December 18, 2020

Kevin Westhuis, Utility Director
City of River Falls Municipal Utilities
222 Lewis Street
River Falls, WI 54022

Re: Post-Flood Dam Safety Inspection and Repair Options Letter for Powell Falls Dam (P-10489)

Dear Kevin:

The Federal Energy Regulatory Commission (FERC) directed the City of River Falls Municipal Utilities (RFMU) to submit two items in the FERC letter dated October 2, 2020:

- A dam inspection report, summarizing observations and findings
- Recommendations for future action, ongoing agency consultation, interim impoundment and powerhouse operations, and other risk mitigation strategies

The FERC's deadline for submitting the above items is December 31, 2020. The FERC also asked the RFMU to submit an impoundment refill plan to the FERC by April 1, 2021.

Selected Portions of Dam History

Powell Falls dam was not constructed all at once in the present-day form. Per the Initial Study Report (January 30, 2020), a wood-framed powerhouse was built at Powell Falls in 1903 with a timber spillway to retain water. A concrete powerhouse was constructed in 1946 - 1947. In 1964, a large flood destroyed the timber dam spillway. A concrete gravity dam was constructed in 1965 - 1966, and that project did not include replacement of the sluiceway walls or powerhouse foundation. Ayres' search of the available historic drawings and records could not confirm that the powerhouse foundation and sluiceway piers are original 1903 concrete, but Figure 1's reinforcement view indicates that the sluiceway wall concrete predates 1947 when ASTM A305 standardized[1] reinforcing deformity patterns.

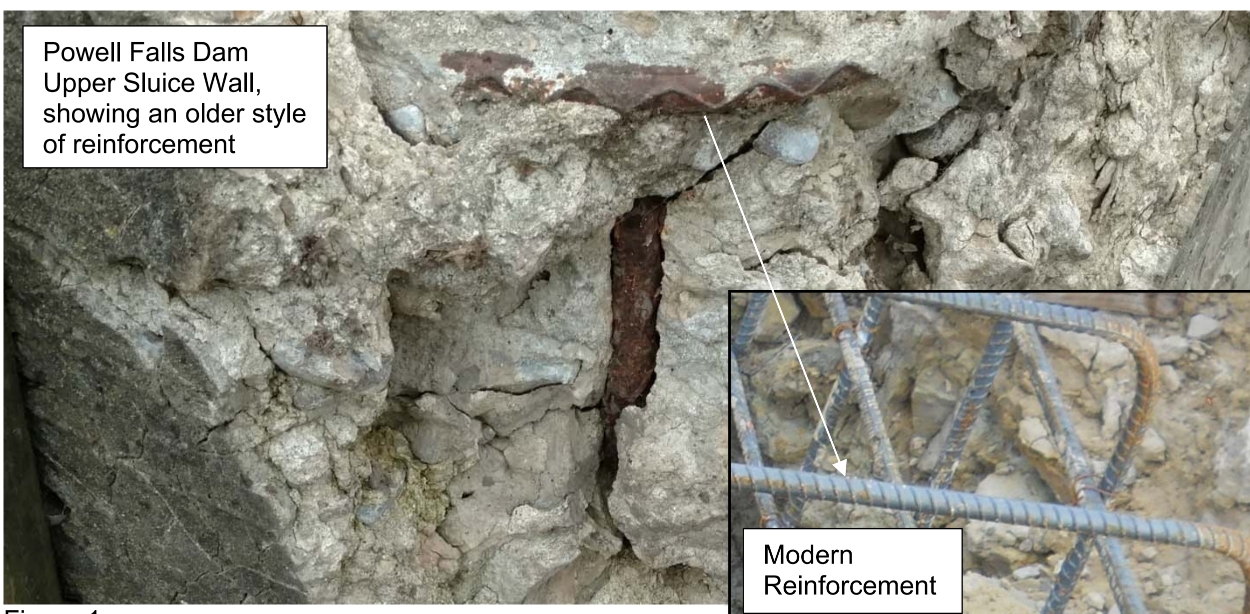

Figure 1

[1] https://crsi.org/index.cfm/basics/history-of-reinforcing-steel

During the project's initial FERC licensure in 1988, the stability analysis required post-tensioned anchors at Junction Falls. After further investigation for both dams, a stability analysis was subsequently completed for Powell Falls in 1991, and the spillway lift joints were found to have structurally inadequate bonds. Anchor lengths changed during construction. The 1992 construction included 13 post-tensioned anchors (rock bolts) to compress the spillway concrete together (13 anchors required) and tie the spillway concrete into the foundation bedrock (7 anchors of the original 13 were anchored into bedrock). Ayres is not fully certain that the designer's stability computations addressed the changed construction conditions.

The Powell Falls dam was inspected multiple times since initial licensure (most recently were December 2009, November 2014, and August 2015). For reference, items discussed in the earlier inspections that are still valid include:

- Deterioration of powerhouse tailrace dewatering slots
- Partial undermining of the powerhouse tail wall
- Deterioration of powerhouse walkway and deck undersides
- Excessive brush and trees around the dam that have roots which could form preferential seepage paths through the adjacent abutments
- Gate leakage
- Significant seepage through the right abutment bedrock

The 2020 inspection is intended to augment those earlier inspections with new observations made after a full drawdown. This 2020 inspection does not include commentary on every crack, spall, or other minor deficiency noted in the earlier reports; but instead, the 2020 inspection seeks to answer the primary question about how suitable is the remaining structure for continued safety during impounded water conditions through the year 2024. Ayres assumes the dam will be fully breached by the end of 2024.

2020 Events Preceding the Dam Inspection

An initial study report was submitted to the FERC on January 30, 2020, outlining a plan to decommission the Powell Falls Dam after 2023 as part of a license application to relicense the Junction Falls Dam.

The spillway passed a significant but unquantified peak flow after a seven-inch rainfall on June 29, 2020, and the RFMU filed a 12.10 dam safety report with the FERC on July 16, 2020. The 12.10 report noted loss of right abutment concrete. A follow-up letter to the FERC dated September 25, 2020, noted uncertainties about how the flood impacted the post-tensioned anchors, scour below Junction Falls spillway, and debris impingement effects on the Powell Falls sluice gate and powerhouse intake.

The RFMU proposed to draw down the impoundment for a dam safety inspection of the Powell Falls spillway lift joints (upstream face), sluice gate, powerhouse intake screen, and Junction Falls tailrace. On October 1, 2020, the FERC authorized an Order granting temporary variance from Article 401 of the project license and authorizing a drawdown from October 2, 2020, to June 1, 2021. The drawdown started on October 2, 2020, but a two-inch rainfall event from 2AM to 4AM caused the impoundment to completely refill by 6:43AM on October 12. Logs jammed in the sluice gate, forcing the RFMU to restart flow through the powerhouse (no load operation) to control impoundment levels. This allowed sand to fill the powerhouse intake bay and part of the turbine bowl but allowed the drawdown to proceed. The turbine flow was stopped at 10AM on October 12 as the impoundment had fallen 4.6 feet in an hour. The debris jam in the sluice gate had apparently released, dropping the impoundment a total of 6.9 feet within hours. Once the debris jam cleared, the RFMU was able to get the impoundment stabilized and continue the slow drawdown through October 15, 2020. At 11:17AM on Thursday, October 15, 2020, the river was no longer hydraulically controlled by the sluice gate.

The realization of how fast the impoundment could rise and fall led Ayres to quickly mobilize to do a dam inspection while the dam was fully drawn down. The inspection was completed on Monday, October 19, 2020.

Dam Inspection Observations and Findings

Ayres' Pete Haug inspected the Powell Falls dam on October 19, 2020. Per the nearest weather station[2], conditions during the survey were 34ºF, and antecedent conditions included a period of higher than normal runoff (2.03 inches of rain on October 12) and a drained impoundment condition (as of October 16). The morning of the October 19 inspection was 22ºF, apparently the first time that local temperatures had fallen below 28ºF since May 13, 2020.

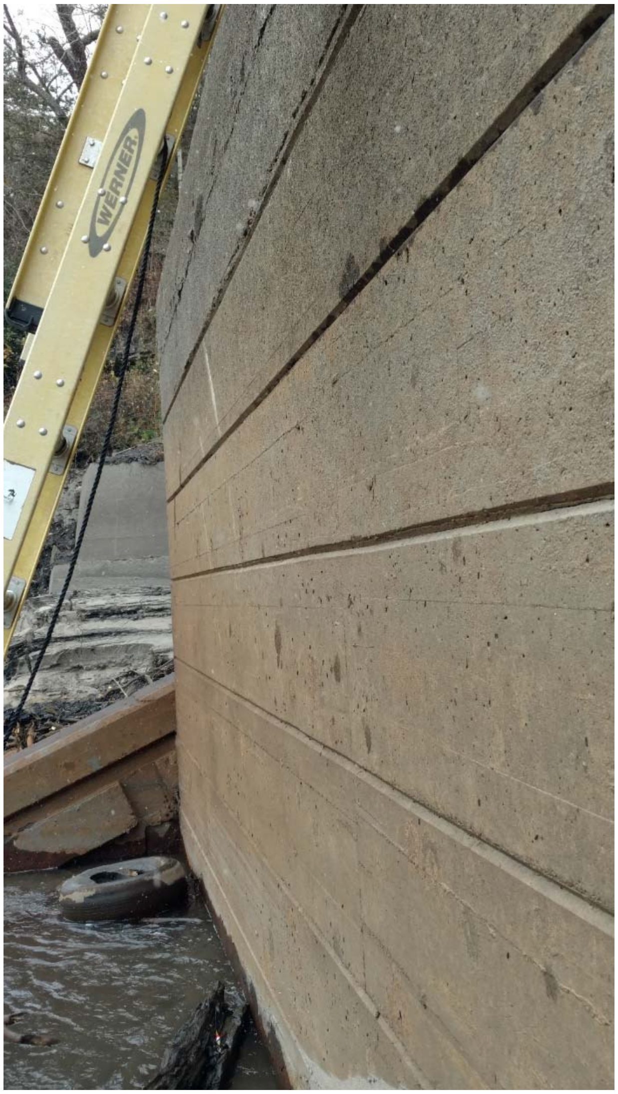

Figure 2, upstream lift joints on left spillway

The RFMU provided a ladder for Ayres to obtain a perpendicular view and up-close visual inspection of the upstream face of spillway concrete (Figure 2). Ayres was able to inspect the left and right ends, plus the third points, of the upstream face with a ladder. The uppermost lift joints had been apparently coated with a flexible (still flexible after installation in 1992) coating shown in Figure 3, though the coating had

2 https://mesonet.agron.iastate.edu/sites/hist.phtml?station=RVFW3&network=WI_COOP&year=2020&month=10

separated from the lift joints in multiple locations and water was found behind the coating in several places. All upstream face concrete (not the coating) sounded solid when struck with hammer.

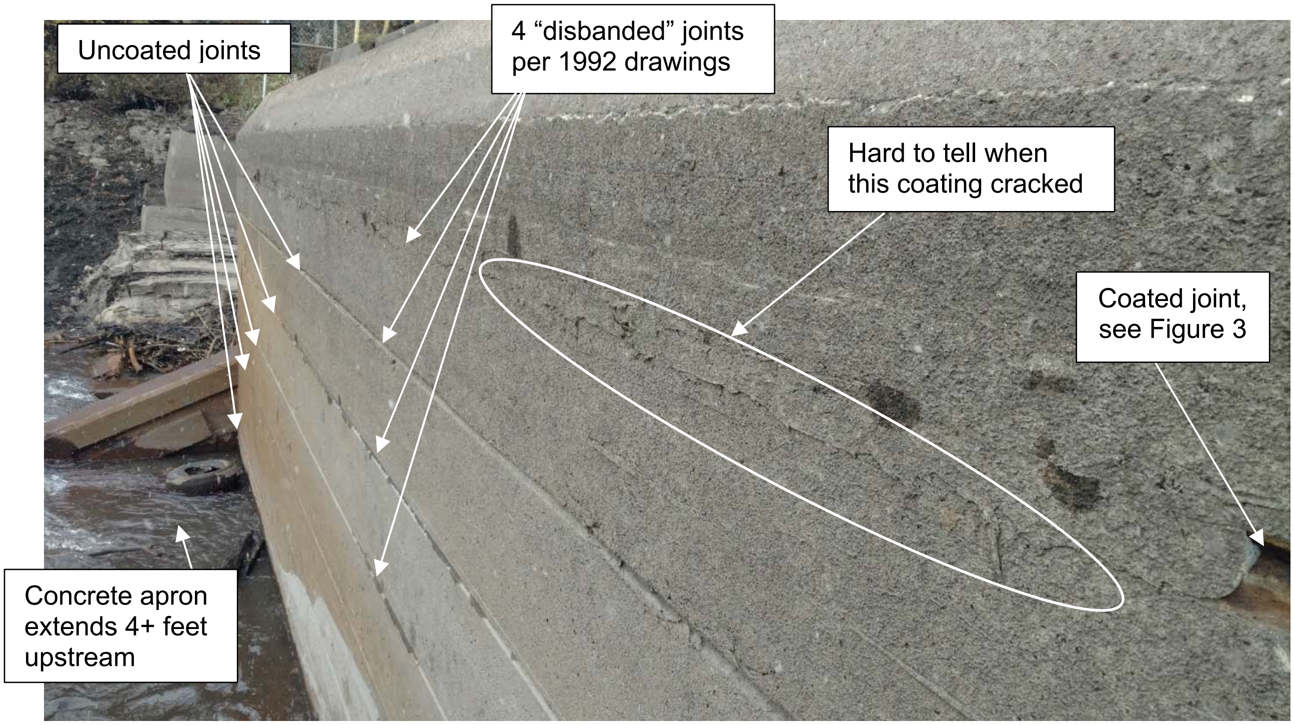

Figure 3. Lift joints, viewed from upstream face of spillway

Figure 4. Closeup of coated lift joint shown on right side of Figure 3, approximate elevation 819.3

Figure 5. Separation of second lift joint, approximate elevation 817.8. Separation does not look recent.

Other than the top two lift joints (Figure 4 and 5), none of the lower lift joints appear to have significant separation. The corner looks tight and free of any major cracks.

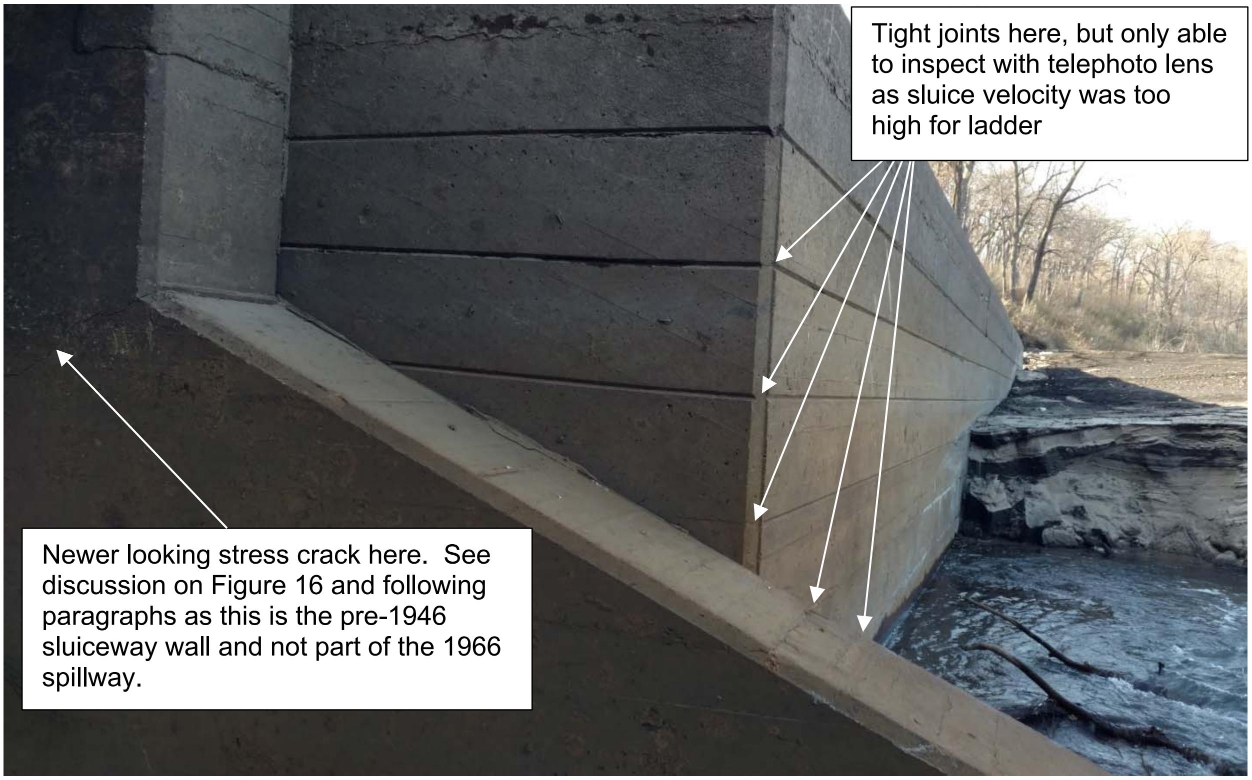

Figure 6. East face of spillway lifts. The sluiceway wall in foreground is much older than the spillway.

Seepage coming from the downstream face of dam near the right abutment was noted from the fourth lift joint down from top. However, Ayres was unable to determine if this seepage was coming from under the right abutment (transferring along crack) or flowing from the impoundment sediments through the crack. Figure 7 shows the lower rock layers are weeping about two feet lower than the lift joint.

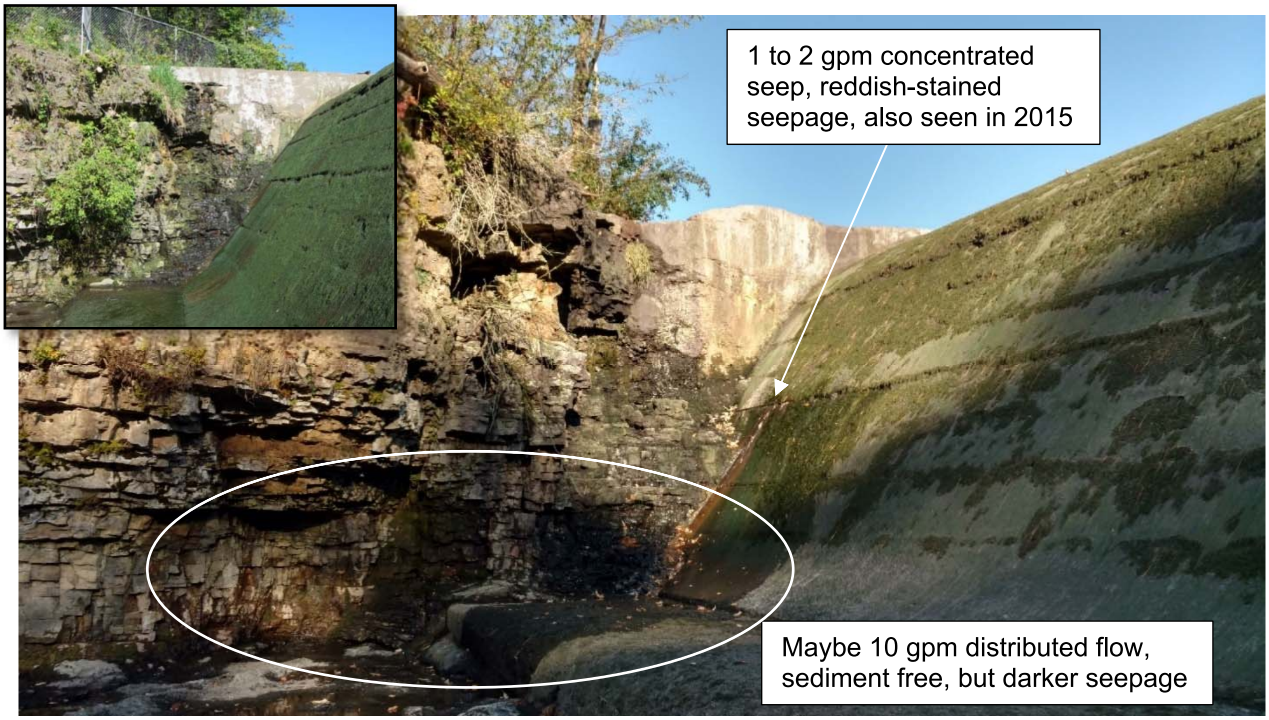

Figure 7. Downstream face of spillway near right abutment. Inset shows condition in 2015.

Figure 8. Typical discharge for clay tile foundation drains, possibly containing iron bacteria (red stains, labeled as "ochre" in the 1992 documents) and indicating significant levels of calcite deposits in drains (2020 minus 1966 is only 54 years, but 6" drain exits are partially blocked with calcite)

Figure 9. Looking eastward along spillway crest at spalling loss of 0.33 feet of concrete depth along deep longitudinal crack that runs from spillway crest down through at least one lift joint. Crack (but not the spall) is shown in October 1992 crack inventory, and no post-tensioned anchor is within damaged concrete area.

Figure 10. Another large spall, looking at top of spillway with upstream face inset to right. This crack extends through at least two lift joints, perhaps this is the same spall noted in 1992 but repaired thereafter. Inset shows view of this crack from upstream after cleaning – note how crack goes down at least through two lift joints (three horizontal monoliths).

Between 9 and 15 inches (variable height along length of prior abutment tie-in wall) of the right abutment concrete and bedrock was removed by the 2020 flood. Figure 11 shows the overall area, and Figure 12 shows the remaining bedrock where the concrete used to hold back headwater.

Figure 11. Looking west at right abutment, noting loss of up to 36 inches of shoreline soil. The tree trunk is approximately 21 inches in diameter at breast height for scale reference. Insets show 2015 condition.

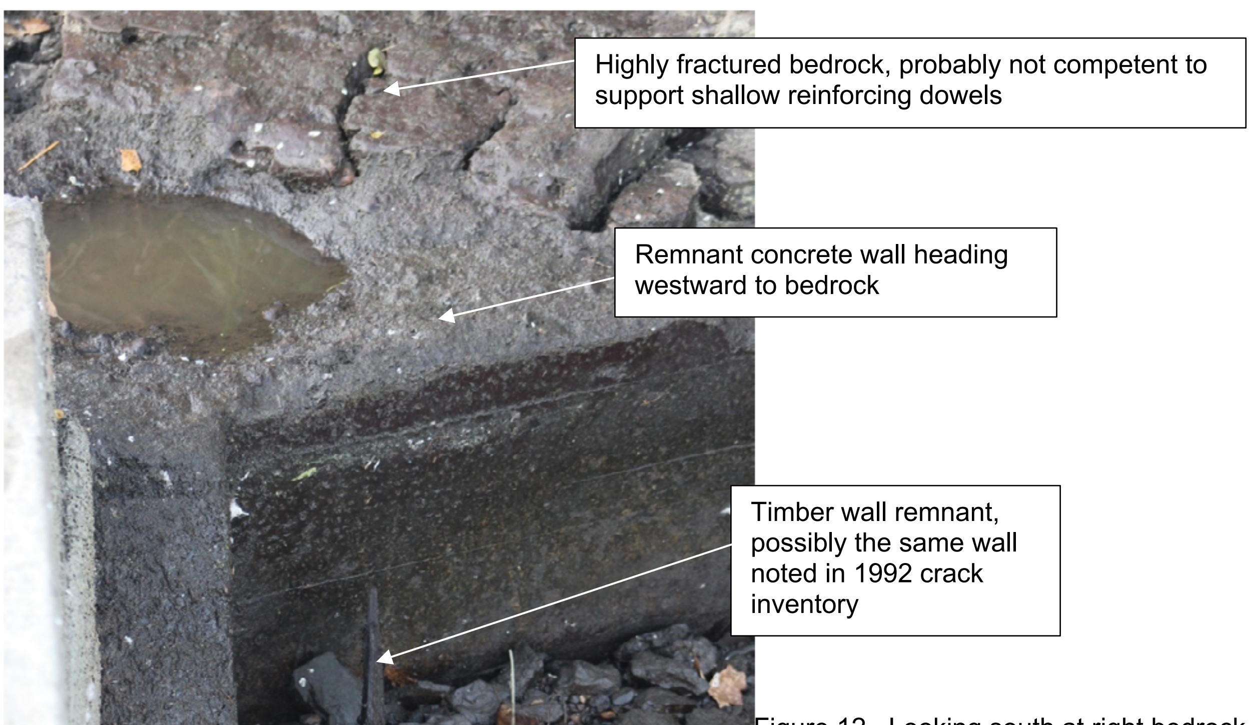

Figure 12. Looking south at right bedrock

The bedrock is most likely the same as recovered in nearby borings to elevation 820 at Junction Falls by SOCON in 1989. If so, this bedrock would be light brown dolomite with vugs, numerous vertical, horizontal, and inclined joints with intermittent shaley seams and a RQD value of 7%. From Ayres' experience on this same bedrock at other local dams, this type of bedrock is susceptible to freeze-thaw damage (external weathering), internal seepage, and hydraulic plucking during overtopping events.

The left abutment of the spillway is sound, but surface weathering and efflorescence are widespread.

Figure 13. Left abutment of spillway, note all these logs are from the October 12 rain event

Figure 14. Looking northeast at spillway and left spillway abutment on October 5 (note lack of logs shown in Figure 13).

Figure 15. Looking downward at sluice gate stem, note loss of structural section, severe corrosion, and possible bow (dashed lines indicate expected edge of beam). Gate was extremely difficult to operate.

Figure 16. Looking southward at sluice gate, note damage to lower chord (log strikes) and strapping

The crack on the right sluice wall was not written in the October 1992 inventory, and this crack does appear newer than the other cracks on the dam. A differential diagnosis of this crack's cause would include impoundment ice pushing southward against the relatively thin sluice structure OR thermal expansion differences between the large spillway mass and relatively thin sluice/powerhouse masses. The crack is a concern as it cannot be monitored directly during impoundment refill events. However, Ayres believes if the City wants to refill the lake, then the sluice deck movement could be monitored with a bubble level (simple inclinometer), regular monument surveys, and/or visual checks.

In Figure 17, the powerhouse trashrack is no less than 50% clogged with debris, which is the same clog percentage noted in 1992. Indeed, some of this debris looks very old. Given the large range in trash size and composition and understanding that cleaning a rack 12 feet below the surface is difficult for manual rakes, this rack plugging is most likely due to inadequate reach on the rack cleaning utensils.

Figure 17. Trashrack, plugged 50%. Also note sand deposits faintly visible in intake bay behind trashrack. Powerhouse intake bay gate is also faintly appearing behind trashrack – note that this gate's invert sill is several feet higher than the sluiceway gate.

After looking at the Powell Falls structure, Ayres did travel to the upstream end of the former Lake Louise to look at the Junction Falls tailrace, and Ayres consulted with dam operator Brian Hatch about ongoing Junction Falls turbine performance after the drawdown. The dam operator confirmed that Junction Fall's turbine has indeed now aerated, and he confirmed the turbine is a James Leffel unit (now part of the Canyon Hydro ownership). From a visual observation of the tailrace surface (water clarity was less than 30 inches), Ayres observed that the Junction Falls tailrace scour hole is not large enough to threaten the dam. However, Ayres did not dive or hydrosurvey the scour hole. Ayres did not survey the tailrace but it appears the tailrace lowered one to two feet from pre-drawdown conditions. Ayres did not evaluate how the lowering of Junction Falls' tailwater will impact the long-term cavitation and power production performance of Junction Falls, but a loss of power production efficiency could be expected if the draft tube aerates.

One solution to stop the aeration of the Junction Falls tailrace is to modify the draft tube (see FERC Exhibit F-14 Drawing) to accommodate the new average tailrace waterline. This would decrease aeration but might exacerbate cavitation potential, so more study would be needed if this option is selected.

Figures 18 and 19 show the tailrace of Junction Falls.

Figure 18. Looking upstream at Junction Falls tailrace. Note that waterline of scour hole is well downstream of spillway toe. However, Ayres did not walk on the toe of the Junction Falls spillway, so this view is as close as Ayres was able to safely access during the inspection.

Figure 19. Looking northward at tailrace of Junction Falls. The scour hole along the training wall does not seem to be under the wall, though Ayres did not dive or hydrosurvey the ponded water.

Unintended Refill Risk Estimation

If the RFMU chooses to keep the impoundment drawn down, there is a risk that the lake would refill during large rain events. To inform RFMU how various Powell Falls management options might impact risks of an unintended refill affecting sediment release and debris plugging between now and the end of the project's license, Ayres conducted high flow frequency and flood routing analyses to estimate the risk of the Powell Falls pool refilling in winter, spring, and summer. Three outflow configurations were considered, representing the range of dam modification options considered to be available in the short term (within the next 12 to 18 months). The discharge rating curves developed for each option are representative but not definitive, as the final design details of each configuration could change.

Discharge Configurations

The three configurations considered for releasing flow through Powell Falls Dam were as follows:

<u>A. Existing condition:</u> 69" high sluice opening (maximum the gate will currently open) with sharp gate bottom lip edge exposed and a correspondingly low discharge coefficient; turbine flow available at up to a 60 percent wicket gate opening beginning at pool elevation 815 (NAVD88 datum, typical throughout report). For this case the estimated maximum outflow at elevation 822.1, the dam crest, is 710 cubic feet per second (cfs).

<u>B. Enhanced sluice opening with turbine machinery removed:</u> Maximum sluice opening height 72" and sharp upper edge eliminated to provide a more favorable discharge coefficient; turbine passage flow controlled by intake sill at low impoundment stages, but by draft tube diameter at higher impoundment stages. Turbine is removed by disconnecting shaft and pulling turbine off to side, anchoring turbine to wall and out of the way of flow passage. For this case the estimated maximum outflow at elevation 822.1, the dam crest, is 900 cfs.

<u>C. Replace turbine with a 6' square "window:"</u> Sluice same as existing condition; turbine removed to expose the full draft tube entrance for flow, and additional flow capacity provided through a 6' by 6' opening in the downstream powerhouse wall with sill elevation 808.7. The corresponding estimated flow capacity at the dam crest is 1,130 cfs.

Other discharge configurations are possible but were not studied hydrologically at this time (though they would be studied in more detail later if these options are selected by RFMU). These other alternatives and the reason they were not studied at this time are:

1) <u>Start dam removal early by removing part or all of the spillway</u>. Of all the options available, Ayres believes this option poses the highest risk for unmitigated sediment release unless RFMU is willing to either invest in upfront channel stabilization or wait several years for the channel to naturally stabilize.
    a. After a large opening is cut into the Powell Falls Dam, the RFMU will have no ability to control sediment cutting during large flood events. If vegetation is not established sufficient to withstand the post-removal lakebed shear stresses, an environmental risk exists that as much as 40,000 cubic yards could be released downstream during a single event. To mitigate this risk, sediment management during early dam removal (while sediments are still wet and before they have consolidated or developed a good vegetative cover) would prudently include dredging of the proposed channel and banks to final grade and width, armoring of the channel to prevent rapid incision and banks to prevent lateral migration, and rapid vegetation of the remaining sediments.
    b. Ayres believes this dredging and restoration plan cannot be approved in time for January-February 2021 implementation (when frozen conditions would be expected), so the

earliest realistic timeframe for this option would be dredging between December 2021 and March 2022 (while the ground is still frozen) with spillway removal starting in August 2022. While Ayres acknowledges that spending more money on upfront dredging and restoration would mitigate risks of sediment release during an early removal, a less costly alternative (see end section of this report) is to wait at least two years prior to proceeding with dam removal so that the Lake Louise sediments can slowly dewater and compact and so that the upstream channel and lakebed have time to develop deep rooted vegetation.

2) Create uncontrolled flow openings. Option C is expected to require localized engineering analyses to show that the remaining powerhouse wall structure is stable. This review and construction authorization is expected to take 30 to 45 days to approve by the FERC because it is a situation that can be controlled still by the intake gate. Based on a very preliminary check of the building, a 6x6 foot opening is not expected to require re-analysis of foundation stability or global stability of the overall dam structure. However, cutting an ungated opening in the powerhouse or sluiceway would require more extensive design and a longer permit review period. So, while Ayres acknowledges that larger openings might be achievable by spring of 2022, there are two key downsides to trying to implement a larger opening earlier (assuming the RFMU could even get a license amendment sooner).
    a. First, the flow going through an ungated opening would not be controllable. Similar to the concerns expressed with excessive sediment incision and lateral migration in the above option, Ayres believes the RFMU would have to spend more funds on pre-dredging and bed armoring efforts prior to cutting a large uncontrolled (ungated) opening in the Powell Falls sluiceway or powerhouse.
    b. Second, removal of larger portions of the powerhouse or sluiceway are not expected to be possible without considerable more design effort which may require a pre-construction potential failure modes analysis and possibly more time and money invested in temporarily (3 years) stabilizing the remaining structure.
    c. In other words, it may be easier to proceed with design of full dam removal (see Option 1 above) than accommodating design risks for removing part of the dam now and still having to keep the remaining portions stable for several more years.

For either of the above alternatives, Ayres has assumed that a FERC Amendment to License is required for early dam removal (Ayres assumes 9-12 months), Chapter NR30 individual dredging permit is required (normally a three to six month process) after updated contaminant testing is completed (two month process), and an Army Corps permit is also required (at least a four month lead time). After dredging, Ayres suggests that to reduce the risk of sediment releases, dredged areas need vegetation roots established prior to removing the dam. We reserve the opportunity to revise our opinions on the above alternatives if stakeholder agencies can confirm our assumed timeline is not accurate.

At least within the interim period (2021-2023), Ayres has completed our refill risk study under the assumption that the above two options will be considered by RFMU as either cost-prohibitive or too risky for sediment release potential. In summary, the refill risks for only Discharge Configurations A, B, and C were studied in more detail.

Hydrograph Development

High flow frequency curves for winter (December-February), spring (March-May), and summer (June-August) were developed from daily flow values at the Kinnickinnic River at County F stream gage for the period of record 2003 to 2020. For each year of record, the highest daily flow in the season of interest was extracted, the seasonal series was plotted against a Weibull plotting position formula, and a logarithmic curve was fit to the series. The daily seasonal flow for each return period was then scaled down to the Powell Falls site by a factor of 0.863, representing a drainage area ratio exponent of 0.7.

Once the 1.1-, 2-, 3-, 5-, 10-, and 20-year daily flows at Powell Falls were estimated for each season, representative winter, spring, and summer hydrographs at a two-minute time scale were developed by scaling observed hydrographs of large seasonal events at the County F gage to match the daily average flow. The gaged flows were recorded at 15-minute intervals, but a two-minute time step proved to be necessary for stable reservoir routing in the next analysis steps.

Reservoir Routing

The hydrographs for each season and return period were routed through Lake Louise and Powell Falls Dam using the three discharge rating curves representing the range of alternatives for powerhouse/sluice modification. The reservoir elevation-storage curve was based on the bathymetry presented in the 2016 Inter-Fluve *Sediment Assessment Report*, but was modified to include Ayres' current understanding of the channel that has been incised upstream of the powerhouse. Figures 20 through 22 show the resulting seasonal stage-frequency curves for powerhouse/sluice modification scenarios A, B, and C above.

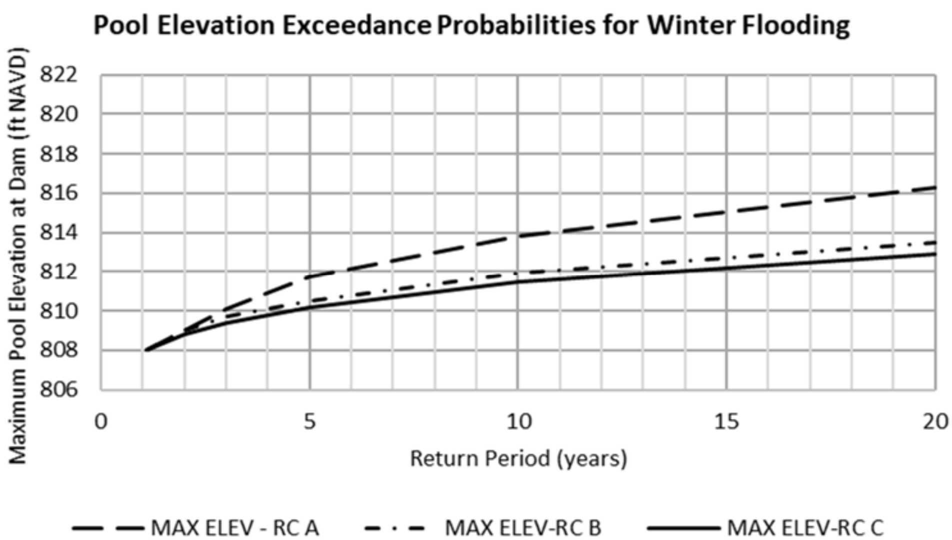

Figure 20

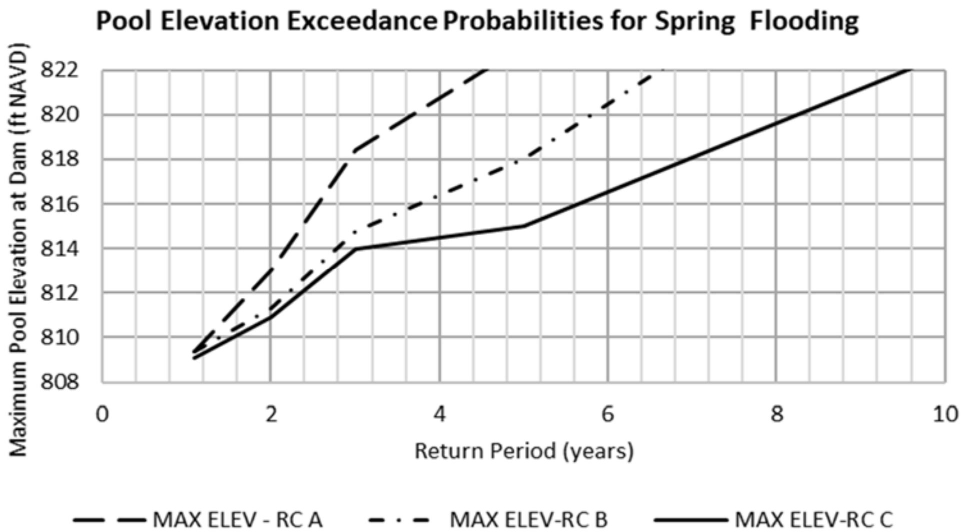

Figure 21

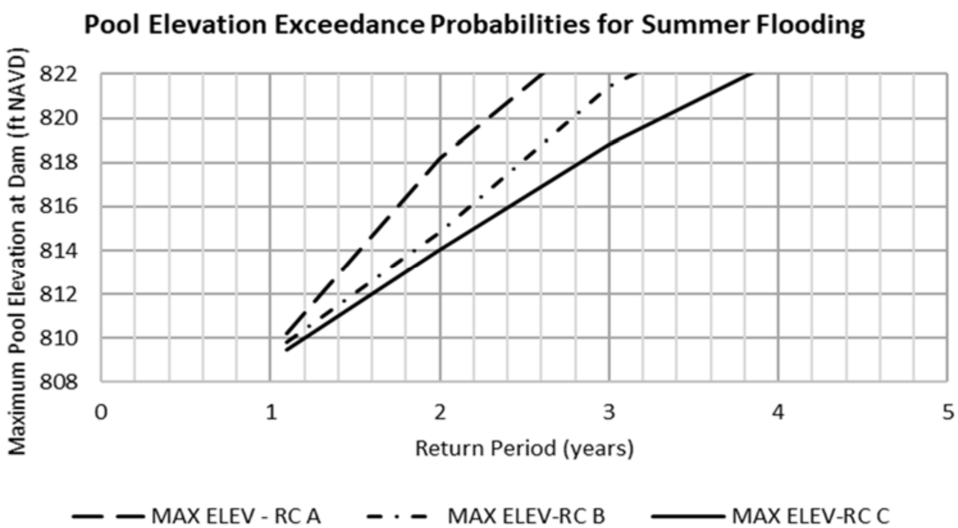

Figure 22

Table 1 summarizes the results shown in Figures 20 through 22 by listing the estimated exceedance probability of two threshold impoundment elevations for each season and discharge configuration considered. The impoundment elevations presented in Table 1 are (a) 822, just below the spillway crest elevation; and (b) 818, or a surface four feet below the spillway crest. This elevation was chosen for listing because it approximately represents the water surface elevation inundating most of the pre-drawdown lakebed, according to the bathymetry presented in the 2016 *Sediment Assessment Report.* Note that the exceedance probabilities listed are seasonal-annual and not overall annual. For example, with the sluice and turbine in their existing condition (Configuration A) there is a 38 percent chance that the dam will be overtopped in any given summer – and there is also a 22 percent chance that the dam will be overtopped in any given spring, including the same year in which a summer overtopping event occurs. Overall, the annual probability of overtopping is larger than either of the individual seasonal probabilities.

Table 1: Estimated Seasonal Lake Louise Elevation Exceedance Probabilities for Three Discharge Configurations

Season	Threshold Elevation	Discharge Configuration		
		A - Existing Condition (drawdown)	B - Improve Sluice Opening Height and Hydraulic Efficiency; remove turbine	C - Remove Turbine and Open 6' Square "Window" in Powerhouse
Winter *(extrapolated)*	822	0.03	<0.02	<0.02
	818	0.04	0.02	0.02
Spring	822	0.22	0.15	0.10
	818	0.34	0.20	0.14
Summer	822	0.38	0.32	0.26
	818	0.50	0.40	0.35

In summary, Ayres found that for any gated option (not an uncontrolled breach) there is little chance of preventing the impoundment from refilling between 2021 and 2023, though the duration of refill may be so small that the reservoir vegetation and bank stability still have a good chance of stabilizing between brief refill events.

Powell Falls' Repair or Management Options

After reviewing the above discharge configurations, do-nothing alternative, and early decommissioning alternative, Ayres believes the RFMU has a continuum of options that can be broken into five option categories as follows:

- Option 1: Repair the dam and refill the Powell Falls impoundment, restoring power generation until a final decision is granted regarding proposed dam removal in 2023.
    - Refill and sediment risk: refill would occur and all sediments will be rewetted. However, the 2024 drawdown will likely face the same challenges observed during the 2020 drawdown. If Option 1 is exercised, Ayres would recommend that this is followed by Option 5 starting in 2024.
    - Repair needs (around[3] $100,000 for design, construction, and permitting)
        - Right abutment must be restored to allow low flow in winter to be distributed across the entire upstream face of spillway to keep ice pressures below the 5000 pounds per linear foot threshold assumed during the 1992 anchor design
            - As a preliminary estimate, this requires 25 cubic feet of reinforced concrete wall, doweled with anchors into the bedrock; and then the upstream bedrock is slush-grouted to prevent seepage through the highly fractured layers of exposed bedrock.
            - A geotechnical engineer should confirm the suitability of this bedrock for reinforcing dowels. From Ayres' surficial inspection, the bedrock is highly fractured, so a geotechnical engineer may prescribe deep dowels and/or removal of the top layer of weak bedrock.
            - Additional concrete placed higher against the right bedrock hillside may be required by the FERC to protect the hillside from further lateral erosion during overtopping events.
        - Divots in spillway should be pressure-washed, cleaned, and repaired in accordance with a suitable concrete repair product. A competent concrete patch should be installed to last at least four years (including three Wisconsin winters).

[3] This opinion of probable project cost is a ballpark estimate based on preliminary data and must be considered no better than 40% accurate.

        - Repair the sluice gate to allow dependable operation during the future proposed decommissioning and dam removal efforts. This repair would include replacement of the gate's bottom chord, strapping, and lift beam, and an overhaul of the gear/actuation system is highly recommended.
        - A thorough trashrack cleaning should be completed prior to refill.
    - Monitoring needs
        - Regular monitoring of the sluiceway deck for movement that might indicate the crack shown in Figure 16 is progressively opening.
        - The powerhouse trashrack should be cleaned completely and adequate utensils procured to allow full rack cleaning. Note that most trashracks are only designed for a few feet of head differential before the rack fails, and debris/ice plugging have been responsible for historical trashrack failures at other projects.
    - Ongoing agency consultation needs
        - Submittal of the FERC required refill plan (due April 2021)
        - Submittal of design report to the FERC division of dam safety for any significant concrete repairs (right abutment wall would be one example) made to the dam.
        - Continued development of a decommissioning plan that includes measures to minimize sediment mobilization downstream (possibly requiring proactive impoundment dredging to pre-form the future channel)
        - Continued monitoring by the state and other stakeholders as budget permits of the downstream reach recovery, especially with regard to how fast or slow sediment is cleared from the tailrace and stabilized in the downstream river reaches.
    - Interim impoundment and powerhouse operations
        - Refill Lake Louise after repairs are made, passing normal flow through the powerhouse and all higher-than normal flows over the spillway
        - Generate power as equipment permits, regularly cleaning the trashrack
        - Do not draw down the impoundment again until final approvals are granted and follow the state and federal conditions of the future dam removal permits.
    - Other risk management strategies
        - Once Lake Louise is refilled, use a barge mounted geotechnical drilling rig to confirm where Lake Louise's historical bed is, particularly with the goal of determining dredging limits.
        - Proactively dredge the future channel expected through Lake Louise after refill in the "wet". Such dredging would need to accommodate new sediment that comes into Lake Louise (like thought probable during the 2020 flood) and excavation to the stable historical bed (possibly deeper than today's channel).

- Option 2: Keep the Powell Falls impoundment drawn down in the current state but do not fix the gate nor pull the turbine. This is the same as Configuration A studied above in this report.
    - Refill and sediment risks:
        - Lake Louise has a 4% chance of rewetting the lakebed sediments at least once per winter, a 34% chance each spring, and a 50% chance each summer.
        - There is a 38% chance each summer that water will pass over the damaged right abutment area, and this becomes a 76% chance of flow passing over this at least once in the next three years.
    - Repair needs (around[4] $10,000)
        - A thorough trashrack cleaning should be completed prior to spring runoff and thereafter as needed to clear the trashrack.
        - Seeding of lakebed in spring 2021 and other stabilization measures as required by the state and federal agencies

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[4] This opinion of probable project cost is a ballpark estimate based on preliminary data and must be considered no better than 40% accurate.

        - Lubricate the sluice gate equipment and provide strong City staff to help crank down and up the gate (existing operability) during and after floods.
        - Sandbag the right abutment area to at least two feet above existing spillway crest elevation.
    - Monitoring needs
        - Impoundment levels will vary considerably during even moderate (2- to 3-inch) rainfall events, and it is likely the impoundment will completely refill two to four times per year.
        - Water will need to be passed as much as possible through the turbine and fully opened sluice gate but as the water level falls in the reservoir, RFMU will need to open/close the powerhouse headgate and sluice gate to moderate the rate of water level recession. The goal is to not drop the impoundment levels faster than 6 inches per day to reduce the risk of upstream banks collapse and sudden sediment surges downstream.
        - The trashrack will need to be regularly cleaned after each major flow event.
    - Ongoing agency consultation needs
        - FERC License amendment to keep the reservoir drawn down for the duration of license. It is Ayres' understanding that the FERC considers any drawdown without intent of restoring generation to be an act of decommissioning so a license amendment would be required.
        - Commitment to an interim sediment stabilization plan (perhaps integral with or submitted as a compliment to the decommissioning plan), knowing that the faster that the lakebed can be recolonized by dense roots, the less sediment will remobilize during each impoundment level bounce.
        - Rewriting the decommissioning plan to account for conversion of the lakebed from fully submerged to intermittently submerged to dewatered to stable upland soils.
        - Continued monitoring of the lakebed stability, including frequent drone flights and other monitoring aids as jointly acceptable to RFMU and agencies
    - Interim impoundment and powerhouse operations
        - Pass all normal flow through the sluice, allowing the Lake Louise to refill (in whole or in part) during moderate rainfall events. Larger rainfall events would likely cause the impoundment to overflow the spillway.
    - Other risk management strategies (at additional costs)
        - Consider installing a small jib crane or other hoisting system to allow the dam operator to clean logs out of the sluice gate entrance and off the powerhouse trashrack. A woody debris management plan could also consider whether logs could be captured upstream of Powell Falls' sluice so the risk of plugging was lessened.
        - As part of the interim sediment stabilization plan, proactively grade flatter and armor the toe of banks to improve slope stability.

- Option 3: Keep the Powell Falls impoundment drawn down in the current state but fix the gate and pull the turbine. This is the same as Configuration B studied above in this report.
    - Refill and sediment risks:
        - Lake Louise has a 2% chance of rewetting the lakebed sediments at least once per winter, a 20% chance each spring, and a 40% chance each summer.
        - There is a 32% chance each summer that water will pass over the damaged right abutment area, and this becomes a 69% chance of flow passing over this at least once in the next three years.
    - Repair needs (around[5] $30,000)

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[5] This opinion of probable project cost is a ballpark estimate based on preliminary data and must be considered no better than 40% accurate.

- A thorough trashrack cleaning should be completed prior to spring runoff and thereafter as needed to clear the trashrack.
- Seeding of lakebed in spring 2021 and other stabilization measures as required by the state and federal agencies
- Detach the turbine shaft and pull the turbine runners upward to add 30% to 50% more flow capacity to the turbine. Flow would be controlled by the headgate.
- Improve operability and reliability for the gate actuation system to allow the gate to be fully raised to clear the concrete opening and to be regularly lowered to slow the rate of impoundment level recession, with a goal of preventing the impoundment from dropping faster than 6 inches per day following any refill from rain events. This could significantly reduce future riverbank collapses in the impoundment.
- Sandbag the right abutment area to at least two feet above existing spillway crest elevation.

- Monitoring needs
  - RFMU will need to be vigilant to monitor forecasted rainfall, be ready to open/close the powerhouse headgate and sluice gate to moderate the rate of water level recession. The goal is to not drop the impoundment levels faster than 6 inches per day to reduce the risk of upstream banks collapse and sudden sediment surges downstream. However, with improved gate operations and a larger flow outlet, it may be possible to keep the impoundment bounce from fully saturating the impoundment bed.
  - The trashrack will need to be regularly cleaned after each major flow event.
- Ongoing agency consultation needs
  - FERC License amendment to keep the reservoir drawn down for the duration of license. Ayres believes the FERC considers any drawdown without intent of restoring generation to be an act of decommissioning so a license amendment would be required.
  - Commitment to an interim sediment stabilization plan (perhaps integral with or submitted as a compliment to the decommissioning plan), knowing that the faster that the lakebed can be recolonized by dense roots, the less sediment will remobilize during each impoundment level bounce.
  - Rewriting the decommissioning plan to account for conversion of the lakebed from fully submerged to intermittently submerged to dewatered to stable upland soils.
  - Continued monitoring of the lakebed stability, including frequent drone flights and other monitoring aids as jointly acceptable to RFMU and agencies
- Interim impoundment and powerhouse operations
  - Pass all normal flow through the sluice and turbine opening, allowing the Lake Louise to refill (in whole or in part) during moderate rainfall events. Larger rainfall events would likely cause the impoundment to overflow the spillway.
- Other risk management strategies (at additional costs)
  - Consider installing a small jib crane or other hoisting system to allow the dam operator to clean logs out of the sluice gate entrance and off the powerhouse trashrack. A woody debris management plan could also consider whether logs could be captured upstream of Powell Falls' sluice so the risk of plugging was lessened.
  - As part of the interim sediment stabilization plan, proactively grade flatter and armor the toe of banks to improve slope stability.
  - As time passes and the lakebed firms up, public will more frequently access the upstream lakebed and Ayres believes the risk increases someone trying to kayak through the dam's sluiceway or wade/fish upstream of this structure. Therefore, site security and public safety should be regularly re-evaluated by decision makers.

- Option 4: Keep the Powell Falls impoundment drawn down and add more flow capacity by opening up a new passage route for runoff to exit the dam
  - Refill and sediment risks:
    - Lake Louise has a 2% chance of rewetting the lakebed sediments at least once per winter, a 14% chance each spring, and a 35% chance each summer.
    - There is a 26% chance each summer that water will pass over the damaged right abutment area, and this becomes a 59% chance of flow passing over this at least once in the next three years.
  - Repair needs (around[6] $100,000 for Option C in this report)
    - Seeding of lakebed in spring 2021 and other stabilization measures as required by the state and federal agencies
    - Detach the turbine shaft and pull the turbine runners upward to add 30% to 50% more flow capacity to the turbine. Flow would be controlled by the headgate.
    - Improve operability and reliability for the gate actuation system to allow the gate to be fully raised to clear the concrete opening and to be regularly lowered to slow the rate of impoundment level recession, with a goal of preventing the impoundment from dropping faster than 6 inches per day following any refill from rain events. This could significantly reduce future riverbank collapses in the impoundment.
    - Remove the powerhouse trashrack. Then open up a section of the powerhouse's southern (downstream) wall to be at least 6 feet wide and 6 feet high. However, flowrate would still be controlled by the powerhouse's intake headgate. A woody debris management plan could also consider whether logs could be captured upstream of Powell Falls' sluice so the risk of plugging was lessened.
    - Sandbag the right abutment area to at least two feet above existing spillway crest elevation.
  - Monitoring needs
    - RFMU will need to be vigilant to monitor forecasted rainfall, be ready to open/close the powerhouse headgate and sluice gate to moderate the rate of water level recession. The goal is to not drop the impoundment levels faster than 6 inches per day to reduce the risk of upstream banks collapse and sudden sediment surges downstream. However, with improved gate operations and a larger flow outlet, it may be possible to keep the impoundment bounce from fully saturating the impoundment bed.
  - Ongoing agency consultation needs
    - FERC License amendment to keep the reservoir drawn down for the duration of license and to start early decommissioning (powerhouse modifications).
    - Submittal of a Supporting Design Report to the FERC division of dam safety for work to be done
    - Commitment to an interim sediment stabilization plan (perhaps integral with or submitted as a compliment to the decommissioning plan), knowing that the faster that the lakebed can be recolonized by dense roots, the less sediment will remobilize during each impoundment level bounce.
    - Rewriting the decommissioning plan to account for conversion of the lakebed from fully submerged to intermittently submerged to dewatered to stable upland soils.
    - Continued monitoring of the lakebed stability, including frequent drone flights and other monitoring aids as jointly acceptable to RFMU and agencies
  - Interim impoundment and powerhouse operations

[6] This opinion of probable project cost is a ballpark estimate based on preliminary data and must be considered no better than 40% accurate.

        - Pass all normal flow through the sluice and turbine opening, allowing Lake Louise to refill (in whole or in part) during moderate rainfall events. Larger rainfall events would likely cause the impoundment to overflow the spillway.
    - Other risk management strategies (at additional costs)
        - Consider installing a small jib crane or other hoisting system to allow the dam operator to clean logs out of the sluice gate entrance and off the powerhouse trashrack.
        - As part of the interim sediment stabilization plan, proactively grade flatter and armor the toe of banks to improve slope stability.
        - As time passes and the lakebed firms up, public will more frequently access the upstream lakebed and Ayres believes the risk increases someone trying to kayak through the dam's sluiceway or powerhouse or wade/fish upstream of this structure. Therefore, site security and public safety should be regularly re-evaluated by decision makers.

- Option 5: Proceed with full dam removal (accelerated ahead by two years from schedule presented in January 2020 Initial Study Report)
    - Repair needs ($1.3M to $1.9M[7] with higher end of costs associated with more upfront dredging and lower end of costs associated with a longer period for the impoundment to stabilize prior to removing the dam)
        - Proceed with implementation of decommissioning plan and full dam removal
    - Monitoring needs
        - The impoundment water elevations would not be monitored because the dam operator would have no control over the rate of impoundment rise or fall.
        - However, because there would be no control over velocities within the former Lake Louise impoundment (no gates to close), the monitoring of the wastewater treatment lines will be critical to intercepting backward erosion during large flood events. See risk mitigation measures below.
    - Ongoing agency consultation needs
        - Submit a FERC license amendment to separate/remove Powell Falls Development from the Junction Falls Development license with the intent of starting the physical dam removal process as soon as the amendment is approved.
        - As soon as possible, apply for state and federal permits for the dam removal activities.
        - Monitoring of site environmental conditions as required by permitting agencies
    - Interim impoundment and powerhouse operations
        - Since the lakebed will not be revegetated prior to decommissioning, dredging is recommended with engineered armor on graded banks to stabilize the channel configuration and limit sediment movement.
    - Other risk management strategies
        - Proactively riprap the grades near the wastewater treatment plan crossing (and perhaps also the other sanitary crossing below Junction Falls to better protect these in case a large flood occurs in the future.

[7] This cost opinion is based on preliminary decommissioning plan results, but the cost accuracy is still no better than 25 percent (waiting on stakeholder input for who is funding restoration plan, how much dredging is required, etc.).

Summary

Dam Safety Inspection findings

The following dam safety items should be addressed prior to refilling the lake:

- Restore the right abutment connection concrete
- Fix the gate stem and operator to allow reliable operation
- Develop a monitoring plan for sluiceway section movement, especially during winter conditions
- Clean trashrack
- Restore unit operations
- Patch concrete divots that might allow ice to bond to the spillway's upper lift
- Prepare a plan to prevent ice forces from overloading of spillway post-tension anchors

The following dam safety items should be addressed if the lake is not refilled:

- Figure out a reliable operation plan maintaining drawdown conditions (the levels of repair costs and extents vary with which option is selected)
- Sandbag the damaged right abutment to lessen risks of additional overtopping damage

Options

Table 2 shows a qualitative opinion of risks and costs associated with the above options. Again, these costs are not fully developed and may change depending on how assumptions and regulatory requirements change throughout this process, but in general Ayres feels the relative differences are captured well in the following table.

Table 2. Summary Table

	2021-2023	2021 - 2023			
	Constr. Costs	Refill risk	Sediment cutting	Bank movement	Vegetation growth
Option 1	$100k	100%	None	None	None
Option 2	$10k	76%	Some	Slow	Moderate
Option 3	$30k	69%	Some	Slow	Moderate to High
Option 4	$100k	59%	Some	Slow	High
Option 5	$1.9M	<10%	Proactive dredging	Proactive dredging	Planted

	2024-2027	2024 - 2027			
	Constr. Costs	Refill risk	Sediment cutting	Bank migration	Vegetation growth
Option 1	upwards of $1.9M	<10%	Proactive dredging	Proactive dredging	Planted
Option 2	$1.3M to $1.5M	<10%	Some	Some	Moderately vegetated
Option 3	$1.3M to $1.4M	<10%	Minor	Minor	Mostly vegetated
Option 4	$1.3M	<10%	Little	Little	Fully vegetated
Option 5	Minor	<10%	Little	Little	Fully vegetated

Ayres presents the above options for RFMU consideration and decision in late January 2021. The RFMU's selected option is expected to be presented by relicensing team during the February 9, 2021, Updated Study Report presentation.

Please feel free to email or call me with questions. As with all feasibility level evaluations of options, Ayres reserves the right to amend our recommendations or findings should new information be provided. Please contact me if you know of additional information that may change the above recommendations.

Sincerely,

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