



GRETCHEN WHITMER
GOVERNOR

STATE OF MICHIGAN
DEPARTMENT OF
ENVIRONMENT, GREAT LAKES, AND ENERGY
LANSING



PHILLIP D. ROOS
DIRECTOR

VIA EMAIL

TO: Sara Thompson, Chief
Wildlife Division
Department of Natural Resources

FROM: Lucas Trumble, P.E., Supervisor
Dam Safety Unit
Water Resources Division

DATE: September 19, 2023

SUBJECT: Trowbridge Dam, Dam ID No. 604; Allegan County

Attached is a copy of our Dam Safety Inspection Report with recommendations for the Trowbridge Dam, Dam ID No. 604, located in Allegan County. This inspection was completed in accordance with the Memorandum of Understanding between the Michigan Department of Natural Resources (MDNR) and the Michigan Department of Environment, Great Lakes, and Energy [EGLE, formerly Michigan Department of Environmental Quality (MDEQ)], entitled "Inspection of MDNR-Owned Dams and Funding of MDEQ's Dam Safety Program."

The purpose of this inspection was to evaluate the structural condition and hydraulic capacity of the dam, as required by Part 315, Dam Safety, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended.

The Trowbridge Dam is in Poor condition. Dam safety deficiency is recognized for loading conditions which may realistically occur. Remedial action is necessary. Poor rating may also be used when uncertainties exist as to critical analysis parameters which identify a potential dam safety deficiency: further investigations and studies are necessary. The following recommended actions assume the dam will remain in place for the next several years and are listed by priority. If dam removal is completed soon, some of these recommended actions may not be necessary:

1. Continue to prepare the design for dam removal of the Trowbridge Dam. Work completed as a part of Phase 1A of the removal project has greatly increased the safety of the dam, but it was intended to provide temporary stabilization until the dam can be fully removed. The anticipated service life of the Phase 1A repairs was 3 years, from completion in 2019. Since the Phase 1A repairs did not incorporate standard design practices for a dam of this size, specifically the design utilized sub-standard stilling basin and energy dissipation practices, the threat of scour and undermining of the structures increases over time. Since the

intended service life has been surpassed, additional monitoring, maintenance, and interim repair of the structure may become necessary to ensure stability until the dam can be removed. Enlist the services of a qualified engineer to assess the stability of the structure for the remaining lifespan of the dam. This stability analysis should be completed by July 1, 2024, and any recommended repairs should be implemented as directed by that engineer.

2. Trowbridge Dam has a significant lack of hydraulic capacity to pass the design flood of the 200-year event. During the design storm, the principal spillway left abutment is expected to be overtopped by approximately six feet, while the pier between the principal and auxiliary spillways is expected to be overtopped by approximately five feet per the 2019 hydraulic model submitted as part of the Phase 1A permit application. The Phase 1A project provided armoring of the earthen abutments to an elevation above the 200-year design flood event, however there is a gap in the armoring at the left embankment between the old grouted riprap on the downstream portion of the embankment and the new riprap on the upstream portion of the embankment behind the new sheetpiling wall. This gap could allow erosion of the earthen abutment or eventual flanking failure of the spillway during a large flood event. Additional armoring material should be added this location to match the elevation of the Phase 1A grouted riprap. There is also a gap between the principal spillway left abutment and Phase 1A sheetpile wall where the gap in grouted riprap exists. Sandbags are stacked in the gap, but flow through or over the sandbags could still cause erosion of the embankment behind the abutment wall and sheet piling. This should also be sealed and armored to protect against erosion. These repairs should be completed by July 1, 2024.
3. Significant voids and cracks in the old grouted riprap on the left embankment downstream slope were observed throughout, especially near the principal spillway outlet. Some brush was growing within larger voids. Flow over the grouted riprap raises concerns of instability during large floods. Also, the left end of the downstream riprap has undermining occurring from tailwater conditions during some flow events. Continued undermining could cause instability of the embankment slope. Monitor grouted riprap areas on a monthly basis for further deterioration. Fill/repair any deteriorated areas as they are observed.
4. Monitor the concrete components of the principal spillway for further deterioration and movement, especially along the left spillway abutment wall, including the downstream training wall that is significant misaligned. Remove all brush and vegetation growing within cracks in the concrete walls and piers of the principal spillway by December 31, 2024.
5. Since the 2022 Dam Safety Inspection, riprap within the auxiliary spillway apron has become displaced from the downstream face of the steel sheet pile spillway crest. It is unclear whether this riprap is crucial to the stability of the steel sheet

piling or if it serves as scour protection and energy dissipation only. Consult with your engineer to determine the function and criticality of this displaced riprap. Implement repairs as directed by your engineer. This consultation should occur before December 31, 2023, and repairs should be implemented as directed by your engineer.

6. Mow, or treat with an acceptable herbicide, the embankments a minimum of two times per year after tree and brush clearing occurs. Clearing should take place on the entirety of the embankments to 10 feet beyond the left and right groins of the embankment and to 10 feet beyond the toes of slope. This clearing should include the brush within the old grouted riprap on the left embankment and within the riprap on the auxiliary spillway and auxiliary spillway right end.
7. Continue to monitor for any flow that discharges from the former powerhouse foundation on a monthly basis. Report any changes in flowrate, color, or sediment deposition to the Dam Safety Program and a consulting engineer. No flow was observed during the inspection, and it is believed the new sheetpiling wall has eliminated the flow.
8. One animal burrow was observed on the crest of the left embankment near the principal spillway. Fill/repair this animal burrow and any other burrows as they are observed with suitable, compacted fill.
9. Review, and update as necessary, the dam's Emergency Action Plan (EAP) in coordination with Allegan County Emergency Management. Confirm and provide the calculated inundation area to comply with Part 315 requirements. Provide any updates to the Dam Safety Program by December 31, 2023.

Please contact Thomas Horak, E.I.T., Dam Safety Program, at 517-231-8594 or HorakT@Michigan.gov, if you have any questions or concerns regarding the inspection report or the recommendations.

Attachment

cc/att: Paul Reusch, U.S. Environmental Protection Agency
Sarah Clark, Allegan County Local Emergency Management Coordinator
Mark Mills, DNR
Jessica Mistak, DNR
Dana Castle, DNR
Thomas Horak, EGLE

**DAM SAFETY INSPECTION REPORT
TROWBRIDGE DAM – DAM ID NO. 604
KALAMAZOO RIVER
ALLEGAN COUNTY – SECTION 12, T 01N, R 13W**



OWNER(S)/OPERATOR(S): MDNR Wildlife Division - Southwestern LP Region
621 North 10th Street
Plainwell, MI 49080-1004
(269) 512-1218

**HAZARD POTENTIAL
CLASSIFICATION:** High

INSPECTION DATE: August 18, 2023

REPORT DATE: September 19, 2023

PREPARED AND INSPECTED BY:

Thomas Horak, E.I.T.
Dam Safety Unit
Water Resources Division
Dept. of Environment, Great Lakes, and Energy
P.O. Box 30458
Lansing, Michigan 48909
517-231-8594

Lucas A. Trumble, P.E.
Dam Safety Unit
Water Resources Division
Department of Environment, Great Lakes, and Energy
P.O. Box 30458
Lansing, Michigan 48909
517-420-8923



INTRODUCTION

The purpose of this inspection was to evaluate the structural condition and hydraulic capacity of the Trowbridge Dam, as required by Part 315, Dam Safety (Part 315), of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended. This inspection was conducted by the Department of Environment, Great Lakes, and Energy (EGLE) per the provisions of its Memorandum of Understanding with the Department of Natural Resources (DNR), the owner of the dam. The report is limited to a discussion of observations based on a visual investigation and review of any available previous inspection reports, plans, and data. This report should not be considered an in-depth engineering investigation. All references to “right” and “left” in this report are based on the observer facing downstream.

CONCLUSIONS AND RECOMMENDATIONS

The Trowbridge Dam is in Poor condition. Dam safety deficiency is recognized for loading conditions which may realistically occur. Remedial action is necessary. Poor rating may also be used when uncertainties exist as to critical analysis parameters which identify a potential dam safety deficiency: further investigations and studies are necessary. The following recommended actions assume the dam will remain in place for the next several years and are listed by priority. If dam removal is completed soon, some of these recommended actions may not be necessary:

1. Continue to prepare the design for dam removal of the Trowbridge Dam. Work completed as a part of Phase 1A of the removal project has greatly increased the safety of the dam, but it was intended to provide temporary stabilization until the dam can be fully removed. The anticipated service life of the Phase 1A repairs was 3 years, from completion in 2019. Since the Phase 1A repairs did not incorporate standard design practices for a dam of this size, specifically the design utilized sub-standard stilling basin and energy dissipation practices, the threat of scour and undermining of the structures increases over time. Since the intended service life has been surpassed, additional monitoring, maintenance, and interim repair of the structure may become necessary to ensure stability until the dam can be removed. Enlist the services of a qualified engineer to assess the stability of the structure for the remaining lifespan of the dam. This stability analysis should be completed by July 1, 2024, and any recommended repairs should be implemented as directed by that engineer.
2. Trowbridge dam has a significant lack of hydraulic capacity to pass the design flood of the 200-year event. During the design storm, the principal spillway left abutment is expected to be overtopped by approximately six feet, while the pier between the principal and auxiliary spillways is expected to be overtopped by approximately five feet per the 2019 hydraulic model submitted as part of the Phase 1A permit application. The Phase 1A project provided armoring of the earthen abutments to an elevation above the 200-year design flood event, however there is a gap in the armoring at the left embankment between the old grouted riprap on the downstream portion of the embankment and the new riprap on the upstream portion of the embankment behind the new sheetpiling wall. This gap could allow erosion of the earthen abutment or eventual flanking failure of the spillway during a large flood event. Additional armoring material should be

added this location to match the elevation of the Phase 1A grouted riprap. There is also a gap between the principal spillway left abutment and Phase 1A sheetpile wall where the gap in grouted riprap exists. Sandbags are stacked in the gap, but flow through or over the sandbags could still cause erosion of the embankment behind the abutment wall and sheet piling. This should also be sealed and armored to protect against erosion. These repairs should be completed by July 1, 2024.

3. Significant voids and cracks in the old grouted riprap on the left embankment downstream slope were observed throughout, especially near the principal spillway outlet. Some brush was growing within larger voids. Flow over the grouted riprap raises concerns of instability during large floods. Also, the left end of the downstream riprap has undermining occurring from tailwater conditions during some flow events. Continued undermining could cause instability of the embankment slope. Monitor grouted riprap areas on a monthly basis for further deterioration. Fill/repair any deteriorated areas as they are observed.
4. Monitor the concrete components of the principal spillway for further deterioration and movement, especially along the left spillway abutment wall, including the downstream training wall that is significant misaligned. Remove all brush and vegetation growing within cracks in the concrete walls and piers of the principal spillway by December 31, 2024.
5. Since the 2022 Dam Safety Inspection, riprap within the auxiliary spillway apron has become displaced from the downstream face of the steel sheet pile spillway crest. It is unclear whether this riprap is crucial to the stability of the steel sheet piling or if it serves as scour protection and energy dissipation only. Consult with your engineer to determine the function and criticality of this displaced riprap. Implement repairs as directed by your engineer. This consultation should occur before December 31, 2023, and repairs should be implemented as directed by your engineer.
6. Mow, or treat with an acceptable herbicide, the embankments a minimum of two times per year after tree and brush clearing occurs. Clearing should take place on the entirety of the embankments to 10 feet beyond the left and right groins of the embankment and to 10 feet beyond the toes of slope. This clearing should include the brush within the old grouted riprap on the left embankment and within the riprap on the auxiliary spillway and auxiliary spillway right end.
7. Continue to monitor for any flow that discharges from the former powerhouse foundation on a monthly basis. Report any changes in flowrate, color, or sediment deposition to the Dam Safety Program and a consulting engineer. No flow was observed during the inspection, and it is believed the new sheetpiling wall has eliminated the flow.
8. One animal burrow was observed on the crest of the left embankment near the principal spillway. Fill/repair this animal burrow and any other burrows as they are observed with suitable, compacted fill.

9. Review, and update as necessary, the dam's Emergency Action Plan (EAP) in coordination with Allegan County Emergency Management. Confirm and provide the calculated inundation area to comply with Part 315 requirements. Provide any updates to the Dam Safety Program by December 31, 2023.

The dam's current High hazard potential rating remains appropriate.

PROJECT INFORMATION

The Trowbridge Dam was originally constructed around 1899. The dam, located on the Kalamazoo River in Section 12, Township 01N, Range 13W in Allegan County, and maintained by the MDNR, Wildlife Division staff, was originally constructed by Consumers Power Company for the purpose of generating hydroelectricity. All generating equipment was removed from the dam in 1965 and ownership was transferred to the then Michigan Department of Conservation (now MDNR) in 1967. The dam's powerhouse was demolished, and the gates were raised to lower the impoundment level a short time after that. In 1986, the remainder of the dam's superstructure and spillway gates were removed, and its concrete piers and abutment walls were lowered. The dam currently creates a recreational impoundment, providing fish and wildlife habitat and recreational opportunities. It consists of a 150-foot long left earthen embankment, an 80-foot wide concrete spillway, a 100-foot auxiliary spillway, and a short right embankment, for a total length of approximately 340 feet. The left earthen embankment consists of sandy fill material and has a crest width of approximately 75 feet, with an upstream slope of approximately 7 horizontal to 1 vertical (7H:1V) and a downstream slope of approximately 2H:1V.

The principal spillway consists of three 24-foot wide, concrete, ogee-crest, spillway bays separated by two 4-foot wide concrete piers. An auxiliary spillway now exists at the historic right embankment with a 100-foot long steel sheetpiling crest and an armored flow section over the embankment.

The dam has a structural height of 25 feet and a hydraulic height of 30.2 feet. It maintains approximately 11 feet of head with 3 feet of freeboard, creating a 59-acre impoundment under normal flow conditions.

The Trowbridge Dam is located within the limits of the Kalamazoo River Superfund site. Sediments contained in the impoundment have become contaminated with Polychlorinated Biphenyls (PCBs) as a result of industrial discharges from historically operated paper mills upstream of the dam. PCBs pose serious health and environmental risk. Failure of the dam could exacerbate the spread of PCB-laden sediments throughout the downstream Kalamazoo River system.

After the 2019 Dam Safety Inspection Report, significant upgrades to the spillway were completed as a temporary repair to prolong the life of the dam while removal plans are developed and implemented under Permit No. WRP016883v1. This project was considered Phase 1A of the Trowbridge Dam removal project. The repair included sheetpile installation at the auxiliary spillway inlet and at both principal spillway abutments, extending through much of the left embankment's upstream slope. A large concrete abutment between the principal and auxiliary spillway was poured, and riprap was placed throughout the slopes of each embankment and at the inlet to the auxiliary

spillway. A large portion of the right embankment was lowered to provide additional spillway capacity. While these repairs have significantly improved the current safety and stability of the dam, they were intended to be a temporary fix until removal can take place.

The dam was previously inspected by Dam Safety Program staff in 1990, 1993, 1996, 2007, 2010, 2013, 2016, and 2022, by Camp, Dresser, & McKee in 1999 and 2004, and by Soil and Materials Engineering, Incorporated, in 2019. In order to comply with a January 13, 2006, MDEQ Order to Repair, Replace, or Remove the dam, it has also been inspected biannually by Soil and Materials Engineering, Incorporated since 2010. Copies of these reports, along with limited repair plans, are on file with the Dam Safety Program. Original construction plans for the dam were not available at the time of this report.

SITE INVESTIGATION

The following discussion of the dam's physical condition and appurtenances is based on observations and photographs obtained on the inspection date.

In addition to the specific findings listed below, it is important to continue good maintenance practices. These practices include regular inspection of the dam embankments and hydraulic structures for any deficiencies. Some of the more common issues that are found include growth of trees and brush, development of erosion areas, and animal burrows.

If woody vegetation is allowed to mature, it could develop an extensive root system. These root systems can lead to piping failure or if the brush and trees are uprooting in a storm, can cause extensive deterioration of the embankment. Embankments should be clear of woody vegetation and mowed 10 feet past the toe of the embankment. Similarly, animal burrows and surface erosion, can propagate into increased seepage and potentially piping failure, as well as lead to slope stability issues.

The following data was collected on the date of the inspection and includes deficiencies observed during the inspection and necessary actions for remediation of the observed deficiencies.

Upstream Slope	
Pool elevation at time of inspection	<i>12 inches below auxiliary spillway sheetpile crest, approximately elevation 657.5 per interpolation with Phase 1A plans</i>
Upstream slope ground cover	<i>Phase 1A sheetpile and grouted riprap up to grassy, weedy embankment on left embankment, riprap on short right embankment</i>
What issues are present on the upstream slope?	<i>Trees, Brush, Rodent Burrows</i>
Slope Protection	
What types of slope protection are used?	<i>Riprap, sheetpile wall as part of Phase 1A repair on left embankment, riprap on short right embankment/auxiliary spillway right wall</i>
Average diameter of riprap	<i>MDOT medium riprap</i>

Condition of riprap	<i>Adequate on upstream slope</i>
Action required for riprap	<i>Monitor the Phase 1A repairs as it is now past its given service life</i>
Trees/Woody Vegetation	
Number of trees	<i>Sparse</i>
Tree DBH	<i>6-12"</i>
Tree location	<i>Some small trees and larger brush are taking root throughout the upstream slope of the left embankment</i>
Action required for trees	<i>Maintenance</i>
Describe action required	<i>Remove all trees and brush from all embankments, from the upstream water edge to 10 feet beyond the downstream toe of slope, and to 10 feet beyond the groins</i>
Brush coverage	<i>Sparse</i>
Brush location	<i>Upstream slope, more present between the boat launch and the upstream end of the Phase 1A sheetpile wall</i>
Action required for brush	<i>Maintenance</i>
Describe action required	<i>Remove all trees and brush from all embankments, from the upstream water edge to 10 feet beyond the downstream toe of slope, and to 10 feet beyond the groins</i>

Crest	
Approximate width of crest (ft)	<i>Varies from 50-75 on left embankment, and tapers thinner as it abuts principal spillway</i>
Approximate freeboard (ft)	<i>Very top of left embankment is at elevation 670+</i>
Crest ground cover	<i>Some old grout near spillway and then grass/weed growth</i>
What issues are present on the crest?	<i>Gaps in armoring</i>
Gap issue	
Specify issue.	<i>Gap exists between spillway left abutment and the Phase 1A sheetpile wall near crest of left embankment. The gap has some sandbags placed to prevent erosion, but some erosion has already occurred. Further, there is a gap in the armoring at the crest between the old grouted riprap and the Phase 1A grouted riprap. The gap area would be expected to overtop during storms with higher recurrence than the design storm. If unarmored, the embankment could experience erosion that would flank the spillway abutment wall and lead to failure of the dam.</i>
Where are the other issues located?	<i>At abutment with principal spillway and left embankment</i>
Action required for other issues	<i>Maintenance</i>
Describe action required	<i>Connect the gap in the grouted riprap on the crest of the left embankment with suitable armoring such as similar grouted riprap over appropriate material. Also add armoring at the gap between the sheetpile and spillway abutment to prevent</i>

	<i>further erosion. Carry the new armoring up to the top elevation of the rest of the Phase 1A armoring.</i>
Trees/Woody Vegetation	
Number of trees	<i>Sparse</i>
Tree DBH	<i>6-12"</i>
Tree location	<i>Some small trees and larger brush are taking root throughout near the crest of the left embankment</i>
Action required for trees	<i>Maintenance</i>
Describe action required	<i>Remove all trees and brush from all embankments, from the upstream water edge to 10 feet beyond the downstream toe of slope, and to 10 feet beyond the groins</i>
Brush coverage	<i>Sparse</i>
Brush location	<i>Some brush present on left embankment crest near principal spillway</i>
Action required for brush	<i>Maintenance</i>
Describe action required	<i>Remove all trees and brush from all embankments, from the upstream water edge to 10 feet beyond the downstream toe of slope, and to 10 feet beyond the groins</i>
Animal Burrows	
Approximate number of rodent burrows	<i>One observed</i>
Location of rodent burrows	<i>Near principal spillway on left embankment, near a small tree</i>
Action required for rodent burrows	<i>Maintenance</i>
Describe action required	<i>Repair/Fill all animal burrows as they are observed with suitable, compacted fill. Work to control rodent populations at the dam. Monitor for more burrows as the embankment gets cleared of trees and woody vegetation</i>

Downstream Slope	
Downstream slope ground cover	<i>Grouted riprap on lower half of left embankment, grass and weed growth above that. Right embankment/auxiliary spillway right wall is completely armored with riprap</i>
What issues are present on the downstream slope?	<i>Cracks, Other</i>
User Defined Issue	
Specify other.	<i>Undermining grouted riprap</i>
Location of undermining	<i>At the left end of the Phase 1A grouted riprap repair on the left embankment, undermining has started, presumably from tailwater eddy conditions during higher flow conditions.</i>
Action required for these other issues	<i>Maintenance</i>
Describe action required	<i>Repair the undermined grouted riprap and further armor to prevent undermining in the future.</i>
Cracking	
Types of cracks present	<i>Primarily transverse cracks in grouted riprap, more significant closer to the principal spillway</i>
How many cracks?	<i>Multiple</i>

Approximate crack length (ft)	<i>Varies up to the complete transverse length of the older grouted riprap</i>
Approximate crack width (ft)	<i>See photo #34 for size reference. Cracks varied in width from hairline to open voids from the cracks</i>
Approximate crack depth (ft)	<i>Though top grout layer. Voids were also found to exist near under some cracks. Some voids have vegetation and brush growth within them. Cracking and voids could be an indication of the presence of seepage and piping below the grouted riprap that has caused the displacement</i>
Location of cracks	<i>Downstream slope of left embankment</i>
Action required for cracks	<i>Monitor, Maintenance</i>
Describe action required	<i>Repair the grouted riprap cracks and fill voids with suitable fill in the areas that would be overtopped during the 200-year storm. Monitor after the repair for further</i>
Embankment / Internal Drains	
What types of embankment drains are present?	<i>None observed</i>
Issues with embankment drains:	<i>None</i>
Action required for embankment drains:	<i>None</i>

Principal Spillway	
What type of spillway is present?	<i>Concrete weir with three bays separated by deteriorating piers</i>
What is the primary material used in the spillway?	<i>Concrete</i>
What issues are present with the primary spillway?	<i>Deteriorating Materials, Other</i>
User Defined Issue	
Specify other.	<i>Gap between spillway left abutment and left embankment</i>
Where are the other issues located?	<i>Explain</i>
Action required for other issues	<i>Maintenance</i>
Describe action required	<i>Monitor and repair</i>
Material Deterioration	
What materials are deteriorating in the spillway?	<i>Concrete</i>
What issues are noted with the concrete components?	<i>The left abutment wall has significant spalling and cracking, including displacement of the left downstream training wall. The right abutment has been significantly upgraded through the Phase 1A repair. The concrete at the left abutment and the two piers at the principal spillway have brush growing within cracks in the concrete. The actual spillway crest and apron were unable to be inspected.</i>
Where are the issues located?	<i>Throughout the spillway piers, left abutment wall</i>
Action required for concrete components of the spillway	<i>Monitor the concrete components of the dam regularly. If dam removal progresses, a more in-depth repair may not be necessary if the concrete shows no further signs of deterioration</i>
Erosion	
Specify issue	<i>At the downstream end of the sheetpiling at the left embankment, there is a gap between the sheetpile and the spillway left upstream abutment</i>

	<i>wall. The gap has been filled in with sandbags. If the headwater rises, water would be able to flow through this gap behind the upstream sheetpiling as well as along the backside of the spillway left abutment wall. Due to riprap placement, it is not expected that this overflow would cause significant damage over a short duration behind the sheetpiling. However, it could lead to further erosion behind the left abutment wall that could eventually lead to embankment failure. This is repeated from the "Crest" section. See that section for recommendations</i>
Erosion Control / Energy Dissipation	
What type of erosion control structure is in place?	<i>Apron at outlet and armored embankment toes</i>
Gates / Valves	
Does the spillway include a gate?	<i>No</i>
Additional comments	<i>Add apron for downstream armoring</i>

Auxiliary Spillway	
What type of spillway is present?	<i>Steel sheetpile weir upstream with a rock and concrete lined embankment that acts as an overflow chute during overtopping flows.</i>
What is the primary material used in the spillway?	<i>Steel sheetpile, grouted channel and riprap armoring</i>
What type of erosion control structure is in place?	<i>Grout and riprap lined chute, further armoring at chute outlet</i>
Are there any issues with the outlet erosion control structure?	<i>Since the 2022 inspection, riprap immediately downstream of the auxiliary spillway sheetpile weir have moved further downstream in the chute. See photos #75 and #76 for 2022 vs. 2023 comparison.</i>
Where are the issues located?	<i>Chute of auxiliary spillway</i>
Action required for other issues	<i>Maintenance</i>
Describe action required	<i>Add heavier riprap where it has become displaced. Consult with your engineer to determine if the riprap is needed for stability of the sheetpile weir</i>

The above monitoring and maintenance items should be addressed in accordance with the Conclusions and Recommendations section of this report.

STRUCTURAL STABILITY

Based upon observations during the inspection, there were no indicators of any conditions that represent an immediate threat to the dam's stability, although, if significant overtopping flow is introduced over the embankment adjacent to the principal spillway left abutment, the deteriorating grouted riprap may not be able to withstand the overtopping flow and could contribute to eventual instability.

HYDROLOGY AND HYDRAULICS

The contributing drainage area to the Kalamazoo River at the Trowbridge Dam is approximately 1,538 square miles. The design discharge for this dam is the 0.5 percent chance flood of 14,000 cubic feet per second (cfs). Previous reports concluded the principal spillway had a maximum capacity of approximately 3,900 cfs with no freeboard at the earthen embankments, which is approximately equal to the 10 percent annual chance (10-year) flood discharge. As part of the Phase 1A removal project, an updated hydraulic model was developed for the new dam configuration of the right embankment being an armored auxiliary spillway. The updated hydraulic model shows the dam can pass the design flow at an elevation of approximately 666, or four feet above the top of the new sheetpile wall at the left embankment and six feet above the principal spillway's left abutment wall. While much of the embankment is armored, especially near the spillway and at the downstream toe, this overtopping flow would still cause concern of the stability of the left embankment near the spillway, especially with the amount of cracking and voids found within the older grouted riprap on the embankment. While the dam is not considered able to safely pass the design flow of the 200-year flood, the Phase 1A project provides acceptable upgrades for the interim time until dam removal occurs, so long as it occurs in the next several years.

The Phase 1A plans called for new grouted riprap to abut the existing grouted riprap on the left embankment. Please note, however, there is a gap in the armoring of the left embankment between the older grouted riprap on the downstream slope and the new riprap behind the new sheetpiling. The gap is shown in photos #37 - #40. This gap could have overgrown riprap as a base that may be able to withstand some overtopping flow. This gap near the crest of the dam is part of the portion of the embankment that would be expected to overtop during events greater than the 2-year flood. This gap between the new and old riprap should be sufficiently armored to prevent erosion during overtopping events. The Phase 1A grouted riprap should be extended to connect to the existing grouted riprap near the crest of the dam. Further, the newly placed armoring on the left embankment should be surveyed to ensure it was extended to the proper elevation the Phase 1A plans called for. The plan set shows the older grouted riprap reaches an elevation of approximately 662.5, so even during a 200-year event, this armored area would be expected to overtop by approximately 3.5 feet at the highest point.

Hydraulic calculations used to make this determination are on file with the Dam Safety Program. Please note that the EGLE flood estimates are from 2022. Any flood flow estimate over one year old is subject to revision. A request for an updated flood flow estimate has been submitted, and a revised report will be issued should the 2023 estimate come back different than the 2022 estimate.

OPERATION AND MAINTENANCE

A written Operations and Maintenance Plan (O&M Plan), outlining procedures for the dam's upkeep and operation, has been prepared for this dam. This plan should be reviewed annually and updated to reflect changes in operation and maintenance procedures.

The MDNR has done a good job of monitoring the dam's condition through frequent dam inspections. Given the deteriorated condition of the dam, it is imperative that this monitoring continue. Incorporate regular brush, tree clearing, and mowing into the plan.

EMERGENCY ACTION PLAN

The Trowbridge Dam is a high hazard potential dam. An EAP has been developed for this dam and is on file with the Dam Safety Program. The EAP was last updated on in 2022. However, there are portions of the EAP that should be confirmed. Part 315, Section 31523(5) states:

Emergency action plans shall include, but not be limited to, the name, address, and telephone number of the person, and of an alternate person, responsible for operation of the dam; the name and telephone number of local emergency management coordinators; and a listing of occupied facilities, buildings, and residences that may be threatened with flooding due to a failure of the dam.

The last requirement, the listing of potentially threatened properties, is unclear in the current EAP. The EAP lists four areas that may be occupied. Please confirm that these are the only potentially impacted occupied areas and include the analysis used to make that determination. The EAP says there is a map in Attachment 2 with those areas highlighted, but the attachment is not included in the most recent version. Please provide the Attachment 2 with any necessary updates. Also, consider including contact information for the downstream dam owners to notify in the event of a dam failure, even if the failure analysis shows minimal impact to the next dams.

APPENDICES

A location map, inspection photographs, and 2022 EGLE estimated flood flows are attached.

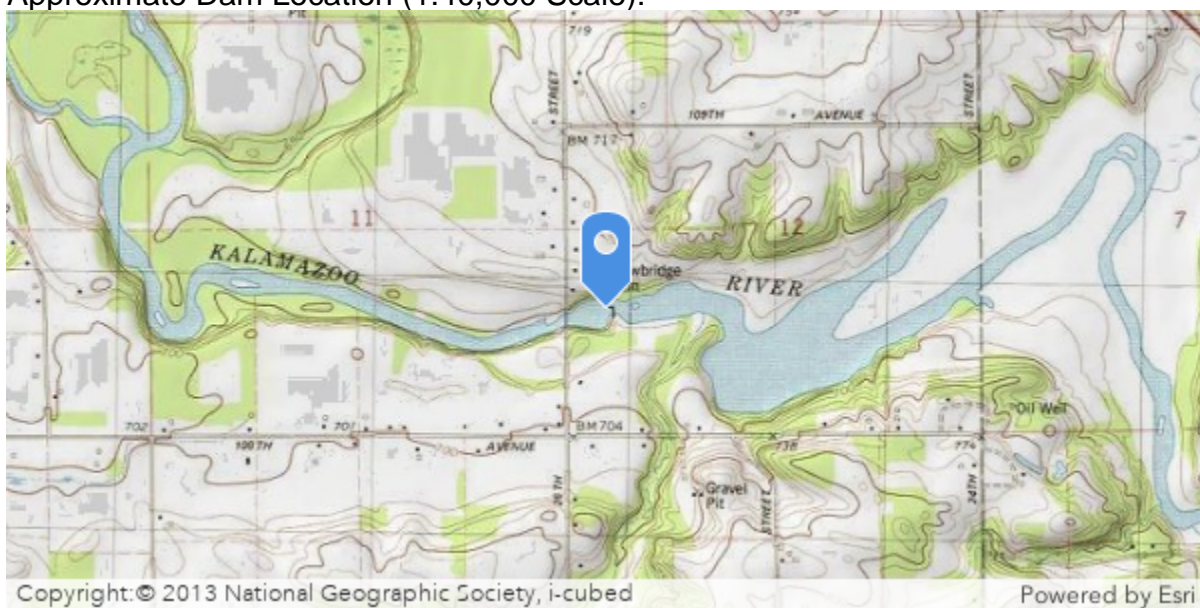
Trowbridge Dam
Dam ID No. 604
Section 12
T 01N
R 13W
Allegan County



Approximate Dam Location (1:70,000 Scale):



Approximate Dam Location (1:40,000 Scale):



**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**

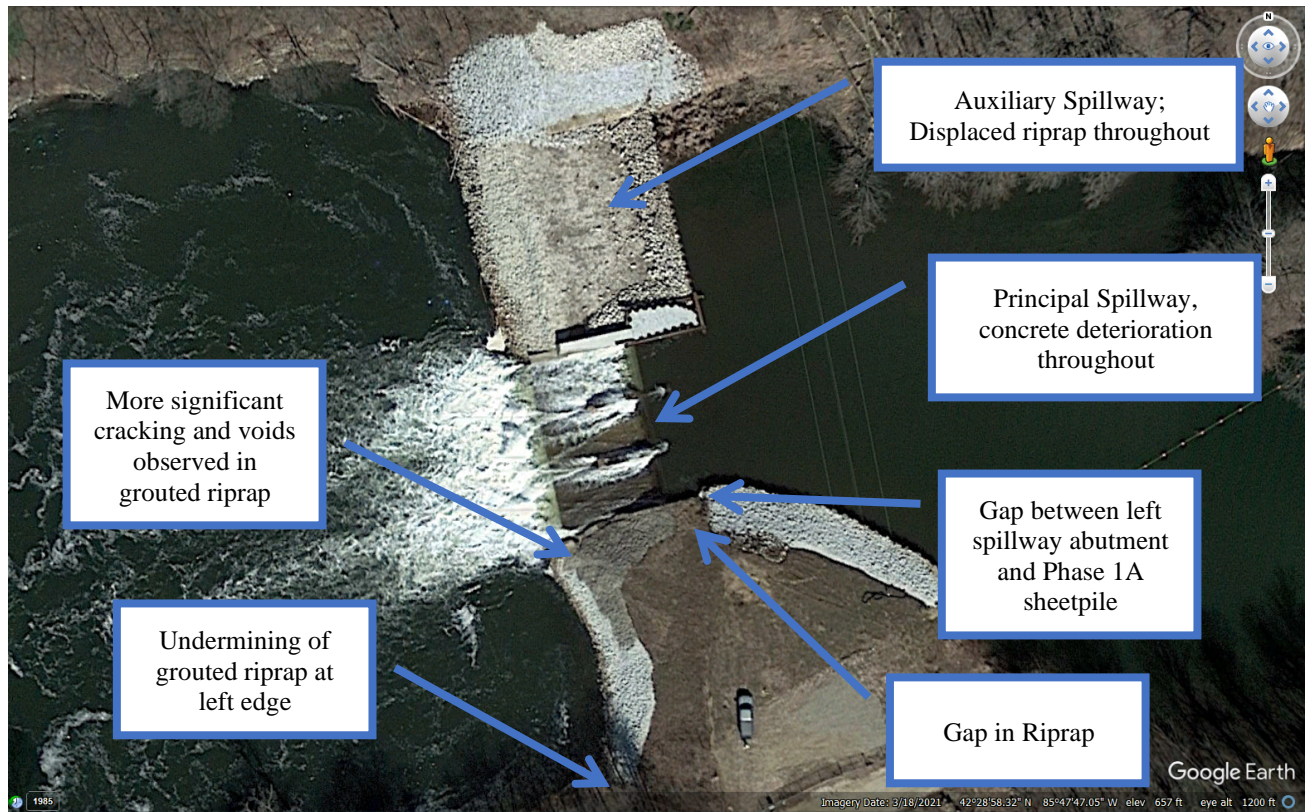


Photo #1 – Aerial imagery of dam after Phase 1A repairs. More significant deficiencies and their locations are identified



Photo #2 - Burrow on left embankment near spillway

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #3 - Upstream slope of left embankment near downstream end of Phase 1A sheetpile wall



Photo #4 - Upstream slope of left embankment, Phase 1A sheetpile wall, grouted riprap armoring. Note some brush growing in grouted riprap

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #5 - Upstream slope of left embankment, Phase 1A sheetpile wall, grouted riprap armor



Photo #6 - Upstream slope of left embankment, Phase 1A sheetpile wall, grouted riprap armor

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #7 - Upstream slope of left embankment, Phase 1A grouted riprap armoring up to weeds on embankment



Photo #8 - Upstream slope of left embankment left of sheetpile wall extent. Note brush

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #9 - Upstream slope of left embankment at left end of Phase 1A sheetpile wall



Photo #10 - Upstream slope of left embankment left of sheetpile wall extent. Note some brush growth

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #11 - Upstream slope of right abutment at edge of auxiliary spillway. Note overgrown riprap



Photo #12 - Crest of left embankment

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #13 - Crest of left embankment



Photo #14 - Crest of left embankment

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #15 - Crest of left embankment



Photo #16 - Crest of left embankment near spillway abutment. Note tree growing

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #17 - Crest of left embankment



Photo #18 - Crest of right embankment at tie in with natural grade

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**

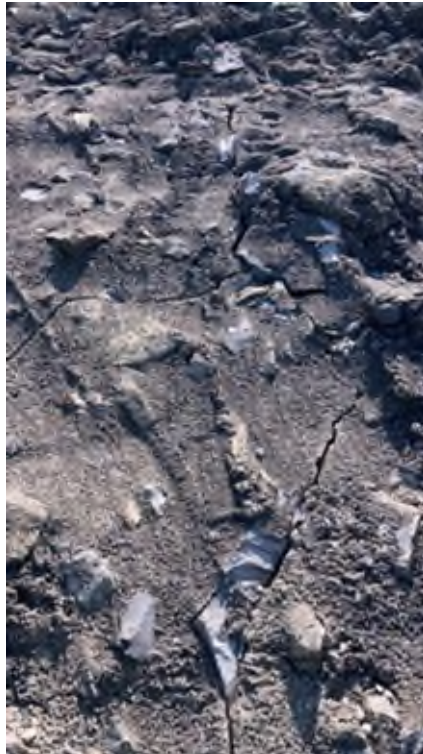


Photo #19 - Downstream slope of left embankment, old grouted riprap. Crack present from top to bottom.



Photo #20 - Downstream slope of left embankment. Void in old grouted riprap

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



**Photo #21 - Downstream slope of left embankment near principal spillway outlet.
Brush growing in holes in grouted riprap**



**Photo #22 - Void in grouted riprap on downstream slope of left embankment near
where brush is growing (see previous photo)**

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #23 - Void in grouted riprap on downstream slope of left embankment near where brush is growing (see previous photos)



Photo #24 - Void under grouted riprap on downstream slope of left embankment near spillway outlet

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #25 - Downstream slope of left embankment where old grouted riprap ends and Phase 1A grouted riprap begins



Photo #26 - Old grouted riprap on downstream slope of left embankment

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #27 - Phase 1A grouted riprap on downstream slope of left embankment



**Photo #28 - Phase 1A grouted riprap on downstream slope of left embankment,
left end**

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #29 - Undermining at left end of Phase 1A grouted riprap armoring on left embankment downstream slope



Photo #30 - Undermining at left end of Phase 1A grouted riprap armoring on left embankment downstream slope

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #31 - Downstream slope of left embankment viewed from left end



Photo #32 - Downstream slope of left embankment near crest

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #33 - Typical crack in old grouted riprap on downstream slope of left embankment



Photo #34 - Typical crack in old grouted riprap on downstream slope of left embankment, boot in shot for size reference

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #35 - Downstream slope of right embankment



Photo #36 - Downstream receiving channel

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #37 - Gap between principal spillway left upstream abutment and Phase 1A sheetpile. Note stacked sandbags and lack of riprap at gap



Photo #38 - Gap between principal spillway left upstream abutment and Phase 1A sheetpile wall

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #39 - Gap between principal spillway left embankment and newer sheetpile



Photo #40 - Some erosion observed at principal spillway left upstream abutment wall by gap

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #41 - Left upstream principal spillway abutment wall



Photo #42 - Left upstream principal spillway abutment wall at gap to Phase 1A sheetpile wall. See sandbags at left end of photo. Concrete shows some loss and undermining

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #43 - Principal spillway left abutment wall



Photo #44 - Principal spillway right upstream abutment wall, new Phase 1A wall

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #45 - Upstream impoundment, Kalamazoo River



Photo #46 - Principal spillway left downstream abutment, viewed from top

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #47 - Left pier within principal spillway. Note concrete deterioration and vegetation growth



Photo #48 - Principal spillway crest

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #49 - Right pier within principal spillway. Note concrete deterioration and vegetation growth



Photo #50 - Principal spillway right downstream abutment wall. Note minor concrete deterioration

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #51 - Principal spillway right downstream abutment wall



Photo #52 - Principal spillway left downstream abutment/training wall. Note vegetation growth

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #53 - Grouted riprap armoring near principal spillway left downstream abutment. Note voids in armoring



Photo #54 - Principal spillway outlet

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



**Photo #55 - Principal spillway left downstream abutment wall at downstream end.
Note concrete deterioration, misalignment of downstream left training wall**



**Photo #56 - Principal spillway left downstream abutment wall at downstream end.
Note concrete deterioration, misalignment of downstream left training wall**

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #57 - Principal spillway viewed from downstream



Photo #58 - Riprap abutment with left spillway downstream wall. Note voids

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #59 - Riprap abutment with left spillway downstream wall. Note voids



Photo #60 - Principal spillway left end

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #61 - Principal spillway



Photo #62 - Right pier within principal spillway

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #63 - Left pier within principal spillway



Photo #64 - Downstream face of pier between principal and auxiliary spillways

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #65 - Downstream face of pier between principal and auxiliary spillways



Photo #66 - Principal spillway left upstream abutment, Phase 1A sheetpile wall

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #67 - Gap between Phase 1A sheetpile wall and left upstream principal spillway abutment wall viewed from right



Photo #68 - Principal spillway left downstream abutment wall

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #69 - Top of pier between principal and auxiliary spillways



Photo #70 - Top of pier between principal and auxiliary spillways

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



**Photo #71 - Principal spillway left downstream abutment wall, downstream end.
Note misalignment in wall and vegetation growth**



Photo #72 - Principal spillway crest

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #73 - Upstream impoundment



Photo #74 - Downstream receiving channel

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #75 - Auxiliary spillway. Note riprap spread throughout spillway. Compare with next photo



Photo #76 - Auxiliary spillway from 2022 inspection. Note riprap is less spread out than the current state

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #77 - Right armored slope of auxiliary spillway



**Photo #78 - Riprap armoring on auxiliary spillway downstream of sheetpile crest,
some displacement**

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #79 - Right upstream end of auxiliary spillway sheetpile wall



Photo #80 - Right armored slope of auxiliary spillway above previous powerhouse wall. Note brush growth

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #81 - Downstream right end of auxiliary spillway, right embankment



Photo #82 - Downstream right end of auxiliary spillway, right embankment

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #83 - Brush growth within auxiliary spillway right armoring



Photo #84 - Downstream end of auxiliary spillway. Minor vegetation growth starting

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #85 - Downstream end of auxiliary spillway. Minor vegetation growth starting



Photo #86 - Auxiliary spillway viewed from downstream

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #87 - Receiving channel downstream of principal spillway



Photo #88 - Auxiliary spillway left downstream end

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #89 - Right face of pier between principal and auxiliary spillways. Note vegetation growth



Photo #90 - Armored surface of auxiliary spillway

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #91 - Displaced riprap downstream of auxiliary spillway crest



Photo #92 - Auxiliary spillway crest

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**



Photo #93 - Previous powerhouse wall, right side of auxiliary spillway



Photo #94 - Water is approximately 12" below auxiliary spillway sheetpile crest

**TROWBRIDGE DAM
ALLEGAN COUNTY
DAM ID NO. 604**

2022 HYDROLOGIC DATA

From: EGLE-wrd-qreq <EGLE-wrd-qreq@michigan.gov>
Sent: Tuesday, March 29, 2022 12:50 PM
To: Horak, Thomas (EGLE) <HorakT@michigan.gov>
Subject: RE: flood or low flow discharge request (ContentID - 168812)

We have processed the discharge request submitted by email on March 16, 2022 (Process No. 20220160), as follows:

Kalamazoo River at Trowbridge Dam, Dam ID 604, Section 12, T1N, R13W, Trowbridge Township, Allegan County, has a drainage area of 1538 square miles. The design discharge for this dam is the 0.5% chance (200-year) flood. The 0.5% chance peak flow is estimated to be 14000 cubic feet per second. (Watershed Basin No. 17 Kalamazoo).

These estimates should be confirmed by our office if an application is not submitted within one year. If you have any questions concerning the discharge estimates, please contact Ms. Susan Greiner, Hydrologic Studies and Floodplain Management Unit, at 517-927-3838, or by email at: GreinerS@michigan.gov.

-----Original Message-----

From: DoNotReply@michigan.gov <DoNotReply@michigan.gov>
Sent: Wednesday, March 16, 2022 1:19 PM
To: EGLE-wrd-qreq <EGLE-wrd-qreq@michigan.gov>
Subject: flood or low flow discharge request (ContentID - 168812)

Requestor: Thomas Horak
Company: EGLE
Address: 525 W. Allegan
City: Lansing
Zip: 48933
Phone: 517-231-8594
Date: 2022-03-16
F0.5percent: Yes
ContactAgency: None Selected
ContactPerson:
Watercourse: Kalamazoo River
LocalName:
CountyLocation: Allegan
CityorTownship: ?
Section: 12
Town: 01N
Range: 02E
Location: Trowbridge Dam #604
FFR1: Dam
fpReqEmailAddr: HorakT@michigan.gov