Spillway Capacity Report

Wambold Dam
Kroll Dam

Prepared for:

Eagle Spring Lake Management District

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Spillway Capacity Report

Eagle Spring Lake
Eagle, Wisconsin

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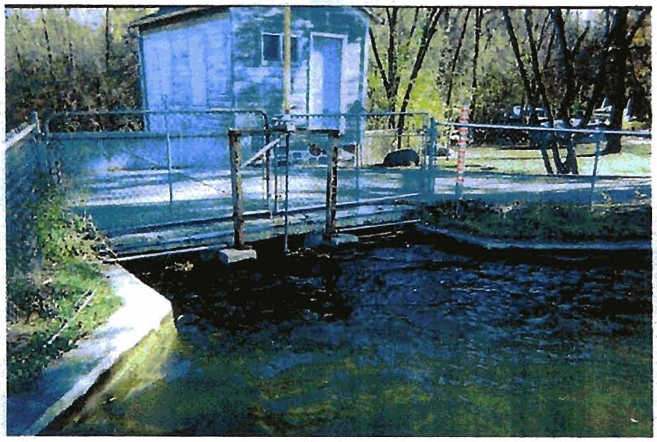
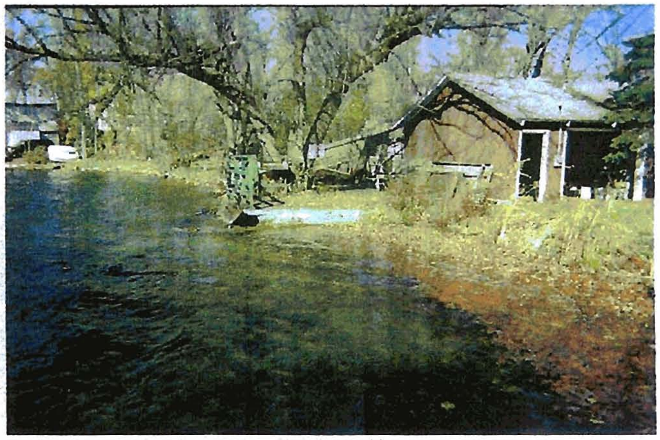
1.0 Introduction

Eagle Spring Lake is approximately 311 acres with a maximum depth of 12 feet and a mean depth of about 4 feet. The Mukwonago River enters the lake from the south and is the major inflow into the lake. Lake level and outflow is controlled by two outlet structures – the Wambold Dam operated by control gate and a former mill race (regarded as Kroll Dam), located in the northeast corner of Eagle Spring Lake, Town of Eagle, Waukesha County, Wisconsin.



Wambold Dam



Kroll Dam

In July 1997, the Department of Natural Resources (DNR) completed an inspection of the Wambold Dam to identify its hazard class rating. The Dam Safety Inspection Report indicates the dam hazard rating for the Wambold Dam as Class III or high hazard. This is based on preliminary flood flow estimates and map surveillance. The hazard rating was completed as required by Wisconsin Administrative Code NR 333.04 and reflects the downstream development that could be affected by a failure of the dam and floodplain zoning in place below the dam. The report indicated that a dam failure analysis be performed by an engineer to verify the above rating by DNR.

In late 2000, Eagle Spring Lake Management District retained Graef, Anhalt, Schlomemer & Associates, Inc. (GAS) to perform a Dam Failure Analysis and develop an Emergency Action Plan (EAP) for the Wambold and Kroll Dams. The results of the analysis confirmed the dam is a high hazard.

The DNR approved the dam failure analysis and assigned the dam a high hazard rating in August 2002. The high hazard rating was set due to the lack of zoning within the dam failure floodplain (hydraulic shadow) downstream of the dam. As a dam with a high hazard, the dam must be capable of passing the 1000-year flood without overtopping. Currently, the dam is unable to safely pass the 1000-year flood.

There are two residences within the hydraulic shadow downstream of the dam that would be inundated should the dam fail. However, the two homes are not inundated to a depth greater than 2 feet. According to the DNR approval letter, the dam could be assigned a significant hazard rating upon written request and proof of zoning within the hydraulic shadow and a demonstration that the dam structure is capable of passing the 500-year flood without overtopping. In early 2004, new zoning maps amended the FEMA approved 100-year floodplain boundary to include the dam failure analysis.

The Eagle Spring Lake Management District has retained Ayres Associates to evaluate the 500-year flood spillway capacity of the Wambold and Kroll Dams to complete the process necessary to move the dam from a high hazard rating to a significant hazard rating.

Project contacts are:

Eagle Spring Lake Management District		Wisconsin DNR		Ayres Associates
Tom Day, Chairman		William Sturtavant		Kristine Anderson, PE
				Matthew Maederer, EIT

Table 1 Project Contacts

2.0 Existing Hydrologic Information

In reviewing the hydrologic information available from the GAS study, SEWRPC, and the DNR, there appears to be some conflicting data. Various studies performed by FEMA, SEWRPC, and GAS show differing discharge-frequency data. The hydrologic analysis included in the dam failure study has been approved by the Wisconsin Department of Natural Resources (WDNR) and therefore provides the basis for design. However, due to the discrepancies, a review of the hydrologic analyses is warranted.

In the Dam Safety Inspection Report, the DNR estimated the 1000-year inflow to be approximately 670 cfs for Eagle Spring Lake. This was based on the best contour maps available at the time for determining the drainage area.

SEWRPC calculated the 100-year recurrence interval inflow and outflow tabular hydrographs for Eagle Spring Lake using the September 20, 1967, version of the US Soil Conservation Service (SCS) TR-20 computer program and the lake elevation-volume-discharge relationship used for hydrograph routing. SEWRPC calculated a 100-year inflow for the lake as 681 cfs.

Due to the closeness of the DNR 1000-year flow and the SEWRPC 100-year flow, GAS performed a rainfall-runoff analysis to determine a 1000-year flow value as a check of the existing information. To calculate the 1000-year flow, the 1000-year 24-hour storm rainfall value must be computed. GAS used the Rainfall Frequency Atlas of the Midwest, Bulleting 71; Illinois State Water Survey, 1992, to calculate a 24-hour storm rainfall value. Using Pondpac software, the TR-20 hydrology information provided by SEWRPC, and information from Bulleting 71, GAS calculated the 1000-year inflow for the dam.

2.1 Inflow Analysis

The following table is a breakdown of all the existing inflow data for the Eagle Spring Lake.

PEAK INFLOW INTO EAGLE SPRING LAKE			
	WDNR	SEWRPC	GAS
Q_{100}(cfs)	N/A	681	757
Q_{1000}(cfs)	670	N/A	2302

(cfs) cubic feet per second

Table 2 Peak Inflow Results

To try to rectify the discrepancies in the flow values calculated by the DNR, SEWRPC, and GAS, a new inflow analysis was completed. SEWRPC used a weighted curve number (CN) of 60 and a time of concentration (Tc) of 30 hours. The watershed covers an area of 21 square miles. The existing hydrology was adopted by the WDNR in 2001.

After checking the curve number and time of concentration, the largest discrepancy appeared to be the rainfall data. SEWRPC used rainfall data that was gathered by the Commission. To be conservative in our approach, Ayres Associates used Bulletin 71 rainfall data and extrapolated the results using probability paper to achieve rainfall depths for the 500-yr and the 1000-yr events. Rainfall results are listed below.

	SEWRPC	Bulletin 71
2-yr event (in)	2.57	2.70
5-yr event (in)	3.14	3.33
10-yr event (in)	3.62	3.86
25-yr event (in)	4.41	4.66
50-yr event (in)	5.11	5.38
100-yr event (in)	5.88	6.24
500-yr event	7.07	7.40
1000-yr event (in)	7.66	8.00

Table 3 Rainfall Data

A new rainfall-runoff model was created using HEC-HMS software. The drainage basin area, time of concentration, and curve number data from the original TR-20 model provided by SEWRPC were all input into HEC-HMS. Rainfall data for the 500-year and 1000-year rain events was interpolated using Bulletin 71. Results from our hydrologic analysis were compared to the values calculated by WDNR, SEWRPC, and GAS. These results are listed below.

PEAK INFLOW INTO EAGLE SPRING LAKE				
	WDNR	SEWRPC	GAS	Ayres Associates
Q_{100}	N/A	681	757	690
Q_{500}	N/A	N/A	1935	959
Q_{1000}	670	N/A	2302	1106

Table 4 Hydrologic Comparison

The difference in the flow numbers calculated above can be attributed to the rainfall data used. Peak inflow calculated for the 100-year storm event using Bulletin 71 closely matched the Q_{100} calculated by SEWRPC. SEWRPC used the rainfall data collected by the Commission, and Ayres Associates used rainfall data collected in Bulletin 71. Bulletin 71 rainfall data is slightly higher than that collected by SEWRPC. Ayres Associates used the more conservative Bulletin 71 rainfall data when developing the inflow peak hydrograph.

The SCS type II rainfall distribution was used when performing the hydrologic analysis. The SCS type II distribution is often viewed as the most conservative distribution. This differed from the hydrologic analysis performed by GAS in that several different distributions were used which could account for the large difference between the GAS analysis and the Ayres analysis. For consistency purposes the SCS type II rainfall distribution was used in the Ayres analysis.

3.0 Hydraulic Analysis

3.1 Outflow Analysis

To perform the outflow analysis, different scenarios were modeled using HEC-HMS v.3.0.1. Rating tables were developed for each scenario. Eagle Spring Lake water surface elevation was assumed to be at 820.68, which is where the lake elevation is normally kept. An elevation of 820.68 corresponds to a gauge reading of 9.55-ft. The gauge is mounted on the northwest wingwall of Wambold Dam. This elevation is 6 inches higher than the recommended water surface elevation by the WDNR and is also discussed in a letter from SEWRPC to the ESLMD dated May 29th, 2001 (Re: SEWRPC No. CA-709-17).

Each scenario was modeled at the 100-year, 500-year, and 1000-yr rainfall events. In order to be assigned a Dam Hazard Rating of "Significant," the dam must safely pass the 500-year event. Since the Eagle Spring Lake Management District would like the Dam Hazard Rating of significant, we will focus on safely passing the 500-year event.

For our outflow analysis, we used the stage-storage information for Eagle Spring Lake developed and provided by SEWRPC. In all scenarios we ran for the project, the top of dam is at elevation 821.80 above which water will run over the road and possibly breach the dam.

3.1.1 Scenario 1 – Wambold Dam (w/ Stop Boards Removed and Gate Open) & Kroll Dam Functioning

The inflow hydrograph calculated from the HEC-HMS model using watershed parameters provided by SEWRPC was routed through Eagle Spring Lake assuming Wambold Dam and Kroll Dam are both functioning. The rating tables developed for Wambold Dam are based on the stop boards removed and the gate fully open. Under this scenario the Dam does not pass the 500-yr event. The Dam is overtopped by 0.35 feet. Results can be seen below in Table 5.

PEAK OUTFLOW w/LOGS OUT & GATE OPEN				
	WDNR	GAS	SEWRPC	Ayres Associates
Q_{500} (cfs)	N/A	627	N/A	441
Water Surface Elev. (ft)			N/A	822.15

Table 5 Scenario 1 Hydraulic Comparison

3.1.2 Scenario 2 – Wambold Dam (w/ Stop Boards in and Gate Open) & Kroll Dam Functioning

The same inflow hydrograph was routed through Eagle Spring Lake assuming the stop boards remain in place at Wambold Dam, but with the gate fully open. The water surface elevation used was again 820.68. Notice that the outflow for each event is lower than the above results. Since the stop logs remain in place at the dam, the outflow is reduced, and the peak water surface elevation rises in each case. As seen below in Table 6, the dam is overtopped by 1.06 feet during the 500-yr event.

PEAK OUTFLOW w/LOGS IN & GATE OPEN				
	WDNR	GAS	SEWRPC	Ayres Associates
Q_{500} & (W.S Elev.)	N/A	N/A	N/A	368
Water Surface Elev. (ft)	N/A	N/A	N/A	822.86

Table 6 Scenario 2 Hydraulic Comparison

3.1.3 Scenario 3 – Wambold Dam Functioning (w/ Stop Boards Removed and Gate Open) & Kroll Dam Plugged

Under this final scenario, the stop boards in Wambold Dam were removed and the gate was opened all the way. However, we assumed the 30" pipe at the Kroll Dam, was plugged. The flows in this scenario push the lake elevation to 822.28, and the dam is overtopped by approximately 0.48 feet. Results can be seen below in Table 7.

PEAK OUTFLOW w/LOGS OUT & GATE OPEN, BUT KROLL PLUGGED				
	WDNR	GAS	SEWRPC	Ayres Associates
Q_{500} & (W.S Elev.)	N/A	N/A	N/A	425
Water Surface Elev. (ft)	N/A	N/A	N/A	822.28

Table 7 Scenario 3 Hydraulic Comparison

3.2 Outflow Analysis Summary

Wambold Dam is the major outlet for Eagle Spring Lake. Under all scenarios listed above the top of dam is overtopped. Scenario 1 can be considered the best case scenario under current conditions. If the stop logs are completely removed during the 500-yr storm event and the gate at the dam is completely open, the dam is only overtopped by 0.35-ft. Several alternatives listed below will alleviate the overtopping during the 500-yr event.

4.0 Proposed Modifications

4.1 Alternative 1 – Lower the Lake Level 0.6-ft

The Eagle Spring Lake Management District (ESLMD) operates the Lake at an elevation of 820.68 due to the shallow depth of the Lake and for recreational purposes. This elevation is generally held throughout the year with minor fluctuations and corresponds to a gauge reading of 9.55-ft that is mounted on the northwest wingwall of Wambold Dam. The recommended water surface elevation from the WDNR is 820.08 or 6 tenths of a foot lower than current operating conditions. The recommended water surface elevation from the WDNR is an elevation that needs to be clarified between the ESLMD and the WDNR. See letter from SEWRPC dated May 29th, 2001 (Re: SEWRPC No. CA-709-17).

By lowering the water surface elevation of the lake, available storage is increased. Adding storage to the lake allows the current outlet structures to safely pass the 500-year event without major modifications to the spillways. Results can be seen in the comparison below. Keeping the lake elevation at 820.06, the 500-yr event can be safely passed.

Normal Pool Elevation	Q_{500} (cfs)	W.S Elev. (ft)
820.68 (9.55 gauge) With No Modification	441	822.15
820.06 With Modification	386	821.77

Table 8 Alternative 1 Comparison

Alternative 1 Advantages

- No cost to lower the lake level to recommended levels by the WDNR.
- Increase the Integrity of the Wambold Dam structure through decreased hydraulic loadings.
- Increase the longevity of the Wambold Dam Structure.
- Safely pass the 500-year storm event and meet the requirements for a "significant" Dam Hazard Rating.

Alternative 1 Disadvantages

- The average depth of Eagle Spring Lake is 4-ft, and lowering the lake level will make the average depth 3.4-ft.
- Lowering the level of the lake will restrict recreational uses on the lake.
- More shoreline will be exposed by lowering the lake level, possibly creating bank erosion problems and other issues for property owners.
- The ESLMD is opposed to this alternative.

4.2 Alternative 2 – Add 5 Feet Weir Length to Wambold Dam

Adding length to the spillway will increase the capacity of the dam. Increasing the weir length from 10.5 to 15.5 feet by adding 5 ft of length allows the lake elevation to remain at current levels and safely passes the 500-year event. See Table 9 for Alternative 2 Comparison.

Weir Length	Q_{500} (cfs)	W.S Elev. (ft)
10.5 feet No Modification	441	822.15
15.5 feet With Modification	542	821.72

Table 9 Alternative 2 Comparison

Alternative 2 Advantages

- Eagle Spring Lake may remain at current operating level of 820.68
- The 500-year storm event is safely passed through the dam.

Alternative 2 Disadvantages

Adding 5 ft of spillway length to the dam will be a significant construction project.

Plans and specifications will need to be prepared by an Engineering firm.

Significant costs will be incurred by the Lake Management District to construct this alternative along with property acquisition.

4.3 Alternative 3 – Increase Orifice Pipe at Kroll Dam

Alternative 3 addresses the option of adding additional spillway capacity at Kroll Dam. Kroll Dam spillway is controlled by a 2.5 sq. ft orifice and 30" RCP running underneath CTH E. Increasing the orifice to a 30" diameter will allow the 30" RCP to flow at full capacity. The existing 2.5 sq. ft orifice will be increased with a 30" gate valve. The gate valve will be operated manually allowing the lake level to remain at current conditions. During large rain events the gate will be opened to safely pass the 500-year event. This increases the overall spillway capacity at Kroll Dam to allow the structures to safely pass a 500-year storm event.

Kroll Dam	Q_{500} (cfs)	W.S Elev. (ft)
No Modification	441	822.15
With Modification	448	821.78

Table 10 Alternative 3 Comparison

Alternative 3 Advantages

Eagle Spring Lake level may remain at current operating level of 820.68.

The 500-year storm event can be safely passed through the dam.

Alternative 3 Disadvantages

- Increasing orifice diameter at Kroll Dam will be a significant construction project due to current condition of Kroll Dam.

  Orifice will be controlled by a manually operated gate valve, which will require lots of turning.

  The Lake Management District will need to obtain County and DNR approval and permits.

  Plans and specifications will need to be completed by an Engineering Firm.

5.0 Recommendations

A hydrologic and hydraulic analysis was performed to determine if the two outlet structures, Wambold and Kroll Dam, on Eagle Spring Lake could safely pass the 500-year storm event. HEC-HMS was used to compute the peak inflow hydrograph using information provided by SEWRPC. The rainfall data used during the hydrologic modeling was taken from Bulletin 71 for Southeastern Wisconsin. The resulting peak inflow computed by Ayres Associates using the SEWRPC watershed characteristics and Bulletin 71 rainfall data was 690 cfs, while that computed by SEWRPC was 681 cfs.

The hydraulic analysis was performed for the 500-year storm event by routing the inflow hydrograph through Eagle Spring Lake with both Wambold and Kroll Dams fully functioning. Rating tables developed in 1967 and provided by SEWRPC were used and modified to meet the current conditions of Wambold and Kroll Dams. Stage storage curves for Eagle Spring Lake were also provided by SEWRPC and used during the hydraulic analysis. Linear interpolation and extrapolation were performed to compute stage-storage above the spillway elevation of Wambold Dam. The current operating level of Eagle Spring Lake is 820.68-ft and was used as the initial Lake Elevation during HEC-HMS modeling.

The resulting peak outflow and peak lake elevation were 441 cfs and 822.15-ft, respectively, for the 500-yr event. This resulted in a dam breach of 0.35-ft.

Three alternatives were modeled to either increase lake storage or construct additional spillway capacity at Wambold and Kroll Dams. All of the alternatives presented will safely pass the 500-year storm event.

The most economical way to pass the 500-yr storm event is to lower the lake level by 0.60-ft to an elevation 820.08. This will increase storage in the lake allowing the current outlet structures at Wambold and Kroll Dams to pass the 500-yr event without significant costs to the Lake Management District. However, it was been brought to the attention of Ayres Associates that the ESLMD is against lowering their lake level. This will have adverse affects for recreational purposes on the already shallow lake.

Alternative 3 will be the second most economical way to safely pass the 500-yr event through increasing the orifice diameter at Kroll Dam with the installation of a 30" gate valve. The increased orifice diameter will allow the 30" RCP to flow full. This will increase spillway capacity allowing the Dam to safely pass the 500-yr event without having to increase lake storage.

Increasing Kroll Dam spillway capacity or increasing lake storage will allow the "significant" hazard dam to safely pass the 500-year event.

Since Eagle Spring Lake has a high recreational use, and the ESLMD is against lowering the current lake level, Ayres Associates recommends the ESLMD to pursue alternative 3. The next step for the ESLMD is to hire an Engineer to design modifications listed in alternative 3. A cost analysis has been prepared and can be found in Appendix F.

EAGLE SPRING LAKE MANAGEMENT DISTRICT					
ALTERNATIVE 3 - ADD 30" ORIFICE OPENING AT KROLL DAM					
21-Nov-06					
OPINION OF COST					
MINIMUM REQUIRED					
				AYRES ESTIMATE	
Item No.	Description	UNIT	Approx. Quantity	Est. Unit Price	Total Price
KROLL DAM 30" ORIFICE OPENING					
1	MOBILIZATION	LS	1	$15,000.00	$15,000.00
2	DEMOLITION	LS	1	$10,000.00	$10,000.00
3	EXCAVATION	CY	225	$100.00	$22,500.00
4	30" GATE VALVE & BOX INSTALLATION	EA	1	$25,000.00	$25,000.00
5	30" RCP PIPE REMOVAL	LF	10	$100.00	$1,000.00
6	RE-LAID 30" STORM SEWER	LF	10	$100.00	$1,000.00
7	DEWATERING	LS	1	$10,000.00	$10,000.00
8	TURBINE REMOVAL	LS	1	$5,000.00	$5,000.00
9	TURBINE REMOVAL VAULT MANHOLE INSTALLATION	LS	1	$10,000.00	$10,000.00
					$99,500.00
TOTAL PROJECT ESTIMATE					**$99,500.00**
CONTINGENCY		15%			$14,925.00
ENGINEERING		10%			$11,442.50
TOTAL PROJECT ESTIMATE					**$125,867.50**
* Note: Erosion Control Costs during construction are not included in this estimate					
* Note: Permitting is also n ot included in this estimate (i.e. Chapter 30 permitting)					
SOURCES:	Wisconsin DOT Bid Express Bid Tabulation Analysis				

ITEM DESCRIPTIONS & SUMMARY

ITEM	DESCRIPTION
1 MOBILIZATION	Mobilizing of contractor's equipment
2 DEMOLITION	Demolition of existing shed housing the turbine
3 EXCAVATION	Excavation of a 10x10x15-ft hole for 30" gate valve installation
4 30" GATE VALVE INSTALLATION	Kennedy Gate Valve or Clow Gate Valve w/ floor stand
5 30" RCP PIPE REMOVAL	Removal of existing 30" RCP storm sewer for 30" gate valve installation
6 RE-LAID 30" STORM SEWER	Relay 30" RCP storm sewer
7 DEWATERING	Sump pumps must be running during construction to keep area dry during valve installation.
8 TURBINE REMOVAL	Existing turbine must be removed for 30" gate valve installation (oils, grease, etc.)
9 VALULT MANHOLE INSTALLATION	Assume 15 vertical feet of manhole. Excavation is included.