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Mineral Ridge Technical Review Panel

January 4, 2018

Meander Water
Attn: Mr. Ramesh D. Kashinkunti
Chief Engineer
1181 Ohltown-McDonald Road
Mineral Ridge, OH 44440

MINERAL RIDGE DAM, OH
TECHNICAL REVIEW PANEL MEETING
DECEMBER 18-20, 2017 – TRP REPORT #01

Dear Sir,

The Technical Review Panel (TRP), comprising the engineers listed in the letterhead, has pleasure in providing this report of its findings from the Meeting held in your premises from December 18-20, 2017. This Report is provided in compliance with Task (vii) of our contract, as described in Section 1.0, below. The Agenda for the Meeting is attached as Appendix 1, and a list of attendees is attached as Appendix 2.

1.0 BACKGROUND AND TRP CHARTER

Mineral Ridge Dam was designed before and during 1928 with construction completed in 1930. The maximum height of the dam is about 60 feet and the reservoir impounded by the dam is 7 miles long, 2,109 acres in area, and is estimated to contain over 11 billion gallons of water. Mineral Ridge Dam is the sole drinking water source for the Mahoning Valley Sanitary District (MVSD), which supplies water to approximately 220,000 people in Mahoning and Trumbull Counties, Ohio, including the cities of Youngstown and Niles.

The dam has undergone periodic inspections, assessments and repair with the last inspection completed in April 2016. As part of that 2016 inspection, the Emergency Action Plan (EAP) has been updated and reviewed with local emergency response agencies. The MVSD is commended for being proactive in this activity. It is common for Owners to not update the EAP and review with local emergency response agencies.

In 1978, the USACE Phase I study described the dam as being in good condition but having inadequate spillway capacity. In 1995, two auxiliary spillways were constructed to address this concern but, to date, have not had water pass over them. Additionally in 1995, the crest of the embankment dam was raised and an 18-inch-high inflatable dam was installed on the principal spillway crest.

Mineral Ridge Dam is a Class I dam. The Ohio Department of Natural Resources (ODNR) defines a Class I dam as 1) having a storage volume greater than five thousand acre-feet, or 2) having a height of greater than 60 feet. Further a dam is placed in the Class I category if sudden failure would result in a) probable loss of human life, or b) structural collapse of at least one residence or one commercial or industrial business.

A two-dimensional dam breach flood analysis, performed by Gannett Fleming, Inc. (Gannett Fleming) indicated that over 500 structures would be flooded in the event of a catastrophic breach at Mineral Ridge Dam. Given the importance of Mineral Ridge Dam as a water source, and the classification of the dam as a Class 1 (high hazard) structure, MVSD has started a program to assess and rehabilitate the dam to meet current regulatory requirements. Since the construction of the dam, engineers have experienced and analyzed dam failures throughout the world, data collection and analysis techniques have improved, and the state of the profession has advanced. ODNR regulatory requirements have changed to account for this information. Rehabilitation of the dam will be required to meet all current ODNR regulations (Ohio Revised Code 1501:21-13).

MVSD has contracted with Gannett Fleming to be the Engineer-of-Record, providing technical and design capabilities with respect to the initial assessment of the dam and preliminary design options. The assessment process is in the initial stages and there is much additional data analysis and design that will be required as the rehabilitation proceeds. To date, Gannett Fleming has completed a review of available historical documents, a 2014 Field Investigation Summary Report, a 2015 Draft Preliminary Design Report for Maintenance Items, a 2016 Preliminary Analysis and Evaluation Report, a 2016 Conceptual Level Design Alternates Report, and a report documenting the subsurface investigation conducted by them during 2016 and 2017.

MVSD has also appointed the Technical Review Panel (TRP). The TRP visited the site on December 18, 2017 and met at the MVSD offices between December 18 and December 20, 2017. During this meeting, Gannett Fleming representatives Paul Schweiger, Christopher Bailey and Timothy Johnson made a series of presentations on the history and design of Mineral Ridge Dam, previous repair work, and summarized initial recommendations for future rehabilitation of the dam. This Presentation is attached for convenience, as Appendix 3 (click here).

The TRP has been tasked to provide a review of the analysis and design options presented by Gannett Fleming to assist the MVSD Board to verify that appropriate and reasonable engineering solutions are pursued as the analysis and design process proceeds. Typically, a TRP will continue to work throughout the design and construction phases of the project to provide continuity and oversight.

At this time, the TRP has been directed to undertake the following tasks:

(i) Serve as independent advisors to MVSD and report directly to the District's Chief Engineer;
(ii) Review all work including reports and tech memos performed by Gannett Fleming related to the identification of potential failure modes (PFMs) at Mineral Ridge Dam and

the development of conceptual level dam modification alternatives and construction cost estimates;

(iii) Provide opinions on the overall acceptability of the above work relative to the standard practice for similar analyses and the current requirements of Ohio Department of Natural Resources (ODNR) Dam Safety Program and all other local and federal requirements;

(iv) Participate in one TRP workshop, which will consist of a 3-day work day session. The workshop will include a walking tour of the dam. The Consultant will interact with the District's Chief Engineer and the Board, other members of the TRP, and with the District's Design Engineer;

(v) Review historic design, construction, inspection reports related to the dam. Review various reports of investigations and analyses performed by the Design Engineer between 2014 and the present. The most recently prepared reports include a conceptual-level dam modification alternatives report with construction cost estimates and a geotechnical data report (raw data from 2016-2017 subsurface investigations with no engineering analyses);

(vi) Provide a preliminary verbal assessment of findings to the District's Chief Engineer and Board at the end of the workshop; and

(vii) Provide a signed written technical memorandum (report) assessment of the findings including a path forward for the final design to the District within 15 calendar days of the workshop.

Tasks (iv), (vi) and (vii) are completed. Tasks (ii) and (v) have been partially completed as part of preparation and participation in the workshop. At this time, no additional work is planned under Tasks (ii) and (v) unless requested by MVSD. For Task (iii), the alternatives for dam rehabilitation are at a preliminary stage and so it is not practical to provide an opinion about their compliance with all state, local and federal requirements.

2.0 GENERAL OBSERVATIONS AND PERSPECTIVE

1. This is a relatively old dam with several different structures, each with its own set of dam safety challenges. To the east, the embankment sits on bedrock, as does the principal spillway. All other structures are founded on overburden. Key structural elevations are summarized in Table 1.

Table 1. Elevations of key elements relating to Mineral Ridge Dam.

	Elevation (feet above mean sea level)
Current top of dam (curb)	Varies from 915.2-917.2 (design elevation: 916.5)
Proposed top of dam	917.2 (minimum)
Top of principal spillway	905.17
Top of rubber dam	906.67
Top of auxiliary spillway	910
Top of core wall	913
Water elevation (probable maximum flood)	917.2

	Elevation (feet above mean sea level)
Normal tailwater elevation	861
PMF tailwater elevation	893.4
Invert elevation	855
Stream channel bank height	874-876

2. To replace this asset would be practically impossible, considering permitting processes, interim loss of revenue and supply problems, and practical construction issues. Furthermore we guess that, for construction alone, the cost would be far in excess of $100 million.

3. Given the consequences of failure, this is a High Hazard Dam of vital importance, and will remain so even after rehabilitation. The design flood, per ODNR regulations, is the PMF and we must analyze and design accordingly. In addition, we must anticipate that ODNR will require a "level dam," and so the topographic low point at the Right Abutment will have to be addressed as part of the crest modification project.

4. Dating back to the USACE Phase 1 Report in 1978, the key (and indeed only) deficiency has been considered to be inadequate spillway capacity. However, the recent review by Gannett Fleming has revealed other potential major deficiencies, such as embankment stability and indeed the nature of the auxiliary spillways that, in our opinion, are equally of concern to dam safety. We believe that ODNR currently remain unaware of these other deficiencies.

5. We do not believe that the dam is in imminent danger of failure: this is not an "emergency" situation. However, it is most likely that, upon analysis, elements of the dam will not meet contemporary standards of acceptability, and so permanent interventions will be required.

6. Gannett Fleming's historical researches reveal that several innovative design and construction details were employed during the original construction. For example, the contractor engaged an independent consultant to conduct peer review of the design. The cutoff wall was an excellent feature, and has most probably saved the dam on several occasions and appears to still be hydraulically effective.

   However, these same contemporary processes have left a legacy which now poses potential dam safety implications. Examples are the relatively steep embankment slopes (2:1), the absence of a drainage/filter system as back-up to the cutoff wall, the use of "puddling" to place embankment fill (including hard clay "chunks") adjacent to the cutoff wall, and placing fill during winter conditions. Further, the top of the cutoff wall is at elevation 913. Given the PMF is at 917.2, this is a fundamental defect not remedied at all by the curb, located upstream of the cutoff wall and not in physical contact with it.

7. We now know the embankment failed twice in certain locations during construction, and even before reservoir filling. Since then, there have been several other downstream slope

failures near the principal spillway structure (1974, 1980, 1983, 1997 and 2009), all of which have been repaired. The cutoff wall reportedly suffered cracking during the initial failures although the extent is unclear. Seepage has been observed at the downstream toe in this vicinity. The interface between an embankment and a concrete structure is always a potential cause of concern for seepage and erosion. The integrity of the contact between the cutoff wall and the spillway wall is also unknown, although photographs from the original construction appear to show the cutoff wall being constructed on top of the battered wall of the principal spillway. This is considered a robust design detail.

8. The trove of historical information and records received by Gannett Fleming in March, 2016, is a vital discovery and has so far provided invaluable insight into the design, construction and performance of the dam. As noted in Point 6, above, the information has led to the development of several PFM's, in addition to those related primarily to the hydraulic deficiency. However, much analysis remains to be conducted, both on the historical information and new studies, to enable remedial options to be developed further. Recommendations for further studies are provided in Section 5.0 of this Report.

9. The deficiencies in the dam are typical for structures of its age, and so have been evaluated previously for other dams. As a result, remedial options addressing such deficiencies are well known and represent good and standard contemporary practices. However, when evaluating and remediating an existing dam under full reservoir conditions, the highest standards of care still apply. There must be no feeling of "familiarity breeds contempt" in any aspect of the rehabilitation

10. As detailed in Section 3.0 of this Report, the dam safety industry is progressing towards the Potential Failure Modes Analysis (PFMA) Process. This has not yet been completely or formally implemented on this project, although Gannett Fleming have appropriately applied the fundamental principles in arriving at their current set of preliminary analysis and remedial options.

11. Some PFMs (i.e. associated with seepage and internal erosion) may take many years to develop and progress, but a relatively short time to manifest themselves. Hence, successful performance over the 85 years of service to date provides no guarantee that a particular PFM can be dismissed.

12. We believe there are major deficiencies in the design of the 1995 auxiliary spillway modification to the extent that, if it were required to operate even for quite limited periods, breaching through the auxiliary spillway could result.

13. Distinction should be drawn between normal operational and maintenance tasks (including regular or visual observations and instrumentation readings) and the permanent rehabilitation concepts described elsewhere in this Report (e.g., Section 4.0).

3.0 REVIEW OF PFMA AND RISK ASSESSMENT PROCESSES

The Potential Failure Mode Analyses (PFMA) process is the state of the practice in dam engineering and an instituted practice and policy of several Federal agencies and other dam owners worldwide. The Federal Guidelines for Dam Safety Risk Management are documented in FEMA publication P-1025, dated January 2015. Federal Agencies that own, operate, and/or regulate dams utilize these Guidelines in specific Agency policy. It is acknowledged that State Dam Safety Agencies typically do not require use of these guidelines. However, the TRP does endorse the application of them to the extent practicable.

The initial element of a risk assessment is the review and updating of the potential defects which could cause the dam to fail. Risk assessments are used to (1) better understand the risk of the dam in relation to other dams (2) guide the planning, design, urgency, and priority for the type of remedial actions needed, and (3) improve the communication of all aspects of the project to stakeholders and the public that share in risk management responsibilities.

The purpose of a PFMA is to identify credible Potential Failure Modes (PFMs) for the existing facilities. The Owner can then focus dam safety efforts on the identified PFMs. Typically, a Dam Safety Surveillance Monitoring Plan (DSSMP) is developed based on the results of the PFMA, and the intent is to focus surveillance and monitoring of the project on the identified PFMs. The process may also highlight the need for additional analyses and investigations necessary to perform remedial construction, and/or for making operational changes that reduce the likelihood of a PFM progression and occurrence. The product of the analysis is not a decision document but an informational resource document to be used by the Owner to enhance their efforts and focus their resources where most appropriate.

Dam Safety consists of three primary components as depicted in Figure 1.

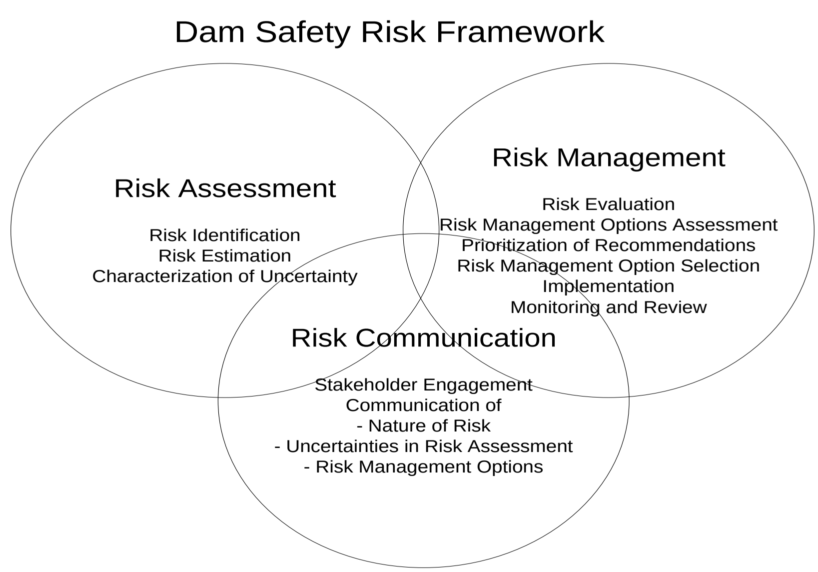

Figure 1. Dam Safety Risk Framework

The components of risk are depicted in Figure 2.

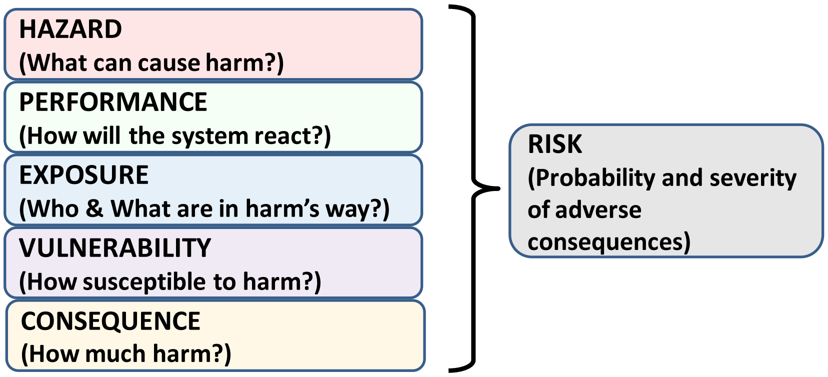

Figure 2. Components of risk in dam safety analyses.

Regarding the three primary components of Dam Safety (Figure 1):

- **Risk Assessment.** Risk Assessment (RA) is a broad term that encompasses a variety of analytic techniques that are used in different situations, depending upon the nature of the risk, the available data, and the needs of decision makers.

  The risk assessment process attempts to answer the following four questions:

  – What can go wrong?
  – How can it happen?
  – What is the likelihood?
  – What are the consequences?

  It is a systematic, evidence-based approach for quantifying and describing the nature, likelihood, and magnitude of risk associated with the existing and future conditions without action and the values of the risk resulting from a changed condition due to some action.

- **Risk Management.** Risk management is the process of problem-finding 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 those technically sound integrated actions to reduce risks after consideration of the effectiveness and costs of each increment of risk reduction. Environmental, social, cultural, ethical, political and legal considerations all factor into the decision made on how much cost will be incurred for each increment of risk reduction (how safe is safe enough?).

  Risk management for dams includes short-term Interim Risk Reduction Measures (IRRM), long-term structural risk reduction measures, and strengthening recurrent activities - such as monitoring and surveillance, emergency action planning, operations and maintenance, and staff training.

- **Risk Communication.** Risk communication is the open, two-way exchange of information, opinion, and preferences about hazards and risks leading to a better understanding of the risks and better risk management decisions. Risk communication is integrated into the assessment and management processes. It is not a task that occurs only after decisions have been made. Risk communication ensures that the decision makers, other stakeholders, and affected parties understand and appreciate the process of risk assessment and in so doing can be fully engaged in and responsible for risk management.

To reiterate, Potential Failure Mode Analysis (PFMA) is a method of analysis where particular faults and initiating conditions are postulated and the analysis reveals the full range of effects of the fault or the initiating condition on the system. The methods of failure are identified, described, and evaluated on their credibility and significances. Failure Modes are ways that failure can occur, described by the means by which element or component failures must occur to cause loss of the sub-system or system function. The failure mode encompasses the full sequence of events from initiation (cause) through to the realization of ultimate failure to include physical, operational, and managerial systems. PFMA is the first step in conducting a risk assessment for an existing dam or a risk reduction action. Thorough failure mode identifications and complete descriptions will lead to a more efficient risk assessment process. Interim risk reduction measures (IRRM's) and instrumentation and study plans can be effectively developed based on the results of the PFMA.

A PFMA session is normally facilitated by a person trained in the identification and examination of potential failure modes (PFM) for a dam on behalf of a diverse team of persons who are qualified by experience and/or education to evaluate the dam. It is based on a review of available data and information, first hand input from field and operational personnel, site inspections, completed engineering analyses, discussion of known issues/problems, a general understanding of dam characteristics, and an understanding of the consequences of failure. The PFMA outcomes will include the following:

- List and detailed description of each PFM with a list of the factors that make the failure mode more likely to occur and a list of the factors that make the failure mode less likely to occur.
- Classification of PFM's as not credible, credible and significant.
- Major findings and understandings.

Uncertainty is the result of imperfect knowledge concerning the present or future state of a system, event, situation, or (sub) population under consideration. Uncertainty leads to lack of confidence in predictions, inferences, or conclusions. It is important to distinguish uncertainty that results from a lack of knowledge from the uncertainty that results from variability. Variability and uncertainty are in many ways interchangeable; variability could be thought of as a specific source of uncertainty. For example, a risk assessor may be very certain that stream flows vary over a year but may be uncertain about the amount of that variability. Collecting more and better data can often reduce uncertainty, whereas variability is an inherent property of the system/population being evaluated. Variability can be better characterized and addressed quantitatively with more data but it cannot be reduced or eliminated. Efforts to clearly distinguish between variability and uncertainty are important because they can influence risk management decisions.

The five potential failure modes identified in Gannett Fleming's Preliminary Analysis and Evaluation (PAE) Report dated March 2016 for Mineral Ridge Dam are listed as follows:

1. Principal Spillway - Failure by sliding
2. Existing Twin Auxiliary/Emergency Spillways - Failure by surface erosion and breaching
3. Dam Embankment - Failure by internal erosion
4. Top of Dam – Failure by seepage, surface erosion and downstream slope instability
5. Inadequate Spillway Capacity (Marginal) – Failure by overtopping and surface erosion of the earth embankment

Based upon review of data presented by Gannett Fleming during the meeting, these failure modes are considered to be appropriate failure modes based on the current level of understanding, but are described in more general terms than is typically done in a facilitated PFMA as previously described. The TRP anticipates that other failure modes involving the foundation, should be developed and analyzed further.

Gannett Fleming has also developed a Data Inventory and Listing (database) that contains historic documents of original design and construction of the dam and including limited information of the spillway modifications completed in 1995. These historical data are critically important to conducting a thorough PFMA. It is virtually impossible to fully evaluate the condition of Mineral Ridge Dam until all available data are organized and summarized. It is critical that this effort be completed.

Based on the five potential failure modes listed previously, Gannett Fleming has developed a range of alternatives to address them and have been documented in detail in the reports prepared and submitted to the MVSD. These alternatives are considered by the TRP to be appropriate based on historical case histories of modifying dams with similar issues. However, it should be noted that the overall status of the project is in the early stages and the rehabilitation alternatives may need reevaluation based on additional investigations and analyses.

Internal erosion failure modes are the most frequent causes of deterioration and failure of embankment dams. Essentially, all dams have seepage. It can usually be characterized by visual inspections and field measurements. However, in some instances, the seepage is not readily detectable, and so its characterization is difficult to achieve. It is a complex phenomenon which can initiate by various mechanisms such as backward erosion, concentrated leak erosion and internal instability. These mechanisms involve soil particle detachment under seepage with sufficient energy. For internal erosion to occur there must be seepage, presence of erodible material along the flow path and a possibility for the eroded material to escape. Internal erosion implies the presence of seepage, but seepage does not necessarily imply internal erosion.

Internal erosion of soil materials may result if transitions between fine-grained soils forming an impervious core and surrounding, supportive shell zones or drainage features are not designed and constructed with properly graded filter zones or are not present. Damage to the impounding capability of the dam would likely remain unseen until substantial and invasive remedial action is required due to the absence of the filter zones

4.0 DISCUSSION OF PRIORITIES AND OPTIONS

The District staff, the TRP and Gannett Fleming staff reviewed the issues and proposed remediation alternatives identified by Gannett Fleming. While the session was not a formal PFMA of the type outlined in Section 3.0, the basic principles were correctly followed. The general intent of this discussion was to confirm the preliminary issues identified by Gannett Fleming and develop an initial recommendation on the prioritization of the remediation alternatives using the information presented during the workshop. The issues were separated into the following for discussion purposes, building on the 5 PFM's listed in Section 3.0:

1. Top of Dam Modifications (Extend Core Wall and Repave)
2. Principal Spillway Sliding/Overturning
3. Principal Spillway Stilling Basin Uplift and Erosion
4. Downstream Embankment Slope Seepage Filter and Stability
5. Upstream Embankment Slope Stability
6. Auxiliary Spillway Control Sections Uplift/Failure
7. Auxiliary Spillway Erosion Failure
8. Gate and Gate House Structure Failure
9. Deferred Maintenance Items (Access roads, concrete repairs, electrical upgrades, and the inflatable dam)

The major discussion topics included:

1. Identification of the critical loading condition and the associated likelihood for the loading condition to occur.
2. An initial assessment of the consequences for each issue (such as dam breach or loss of reservoir operation).
3. The identification of potential dependency between the issues and the recommended remediation alternatives.
4. Interim risk reduction measures that could potentially be considered for implementation prior to a final remediation alternative be designed and constructed.

The District staff, TRP members and Gannett Fleming staff were then asked to individually develop a ranking for the priority of the issues based on their judgment without additional discussion/input from other present. This initial ranking was intended to limit potential biases in the ranking. These initial rankings were then tabulated and averaged based on the 3 groups (TRP members, District staff and Gannett Fleming staff). Differences between individuals and groups were then used as a basis to aid the discussion of the different interpretations of risk/relevance associated with the rankings. The areas where the individual rankings varied the most were generally associated with the personal perception and rationalization of consequences versus potential of occurrence.

The summary table developed as part of this work is included as Table 2. The prioritization ranking was developed with a ranking that associated a lower number with higher priorities and higher number having a lower priority. The actual individual rankings are included, for convenience and completeness, in Appendix 4.

Table 2. Summary and Prioritization of Issues Identified by Gannett Fleming

	Dam Feature/ Deficiency	Critical Loading Condition and Potential to Occur	Consequence	Dependency	Interim Risk Reduction Measure(s)	Ranking
1	Top of Dam Modifications (Extend Core Wall and Repave)	Near-PMF (Low): Above Top of Corewall at El. 913.0	Saturation/ Erosion of downstream slope	Could be dependent/integral with downstream slope	Lower pool; Have an intervention plan in place including readily available materials and equipment	4.0
2	Principal Spillway Sliding/Overturning	Requires MCE (Maximum Credible Earthquake - 1/10,000 year event)	Loss of reservoir / catastrophic failure	None	Lower pool; Redrill drains; monitor uplift	5.0
3	Principal Spillway Stilling Basin Uplift and Erosion	High	Could lead to or exacerbate PMF 2	Could be done integral with redrilling the drains	Monitor; further inspect; redrill drains, develop as-built profile	3.3
4	Downstream Embankment Slope Seepage Filter and Stability (incl. seismic loading)	High for all stability loading conditions; Moderate for seepage/piping failure	Loss of reservoir / catastrophic failure	Must modify spillway training walls and top of dam	Have an intervention plan in place including readily available materials and equipment; regular inspections including structural monitoring, seepage/piezometer monitoring, continue grass maintenance; lower pool level; remove woody vegetation in area of West Embankment seepage point; remove riprap at auxiliary spillway to provide improved observation/ monitoring	3.0

	Dam Feature/ Deficiency	Critical Loading Condition and Potential to Occur	Consequence	Dependency	Interim Risk Reduction Measure(s)	Ranking
5	Upstream Embankment Slope Stability	Rapid Drawdown unlikely given limited outlet works capacity	Loss of water supply / repair required	None	Operational controls	7.3
6	Auxiliary Spillway Control Sections Uplift/Failure	Initiated for Approx. 100-year Event: Above Top of Corewall at El. 908.5	Loss of control section; exposure and failure of corewall; breaching of spillway	None	Have an intervention plan in place including readily available materials and equipment; continuous monitoring during events exceeding 100-yr return period; plug spillway drains that lead to the spillway; continue practice of deflating the inflatable gate in advance of storm events; confirm operability of auto-deflate mechanism	2.7
7	Auxiliary Spillway Erosion Failure	Reservoir levels above El 910	Breaching of the spillway	None	Have an intervention plan in place including readily available materials and equipment; continuous monitoring during events exceeding 100-yr return period; inspect grass cover and remove any woody vegetation;	3.6
8	Gate and Gate House Structure Failure	Low / MCE?	Low	None	Exercise regularly; Keep manual controls available; evaluate seismic loading of gate house	7.6
9	Deferred Maintenance Items (Access roads, concrete repairs, electrical upgrades, inflatable dam…)	N/A	Increase risk of defective operation; public relations	None	None	8.9

The TRP considers the following discussion points to be of particular relevance:

1. The deficiency with the highest prioritization was related to the auxiliary spillway crest (Deficiency #6). The TRP and Gannett Fleming staff concurred that the drains under the auxiliary spillway crest should be sealed to limit the potential direct hydraulic connection between the reservoir and the underside of the concrete lining the auxiliary spillway chute.

2. The ranking for the second highest deficiency, Downstream Embankment (Deficiency 4), was largely influenced by the past performance issues as well as its ongoing potential risk under normal operating conditions.

3. The primary spillway stilling basin stability was generally ranked at as a higher deficiency given the concerns that the slab could easily be exposed to hydraulic loading conditions that are more severe than those that were evaluated for the inspection case. The spillway inspection was not able to be completed in the dry due to concerns about the uplift forces under the slab potentially exceeding the weight of the concrete slab. The layout of the unlined portions of the auxiliary spillway channel was a concern with regard to potential erosion due to both the estimated velocities was well as the turbulent flow conditions that would be inherent given the non-conventional geometry.

4. Deficiencies 5, 8 and 9 were given the lowest prioritization based on either the likelihood of occurrence or the extent of the anticipated consequences.

5. While the modifications to the dam crest were given a fairly low priority ranking based on risk, the modifications should be completed with the downstream embankment modifications due to the positive incremental cost to risk reduction benefit.

6. The re-drilling of the drains within the gallery of the principal spillway should be considered both as an interim risk reduction measure as well as a measure that could be used to facilitate modifications to the principal spillway stilling basin.

7. Deficiencies 5, 8 and 9 were given the lowest prioritization based on either the likelihood of occurrence or the extent of the anticipated consequences.

8. The current project estimate for the full scope of the rehabilitation by Gannett Fleming is in the range of $22-30 million (in 2018 dollars) as detailed in <u>Appendix 5</u>. The breakdown of the costs for the deficiencies are as follows:

   12% Downstream Embankment and Dam Crest Modifications (#1 and #4)
   39% Principal Spillway (Issues 2 and 3)
   39% Auxiliary Spillway (Issues 6 and 7)
   10% Deferred Maintenance (Issue 9)

There are currently no remediation costs attributed to Issues 5 and 8.

5.0 SUMMARY OF RECOMMENDATIONS

Excellent progress has, to date, been made by Gannett Fleming in collecting and analyzing information relating to the safety of the various components of this dam. However, much remains to be done, and the TRP strongly recommends that MVSD commission the following tasks:

Group A (Desk Studies)

- Complete the analysis of the historical data, and especially those relating to the 1995 modifications.
- Prepare a Geotechnical Interpretative Report (GIR) based on the Geotechnical Data Report (GDR), updated as appropriate.
- Prepare a Final Report on the hydrologic issues and submit to ODNR for concurrence as early as possible.
- Provide a synthesis of the dam instrumentation data gathered to date (specifically piezometric levels, seepages, and structural movement).
- Develop a baseline hydrogeological model.
- Conduct stability analyses of all structural components under both static and seismic load cases.
- Conduct a seepage analysis.
- Conduct a petrographic analysis of the concrete to determine current properties including susceptibility to AAR.
- Conduct a full, formal PFMA for this dam, using all the available data and analyses.
- Progress the remedial options analysis to a level that projected costs can be better defined.
- Compile a review of case histories relating to the use of RCC for Auxiliary Spillway construction that have similar hydraulic conditions (i.e. unit discharges, velocities, etc.) to those proposed for Mineral Ridge Dam. These reviews should specifically consider operational performance to date for freeze thaw durability, and for operational flow conditions.

Group B (Field Investigation)

- Consider conducting a bathymetric survey of the reservoir to revise storage capacity estimates. If the reservoir storage capacity is reduced below levels acceptable to MVSD, modifications to the principal and/or auxiliary spillway alternatives may be warranted as a cost effective means to restore storage capacity without the need to complete an additional project in the near future.

- Conduct a dam instrumentation audit to assure that the current disposition is adequate to monitor the major PFM's, and measure the benefit of the Risk Reduction Measures (e.g., due to uplift upon dewatering).

- Conduct a condition survey of the Principal Stilling Basin Slab, while causing it no harm from hydrostatic uplift forces.

- Remove trees and other vegetation below the toe of the west embankment adjacent to the principal spillway to permit observation and measurement of seepage.

Group C (Outreach)

- When District staff and the Engineer-of-Record judge that sufficient progress has been made on the studies and evaluations, share the interim findings with ODNR so that any requests/ requirements/recommendations they may have can be dealt with in an efficient and effective manner.

- Consider developing a Communications Plan addressing both internal and external shareholders.

As a final point, based on what we have learned to date, the TRP is unanimous in its recommendation that major and permanent remedial efforts are required to bring certain structures of this project into compliance with contemporary standards. In particular, attention to the embankments, the Auxiliary Spillway, and the Principal Spillway Stilling Basin Slab is especially warranted. As described in Section 4.0, we concur that the crest repair and the placement of a filter blanket on the embankment represents "low hanging fruit" which could be plucked in an expeditious manner while other interventions are planned. Our opinion is based purely on technical arguments. The TRP is, of course, aware that these interventions will come with significant impact on the District's expenditures and cash flow. However, we do not consider it within our Charter to comment further on the economic case, except as may be specifically requested by District at some point in the future.

6.0 LIMITATIONS

This review has been conducted and the report has been prepared in general accordance with the current standard of practice for the purpose of providing an independent assessment of the rehabilitation concepts proposed by Gannett Fleming. It consists of a review of work prepared by others, a site visit, and discussions with Gannett Fleming. It has not involved an in-depth analysis of site conditions, detail checking, or independent analysis. This work is not an endorsement of the design, nor does it represent any guarantees or warranties, either expressed or implied.

7.0 CLOSURE

The TRP thanks MVSD for the invitation to participate in this important review process and commends MVSD for initiating the process. The TRP has formalized its preliminary verbal assessment (presented to the MVSD Board on December 20, 2017) in this technical report. The TRP may also provide a consolidated review and comments on reports prepared by the Design Engineer between 2014 and 2017, in accordance with Tasks (ii) and (v) as detailed in Section 1.0, although we acknowledge that MVSD is currently considering the scheduling of completion of these tasks.

Respectfully submitted,

David B Paul

David B. Paul

Donald A. Bruce

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Appendices:

1. Meeting Agenda
2. List of Attendees
3. Gannett Fleming Inc. Presentations on the History and Design of Mineral Ridge Dam
4. Individual participant rankings
5. Breakdown of Budget Rehabilitation Costs