LOWER BEAVER BROOK DAM

ALTERNATIVES ANALYSIS REPORT
FOR DAM SAFETY MITIGATION

Prepared for the
Lookout Mountain Water District
1202 Bergen Parkway, Suite 215
Evergreen, CO 80439

October 2, 2017
EXECUTIVE SUMMARY

Lower Beaver Brook Dam was originally constructed in 1903 and is located in Clear Creek County, Colorado. It is classified as a small-sized, high-hazard potential dam, with the potential of loss of human life as a result of the failure of the dam. The goal of the Lower Beaver Brook Dam Alternatives Analysis Report was to evaluate the identified dam safety issues at Lower Beaver Brook Dam and develop the most practical reasonable solution to address the identified dam safety issues. The dam is owned by the Lookout Mountain Water District (LMWD) that supplies potable water to approximately 480 residential taps and several other facilities, including a high school, in Jefferson and Clear Creek Counties.

Several dam safety issues have been identified at Lower Beaver Brook Dam, including a significantly undersized spillway for routing the inflow design flood (IDF). The spillway is capable of passing approximately 300 cubic feet per second (cfs) before embankment overtopping is expected to occur, which is less than the 2-year flood (GEI, 2016). Other dam safety issues include uncontrolled embankment and/or foundation seepage; concerns associated with the stability of the embankment; and concerns associated with the age and operability of the outlet works components.

W. W. Wheeler and Associates, Inc. evaluated six alternatives to mitigate the dam safety issues at Lower Beaver Brook Dam, which are briefly summarized in Table No. ES-1. Alternative Nos. 1, 2, and 3 were from a previous study by GEI Consultants, Inc. (GEI, 2015). After considering each alternative’s ability to adequately address the dam safety issues; their construction and long-term stability; their ability to maintain the LMWD’s water storage, water level, and water rights for operation; their ability to maintain existing routine flow conditions for the downstream floodplain; and their expected future maintenance work; Alternative No. 5, a new concrete dam, was considered to be the preferred alternative. Alternative No. 4, Dam Rehabilitation with RCC Overtopping Protection, is considered a secondary alternative.

Table ES-1 – Summary of Alternatives and Selection

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<th>Evaluation</th>
</tr>
</thead>
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<td>1 – Lower normal pool with a 100-foot-wide spillway</td>
<td>Eliminated from consideration based on concerns with flow; rock slope excavation and stability concerns; the lower normal pool not being favorable for operations of the water treatment facility; and the additional discharges that would be released from the dam during routine flow conditions that could impact the downstream floodplain.</td>
</tr>
<tr>
<td>2 - Lower normal pool with a 60-foot-wide spillway and a 3-foot-high parapet wall dam raise</td>
<td></td>
</tr>
<tr>
<td>3 - Lower normal pool with a 45-foot-wide spillway and a 5-foot-high MSE wall dam raise</td>
<td></td>
</tr>
<tr>
<td>4 - Dam Rehabilitation with RCC Overtopping Protection</td>
<td>This alternative was not selected because of expected maintenance issues associated with a portion of the 114-year-old embankment remaining.</td>
</tr>
<tr>
<td>5 - New Concrete Dam</td>
<td><strong>This is the preferred alternative.</strong> This alternative eliminates the identified dam safety deficiencies and provides the best long-term solution.</td>
</tr>
<tr>
<td>6 - Dam (and reservoir) Removal</td>
<td>Eliminated from consideration due to the value of the reservoir storage.</td>
</tr>
</tbody>
</table>
# Lower Beaver Brook Dam
## Alternatives Analysis Report

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1.0 INTRODUCTION

1.1 Objective
The objective of the Lower Beaver Brook Dam Alternatives Analysis Report was to evaluate the identified dam safety issues at Lower Beaver Brook Dam and develop the most practical reasonable solution to address the dam safety issues. This Lower Beaver Brook Dam Alternatives Analysis Report is a comprehensive report, including previous work completed in 2015 by GEI Consultants, Inc. (GEI, 2015) as well the documentation of the development of additional conceptual alternative plans for mitigation of the identified dam safety deficiencies at Lower Beaver Brook Dam. This report provides the Lookout Mountain Water District (LMWD), the owner of Lower Beaver Brook Dam, with a recommended plan for mitigating the identified dam safety deficiencies at Lower Beaver Brook Dam.

1.2 Authorization
The work documented in this report was prepared by W. W. Wheeler and Associates, Inc. (Wheeler) in accordance with an agreement authorized by the Lookout Mountain Water District on January 9, 2017.

1.3 Scope of Work
Wheeler performed the following work as part of the Lower Beaver Brook Dam Alternatives Analysis Report.

1. Previous studies were reviewed and evaluated, including previously developed alternatives for mitigating the spillway issues at Lower Beaver Brook Dam by GEI, 2015.
2. Wheeler performed a dam inspection and reviewed information from previous dam safety inspections performed by the Colorado Division of Water Resources (DWR).
3. Additional conceptual alternative plans were developed to address the spillway and other dam safety deficiencies at Lower Beaver Brook Dam.
4. Feasibility-level designs and opinions of probable costs were developed for each additional alternative plan.
5. Alternatives were evaluated based on their ability to adequately address the dam safety issues; their construction and long-term stability; their ability to maintain the LMWD’s water storage, water level, and water rights for operation; their expected future maintenance work; and their comparative costs.
6. Wheeler met with the LMWD Board of Directors and Treatment Technology, who operates the water treatment facility, to discuss the alternatives and their associated benefits and costs.
7. The Lower Beaver Brook Dam Alternatives Analysis Report was developed summarizing the conceptual alternative plans and the recommended plan for mitigation of the dam safety deficiencies at Lower Beaver Brook Dam.

1.4 Planning Process
The LMWD was formed in 1988 as a special district that owns and operates facilities to support the water service to approximately 480 residential taps and several other facilities, including a high school, in Jefferson County and Clear Creek County, Colorado. The LMWD owns and operates three reservoirs (dams) to support the water system.

The Colorado Division of Water Resources (DWR) Dam Safety Branch implemented a Dam Safety Compliance Plan for Lower Beaver Brook Dam on February 9, 2016 based on the spillway inadequacy and deficiencies associated with the outlet works. In accordance with the Compliance Plan, LMWD finalized the Incremental Damage Assessment (IDA) to size the Lower Beaver Brook Dam spillway and completed an inundation map for Lower Beaver Brook Dam in 2016 and 2017. The Compliance Plan recommends that an interim design be prepared for the Lower Beaver Brook spillway by November 1, 2017. The LMWD has met with the Colorado DWR and have expressed their interest in focusing on securing funding for the design and construction of a comprehensive Lower Beaver Brook Dam rehabilitation project as opposed to a costly, interim fix. The LMWD and Colorado DWR are in agreement on modifying the Dam Safety Compliance Plan and the LMWD plans to propose modifications to the compliance plan to suggest various temporary solutions to provide additional residual flood storage in the drainage basin above Lower Beaver Brook Dam.

The LMWD has been proactive in working towards addressing the Colorado DWR's concerns on the spillway size. In 2015, prior to the issuance of the Dam Safety Compliance Plan, the LMWD contracted with GEI to develop conceptual level alternatives for mitigating the spillway size deficiency. The preferred alternative, based on the conceptual design alternatives developed by GEI, was a conceptual design to modify the existing dam with Roller Compacted Concrete (RCC) overtopping protection for the dam crest and downstream slope.

The LMWD has been proactive in researching funding options for the design and construction for the Lower Beaver Brook Dam rehabilitation. The LMWD elected to retain W. W. Wheeler and Associates, Inc. (Wheeler) to perform an independent review of the GEI conceptual alternatives and associated costs for spillway repairs; evaluate if other alternatives should be considered; and ultimately to develop a feasibility-level design to address the identified dam safety issues. Wheeler's work is summarized in this report.
1.5 **Lookout Mountain Water District Overview**

The Lookout Mountain Water District is a special district as governed by Title 32 of the Colorado Revised Statutes (C.R.S.). Two of the LMWD reservoirs (and associated dams, including Lower Beaver Brook Dam) and one water treatment facility are in Clear Creek County, Colorado. The LMWD water consumers reside or operate in the unincorporated areas of Evergreen and Golden, primarily in the area known as Lookout Mountain in Jefferson County (zip codes 80401 and 80439), Colorado. The LMWD operates as a system comprised of tap owners and property owners included in the LMWD’s boundaries; the elected Board of Directors; and the contractors and consultants who provide operation and management.

LMWD assets include land, dams and reservoirs, water rights, a treatment facility, and components of the distribution system, such as the main pipeline and meters. Approximately 480 households, 14 governmental sites including a high school and about 10 business or church sites are served by LMWD taps and fire hydrants; some additional tap owners do not currently have active service but will be connected in future years. The LMWD provides water for domestic uses and fire suppression to a critical communications infrastructure site serving Jefferson County and the adjacent counties. Governmental sites are operated by Evergreen Fire Protection District, Clear Creek School District RE-1, Denver Mountain Parks, Jefferson County and Jefferson County Open Space, Foothills Fire Protection District and Highland Rescue Ambulance District. Together the described served households, tap owners, and sites (also known as customers) will be referred to as “Water Consumers”.
2.0 BACKGROUND

2.1 Lower Beaver Brook Dam Description
Lower Beaver Brook Dam is located in Clear Creek County Colorado approximately 7.1 miles northwest of Evergreen, Colorado. See the location on Figure No. 1. Lower Beaver Brook Dam is owned by the LMWD and is operated by Treatment Technology. The Upper Beaver Brook Dam is located upstream of the Lower Beaver Brook Dam.

Lower Beaver Brook Dam is a small, high-hazard, concrete-face rockfill dam with a reinforced concrete slab installed on the upstream slope. The dam was originally constructed in 1903 and was modified in 1936 by reinforcing the upstream concrete face and flattening the downstream slope (Gardner, 1936). Lower Beaver Brook Dam has a crest length of 224 feet and a crest width of 12 feet at Elevation 7840.01. The dam height, as measured from the dam crest to the downstream invert of the outlet works is about 39 feet. The upstream slope is approximately 0.7H:1V (Horizontal to Vertical) and the downstream slope is about 1.25H:1V. Lower Beaver Brook Dam impounds approximately 27.9 acre-feet of water at the normal operating level (spillway crest) elevation of 7837.7 feet (GEI, 2016).

The spillway is an uncontrolled rectangular channel with a width of approximately 29 feet located on the right abutment. The spillway has an upstream concrete control sill that is approximately 2 feet long at Elevation 7837.7 feet. The spillway discharge channel is an open channel founded on exposed bedrock with several near-vertical drops and a concrete-constructed drop structure. The spillway capacity is approximately 313 cubic feet per second (cfs) (GEI, 2016).

The outlet works consists of two 14-inch-diameter steel pipes extending through a rock tunnel. The rock tunnel is constructed through the foundation bedrock beneath the right half of the dam. A concrete bulkhead is installed on the upstream end of the rock tunnel. The 14-inch-diameter pipe on the right was lined with a 12-inch-diameter HDPE pipe in 1988. This pipe provides water to the water treatment facility and is operated in a constant pressurized condition. The 14-inch-diameter pipe on the left routes discharges to the downstream channel; the downstream discharge elevation of this pipe is approximately 7801.0 feet. Both pipes have gate valves installed immediately downstream of the bulkhead at the upstream end of the rock tunnel. It is our understanding that the gate valve on the right (for the pipe that extends to the water treatment facility) has not been operated in years and the left gate valve is operated occasionally for releases. A 4-inch-diameter PVC bypass pipe is installed extending from the springline of the right 14-inch-diameter pipe, routing discharges into the crown of the left 14-inch-diameter pipe that ultimately discharges into the downstream channel. This bypass system is used to release discharges of a lesser amount from the reservoir.

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1 Elevations in this report are based on the National Geodetic Vertical Datum of 1929 (NGVD 29) to be consistent with the original construction drawings.
2.2 **Identified Dam Safety Issues**

Several dam safety deficiencies have been identified at Lower Beaver Brook Dam. A majority of these deficiencies were initially identified by the Colorado DWR during the Dam Safety Engineer Inspections and were confirmed by Wheeler during a January 2017 site visit. The 2015 and 2016 Colorado DWR Engineer's Inspection Reports are included in Appendix A. The identified issues include the following:

1. **The spillway is undersized to pass the Inflow Design Flood (IDF) and is deteriorated.** The existing spillway has a normal freeboard of approximately 2.3 feet (from the dam crest to the spillway crest) and is capable of passing approximately 300 cfs before embankment overtopping is expected to occur, which is less than the 2-year flood (GEI, 2016). The IDF for Lower Beaver Brook Dam has a peak inflow of 4,755 cfs (GEI, 2016). The existing spillway can only pass approximately 6% of the IDF prior to embankment overtopping occurring.

   The upstream concrete control sill for the spillway has severe concrete deterioration. This deterioration was documented in a 1993 inspection and repairs have not been made.

2. **The dam is experiencing a significant amount of uncontrolled embankment and/or foundation seepage.** Dam safety inspections have estimated seepage downstream of the embankment of 40 to 100 gallons per minute (gpm), which emanates along the toe of the dam. The source of seepage is unknown; potential sources of seepage may include the deteriorated upstream concrete facing (likely at the construction joints that have been noted to be deteriorated since 1993), through the foundation since foundation grouting was not performed with construction, or from the concrete facing/foundation contact. The 2016 Colorado DWR dam safety inspection recommended that the LMWD consider performing a dive inspection of the upstream facing and dye testing to locate the source of the seepage.

3. **There are concerns associated with the stability of the dam embankment.** The upstream slope is approximately 0.7H:1V and the downstream slope is about 1.25H:1V. A typical rockfill dam has slopes of 1.3H:1V and a downstream slope of 1.5H:1V. Documentation of an embankment stability analysis is not available for review.

4. **There are concerns associated with the age (and potential condition) of some of the outlet works components.** The gate valve to the 14-inch-diameter steel pipe that extends to the water treatment facility has not been operated in years and its operability is unknown. The 14-inch-diameter steel pipe and gate valve for the outlet works is unlined and is at least 80 years old.
2.3 Inflow Design Flood (IDF)

The Colorado DWR Rules and Regulations (DWR, 2007) requires that the spillway be designed to route the storm generated by a percentage of the Probable Maximum Precipitation (PMP) developed using Hydrometeorological Report No. 55 (HMR-55) for a small size, high hazard-potential dam, or a lesser flood supported by an Incremental Damage Assessment (IDA). An IDA was performed for the dam and the IDF is 27.5% of the PMP which results in a peak inflow of 4,755 cfs (GEI, 2016). The analyses supporting the IDF is included in Appendix B-1.

The Lower Beaver Brook Dam has a total contributing drainage basin of 7.45 square miles with 6.5 square miles contributing water to Upper Beaver Brook Dam, through the spillway, then to Lower Beaver Brook Dam and an uncontrolled 0.95 square mile drainage basin routing flows directly to Lower Beaver Brook Dam. The Upper Beaver Brook Dam spillway is 3 cycle labyrinth weir structure that is capable of passing approximately 22,500 cfs with the water at the dam crest (10.75 feet of head over the spillway). The labyrinth weir spillway is capable of passing the IDF for Lower Beaver Brook Dam (~4,755 cfs) with approximately 2 feet of head over the labyrinth weir spillway crest.
3.0 ALTERNATIVE DEVELOPMENT

3.1 Alternative Development Process
The LMWD retained GEI to develop conceptual design alternatives to mitigate the spillway size deficiencies in 2015. GEI developed conceptual designs and costs for four alternatives: three alternatives including a combination of widening the spillway into the right abutment and raising the dam crest, and one alternative of modifying the existing dam so it could be safely overtopped during the IDF. The conceptual designs and costs for the alternatives developed by GEI did not include costs or designs for mitigating the other dam safety issues identified at Lower Beaver Brook Dam.

The LMWD retained W. W. Wheeler and Associates, Inc. (Wheeler) to perform an engineering review of the conceptual design alternatives developed by GEI in 2015 and to assess if any additional conceptual alternatives should be evaluated that may be more effective. As part of this evaluation, Wheeler determined that further refinement to GEI’s alternative for overtopping protection so it could be safely overtopped during the IDF were necessary to address the other dam safety concerns and that a new concrete dam should be developed as a conceptual design alternative.

As a result, two additional conceptual design alternatives (Alternative Nos. 4 and 5) were evaluated by Wheeler to mitigate the identified dam safety deficiencies for Lower Beaver Brook Dam documented in Section 2.2. Wheeler’s evaluations included performing preliminary hydraulic analyses, preparing conceptual-level design drawings, and estimating the construction costs.

Based on the alternative development process, six alternatives were identified and are generally described below.

1. **Alternative No. 1 – 100-foot-wide spillway** – Alternative No. 1 consists of lowering the existing spillway elevation (and normal high water line) by approximately 4.5 feet and extending the spillway approximately 71 feet into the right abutment to have a total spillway length of 100 feet. This alternative was developed by GEI in 2015 and only addresses the spillway deficiencies.

2. **Alternative No. 2 – 60-foot-wide spillway with a 3-foot-high parapet wall** – Alternative No. 2 consists of lowering the existing spillway elevation (and normal high water line) by approximately 4.5 feet, extending the spillway approximately 31 feet into the right abutment to have a total spillway length of 60 feet, and the installation of a 3-foot-high parapet wall on the dam crest. This alternative was developed by GEI in 2015 and only addresses the spillway deficiencies.

3. **Alternative No. 3 – 45-foot-wide spillway with a 5-foot-high Mechanically Stabilized Earth (MSE) wall** – Alternative No. 3 consists of lowering the existing spillway elevation (and normal high water line) by approximately 4.5 feet,
extending the spillway approximately 16 feet into the right abutment to have a total spillway length of 45 feet, and the installation of a 5-foot-high MSE wall on the dam crest. This alternative was developed by GEI in 2015 and only addresses the spillway deficiencies.

4. **Alternative No. 4 – Dam Rehabilitation with Roller Compacted Concrete (RCC) Overtopping Protection** – Alternative No. 4 consists of modifying the existing dam to be safely overtopped routing the IDF. This includes RCC constructed on top of the existing dam crest with a stair-stepped RCC downstream facing. The original concept of this alternative was evaluated by GEI in 2015; however, the concept drawings did not have adequate details and only addressed the spillway deficiencies. This conceptual design was further developed by Wheeler to account for additional details and the other dam safety deficiencies including flattening the embankment slopes for stability; a new upstream concrete facing on the modified upstream slope and foundation grout curtain to address the seepage concerns; an upgraded spillway; and a new outlet pipe and upstream gate valves.

5. **Alternative No. 5 – New Concrete Dam** – Alternative No. 5 consists of constructing a new concrete dam downstream of the existing dam, and removing the existing dam. The new dam eliminates all of the identified dam safety concerns.

6. **Alternative No. 6 – Dam Removal** – Alternative No. 6 consists of removing the existing dam. In order for the LMWD to continue providing water services to the water consumers, a storage tank would need to be constructed upstream and modifications made to route the raw water into the water treatment facility. This conceptual alternative was identified; however, a conceptual design and cost was not developed.

3.2 **Design Criteria and Assumptions**

The design criteria and assumptions to mitigate the dam safety deficiencies at Lower Beaver Brook Dam for Wheeler’s feasibility designs of the additional alternatives are as follows:

1. In general, the designs should comply with the dam-safety requirements of the Colorado Dam Safety Branch, Division of Water Resources (DWR, 2007).

2. The new spillway or modified spillway should safety pass the IDF (see Section 2.3) with one foot of minimum freeboard.

3. The modified embankment should meet the stability requirements of both the upstream slope and downstream slope under various loading conditions. Compliance of this requirement will require flattening of the upstream and
downstream slopes of the embankment in the rehabilitation alternative (Alternative No. 4).

4. The normal pool elevation of 7837.7 should be maintained for spillway designs for Alternative Nos. 4 and 5, as requested by LMWD to maintain the current storage in the reservoir and to maintain current operations of the water treatment facility.

5. The modified outlet works should meet the reservoir drawdown requirements per the Colorado Dam Safety Branch, Division of Water Resources (DWR, 2007).

6. The construction work will be performed “in the dry”.

For Alternative Nos. 4 and 5, reservoir routing of the IDF was performed to size the spillways and to estimate the maximum reservoir water surface. Wheeler did not perform stability analyses and seepage analyses for the modified embankment and new concrete dam. Wheeler’s designs were based on published empirical data, judgment, and experience. Wheeler’s understanding of the geology and foundation conditions is based on existing design and construction documents that were provided by the LMWD, and observations made during our site visits of the exposed soil and rock materials.

The new concrete replacement dam will be located immediately downstream of the existing embankment. The new dam footprint will not encroach on the existing water treatment facility on the downstream left abutment.
4.0 CONCEPTUAL ALTERNATIVE PLANS

The conceptual alternative plans are presented and evaluated in this section, including the three spillway alternatives proposed by GEI. The additional conceptual alternatives developed by Wheeler were designed based on the design criteria and assumptions presented in Section 3.2. Brief descriptions of the conceptual alternative plans are provided in Table No. 4.1.

Table 4.1 - Conceptual Alternative Plans

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Description</th>
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<tbody>
<tr>
<td>1</td>
<td>Lower normal pool with a 100-foot-wide spillway</td>
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<td>2</td>
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<td>New Concrete Dam</td>
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<tr>
<td>6</td>
<td>Dam Removal</td>
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4.1 Conceptual Alternative Plan Design Descriptions

A brief description of the alternative designs and assumptions used to evaluate the alternatives are described below.

4.1.1 Alternative Nos. 1 - 3 – Spillway Size Alternatives

Alternative Nos. 1 through 3 were developed by GEI in 2015. The complete documentation of these alternatives is provided in Appendix B-2. A brief description of these alternatives is provided below. These alternatives only address the dam deficiencies related to the capacity of the spillway for routing the IDF and did not mitigate the other dam safety issues listed in Section 2.2.

Alternative No. 1 lowers the spillway crest and normal high water line by approximately 4.5 feet to Elevation 7833.25 and extends the spillway into the right abutment by approximately 71 feet for a total spillway width of 100 feet. Widening the spillway by 71 feet results in approximately 22,600 CY of rock excavation and excavation depths exceeding 80 feet.

Alternative No. 2 lowers the spillway crest and normal high water line by approximately 4.5 feet to Elevation 7833.25 and extends the spillway into the right abutment by approximately 31 feet for a total spillway width of 60 feet. Widening the spillway by 31 feet results in approximately 8,700 CY of rock excavation and excavation depths exceeding 55 feet. Alternative No. 2 includes a 3-foot high parapet wall constructed on the dam crest to raise the dam crest to Elevation 7843.
Alternative No. 3 lowers the spillway crest and normal high water line by approximately 4.5 feet to Elevation 7833.25 and extends the spillway into the right abutment by approximately 16 feet for a total spillway width of 45 feet. Widening the spillway by 16 feet results in approximately 5,700 CY of rock excavation and excavation depths exceeding 40 feet. Alternative No. 3 includes a 5-foot high mechanically stabilized earth (MSE) wall constructed on the dam crest to raise the dam crest to Elevation 7845.

4.1.2 Alternative No. 4 – Dam Rehabilitation with RCC Overtopping Protection
For Alternative No. 4, the existing embankment dam will be rehabilitated to mitigate the identified dam safety deficiencies, namely, the inadequate spillway capacity, potential inadequate slope stability, uncontrolled seepage, and structural deterioration of the service spillway and outlet works. The main feature of this alternative is to armor the dam crest, downstream face, downstream toe, and both abutments with roller compacted concrete (RCC) to protect the dam from erosion during floods in excess of the capacity of the spillway resulted in dam overtopping up to the IDF. This overtopping protection scheme essentially converts the entire dam into an emergency spillway. The conceptual dam plan view, maximum dam section, and details for construction of Alternative No. 4 are provided in Appendix C.

Alternative No. 4 includes flattening of the upstream and downstream slopes to mitigate the potential slope stability issues. The upstream and downstream slope for the conceptual design are based on typical slopes of rockfill dams since a stability analysis has not been performed. Table 4.2 contains typical rockfill embankment slopes of 25 dams. For the upstream slope, the existing upstream earthfill berm will be excavated, and then the existing deteriorated concrete facing will be demolished and removed. The upstream slope will then be rebuilt to an overall slope of 1.5H:1V (horizontal: vertical) with new compacted rockfill. The new concrete facing is a reinforced concrete slab with a thickness of 12 inches and keyed into the bedrock with a footing known as “plinth”. A transition material will be installed between the concrete facing and the rockfill embankment. The foundation will be pressure-grouted through drill holes into the plinth. The new concrete facing and the foundation grouting are intended to mitigate the uncontrolled seepage observed at the toe and abutments of the existing dam.
The plan view of the RCC embankment overtopping protection and the maximum section of the downstream slope and toe are shown in Appendix C. Four feet of RCC is used to armor the dam crest, which maintains the same elevation of 7840. Two RCC training berms, one at each end of the dam, are used to train the overtopping flows toward the middle of the embankment and prevent erosion of the abutments. The training berms have a crest elevation 7845, providing more than one foot of minimum freeboard during the IDF. The downstream slope of the embankment will be flattened to 1.5H:1V, and will be armored with 10 feet (measured horizontally) of RCC constructed in a stair-step fashion. The RCC on the downstream slope will be keyed into the bedrock abutment. A 20-foot-wide RCC stilling basin at the toe of the dam provides the energy dissipation.
The service spillway will remain in the same location. The deteriorated reinforced concrete sill will be demolished and removed, and a new 23-foot-wide reinforced concrete sill will be constructed, with the same crest elevation of 7837.7. Therefore, there is no change in the normal pool elevation for this alternative. Flow through the service spillway will be discharged through the same downstream channel in rock, and then terminated in the new RCC stilling basin.

Modifications of the existing outlet works consist of replacing the two original gate valves with new gate valves (12-inch for the water-supply line, and 14-inch for the outlet pipe), extending the inlet pipes under the flattened upstream slope, and replacing the existing 14-inch-diameter outlet pipe with new 14-inch-diameter steel outlet pipe.

Construction of Alternative No. 4 will require draining the reservoir, and maintaining the reservoir in a drained condition with a temporary upstream cofferdam installed for protection from flows during construction. The existing outlet works can be used for stream diversion and controlling the reservoir levels during construction. A temporary diversion upstream of the dam will be needed to provide continued water supply to the water treatment facility. Wheeler assumed that an on-site borrow area near the dam will be available for the materials for the new rockfill, riprap, and RCC aggregates in the cost analysis. RCC was assumed to be batched on site. A preliminary construction schedule was developed and included in Appendix F. With the construction of the left training berm (looking downstream), there will be no vehicle access to the new dam crest.

4.1.3 Alternative No. 5 – New Concrete Dam
For Alternative No. 5, the existing embankment dam will be removed, and a new concrete gravity dam will be constructed immediately downstream of the existing dam. Even though geology and subsurface data is currently unavailable for this dam, it is Wheeler’s opinion that the gneiss bedrock that is exposed in the right abutment of the dam is suitable as a foundation for a relatively small concrete gravity dam. The new gravity dam can be designed and constructed either with conventional mass concrete, or with roller compacted concrete (RCC). For this study, the new dam was assumed to be constructed with RCC, but a conventional concrete gravity is equally applicable for this site. The conceptual dam plan view, maximum dam section, and details for construction of Alternative No. 5 are provided in Appendix D.

The new concrete dam has a non-overflow crest at elevation 7845 at each end, with a central emergency spillway in the middle. The emergency spillway is 125 feet wide with a crest elevation of 7840. The existing service spillway on the right abutment will be rehabilitated to maintain the same normal pool elevation of 7837.7. The RCC cross section is designed conservatively based on Wheeler’s experience with dam
construction and judgment, and no stability analysis was performed to size the dam. The RCC section has a vertical upstream face, a 20-foot-wide crest, and vertical chimney section from the crest to elevation 7815, and a 0.8H:1V (horizontal: vertical) downstream face from elevation 7815 to the toe of the dam. The upstream face, dam crest, and the downstream face are protected from freeze-thaw damages with a grout-enriched RCC. A 20-foot-wide RCC stilling basin is provided at the downstream toe to dissipate energy from the emergency spillway flow.

The outlet works of the new dam consists of two slide gates mounted on the upstream face of the dam, with an 18-inch-diameter steel outlet pipe in the dam. The two slide gates will provide a multi-level withdrawal from the reservoir. The release from the outlet pipe is bifurcated at the downstream toe: one pipe providing water supply to the treatment plan, and one pipe for reservoir drawdown. The reservoir drawdown pipe enters into the same RCC stilling basin that is used for the spillway.

Construction of the new dam will require draining of the reservoir. The existing rockfill embankment can be excavated in stages for three reasons: (a) the rockfill materials removed from the top portion of the dam can be processed as a source of the RCC aggregate; (b) the remaining embankment can function as a cofferdam for flood protection; (c) the lowered embankment provides a suitable flat area for the RCC batch plant. After the new dam is constructed, the existing embankment can be partially breached or completely removed. It is anticipated that the existing embankment will supply adequate materials for the new RCC dam, and no on-site borrow area was assumed to be required. A preliminary construction schedule was developed and included in Appendix F.

4.1.4 Alternative No. 6 – Dam Removal – Water Storage Tank
This alternative was not fully developed at the request of the LMWD. However, the general concept includes an upstream diversion structure on Beaver Brook that diverts water into a pipeline that is routed to a water storage tank. A pipeline would be connected from the water storage tank to the water treatment facility.

4.2 Alternatives Evaluation and Benefit Analysis
The alternatives were qualitatively evaluated based on the effectiveness of the alternatives and the impacts associated with implementing the conceptual level designs. The benefits and impacts are summarized in Table 4.3.
### Table 4.3 - Summary of Preliminary Benefits and Impacts of each Alternative

<table>
<thead>
<tr>
<th>Benefits &amp; Impacts</th>
<th>Alternative</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Highlighted - Result is considered not favorable.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Addresses the spillway capacity dam safety issue</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Maintains the existing reservoir storage pool</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Additional discharges expected in the downstream floodplain during routine flow conditions</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Addresses the non-spillway related dam safety issues</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Likely require rock blasting of the right hillside</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Significant impacts to right hillside</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Requires decreasing the normal pool elevation</td>
<td>Yes, decreases by 4.5 feet</td>
<td>Yes, decreases by 4.5 feet</td>
<td>Yes, decreases by 4.5 feet</td>
<td>No</td>
<td>No</td>
<td>Yes, eliminates pool</td>
<td></td>
</tr>
</tbody>
</table>

Alternative Nos. 1 – 3 were evaluated in terms of the LMWD’s requirements, technical feasibility, constructability, and other risks and unknowns, and have the following comments:

1. Lowering the normal operating pools by 4.5 feet assumed in all three alternatives is contrary to the operational requirements of LMWD, who prefers to maintain the same normal pool;

2. The hydraulics of the enlarged spillway will require further evaluation and analysis for hydraulic stability. There is a significant convergence of the enlarged spillway discharge channel. The converged channel also includes a 45-degree bend to the left (looking downstream) along a very steep chute, eventually terminating in a small plunge pool stilling basin. The flow convergence and the bend in the chute under high flow velocities may result in flow instability and erosion of the right side of the embankment.
3. The excavation for the spillway is in a hard rock in the right abutment, which will require blasting. The effects of blasting vibration may have adverse effects on the existing embankment and outlet works, and would need to be further evaluated. In addition, there appears to be a residential structure on top of the right abutment, and how the excavation will affect this structure has not been addressed.

4. The temporary and permanent rock slope stability of the massive and steep (0.5H:1V) spillway cuts (in the range of 45 to 80 feet high, will require detailed analysis and evaluation.

5. Widening the service spillway will result in higher discharges being released from the dam at lower storage levels. This could impact the downstream floodplain during routine flow conditions.

In Wheeler's opinion, the spillway designs in Alternative Nos. 1 to 3 contain significant risk and uncertainties which may affect the feasibility of further development. As a result, these alternatives were eliminated from consideration are not discussed further in the report. GEI developed costs related to Alternative Nos. 1, 2, and 3; however, these costs did not include the additional costs associated with addressing the dam safety deficiencies other than the spillway capacity deficiency. As a result, the costs for Alternative Nos. 1, 2, and 3 would be higher if all the dam safety issues were addressed, thus these costs are not directly comparable to the costs for Alternative Nos. 4 and 5. Additional information on these alternatives are included in Appendix B-2.

The Alternative No. 6, dam removal, conceptual design was not further developed. The LMWD considers the storage in Lower Beaver Brook Reservoir and the associated water rights as a very important component of their water rights portfolio. The water storage also serves a very important role in drought protection. As a result, the LMWD cannot accept Alternative No. 6 as a viable alternative. Other potential impacts that were considered not favorable for this alternative include the loss of reservoir aesthetics and floodplain aesthetics, potential wetland impacts, and potential habitat impacts.

4.3 Alternative Costs
Wheeler developed feasibility-level opinions of probable costs for Alternative Nos. 4 and 5. Direct construction costs include items directly related to the dam construction. The indirect costs include a budget for non-construction items that are required to develop the project such as engineering and permitting. A summary of the opinion of probable direct construction and indirect project development costs are provided in Table No. 4.4 presented in 2020 dollars, which is the planned construction year. Additional details of Wheeler’s feasibility-level opinion of probable project costs for Alternatives 4 and 5 are provided in Appendix E.
The costs associated with this level of cost are within an expected accuracy range (USSD, 2012). The range of expected project costs is included in Table 4.4.

Table 4.4 - Summary of Alternatives - Opinions of Probable Costs

<table>
<thead>
<tr>
<th>Alternative No.</th>
<th>Description</th>
<th>Direct Construction Costs</th>
<th>Indirect Construction Costs</th>
<th>Total Project Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Dam Rehabilitation with RCC Overtopping Protection</td>
<td>$3,245,000</td>
<td>$788,000</td>
<td>$4,033,000 (3.6M - 4.8M)</td>
</tr>
<tr>
<td>5</td>
<td>New Concrete Dam</td>
<td>$4,262,000</td>
<td>$1,055,000</td>
<td>$5,317,000 (4.8M - 6.4M)</td>
</tr>
</tbody>
</table>

A  Costs presented are in 2020 dollars, which is the planned construction year.
B  Range of expected costs based on a Class 4 cost estimate for a Feasibility level design (USSD, 2012).
C  For these costs, the new concrete dam was assumed to be constructed with RCC.

### 4.4 Benefit-Cost Comparison

Alternative Nos. 4 and 5 include the mitigation of the identified dam safety concerns, namely including the inadequate spillway, slope stability concerns, seepage concerns, and outlet works upgrades. Both alternatives also maintain the existing normal high water line and reservoir storage for the water treatment facility operations and storage for drought protection. As a result, both of these alternatives are considered equal in their ability to maintain the reservoir aesthetics and preserve the habitat and wetlands associated with the reservoir.

The benefits associated with Alternative No. 5, a new concrete dam, are primarily the benefits in having a new structure which will likely result in less future maintenance expenses and time, the dam is expected to last longer, and the construction of the entire dam will be well-documented.

A summary of the advantages and disadvantages associated with the Alternative Nos. 4 and 5 are summarized below.
### Table 4.5 - Advantage vs. Disadvantage Summary Comparison for Alternative Nos. 4 and 5

<table>
<thead>
<tr>
<th>Evaluation Factor</th>
<th>Alternative No. 4 Dam Rehabilitation with RCC Overtopping Protection</th>
<th>Alternative No. 5 New Concrete Dam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Expected Opinion of Probable Cost is $1.3M less (~30-percent)</td>
<td>Expected Opinion of Probable Cost is $1.3M more (~30-percent)</td>
</tr>
<tr>
<td>Construction Period</td>
<td>Construction period expected to be approximately 8 months.</td>
<td>Construction period expected to be approximately 8.5 months.</td>
</tr>
<tr>
<td>New Construction vs. Rehabilitation</td>
<td>A portion of the 114-year-old dam still exists. The exact material composition and design standards used are (and will likely always be) unknown for the existing portion of the embankment.</td>
<td>Complete modern design. Construction will be documented in accordance with the Colorado DWR Dam Safety Rules.</td>
</tr>
<tr>
<td>Design Life</td>
<td>The life span is expected to be less than the new dam considering some of the 114-year-old embankment and features will still exist.</td>
<td>Expected to have a longer life span since the entire dam and appurtenant features will be new.</td>
</tr>
<tr>
<td>Maintenance</td>
<td>More frequent and costly maintenance items are expected considering parts of the dam are in excess of 114-year-old.</td>
<td>Less frequent maintenance items are expected to arise considering the entire dam and appurtenant features will be new.</td>
</tr>
</tbody>
</table>

### 4.5 Summary of Conceptual Alternative Plans

The alternatives that were evaluated present a range of different approaches to address the dam safety deficiencies for Lower Beaver Brook Dam. Table No. 4.6, Alternative Plan Summary, presents a brief description of the basis for the selection of Alternative No. 5.
Table 4.6 – Alternative Plan Summary

<table>
<thead>
<tr>
<th>Alternative Description</th>
<th>Summary of Selection/Elimination Reasoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – Lower normal pool with a 100-foot-wide spillway</td>
<td>Eliminated from consideration based on concerns with flow; rock slope excavation and stability concerns; the additional discharges that would be released from the dam during routine flow conditions that could impact the downstream floodplain; and the lower normal pool not being favorable for operations of the water treatment facility.</td>
</tr>
<tr>
<td>2 - Lower normal pool with a 60-foot-wide spillway with a 3-foot-high parapet wall dam raise</td>
<td></td>
</tr>
<tr>
<td>3 - Lower normal pool with a 45-foot-wide spillway with a 5-foot-high MSE wall dam raise</td>
<td></td>
</tr>
<tr>
<td>4 - Dam Rehabilitation with RCC Overtopping Protection</td>
<td>This alternative mitigates the identified dam safety issues and maintains the current reservoir storage and normal high water line, which should maintain the existing LMWD water treatment facility operations, storage, habitat, and wetlands associated with the reservoir. This alternative was approximately 30-percent cheaper than Alternative No. 5; however, a portion of the embankment will be in excess of 114 years old. This is considered a secondary alternative.</td>
</tr>
<tr>
<td>5 - New Concrete Dam</td>
<td>This is the preferred alternative. This alternative mitigates the identified dam safety issues and maintains the current reservoir storage and normal high water line, which should maintain the existing LMWD water treatment facility operations, storage, habitat, and wetlands associated with the reservoir. This alternative was approximately 30-percent more expensive than Alternative No. 5; however, the LMWD considered the benefits associated with the expected increased life span and decreased annual maintenance was favorable since the dam will be new. A conventional concrete gravity dam as opposed to an RCC dam can be considered in final design as for a potential reduction in construction costs for this alternative.</td>
</tr>
<tr>
<td>6 - Dam (and reservoir) Removal</td>
<td>Eliminated from consideration due to the value of the water rights and reservoir storage. Other potential impacts that were considered not favorable for this alternative include the loss of reservoir aesthetics and floodplain aesthetics, potential wetland impacts, and potential habitat impacts.</td>
</tr>
</tbody>
</table>
5.0 RECOMMENDED PLAN

Six alternatives were evaluated in this alternatives analysis report. After considering each alternative’s ability to adequately address the dam safety issues; their constructability and long-term stability; their ability to maintain the LMWD’s water storage, water level, and water rights for operation; and their expected future maintenance work; Alternative No. 5, a new concrete dam, is considered to be the preferred alternative. Alternative No. 4, Dam Rehabilitation with RCC Overtopping Protection, is considered a secondary alternative.

5.1 Basis for Selection

The primary objective defined at the outset of the study was to mitigate the dam safety concerns identified at Lower Beaver Brook Dam. Alternative No. 5, the new concrete dam, was selected for several reasons including:

1. It mitigates the identified dam safety issues,

2. It maintains the existing reservoir storage and normal high water line which will maintain the LMWD’s reserves for drought protection and the current water treatment facility operations,

3. It maintains the reservoir at the current level for habitat and wetland benefits,

4. It provides the LMWD with the benefits of having a new dam, which is expected to result in less annual maintenance and a longer future life span for operations.
6.0 REFERENCES

7. FEMA, (FEMA, 2013), Light Detection and Ranging (LiDAR), Resolution 0.7 meter, Vendor: Photoscience, Inc., available through Colorado GeoData Cache, Acquisition Date: 10/16/2013.
8. Gardner, M.W., City Engineer (Gardner, 1935) Repairs for Golden Reservoir and Dam No. 1 being Lower Beaver Brook Dam including Bypass Tunnel and Concrete Face and Loose Rock Backfill for Dam, October 1935.
APPENDIX A

ENGINEER’S INSPECTION REPORTS
COLORADO DIVISION OF WATER RESOURCES DAM
SAFETY ENGINEER
**UPSTREAM SLOPE**

PROBLEMS NOTED:  
☐ (0) NONE  ☐ (1) RIPRAP - MISSING, SPARSE, DISPLACED, WEATHERED  ☐ (2) WAVE EROSION - WITH SCARPS  
☐ (3) CRACKS WITH DISPLACEMENT  ☐ (4) SINKHOLE  ☐ (5) APPEARS TOO STEEP  ☐ (6) DEPRESSIONS OR BULGES  ☐ (7) SLIDES  
☐ (8) CONCRETE FACING - HOLES, CRACKS, DISPLACED, UNDERMINED  ☐ (9) OTHER

**PAST RECOMMENDED ACTIONS:**  
1. Repairs to the upstream slope will eventually need to be performed. (2014)

**CONDITIONS OBSERVED:**

The upstream slope generally appears to be in good condition. There are three areas that display spall damage at the normal high water line, and three vertical cracks that don't appear to be intentional construction joints due to a lack of expansion material or water stop. Two of the cracks extend to depths beyond view, while the third appears to terminate about 5 to 6 feet below the crest. These conditions are not new and have been observed in the past inspections.

Cracks at:  
- 50’ from left abutment  
- 50’ from spillway  
- 40’ from spillway

Spalls at:  
- 60’ from left abutment  
- 90’ from left abutment  
- 120’ from left abutment

A small diameter pipe was observed at the NHWL at the left abutment, which Jeremy identified as the original diversion inflow pipe from North Beaver Brook. The pipe was cut when the WTP was built and therefore is no longer in service. Jeremy also mentioned that there was no spilling from the outfall near the WTP when the reservoir was at its peak in 2013.

The openings & deterioration of the upstream concrete facing have not historically been closely monitored other than qualitative assessments. What’s more, the LMWD maintains a near full reservoir level as a necessity for water delivery to the District treatment plant on the left abutment, thereby preventing observation of the majority of the upstream face during routine dam safety inspections. The presence of relatively large seepage flows at the downstream toe suggests that a portion of the upstream facing may be compromised, presumably at one of the seven construction joints. To evaluate this possibility, the District may want to consider a dive inspection of the construction joints including joint measurements and dye testing for seepage. Identification of high seepage areas would help determine and prioritize upstream facing repairs. The dive inspection could simultaneously evaluate the degree of sedimentation in the bottom of the reservoir.

**CURRENT RECOMMENDED ACTIONS:**  
1. See item #1 and discussion above. It is noted that Colorado Dam Safety does not consider this item a high priority at this time.
ENGINEER'S INSPECTION REPORT
DATE: 7/13/2016
DAM NAME: LOWER BEAVER BROOK
DAM I.D.: 070102

Crest

Problems Noted:
- (10) None
- (11) Ruts or puddles
- (12) Erosion
- (13) Cracks - with displacement
- (14) Sinkholes
- (15) Not wide enough
- (16) Low area
- (17) Misalignment
- (18) Improper surface drainage
- (19) Other

Past Recommended Actions:
1. Modifications to the dam crest should be completed as part of a future larger rehabilitation project. The objective would be to regrade the crest to a uniform elevation and cross slope for even drainage. (2014)

Conditions Observed:
No changed conditions observed. There is a known low area near the left abutment, which is where the reservoir elevation is monitored. Also of note is that the elevation stamped on the movement monument at the spillway is about 10 feet lower than shown in the record drawings, which raises questions about the accuracy of the drawings and volume of reservoir.

Current Recommended Actions:
1. See item #1 above.

Downstream Slope

Problems Noted:
- (20) None
- (21) Livestock damage
- (22) Erosion or gullies
- (23) Cracks - with displacement
- (24) Sinkhole
- (25) Appears too steep
- (26) Depressions or bulges
- (27) Slide
- (28) Soft areas
- (29) Other

Past Recommended Actions:
None.

Conditions Observed:
No changed conditions observed.

The downstream slope is rather steep (nearly 1H:1V per C-0292 record drawings). The described rockfill nature of the embankment material has been physically adequate to support this slope since the last modification project in 1933; however it is unclear whether this slope meets the slope stability requirements under the recently revised IDF conditions. Subsurface investigations and geotechnical lab testing is anticipated to be necessary to support slope stability analyses required for the pending freeboard modification project.

Current Recommended Actions:
None at this time.

Seepage

Problems Noted:
- (30) None
- (31) Saturated embankment area
- (32) Seepage exits on embankment
- (33) Seepage exits at point source
- (34) Seepage area at toe
- (35) Flow adjacent to outlet
- (36) Seepage increased / muddy
- (37) Flow increased / muddy
- (38) Drain dry / obstructed
- (39) Other

Past Recommended Actions:
1. Modification of the existing seepage measurement device or installation of a new seepage measurement system should be a high priority on a list of maintenance tasks for the District. (2013)

Conditions Observed:
A minor seep was noted immediately adjacent to the outflow measurement flume. The flow rate is about 0.5 gpm and is not captured in the flow measurement flume, but does not appear to be a dam safety issue. Other than that, the seepage conditions appear about the same as in the past. Majority of the flows surface at the left toe of the dam, but some contribution from the outlet tunnel was also observed. Jeremy stated that the flows are generally around 30-40 gpm, though there is no reliable method of measurement when the spillway is active. Past records suggest that there’s an internal clay tile drain within about 10 feet of the toe, but the pipe is not visible and therefore cannot be conformed. There is also no detail for this drain, so filter compatibility cannot be checked.

Current Recommended Actions:
1. See item #1 above.

The poor rating is based on a lack of seepage quality and measurement ability.
ENGINEER’S INSPECTION REPORT

DAM NAME: LOWER BEAVER BROOK

DATE: 7/13/2016
DAM I.D.: 070102

OUTLET

PROBLEMS NOTED: [ ] (40) NONE [ ] (41) NO OUTLET FOUND [ ] (42) POOR OPERATING ACCESS [ ] (43) INOPERABLE
[ ] (44) UPSTREAM OR DOWNSTREAM STRUCTURE DETERIORATED [ ] (45) OUTLET OPERATED DURING INSPECTION [ ] YES [ ] NO
INTERIOR INSPECTED [ ] (120) NO [ ] (121) YES [ ] (46) CONDUIT DETERIORATED OR COLLAPSED [ ] (47) JOINTS DISPLACED [ ] (48) VALVE LEAKAGE
[ ] (49) OTHER

PAST RECOMMENDED ACTIONS:
1. The pipe supports in the outlet tunnel should be replaced or reinforced as soon as possible to prevent accidental and sudden collapse of the pipe supports and damage to the pipe, which could result in sudden loss of the entire reservoir contents. (2014)
2. The right pipe is overdue for an interior inspection. This will be complicated by the lack of access to the pipe interior. The District should begin developing plans for providing camera access to the pipeline interior. (2014)
3. The emergency drawdown capacity of the small diameter PVC pipe should be evaluated to determine adequacy with Rule 5.9.6.2.1.
4. Better tunnel access provisions should be established such that the District staff are comfortable accessing the outlet controls at the upstream end of the tunnel.

CONDITIONS OBSERVED:
the outlet appears to be in the same condition as observed in the past.
- The right pipe was lined with HDPE through the outlet tunnel concurrent with the WTP construction project.
- The District has reportedly reinstated operation of the left pipeline that serves as a direct stream discharge, therefore item #3 above may be disregarded.
- The District have made notable progress towards improving tunnel accessibility, including addition of lighting and ventilation. Placement of pea gravel or other material to provide a firm foundation in the upstream half of the tunnel is a remaining item to be addressed.

CURRENT RECOMMENDED ACTIONS:
1. See item #1 above. (2014)
2. See item #2 above. It should be noted that the State Dam Safety Office does not consider this a high priority in light of other District priorities at this time. (2014)
3. Continue to improve outlet tunnel accessibility by adding pea gravel or other material along the floor of the tunnel, particularly along the upstream half of the tunnel. (2014)

CONDITIONS OBSERVED: [ ] Good [x] Acceptable [ ] Poor

SPILLWAY

PROBLEMS NOTED: [ ] (50) NONE [ ] (51) NO EMERGENCY SPILLWAY FOUND [ ] (52) EROSION WITH BACKCUTTING [ ] (53) CRACK - WITH DISPLACEMENT
[ ] (54) APPEARS TO BE STRUCTURALLY INADEQUATE [ ] (55) APPEARS TOO SMALL [ ] (56) INADEQUATE FREEBOARD [ ] (57) FLOW OBSTRUCTED
[ ] (58) CONCRETE DETERIORATED / UNDERMINED [ ] (59) OTHER hydrologically inadequate

PAST RECOMMENDED ACTIONS:
1. Continue to make progress towards rehabilitating the spillway to meet the requirements identified in the Dam Safety Rules for the long term. (2014)

CONDITIONS OBSERVED:
No changes since the last inspection.

The District has entered into a compliance plan with the State Engineer's Office that includes completion of an incremental damage assessment (IDA) by the end of this year and construction of a modified spillway to address freeboard inadequacy by May 2020. The District appears to be on track to meet these requirements.

CURRENT RECOMMENDED ACTIONS:
1. See item #1 above. (2014)

The acceptable rating is based on the District's continued efforts toward bringing the spillway into compliance with the State Dam Safety rules.

CONDITIONS OBSERVED: [ ] Good [x] Acceptable [ ] Poor
ENGINEER'S INSPECTION REPORT  
DATE: 7/13/2016  
DAM NAME: LOWER BEAVER BROOK  
DAM I.D.: 070102  

EXISTING INSTRUMENTATION FOUND  
☐ (110) NONE  ☑ (111) GAGE ROD  ☐ (112) PIEZOMETERS  ☐ (113) SEEPAGE  ☐ (114) SURVEY MONUMENTS  ☐ (115) OTHER  

MONITORING OF INSTRUMENTATION  
☐ (116) NO  ☑ (117) YES  
PERIODIC INSPECTIONS BY:  
☐ (118) OWNER  ☑ (119) ENGINEER  

PAST RECOMMENDED ACTIONS:  
None.

CONDITIONS OBSERVED:  
There are no functioning seepage monitoring instrumentation at this dam despite the rather heavy seepage at the downstream toe, therefore there is no data to review during routine dam safety inspections. A flow measurement device is present below the spillway discharge channel, however the persistent spillway flows prevents accurate measurement of seepage flows with this device. Recommendations to improve seepage monitoring is discussed in the Seepage section of this report.

CURRENT RECOMMENDED ACTIONS:  
None.

CONDITIONS OBSERVED:  
☐ Good  ☑ Acceptable  ☐ Poor

PROBLEMS NOTED:  
☐ (60) NONE  ☐ (61) ACCESS ROAD NEEDS MAINTENANCE  ☐ (62) CATTLE DAMAGE  
☐ (63) BRUSH ON UPSTREAM SLOPE, CREST, DOWNSTREAM SLOPE, TOE  ☐ (64) TREES ON UPSTREAM SLOPE, CREST, DOWNSTREAM SLOPE, TOE  
☐ (65) RODENT ACTIVITY ON UPSTREAM SLOPE, CREST, DOWNSTREAM SLOPE, TOE  ☐ (66) DETERIORATED CONCRETE - FACING, OUTLET, SPILLWAY  
☐ (67) GATE AND OPERATING MECHANISM NEED MAINTENANCE  ☐ (68) OTHER

PAST RECOMMENDED ACTIONS:  
None.

CONDITIONS OBSERVED:  
The District has been very responsive and proactive with maintenance efforts in recent years, which is greatly appreciated. A small shrub is present just below the dam crest on the downstream slope that should be removed. The grass along the toe should also be trimmed.

CURRENT RECOMMENDED ACTIONS:  
1. Remove shrub on downstream slope and from grass along toe area. (2016)

CONDITIONS OBSERVED:  
☐ Good  ☑ Acceptable  ☐ Poor

Go to next page for Overall Conditions and Items Requiring Actions
The down appears to be in acceptable condition with exception of the spillway deficiency. The District's progress toward compliance with this issue is noted and appreciated.

The emergency action plan was updated in 2014 and appears to contain current contact information for State representatives. The inundation mapping is rather outdated and poorly defined. The District has expressed an interest in developing updated mapping and in taking advantage of the State inundation mapping grant to do so. A scope of work and grant application were provided to the District in advance of this inspection.

The extent of dam safety concerns at this dam are sufficient to warrant a storage restriction. A partial storage restriction would provide little benefit to address the safety concerns associated with either the outlet or spillway. A zero storage restriction could be warranted, however it is recognized that the District would be completely unable to provide water to its constituents depending on the restricted level, which would only push the problems downstream to a different population. Additionally, the low level outlet is unlikely to have sufficient capacity to keep up with normal reservoir inflows. Therefore, a conditionally satisfactory rating will be assigned on the basis that the District continues to make demonstrable progress towards addressing the dam safety concerns.

Based on this Safety Inspection and recent file review, the overall condition is determined to be:

- [ ] (71) SATISFACTORY
- [ ] (72) CONDITIONALLY SATISFACTORY
- [ ] (73) UNSATISFACTORY

**ITEMS REQUIRING ACTION BY OWNER TO IMPROVE THE SAFETY OF THE DAM**

<table>
<thead>
<tr>
<th>Item</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>(80)</td>
<td>PROVIDE ADDITIONAL RIPRAP:</td>
</tr>
<tr>
<td>(81)</td>
<td>LUBRICATE AND OPERATE OUTLET GATES THROUGH FULL CYCLE:</td>
</tr>
<tr>
<td>(82)</td>
<td>CLEAR TREES AND/OR BRUSH FROM:</td>
</tr>
<tr>
<td>(83)</td>
<td>INITIATE RODENT CONTROL PROGRAM AND PROPERLY BACKFILL EXISTING HOLES:</td>
</tr>
<tr>
<td>(84)</td>
<td>GRADE CREST TO A UNIFORM ELEVATION WITH DRAINAGE TO THE UPSTREAM SLOPE:</td>
</tr>
<tr>
<td>(85)</td>
<td>PROVIDE SURFACE DRAINAGE FOR:</td>
</tr>
<tr>
<td>(86)</td>
<td>MONITOR:</td>
</tr>
<tr>
<td>(87)</td>
<td>DEVELOP AND SUBMIT AN EMERGENCY ACTION PLAN:</td>
</tr>
<tr>
<td>(88)</td>
<td>OTHER:</td>
</tr>
<tr>
<td>(89)</td>
<td>OTHER:</td>
</tr>
<tr>
<td>(90)</td>
<td>PROVIDE ADDITIONAL RIPRAP:</td>
</tr>
<tr>
<td>(91)</td>
<td>CLEAR TREES AND/OR BRUSH FROM:</td>
</tr>
<tr>
<td>(92)</td>
<td>INITIATE RODENT CONTROL PROGRAM AND PROPERLY BACKFILL EXISTING HOLES:</td>
</tr>
<tr>
<td>(93)</td>
<td>GRADE CREST TO A UNIFORM ELEVATION WITH DRAINAGE TO THE UPSTREAM SLOPE:</td>
</tr>
<tr>
<td>(94)</td>
<td>PROVIDE SURFACE DRAINAGE FOR:</td>
</tr>
<tr>
<td>(95)</td>
<td>MONITOR:</td>
</tr>
<tr>
<td>(96)</td>
<td>DEVELOP AND SUBMIT AN EMERGENCY ACTION PLAN:</td>
</tr>
<tr>
<td>(97)</td>
<td>OTHER:</td>
</tr>
<tr>
<td>(98)</td>
<td>OTHER:</td>
</tr>
<tr>
<td>(99)</td>
<td>OTHER:</td>
</tr>
</tbody>
</table>

**SAFETY STORAGE LEVEL: RECOMMENDED AS A RESULT OF THIS INSPECTION**

<table>
<thead>
<tr>
<th>Level</th>
<th>FT. BELOW DAM CREST</th>
<th>FT. BELOW SPILLWAY CREST</th>
<th>FT. GAGE HEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>FULL STORAGE</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CONDITIONAL FULL STORAGE</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>RECOMMENDED RESTRICTION</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CONTINUE EXISTING RESTRICTION</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**REASON FOR RESTRICTION**

**ACTIONS REQUIRED FOR CONDITIONAL FULL STORAGE OR CONTINUED STORAGE AT THE RESTRICTED LEVEL**

**Action Item (90)**

Engineer's Signature: [Signature]

Owner's Signature: [Signature]
GUIDELINES FOR DETERMINING CONDITIONS

### CONDITIONS OBSERVED - APPLIES TO UPSTREAM SLOPE, CREST, DOWNSTREAM SLOPE, OUTLET, SPILLWAY

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GOOD</strong></td>
<td>In general, this part of the structure has a near new appearance, and conditions observed in this area do not appear to threaten the safety of the dam.</td>
</tr>
<tr>
<td><strong>ACCEPTABLE</strong></td>
<td>Although general cross-section is maintained, surfaces may be irregular, eroded, rutted, spalled, or otherwise not in new condition. Conditions in this area do not currently appear to threaten the safety of the dam.</td>
</tr>
<tr>
<td><strong>POOR</strong></td>
<td>Conditions observed in this area appear to threaten the safety of the dam.</td>
</tr>
</tbody>
</table>

### CONDITIONS OBSERVED - APPLIES TO SEEPAGE

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GOOD</strong></td>
<td>No evidence of uncontrolled seepage. No unexplained increase in flows from designed drains. All seepage is clear. Seepage conditions do not appear to threaten the safety of the dam.</td>
</tr>
<tr>
<td><strong>ACCEPTABLE</strong></td>
<td>Some seepage exists at areas other than the drain outfalls, or other designed drains. No unexplained increase in seepage. All seepage is clear. Seepage conditions observed do not currently appear to threaten the safety of the dam.</td>
</tr>
<tr>
<td><strong>POOR</strong></td>
<td>Seepage conditions observed appear to threaten the safety of the dam. Examples: 1) Designed drain or seepage flows have increased without increase in reservoir level. 2) Drain or seepage flows contain sediment, i.e., muddy water or particles in jar samples. 3) Widespread seepage, concentrated seepage, or ponding appears to threaten the safety of the dam.</td>
</tr>
</tbody>
</table>

### CONDITIONS OBSERVED - APPLIES TO MONITORING

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GOOD</strong></td>
<td>Monitoring includes movement surveys and leakage measurements for all dams, and piezometer readings for Class I dams. Instrumentation is in reliable, working condition. A plan for monitoring the instrumentation and analyzing results by the owner's engineer is in effect. Periodic inspections by owner's engineer.</td>
</tr>
<tr>
<td><strong>ACCEPTABLE</strong></td>
<td>Monitoring includes movement surveys and leakage measurements for Class I 11 dams; leakage measurements for Class III dams. Instrumentation is in serviceable condition. A plan for monitoring instrumentation is in effect by owner. Periodic inspections by owner or representative. OR, NO MONITORING REQUIRED.</td>
</tr>
<tr>
<td><strong>POOR</strong></td>
<td>All instrumentation and monitoring described under &quot;ACCEPTABLE&quot; here for each class of dam, are not provided, or required periodic readings are not being made, or unexplained changes in readings are not reacted to by the owner.</td>
</tr>
</tbody>
</table>

### CONDITIONS OBSERVED - APPLIES TO MAINTENANCE AND REPAIR

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GOOD</strong></td>
<td>Dam appears to receive effective on-going maintenance and repair, and only a few minor items may need to be addressed.</td>
</tr>
<tr>
<td><strong>ACCEPTABLE</strong></td>
<td>Dam appears to receive maintenance, but some maintenance items need to be addressed. No major repairs are required.</td>
</tr>
<tr>
<td><strong>POOR</strong></td>
<td>Dam does not appear to receive adequate maintenance. One or more items needing maintenance or repair has begun to threaten the safety of the dam.</td>
</tr>
</tbody>
</table>

### OVERALL CONDITIONS

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SATISFACTORY</strong></td>
<td>The safety inspection indicates no conditions that appear to threaten the safety of the dam, and the dam is expected to perform satisfactorily under all design loading conditions. Most of the required monitoring is being performed.</td>
</tr>
<tr>
<td><strong>CONDITIONALLY SATISFACTORY</strong></td>
<td>The safety inspection indicates symptoms of structural distress (seepage, evidence of minor displacements, etc.), which, if conditions worsen, could lead to the failure of the dam. Essential monitoring, inspection, and maintenance must be performed as a requirement for continued full storage in the reservoir.</td>
</tr>
<tr>
<td><strong>UNSATISFACTORY</strong></td>
<td>The safety inspection indicates definite signs of structural distress (excessive seepage, cracks, slides, sinkholes, severe deterioration, etc.), which could lead to the failure of the dam if the reservoir is used to full capacity. The dam is judged unsafe for full storage of water.</td>
</tr>
</tbody>
</table>

### SAFE STORAGE LEVEL

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FULL STORAGE</strong></td>
<td>Dam may be used to full capacity with no conditions attached.</td>
</tr>
<tr>
<td><strong>CONDITIONAL FULL STORAGE</strong></td>
<td>Dam may be used to full storage if certain monitoring, maintenance, or operational conditions are met.</td>
</tr>
<tr>
<td><strong>RESTRICTION</strong></td>
<td>Dam may not be used to full capacity, but must be operated at some reduced level in the interest of public safety.</td>
</tr>
</tbody>
</table>

### HAZARD CLASSIFICATION OF DAMS

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CLASS High hazard</strong></td>
<td>Loss of human life is expected in the event of failure of the dam, while the reservoir is at the high water line.</td>
</tr>
<tr>
<td><strong>CLASS Significant hazard</strong></td>
<td>Significant damage to improved property is expected in the event of failure of the dam while the reservoir is at the high water line, but no loss of human life is expected.</td>
</tr>
<tr>
<td><strong>CLASS Low hazard</strong></td>
<td>Loss of human life is not expected, and damage to improved property is expected to be small, in the event of failure of the dam while the reservoir is at high water line.</td>
</tr>
</tbody>
</table>

Class NPH hazard - No loss of life or damage to improved property, or loss of downstream resource is expected in the event of failure of the dam while the reservoir is at the high water line.
Photo 1: Aerial view of Lower Beaver Brook Dam

Water Treatment Plant

Outlet direct discharge outfall

Seepage flow measurement weir

Toe seep

10" drain pipe (according to C-0292 record drawings & specs; not field verified)

Left outlet pipe (Operationally abandoned)

Right outlet pipe (HDPE Lined & pressurized)

Spillway

Outlet tunnel access door

"Cave"

Downstream discharge flow measurement flume

Lower Beaver Brook Dam
Dam ID No. 070102

July 13, 2016
Photo 2: Intentional construction joint with exposed copper waterstop (left); spall damage along NHWL (center); example vertical crack (right)

Photo 3: Sandbag dike along upstream shoulder and reservoir staff gage
Photo 4: Typical view of dam crest (left); typical movement monument (center and right)

Photo 5: Downstream slope and seepage collection pool (left); downstream slope from right abutment facing west (right)
Photo 6: Flow measurement flume

Photo 7: New seep area adjacent to the flume attributed to either flows from spillway or losses from treated water main

Photo 8: Outlet valves at upstream end of tunnel (left); small diameter drain tap from service line to drain line (right)
Photo 9: Exposed bedrock in upstream half of outlet tunnel - right wall (left) and ceiling (right)

Photo 10: Spillway sill (left); historic patch on downstream left end of spillway sill (right)

Photo 11: Spillway discharge channel with pile of debris removed from spillway channel last year
**ENGINEER'S INSPECTION REPORT**

**OFFICE OF THE STATE ENGINEER - DIVISION OF WATER RESOURCES - DAM SAFETY BRANCH**  
1313 SHERMAN STREET, ROOM 818, DENVER, CO 80203, (303) 866-3581

<table>
<thead>
<tr>
<th>FIELD CONDITIONS OBSERVED</th>
<th>WATER LEVEL:</th>
<th>GROUND MOISTURE CONDITION:</th>
<th>GAGE ROD READING:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Spillway</td>
<td>FT.</td>
<td>Wet</td>
<td>inundated</td>
</tr>
<tr>
<td>Below Dam Crest</td>
<td>FT.</td>
<td>Dry</td>
<td></td>
</tr>
</tbody>
</table>

**DIRECTIONS:** MARK AN X FOR CONDITIONS FOUND AND UNDERLINE WORDS THAT APPLY

### UPSTREAM SLOPE

**PROBLEMS NOTED:**

- (0)NONE
- (1)RIPRAP - MISSING, SPARSE, DISPLACED, WEATHERED
- (2)WAVE EROSION - WITH SCARPS
- (3)CRACKS - WITH DISPLACEMENT
- (4)SINKHOLE
- (5)APPEARS TOO STEEP
- (6)DEPRESSION OR BULGES
- (7)SLIDES
- (8)CONCRETE FACING - HOLES, CRACKS, DISPLACED, UNDERMINED
- (9)OTHER

**CONDITIONS OBSERVED:** The upstream slope appears to be in the same condition as was observed in past inspections; though the high, murky water prevented inspection of the slope below the reservoir water level.

**RECOMMENDED ACTIONS:** Repairs to the upstream slope will eventually need to be performed.

### CREST

**PROBLEMS NOTED:**

- (0)NONE
- (1)RIPRAP - MISSING, SPARSE, DISPLACED, WEATHERED
- (2)WAVE EROSION - WITH SCARPS
- (3)CRACKS - WITH DISPLACEMENT
- (4)SINKHOLE
- (5)APPEARS TOO STEEP
- (6)DEPRESSION OR BULGES
- (7)SLIDES
- (8)CONCRETE FACING - HOLES, CRACKS, DISPLACED, UNDERMINED
- (9)OTHER

**CONDITIONS OBSERVED:** The dam crest appears to be in the same condition as was observed in the past. The crest is narrower than preferred, adversely graded, has at least one minor depression and a low area near the left abutment that reduces the spillway freeboard from 2 feet to about 13 inches. The upstream shoulder displays minor alignment deviations; however these are assumed to be remnant from original construction.

**RECOMMENDED ACTIONS:** Modifications to the dam crest should be completed as part of a future larger rehabilitation project. The objective would be to regrade the crest to a uniform elevation and cross slope for even drainage.

### DOWNSTREAM SLOPE

**PROBLEMS NOTED:**

- (0)NONE
- (1)RIPRAP - MISSING, SPARSE, DISPLACED, WEATHERED
- (2)WAVE EROSION - WITH SCARPS
- (3)CRACKS - WITH DISPLACEMENT
- (4)SINKHOLE
- (5)APPEARS TOO STEEP
- (6)DEPRESSION OR BULGES
- (7)SLIDE
- (8)SOFT AREAS
- (9)OTHER

**CONDITIONS OBSERVED:** No noticable changes from the last inspection were observed.

From recent past inspections: "The downstream slope has an irregular convex appearance, presumed to be remnant from original construction. The rockfill appears well-placed and interlocked. A bulge approximately 10-feet upslope of the downstream toe has historically been a point of consternation, however review of the C-292 record drawings (1936) suggests that the bulge is a relic of the past construction project. This lower slope appears oversteepened as a result of the bulge, however a stability analysis has not been performed to substantiate instability at this point."

**RECOMMENDED ACTIONS:** A slope flattening project may be necessary in the future if the dam stability is found to be inadequate; however no modifications are necessary at this time.
SEEPAGE

PROBLEMS NOTED
☐ (30) NONE ☐ (31) SATURATED EMBANKMENT AREA ☐ (32) SEEPAGE EXITS ON EMBANKMENT
☐ (33) SEEPAGE EXITS AT POINT SOURCE ☐ (34) SEEPAGE AREA AT TOE ☐ (35) FLOW ADJACENT TO OUTLET ☐ (36) SEEPAGE INCREASED / MUDDY
☐ (37) FLOW INCREASED / MUDDY ☐ (38) DRAIN DRY / OBSTRUCTED
☐ (39) OTHER

DRAIN OUTFALLS SEEN
☐ No ☐ Yes
Show location of drains on sketch and indicate

CONDITIONS OBSERVED:
Seepage along the toe near the maximum section appears to be moderately worse than observed in the past; however a lack of effective flow measurement device prevents quantifiable verification. Total seepage flows appear to be in the 50-100gpm range, and are most significant at the bottom left side of the valley, directly over the presumed 10 inch drain pipe location, though the drain pipe is completely buried (if it exists) and cannot be observed. Seepage is also present at the base of the outlet tunnel access port and within the “cave” at the right downstream groin to varying degrees up to several gpm each.

RECOMMENDED ACTIONS: Refer to recommendations in the 2014 inspection report.

OUTLET

PROBLEMS NOTED
☐ (40) NONE ☐ (41) NO OUTLET FOUND ☐ (42) POOR OPERATING ACCESS ☐ (43) INOPERABLE
☐ (44) UPSTREAM OR DOWNSTREAM STRUCTURE DETERIORATED ☐ (45) OUTLET OPERATED DURING INSPECTION ☐ YES ☐ NO
☐ (46) CONDUIT DETERIORATED OR COLLAPSED ☐ (47) JOINTS DISPLACED ☐ (48) VALVE LEAKAGE
☐ (49) OTHER

CONDITIONS OBSERVED:
The outlet tunnel was not accessed or observed on this day. The outlet was discharging directly to the stream at the maximum capacity on this day due to concerns about the high water levels. Treatment Technology reps reported no changes to the outlet system since the last inspection.

An internal inspection of the outlet works was performed in 2014 and a copy was submitted to this office for review. The video shows the interior of 110 feet of the 14 inch steel pipe, which appears to be in acceptable condition. The points of initiation and termination are somewhat unclear and the outlet modifications with the small diameter PVC pipes were not inspected; however the efforts to perform and provide this inspection is appreciated. The interior inspection of the outlet pipe is acceptable; therefore another interior inspection will be due again in 2024.

RECOMMENDED ACTIONS: Refer to recommendations in the 2014 inspection report.

SPILLWAY

PROBLEMS NOTED
☐ (50) NONE ☐ (51) NO EMERGENCY SPILLWAY FOUND ☐ (52) EROSION WITH BACKCUTTING ☐ (53) CRACK - WITH DISPLACEMENT
☐ (54) APPEARS TO BE STRUCTURALLY INADEQUATE ☐ (55) APPEARS TOO SMALL ☐ (56) INADEQUATE FREEBOARD ☐ (57) FLOW OBSTRUCTED
☐ (58) CONCRETE DETERIORATED / UNDERMOUND ☐ (59) OTHER

CONDITIONS OBSERVED:
The spillway is in the same condition as was observed in past inspections. A sandbag dike was constructed along the dam crest around the same time as this inspection in response to elevated reservoir water levels encroaching to within 7 inches of the dam crest. As a result, the total freeboard provided by the spillway and sandbag dike is approximately 28 inches, up from about 13 inches. Additional freeboard will be necessary to fully address the spillway capacity inadequacy.

The spillway is known to be undersized according to the Dam Safety Rules and Regulations (Jan. 2007), and an incremental damage assessment (IDA) has recently been performed to address this deficiency. The IDA is presently under review by this office, and the owner has stated plans to construct permanent modifications to the spillway once the IDA and a design for modifications are approved, and when funding becomes available. Since this may not happen for years to come, additional freeboard may be achievable in the short term by removing the 3- to 4-foot high concrete spillway sill.

RECOMMENDED ACTIONS: Continue to make progress towards rehabilitating the spillway to meet the requirements identified in the Dam Safety Rules for the long term. Controlled removal of the concrete spillway sill would greatly improve the safety of the dam in the near term until permanent modifications can be completed.

The rating has been increased to “Acceptable” based on the progress made towards addressing known spillway deficiencies.

CONDITIONS OBSERVED:

MONITORING

EXISTING INSTRUMENTATION FOUND
☐ (110) NONE ☐ (111) GAGE ROD ☐ (112) PIEZOMETERS ☐ (113) SEAEPAGE ☐ WEIRS / FLUMES
☐ (114) SURVEY MONUMENTS ☐ (115) OTHER

CONDITIONS OBSERVED:
The water treatment plant is located at the downstream left abutment and is staffed full time. WTP staff visually monitor the dam and reservoir on a daily basis. Seepage monitoring is discussed in the SEEPAGE section of this report.

RECOMMENDED ACTIONS: None.
## MAINTENANCE AND REPAIRS

<table>
<thead>
<tr>
<th>PROBLEMS NOTED</th>
<th>(60) NONE</th>
<th>(61) ACCESS ROAD NEEDS MAINTENANCE</th>
<th>(62) LIVESTOCK DAMAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(63) BRUSH ON UPSTREAM SLOPE, CREST DOWNSTREAM SLOPE, TOE</td>
<td>(64) TREES ON UPSTREAM SLOPE, CREST DOWNSTREAM SLOPE, TOE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(65) RODENT ACTIVITY ON UPSTREAM SLOPE, CREST DOWNSTREAM SLOPE, TOE</td>
<td>(66) DETERIORATED CONCRETE - FACING, OUTLET SPILLWAY</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(67) GATE AND OPERATING MECHANISM NEED MAINTENANCE</td>
<td>(68) OTHER</td>
<td></td>
</tr>
</tbody>
</table>

### CONDITIONS OBSERVED:
Woody shrubs noted on the last inspection report have been removed. Maintenance efforts are appreciated.

### RECOMMENDED ACTIONS:
None.

CONDITIONS OBSERVED:  
- [x] Good
- [ ] Acceptable
- [ ] Poor

*Go to next page for Overall Conditions and Items Requiring Actions*
The dam appears to be functioning as intended, and significant efforts by the owner and Treatment Technology have been made since the last inspection to bring the dam up to standard. Nevertheless, several significant issues remain that will continue to require attention for some time to come, including the excessive seepage without adequate monitoring, the inadequate spillway capacity, and the potentially insufficient outlet discharge capacity.

The emergency action plan appears to be up to date. The recent emergency incident highlighted the need for an updated inundation map, which should be developed as part of the spillway modification project.

The extent of dam safety concerns at this dam are sufficient to warrant a storage restriction. A partial storage restriction would provide little benefit to address the safety concerns associated with both the outlet or spillway. A zero storage restriction could be warranted, however it is recognized that the District would be completely unable to provide water to its constituents depending on the restricted level, which would only push the problems downstream to a different population. Additionally, the low level outlet is unlikely to have sufficient capacity to keep up with normal reservoir inflows. Therefore, a conditionally satisfactory rating will be assigned on the basis that the District continues to make demonstrable progress towards addressing the dam safety concerns.

Based on this Safety Inspection and recent file review, the overall condition is determined to be:

- [ ] (71) SATISFACTORY
- [✓] (72) CONDITIONALLY SATISFACTORY
- [ ] (73) UNSATISFACTORY

### OVERALL CONDITIONS

#### Safe Storage Level: Recommended as a Result of this Inspection

<table>
<thead>
<tr>
<th>Action Item</th>
<th>Description</th>
<th>Reason for Restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td>(101) FULL STORAGE</td>
<td>- FT. BELOW DAM CREST</td>
<td></td>
</tr>
<tr>
<td>(102) CONDITIONAL FULL STORAGE</td>
<td>- FT. BELOW SPILLWAY CREST</td>
<td></td>
</tr>
<tr>
<td>(103) RECOMMENDED RESTRICTION</td>
<td>- FT. GAGE HEIGHT</td>
<td></td>
</tr>
<tr>
<td>(104) CONTINUE EXISTING RESTRICTION</td>
<td>- NO STORAGE - MAINTAIN OUTLET FULLY OPEN</td>
<td></td>
</tr>
</tbody>
</table>

### ITEMS REQUIRING ACTION BY OWNER TO IMPROVE THE SAFETY OF THE DAM

**MAINTENANCE - MINOR REPAIR - MONITORING**

- [ ] (80) PROVIDE ADDITIONAL RIPRAP
- [ ] (81) LUBRICATE AND OPERATE OUTLET GATES THROUGH FULL CYCLE
- [ ] (82) CLEAR TREES AND/or BRUSH FROM
- [ ] (83) INITIATE RODENT CONTROL PROGRAM AND PROPERLY BACKFILL EXISTING HOLES
- [ ] (84) GRADE CREST TO A UNIFORM ELEVATION WITH DRAINAGE TO THE UPSTREAM SLOPE
- [ ] (85) PROVIDE SURFACE DRAINAGE FOR
- [ ] (86) MONITOR as described in the SEEPAGE section of this report
- [ ] (87) DEVELOP AND SUBMIT AN EMERGENCY ACTION PLAN
- [ ] (88) OTHER as described in the OUTLET section of this and the 2014 inspection reports
- [ ] (89) LUBRICATE AND OPERATE OUTLET GATES THROUGH FULL CYCLE

**ENGINEERING - EMPLOY AN ENGINEER EXPERIENCED IN DESIGN AND CONSTRUCTION OF DAMS TO**

- [ ] (90) PREPARE PLANS AND SPECIFICATIONS FOR REHABILITATION OF THE DAM: as described in the OUTLET and SPILLWAY sections of this report
- [ ] (91) PREPARE AS-BUILT DRAWINGS OF
- [ ] (92) PERFORM A GEOTECHNICAL INVESTIGATION TO EVALUATE THE STABILITY OF THE DAM
- [ ] (93) PERFORM A HYDROLOGIC STUDY TO DETERMINE REQUIRED SPILLWAY SIZE
- [ ] (94) PREPARE PLANS AND SPECIFICATIONS FOR AN ADEQUATE SPILLWAY
- [ ] (95) SET UP A MONITORING SYSTEM INCLUDING WORK SHEETS, REDUCED DATA AND GRAPHED RESULTS
- [ ] (96) PERFORM AN INTERNAL INSPECTION OF THE OUTLET
- [ ] (97) OTHER as described in the UPSTREAM SLOPE, CREST and DOWNSTREAM SLOPE sections of this report
- [ ] (98) OTHER as described in the OUTLET and SPILLWAY sections of this report
- [ ] (99) OTHER:

**SAFE STORAGE LEVEL: RECOMMENDED AS A RESULT OF THIS INSPECTION**

<table>
<thead>
<tr>
<th>Action Item</th>
<th>Description</th>
<th>Reason for Restriction</th>
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</thead>
<tbody>
<tr>
<td>(101) FULL STORAGE</td>
<td>- FT. BELOW DAM CREST</td>
<td></td>
</tr>
<tr>
<td>(102) CONDITIONAL FULL STORAGE</td>
<td>- FT. BELOW SPILLWAY CREST</td>
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<td>(103) RECOMMENDED RESTRICTION</td>
<td>- FT. GAGE HEIGHT</td>
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<tr>
<td>(104) CONTINUE EXISTING RESTRICTION</td>
<td>- NO STORAGE - MAINTAIN OUTLET FULLY OPEN</td>
<td></td>
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</tbody>
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**REASON FOR RESTRICTION**

**ACTIONS REQUIRED FOR CONDITIONAL FULL STORAGE OR CONTINUOUS STORAGE AT THE RESTRICTED LEVEL**

**Action Item (90)**

Engineer’s Signature

INSPECTED BY

Owner’s Signature

OWNER/OWNER’S REPRESENTATIVE

DATE: / /
GUIDELINES FOR DETERMINING CONDITIONS

CONDITIONS OBSERVED - APPLIES TO UPSTREAM SLOPE, CREST, DOWNSTREAM SLOPE, OUTLET, SPILLWAY

GOOD
In general, this part of the structure has a near new appearance, and conditions observed in this area do not appear to threaten the safety of the dam.

ACCEPTABLE
Although general cross-section is maintained, surfaces may be irregular, eroded, rutted, spalled, or otherwise not in new condition. Conditions in this area do not currently appear to threaten the safety of the dam.

POOR
Conditions observed in this area appear to threaten the safety of the dam.

CONDITIONS OBSERVED - APPLIES TO SEEPAGE

GOOD
No evidence of uncontrolled seepage. No unexplained increase in flows from designed drains. All seepage is clear. Seepage conditions do not appear to threaten the safety of the dam.

ACCEPTABLE
Some seepage exists at areas other than the drain outfalls, or other designed drains. No unexplained increase in seepage. All seepage is clear. Seepage conditions observed do not currently appear to threaten the safety of the dam.

POOR
Seepage conditions observed appear to threaten the safety of the dam. Examples:
1) Designed drain or seepage flows have increased without increase in reservoir level.
2) Drain or seepage flows contain sediment, i.e., muddy water or particles in jar samples.
3) Widespread seepage, concentrated seepage, or ponding appears to threaten the safety of the dam.

CONDITIONS OBSERVED - APPLIES TO MONITORING

GOOD
Monitoring includes movement surveys and leakage measurements for all dams, and piezometer readings for High hazard dams. Instrumentation is in reliable, working condition. A plan for monitoring the instrumentation and analyzing results by the owner's engineer is in effect. Periodic inspections by owner's engineer.

ACCEPTABLE
Monitoring includes movement surveys and leakage measurements for High and Significant hazard dams; leakage measurements for Low hazard dams. Instrumentation is in serviceable condition. A plan for monitoring instrumentation is in effect by owner. Periodic inspections by owner or representative. OR, NO MONITORING REQUIRED.

POOR
All instrumentation and monitoring described under "ACCEPTABLE" here for each class of dam, are not provided, or required periodic readings are not being made, or unexplained changes in readings are not reacted to by the owner.

CONDITIONS OBSERVED - APPLIES TO MAINTENANCE AND REPAIR

GOOD
Dam appears to receive effective on-going maintenance and repair, and only a few minor items may need to be addressed.

ACCEPTABLE
Dam appears to receive maintenance, but some maintenance items need to be addressed. No major repairs are required.

POOR
Dam does not appear to receive adequate maintenance. One or more items needing maintenance or repair has begun to threaten the safety of the dam.

OVERALL CONDITIONS

CONDITIONALLY SATISFACTORY
The safety inspection indicates symptoms of structural distress (seepage, evidence of minor displacements, etc.), which, if conditions worsen, could lead to the failure of the dam. Essential monitoring, inspection, and maintenance must be performed as a requirement for continued full storage in the reservoir.

UNSATISFACTORY
The safety inspection indicates definite signs of structural distress (excessive seepage, cracks, slides, sinkholes, severe deterioration, etc.), which could lead to the failure of the dam if the reservoir is used to full capacity. The dam is judged unsafe for full storage of water.

SAFE STORAGE LEVEL

FULL STORAGE
Dam may be used to full capacity with no conditions attached.

CONDITIONAL FULL STORAGE
Dam may be used to full storage if certain monitoring, maintenance, or operational conditions are met.

RESTRICTION
Dam may not be used to full capacity, but must be operated at some reduced level in the interest of public safety.

HAZARD CLASSIFICATION OF DAMS

High hazard
Loss of human life is expected in the event of failure of the dam, while the reservoir is at the high water line.

Significant hazard
Significant damage to improved property is expected in the event of failure of the dam while the reservoir is at the high water line, but no loss of human life is expected.

Low hazard
Loss of human life is not expected, and damage to improved property is expected to be small, in the event of failure of the dam while the reservoir is at high water line.

NPH hazard - No loss of life or damage to improved property, or loss of downstream resource is expected in the event of failure of the dam while the reservoir is at the high water line.
Photo 2: Dam crest and downstream slope (typical)

Photo 3: Downstream slope, outlet works tunnel access door and direct discharge pipe; and spillway discharge channel (left); dam crest after sandbag dike construction (right)
Engineer’s Inspection Report

Photo 4: Seepage at left downstream toe of maximum section near supposed 10-inch VCP drain

Photo 5: Seepage exiting outlet works tunnel (left); gage rod at low point near left abutment
Photo 6: Spillway control sill (left); spillway discharge channel immediately below sill (right)