Buckeye Lake Dam

Fairfield and Licking Counties, Ohio

REVIEW OF PAST REPORTS AND EXISTING CONDITIONS AND RECOMMENDATIONS FOR INTERIM RISK REDUCTION MEASURES, OPERATION, AND MAINTENANCE

Huntington District, Great Lakes and Ohio River Division

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers, Huntington District (the District) and the Ohio Department of Natural Resources (ODNR) have a long history of cooperation with regard to dam safety issues. From June 2014 to February 2015, the District, as an external expert, was retained by ODNR to complete an assessment of the condition of Buckeye Lake Dam, Ohio using engineering best practices. The assessment included evaluation of previous engineering consultant reports, site reconnaissance, and public meeting participation. Completion of these tasks resulted in the identification of extensive embankment defects deemed by the District to pose significant public risks, conclusions regarding these defects, and recommendations to ODNR for development and implementation of a risk reduction plan for Buckeye Lake Dam. During the assessment period the District gained further knowledge of ODNR's risk-informed inventory management processes and visited current ODNR dam risk reduction projects , including construction at Roosevelt Lake and Pond Lick Dams. The District acknowledges and concurs with ODNR's programmatic efforts focused on dam safety risk assessment and reduction.

After a review of the consultant reports and past USACE high pool observation records, and during the period from August 2014 through December 2014, the District conducted site reconnaissance and participated in public meetings. These efforts resulted in the determination that numerous defects, of which the most significant are many encroachments by private interests, exist along the entire 4.1 miles of the embankment at Buckeye Lake. The District has concluded, using applicable engineering standards of practice, that the Buckeye Lake Dam embankment does not meet current dam safety requirements. Additionally, several seepage and internal erosion initiation observations were documented by USACE and ODNR personnel during 1968 and 1990 emergency reponses. Embankment defect conditions observed during the 2014 site reconnaissance included sheet pile and masonry wall deterioration, trees rooted in the embankment, seepage, wet areas, and subsidence features. Most importantly, approximately 370 houses with associated structures, utilities, and open excavations have displaced or disrupted large portions of the embankment. Of these structures, more than 15 percent show misalignment of walls and retaining features, which is indicative of differential settlement. The extent of these man-made embankment defects for designed water-retaining structures is unprecedented in the experience of the District. The design and construction of this dam did not contemplate the secondary placement of these structures. It is likely that embankment defects beyond those observed during reconnaissance exist since large areas of the dam cannot be inspected due to the presence of residences, appurtenant structures, and vegetation. Limited stability analyses described in previous reports also have not adequately defined embankment defects and failure modes, which resulted in the apparent underestimation of internal erosion and overtopping failure risks.

The previously referenced engineering consultants, retained during the period from 1978 to 2003, appropriately used the data and methodology available during that time. However, the advent and complete implementation of risk-based analysis methodology includes more comprehensive evaluations of known or potential defects in dams and appurtenant structures. Additionally, significant advances in both semi-quantitative and quantitative analysis and modeling would

include more extensive subsurface explorations and laboratory testing to better characterize embankment and foundation conditions.

The District acknowledges limitations, as did the previously retained consultants, Ohio Department of Natural Resources, and the public, regarding geotechnical, hydrologic, and hydraulic information as would be required for more comprehensive modeling, analysis, and risk assessments of Buckeye Lake Dam. These limitations include limited data regarding embankment foundation conditions, fill characteristics, seepage pathways and gradients, prior reconstruction efforts, and detrimental modifications to the dam resulting from the construction of numerous homes and related components. Nevertheless, the available data are sufficient to support the District's opinion that the likelihood of dam failure is high based on prior near-failures and adverse conditions at and above normal pool, including but not limited to seepage, wall and dam misalignment, and requirements on several occasions for emergency response actions to prevent breaching. Available geotechnical data substantiates that the embankment is comprised of random, uncompacted material without filters or cutoffs to intercept internal erosion processes that could lead to breaching. The extent of cracks and depressions along the crest of the embankment, together with collapsed structures which were built into the downstream slope of the dam, pose serious stability related risks. Potential failure modes include internal erosion of the embankment fill and foundation soils, instability of the embankment, and overtopping and erosion of the embankment.

Although additional hydraulic, loss of life, and economics data is recommended to better quantify the consequences of dam failure, the District has determined that embankment breaching, downcutting, and lake discharge and resulting flooding would most probably occur without sufficient warning or evacuation time. Numerous residences built within the downstream embankment slope and immediately downstream of the appurtenant structures would likely be adversely impacted in the event of a breach. Considering the immediate proximity of the downstream population, a catastrophic breach of Buckeye Lake Dam could pose unacceptable life loss and economic consequences. Therefore, immediate interim risk reduction measures are recommended to reduce risk of catastrophic dam failure as a result of breaching during normal pool retention.

The District recommends that interim risk reduction measures be implemented immediately. The District further recommends that comprehensive risk reduction alternatives be evaluated, selected, and implemented by ODNR. Selection of remediation alternatives should be based on the potential for proposed actions to reduce risk to a tolerable level. If no action is taken, the public would remain at significant risk of embankment failure and subsequent flooding, even at normal pool elevation. More detailed analysis of hydrologic and hydraulic parameters, using current modeling methodology, and additional geotechnical site characterization are recommended. This site characterization would be used to better determine when and where embankment failures are most likely to occur (to improve emergency response planning), perform additional risk analysis, and design the selected major remediation alternative(s).

1 INTRODUCTION

1.1 ODNR-ARMY CORPS OF ENGINEERS SCOPE OF WORK

The U.S. Army Corps of Engineers, Huntington District (the District) was tasked by the Ohio Department of Natural Resources (ODNR) to conduct an assessment of the condition of Buckeye Lake Dam and appurtenant structures, as well as to make recommendations for the repair, operation, and maintenance of the dam utilizing engineering best practices. Specific efforts included participation during technical meetings with ODNR staff, field reconnaissance, and review of previous consultant reports and other technical documents, which included the ODNR's continuing site evaluations, assessments of embankment and foundation conditions, and replacement design alternatives. The Huntington District was also tasked to provide engineering support to the ODNR during public meetings and technical briefings. This report summarizes District evaluations of the dam's stability and related comprehensive risk reduction alternatives along with recommendations for interim operations and maintenance. The report also presents recommendations regarding more detailed geotechnical, hydraulic, and hydrologic analyses. While this assessment is specific to Buckeye Lake Dam, the process and assessment methodology used would be applicable to other dams statewide.

Table 1: Task/Milestones and Deliverables

Task	Action	Due Date
Task 1	Coordination Meeting with ODNR	18 June 2014
Task 2	Review Existing Reports	19 June – 24 August 2014
Task 3	Stakeholder Meeting	4 August 2014
Task 4	Site Visit/Reconnaissance	25-28 August 2014
Task 5	Community Meetings	28-29 October and 18 November 2014
Task 6	Draft Report Preparation and Submittal to ODNR for Review	30 October 2014 - 20 January 2015
Task 7	Revise Draft (if necessary) and Submit Final Report to ODNR	21 January 2015 – 28 March 2015

1.2 BACKGROUND OF BUCKEYE LAKE DAM

Buckeye Lake Dam is part of Buckeye Lake State Park, situated near the edge of Millersport and the Village of Buckeye Lake in Fairfield, Licking, and Perry counties of Ohio, approximately 23 miles east of downtown Columbus, 9 miles south of Newark, and 22 miles west of Zanesville. The earthen embankment was constructed from 1825 to 1832 and is approximately 4.1 miles long. Buckeye Lake, previously named the “Big Swamp” and “Licking Summit Reservoir,” functioned to maintain minimal water depths for navigation within adjacent and downstream reaches of the Ohio and Erie

Canal System. Notably, the dam was not designed for the purpose of retaining a permanent recreational pool or as a foundation for adjacent structures.

In 1894 the Ohio legislature designated Buckeye Lake as a public park. In 1895 the State sold downstream portions of the embankment and adjacent acreages to private interests. These interests constructed industrial and retail structures and leased undeveloped lands adjacent to, and within, the embankment footprint for fishing camps and cottages. Subsequent development included an amusement park, hotels, docks, and marinas. Access to the site was provided by extensive road systems and by rail.

The State re-designated the lake and the state owned land as a state park in 1949. From 1949 to the 1960s attendance for the adjacent amusement park began to decline, and park structures were subsequently removed and backfilled with debris. Buckeye Lake continues to support recreational uses such as fishing and boating and is not established for flood control. The dam is a partially state-owned structure, for which ODNR has accepted operation and maintenance responsibility. However, complex shared ownership and use creates ambiguities regarding the extent of mutual responsibilities and liabilities for dam failure. Today Buckeye Lake State Park attracts many visitors, and there are numerous residents who live adjacent to the lake and within the village of Buckeye Lake.

1.3 Project Description

Buckeye Lake Dam consists of an earthen embankment (West Bank and North Bank reaches), a primary spillway (Amil gate spillway), a secondary spillway (Sellers Point spillway), low-level drains, the Crane Lake closure structure, and the Thornport diversion structure. West Bank is 8400 feet long and is located to the west of the Sellers Point spillway. North Bank is 13,000 feet long and is located to the east of the Sellers Point spillway. The maximum height of the embankment is about 16 feet. The shoreline along about 40 percent of West Bank and all of North Bank is protected with sheet piling. The sheet piling provides protection against wave related erosion and was not designed as a structural component of the dam. The Amil gate spillway was designed to maintain the normal pool level during frequently occurring rainfall events. The Sellers Point spillway is a 472 feet long concrete ogee weir. It was designed to discharge water from the lake during infrequently occurring floods. Both spillways have gated low-flow pipes that can be used to lower the lake level to winter pool elevation. The Crane Lake closure structure and the Thornport diversion structure are appurtenances that better assure impoundment of the lake and management of the pool level.

Buckeye Lake surface area is 3,030 acres at the top of the dam (approximately El. 894.5 ft.) and 2,800 acres at summer pool (El. 891.75 ft.). Lake storage capacity is approximately 14,000 acre-feet at summer pool elevation. The embankment was constructed using random, uncompacted earth fill without filters, cutoffs, or foundation treatment. Historical mapping and reports indicate that two borrow areas were used for embankment fill materials; however, the characteristics of these materials and their placement locations within the dam were not documented. The dam failed upon initial filling in 1832 in an area on the North Bank known as the Black Diamond Wreck site and was repaired by placing 10,000 wagon loads of random earthfill consisting of "coarse stone"

(Gardner, 1995). The project continued to be operated and maintained by the State of Ohio and others until 1894. Subsequent operation and maintenance of the canal system required dredging, on-site dredge materials disposal, and embankment protection. The reservoir also required construction of diversion structures for both inflows and the discharge of excess storm waters to the South Fork Licking River (SFLR) and Muskingum watersheds.

The site geology includes glacial outwash, glacial till, lacustrine, and alluvial deposits. Glacial outwash, lacustrine, and alluvial deposits tend to be highly variable and intermixed with permeable layers. These geologic conditions are complex and require extensive foundation characterization and analysis for engineering design of a dam. A description of site-specific geology is included as Appendix A. A limited number of soil borings were performed by Dodson-Lindblom Associates, Inc. (DLA, 1987, 1995) and Paul C. Rizzo Associates, Inc. (1997) within the embankment, foundation, and lake bed. The embankment materials were classified as clayey silts and silty clays with various amounts of sand, gravel, and organics. Sand and silt lenses were also encountered within the embankment. A layer of organic silt was encountered within the earthen foundation directly beneath the embankment.

Elevation data for the dam are summarized in Table 2. For referenced pool elevations and project features, the District assumed the National Geodetic Vertical Datum of 1929 (NGVD 29) in this study.

Table 2: Pertinent Elevation Data (NGVD 29)

Feature	Elevation (ft.)
Approximate Top of Dam	893-897
27 May 1968	894.17
10 June 1990 High Pool	893.74
Pool When Increased Seepage has been Observed	892.25
Sellers Point Spillway Crest	892.2
Amil Gate Spillway Crest	891.75
Summer (Normal) Pool	891.75
Winter Pool	888.75

1.4 Past USACE High Pool Performance Observations

The USACE memorandum dated 29 March 1939 (Appendix G) documented conditions observed during reconnaissance performed during the period of 14 to 15 March 1939 and included general recommendations. Based on frequently observed seepages through the embankment, strengthening of the embankment was recommended. This through-seepage was attributed to scour of embankment soils following failure of sheet pile and masonry walls at several locations, animal burrowing, and by decomposition of embedded tree roots. Preliminary hydraulic calculations suggested the spillway capacity might have been inadequate for a flood with a 110-year recurrence interval. Therefore it was recommended to increase the discharge capacity of the spillway from 3,600 to 28,000 cubic feet per second.

On 04 November 1968, a USACE memorandum (Appendix G) documented an event at Buckeye Lake during which 5.47 inches of rain fell during the period of 24-27 May 1968. This precipitation resulted in rapid filling of Buckeye Lake "to a height that became quite alarming." Increased seepage was documented as occurring through the embankment and into the basements of houses which had been constructed in and adjacent to the dam. The Ohio National Guard was deployed to Buckeye Lake on the evening of 27 May to reinforce the dam with 50,000 sand bags and straw to prevent catastrophic overtopping. Lake waters crested at around 12:00 am on the morning of 28 May and then began to recede. The maximum pool elevation experienced during this event was documented as "23 [inches] over the [relic] spillway at the crest," corresponding to an approximate elevation of 894.17 feet. Overtopping of the embankment did not occur; however, seepage through the dam developed such that reinforcement by sandbagging was required to prevent dam failure.

USACE conducted site reconnaissance on 28 June 1990 (Appendix G) to document defects and other problematic site conditions observed during and subsequent to a storm event that occurred 08-09 June 1990. During the storm event, which continued for 6 hours, 3.5 to 4.0 inches of rain fell within the Buckeye Lake and adjacent drainage areas. Initiation of internal erosion was observed in a failing foundation wall within the basement of a residence at Station 153+75. The Ohio National Guard was deployed to sandbag the floor area adjacent to the failing wall to counterbalance the hydrostatic head. Low areas along the dam crest were sandbagged to prevent dam failure. Embankment seepage was noted at Lakeside, Sellers Point, Black Diamond Point, and the Amusement Park. However, it is probable that not all seepage areas were identified and adequately documented due to inundation of the dam toe. Several embankment subsidence areas and cavities were noted adjacent to the sheet pile and masonry walls were noted in the 1990 reconnaissance. Depressions within the embankment were also noted.

2 Review of Previous Engineering Consultant Reports

Engineering reports from consultants submitted during the period from 1978 to 2003 defined project conditions from visual observations, limited subsurface exploration data, and stability and seepage analyses. These reports also included the submittal of preliminary geotechnical and structural design concepts for the remediation of deficiencies as cited by some consultants. Some reports included limited drainage basin hydrology and hydraulic characterizations and related modeling efforts. District reviews of these reports and analyses formed one of the bases for subsequent recommendations. However, the District does not concur with all of the consultant findings and recommendations. Detailed discussion and resolution of variances among these reports was not included in the scope of this assessment.

2.1 Summary of Findings from Consultant Reports

A USACE report, as prepared by GAI Consultants, Inc. (1978), concluded that the overall condition of the facility was poor and potentially unsafe. The consultant identified potential serious maintenance and operations related problems including an inadequate spillway system, seepage through the embankment, instability of the shore protection walls, and embankment irregularities and distress along the dam crest.

Dodson-Lindblom Associates , Inc. (DLA, 1987) performed a study of spillway and lake storage capacity requirements and an analysis of embankment structural integrity. This analysis concluded that the embankment was stable under normal and elevated pool conditions. However, the consultant also noted that this preliminary conclusion was limited by assumptions regarding probable hydrologic events and durations and by inadequate information with respect to residential basement wall designs and related features. Proposed embankment remedial actions included reach specific construction of a partial cutoff wall or embankment toe drain, diversion of all drainage away from the reservoir, and removal of all four- to six-inch or larger diameter trees from the crest. The consultant recommended the construction of a U-shaped, concrete gravity spillway at Sellers Point and the replacement of the existing spillway with a gated outlet structure. These spillway recommendations were implemented in 1992. Additional recommendations included the construction of a concrete parapet wall along the crest of the embankment and modifications to the SFLR to improve conveyance. SFLR channel cleaning was completed in 2014.

Gardner and Associates (1995) provided technical responses to the 1987 DLA report, including statements that the dam had the following deficiencies: the embankment was poorly compacted and leaky, slope instability occurred at pools greater than elevation 892 feet, and the dam would be overtopped during the probable maximum flood (PMF). The consultant also concluded that the construction of a parapet wall could result in an embankment failure during PMF, which was understood by this consultant to require a lake pool elevation of 896.5 feet, due to the effects of the resulting increase in hydrostatic head. The consultant therefore recommended that PMF related conditions be addressed by other alternatives.

Dodson-Lindblom Associates , Inc. (DLA, 1995) evaluated the sheet piling at Buckeye Lake. Based on visual and ultrasonic investigations and analysis, the consultant recommended the 1940s and 1960s sheet piling sections be replaced. The 1940s sheet piling installation was determined to have reached the end of its useful life, requiring approximately 1,100 linear feet of replacement piling. The 1960s piling installation was determined to have 10 to 15 years of remaining life, resulting in the recommendation for replacement of an additional 3,680 linear feet.

DLA responses to Gardner and Associates (1996) comments included reanalysis of embankment slope stability and an underseepage analysis. Resulting slope stability safety factors were stated as being slightly below the generally accepted minimum required safety factor of 1.5 at the Sellers Point Spillway crest elevation (892 ft.). Additionally, slope stability analyses were not performed for pool levels higher than 892 feet.

Gardner and Associates (1996) evaluated the adequacy of the U-shape, concrete gravity spillway to pass the outflow of the PMF or other high pool events and thereby prevent overtopping of the embankment crest during these events. Consultant reanalysis of spillway discharge conditions established that the crest elevation was not sufficient to prevent PMF overtopping of the embankment. Therefore, Gardner and Associates recommended modifications to the U-shaped, concrete gravity spillway. These modifications included addition of four radial arm gates along the spillway crest which would function to regulate PMF discharges.

DLA (1996) noted that there were some inconsistencies in the analysis by Gardner and Associates. However, both consultants determined that embankment overtopping would occur during the PMF. Additionally, DLA noted that Gardner and Associates' proposed spillway modifications would not be sufficient to regulate PMF related discharges and prevent embankment overtopping. Therefore, DLA determined that raising the embankment crest, together with Sellers Point spillway modifications, would be required to minimize risk of overtopping and preclude uncontrolled release of lake waters to the SFLR during the PMF.

Paul C. Rizzo Associates, Inc. (1997) concluded that the dam crest could be raised an additional two feet without compromising embankment stability. This determination was established by field observations, subsurface explorations, laboratory testing, piezometer and observation well data, evaluations, and stability analysis. The consultant conclusions were based on limited information and on the assumption that house foundations built into the embankment would not contribute to failure. This consultant also stated, without the opportunity to obtain additional hydrologic and hydraulic data, analysis, or modeling, that raising the embankment crest to elevation 896.5 feet to retain the PMF would only marginally affect discharge and flood related impacts downstream of the SFLR.

T. Davis Syndor (2002) submitted vegetation evaluations and maintenance recommendations and concluded that tree roots stabilize slopes and have been "used to armor levees." This conclusion seems to be based on the assumption that mature tree root systems would not result in additional embankment defects and internal erosion pathways. Additional vegetation related concerns referenced toppling of mature trees and related root wad displacements of embankment soil.

A DLZ report (2003) included mapping of the embankment, evaluations of trees and related defects along the embankment crest, an assessment of sheetpile wall conditions, and conceptual remedial designs intended to bring the embankment into compliance with dam safety requirements. Project mapping (perfomed in 2000) included comparisons with the 1990 surveys. Vegetation maintenance recommendations were reviewed. Evaluations of sheet pile wall systems included visual reconnaissance, ultrasonic testing, coupon sampling, and test pit excavations. Using the sheet pile data, the consultant established rates of corrosion for the walls. Calculations were performed to determine factors of safety based on the yield stress limits as defined by the steel thicknesses. Factors of safety (yield stress=1.0) ranged between 1.2 and 1.9. The 1948, 1961, and 1962 sheet piling strengths were at or below the allowable stresses and approaching the yield stresses. A schedule was developed for phased replacement of the dam sheet pile walls. Data from geotechnical exploration programs were also reviewed by DLZ, and during this phase of project evaluations, DLZ considered embankment improvement alternatives as well as requirements for an adjacent retention structure to be constructed within the lake. The consultant generally defined the soils within the lake, in the area of the proposed adjacent structure, as consisting of loose sediment and soft, medium, and stiff clayey silts and silty clays with interbedded sand and gravel layers. Alternatives for the adjacent structure included post and panel wall, double row sheet pile wall, I-wall, inverted T-wall, and pre-cast concrete box. A double row sheet pile wall was the recommended remediation alternative.

Fuller, Mossbarger, Scott & May Engineers (FMSM, 2003) developed a watershed management plan for the SFLR. Five alternatives were presented to reduce flooding downstream of the Sellers Point spillway. Alternatives included design and construction of an outlet to Jonathon Creek, design and construction of an outlet at Maple Bay, installation of gates at the Sellers Point Spillway, modifications to improve conveyance within adjacent and down channel reaches of the SFLR, and design and construction of channels which would divert flows from the Kirkersville Feeder canal and a reach of the SFLR to a tributary stream north of Interstate 70. The consultant recommended an alternative which included modifications to improve conveyance of the SFLR. These modifications are now complete.

2.2 Evaluations of Consultant Reports

District staff continued to review the consultant reports and other data obtained during site reconnaissance and open house public meetings. As previously noted, these reports contained relevant geotechnical and hydraulic data. During this evaluation the District relied substantially on these consultant reports, field observations, and dam and levee safety guidance.

2.2.1 Geotechnical Evaluation

The District has concluded that the consultants were in general agreement regarding geotechnical conditions and relic construction methods as limiting their ability to analyze embankment conditions. Sufficient approximations of complex site conditions, resulting from both initial embankment construction and subsequent modifications, could not be made for these analyses. Modifications included maintenance, repairs, and the placement of numerous residential and commercial structures within and adjacent to the embankment. Embankment sections evaluated for stability were analyzed without sufficient consideration of excavated areas where numerous privately owned structures have been constructed into the dam. Paul C. Rizzo Associates, Inc. (1997) modeled a hypothetical embankment section which included a house structure. However, this house structure condition was predicated on assumed wall characteristics. Recent observations of basement walls, foundations, and retaining walls indicate substantially less favorable site conditions than those considered by this consultant.

Seepage and internal erosion related embankment and foundation conditions were not adequately evaluated in the previously referenced reports. The term “internal erosion” is used generically to describe erosion of particles by water passing through a body of soil. Internal erosion is a significant threat to earthen embankment stability and can lead to dam failure. Types of internal erosion mechanisms include backward erosion piping, concentrated leak erosion, and contact erosion, resulting in embankment subsidence and breaching.

Limited seepage analyses were performed by consultants to establish phreatic surfaces as related to embankment slope stability, but only one analysis was performed to address internal erosion related failure modes. This simplified flow net analysis was used to approximate factors of safety against initiation of internal erosion through the embankment foundation, as was cited in DLA’s responses to Gardner and Associates' Report (1996). This analysis resulted in acceptable factors of safety. However, as with the previously referenced stability analyses, the embankment section evaluated did not include fill characterization, excavations, embedded structures, or other anomalies that would increase embankment susceptibility to internal erosion by shortening seepage paths and forming pathways for concentrated seepage flows. Additionally, this analysis did not evaluate the potential for internal erosion through the embankment. The analysis also assumed a spillway crest defined pool condition of 892.2 feet. However, seepage has been observed to increase within various embankment locations at higher pools. Evidence of internal erosion initiation, such as subsidence features in the downstream embankment toe area, was encountered during the August 2014 inspection. Additionally, none of the previously referenced models were calibrated using piezometer readings or seepage observations during elevated pools. Due to observed conditions indicative of internal erosion processes and excessive seepage through the embankment and foundation at numerous locations, as well as limitations to the above mentioned seepage analysis, the District does not consider this seepage analysis to be comprehensive or reliable for evaluation of Buckeye Lake Dam conditions. Therefore, the District has concluded that these analyses do not sufficiently define defects as observed in the field during prior high pool conditions and during the August 2014 reconnaissance, and that the result has been the apparent underestimation of internal erosion and overtopping failure risks.

2.2.2 Hydrologic and Hydraulic Evaluation

The Buckeye Lake PMF was originally developed in 1987 by Dodson-Lindblom Associates for the Spillway Adequacy and Embankment Stability and Seepage Study. As part of the Dodson analysis, the Snyder Method and Soil Conservation Service (SCS) Method were both used to develop synthetic unit hydrographs for the Buckeye Lake watershed. This practice is currently not recommended due to the vast differences in parameter development between the two methods. For consistency, only one unit hydrograph method should be considered for use during a hydrological analysis.

The Probable Maximum Precipitation (PMP) rainfall referenced in the Dodson study was 23.6 inches using a 6-hour duration event based on Hydrometeorological (HMR) Report 51. HMR 51 provides estimates of area-averaged PMP for the United States east of the 105th meridian. HMR 52 provides a procedure for obtaining drainage area averaged PMP amounts from the storm area averaged PMP provided in HMR 51. This procedure determines isohyetal values for up to twelve 6-hour periods, a total of 72 hours, for an elliptical precipitation pattern. Included in the technique are adjustments for both basin shape and effects of storm pattern orientation. The Dodson study does not appear to have followed the procedure outlined in HMR 52.

In 2000, Fuller, Mossbarger, Scott, & May Engineers (FMSM), published an updated study of the PMF for Buckeye Lake. The FMSM study followed the procedures outlined in HMR 52. However, the PMP was focused on a 6-hour duration instead of a 72-hour duration event. The District recommends that the PMF be updated using a 72-hour duration event and by following the procedures outlined in HMR 52. Furthermore, other storm events have occurred in the Buckeye Lake basin since the Dodson study was published in 1987. Precipitation and streamflow data for these storms is available, and updated unit hydrographs could be computed and used to update the

PMF. Wave run up and freeboard calculations should also be considered to provide additional information. An updated PMP study was developed for the State of Ohio in 2013. This study could be used to evaluate the probability of dam overtopping in lieu of HMR 51 and 52.

The use of frequency rainfall data to develop storm inflow and pool elevations related to frequency, which, in lieu of statistical analysis of historical pool levels, would provide a hypothetical measurement of probability/frequency of occurrence which is a major component of risk analysis. Projected frequency intervals for flood events could be analyzed using available historical inflow and pool elevation data. If this historical data is not available, inflow data could be estimated using frequency rainfall from the National Weather Service NOAA Atlas 14 and computed using a hydrologic software program such as HEC-HMS. Pool elevations based on the inflows computed from the frequency rainfall could also be estimated in HEC-HMS. The data computed from this analysis could then be used to identify an estimated frequency of overtopping. This analysis would also provide a relative indication of the frequency of dam overtopping. The District recommends that existing stream gages be modified or new gages installed, to measure and record inflow and outflow data daily.

The last dam break model for Buckeye Lake was developed in 1987 using National Weather Service (NWS) DAMBRK. DAMBRK was a DOS-based numerical model developed in the late 1970s to forecast downstream flooding resulting from dam failures. Dam breach parameters were calculated using the latest 1980s criteria and input into the DAMBRK model to simulate flow through a breach in the dam. At that time, DAMBRK was the best method for analyzing a dam breach.

Additional methodology is now available to assess the safety of a dam and consequences associated with failure. Criteria for developing breach parameters have changed since the referenced dam break model was developed, and that model is no longer used. Additional studies have been conducted which now provide a wider array of breach characterizations. Dam break models are now simulated by unsteady flow analysis using HEC-RAS, a software package developed by the US Army Corps of Engineers Hydrologic Engineering Center.

The recently developed 100-year storm inundation mapping for the Buckeye Lake Emergency Action Plan (EAP) was revised in 2012. This mapping shows impacted areas immediately downstream of the project. However, impacted areas further downstream within locations, such as the City of Newark, have not been included. The SFLR drainage area and Buckeye Lake discharges should be modeled for areas downstream of the dam to and including the headwaters of Dillon Lake. Updated modeling would incorporate embankment breach parameters as established by the latest criteria. Numerous potential failure and non-failure scenarios would then be calculated. This analysis would also include major tributaries of the Licking River as well as main stem conveyance so that backwater conditions could be defined for embankment failure or non-failure scenarios.

Inundation mapping could be generated based on the results of the new dam break model and updated PMF for failure and non-failure scenarios. More accurate flooding consequences could then be determined based on the results of the new model. Failure consequences, such as potential loss of life and property damages, could be determined using travel times, Federal Emergency

Management Agency (FEMA) delineations, and the revised inundation mapping. The new dam break models and inundation maps could also be used to update the current Emergency Action Plans (EAP) to assist state, county, and local officials during potential emergencies.

3 USACE Site Reconnaissance

Prior to the 25-28 August 2014 reconnaissance, the USACE published a notice of intent, which included a request for input from property owners and others. Property owners were asked to flag areas of concern and to provide photographs and other information for review during the reconnaissance. The public also provided comments to the District and ODNR during open house meetings on 28 and 29 October and 19 November 2014. During the period from 25-28 August and 15 December, Huntington District, ODNR, and local interests conducted embankment, structures, spillway, and shoreline evaluations. Limited reconnaissance of South Fork Licking River and adjacent canal reaches was also completed. The pool elevation at the time of the 25-28 August inspection was 891.8 feet. No precipitation occurred during this inspection period.

During the reconnaissance, staff encountered numerous defects which could affect embankment stability (see Figures 1-3). These conditions were observed throughout both the West Bank and the North Bank. These defects included docks, wall systems, house foundations and adjacent structures, embedded utilities, and subsidence areas. Indications of additional defects include structural misalignments, several drainage sumps, and wet areas within the entire 4.1 mile reach of the embankment. However, exterior observations of the 370 homes were limited since complete structural and geotechnical analysis could not be effected during the District's reconnaissance and evaluations of the Buckeye Lake Dam.

The observed defects and related potential failure modes are shown in Table 3. It should be noted that the embankment overtopping failure mode would include subsequent embankment downcutting and breaching. Internal erosion failure modes encompass a variety of interrelated erosion mechanisms and subsequent breach. These include but are not limited to backward erosion piping, concentrated leak erosion, and contact erosion.

Table 3: Buckeye Lake Embankment Defects Observed During 2014 USACE Site Recoinnaissance with Related Potential Failure Modes

Embankment Defects Observed	Related Potential Failure Modes		
	Embankment overtopping	Internal erosion	Slope failure
Variability in embankment crest elevations	X		
Shoreline erosion, tree root decay, excavations, and random backfilling evidenced by embankment crest depressions and voids	X	X	
Tree root penetrations		X	
Damaged or deteriorated masonry, sheet pile, and block wall related defects and misalignments	X	X	X
Embankment voids and settlement, which are indicated by patio and sidewalk displacement	X	X	
Utility penetrations of the embankment and sheet pile wall systems		X	
Privately owned structures, docks, boat houses, which would adversely affect wall and embankment and shorten pool related seepage pathways		X	X
Wet areas along the embankment, several of which were noted by ODNR to exist throughout the year, indicative of pool related seepage		X	X
Variability in residential basement sump pump operations, some of which may be unrelated to precipitation events, indicative pool related seepage		X	
Piezometer misalignments or blockages possibly indicative of embankment instability			X
Water quality parameters which may be indicative of pool related seepage conditions at a location within the embankment		X	
Recently observed unsupported open excavations within the embankment		X	X
Exposed residential basement wall defects within the embankment, indicative of failures and unsuccessful remedial reconstruction		X	X
Displaced residential foundation slabs and underlying voids		X	X
Soft saturated embankment soils		X	X
Lack of embankment erosion protection, as would be required in the event of high pools and overtopping	X		
Surficial erosion of embankment from stormwater runoff			X
Displacement and erosion of embankment material through joints at Sellers Point spillway abutments		X	

Figure 1. Typical Embankment Distress Observations 1) Differential settlement of structure built into crest/embankment longitudinal cracking 2) Failing masonry unit wall supporting landside embankment materials 3) Unsupported excavation into downstream face of embankment which could cause weakening of embankment soils and embankment failure 4) Several rows of masonry unit walls were noted in old house foundations likely indicating seepage related displacement

Figure 2. Typical Distress Observations 1) One of many depressions behind masonry wall 2) Tree with root system spanning the entire embankment crest 3) Numerous cracks within base of, and pipe/utility penetrations through, masonry wall observed during winter pool drawdown 4) Dock structures cantilevering from the dam put stress on the sheetpiling for which it was not designed

Figure 3. Other Wall and Seepage Observations 1) Displaced portion of masonry wall 2) Numerous rust holes observed in sheetpiling 3) Several depressions possibly due to boils, together with very shallow ground water conditions, were observed 4) Location of persistent seepage near Black Diamond Point

Evidence of ODNR maintenance activities included random fill placement at numerous embankment subsidence locations. Steady flows were observed within the adjacent sewer system. During reconnaissance, staff observations were limited by dense vegetation cover, landscaping and patios, docks and boat houses, and impounded lake water, all of which obscured the embankment and wall systems.

Water quality testing was performed for piezometers and adjacent lake waters within the embankment to determine upstream to downstream seepage continuity with the lake. At one piezometer, B-13A-2, water was measured to have comparable specific conductance, dissolved oxygen, pH, and temperature when referenced to lake water. These similarities in piezometer and lake water parameters may be indicative of a defect within the embankment foundation at this location. Piezometer B-13A-2 is located near Station 113+00 (referencing DLZ, 2003 stationing) on the downstream slope of the embankment, and the sensing zone is located in the dam foundation. Although this seepage relationship was established for only one piezometer, it is likely that, considering the limited number of piezometers along the 4.1 miles of embankment, other seepage locations exist.

During the reconnaissance the SFLR riparian clearing and channelization project was noted to have resulted in fluvial geomorphic impacts which will require additional excavation of depositional features and bank stabilization. These requirements could be included in a revised operation and maintenance manual to better assure necessary long-term bank full channel conveyance.

4 Existing Embankment Conditions with Respect to Established Dam Safety Guidance and Engineering Best Practices

As referenced, Ohio designated Buckeye Lake as a State Park in 1949. The District has determined, using applicable engineering standards of practice, that the Buckeye Lake Dam embankment does not meet dam safety standards. Furthermore, it is the District's opinion that the likelihood of dam failure is high and poses significant risks to the public, based on prior near-failures and adverse conditions at and above normal pool, including but not limited to seepage, wall and dam misalignment, and requirements on several occasions for emergency response actions to prevent breaching. Potential dam failure modes include internal erosion of the embankment fill and foundation soils, instability of the embankment, and overtopping and erosion of the embankment.

The District concluded that the relic embankment, constructed as a canal system component in 1832, was completed with currently unacceptable foundation and fill placement practices, which did not include filters or positive cutoffs. Additionally, the land transfer of 1894, which included a portion of the embankment and adjacent lands, did not restrict the placement of structures within the dam. This transfer allowed for the construction of numerous residential and commercial structures, which are defects as defined by established dam safety standards. Concerns regarding these structures include excavation of embankment fill during construction, shortened seepage paths, and resulting higher global and exit gradients, concentrated leak erosion along embankment-wall foundation contacts and associated utility alignments, increased probability of an unfiltered seepage exit condition developing due to embankment material filter incompatibility with house foundation drains, and additional embankment instability resulting from house foundation and retaining wall defects.

The ODNR has designated Buckeye Lake Dam as a Class I high-hazard potential dam. A high-hazard potential dam classification signifies the adverse consequences to lives and property that would occur in the event of a catastrophic dam failure. Additionally, consequences of embankment failure and spillway releases would include economic damages and probable loss of life within adjacent and downstream areas. The District recommends that ODNR continue to reevaluate the consequences of embankment failures and South Fork Licking River flooding to better define present extents of inundation damages and loss of life. Selection of remediation alternatives should be based on the potential for proposed actions to reduce risk to a tolerable level. As previously mentioned, limited stability analyses have not adequately defined embankment defects and failure modes, which resulted in the apparent underestimation of internal erosion and overtopping failure risks. The District has determined that embankment breaching, downcutting, and lake discharge and resulting flooding would most probably occur without sufficient warning or evacuation time. Estimates for breach, non-breach, and incremental consequences of this unstable embankment have not been fully developed. However, numerous residences built within the downstream embankment slope and immediately downstream of the embankment and appurtenant structures would likely be adversely impacted in the event of a breach.

5 Risk Reduction

The US Army Corps of Engineers (USACE) risk assessment process is a systematic and evidence-based approach for quantifying and describing the nature, likelihood, and magnitude of risks associated with existing and future conditions without actions and the values of the risk reduction resulting from a changed condition due to some action. The risk management process involves determining problems and initiating actions to identify, evaluate, select, implement, monitor, and modify actions taken to alter levels of risk, as compared to taking no action. The purpose of risk management is to choose and implement technically sound integrated actions to reduce risks after consideration of the effectiveness and costs of each increment of risk reduction. Risk management for dams includes short-term Interim Risk Reduction Measures (IRRMs); improvements to monitoring and surveillance activities, emergency action planning, operations and maintenance, and staff training; and implementation of comprehensive risk reduction alternatives.

Additional information would be obtained by implementing the USACE risk assessment process for Buckeye Lake Dam; however, this process was not included in this scope of work. Presently ODNR uses an indexing approach for assessing risk and prioritization of its dams, including 56 Class I dams.

5.1 Interim Risk Reduction Measures (IRRMs)

These interim risk reduction measures would be implemented to reduce the probability and consequences of catastrophic failure, to the extent that is practicable, during the period that comprehensive risk reduction alternatives are selected and finalized. The District recommends implementation of the following IRRMs.

1) Draw down to winter or lower pool elevation to partially address existing critical embankment conditions until completion of selected comprehensive risk reduction alternative(s). This measure would increase storage capacity for storm event inflows and minimize the probability of reaching pool elevations where excess seepage is known to occur, thus reducing risk of internal erosion related failure. In addition, operating with a decreased volume of water stored in the lake will reduce the flooding impact in the event of a catastrophic dam failure.
2) Update the Emergency Action Plan and implement related training and exercises to improve emergency preparedness.
3) Educate the public about risks, and implement a system for the public to communicate or report potential adverse conditions to ODNR.
4) Stockpile sand and bags onsite for emergency responses.

5) Stockpile emergency filter aggregate and stone on site for emergency responses.
6) Re-establish and maintain emergency access to and along the dam crest to transport and allow placement of sand bags, aggregate, and stone at critical areas.
7) Complete embankment crest profile surveys to better determine locations of subsidence areas, and sandbag these areas to temporarily restore them to required elevations.
8) Continue site characterization to better locate and define defects. These efforts would facilitate planning for and implementation of additional emergency responses. These efforts may include the following:
   a) Conduct video inspections of sewers adjacent to the downstream toe of dam.
   b) Conduct geochemical characterization to better define lake water, embankment seepage, outslope area springs, and extents of comingling.
   c) Perform geophysical investigations and additional subsequent subsurface explorations together with sampling and laboratory testing to better define embankment fill characteristics and adjacent wall system voids and subsidence features. Geophysical investigations could include Multichannel Analysis of Surface Waves (MASW) and Electrical Resistivity Measurements.
   d) Using data obtained during subsurface investigations and high pool seepage observations, complete more comprehensive embankment characterization and stability and seepage analyses and modeling.
   e) Perform thermal sensing of the embankment, house foundations and walls, and adjacent areas to define voids and seepage conditions.
9) Reroute residence drainage and utility features away from the embankment crest and backfill excavations with compacted impervious materials to reduce risks associated with internal erosion failure mechanisms.
10) Consider clearing and grubbing of large trees located within the dam crest and adjacent to the wall systems. Root excavation areas would then be backfilled and compacted with suitable impervious material, These measures would reduce risks associated with internal erosion mechanisms.
11) To the extent allowable, prevent additional construction of residences and appurtenant structures (i.e. wall systems, patios, swimming pools, sidewalks, and utilities) within the embankment, which would otherwise constitute additional embankment defects.
12) Limit dock construction or reconstruction to require placement of floating or self-supported structures separate from the wall system and embankment, to prevent further damage to the embankment and wall system.
13) Continue to purchase properties, as they become available on the open market, to increase embankment access and stockpiling areas.
14) Modify existing gages or install new gages to measure and record inflow and outflow data to provide data for hydrologic and hydraulic analysis, to better establish operational schedules, and to provide for emergency responses.
15) Complete additional hydrologic and hydraulic analysis to better determine optimum discharge requirements and consequences, and revise lake spillways operations schedules accordingly.

5.2 Operation & Maintenance (O&M) Recommendations

1) Considering the size and high hazard potential classification of the dam, one or more full-time dam tenders should be employed.
2) Continue to work with the public and others to monitor and evaluate defects or other potentially problematic conditions along the embankment crest and outslope areas during both extended rainfall events and elevated lake pools. Conduct workshops and provide dam safety training to identify these conditions. Locations of concerns should be mapped, and annotated photographs should be retained by ODNR to reference site conditions.
3) Implement comprehensive site surveillance plans, including defined response requirements during elevated pools, to affect timely emergency actions.
4) Complete additional embankment crest profile surveys during 2015 and thereafter at yearly intervals.
5) Read piezometers and observation wells monthly when lake elevations are at or below El. 892.25 ft (Sellers Point Spillway crest). Since embankment seepage has been observed at elevations above 892.25 ft, the piezometers and observation wells should be read more frequently during lake impoundment above this pool in order to better correlate hydrostatic heads and phreatic surfaces within the embankment and foundation to lake pool levels.
6) Install additional piezometers, and obtain readings to better define hydrostatic head and related stability and seepage conditions within the embankment crest, slope, toe, and adjacent downstream areas.
7) Monitor embankment wall systems since many sections of sheet piling (1948, 1961 and 1962) were determined to be "essentially already at or beyond their allowable stress limit" (DLZ, 2003). These sections of sheet piling may have been subjected to additional corrosion related loss of steel, which would continue to affect the stability of the wall in the near future.
8) Monitor subsidence features and backfill with suitable impervious materials.
9) Document and characterize maintenance dredging and survey sediment depositional areas adjacent to the embankment.
10) Inspect, monitor, and maintain spillway discharge stilling features, downstream channel slope protection, and effect vegetation controls to ensure required conveyance. The established operations plans could be modified to provide for additional releases from the Sellers Point Spillway conduits to improve downstream environmental quality.
11) Maintain dense grass cover within embankment and downslope areas.
12) Dredge and maintain SFLR conveyance to reduce out of bank flooding conditions.
13) Measure and record inflow, outflow, and pool elevation daily.

5.3 Comprehensive Risk Reduction Alternatives

This abreviated assessment has resulted in the recommendation that comprehensive risk reduction actions should be considered for Buckeye Lake Dam. The District suggests several alternatives that may better assure public safety. If no action is taken to make significant structural improvements, then the existing defects would become more severe, resulting in increased public risk due to embankment failure and subsequent flooding. The risks identified during normal pool loading are most probably high. The District also acknowledges that this project is not a flood risk management structure and is intended for recreational purposes only. The following risk reduction alternatives are based on reviews of consultant reports together with site reconnaissance and public input.

- Breach of the embankment, dewatering the lake, and re-routing drainage from the lake area
- Relocation of downstream at-risk population
- Repair or replacement of the dam
- Partial rerouting of inflows to and outflows from the lake without changes to the dam
- Modification or addition of outlet structures
- Installation of toe drains, relief wells and stability berms at locations along existing dam

5.3.1 *Breach of the Embankment and Rerouting Drainage from the Lake Area*

Breaching the embankment, dewatering the lake, and rerouting drainage from the lake area could mitigate the consequences of dam failure. Although Buckeye Lake was not designed as a flood risk reduction project, rerouting drainage could result in additional localized flooding and downstream channel erosion. Additional adverse impacts would include degradation within adjacent channels, elimination of recreational benefits, and significant economic impacts. Furthermore, inadvertent impoundment of localized storm event runoff may occur. Significant adverse local economic, cultural, and social impacts would occur.

5.3.2 *Relocation of Downstream At-Risk Population*

Relocating the downstream at risk population, including those residing on the dam, would reduce the potential for loss of life and economic consequences from flooding. Relocating this population would be disruptive, costly, and most probably not allowable under existing ownership rights. Significant adverse local economic, cultural, and social impacts would occur.

5.3.3 *Repair or Replacement of the Existing Dam*

Repair or replacement of the existing dam would require resolution of complex ownership issues. Either of these alternatives would substantially address embankment deficiencies and better assure safe operation of the dam or replacement structure. These actions would reduce the risk of dam breach related downstream flooding. Additionally, privately owned structures within and on the existing dam embankment would be less susceptible to seepage and internal erosion related conditions. Significant impacts to the lakeside property owners would occur during and after construction. Additional real estate interests would be required, and existing private property ownership rights would require subordination to better assure the continued safe operation and maintenance of the dam and adjacent structures.

5.3.3.1 *Limited Repair of the dam*

This repair of the embankment could include placement of sheet pile or slurry walls within the dam. These structures would strengthen the embankment and partially reduce seepage and related internal erosion. However, the functional integrity of these structures would be significantly affected by the indeterminant problematic characteristics of the embankment and foundation and artesian groundwater flows. Distress currently evidenced in and adjacent to the embedded houses could become more severe as a consequence of these construction activities.

5.3.3.2 *Replacement of the existing dam*

ODNR has previously evaluated independent lakeside structure alternatives. Of the alternatives evaluated, the consultant (DLZ, 2003) proposed double row sheet pile, I-wall, inverted T-wall, or U-frame precast concrete box structures for consideration. Selection of a replacement alternative would require additional studies, including explorations, evaluations, and analysis, as referenced in this report. Additionally, private development, including incidental structural or surficial features, should not be attached to or permitted within or adjacent to the new structure.

5.3.4 Partial rerouting of inflows and outflows from the lake without changes to the dam

Rerouting of inflows to and outflows from the lake could somewhat mitigate the risk of dam failure by reducing the probability of elevated pool related breaching. Partial diversions of inflows and outflows from the lake to adjacent drainage features could result in increased localized flooding. Lake water quality would be degraded by this proposed action and recreational uses diminished within the area. Adverse economic impacts would be similar to those as previously described for alternative 5.1.2.

5.3.5 Modification or addition of outlet structures

Modifications to the existing Amil gate or Sellers Point spillways together with additional outlet structures would regulate discharges to adjacent drainage features. Controlled diversion of outflows from the lake would somewhat mitigate the risk of dam failure by reducing the probability of elevated pool related breaching. However, these modifications would not signicantly reduce risks associated with previously referenced geotechnical embankment failure modes. Additionally, diverting outflows to adjacent drainage could result in increased localized flooding.

5.3.6 Installation of toe drains, relief wells, or stability berms along existing dam

Installation of toe drains and relief wells along the toe of the embankment would reduce gradients within the foundation; however, these features would not address embankment through-seepage conditions. While installation of stability berms would reduce the potential for initiation of some internal erosion mechanisms, berm construction would require access through adjacent lands and removal of private structures along the toe of the dam.

5.4 Additional Considerations

The District has made observations and formed recommendations that are related to, but are outside the scope of, this report. However, ODNR may wish to consider these points in its decision making process, so they have been briefly described below.

- Spillway adequacy and SFLR conveyance should be re-evaluated during the continuing design phases to further determine required discharge conditions and to establish the basis for additional modifications.

- Extents and long-term functionality of the SFLR channel improvements project, together with down channel conditions, should be reviewed. This review should include FEMA delineations of potentially impacted floodplains and floodways within areas downstream of the SFLR channel improvements.

- The lake and adjacent discharge channels, together with tributary and SFLR aquatic and riparian habitat areas, are severely impacted by baseline environmental conditions. These impacts include intermittent stranding of fish, lack of vegetation related shading and habitat, high seasonal water temperatures, and reduced dissolved oxygen. Proposed actions could include modification of spillway operations to maintain low flow conditions which would result in improved aquatic and riparian habitats.

- During site reconnaissance and public meetings, several property owners discussed individual and collective interests in continuing to review project proposals and alternatives which would better assure long term operational requirements for Buckeye Lake. Therefore, the District recommends that ODNR continue to schedule public meetings with these property owners and others during the selection process. ODNR would review this input to better assure participation of interested parties. A summary of findings from these coordination meetings would become a part of the decision making process.

6 CONCLUSIONS

The District has completed assessments which included a review of project history (including past failures), technical publications, site reconnaissance, public coordination, and identification of defects. Upon completion of these tasks, the District recommends that immediate non-structural risk reduction measures should be implemented, and comprehensive risk reduction alternatives should be further analyzed, selected, and effected by ODNR.

The District acknowledges data limitations, as did the previously retained consultants, Ohio Department of Natural Resources, and the public. These limitations included geotechnical, hydrologic, and hydraulic information required for more comprehensive analysis and risk assessments of Buckeye Lake dam. Specifically, there is limited data regarding embankment foundation conditions, fill characteristics, seepage pathways and gradients, prior reconstruction efforts, and detrimental modifications to the dam resulting from the construction of numerous homes and related components. Nevertheless, the available data are sufficient to support the District's opinion that the likelihood of embankment failure is high based on adverse conditions existing and occuring frequently at and above normal pool, posing significant risks to the public.

Prior experience, together with consultant reports and evaluations, input from ODNR including the determination of the project as a Class I high hazard potential dam, project performance history, and site reconnaissance resulted in the District's conclusion that the Buckeye Lake Dam embankment has extensive defects requiring comprehensive risk reduction actions. ODNR should consider comprehensive risk reduction alternatives based on the outcome of site geotechnical and hydraulic characterization and further evaluations of project risk. ODNR should consider the implementation of the preferred alternatives. Concurrently with evaluation, selection, and implementation of comprehensive risk reduction actions, ODNR should consider the immediate implementation of IRRM and O&M recommendations. It should be emphasized that IRRMs, by definition, are interim measures designed to immediately reduce risk as much as practicable until comprehensive risk reduction measures are completed.

APPENDIX A
Geology and History of Buckeye Lake

Regional Geology

Buckeye Lake Dam is in Fairfield, Licking, and Perry counties of Ohio, approximately 23 miles east of downtown Columbus, 9 miles south of Newark, and 22 miles west of Zanesville. It lies in the Till Plains section of the Central Lowlands of the Appalachian Plateau. The lake lies near the far eastern boundary of the edge of the low Plateau as shown in Figure A.1. The Till Plain is virtually featureless except for low broad successions of end-moraines and a few large stream valleys that cut up to 50 feet below surface. The western and northern parts of the Appalachian Plateau were glaciated during the Pleistocene Ice Ages, which resulted in the hills being of lower relief and the valleys more broad. Buckeye Lake is located just west of this boundary.

In the Pleistocene, there were four major glacial advances and retreats recognized in North America; the Nebraskan, Kansan, Illinoian, and Wisconsin. The last two glacial episodes, the Illinoian and Wisconsin covered the area of Buckeye Lake and had the greatest impact. The Illinoian Glacial Stage (~300,000 to 130,000 years ago), and Wisconsin Glacial Stage (~24,000 to 14,000 years ago in Ohio) are major divisions of geologic time and resulted in the deposition of extensive glacial deposits in North America during the late Pleistocene. Pre-existing valleys were blocked with glacial outwash, streams were diverted, and modified drainage patterns were formed in areas untouched by glacial ice. The landforms, which are characteristic of those formed by a dynamic river system, resulted during long periods of time in regions of moderate elevation underlain by thin and gently dipping sedimentary beds with varying resistance to erosion. Many of the areas that remained prominent were sandstone ridges that were more resistant to erosion. After the Illinoian glaciation, the Sangamonian interglacial period lasted approximately 100,000 years, before the subsequent Wisconsin Glacial episode commenced, during which, streams eroded much of the glacial outwash deposited during the Illinoian episode.

The Wisconsin ice eroded and transported additional entrained rock debris. Glacial till was deposited directly by the glacier and is derived from subglacial erosion and entrainment from movement of the ice over unconsolidated sediments. The content of till can vary from clays to mixtures of clay, sand, gravel and boulders.

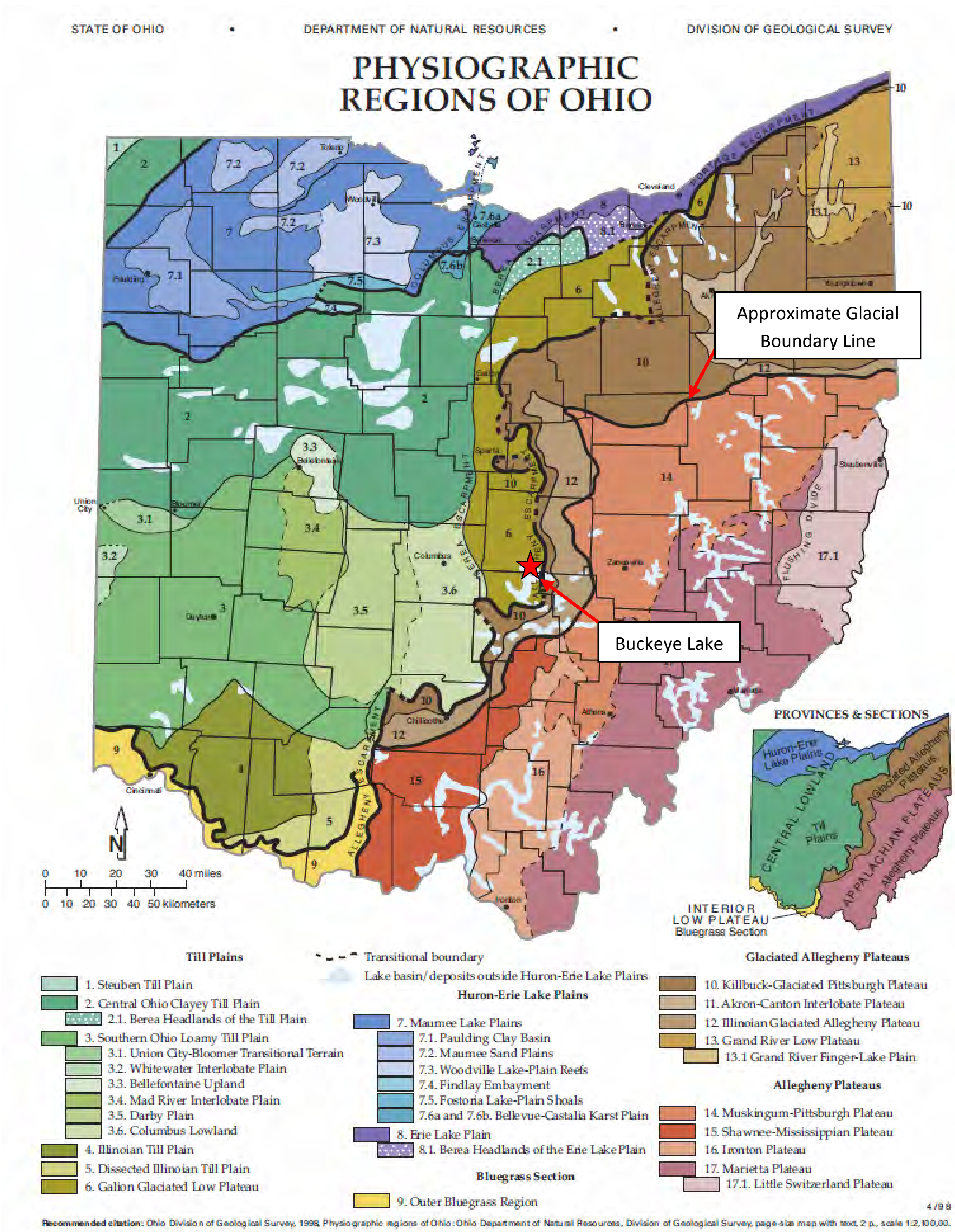

Figure A.1 Allegheny Plateau extending from Southwestern New York to Northeastern Kentucky (Musser, 2007).

Drainage History

One of the biggest changes as a result of the glaciations during the Pleistocene were changes in drainage patterns of major streams and rivers. During pre-glacial times, the area was drained by the Teays River system which flowed in south and west directions from the higher ground of the Allegheny Plateau to the northeast to the Low Plateau and created a drainage divide across Ohio, Figure A.2.

Figure A.2 Pre-Kansan Teays Stage Drainage Divide (Stout et. al., 1943)

The Kansan ice sheet brought the first change to the natural drainage system, filling pre-existing valleys with glacial drift. The damming of the Teays River and several of its tributaries caused them to divert and new streams to form. The Newark River, originating at the southern border of the ice sheet (Figure A.3), extended in a southwest direction from Carroll County to Circleville which now drains the area previously drained by the Groveport tributary of the Teays River. The Newark River passed through Licking County along the Cambridge River Valley.

Figure A.3 Post-Kansan Deep Stage Drainage (Stout et. al. 1943)

The recession of the Kansan ice sheet caused regional uplift to take place and the rivers began a new cycle of down-cutting. Uplift ended during the Illinoian glaciations and thus ended the accelerated erosion. The extent of the Illinoian ice sheet was blocked by a sandstone escarpment east of Newark which contained the eastern flow of the ice sheet (Franklin, 1961). The Newark River became dammed by the Illinoian ice sheet when it reached this sandstone ridge. The Newark River valley was filled with glacial outwash and lacustrine deposits. As the ice sheet receded, a series of terminal moraines were formed at different stages of recession. The moraines formed natural dams which obstructed drainage of rivers and ice melt water. A large terminal moraine mapped just north of Hanover, created a natural dam that blocked flow of the natural preglacial drainage. This blockage created glacial Lake Licking in the area of Marne, approximately 14 miles northeast of Buckeye Lake (Frolking and Pachell, 2006). The waters of Lake Licking rose until they overtopped and eroded sandstone ridges south of Hanover (Tight, 1897). The waters of the Newark River and those of Lake Licking were shifted to the Licking River. The water flowed south and eroded the present Licking River valley to Zanesville where it joins the Muskingum River.

The Wisconsin glaciation did not alter the drainage pattern in the area; however, the new drainage system carried sand and gravel outwash and deposited throughout the valleys of the Licking River. The present drainage system is shown in Figure A.4.

Figure A.4 Present drainage system (Kmusser, 2007).

Site Geology

The Wisconsin and Illinoian extents lie just east of Buckeye Lake as shown in Figure A.5. Wisconsin terminal moraines are mapped northeast, east, and southeast of the lake. The topography of the region flattens out southwest of Newark to form the till plain in this area.

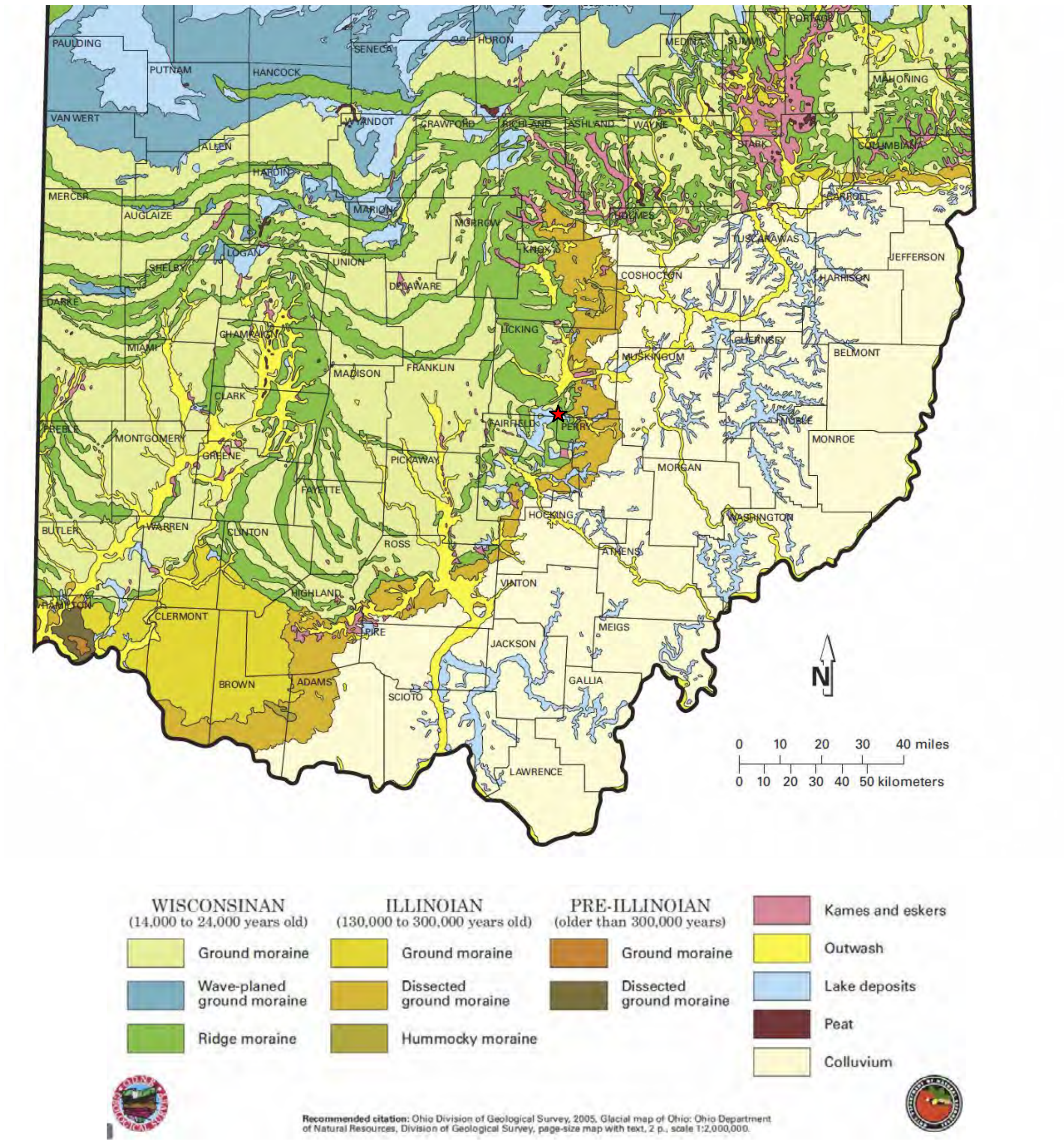

Figure A.5 Glacial Geology of Ohio, location of Buckeye Lake at red star (ODNR, 2005)

In the Geology of Licking County report, Read (1878) interprets a postglacial lake of considerable size covered the area south and southwest of Newark, including Buckeye Lake area, during the late Pleistocene. The limited data at the site and mapping of the region in 2005, Figure A.6, suggests that the lacustrine deposits do not cover the entire till plains area but surround several existing or historic lakes, swamps, and bogs. It is suggested that many kettle lakes formed in these low lying areas as a result of ice calving off as the Wisconsin glacier receded and melted. The ice was partially buried and filled in by glacial outwash transported by melt waters from the receding glacier. When the ice blocks melted they left behind depressions called kettles which filled with water and debris. Kettle lakes formed within the ground moraine region behind the terminal moraines to the east.

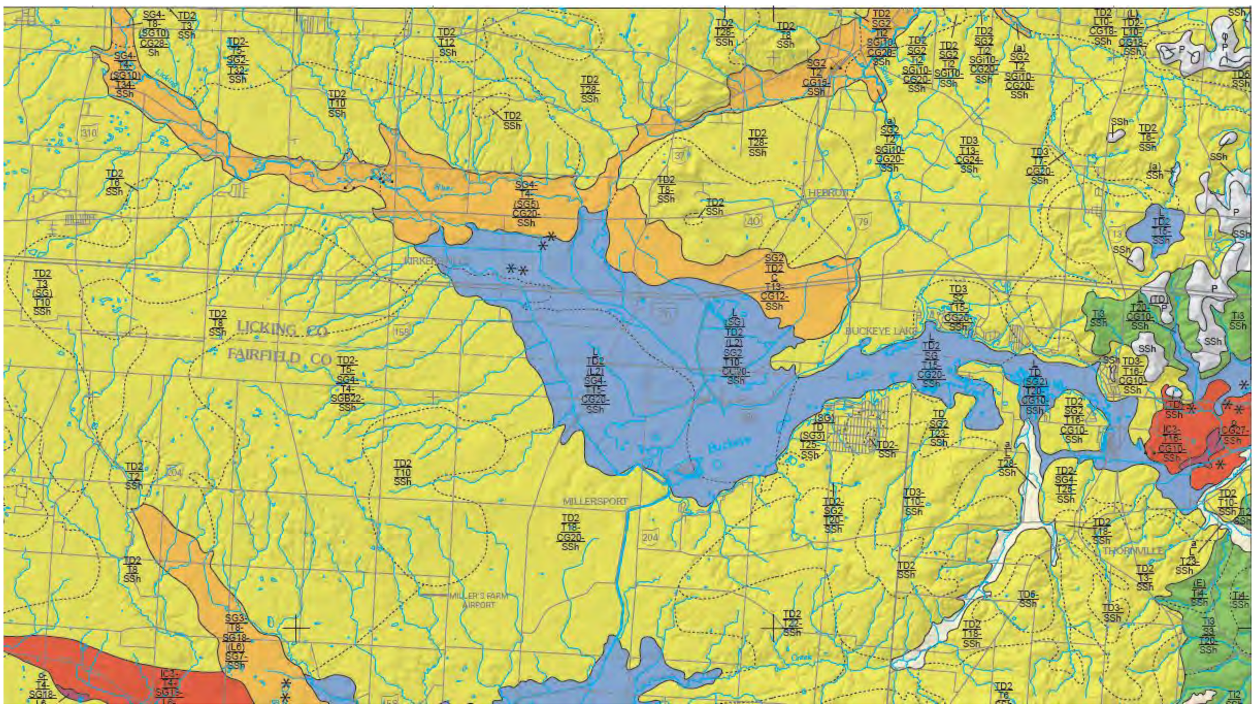

Figure A.6 Surficial Geology Map (ODNR, 2005)

Present swamps and bogs are remnants of the postglacial kettle lakes. Water in kettles can become acidic due to decomposing organic matter and become a kettle bog. Theses bogs and swamps often dry up with time but those such as the Cranberry Marsh at Buckeye Lake still exist in low lying areas due to a perched water table created by the low permeability lakebed sediments and underlying silty clay till.

Along the northern rim of Buckeye Lake and in the drainage valley of the South Fork Licking River, valleys are filled with 20 to 40 feet of Wisconsin outwash (orange in Figure A.6), composed of sands and gravels interbedded with discontinuous layers of silt, clay, and till. Approximately 100 feet of Wisconsin till underlies the outwash deposits. The till is composed of soft to hard silty clay with trace fine sand and rock fragments. North of the outwash deposits and south of Buckeye Lake, Wisconsin till (yellow in Figure A.6) is mapped at the surface with varying depths but a maximum of 300 feet. In both areas, the till is underlain by interbedded shales, siltstones, and sandstones of the Mississippian age Logan and Cuyahoga Formations.

Borings through the embankment and into the foundation were performed by DLA in 1987 and Paul C.Rizzo Associates, Inc. (Rizzo) in 1997. Both exploration programs were limited in extent and cover a small portion of the site, DLA borings extend a maximum of 20 feet into the foundation and Rizzo borings extend 10 feet. DLA (1987) borings indicate that the soils underlying the embankment consist of lacustrine deposits with silts and clays commonly laminated and interbedded together with sand and gravel layers, containing organic matter. These deposits overlie glacial till. Rizzo (1997) reclassified the lacustrine deposits previously mapped by DLA to be either embankment fill material or till, composed of silty clay with trace fine sand and rock fragments. However, the lacustrine materials and till have similar classifications, both being a silty clay or clayey silt (CL to ML), and Rizzo notes zones beneath the embankment fill which contained organic materials and laminations that could be attributed to the lacustrine kettle lake soils. Rizzo also mapped lenses of loose sand and gravel with trace amounts of silt and clay within embankment and the foundation till at varying depths. Although these deposits have not been fully mapped or characterized by these limited explorations to date, Wisconsin outwash is expected beneath the embankment and the lake. During the formation of the kettle lake, some of the outwash would have collapsed into the depression, although there may have been some reworking of the outwash and underlying till materials. The lacustrine sediments and till are generally soft to medium stiff in the upper 5 to 10 feet of the foundation, with increasing stiffness at depth. At a depth of approximately 100 feet, Mississippian age interbedded shales, siltstones, and sandstones underlie the Wisconsin till.

Canal and Dam History

A canal system for the transportation of goods in Ohio was proposed in the early 1800s. In 1822, the state legislature commissioned a canal feasibility survey. In 1825, work began on the Erie Canal starting at Licking Summit. A dike was constructed around the "Big Swamp" at Licking Summit to contain and raise the water level. The "Big Swamp", termed by Native Americans, was renamed "Licking Summit Reservoir" in 1830 when the reservoir was filled with water.

After completion of the canal, a large addition to the reservoir on the west end was constructed to increase the storage capacity of the canal system. An earthen embankment was constructed using random and uncompacted earth fill without filters, cutoffs, or foundation treatment. "Additional embankment materials were provided in 1832 after failure of the dam on initial filling. These materials consisted of "coarse stone" and were used to help repair the breach" (GAI, 1995). Limited borings were performed by DLA (1987) and Rizzo (1997) through the embankment at various cross sections. The embankment materials were classified as clayey silts with various amounts of sand, gravel, and organics. Sand and silt seams were also encountered within the embankment.

The canal and towpath extended from Seller's Point to Millersport. Figure A.7 shows the system at its peak of usage with almost 1,000 miles of canals. From 1855 to 1861, the arrival of railroads ended the use of the canals for freight. The canals served as a water source for industries and towns until 1913 when the system came to an end. Winter that had record amounts of snow and rainfall which caused severe flooding, washed out banks, and destroyed parts of the canal. Adjacent lands were sold to private individuals or transferred to other public agencies. In 1894, the Ohio General Assembly passed an act dedicating the Licking Summit Reservoir as a public park to be known as "Buckeye Lake."

Figure A.7 Ohio Canal System 1825-1913, location of Buckeye Lake at red star (The Ohio Historical Society, 1971).

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APPENDIX B
Piezometer Data from Site Reconnaissance

Piezometer Readings

Eighteen piezometers and nine monitoring wells were read during this assessment. Most of the piezometers were installed during the Paul C. Rizzo Associates, Inc. (Rizzo) study. Boring logs and piezometer installation logs from the Rizzo report indicate that most of the sensing zones are along the base of the embankment or within the foundation. No logs or installations reports were available for the monitoring wells at Mud Island or the piezometers at Station 113+35. Two sets of readings were obtained when USACE staff were on site. Piezometer and monitoring well readings were taken 26-27 August 2014 during the site reconnaissance at pools of El. 891.8 feet and 19 November 2014 at an El. 891.7 feet pool. Readings taken at the piezometers correlate very closely with those taken during the Rizzo study while under normal pool conditions. Without readings taken during elevated pools, it is not possible to project piezometer readings which may occur during higher pools up to the embankment crest elevation.

Hydrolab Readings

When piezometers were read on 19 November 2014, water samples were collected using a bailer. A hydrolab was used to compare specific conductance, dissolved oxygen, pH, and temperature with pool parameters. A correlation between piezometer and pool parameters could be indicative of a seepage path connection to the pool. Of all the piezometers installed in the 4.1-mile reach of embankment, readings at piezometer B13A-2 indicated water quality conditions similar to pool. B13A-2 is a downstream slope piezometer at Station 113+35, and based on a measured depth, it is probable that the sensing zone is within the embankment foundation.

Possible evidence of embankment movement

While making readings in the piezometers, total depth soundings were obtained. Most of the piezometer soundings indicated relative depths within 1 foot of the original installation. Piezometer soundings may vary as a result of accumulations of iron precipitants from bio-fouling, sediment introduced at open pipe joints, or sensing zone filter incompatibility. Piezometer B1A-1B at Station 50+80 was originally installed to a depth of 17.5 feet; however, it was only possible to insert the water level indicator to a depth of 4.78 feet. Based on embankment sections as presented in the Rizzo report, this depth of 4.78 feet corresponds to the base of the embankment. It is possible that this piezometer has been sheared at the embankment-foundation contact. Also, while collecting water samples, the bailer insertion required force at piezometer B2-A3 near Station 65+00 because this riser pipe was bent within the top two feet. This displacement could also be a result of embankment movement.

APPENDIX C
Site Reconnaissance Photos

BUCKEYE LAKE 25 AUGUST 2014
Photo 001 – Beginning of west embankment masonry wall as seen from the west abutment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 002 – Masonry wall alignment as seen from west abutment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 003 – Some voids in the masonry wall allow a tile probe to penetrate through the wall and contact the embankment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 004 – One of many depressions observed behind the masonry wall along the west embankment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 005 – Typical settlement feature observed behind the masonry wall along the west embankment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 006 – Drainage pipes penetrate through the masonry wall along the west embankment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 007 – Settlement induced cracking observed in numerous structures along the west embankment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 008 – One of many large trees rooted along the west embankment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 007 – Structural distress in relatively new house resulting from embankment displacement along the west embankment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 008 – Structure exhibiting distress resulting from embankment differential settlement and movement. Although not evident in this photo, the lakeside of house was several inches out of alignment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 009 – A concrete block wall from an old structure is leaning 3-4 inches from vertical and concaved in alignment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 010 – Lagoon behind western embankment intercepts flow from reservoir through a steel pipe with no flap gate.

BUCKEYE LAKE 25 AUGUST 2014
Photo 011 – Flap gate on a drainpipe connecting the pool to a downstream lagoon is missing.

BUCKEYE LAKE 25 AUGUST 2014
Photo 012 – Wood decks and patio structures inhibit monitoring the crest of the dam for signs of distress. Additionally they preclude grass growth which provides erosion protection of this earthen dam.

BUCKEYE LAKE 25 AUGUST 2014
Photo 013 – One of many misaligned sections in the masonry wall.

BUCKEYE LAKE 25 AUGUST 2014
Photo 014 – Hole in base of misaligned segment of masonry wall.

BUCKEYE LAKE 25 AUGUST 2014
Photo 015 – Displaced masonry wall in western embankment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 016 – Boathouse structure excavated halfway through the lakeside of the embankment by Mud Island.

BUCKEYE LAKE 25 AUGUST 2014
Photo 017 – Failing concrete block wall from an old structure built into the embankment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 018 – Excavation into downstream face of embankment to construct new house. Note that no bracing is in use. This is very risky construction practice with regard to dam safety.

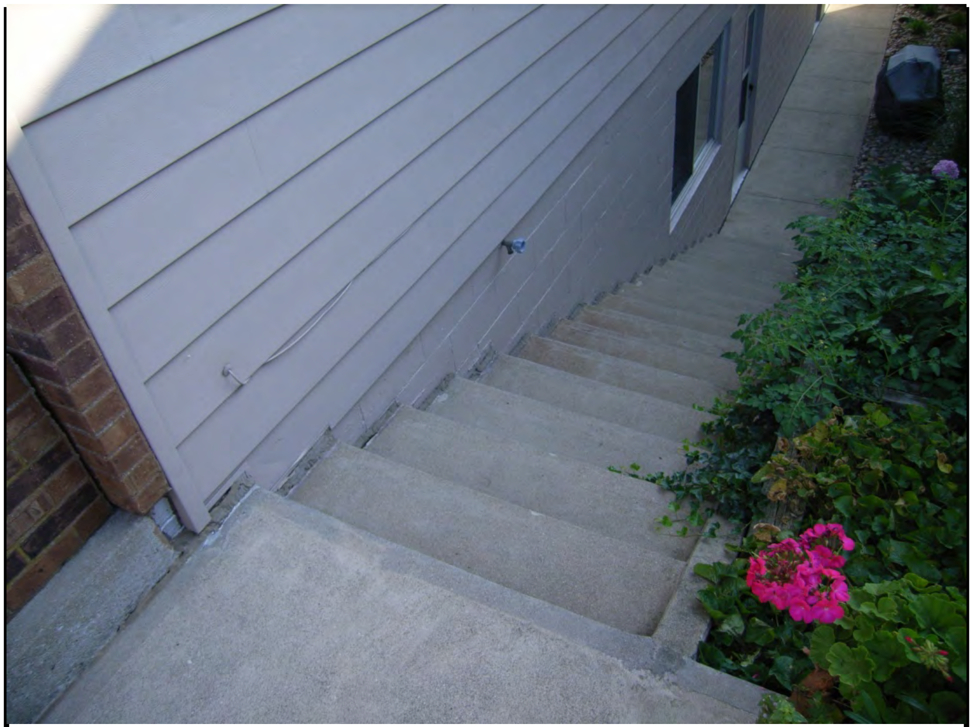
BUCKEYE LAKE 25 AUGUST 2014
Photo 019 – Sinkholes along masonry wall and several trees growing through the wall.

BUCKEYE LAKE 25 AUGUST 2014
Photo 020 – Current flow from Amil Gate Spillway should be evaluated. Fish were observed to be trapped and dead in the rocks downstream.

BUCKEYE LAKE 25 AUGUST 2014
Photo 021 – View from west side of Sellers Point spillway. Note the large amount of eroded material deposited along the base of east training wall.

BUCKEYE LAKE 25 AUGUST 2014
Photo 022 – Settlement along sidewalk behind eastern training wall at Sellers Point spillway.

BUCKEYE LAKE 25 AUGUST 2014
Photo 023 – Cracks in sidewalks and porches along the crest of the dam and adjacent to houses which formed as a result of embankment displacement along northern dam reach.



BUCKEYE LAKE 25 AUGUST 2014
Photo 024 – Another photograph of same structure in Photo 023. Note that the sidewalk is misaligned with structure indicating embankment displacement.

BUCKEYE LAKE 25 AUGUST 2014

Photo 025 – Drain pipe penetrations through the sheetpile wall along north reach of the embankment.

BUCKEYE LAKE 25 AUGUST 2014

Photo 026 – Concrete masonry unit wall left from after a house was removed. Note redundant concrete walls most probably due to seepage related displacement and distress along upstream wall.

BUCKEYE LAKE 25 AUGUST 2014
Photo 027 – Although small vegetation is not harmful to the dam, it hinders monitoring capability for depressions and cracking.

BUCKEYE LAKE 25 AUGUST 2014
Photo 028 – Sheetpiling was bowed out and embankment fill material was settling behind Smitty's Tavern.

BUCKEYE LAKE 25 AUGUST 2014

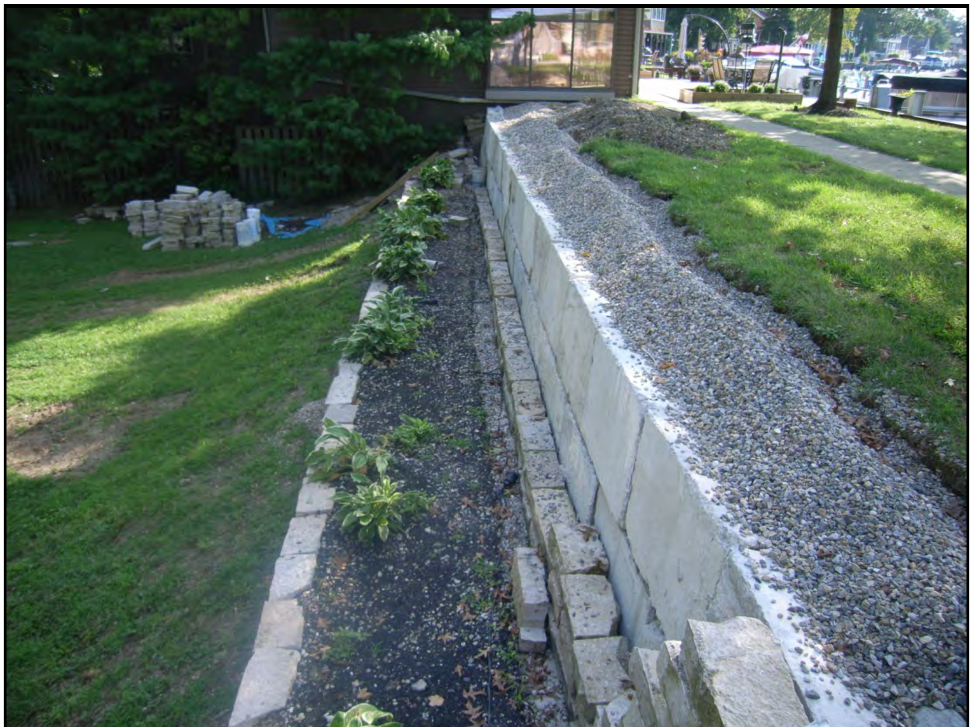
Photo 029 – Dock structures cantilevered off of the dam put stress on the sheetpiling that it was not designed for and have caused the wall to bow out.

BUCKEYE LAKE 25 AUGUST 2014

Photo 030 – House at Station 107+50 exhibiting significant differential settlement along embankment. Note settlement in crest between sidewalk and front of house.

BUCKEYE LAKE 25 AUGUST 2014
Photo 031 – Damaged waler on top of the sheetpiling.

BUCKEYE LAKE 25 AUGUST 2014
Photo 032 – Several depressions were observed in the crest between Stations 107+00 and 107+50.



BUCKEYE LAKE 25 AUGUST 2014
Photo 033 – Large segmental block wall constructed as a retaining wall. Note that the #57 stone used as drainage material is not filter compatible with embankment materials.

BUCKEYE LAKE 25 AUGUST 2014
Photo 034 – Numerous rust holes were observed in the waler along the 1948 sheet piling. Also, several pipe penetrations were observed.

BUCKEYE LAKE 25 AUGUST 2014
Photo 035 – Dock structures cantilevering off of the dam put stress on the sheet piling that it was not designed for.

BUCKEYE LAKE 25 AUGUST 2014
Photo 036 – Concrete masonry unit wall with numerous cracks.

BUCKEYE LAKE 25 AUGUST 2014
Photo 037 – Several depressions approximately 3.6 feet deep were noted near the center of the embankment crest between Stations 129+16 to 139+70.

BUCKEYE LAKE 25 AUGUST 2014
Photo 038 – Failing shallow retaining wall.

BUCKEYE LAKE 25 AUGUST 2014
Photo 039 – Area of nearly year round seepage pointed out by resident. Station 152+50 along Black Diamond Bend. Note seepage was not occurring during the day of inspection.

BUCKEYE LAKE 25 AUGUST 2014
Photo 040 – Failing concrete wall built into the downstream embankment slope along the north reach.

BUCKEYE LAKE 25 AUGUST 2014
Photo 041 – Construction of new residential structure at the toe of the landward side of the embankment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 042 – Several depressions approximately 3.5' deep near centerline of crest between Stations 171+50 and 176+49.

BUCKEYE LAKE 25 AUGUST 2014

Photo 043 – South Fork Licking River channel (facing upstream) after ODNR widening project. Note the recent deposition. A maintenance program will be essential to maintain conveyance capacity.

BUCKEYE LAKE 25 AUGUST 2014

Photo 044 – Unsupported excavation into embankment.

BUCKEYE LAKE 25 AUGUST 2014
Photo 045 – Residence at Station 112+25 with several depressions at the ground surface possibly from boils. Soil was very soft and groundwater was very shallow at this location.

BUCKEYE LAKE 25 AUGUST 2014
Photo 046 – Thinning and loss of sheetpile wall. Holes were observed through the wall. The wall beneath the water surface was not observed during the August inspection.

BUCKEYE LAKE 15 DECEMBER 2014
Photo 047 – Segment of masonry wall with attempted repair as observed at winter pool. Note the voids and cracks beneath the upper section of wall and the pipe penetration.

BUCKEYE LAKE 25 AUGUST 2014
Photo 011 – Flap gate on a drainpipe connecting the pool to a downstream lagoon is missing.

BUCKEYE LAKE 25 AUGUST 2014
Photo 012 – Wood decks and patio structures inhibit monitoring the crest of the dam for signs of distress. Additionally they preclude grass growth which provides erosion protection of this earthen dam.

APPENDIX D
Dam Safety Guidance

The dam safety guidance referenced within this appendix is not intended to be all encompassing. These and other local, state, and federal documents are available and can be accessed by the public and others.

Buckeye Lake features that do not meet current dam safety guidelines	USACE and Other Guidance
Encroachments through embankment and open excavations into the downstream slope of the embankment	CFR-2011-33-3-208.10.5: No improvement shall be passed over, under, or through the walls, levees, improved channels or floodways, nor shall any excavation or construction be permitted within the limits of the project right-of-way, nor shall any change be made in any feature of the works without prior determination by the District Engineer or the Department of the Army or his authorized representative that such improvement, excavation, construction, or alteration will not adversely affect the functioning of the protective facilities. Such improvements or alterations as may be found to be desirable and permissible under the above determination shall be constructed in accordance with standard engineering practice. ODNR, Ohio Dam Safety Laws, Section 1521.06.5: The repair, maintenance, improvement, alteration, or removal of a dam or levee that is subject to section 1521.062 of the Revised Code, unless the construction constitutes and enlargement or reconstruction of the structure as determined by the chief USACE, (2006), "Levee Owner's Manual for Non-Federal Flood Control Works". (reference 2.3) Numerous examples of unacceptable encroachments within earthen embankments are given within Section 2.3 of the Levee's Owner's Manual document.
Unknown foundation treatment during construction, with problematic soils known to exist	Federal Emergency Management Agency, (2004), "Federal Guidelines for Dam Safety" (reference B.3.d): Foundations subject to differential settlement or foundations having highly compressible anomalies can cause stress concentrations or cracking in dams. The foundation excavation should be shaped to remove abrupt changes in elevations to preclude excessive differential settlement or stress concentrations. Low shear strength material in a foundation can cause shear failure. Excavation and replacement of low strength material is a positive method for treating a foundation that has either or both of these unfavorable conditions.
Unknown compaction during construction	EM 1110-2-1913. Design and Construction of Levees. Table 7-2: Inadequate compaction of embankment (lifts too thick, haphazard coverage by compacting equipment, etc.) can result in excessive settlement, inadequate strength, and through seepage.
Adequate grass cover	ER 1110-2-1156 AC.3.1: Beneficial Vegetation. Beneficial vegetation, such as grass cover, can assist in preventing erosion, controlling dust,

	defining zones of use, and creating a pleasant environment. Uniform grass cover enhances visual inspection, allowing the detection of seeps, settlement, displacements, and other evidence of distress. Robust grass coverage along embankments and discharge channels can help deter the natural establishment of trees and other deep rooted species.
Trees and woody vegetation in the dam, dam toe area,	ER 1110-2-1156 AC.4.1 – AC.4.1.5: The following areas must remain free of trees and other woody vegetation such as shrubs and vines: the dam and dam toe area, in or around seepage monitoring systems or critical areas for seepage observation, abutments and groins, emergency spillways and regulating outlet channels, including channel floors, side slopes and approaches, outlet works discharge channels ETL 1110-2-571, "Guidelines for Landscape Planting and Vegetation Management at Levees, Floodwalls, Embankment Dams, and Appurtenant Structures" (reference A.95). Federal Emergency Management Agency, (2005), "Technical Manual for Dam Owners: Impacts of Plants", FEMA Document 534, Washington, DC (reference A.118).
Seepage control measures and embankment filter zones	Federal Emergency Management Agency, (2004), "Federal Guidelines for Dam Safety" (reference B.3.d): The potential of transverse cracking of the embankment caused by differential settlement, tension zones, and possible hydraulic fracturing should be minimized by careful consideration of abutments, foundation and cutoff trenches, and their geometry and treatment. Filter zones of adequate size should be positioned upstream and downstream of the impervious zone at all locations where there is a possibility of transverse cracking regardless of cause. Potential problems of differential settlement should be considered in establishing the construction sequence. EM 1110-2-1901 8-1.a: All earth and rock-fill dams are subject to seepage through the embankment, foundation, and abutments. Seepage control is necessary to prevent excessive uplift pressures, instability of the downstream slope, piping through the embankment and/or foundation, and erosion of material by migration into open joints in the foundation and abutments. EM 1110-2-1901 8-4.c: Filters may be required in various locations in earth dams such as vertical (or inclined) and horizontal drains within the downstream section of the embankment, around outlet conduits passing under the downstream portion of the embankment, under concrete structures such as stilling basins, around relief wells, beneath riprap where drawdown may occur, and between the embankment and abutment.
Low spots in embankment crest	Bureau of Reclamation, (2012), "Design Standards No. 13 Embankment Dams" (reference 6.3.2.1) When overtopping is a potential concern, low spots concentrate flow and thus are far more

	likely to lead to erosion as compared to a dam that has a uniform elevation and sheet flow during overtopping. Usually, the two lowest crest areas on an embankment dam are at the two ends where the camber is least. A crest survey should be performed to determine actual crest elevations and the existence of low spots.
Foundation treatment during construction of the dam	Federal Emergency Management Agency, (2004), "Federal Guidelines for Dam Safety" (reference B.3.d): Foundation subject to differential settlement or foundations having highly compressible anomalies can cause stress concentrations or cracking in dams. The foundation excavation should be shaped to remove abrupt changes in elevation to preclude excessive differential settlement or stress concentrations. Low shear strength material in a foundation can cause shear failure. Excavation and replacement of low strength material is a positive method for treating a foundation that has either or both of these unfavorable conditions.

APPENDIX E
Glossary of Terms

Abbreviations

DLA .... Dodson Lind-blom and Associates, Inc.

EAP .... Emergency Action Plan

FEMA.. Federal Emergency Management Agency

FMSM .... Fuller, Mossbarger, Scott & May Engineers

HEC-HMS.. Hydrologic Engineering Center Hydrology Modeling System

HMR.. Hydrometeorological Report

IRRM .... Interim Risk Reduction Measure

NGVD 29 .... National Geodetic Vertical Datum of 1929

NOAA .... Nation Oceanic and Atmospheric Administration

NWS.. National Weather Service

ODNR .... Ohio Department of Natural Resources

O&M.. Operations and Maintenance

PMF... Probable Maximum Flood

PMP... Probable Maximum Precipitation

SCS…… U.S. Department of Agriculture, Soil Conservation Service

SFLR…… .... South Fork Licking River

The District...................................... U.S. Army Corps of Engineers, Huntington District

USACE .... United States Army Corps of Engineers

Terms

Acceptable Risk – A risk, for the purposes of life or work, everyone who might be impacted is prepared to accept assuming no changes in risk control mechanisms. Such risk is regarded as insignificant and adequately controlled. Action to father reduce such risk is usually not required.

Acre-foot – A unit of volumetric measure that would cover 1 acre to a depth of 1 foot. It is equal to 43, 560 cubic feet. This is approximately 325,851.4 U.S. gallons.

Adverse Consequences – The outcome of the failure of a dam or its appurtenances, including immediate, short and long-term, direct and indirect losses and effects. Loss may include human casualties, project benefits, monetary and economic damages, and environmental impact.

Appurtenant structure – Ancillary features of a dam such as inlet and outlet works, spillways, tunnels, or power plants.

Berm – A nearly horizontal step in the sloping profile of an embankment dam. Also a step in a rock or earth cut.

Borrow area – The area from which natural materials, such as rock, gravel or soil, used for construction purposes is excavated.

Breach – An opening through a dam that allows the uncontrolled draining of a reservoir. A controlled breach is a constructed opening. An uncontrolled breach is an unintentional opening caused by discharge from the reservoir. A breach is generally associated with partial or total failure of the dam.

Channel – A general term for any natural feature or artificial facility for conveying water.

Clays – Fine grain soils with particle diameters less than 0.075 mm. These soils have cohesion, low permeability, and low shear strength.

Clearing – Removal of larger vegetation, structures, obstructions, etc., in an area.

Compaction – Immediate removal of air from the pore spaces within a soil matrix, typically via mechanical action.

Conduit – A closed channel to convey water through, around, or under a dam.

Consolidation – Removal of water from the pore spaces within a soil matrix as a consequence of changes in effective stresses over a period of time.

Cross section – A section formed by a plane cutting through an object, usually at right angles to an axis.

Cutoff trench – A foundation excavation to be filled with impervious material so as to limit seepage beneath a dam.

Cutoff wall – A wall of impervious material usually of concrete, asphaltic concrete, or steel sheet piling constructed in the foundation and abutments to reduce seepage beneath and adjacent to the dam.

Dam – An artificial barrier, including appurtenant works, constructed for the purpose of storage, control, or diversion of water.

Dam, earth – An embankment dam in which more than 50 percent of the total volume is formed of compacted earth material.

Dam, embankment – Any dam constructed of excavated natural materials.

Dam failure – Failure characterized by the sudden, rapid, and uncontrolled release of impounded water. It is recognized that there are lesser degrees of failure and that any malfunction or abnormality outside the design assumptions and parameters that adversely affect a dam's primary function of impounding water is properly considered a failure. These lesser degrees of failure can lead to loss of services and progressively lead to, or heighten, the risk of a catastrophic failure.

Dam Safety – Dam safety is the science of ensuring the integrity and viability of dams such that they do not present unacceptable risks to the public, property, and the environment. It requires the collective application of engineering principles and experience, and a philosophy of risk management that recognizes that a dam is a structure whose safe functioning is not explicitly determined by its original design and construction. It also includes all actions taken to routinely monitor, evaluate, identify or predict dam safety issues and consequences related to failure including ensuring all reservoir regulation activities are performed in accordance with established water control plans in support of dam safety concerns. These actions are to be performed in concert with activities to document, publicize, and reduce, eliminate, or remediate unacceptable risks.

Dam Safety Deficiency – A material defect or condition that results in dam failure.

Dam Safety Issue – Any confirmed or not yet confirmed condition at a dam that could result in intolerable life safety, economic, and environmental risks.

Dam Safety Modification – A Dam Safety Modification is any planning, design, or construction activity whose execution or improper execution could significantly impact the project's ability to operate as intended.

Dam Safety Modification Risk Assessment – The risk assessment addresses the life safety, economic, and environmental risks associated with the identified potential failure modes and the risk reduction that can be achieved with risk reduction measures, including potential staged implementation options.

Dam Safety Modification Study – The safety case that presents the investigation, documentation, and rationale for modifications for dam safety at USACE projects. The report presents the formulation and evaluation for a full range of risk reduction alternatives with preliminary level cost estimates. A detailed risk assessment is required to evaluate incremental risk reduction alternatives that together meet the tolerable risk guidelines and cost effectiveness of reducing the risk to below the minimum safety criteria. The level of detail should only be what is needed to justify the modification decision. The resultant Dam Safety Modification Decision Document will present a comparison of alternatives and the recommended risk management plan to include actions, components, risk reduction by increments or stages, implementation plan, and detailed cost estimate.

Datum – A reference element, such as a line or plane, in relation to which the position of other elements are determined. Also called the "reference plane" or "datum plane".

Differential settlement – When a foundation settles unequally in different areas.

Discharge – The quantity of water passing a given cross sectional area in a given unit of time.

Drain, toe – A system of pipe or pervious material along the downstream toe of a dam used to collect seepage from the foundation and embankment and convey it to a free outlet.

Drainage area – The area which discharges to a particular point on a river or stream.

Drawdown – The fluctuation between water levels in a reservoir within a particular time. Used as a verb, it is the lowering of the water surface.

Economic Consequences – Direct and indirect losses resulting from the failure of a dam and other economic impacts on the regional or national economy. Part of the direct losses is the damage to property located downstream from the dam due to failure. Items in this category include those commonly computed for the National Economic Development (NED) account in a flood risk management study.

Economic Damages – These include damage to private and public buildings, contents of buildings, vehicles, public infrastructure such as roads and bridges, public utility infrastructure, agricultural crops, agricultural capital, and erosion losses to land.

Elevation – The vertical distance from the datum, usually mean sea level (msl), to a point or object on the earth's surface.

Embankment – A raised structure of earth, rocks, or gravel, usually intended to retain water or carry a roadway.

Emergency – In terms of dam operation, a condition which develops unexpectedly, endangers the structural integrity of the dam or adversely impacts downstream property and human life, and requires immediate action.

Emergency Action Plan (EAP) – An action plan that provides detailed instructions for agencies and individuals for responding to emergencies such as a potential dam failure. Plans typically include threat recognition, emergency action message formulation, message dissemination to authorities and the public, provisions for search and rescue, and early stages of recovery.

Encroach – To advance beyond proper, established, or usual limits.

Erosion – A general term that describes the physical breaking down, chemical solution, and movement of fragments and soils from place to place on the surface of the earth.

Failure mode – The means by which element or component failures must occur to cause loss of the function of a dam that could result in failure.

Filter (filter zone) – One or more layers of granular material graded (either naturally or by selection) so as to allow seepage through or within the layers while preventing the migration of material from adjacent zones.

Flood – A general and temporary condition of partial or complete inundation of normally dry land from: (1) overflow of inland waters; or (2) unusual and rapid accumulation or runoff of surface waters.

Flood Level – The size of a flood may be expressed in terms of probability, of exceedance per year or expressed as a fraction of the probable maximum flood or other referenced floods.

Flood Control –The construction of levees, floodwalls, channel improvements, and reservoirs to reduce flood damages.

Flood Damage Reduction – The term flood damage reduction was adopted in recognition that the structures built for flood control only reduced the level of flooding and could not totally control all floods. Projects developed for flood damage reduction also include non-structural elements.

Flood Risk Management – This term recognizes that there are different levels of risks in flood control works and in flood damage reduction activities. Since all flood management structures and other features have a risk of failure, the current practice is to seek to reduce the risk to a tolerable level.

Flood, Probable Maximum (PMF) – The most severe flood that is considered reasonably possible at a site as a result of meteorological and hydrologic conditions.

Floodplain – An area adjoining a body of water or natural stream that has been covered by floodwater.

Freeboard – Vertical distance between maximum pool and the top of dam.

Geology – The science dealing with the structure of the earth's crust and the formation and development of its various layers. It includes the study of individual rock types and early forms of life found as fossils in rocks.

Glacial outwash – Pertaining to deposits made by streams flowing from glaciers.

Glacial till – The product of abrasion carried on by the glacier's ice sheet as it moved over the land.

Glaciation – The alteration of a land surface by movement of glaciers.

Glacier – A body of ice and water, consisting mainly of recrystalized snow, flowing on a land surface.

Groundwater – That water beneath the earth's surface which is contained in the pore spaces within the soil and bedrock.

Head, hydrostatic – A measure of pressure at a given point in a liquid in terms of the vertical height of a column of the liquid which would produce the same pressure.

Height, above ground – The maximum height from natural ground surface to the top of a feature.

Height, dam – The dam height is the vertical distance between the lowest point on the crest of the dam and the lowest point in the foundation.

Hydraulic gradient – The slope of a piezometric line, found by determining the difference in height between two points and dividing by the horizontal distance between those two points.

Hydrograph – A graph showing, for a given point on a stream, the discharge, stage, velocity, or other flow measurement of water with respect to time.

Hydrology – A science dealing with the properties, distribution, and circulation of water on the surface of land, in the soil, and underlying rocks, and in the atmosphere.

Indirect economic impacts – Impacts associated with the destruction of property and the displacement of people due to the failure. This destruction, due to the flood related failure, can have significant impacts on the local and regional economy as businesses at least temporarily close resulting in loss of employment and income. Similarly, economic activity linked to the services provided by the dam will also have consequences. Indirect losses are an increment to flood losses above those that would have occurred had the dam not failed.

Initial reservoir filling – First impoundment of water to meet project purposes.

Interim Risk Reduction Measure (IRRM) – Dam safety risk reduction measures that are to be formulated and undertaken for dams that are not considered to be tolerably safe. These measures are intended as interim until more permanent remediatial measures can be implemented. Increased monitoring and reservoir restrictions are examples of these interim measures.

Internal erosion – Removal of soil particles within an embankment dam or its foundation by seepage or leakage. Internal erosion development leading to dam failure can be represented by four phases: initiation, continuation, progression, and breach.

Inundation – Coverage of an area by water.

Lacustrine deposit – Material deposited in a lake environment.

Leakage – Concentrated flow through preferential paths (e.g., crack in cohesive soil, open rock defect)

Lens – A stratum that is thicker in the middle and thinner towards the edges.

National Geodetic Vertical Datum of 1929 – The vertical control datum established for vertical control surveying in the United States of America by the General Adjustment of 1929.

Non-structural risk reduction – Risk reduction by measures that do not require structural modification or construction related to the dam and its appurtenant works.

Observation well – Perforated casing which is advanced through the ground and is used to determine the groundwater surface.

Outlet – A designed opening through which water can be discharged downchannel from a reservoir.

Outlet structure – A dam appurtenance that provides release of water (generally controlled) from a reservoir.

Parapet wall – A wall built along the top of a dam to provide additional freeboard.

Periodic Assessments (PA) – A USACE study which occurs on a 10 year frequency for each dam project and consists of a site visit, a potential failure modes analysis, and a semi-quantitative risk assessment. Primary purposes of the PA include evaluating project conditions and associated risks; prioritizing data collection, analyses, and study needs. Operations and maintenance requirements would be reviewed. Emergency action planning, training, and other reoccurring needs would be identified.

Periodic Inspections (PI) – USACE inspections which occur on a 5 year frequency performed for dams and other civil works structures where failure or partial failure would adversely affect the operational integrity of the project, endanger the lives and safety of the public or cause substantial property damage.

Phreatic surface – A vertical location which may define the water table within which the pore water pressure is under atmospheric conditions.

Piezometer – An instrument used for measuring fluid pressure (air or water) within soil, rock, or concrete.

Population at risk – The population downstream of a dam that would be subject to risk from flooding.

Potential failure mode (PFM) – The sequence of events leading to either partial or complete dam failure.

Probable Maximum Precipitation (PMP) – Highest precipitation likely to occur under known meteorological conditions.

Reconnaissance – A general examination of an area.

Remediation – Implementation of long-term structural and non-structural risk reduction measures to resolve dam safety issues.

Reservoir surface area – The area covered by a reservoir at a particular water surface elevation.

Riparian – An environment defined by areas subject to frequent inundation.

Risk – A measure of the probability and severity of undesirable consequences or outcome.

Risk assessment - A term that encompasses analytic techniques that are used to define different conditions, depending upon the nature of the risk. This assessment is a systematic, evidence based approach for quantifying and describing the nature, likelihood, and magnitude of risk associated with the current condition, and consequences resulting from a changed condition due to some action. This assessment includes acknowledgment of risk related uncertainties. As applied to dam safety, this process identifies the likelihood and consequences of dam failure which provides the basis for informed decision making and selected course of action.

Risk-informed – This requirement is necessary to define the decision making process as related to dam safety.

Risk management – This process is used to initiate actions which identify, evaluate, select, implement, monitor, and modify projects to reduce levels of risk, as compared to taking no action. The purpose of this action is to choose and prioritize work, as required, to reduce risk.

Risk reduction measures – These actions are formulated and undertaken to reduce risk.

Sand – A granular soil having particle diameter ranging from 0.075 mm to 4.75 mm. These soils are cohesionless, high in permeability, and susceptible to erosion.

Sediment – Rock or soil material that has been transported and deposited by water, air, or ice.

Sedimentation – The settling of solids, such as soil particles, by gravity.

Seepage – Flow through porous media.

Silt – Fine grain soils with particle diameters less than 0.075 mm. These soils have little to no cohesion and relatively low permeability.

Soil – Uncemented aggregate of mineral grains and decayed organic matter with liquid and gas in the void spaces between and within particles.

Spillway – A structure over or through which flow is discharged from a reservoir. If the rate of flow is controlled by mechanical means such as gates, it is considered a controlled spillway. If the geometry of the spillway is the only control, it is considered an uncontrolled spillway.

Spillway channel – An open channel or closed conduit conveying water downstream from the spillway inlet.

Spillway crest – The lowest level at which water can flow over the spillway.

Storage – The retention of water or delay of runoff either by planned operation, as in a reservoir, or by temporary filling of overflow areas.

Subsidence – Movement in which material is displaced downward.

Tailwater level – The level of water in the vicinity of the downstream toe of the dam.

Toe of dam – The intersection of the face of a dam with the foundation surface.

Tolerable risk – Risk within a range that is acceptable to effect the benefits provided by the project.

Tolerable risk guidelines – These guidelines are used to define the process of examining and determining the significance of risks defined during the assessment. Meeting or achieving the tolerable risk guidelines is the goal for all risk reduction measures including permanent and interim measures.

Top of dam – The elevation of the uppermost surface of a dam.

Wave run-up – Wind or navigation related wave generation above the elevation of a retained pool.

APPENDIX F
USACE Past Observations During High Pools

Return to Haynie

(25)

SPECIAL REPORT

BUCKEYE LAKE - OHIO

Date of Inspection: March 14 and 15, 19[illegible].

Location: In Licking, Fairfield and Perry Counties. (See attached sketch).

Drainage Area: [illegible] square miles.

Normal lake area: 4200 acres.

Shore Line: About 26 miles.

Average depth of lake: 10 feet.

The lake was formed artificially as a feeder for old Ohio & Erie Canal in about the year 1825. The lake is fed by very small creeks and runs entering the lake at several different points. There is about 4 miles of levee built to inclose the lake. The average levee height is 12 feet; maximum 19 feet. This levee has never been overtopped and has an average freeboard above normal lake level of about 4 feet. Attached is a rough sketch showing general dimensions of the levee section. You will note that the lakeside slope of the levee is 1 on 1 or steeper and the general outside slope is 1 on 1 with the top width of the levee, varying from 10 to 24 feet. There is a bank protection sea wall along the full length of the levee on its lakeside, extending from the crest of the levee down the slope for a vertical distance of about 6 feet. Leaks through the levee occur frequently (4 or 5 times per year) and are repaired as they are discovered. The causes of these levee leaks are attributed to the following:

(1) Wave action undermines the levee sea wall from time to time at various points and scours into the levee bank seriously weakening the levee. This scouring frequently results in leaks through the levee and/or failure of the sea wall. Some 1100 feet of steel sheet piling has been driven at two locations along the inside slope of the levee to arrest seepage through the levee due to this undermining scour action.

(2) Occasional leaks discovered and repaired in the levee are found to have been started by muskrats tunneling into the levee wall.

(3) Other leaks which have been repaired are the result of decomposition of roots and tree limbs which were embedded or have grown into the levee bank.

Overflow from lake is through a controlled concrete spillway and then through a short canal into South Fork of Licking River. This spillway consists of 5 bays, 1[illegible] feet wide, with provisions for two 10-inch wide flash boards above the crest of the spillway. There are 5 sluice gate openings, one in each spillway bay to regulate the flow from the lake. These openings are 3 feet wide by 5 feet high, and are controlled by hand operation (rack and hand wheels) from the top of the spillway. The bottom of the sluice openings is about 12 feet below the normal lake level. The present concrete spillway structure was built in about the year 1914, and appears to be in fair condition, except for slight weathering of the concrete at the points of the pier noses. The full damming height of the spillway is about 16 feet. Cross sections, plans or design data for the spillway were not available at Lake Field Office. They may be obtained from Mr. Carl Miller, Bureau of Inland Lakes, Department of Agriculture, Columbus, Ohio.

There is a stilling pool below the spillway structure, created by a small dam (about 5 feet high) built by the W.P.A. a few years ago.

This one spillway is the only outlet from the lake except for a 24-inch pipe used to allow fresh water to flow into a short section of the old canal which is stocked with fish.

The State of Ohio, at the recent session of its legislature, appropriated some $60,000 to construct two 36-inch round sluices and an outlet canal in the extreme east end of the lake which will allow a small amount of water from the lake to flow into Johnathan Creek and thence into the Muskingum river near Zanesville. This outlet is to provide a flow of water toward this end of the lake to favor propagation of marine life and has no flood control or lake level regulation value whatsoever.

At the present time the lake level is drawn down about 14 inches below normal and this level will be maintained until April 1, 1939, when the level of the lake will be gradually raised until within about 5 or 6 inches of normal level. This procedure is being followed as a flood control measure for the South Branch of the Licking River during the spring rains and thaws.

It is reported that there are about 1000 acres of unimproved land adjacent to the lake on its south side, which will overflow when the lake reaches a level about 1½ feet below the top of the levee. This overflow area will provide several thousand acre-feet of reserve overflow storage before the levee would fail, due to its being overtopped as a result of a super storm in the lake watershed.

Mr. Waters, Director, State of Ohio, Division of Conservation, was contacted at Massillon, Ohio, on March 16, 1939, and the condition of the Buckeye Lake Levee was discussed with him. Mr. Waters recognizes the fact that the levee is unsafe and he says that his Bureau of Inland Lakes and Parks, anticipate the formulation of plans for strengthening this levee, which plans will be presented to the next session of the legislature for appropriations.

The lake is owned, maintained and operated by the State of Ohio, and is under the jurisdiction of the Ohio Department of Agriculture, Division of Conservation, Bureau of Inland Lakes and Parks.

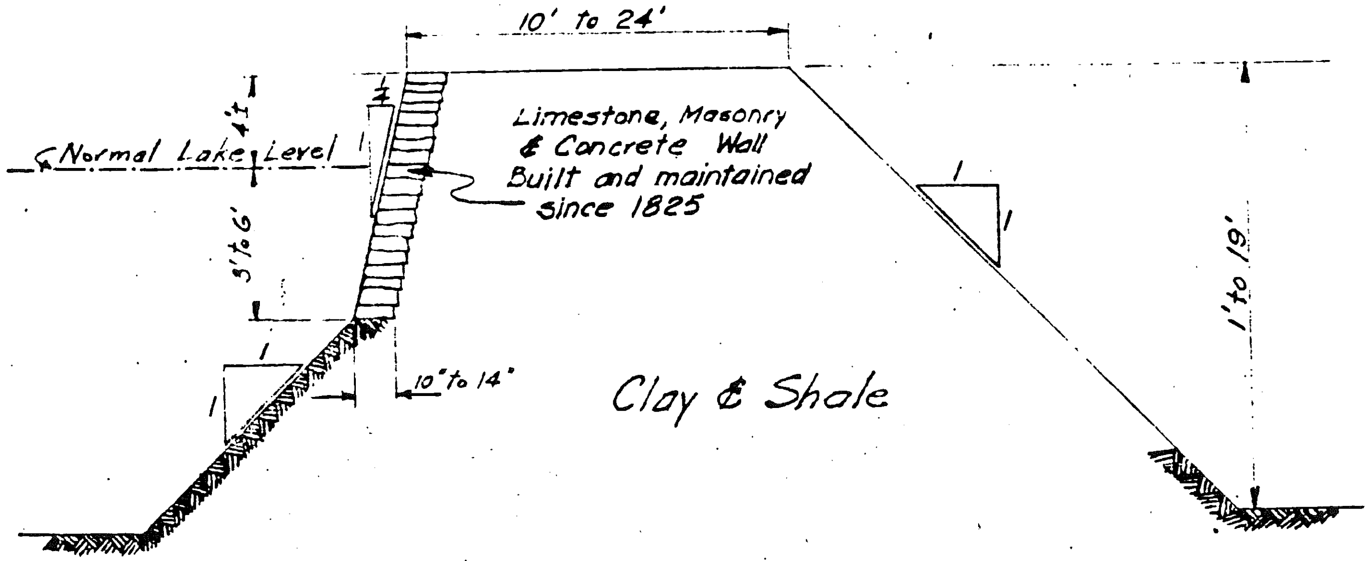
Mr. Ed. Little is Resident Engineer at the lake and he is assisted by 1 patrolman. These men are full time employees at the Lake Field Office.

The foregoing information was obtained from observation and from Mr. Little in the Lake Field Office. Several photographs taken of the spillways and levees are attached.

John J. Konrad

John J. Konrad,
Assistant Engineer.

Buckeye Lake Levee



General Section

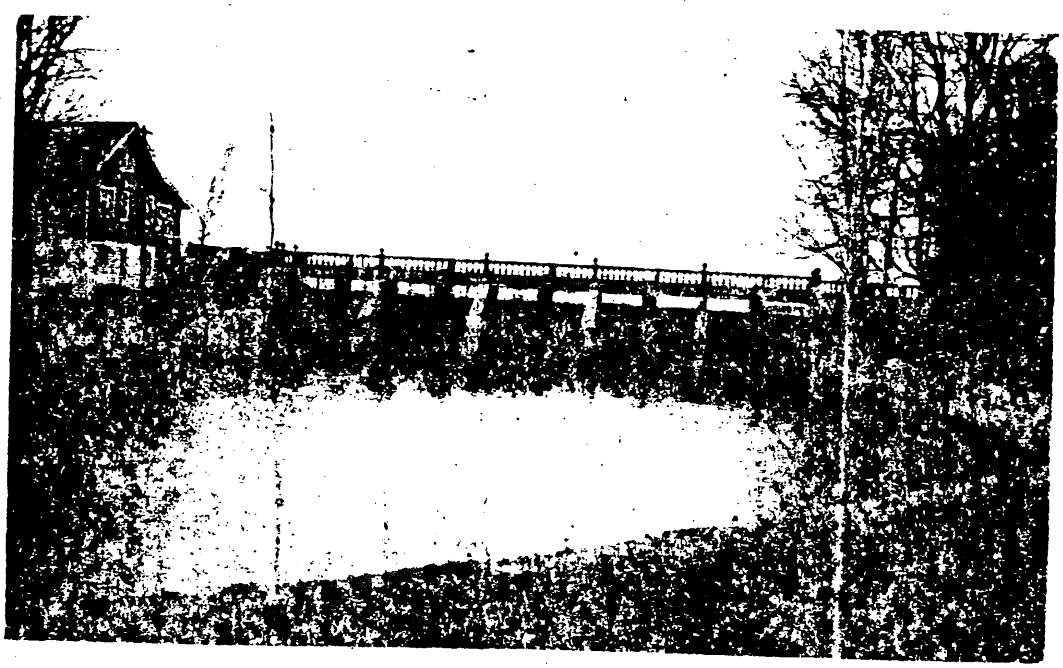
Buckeye Lake.

View of sea wall and Levee

View of landside levee slope
Note cottages built on
levee bank.

Buckeye Lake

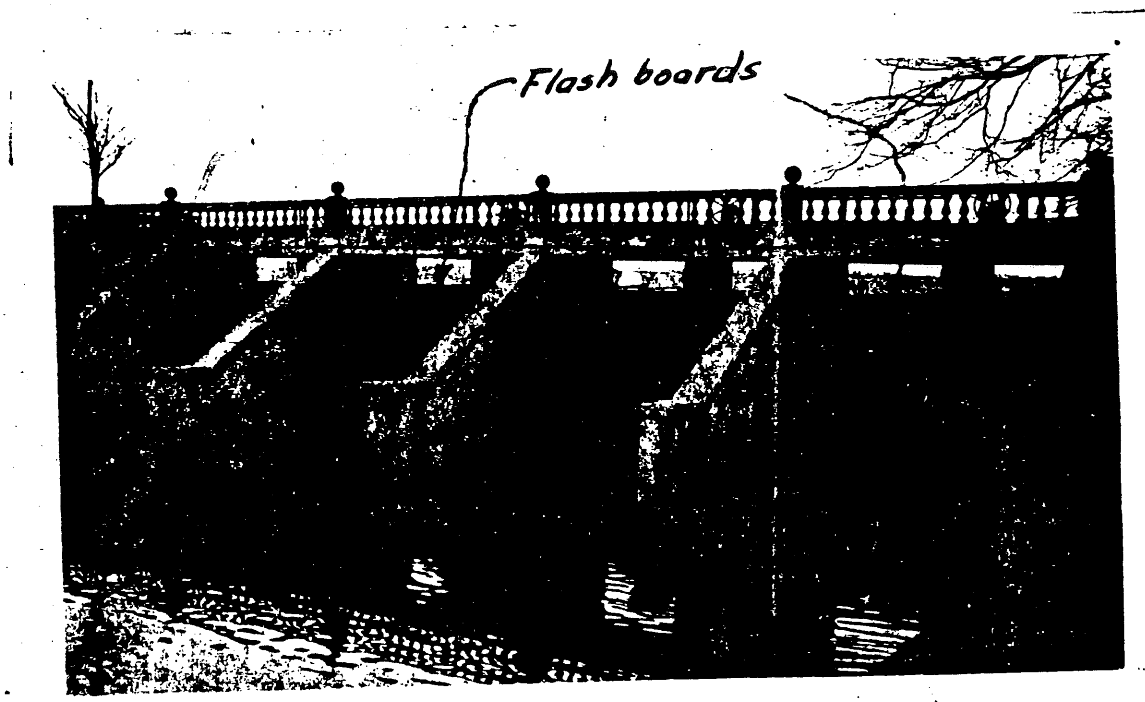
View of spillway structure on Lake Side.



View of spillway structure Lower (outlet) side.

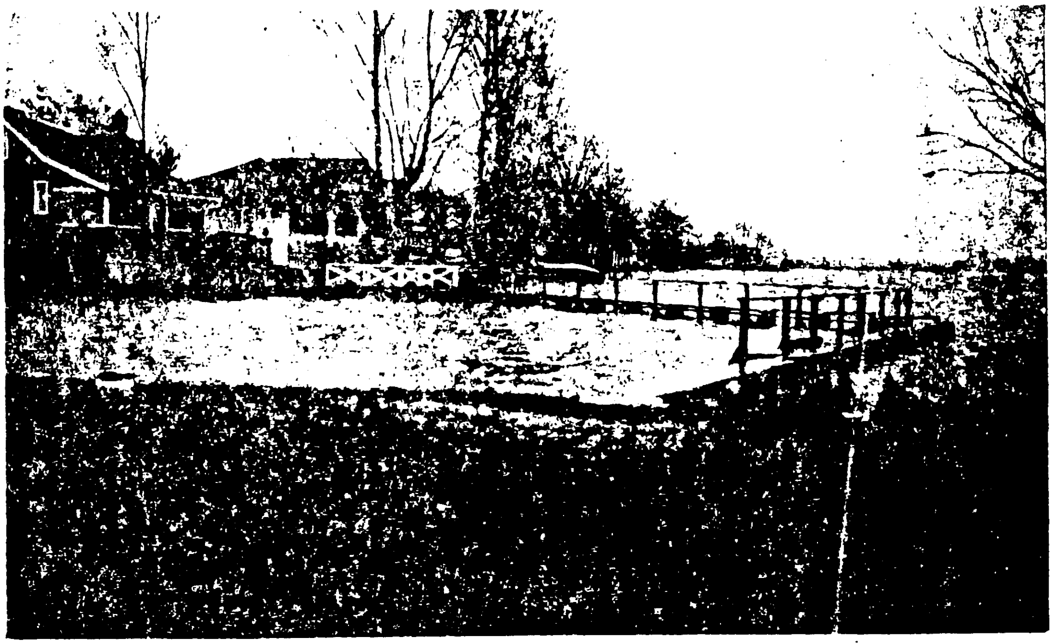
Buckeye Lake

View of outlet spillway structure on Lake side.



View of outlet spillway structure. Lower (outlet) side.

Buckeye Lake



View of trash and fish rack structures in forebay for outlet spillway.

Buckeye Lake.

View of stilling basin dam located in [redacted] outlet canal below spillway

View of stilling basin dam

Hydraulics & Reports Section,
U. S. Engineer Office,
Huntington, W. Va.
March 29, 1939.

Subject: Newark Local Protection - Buckeye Lake Spillway.

OFFICE MEMORANDUM

1. Preliminary calculations indicate that the present spillway capacity is inadequate for handling the maximum flood flow to be expected. This conclusion is based on meager data but the assumptions made are reasonable and similar to studies made on adjacent drainage areas. These assumptions are discussed in para. a&k, general data.

2. According to Konrad's report of March 15, 1939, the levees have never been overtopped since the lake was formed in 1825 in spite of the fact that there is only 5 feet of freeboard during the spring months and about 4 feet during the remainder of the year. Apparently the present spillway is adequate for a flood of 110-year frequency. An inspection of the quadrangle sheets indicates several swamps adjacent to the lake and large flat areas apparently tributary to the reservoir feeder canal between Kirkersville and Buckeye Lake. The flat areas and swamp land affect the peak storm flow into the lake and for this reason the levees have never been overtopped.

3. Recommendations:

(1) The levees around the lake should be strengthened. (The State Legislature is now being urged to appropriate money for this project.)

(2) The capacity of the discharge outlets from the lake should be increased from 3,600 c.f.s. to 28,000 c.f.s. It is believed inadvisable to utilize any of the 4-foot freeboard above the normal pool level because of danger from overtopping during severe storm. Stevenson's formula for wave heights resulting from a wind velocity of 50 miles per hour and fetch of 1 mile indicates that the wave height would be 2.7 feet.

4. General Data.

a. Drainage area, 45 sq.mi. The determination of the actual drainage area tributary to Buckeye Lake is somewhat complicated because the lake is fed by a reservoir feeder canal. This reservoir feeder canal branches off

Subject: Newark Local Protection - Buckeye Lake Spillway. (Office Memorandum, March 29, 1939.)

of South Fork at Kirkersville and flows in a southeasterly direction through flat land to Buckeye Lake. There are about 20 square miles tributary to this canal between Kirkersville and the Lake. The area directly tributary to the lake is 26.5 square miles. Assuming that all flow in South Fork remains in South Fork and that the only water which can enter the lake is from the area directly tributary to it and the reservoir feeder canal, the drainage area is ~~45~~ 47 square miles.

b. Normal pool elevation - elevation 892. This normal pool elevation is maintained by flashboards on the spillway. The crest of the spillway is elev. 890.

c. Normal lake area, 4,200 acres (Konrad's report). Ohio Stream Flow, Part I, gives 4.15 sq.mi. = 2,660 acres. 4,200 acres was used for el. 892. Area at 894.5 = 5,200± acres (Konrad's report).

d. Shore line, 26 miles (Konrad's report 3-15-39).

e. Average depth - 10 feet (Konrad's report). (Less than 6 feet as given in Ohio Stream Flow.)

f. Freeboard: Elev. of levee = 896±. Normal freeboard about 4½ feet. During spring, freeboard = 5.0± feet.

g. Spillway: 10 openings 6'6" long x about 4' high. Flat top about 15 inches wide - elev. 896.

h. Sluice gates. 3 - 3' x 5.0' gates. Elev. of bottom of sluice = 879.6± (Zanesville Work Sheets).

i. Maximum flood flow. 45 sq. mi. x 620 c.f.s./sq.mi. = 28,000 c.f.s. Max. flood flow chart for Ohio.

j. Capacity of sluice - Pool elev. 896 = 1,510 c.f.s.
Capacity of Spillway - " " " = 2,070 c.f.s.
Total - [illegible],580 c.f.s.

k. Volume in Lake - Elev. 896-892 = 13,600 ac. ft.

A. J. Moore,
Junior Engineer.

D. O. Form No. 23

WAR DEPARTMENT

UNITED STATES ENGINEER OFFICE, HUNTINGTON, W. VA.

Page 1

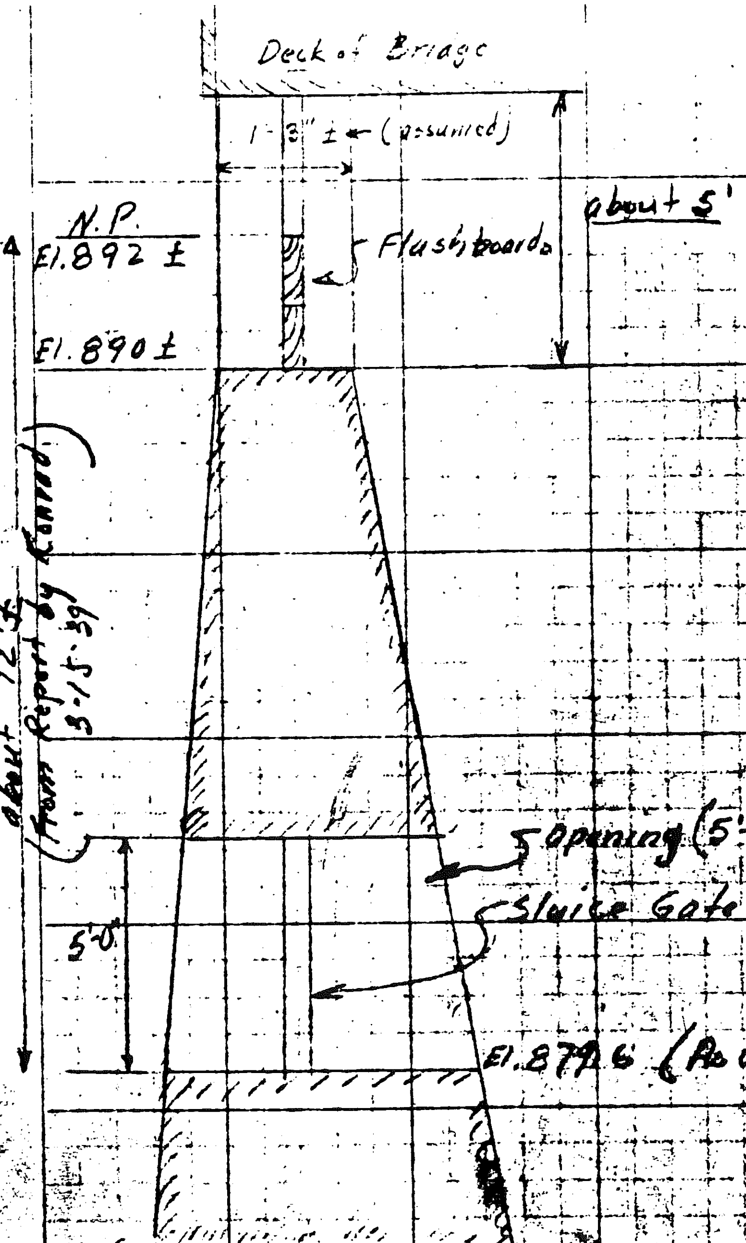
Subject Newark Local Protection Project

Computation Present Capacity of Buckeye Lake Spillway **No.**

Computed by Moore **Checked by** **Date** 3-27-39

See Sketch made by C. H. Roy 7-11-37

10 openings at 6'-6"



Assumptions:

(1) Shape of profile of spillway

(2) "C" in $Q = CLH^{3/2}$ = 2.85

(3) "C" in $Q = CA\sqrt{2gh}$ = 0.70

D. O. Form No. 28

WAR DEPARTMENT

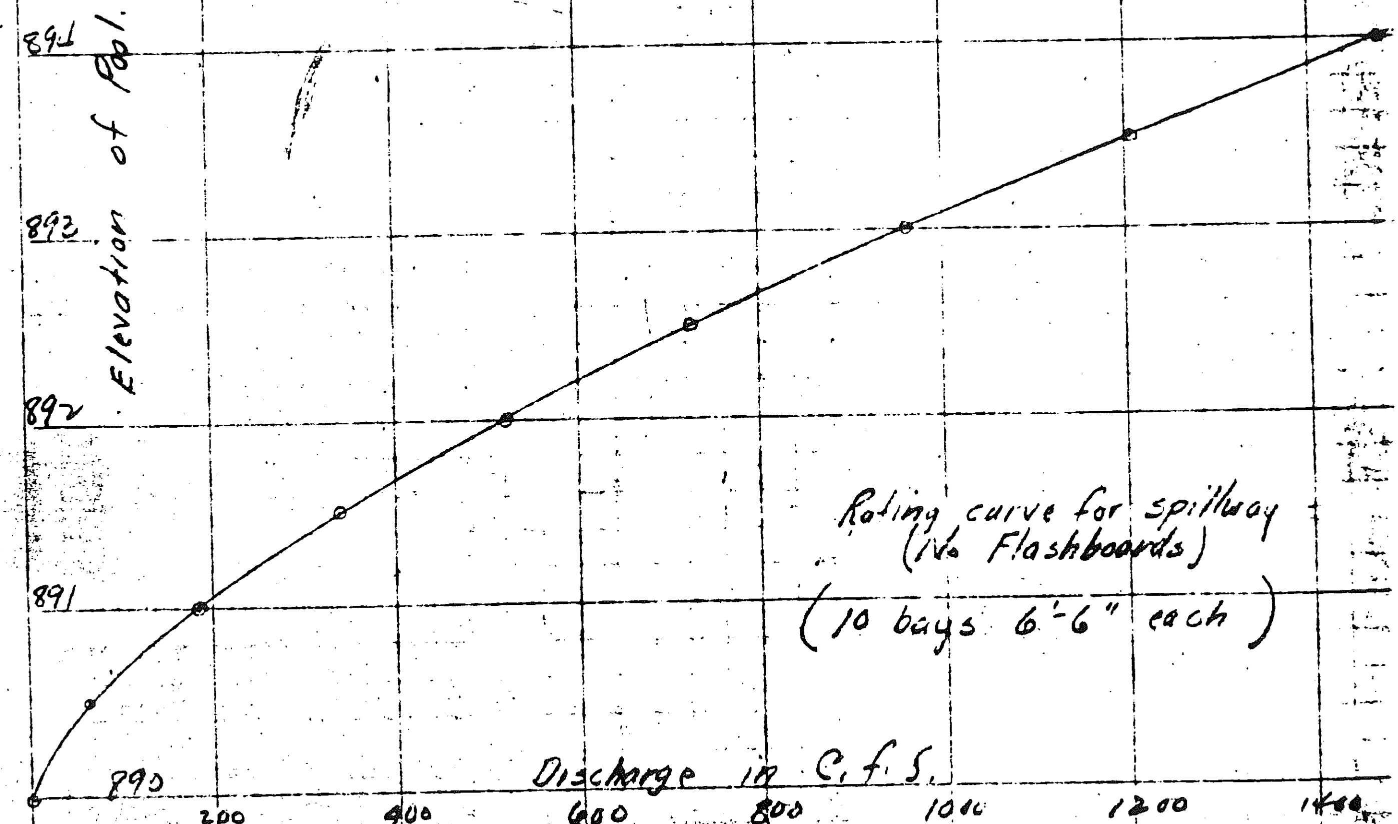
UNITED STATES ENGINEER OFFICE, HUNTINGTON, W. VA.

Subject Newark L.P.P.

Computation of Rating Curve for Spillway - Buckeye Lake **No.**

Computed by Moore **Checked by** **Date** 3-27-39

Elev.	H	C L	$H^{3/2}$	$Q = 10CLH^{3/2}$
890	0	2.85 × 6.5 = 18.5		c.f.s.
890.5	0.5	18.5	.354	65.6
891	1.0	↓	1.00	185.2
891.5	1.5		1.837	340
892	2.0		2.828	523
892.5	2.5		3.953	729
893.0	3.0		5.196	960
893.5	3.5		6.548	1210
894.0	4.0	↓	8.000	1480
895.0	5.0	"	11.18	2070



D. O. Form No. 23

WAR DEPARTMENT

UNITED STATES ENGINEER OFFICE, HUNTINGTON, W. VA.

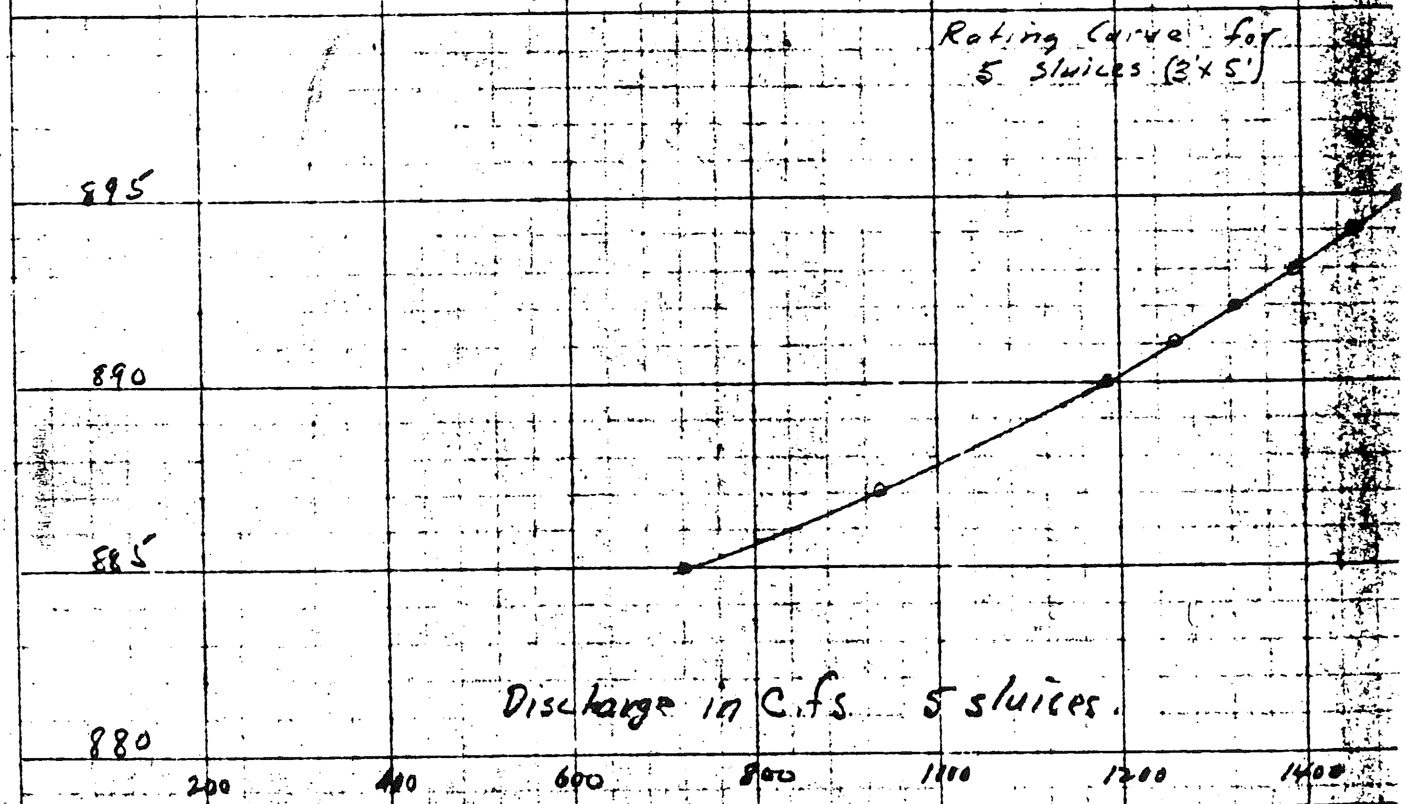
Subject: Newark LPP Buckeye Lake.

Computation: Capacity of Sluices in Dam No.

Computed by: Moors Checked by Date: 5-27-39

5 sluices 5'-0" x 3'-0" Q sluices = 879.6 / 2.5 / 882.1

Flev	H	$H^{\frac{1}{2}}$	$CA\sqrt{2g} \times H^{\frac{1}{2}}$ $5 \times .70 \times 15 \times 8.02$ $= 421.5 H^{\frac{1}{2}}$
885	2.9	1.702	720 c.f.s.
887	4.9	2.215	934
890	7.9	2.81	1185
891	8.9	2.98	1259
892	9.9	3.14	1325
893	10.9	3.30	1391
894	11.9	3.45	1456
895	12.9	3.59	1510



D. O. Form No. 22

WAR DEPARTMENT

UNITED STATES ENGINEER OFFICE, HUNTINGTON, W. VA.

Page ✓

Subject: Newark L.P.P. Buckeye Lake Spillway

Computation: Summary

No.

Computed by: R.J.M. Checked by

Date: 2-28-39

Capacity at El. 895 Flashboards not used

5 - sluices 1510 c.f.s. from Curves

Spillway, labor. 2070 c.f.s "

3580 c.f.s. "

Area tributary to Buckeye Lake.

Directly tributary = 45 sq. miles

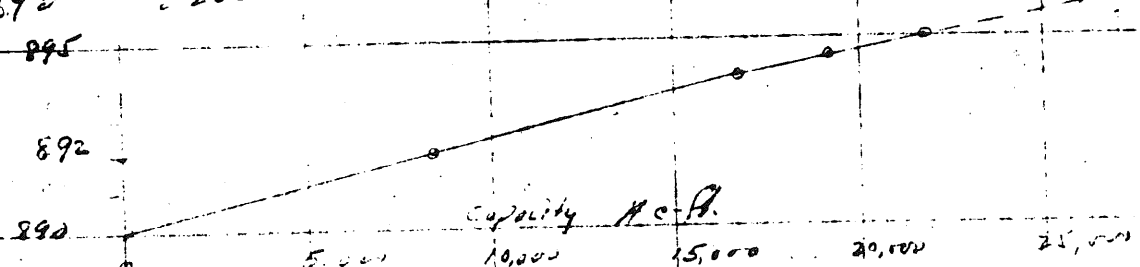
Capacity of Lake above Spillway Crest El. 890 -

Area at 892 = 4200 acres

" 894 = 4200 acres ±

" 894.5 = 5200 acres

Elev.	Area	Avg. Area	Depth	Volume	Capacity
890	4200				0
		acres 4200	2 ft.	8400 ac-ft	8400 ac-ft.
892	4200				
		4200	2	8400	16,800
894	4200				
		4700	.5	2350	19,200
894.5	5200				
		5200	.5	2600	21,800
895	5200				



WAR DEPARTMENT

UNITED STATES ENGINEER OFFICE, HUNTINGTON, W. VA.

Subject: Buckeye Lake

Computation: No.

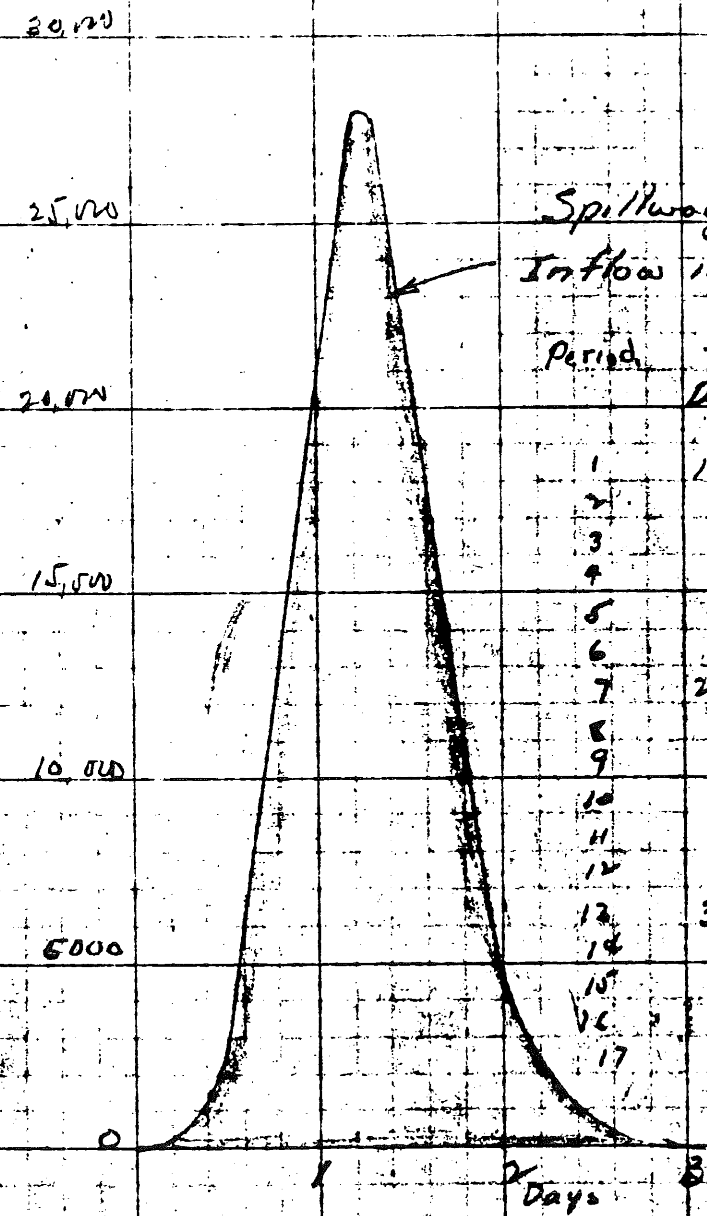
Computed by: Moors   Checked by: Date: 3-28-39

Area Tributary = 45 sq. miles

Max. Flood Flow to be expected

620* c.f.s./sq. mi. × 45 = 28,000 c.f.s.

* Max. Flood Flow for Ohio.



Spillway Design hydrograph
Inflow into Lake.

Period	Time Day	Time Hour	Inflow at End of Period c.f.s.	Av. Inflow c.f.s.	[illegible]
1	1	4	200	100	[illegible]
2		8	1000	600	[illegible]
3		12	3000	2000	[illegible]
4		16	8500	6750	[illegible]
5		20	14500	11500	[illegible]
6		24	21000	17750	[illegible]
7	2	4	27500	24250	[illegible]
8		8	27000	27250	[illegible]
9		12	21000	24000	[illegible]
10		16	15500	18250	[illegible]
11		20	9800	12500	[illegible]
12		24	5000	7250	[illegible]
13	3	4	2700	3850	[illegible]
14		8	1200	1950	[illegible]
15		12	500	850	[illegible]
16		16	200	350	[illegible]
17		20	0	100	[illegible]

10" Run-off = 10 × 26,889 × 45 × 2 = 24,500 ac-ft.

D. O. Form No. 33

WAR DEPARTMENT

UNITED STATES ENGINEER OFFICE, HUNTINGTON, W. VA.

Subject Newark L.P.P

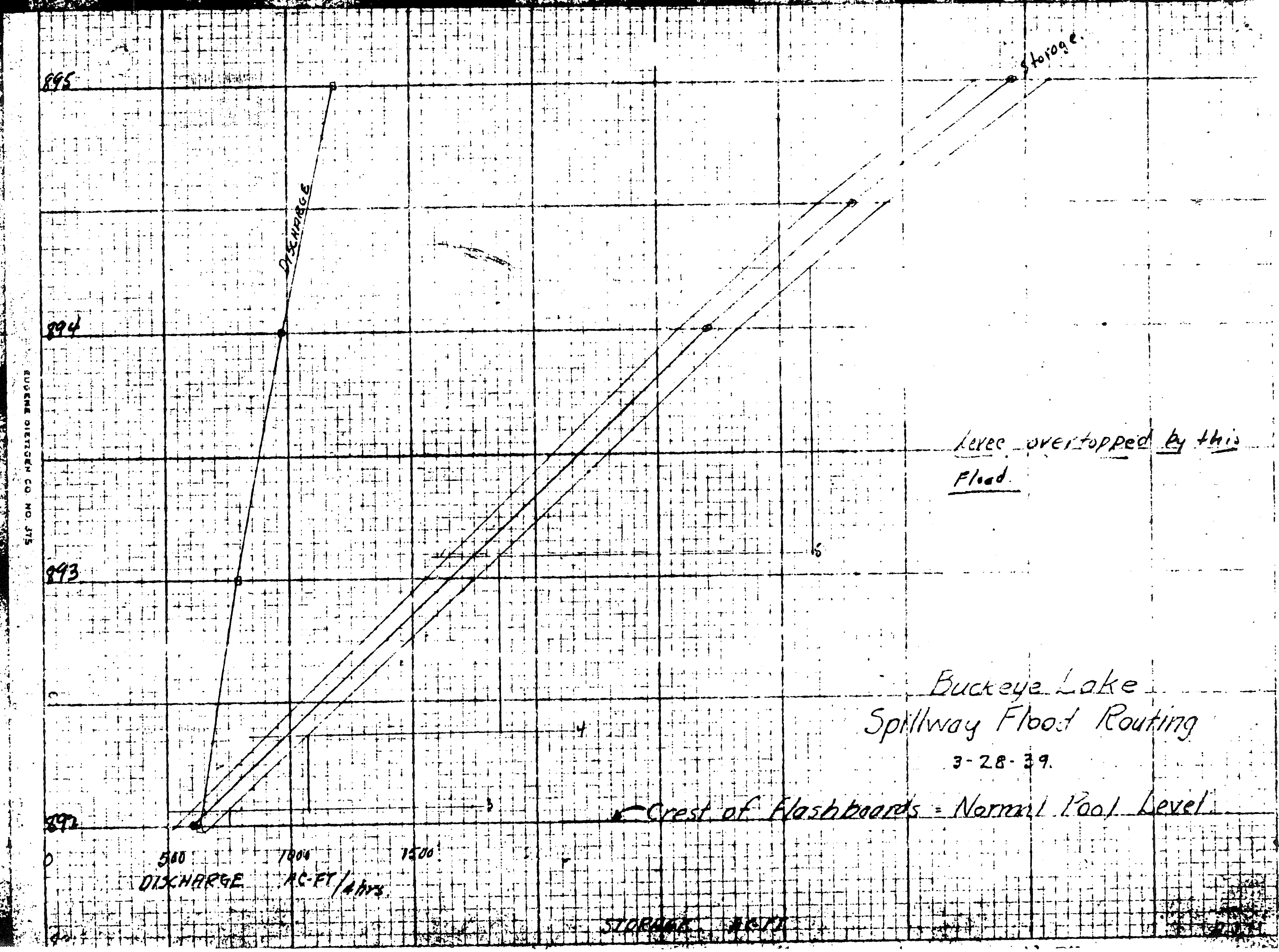
Computation Spillway Discharge **No.**

Computed by Moore **Checked by** **Date** 3-28-39

GPO 3—10578

Elev.	Spillway c.f.s	Sluices c.f.s	Total c.f.s	Ac-ft/4hrs
890	0	1185	1185	395
891	185	1259	1444	481
892	523	1325	1848	616
893	960	1391	2351	784
894	1480	1456	2936	978
895	2070	1510	3580	1193

These are lower than the values plotted = the Dam Safety Report.



Buckeye Lake
Spillway Flood Routing
3-28-39.
Crest of Flashboards = Normal Pool Level.
Levee overtopped by this Flood.
Storage.
DISCHARGE
895
894
893
892
0
500
1000
1500
DISCHARGE AC-FT/4 hrs
STORAGE AC-FT
EUGENE DIETZGEN CO. NO. 375

D. O. Form No. 23

WAR DEPARTMENT

UNITED STATES ENGINEER OFFICE, HUNTINGTON, W. VA.

Subject Newark L.P.P. Buckeye Lake Spillway

Computation Area tributary to Lake. **No.**

Computed by Moore **Checked by** **Date** 3-30-39

GPO 3—10876

Area directly tributary = (Includes area tributary to Feeder Canal)

9596 > 3105 > 3103
6491 > 3100
3291

At 39° 57' 30" 15'x15' = 228.91 sq miles

$\frac{3103}{1640} \times \frac{228.91}{9} = 48.2$ sq. miles

Area tributary to South Fork above Kirkersville, O.

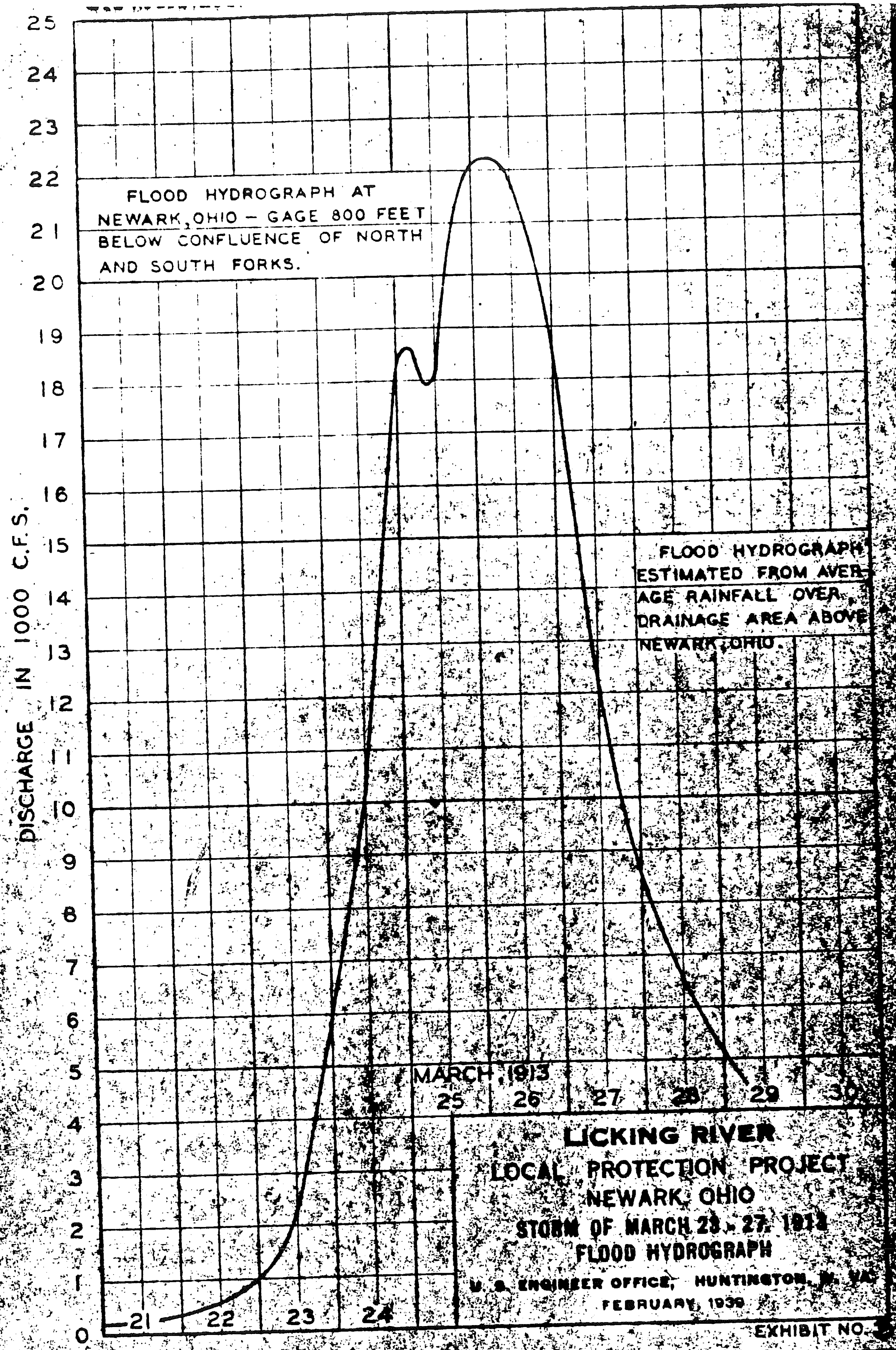
9717 > 3329 > 3331
6388 > 3333
3055

At 40°00'00" 15'x15' = 228.81 sq. miles

$\frac{3331}{1640} \times \frac{228.81}{9} = 51.5$ sq. miles

Plan Constant · for 5 min. x 5 min.

9501 > 1644 > 1640 = 5 sq. minutes
7867 > 1637
6230



FLOOD HYDROGRAPH AT NEWARK, OHIO – GAGE 800 FEET BELOW CONFLUENCE OF NORTH AND SOUTH FORKS.
FLOOD HYDROGRAPH ESTIMATED FROM AVERAGE RAINFALL OVER DRAINAGE AREA ABOVE NEWARK, OHIO.
DISCHARGE IN 1000 C.F.S.
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
MARCH, 1913
21
22
23
24
25
26
27
28
29
30
LICKING RIVER
LOCAL PROTECTION PROJECT
NEWARK, OHIO
STORM OF MARCH 23 - 27, 1913
FLOOD HYDROGRAPH
U. S. ENGINEER OFFICE, HUNTINGTON, W. VA.
FEBRUARY, 1939
EXHIBIT NO.

ORHOP (   )
SUBJECT: Buckeye Lake, Ohio

THRU: District Engineer   Chief, [illegible]   DATE   CMT 2

TO: Chief, [illegible] Division

1. The following report [illegible] for your information and for incorporation in reports to proper [illegible], Division Engineer and Chief of Engineers, Attention: [illegible] 1110-2-101, Change 2, dated 4 november 1968.

2. Buckeye Lake has a normal pool surface area of about 3800 acres with approximately 40% of the lake 9 feet deep or deeper. On 28 May 1968 the pool surface area was estimated to be near 6000 acres with an approximate average depth of 12 feet.

3. Over topping of the earth embankment with subsequent erosion could have dumped several thousand acre feet of the impoundment into the South Fork of the Licking River. This sudden dumping of waters could have had an adverse effect on the Newark, Ohio Local Protection Project and could have seriously effected the flood control storage of Dillon Reservoir.

4. 2.26" of rainfall was reported at Buckeye Lake for the 24 hour period ending at 7:00 A.M., 24 May 1968. Heavy rains again occurred at Buckeye Lake beginning at 2:00 P.M., 26 May and ending at 3:00 P.M. 27 May with a total of 3.21 reported for this period. The previous heavy rains and the saturated condition of the ground contributed to the rapid filling of Buckeye Lake to a height that became quite alarming. This lake, which was constructed in 1825-1826 [illegible] a feeder for the old canal system, was developed by the Ohio Department of Natural Resources for recreational purposes and has extensive private developments of cottages, homes, and service type facilites around the shoreline.

ORHOP ( )
SUBJECT: Buckeye Lake, Ohio

5. Late in the day on 27 May the water level at Buckeye Lake reached the low points in the retaining embankment creating the lake near Sellers Point. There was also considerable seepage thru the embankment around and through the basement of houses built along the downstream toe of the embankment. The Ohio National Guard was called out that night and the embankment was reinforced with sand bags and straw. Around midnight the lake level crested, and by early morning the lake was falling very slowly. The sand bagging operations were called off after the lake level began to drop. Tom Lilly, Project Supt., Dillon Dam, checked on the situation on the night of 27 May.

6. The following morning Mr. Frank Hollingsworth, Chief, Muskingum Area, and Mr. Lilly met Col. W. D. Falck, District Engineer; Major Roy Brown, Deputy District Engineer; and Bo Copley, Chief of Flood Projects, Operations Branch and toured the flooded area at Buckeye Lake. The seepage was still present although the lake level had receded between 1 and 2 inches. The rain had ended, and the weather outlook was favorable at that time. The valley downstream from Buckeye Lake along South Fork continued to be flooded although water was receding, and the flow from the lake was over the spillway as all gates remained closed. Additional discharge could have been carried in the channel just downstream from the outlet from the lake, but further downstream the outlet creek channel is obstructed by heavy bank growth reducing the channel capacity. There was also back water in this region during the heavy runoff from the South Fork of the Licking River. Photographs taken at the State Park at Sellers Point and at the spillway on the west end of Buckeye Lake, together with aerial photographs of the area, are inclosed.

7. On 3 October 1968 Mr. Hollingsworth again visited Buckeye Lake and contacted Mr. H. F. Williams, Park Manager. The general situation of Buckeye Lake was reviewed.

ORHOP ( )
Subject: Buckeye Lake, Ohio

8. The lake level was then 1' below the crest of flash boards which control normal pool in contrast to 23" over the spillway at the crest of the May 1968 flood. The present flash boards are 10" high and were placed in the concrete spillway section about 3 years ago replacing deteriorated wood flash boards which had been about 2" higher. These flash boards are wedged in place and have not been removed. The drawdown of the lake is apparently from evaporation from the lake and from small releases through the canal gates for the U. S. Fish Hatchery at Hebron and to keep this section of canal channel filled. It has been their policy to draw ~~down~~ the lake down 30" during the winter months. This practice ~~is to be~~ was followed again this fall, with releases for drawdown ~~to begin~~ beginning on 15 November and refilling to summer lake level to begin 1 March. The lake is listed as 3300 acres surface area in state publications, but they have reported 3800 acres on their project reports. The state ~~xxx~~ owns only 40 - 50 acres of land which is used for public access points, parking, picnicking, and bathing beach. The ~~remainder~~ remaining land is in private ownership. The State Division of Parks continues to maintain the lake and control the gates. They keep a record of the lake level at a gage near the park office at the west end of the lake near Millersport. Previously this project ~~created back in 1825-26 as a canal feeder lake~~ was pperated by the Ohio Department of Public Works.

9. The inflow into the lake is from rainfall on the surrounding area. The Kirkersville feeder, at one time during canal operations, was gated so that water from South Fork could be diverted ~~thru~~ through it to the lake. These gates are no longer in existence nor is the upper end of the feeder canal open. On the night of 27-28 May the north bank of the Kirkersville feeder broke, relieving the critical condition in Buckeye Lake, which had reached within 1" of the top of the levee embankment; but the area

ORHOP (   )
SUBJECT: Buckeye Lake, Ohio

along South Fork, particularly U.S. Route 79, was flooded. The Ohio Department of Parks ~~paid for~~ 1500 grain bags and 397 tons of sand for emergency operations ~~in charge of~~ National Guard to save the levee. It was reported that 50,000 sand bags were hauled in, many of them provided by the Corps of Engineers from Marietta. The Newark National Guard salvaged the sand bags ~~not used~~ and stored them at their armory.

10. Mr. Williams, Park Manager, reported that sand bagging operations had also been required on a short section of the levee near the amusement area. This section, 150 to 200 feet in length, between the Buckeye Lake yacht club and Sayre's Marina had been reinforced ~~on both the lake and outside of the levee with~~ sand bags that still remain in place. At this point, there is an old building along the lake banks that has been used for covered boat anchorage. The old stone wall along the lake side of the fill was not extended thru this section. Although the levee was not overtopped, the unprotected banks became wet and spongy, and seepage thru it developed to the point where it was very unstable and required extensive reinforcing to protect it from failing.

11. Mr. Ned Williams, Chief Engineer, Ohio Department of Natural Resources, recently was contacted regarding their plans for remedial measures at the Buckeye Lake. Mr. Williams stated that plans are substantially completed and that the Department planned to advertise for the work shortly and hopefully could award a ~~later~~ contract in March 1969. The proposed plans are to drive sheet piling along about 8700' of levee in the vicinity of the yacht club and the amusement park. Total estimated cost would be about $250,000.

12. Mr. Williams stated that what the State plans to do will not completely solve the problem of flooding at Buckeye Lake. He stated that the Kirkersville feeder is

perhaps the biggest single problem. He felt that the total scope of the problem at Buckeye Lake was beyond the control of the State of Ohio Department of Natural Resources. He is hopeful that some federal agency can aid the State of Ohio at Buckeye Lake. He specifically mentioned the Corps of Engineers and the Soil Conservation Service.

13. It is suggested that Mr. Williams be contacted to ascertain in detail the proposed plans for remedial work. It is further suggested that the entire situation be investigated and studied to determine what effect failure of Buckeye Lake would have on areas downstream.

M. W. WOOD
Chief, Operations Division

I Incl
1. Photographs
2. Info. Folder, Buckeye Lake
3. Newspaper clipping dtd 1 Dec 1968 Columbus Dispatch, 3 tea

17 August 1990

TRIP REPORT
BUCKEYE LAKE, OHIO
Meeting with ODNR Staff
and Project Reconnaissance

1. On 28 June 1990, the following Ohio Department of Natural Resources and consultant staffs and Huntington District personnel met at Buckeye Lake, Ohio;

George E. Mills	ODNR	614-265-6723
Dan Stowers	ODNR	614-265-6956
Edward L. Frank III	Buckeye Lake State Park	614-467-2690
Doyle Hartman	Dodson - Lindblom	614-224-1251
Paul deVertenid	Dodson - Lindblom	614-224-1251
Michael P. Griffith	Dodson - Lindblom	614-224-1251
Jerry W. Phelps	COE	304-529-5231
Michael F. Spoor	COE	304-529-5514

A briefing was conducted at the Buckeye Lake State Park managers office in Millersport, Ohio. Reports and design analysis were reviewed by the Consultant, Dodson-Lindblom and Associates. Historical embankment failures, prior storm and high lake level conditions, homeowner commentary regarding possible wave swash and seepage related embankment damage, and logs of conditions observed during the period from 8 thru 14 June 1990 were reviewed. Numerous repair and rehabilitation alternatives were presented and discussions included comments regarding extents of sheet pile installations, probable embankment characteristics, and embankment and stone wall foundation conditions. It was concluded that construction of a new spillway within the dry dock area near Sellers Point and rehabilitation of the existing spillway structure are most critical priorities. It was noted that this work is scheduled for construction during the late summer and fall of 1990.

2. A limited reconnaissance was then conducted along the embankment and included reaches of sheet pile and a stone masonry wall and at tracts where cavities had been reported and/or seepage noted during and after the storm event of 8 and 9 June 1990. A list of properties where seepage was observed on 9 and 10 June and referenced tracts which were viewed on 28 June is attached. Seepage from the downstream embankment face was not encountered on 28 June 1990. Several embankment subsidence areas and cavities appear to have been formed by wave swash induced erosion at handling holes within the adjacent sheet pile wall. Depressions and cavities had also formed at locations of cracking and mortar deterioration and rock spalling in the stone masonry wall.

Depressions within the embankment crest were also noted at large tree stumps, where concrete debris had been removed, and adjacent to pipe drain installations.

3. We remain concerned about the effects of trees, including root penetration and decay, within the embankment. Excavation and random backfilling of the dam has most probably formed other areas with unsuitable embankment characteristics. The partial collapse of a trench recently advanced to effect basement wall sealing at the Leach property is noted as an example of such activities. The extent and soundness of house drainage and foundation walls within the embankment were not established. The determination that these sheet pile walls may act as an effective membrane and cutoff along the upstream face of the embankment has not been fully established. Several locations of sheet pile wall misalignment and stone masonry wall deterioration were noted.

4. It is recommended that frequent contacts with property owners together with a scheduled monitoring program be maintained to allow timely notice and proper corrective action should additional embankment deterioration occur. An interdisciplinary engineering team should reconnoiter the entire embankment at least once each year after the lake is at or below winter pool elevation. All excavations within the embankment should be properly regulated. The installation of drainage interception systems is suggested. These systems should conduct all house roof drainage away from the lake. Many houses have roof drain pipes passing through the levee to the lake. These pipes are a source of seepage, as they were not designed to be water tight. Failure of the levee could be initiated by these roof drain pipes. We concur with the proposal to remove the spillway flash boards and maintain the lake at a lower summer pool elevation. Additional investigations including far infrared scanning to define void and drainage system extents and soniscope pulse velocity measurements to better establish wall conditions should be accomplished prior to the finalization of a recommended design for increasing the embankment to a minimum elevation of 896.5. Embankment reconstruction may be necessary.

5. We are unaware of an authority that would allow the Corps of Engineers to participate in either construction or rehabilitation at the Buckeye Lake State Park.

JERRY W. PHELPS, P.E.
Chief, Soils Section

MICHAEL F. SPOOR, E.G.
Geotechnical Branch

Buckeye Lake Embankment
Seepage Locations

ODNR Reconnaissance 10 June 90	COE Reconnaissance 9,10 June 90	ODNR/COE Reconnaissance 28 June 90
12512 West Bank		12512 West Bank
12524 West Bank		12524 West Bank
12544 West Bank		
12624 West Bank		
12646 West Bank		12646 West Bank
12768 West Bank		12692 West Bank
12670 West Bank		12738 West Bank
12786 West Bank		12786 West Bank
12820 West Bank		
12934 West Bank		
12970 West Bank		
13038 West Bank		
13216 West Bank		
13244 West Bank		
13304 West Bank		
13436 West Bank		
13444 West Bank		
13464 West Bank		
Lakeside	Lakeside	
3301 Shepard	3301 Shepard	
Smittys Tavern and Adjacent Homes (2)	Smittys Tavern and Adjacent Homes (2)	Smittys Tavern and Adjacent Homes (2)
4259 North Bank	4259 North Bank	
4265 North Bank	4313 North Bank	
4267 North Bank	4321 North Bank	
4345 North Bank	4345 North Bank	4345 North Bank
4445 North Bank	4445 North Bank	
4721 North Bank	4721 North Bank	
4767 North Bank	4767 North Bank	
4789 North Bank	4789 North Bank	
4929 North Bank		
5015 North Bank	5015 North Bank	
5121 North Bank	5121 North Bank	

Attachment
Number 1

26 June 1990

TRIP REPORT
BUCKEYE LAKE, OHIO

1. On 9 and 10 June 1990, Huntington District, Operations and Readiness Division and Engineering Division staff were mobilized to Buckeye Lake, Ohio to monitor project conditions, provide general technical advice, and to participate in emergency response to address possible dam failure conditions at this project. During the evening of 8 June 1990, and continuing for a six hour period, three and a half to four inches of rain fell within the Buckeye Lake area. As a result of this precipitation, the Kirkersville, Ohio feeder canal which flows to Buckeye Lake failed by embankment overtopping at two locations. At Palmer Road, breaching of the canal left embankment and related downcutting to approximately three feet below the canal invert resulted in a diversion of flows from the canal towards I-70 and State Route 79. These canal breaches most probably diverted flows greater than maximum possible spillway discharges from Buckeye Lake and thus prevented probable overtopping of the dam. On 9 June 1990, during spillway discharges of approximately 1000 cubic feet per second, the lake rose to elevation 893.74 or less than three inches from dam crest. It was noted that during these discharges, the waste weir run was approximately bank full. The dam and this spillway structure which was completed in 1910 were determined to be inadequate in a report prepared by the United States Corps of Engineers in 1939. Reports by General Analytics in 1978 and Dodson-Lindblom and Associates in 1987 also conclude that the spillway is deficient and requires replacement. We understand that an additional uncontrolled spillway at the old drydock location is scheduled for construction this year. Rehab of the existing spillway and other embankment modifications are apparently deffered due to funding limitations. On 9, 10 June 1990 staff noted that a 24 inch pipe was discharging from the lake into the abandoned Ohio and Erie Canal and thence to the Hebron, Ohio fish hatchery.

2. The four mile long dam extends from Liebs Island near Middleport, Ohio along the north side of Buckeye Lake to Crane Lake near the community of Buckeye Lake, Ohio. The embankment constructed between 1825 and 1832 presently has crest elevations which vary from 894 to 897. The dam embankment consists of clay silt placed on lacustrine deposits and extending along the downstream face on a slope of one vertical on two horizontal to approximately a fifteen foot height. The width of the dam crest is approximately twenty feet and on the upstream or lakeside, the embankment has been retained by a stone masonary wall extending

along virtually the entire length of the dam. In 1832 the dam embankment failed and was repaired with 10,000 wagon loads of coarse stone. Because of stone masonary wall deterioration, sheet pile walls were added along most of the length of the dam for additional shore line protection and to restrict seepage through the embankment.

3. Since completion of the project, as a feeder lake for the Ohio and Erie Canal, significant encroachment has occurred by excavation into the embankment to construct basement walls and drainage systems for homes located along nearly the entire length of the embankment. Drains also discharge to the lake at elevations approximately three feet below the summer pool at 891.75. Some handling holes and tie back holes were noted within the sheet pile wall systems. Large trees and rooted stumps were observed along the dam crest and within the downstream embankment face. Seepages observed at the downstream embankment face included house foundation and wall areas, drains, sumps and wells, and excavations. Some movement of sand size material (piping) was observed in the basement of the Leach residence. COE personnel suggested sandbagging to counterbalance the head. ODNR personnel had the National Guard sandbag as requested. Dam embankment seepages were encountered within Lakeside, Sellers Point, Black Diamond Point, and the Amusement Park. Identification of all seepage areas was not possible because of discharge from an adjacent storm sewer and inundation of portions of the toe of dam by waters from an adjacent swamp. Ohio Department of Natural Resources personnel requested that property owners cease pumping flooded basements for several hours on 9 June 1990. ODNR, together with the Ohio Natural Guard effected sandbagging along a limited reach of low dam crest to prevent possible overtopping. Sandbag placement was questionable and proper sandbagging detail diagrams were provided to ODNR on 10 June 1990 by Dave Thomas, COE (Operations Division).

4. Suggested immediate remedial actions for Buckeye Lake Dam should include welding of steel plates over handling holes in the sheet pile wall to address washing out of granular bank fill and to prevent entry of lake water at these openings. Crest area drains and homesite discharges to the lake should be relocated to the downstream embankment face.

5. House foundations and walls and drainage systems should be evaluated. A storm sewer near the dam and within the North Bank area should be scanned and sealed and reconstructed as necessary. Failed segments of the Kirkersville feeder canal embankment should be reconstructed in a permanent manner. Drift accumulations on the South Fork of the Licking River within a reach bounded by State Route 79, US Route 40, and I-70 should be removed. The construction of an adequate spillway for Buckeye Lake is of critical importance and should be accomplished as soon

as possible. Additional evaluations and analysis of the Buckeye Lake Dam to insure structural stability from both the mechanisms of slope stability and internal erosion (piping failure) should be performed as soon as possible. Remedial measures would most likely be required as a result of these evaluations.

JERRY W. PHELPS, P.E.

DAVID F. MEADOWS, P.E.

MICHAEL F. SPOOR, E.G.

CF:
CEORH-OR
CEORH-ED
CEORH-ED-H
CEORH-ED-A
CEORH-ED-G
CEORH-ED-GD
CEORH-ED-GS
CEORH-ED-GG

APPENDIX G
ODNR-USACE Buckeye Lake Support Agreement

SUPPORT AGREEMENT

1. AGREEMENT NUMBER *(Provided by Supplier)*	2. SUPERSEDED AGREEMENT NO. *(If this replaces another agreement)*	3. EFFECTIVE DATE *(YYYYMMDD)*	4. EXPIRATION DATE *(May be "Indefinite")*
		20140417	Indefinite

5. SUPPLYING ACTIVITY	6. RECEIVING ACTIVITY
a. NAME AND ADDRESS Ohio Department of Natural Resources 2045 Morse Road Columbus, OH 43229-6693	a. NAME AND ADDRESS U.S. Army Corps of Engineers, Huntington District 502 8th Street Huntington, WV 25701-20170
b. MAJOR COMMAND	b. MAJOR COMMAND

7. SUPPORT PROVIDED BY SUPPLIER

a. SUPPORT *(Specify what, when, where, and how much)*	b. BASIS FOR REIMBURSEMENT	c. ESTIMATED REIMBURSEMENT
The U.S. Army Corps of Engineers, Huntington District will provide the Ohio Department of Natural Resources with an assessment of the existing conditions of Buckeye Lake Dam, as well as make recommendations for the repair, operation, and maintenance of the dam. Specific efforts include participating in technical meetings with ODNR staff, conducting field visits, and reviewing technical documents including the ODNR's continuing site evaluations, assessments of foundation conditions and design alternatives. The Huntington District also will provide engineering support to the ODNR during public meetings and technical briefings. It shall submit for review a draft report to the ODNR summarizing its evaluation of the dam's stability and related repair requirements, and its determination as to whether or not more detailed analysis is required. Following the receipt of the ODNR's written comments on the draft report, the District will provide written responses to the ODNR and revise the report, if necessary, and submit it to the ODNR in final form. Upon execution of the Support Agreement and transfer of funds the District shall accomplish the work within 6 months.	Upon execution of this Support Agreement, the ODNR shall advance funds to the Huntington District. The District shall draw from the funds incrementally as work progresses and the balance of any remaining funds will be returned to the ODNR.	$140,000

ADDITIONAL SUPPORT REQUIREMENTS ATTACHED: ☐ YES ☐ NO

8. SUPPLYING COMPONENT		9. RECEIVING COMPONENT	
a. COMPTROLLER SIGNATURE: [signature]	b. DATE SIGNED: 4-17-14	a. COMPTROLLER SIGNATURE: [signature]	b. DATE SIGNED: 4/14/14
c. APPROVING AUTHORITY		c. APPROVING AUTHORITY	
(1) TYPED NAME: Crystal Adkins		(1) TYPED NAME: Thomas Johnston	
(2) ORGANIZATION: Resource Management Office	(3) TELEPHONE NUMBER: (304) 399-5959	(2) ORGANIZATION: Ohio Department of Natural Resources	(3) TELEPHONE NUMBER
(4) SIGNATURE: [signature]	(5) DATE SIGNED: 4/21/14	(4) SIGNATURE: [signature]	(5) DATE SIGNED: 4/14/14

10. TERMINATION *(Complete only when agreement is terminated prior to scheduled expiration date.)*

a. APPROVING AUTHORITY SIGNATURE	b. DATE SIGNED	c. APPROVING AUTHORITY SIGNATURE	d. DATE SIGNED

11. **GENERAL PROVISIONS** *(Complete blank spaces and add additional general provisions as appropriate: e.g., exceptions to printed provisions, additional parties to this agreement, billing and reimbursement instructions.)*

a. The receiving components will provide the supplying component projections of requested support. *(Significant changes in the receiving component's support requirements should be submitted to the supplying component in a manner that will permit timely modification of resource requirements.)*

b. It is the responsibility of the supplying component to bring any required or requested change in support to the attention of the Ohio Department of Natural Resources' Project Manager prior to changing or cancelling support.

c. The component providing reimbursable support in this agreement will submit statements of costs to: the Ohio Department of Natural Resources' Project Manager.

d. All rates expressing the unit cost of services provided in this agreement are based on current rates which may be subject to change for uncontrollable reasons, such as legislation, DoD directives, and commercial utility rate increases. The receiver will be notified immediately of such rate changes that must be passed through to the support receivers.

e. This agreement may be cancelled at any time by mutual consent of the parties concerned. This agreement may also be cancelled by either party upon giving at least 180 days written notice to the other party.

This agreement also may be modified at any time by mutual consent of the parties.

f. In case of mobilization or other emergency, this agreement will remain in force only within supplier's capabilities.

ADDITIONAL GENERAL PROVISIONS ATTACHED: ☐ YES ☐ NO

12. **SPECIFIC PROVISIONS** *(As appropriate: e.g., location and size of occupied facilities, unique supplier and receiver responsibilities, conditions, requirements, quality standards, and criteria for measurement/reimbursement of unique requirements.)*

Support Agreement (1)

Pursuant to the Memorandum of Agreement (MOA) between the Ohio Department of Natural Resource (ODNR) and the Department of the Army (DA), U.S. Army Corps of Engineers, Huntington District, which was executed on March 24, 2014.

The DA will provide the ODNR with an assessment of the safety of Buckeye Lake Dam as well as the proposed repair design, operation, maintenance and owner/operator concerns for the Buckeye Lake Dam.

ADDITIONAL SPECIFIC PROVISIONS ATTACHED: ☐ YES ☐ NO

13. ADDITIONAL PROVISIONS *(Use this space to continue general and/or specific provisions, as needed.)*

Targeted Technical Review for Priority Repairs (Deliverables): Buckeye Lake Dam

Tasks:
a. Technical meeting with ODNR
b. Field site visit
c. Stakeholder input meeting
d. Review of related technical documents
e. Status meeting
f. Draft report to ODNR addressing the condition of the dam, repair approach and whether or not a more detailed analysis is needed
g. ODNR comments back to USACE
h. Final draft to ODNR

Timeframe for Deliverables (6 months) following receipt of funds

Projected Cost to the DA to provide deliverables - DA projects the cost to be $140,000. ODNR shall provide the funds in advance of beginning the study.

The Huntington District Project Manager will provide the ODNR Project Manager with monthly reports describing accomplishments during the month, a breakdown of expenditures, a schedule update, activities planned for the following month, and any significant issues or concerns,

APPENDIX H
List of Consultant Reports

Dodson-Lindblom Associates, 1987. *Buckeye Lake Dam: Spillway Adequacy and Embankment Stability and Seepage Study*. Prepared for Ohio Department of Natural Resources.

Dodson-Lindblom Associates, 1995. *Buckeye Lake Dam, Fairfield and Licking Counties, Ohio: Evaluation of Existing Sheet Piling*. Prepared for Ohio Department of Natural Resources.

Dodson-Lindblom Associates, 1996. *DLA's Responses to Gardner and Associates' Report*. Prepared for Ohio Department of Natural Resources.

DLZ Ohio, 2003. *Preliminary Design Report, Dam Improvements, Buckeye Lake State Park*. Prepared for Ohio Department of Natural Resources.

Fuller, Mossbarger, Scott, and May Engineers, 2003.*South Fork Licking River Watershed Study.* Prepared for Ohio Department of Natural Resources.

GAI Consultants, 1978. *Buckeye Lake Dam, Licking, Fairfield, and Perry Counties, Ohio.* Phase I Inspection Report, National Program of Inspection of Non-Federal Dams. Prepared for the U.S. Army Corps of Engineers, Pittsburgh District.

Gardner, W.S. and Associates, 1995. *Buckeye Lake Dam, Review of Embankment Stability,* Overview, Buckeye Lake Dam, ODNR Phase III. Prepared for Buckeye Lake Association.

Gardner, W.S. and Associates, 1996. Buckeye Lake: Spillway adequacy. Prepared for the Save the Lake Committee.

Rizzo, Paul C. Associates, 1997. *Report: Buckeye Lake Dam Stability Study, Buckeye Lake State Park, Fairfield, Licking, and Perry Counties, Ohio*, Project No. 95-1590. Prepared for Ohio Department of Natural Resources.

Snyder, T.D., 2002. *Trees on the Dam at Buckeye Lake.* Prepared for the Save the Lake Committee.

APPENDIX I
Ohio Administrative Code – Chapter 1501:21-13 Classification and Design of Dams, Dikes, and Levees

Chapter 1501:21-13 Classification and Design of Dams, Dikes, and Levees

1501:21-13-01 Classification of dams.

(A) For the purpose of this chapter, dams shall be divided into four classes, which shall be known as class I, class II, class III, and class IV. The chief shall establish a dam's appropriate classification by using the following criteria as a guideline. Such classification shall be established by the chief during the preliminary review described by rule 1501:21-5-02 of the Administrative Code or during the periodic inspection described by rule 1501:21-21-01 of the Administrative Code. The chief reserves the right to reclassify any dam at any time as a result of circumstances not in existence or not known at the time said dam was initially classified.

(1) Dams having a total storage volume greater than five thousand acre-feet or a height of greater than sixty feet shall be placed in class I. A dam shall be placed in class I when sudden failure of the dam would result in one of the following conditions.

(a) Probable loss of human life.

(b) Structural collapse of at least one residence or one commercial or industrial business.

(2) Dams having a total storage volume greater than five hundred acre-feet or a height of greater than forty feet shall be placed in class II. A dam shall be placed in class II when sudden failure of the dam would result in at least one of the following conditions, but loss of human life is not probable.

(a) Disruption of a public water supply or wastewater treatment facility, release of health hazardous industrial or commercial waste, or other health hazards.

(b) Flooding of residential, commercial, industrial, or publicly owned structures. At the request of the dam owner, the chief may exempt dams from the criterion of this paragraph if the dam owner owns the potentially affected property.

(c) Flooding of high-value property. At the request of the dam owner, the chief may exempt dams from the criterion of this paragraph if the dam owner owns the potentially affected property.

(d) Damage or disruption to major roads including but not limited to interstate and state highways, and the only access to residential or other critical areas such as hospitals, nursing homes, or correctional facilities as determined by the chief.

(e) Damage or disruption to railroads or public utilities.

(f) Damage to downstream class I, II or III dams or levees, or other dams or levees of high value. Damage to dams or levees can include, but is not limited to, overtopping of the structure. At the request of the dam owner, the chief may exempt dams from the criterion of this paragraph if the dam owner owns the potentially affected property.

(3) Dams having a total storage volume greater than fifty acre-feet or a height of greater than twenty-five feet shall be placed in class III. A dam shall be placed in class III when sudden failure of the dam would result in at least one of the following conditions, but loss of human life is not probable.

(a) Property losses including but not limited to rural buildings not otherwise described in paragraph (A) of this rule, and class IV dams and levees not otherwise listed as high-value property in paragraph (A) of this rule. At the request of the dam owner, the chief may exempt dams from the criterion of this paragraph if the dam owner owns the potentially affected property.

(b) Damage or disruption to local roads including but not limited to roads not otherwise listed as major roads in paragraph (A) of this rule.

(4) Dams which are twenty-five feet or less in height and have a total storage volume of fifty acre-feet or less may be placed in class IV. When sudden failure of the dam would result in property losses restricted mainly to the dam and rural lands, and loss of human life is not probable, the dam may be placed in class IV. Class IV dams are exempt from the permit requirements of section 1521.06 of the Revised Code pursuant to paragraph (C) of rule 1501:21-19-01 of the Administrative Code.

(B) All pertinent information including any unusual circumstances shall be considered by the chief in establishing an appropriate classification for a dam. Probable future development of the area downstream from the dam that would be affected by its failure shall be considered. Completed downstream hazard mitigation such as acquisition, removal or protection of downstream property may also be considered. However, the above criteria shall in no way preclude the chief's requirement of greater safety in the interest of life, health, or property.

Effective: 05/23/2010
R.C. 119.032 review dates: 03/08/2010 and 05/15/2015
Promulgated Under: 119.03
Statutory Authority: 1521.06
Rule Amplifies: 1521.06 , 1521.061
Prior Effective Dates: 4-15-72; 10-15-81; 12-9-99; 1-16-05

1501:21-13-02 Design flood for dams and determination of critical flood.

The magnitude of the design flood for each dam shall be set by the chief and determined from actual streamflow and flood frequency records or from synthetic hydrologic criteria based on current publications prepared by the division, the United States army corps of engineers, the United States geological survey, the national oceanic and atmospheric administration, or others acceptable to the chief.

(A) The minimum design flood will be:

(1) For class I dams, the probable maximum flood or the critical flood;

(2) For class II dams, fifty percent of the probable maximum flood or the critical flood; and,

(3) For class III dams, twenty-five percent of the probable maximum flood or the critical flood.

(B) Selection of a critical flood as the design flood is acceptable. The design for the critical flood shall be for site-specific conditions and based on a quantitative and relative impact analysis of the downstream critical routing reach. In determining the critical flood, the spillway and storage capacity for the dam shall be designed so that there will be no additional potential for loss of life, health or property in the critical routing reach from overtopping failure of the dam when compared to the potential for loss of life, health or property caused by the flood in the absence of a dam overtopping failure.

(1) Where the incremental depth of flow between the failure and non-failure floods is 2.0 feet or greater, or the product of the average floodplain flow velocity (in feet per second) and the incremental flood depth (in feet) is greater than 7.0, additional potential for loss of life, health or property in the critical routing reach is expected.

(2) If the incremental depth of flow between the failure and non-failure floods is less than 2.0 feet, and the product of the average floodplain flow velocity (in feet per second) and the incremental flood depth (in feet) is less than 7.0, it does not necessarily mean that the critical flood has been determined. Further investigation will be required to determine that no additional potential for loss of life, health or property will occur.

(C) The minimum critical flood shall be as follows:

(1) Forty per cent of the probable maximum flood for a class I dam,

(2) Twenty per cent of the probable maximum flood for a class II dam, and

(3) The one-hundred-year flood for a class III dam.

(D) The owner or applicant shall submit to the chief, in writing, a request for consideration of the critical flood as the design flood. This request shall be accompanied by appropriate supporting calculations. The chief will not consider risk assessment based upon planned evacuation, probability of inhabitation, or monetary recovery of property damage.

(E) If downstream hazard conditions change at any time during the life of the structure, a reevaluation of the critical routing reach and modification of the critical flood may be required by the chief.

R.C. 119.032 review dates: 03/08/2010 and 03/05/2015
Promulgated Under: 119.03
Statutory Authority: 1521.06
Rule Amplifies: 1521.06 , 1521.061 , 1521.062
Prior Effective Dates: 12-9-99; 1-16-05

1501:21-13-03 Spillway design, general requirements.

(A) Every dam shall have a spillway system which will safely operate during the design flood without endangering the safety of the dam.

(B) Each spillway shall include a means of dissipating the energy of flow without endangering the safety of the dam.

(C) The capacity of the spillway system shall be equal to the peak inflow rate of the design flood unless the applicant has demonstrated by flood routing procedures that the dam will safely pass the design flood with the spillway system.

(D) Every upground reservoir shall have an overflow or other device to preclude overfilling the reservoir during normal filling operations. Local watershed drainage into the reservoir must also be included in the design of the overflow device if applicable.

(1) The elevation of an overflow device shall be no more than 0.5 foot above the designed maximum operating pool level of the reservoir.

(2) A device other than an overflow that is used to preclude overfilling must prevent the reservoir from rising 0.5 foot above the designed maximum operating pool level.

R.C. 119.032 review dates: 03/08/2010 and 03/05/2015
Promulgated Under: 119.03
Statutory Authority: 1521.06
Rule Amplifies: 1521.06 , 1521.061
Prior Effective Dates: 4-15-72; 10-15-81; 12-9-99; 1-16-05

1501:21-13-04 Pipe conduit spillways, general requirements.

(A) All pipe conduits shall convey flow at the maximum design velocity without damage to the interior surface.

(B) Seepage control devices acceptable to the chief shall be installed. .

(C) Adequate allowances shall be incorporated in the design to compensate for settlement and possible elongation of the pipe conduit.

(D) An anti-vortex device that is satisfactory to the chief shall be installed at the intake of all pipe and riser spillway systems. Anti-vortex devices may also be required for other spillway types as necessary to improve the performance of the spillway.

(E) A trash rack that is satisfactory to the chief shall be installed at the intake of all pipe and riser and/or drop inlet type spillway systems to prevent clogging the pipe conduit. Trash rack devices may also be required for other spillway types as necessary to ensure the performance of the spillway.

(F) An emergency overflow spillway shall be required, except when specifically exempted by the chief. A vegetated or unlined emergency spillway will be approved by the chief, but only after the applicant has demonstrated that it will pass the design flood without jeopardizing the safety of the structure. The average frequency of use for a vegetated or unlined emergency spillway must be predicted to be less than the following criteria unless otherwise approved by the chief:

(1) Once in fifty years for class I dams;

(2) Once in twenty-five years for class II dams; and

(3) Once in ten years for class III dams.

(G) The pipe conduit shall be of such size as to remove from the reservoir within ten days following passage of the design flood peak at least eighty percent of the water temporarily detained in the reservoir above the elevation of the primary (principal) spillway.

R.C. 119.032 review dates: 03/08/2010 and 03/05/2015
Promulgated Under: 119.03
Statutory Authority: 1521.06
Rule Amplifies: 1521.06 , 1521.061 , 1521.062
Prior Effective Dates: 4-15-72; 10-15-81; 12-9-99; 1-16-05

1501:21-13-05 Pipe conduit spillways, special requirements.

(A) Pipe conduits shall be of such design as to safely support the total external loads and shall convey flow without rupture or leakage.

(B) Unless otherwise approved by the chief, the minimum inside dimension of the pipe conduit shall be:

(1) Twenty-four inches for class I and class II dams.

(2) Eighteen inches for class III dams.

(C) All pipes shall have the ability to resist corrosion from surrounding soils and impounded materials based on current acceptable testing standards.

(D) Corrugated metal pipe shall not be used.

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1501:21-13-06 Requirements for drains and other pipe conduits.

(A) Dams in class I, class II, and class III shall include a device to permit draining the reservoir within a reasonable period of time as approved by the chief. Pipe conduits used for lake drains shall have a minimum inside diameter of not less than four inches.

(B) Valves or sluice gates in pipe conduits shall be installed upstream from the centerline of the dam unless otherwise approved by the chief.

(C) All pipe conduits used as drains, water supply lines, or other pressure-flow conduits, regardless of classification of the dam, shall meet the requirements of paragraphs (A), (B), (C), and (E) of rule 1501:21-13-04 of the Administrative Code and paragraphs (A), (C), and (D) of rule 1501:21-13-05 of the Administrative Code.

(D) When the drain outlets into a pipe-conduit upstream from the centerline of the dam, seepage control devices may be omitted from the drain.

(E) All new dam construction shall include a bulkhead for the outlet works unless specifically exempted by the chief.

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1501:21-13-07 Freeboard requirements for dams.

Sufficient freeboard shall be provided to prevent overtopping of the top of the dam due to passage of the design flood and other factors including, but not limited to, ice and wave action. The chief may approve a lower freeboard requirement if the dam is armored against overtopping erosion.

(A) For class I and class II dams that are upground reservoirs, the minimum elevation of the top of the dam shall be at least five feet higher than the elevation of the designed maximum operating pool level unless otherwise approved by the chief.

(B) For class III dams that are upground reservoirs, the minimum elevation of the top of the dam shall be at least three feet higher than the elevation of the designed maximum operating pool level unless otherwise approved by the chief.

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1501:21-13-08 Additional design requirements for dams.

(A) The safety factors for the various elements of the dam shall conform to good engineering practice as approved by the chief. The safety factors and the design standards that are used by the applicant shall agree with the approved design assumptions.

(B) Inspection devices such as piezometers, settlement platforms, stand-pipes, tell-tale stakes, monitoring weirs, inclinometers, and permanent bench marks, may be required by the chief for the division's and the owner's use in the inspection of the structure during and after completion of construction.

(C) The chief may require dams to have a staff gauge to allow monitoring of lake levels within a range from the lower of five feet below normal pool or the normal drawdown level, to the top of dam elevation. The design of the staff gauge will be reviewed and approved by the chief.

(D) Grass vegetation or other vegetation of similar properties are the only acceptable vegetative covers for earthen dam embankment surfaces or vegetated earth spillways. Trees and brush are not acceptable surface covers.

(E) The applicant shall demonstrate to the satisfaction of the chief that the structure will be consistent and in accordance with all applicable state and local floodplain regulations and requirements.

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1501:21-13-09 Classification of levees.

(A) For the purpose of this chapter, levees shall be divided into four classes, which shall be known as class I, class II, class III, and class IV. The chief shall establish a levee's appropriate classification by using use the following criteria as a guideline. Such classification shall be established by the chief during the review of the preliminary design report described by rule 1501:21-5-02 of the Administrative Code or during the periodic inspection described by rule 1501:21-21-01 of the Administrative Code. The chief reserves the right to reclassify any levee at any time as a result of circumstances not in existence or not known at the time said levee was initially classified.

(1) A levee shall be placed in class I when sudden failure of the levee would result in one of the following conditions.

(a) Probable loss of human life.

(b) Structural collapse of at least one residence or one commercial or industrial business.

(2) A levee shall be placed in class II when sudden failure of the levee would result in at least one of the following conditions, but loss of human life is not probable.

(a) Disruption of a public water supply or wastewater treatment facility, or other health hazards.

(b) Flooding of residential, commercial, industrial, or publicly owned structures.

(c) Flooding of high-value property.

(d) Damage or disruption to major roads including but not limited to interstate and state highways, and the only access to residential or other critical areas such as hospitals, nursing homes, or correctional facilities as determined by the chief.

(e) Damage or disruption to railroads or public utilities.

(3) A levee shall be placed in class III when sudden failure of the levee would result in at least one of the following conditions, but loss of human life is not probable.

(a) Property losses including but not limited to rural buildings not otherwise described in paragraph (A) of this rule.

(b) Damage or disruption to local roads including but not limited to roads not otherwise listed as major roads in paragraph (A) of this rule.

(4) A levee having a height of not more than three feet shall be placed in class IV. When sudden failure of the levee would result in property losses restricted mainly to the levee and to the owner's property or to rural lands, and loss of human life is not probable, the levee may be placed in class IV. Class IV levees are exempt from the permit requirements of section 1521.06 of the Revised Code pursuant to paragraph (C) of rule 1501:21-19-01 of the Administrative Code.

(B) All pertinent information including any unusual circumstances shall be considered by the chief in establishing an appropriate classification for a levee. Probable future development of the area adjacent to the levee shall be considered. However, the above criteria shall in no way preclude the chiefs requirement of greater safety in the interest of life, health, and property.

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1501:21-13-10 Levees, general requirements.

(A) Future development of areas upstream, downstream, and adjacent to the levee shall be considered in the design.

(B) The levee shall operate safely during all floods up to the design flood elevation.

(C) Provisions for drainage of the area protected by the levee shall be incorporated into the structure. Measures shall be included to prevent flooding of this area by backflow through the drainage system.

(D) The levee must be protected from or designed to prevent erosive velocities along the structure and its foundation.

(E) Grass vegetation or other vegetation of similar properties are the only acceptable vegetative covers for earthen levee embankment surfaces. Vetch, trees and brush are not acceptable surface covers.

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1501:21-13-11 Levees, special requirements.

(A) Hydraulic analyses shall be conducted to determine flood elevations for stream reaches affected by the construction of a levee and in accordance with rule 1501:21-13-10 of the Administrative Code. The analyses must provide flood depth and velocity data during the one-hundred-year, twenty-five-year, and five-year flood events, and for the top-of-levee flood event. For construction of new levees, the flood depths and velocities must be determined with and without the levee. The impact of increased flood depths and velocities on property and structures must be provided.

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1501:21-13-12 Design flood for levees.

(A) The design flood shall be established by the chief in concert with the applicant's desired level of protection, but with the utmost interest in safeguarding life, health, and property. For class I levees, the minimum design flood will be the one-hundred-year flood or the critical flood. The design for the critical flood shall be for site-specific conditions and based on a quantitative and relative impact analysis of the protected area. In determining the critical flood, the levee shall be designed so that there will be no additional potential for loss of life, health or property from overtopping failure of the levee when compared to the potential for loss of life, health or property caused by the flood in the absence of a levee overtopping failure.

(B) The magnitude of the design flood shall be determined from actual streamflow and flood frequency records or from synthetic hydrologic criteria based on current publications prepared by the division, the national oceanic and atmospheric administration (NOAA), the United States army corps of engineers, the United States geological survey, or others specifically approved by the chief.

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1501:21-13-13 Freeboard requirements for levees.

(A) For levees in class I, the minimum elevations of the top of the levee shall be at least three feet higher than the maximum adjacent water surface elevations during passage of the design flood. The chief may approve a lower freeboard requirement with acceptable documentation.

(B) For levees in class II and class III, the minimum elevations of the top of the levee shall be two feet higher than the maximum adjacent water surface elevations during passage of the design flood.

(C) Where special conditions of severe frost damage, ice damage, stream obstruction, wave action, or impact of other structures may occur, the chief may require elevations higher than required in paragraph (A) of this rule.

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1501:21-13-14 Additional design requirements for levees.

(A) The safety factors of the various elements of the levee shall conform to good engineering practice as approved by the chief. The safety factors and the design standards that are used by the applicant shall agree with the approved design assumptions.

(B) Design references that are used shall be cited in the information that is submitted to the chief.

(C) Inspection devices, which include but are not necessarily restricted to settlement platforms, tell-tale stakes, inclinometers and permanent bench marks, may be required by the chief for the division's and the owner's use in the inspection during and after completion of construction.

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