ever built in this country. They are of the Kaplan type and have an adjustable five blade propeller in order to obtain the best efficiency at variable flows and heads. Each turbine operates under an effective head of 53 feet and runs at 109.1 R. P. M.

Aside from these there are two smaller turbines for service use which are of the Francis type and operate at 180 R. P. M.

THE GENERATORS

Each turbine is direct-connected by a vertical shaft to an electric generator. The main generators now installed generate 3-phase, 60 cycle, 13,800 volts and have a capacity to carry 31,111 kva. at 80% power factor. The two service generators generate 3-phase, 60 cycle, 480 volts and can carry 2500 kva. at 70% power factor.

Mounted above each alternator is a smaller generator the duty of which is to supply power to a motor generator set that supplies excitation for the main alternator. All of this produces a dead weight of about 500 tons which is supported by a thrust bearing in addition to 100 tons caused by the water.

Of the two units to be installed in the near future, one will be equipped with a 60 cycle geherator while the other will generate single phase, 25 cycle current to be used by the Pennsylvania Railroad Company to operate their trains from Havre De Grace to Washington.

THE TRANSFORMERS

From the generators the current passes through switching and bus bars to the transformers situated on the upstream side of the Power House. Two banks of three single phase units, Y connected are used for stepp- the voltage up to 230,000 volts for transmission to Baltimore. Also two 3- phase transformers with a rating of 69,000 kva. are used for the transmission system of the Pennsylvania Water and Power Company. Aside from these main units there are 6 smaller transformers, two each for service at the plant, the village and for "A" station.

The oil used in the operation of these transformers is cooled by water drawn from the lake by pumps.

TRANSMISSION OF POWER TO BALTIMORE VIA CABLES

From the large transformers the output of the generators passes over aluminum cables supported on steel towers to Baltimore. Five cables are stretched over the towers two of serve as lightning safeguards. These two cables are placed about 25 feet directly above the power lines and so form an effective screen against lightning bolts. Should lightning strike one of the uppermost cables it is immediately conducted to the nearest tower where it is grounded.

These cables must be strong enough to support an ice covering six inches in diameter at a temperature of 0 C and with a wind blowing at the rate of 70 miles per hour. They are constructed of a steel core with a light outer ring of aluminum to transmit the current. They are a marked improvement over the old heavier type which required a tower of about twice the dimensions of the present ones.

In the early lines the cables were strung one above the other and no cross bars were necessary. During sleet storms however it was discovered that sometimes an ice covering would drop off of the lower cable first causeing it to spring up and come in contact with the cable just above it resulting in a short circuit and considerable trouble. To avoid this trouble the cables are now stretched in a horizontal plane 58 feet wide. Far enough to prevent any danger of contact during a strong wind.

One of the major problems of the construction of the power lines was the crossing of the river at the plant. The main channel of the river runs near the east bank where the power lines are installed and the first step in getting this power to Baltimore lay in reaching the west bank of the river. the river is some 5,000 feet wide at this point and the towers on each bank stand over 200 feet higher than the water. It was necessary to build a tower on Else Island in mid river just below the dam and to divide the distance into two 3,000 feet spans.

In addition to the river itself there were two railroads to span and instead of five cables there were ten stretched, the five extra to take care of the future supply. Because of these added cables and the greater span these towers are about twice as large as the others being approximately 200 feet high and 110 feet wide at the cross arms.

MISCELLANEOUS EQUIPMENT

Downstairs below the control room there are numerous motors, pumps, compressors, etc., for various jobs around the plant. One motor is utilized to pump oil to the transformers, several others for pumping water to the village and three large air compressors which are used for supplying air to for the air bubbler system. There is also a small purification system for purifying the water used in the village. It consists of a filtration sand bed and two small devices for the purpose of adding the proper amount of alum and soda in the water. Aside from this there is also an oil purification system which is used to puify the oil used in the transformers.

RELOCATING 8 MILES OF RAILROAD

The raising of the water level by 53 feet brought the surface just about to the height of the original track of the Pennsylvania Railroad. In order to protect the tracks from being flooded it was necessary to raise them for a distance of 8 miles, the average rise being only four feet. By agreement with the Power Company the Railroad Company took advantage of favorable construction conditions to double-track the road bed and straighten the existing track.

CONCLUSION

In bringing this thesis to a close it may be added that the Safe Harbor developement was planned, and is now operated, by the men who successfully placed the Holtwood plant in service and who have since operated it. Safe Harbor with it's output of 255,000 horse power and Holtwood with it's 180,000 horse power constitutes one of the largest hydroelectric developements on this continent, and bids well, with it's ultimate installation, to become the largest.

BIBLIOGRAPHY

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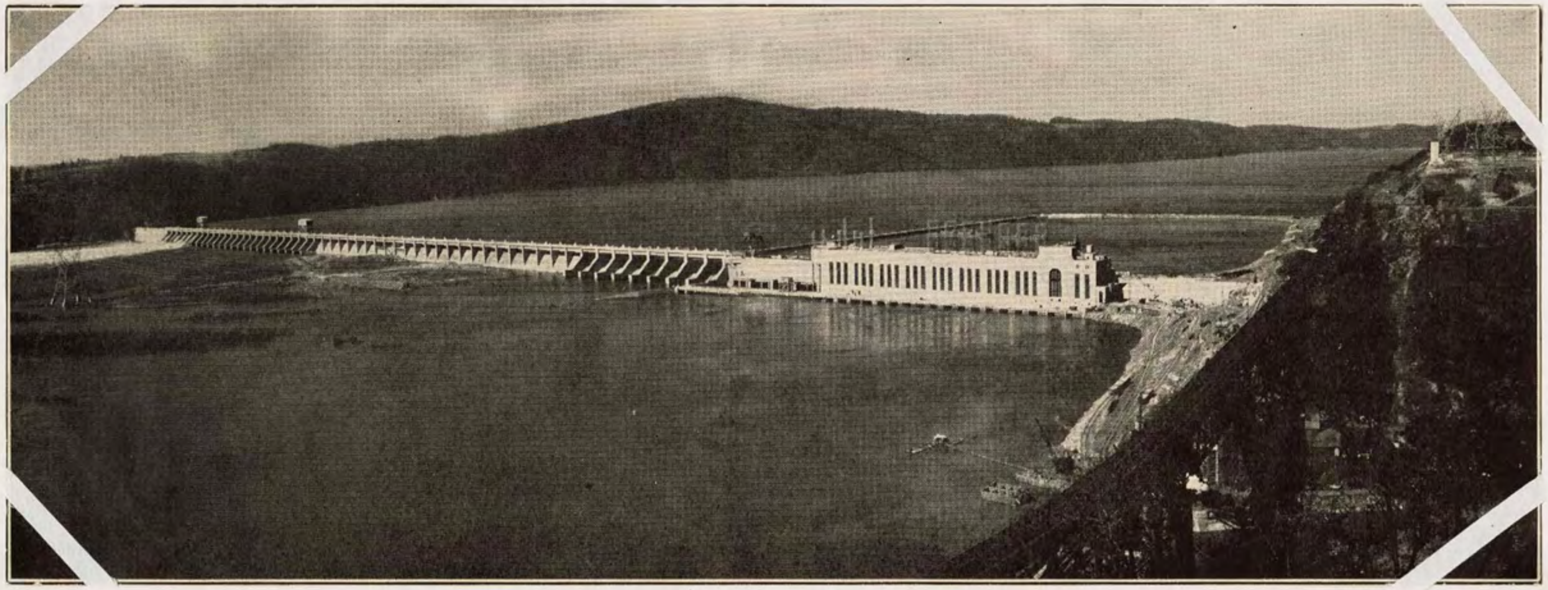
Mr. W. M. H. Ballantine; Pennsylvania Water and Power Company, Lexington Street Building, Baltimore, Maryland.

Mr. Frank Morgan; Pennsylvania Water and Power Company, Lexington Street Building, Baltimore, Maryland.

MAPS AND ILLUSTRATIONS

of

Safe Harbor Power Development



Top section of one of the 32 huge crest gates

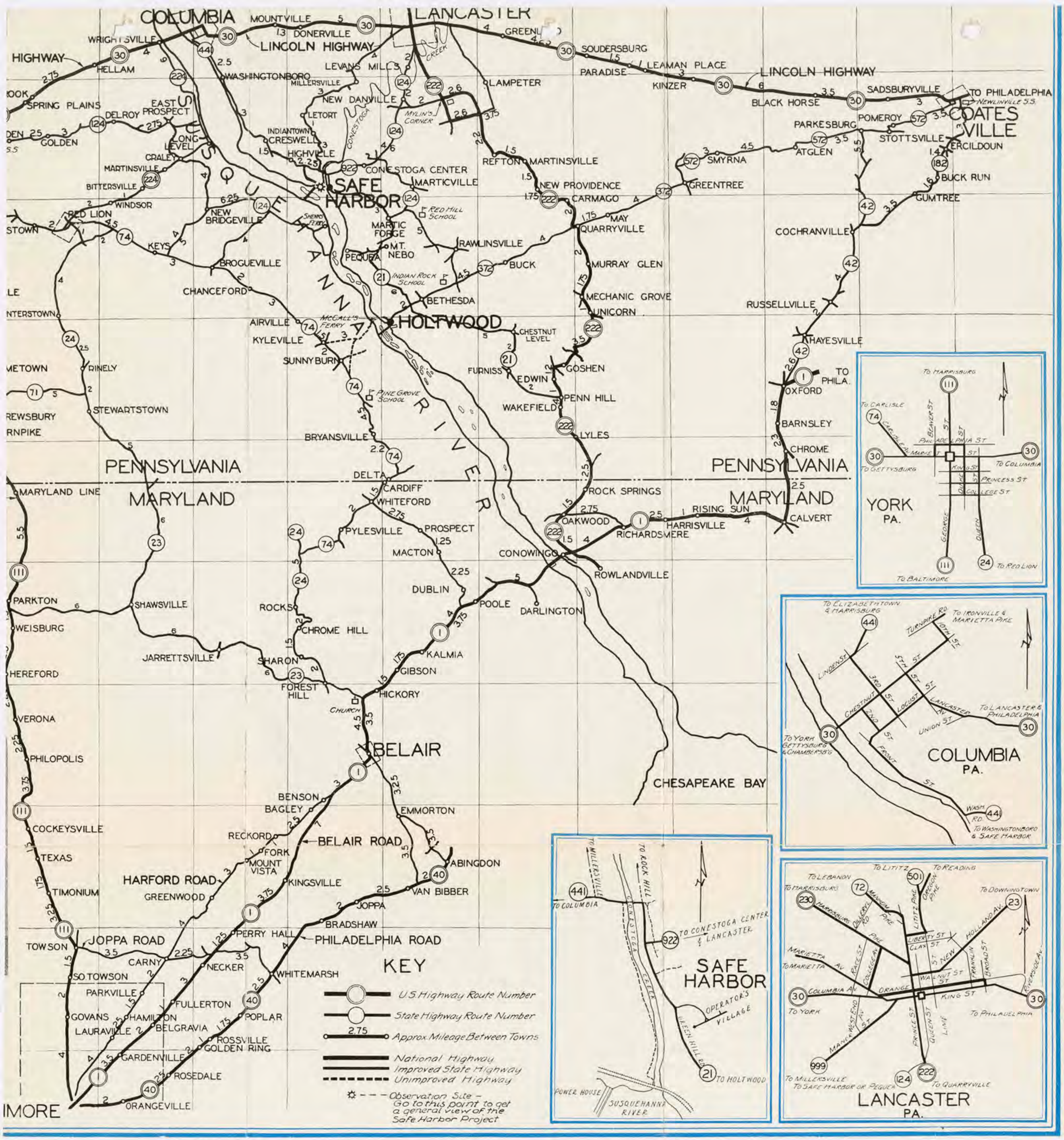
Standing on skimmer wall looking at Power House

230,000 kva. Transformer---Westinghouse Design

Looking down on Tailrace from Dam

View showing section of Dam and 150 ton gantry crane

Indian markings on rock in Susquehanna River



COLUMBIA
LANCASTER
MOUNTVILLE
DONERVILLE
WRIGHTSVILLE
LINCOLN HIGHWAY
HIGHWAY
HELLAM
WASHINGTONBORO
MILLERSVILLE
LEVANS MILLS
CREEK
GREENLAND
SOUDERSBURG
PARADISE
LEAMAN PLACE
KINZER
LINCOLN HIGHWAY
LAMPETER
SADSBURYVILLE
BLACK HORSE
TO PHILADELPHIA
NEWLINVILLE
COATES VILLE
POMEROY
PARKESBURG
STOTTSVILLE
ERCILDOUN
SPRING PLAINS
EAST PROSPECT
DELROY
GOLDEN
LONG LEVEL
CRALEY
MARTINSVILLE
BITTERSVILLE
WINDSOR
RED LION
NEW DANVILLE
LETORT
MYLIN'S CORNER
CONESTOGA
INDIANTOWN
CRESWELL
HIGHVILLE
CONESTOGA CENTER
MARTICVILLE
SAFE HARBOR
REFTON
MARTINSVILLE
NEW PROVIDENCE
CARMAGO
SMYRNA
ATGLEN
GREENTREE
BUCK RUN
GUMTREE
SUSQUEHANNA RIVER
NEW BRIDGEVILLE
SHENKS FERRY
RED HILL SCHOOL
MARTIC FORGE
MT. NEBO
PEQUEA
RAWLINSVILLE
MAY
QUARRYVILLE
COCHRANVILLE
KEYS
BROGUEVILLE
INDIAN ROCK SCHOOL
BUCK
MURRAY GLEN
CHANCEFORD
BETHESDA
MECHANIC GROVE
UNICORN
RUSSELLVILLE
AIRVILLE
McCALL'S FERRY
HOLTWOOD
CHESTNUT LEVEL
KYLEVILLE
HAYESVILLE
SUNNYBURN
FURNISS
EDWIN
GOSHEN
TO PHILA.
OXFORD
PINE GROVE SCHOOL
PENN HILL
WAKEFIELD
LYLES
BARNSLEY
CHROME
BRYANSVILLE
RINELY
STEWARTSTOWN
PENNSYLVANIA
MARYLAND
MARYLAND LINE
DELTA
CARDIFF
WHITEFORD
ROCK SPRINGS
RISING SUN
CALVERT
OAKWOOD
HARRISVILLE
RICHARDSMERE
PYLESVILLE
PROSPECT
MACTON
CONOWINGO
ROWLANDVILLE
DUBLIN
POOLE
DARLINGTON
PARKTON
SHAWSVILLE
WEISBURG
ROCKS
CHROME HILL
KALMIA
JARRETTSVILLE
SHARON
GIBSON
HEREFORD
FOREST HILL
HICKORY
CHURCH
VERONA
BELAIR
PHILOPOLIS
CHESAPEAKE BAY
BENSON
BAGLEY
EMMORTON
COCKEYSVILLE
RECKORD
BELAIR ROAD
FORK
MOUNT VISTA
TEXAS
HARFORD ROAD
KINGSVILLE
ABINGDON
TIMONIUM
GREENWOOD
VAN BIBBER
JOPPA
BRADSHAW
JOPPA ROAD
PERRY HALL
PHILADELPHIA ROAD
TOWSON
CARNY
NECKER
SO. TOWSON
WHITEMARSH
PARKVILLE
FULLERTON
GOVANS
HAMILTON
POPLAR
LAURAVILLE
BELGRAVIA
ROSSVILLE
GOLDEN RING
GARDENVILLE
ROSEDALE
ORANGEVILLE
IMORE
KEY
U.S. Highway Route Number
State Highway Route Number
2.75
Approx. Mileage Between Towns
National Highway
Improved State Highway
Unimproved Highway
Observation Site – Go to this point to get a general view of the Safe Harbor Project
TO HARRISBURG
TO CARLISLE
BEAVER ST
PHILADELPHIA ST
MARKET ST
KING ST
PRINCESS ST
COLLEGE ST
TO GETTYSBURG
TO COLUMBIA
GEORGE
QUEEN
TO BALTIMORE
TO RED LION
YORK PA.
TO ELIZABETHTOWN & HARRISBURG
TURNPIKE RD.
TO IRONVILLE & MARIETTA PIKE
LINDEN ST
5TH ST
3RD ST
CHESTNUT ST
LOCUST ST
LANCASTER AV
UNION ST
TO LANCASTER & PHILADELPHIA
TO YORK GETTYSBURG & CHAMBERSB'G
FRONT ST
WASH. RD.
TO WASHINGTONBORO & SAFE HARBOR
COLUMBIA PA.
TO MILLERSVILLE
TO ROCK HILL
TO COLUMBIA
CONESTOGA CREEK
TO CONESTOGA CENTER & LANCASTER
SAFE HARBOR
OPERATOR'S VILLAGE
GREEN HILL RD.
TO HOLTWOOD
POWER HOUSE
SUSQUEHANNA RIVER
TO LITITZ
TO READING
TO LEBANON
TO HARRISBURG
HARRISBURG PIKE
MANHEIM PIKE
LITITZ PIKE
OREGON PIKE
TO DOWNINGTOWN
LIBERTY ST
CLAY ST
NEW HOLLAND AV.
MARIETTA AV
TO MARIETTA
COLLEGE AV
ORANGE
WALNUT ST
KING ST
COLUMBIA AV
TO YORK
TO PHILADELPHIA
PRINCE ST
QUEEN ST
LIME
FRANKLIN
BROAD ST
DUKE
TO MILLERSVILLE TO SAFE HARBOR OR PEQUEA
TO QUARRYVILLE
LANCASTER PA.

"THE HISTORY AND CONSTRUCTION OF THE GEORGE WASHINGTON MONUMENT AT BALTIMORE, MARYLAND"

A THESIS PRESENTED TO

TAU BETA PI

BETA CHAPTER OF MARYLAND

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