October 28, 2024

Joshua Goodwin, P.E.
Project Manager
Colorado Water Conservation Board
1313 Sherman St., Rm 718
Denver, CO 80203

Re: FINAL REPORT
Lower Beaver Brook Dam, Upper Beaver Brook Outlet Works and SCADA System
CT2021-3115, WSRF Grant POGG1 2021-2565

Dear Joshua:

Lookout Mountain Water District is providing this letter summarizing the above referenced project. The project is now at substantial completion. The remaining work includes installing a redesigned measurement flume for Upper Beaver Brook Dam's toe drains and final tweaks on software to assure the SCADA system is accurately reporting data. Algorithms for setting release levels also will be adjusted as we watch the "owe the river account".

Summary of Project Impact

1) The high hazard Lower Beaver Brook Dam was totally taken down and rebuilt. Risks to people and property downstream have been greatly reduced by the new RCC dam. The spillway is now significantly larger; designed for 1 in a thousand year flood risk. The reservoir no longer needs to stay near full to push water to the WTP. Line pumps can move water to the WTP as needed with water levels as low as 6 feet. The hydraulicly actuated gate is controlled by the SCADA system, though movements are being restricted to manual application entries at this point.
2) Concrete placements for flumes while the dam was being constructed allowed much more solid structures to be built at a more efficient cost. The inlet flume for Lower Beaver Brook Reservoir, the outlet flume for Lower Beaver Brook Reservoir and the confluence flume (North Fork of Beaver Brook flows into Beaver Brook) were all constructed during the dam construction. These flumes are all working with the SCADA system and reporting accurate data. Some drainage work needs to be done around the confluence flume to keep road sand and gravel from settling in the flume when heavy rains hit. Measurements not available in the past will help us manage water, making the best decisions to meet release requirements, but still maximize storage.
3) The Upper Beaver Brook outlet works became a much more complex project than originally envisioned. The outlet pipe ended up being relined with PVC and grout injected between the old and new pipe. The eminent risk of leakage in the outlet pipe and failure of the gate and movement mechanism is gone. A new head plate, gate and trash rack we installed on the modified original base of the old outlet structure. The new gate is hydraulically actuated with SCADA software controls. All work was done with the reservoir close to full. Flow was maintained with a pump and hose line over the spillway.

4) The outlet flume for Upper Beaver Brook reservoir was also rebuilt after the outlet work was complete. A new concrete structure was built and galvanized flume was installed that should allow year round readings through a wide range of flows. All instruments are installed, but the water commissioner has asked that we revise the toe drain measurement flume, so that separate flume is being redesigned by HydroLogik.
5) A water management plan was developed to allow LMWD to meet all Beaver Brook downstream flow requirements while maximizing the storage in our reservoirs. The SCADA system will follow this plan and make managing the requirements much less complex. Even before the SCADA system was able to gather data from all measuring points, we could see the plan was improving our stored water totals. During the wet spring, both upper and lower reservoirs were both full and spilling for the first time since Upper Beaver Brook reservoir was enlarged to a capacity of almost 400 acre feet. Momentum Engineering's projections show the amount of additional water stored each year should average above 25 acre feet. So far, so good!

Timeline for Lower Beaver Brook dam replacement

2017 - A new labyrinth spillway at Upper Beaver Brook reservoir was completed in the spring, increasing the storage capacity by 200 acre feet. To approve this additional storage, Colorado State Engineer required that LMWD must construct an approved upgrade or replacement of the LBB Dam, built in 1903. It was soon determined that replacement of the 115 year old LBB dam made more sense. Estimated cost was $6.5 million.

2018 - SEO advised the District of potential FEMA grant applicable to the LBB dam. W.W. Wheeler hired to pull together grant application.

2020 - The application was completed and submitted to FEMA. In June the District was informed the LBB dam project was selected to receive a FEMA grant of $3.4 million.

August, RFP published for design and construction management. W.W. Wheeler and GEI were finalists; GEI's bid was about 30% lower as well as their estimate to build an RCC dam was over 10% less than Wheeler's projected costs. GEI was selected by the committee.

GEI began drilling into dam and damsite to determine optimal design. Xcel gas line near the west edge of the new dam layout had been prioritized for relocation. As GEI's work was progressing, Xcel shifted its position and told LMWD it to pay $450,000 to move the gas line which Xcel had routed dangerously close to the old dam. Instead design changes moved the dam position to allow sufficient space between the dam and the gas line. This reduced the capacity of LBB reservoir by about 7 acre feet and cost over $20K for design changes.

Plans were also being outlined to replace the outlet structure on Upper Beaver Brook Dam. The District desired to manage water releases more accurately and use a SCADA system to help automate some functions. A gate failure represented a significant risk to the newly improved reservoir.

In November the CWCB approved a $3.5 million dollar loan for the construction of the new LBB dam and the upgrades to the UBB outlet works and SCADA system.

2021 - The final design for the removal and replacement of the LBB dam was approved by the LMWD Board in January and the RFP was published February 3rd. 3 firms submitted bids.

March 18th Zak Dirt was awarded the contract at $5.3 million.

April, the reservoir was drained, and a "staging" area was levelled in the bottom of the reservoir area upstream from the construction site.

May through June, demolition of the old LBB dam took place. A 36" diversion pipe for the flow of Beaver Brook was installed. To provide water to the Water Treatment Plant during construction, an 8" heavy duty polyethylene (HDPE) pipe was installed along the west side of the reservoir, taking water from a small coffer dam upstream of the reservoir, down to the WTP.

RCC process test was done in July by Zak Dirt, forming and pouring the 4' deep, 16' by 24' slab. After curing, sections were cut for inspections and approved by LMWD, GEI and the Dam Safety Officer from the SEO.
September through December, Zak Dirt completed the excavation for the new dam, taking all usable material to the south end of the reservoir area. A rock crusher was brought in to break down the material to use in the RCC process.
Zak Dirt took the site down to competent bedrock and placed a conventional concrete level base. A drilling and grouting program was executed. Dental concrete was applied to areas of rock would touch the dam. From this base, RCC was placed in 12" lifts, up approximately 60 feet in total height. Forms were placed on the upstream side, allowing a 2' conventional concrete "face and top." Approximately 8,025 cubic yards of RCC comprised the rest of the dam.
2022 - January through April, a concrete base for the new outlet works was placed. A new conventional concrete spillway was formed and poured (enlarged considerably from the GEI design as directed by the SEO.) Several 4" pipes to provide conduit for the hydraulic control fluid tubes to the new outlet works were protected by a conventional concrete chase down the upstream face. The hydraulic power unit (HPU) building was constructed at the east end of the dam. The controls and measuring components of the SCADA system were installed.
After conventional concrete operations were completed for the dam, Zak Dirt built the concrete base structures for the LBB inlet and outlet flumes and the confluence flume below the North Fork entry into Beaver Brook. This was an addon to the original contract of $90,000.
The temporary diversion pipe was removed, and the natural flow of Beaver Brook was resumed. May 18, 2022 a final inspection by the SEO was conducted and the formal "commissioning" of the new Lower Beaver Brook dam took place. A slow, measured filling of the reservoir continued through May and June, with the temporary feed to the WTP finally removed in late June.
Zak Dirt de-mobilized in June and the Water Treatment Plant resumed more normal operations.
2023 – After the first fill of the LBB reservoir, seepage was closely monitored. Initially everything seemed fine, then high pH levels were detected downstream, and it was traced back to the dam seepage. GEI assured LMWD that this was normal with large new concrete structures and that the pH would soon return to normal as the concrete cured. The problem did not go away, so a defect was declared. LMWD believes the original man tunnel which was filled in with lightweight cement and contains the outlet pipes is being washed away slowly by seepage. The seepage is now treated with CO2, which allows us to bring pH levels down to about an 8-9 versus 12 without treatment. With dilution in Beaver Brook, the limited seepage at 8 to 9 pH has met Army Corp requirements downstream. We want permanent solutions. Talks continue with GEI and Zak Dirt, but this may end up in litigation.

Contractors on Lower Beaver Brook dam replacement:
Design and Construction Engineers – GEI
Main Contractor for dam construction, concrete work on 3 flumes – Zak Dirt, Inc
SCADA design and components, flume assembly – HydroLogik
Flume. WTP feed pump design – W2E
WTP feed pump construction – Canterbury Construction

Timeline for Upper Beaver Brook dam outlet improvements 2017- 2023

- During construction of the UBB spillway in 2017, the District was made aware of the deterioration of the dual outlet works. One valve was inoperable and the other was in danger of breaking at any time.
- State Engineers Office strongly recommended replacement of the outlet works, with an added requirement of "slip-lining" the 425 foot outlet pipe running under the dam.
- The RFP for engineering and management of the project was published with no responses. Personal requests for engineering quotes were made to W.W. Wheeler and GEI. Wheeler declined to submit, leaving only GEI with a bid of $127,759.
- Due to the complexity of the project, RFPs were sent to Global Diving in Seattle, Inland Marine in Denver and Marine Diving Solutions. After several site visits by all three, Global offered a "ballpark" estimate of $3,500,000; Inland Marine submitted a firm quote of $975,000 and MDS a bid of $1,315,000. MDS was selected due to their experience and success with similar projects.
- September 19, 2022 - A kick-off meeting with MDS, GEI, SEO (dam safety) and LMWD (owner) was held at GEI headquarters. A construction schedule of May 15, 2023 to September 1, 2023 was submitted by MDS. The key agenda item was the lead-time required for the gate valve to meet LMWD requirements - estimated to be six months.
- Mobilization took place in May 2023. Work plan was as follows;
    - Assemble barge with equipment.
    - MDS divers locate and mark existing intake structure with rope and buoy.
    - Install silt curtain around the intake structure and other pollution prevention BMPs.
    - Moor barge over intake structure.
    - Remove vegetation around the outlet, the existing trash rack, and sediment around intake structure.
    - Install HDPE pulling head, re-direct pulley, and associated temporary facilities.
    - Slip line the existing outlet works conduit with HDPE pipe and grout the annulus. Installation of the 425 foot 15" I. D. HDPE pipe was completed in June.
    - Install bulkhead with valve at the downstream end to the grouted HDPE pipe.
    - Demolish the existing outlet works intake structure and tee. (Ended up leaving concrete base using it to mount the new modified structure.)
    - Excavate accumulated silt and prepare to alter intake structure for new design.
    - Underwater concrete forming and placement via tremie.
    - Install the outlet works control building, solar panels, and electrical systems.
    - Perform and install modifications on original concrete intake structure base, joints, and other couplings.
    - Install hydraulic lines, carrier tubes, and vent piping; tie hydraulic lines into HPU.
    - Install new trash rack.
    - Test the new gate. Gate was not received until November 2023. Returned to perform that test and installation.
    - Disassemble barge and remove temporary facilities; restore the site and demobilize. This work was done by the end of August 2023.
    - The SEO dam safety officer signed off with a final inspection in November.

Details on Delays - Based on work done by Inland Marine inspecting the intake structure years earlier for GEI and GEI's plans, MDS ordered an intake vault and gate valve for the project. MDS's own measurements of the existing concrete structure found it to be much larger than anticipated, plans to use the vault changed. The existing structure was too large to demolish, so it was used as the base of the new outlet structure. This resulted in a change order of $80,603, bringing the total construction cost to $1,395,603.

Review of operational requirements for the gate also found the specified gate to be oversized and would not meeting the District's requirements. Both these events impacted cost and delayed the completion of the project. The new gate valve did not arrive as promised in the summer of 2022, but was finally delivered in November 2023 and installed before winter freeze.

Contractors Upper Beaver Brook outlet pipe lining, gate replacement and SCADA system:

Design and Construction Engineers – GEI
Main Contractor for relining outlet pipe and replacing gate – Marine Diving Solutions
Subcontractor for outlet pipe slip lining – United Pipeline
SCADA design and components, install of HPU – HydroLogik
SCADA programming – Mountain Peaks
Development of Water Management Plan – Momentum Engineering, Martin & Woods

Financial Results

Lower and Upper Beaver Brook Improvements Project

	Budgeted	**Actual**
LBB dam and reservoir design Costs already incurred prior to loan	$600,000	$601,042
Lower Beaver Brook dam replacement	$6,748,000	$6,239,136
Construction Management on dam	$600,000	$601,827
Tank and Pump intake system for WTP	$200,000	$259,051
Relining of UBB outlet pipe, gate replacement	$600,000	$1,727,857
SCADA system design, install and integrate	$150,000	$96,359
Total	$8,298,000	$8,924,230
Four New flumes not initially budgeted		$154,430
Project Totals	$8,298,000	$9,078,660
FEMA Grant total	$4,437,500	$4,402,350
CWCB Loan Totals	$3,500,000	$3,320,712
Grant from State for UBB SCADA portion		$150,000
Paid from reserves over past 5 years		$1,205,598

These costs include amounts incurred for District Engineer's time and other non-budgeted costs. LMWD anticipated these costs would be covered through yearly cash flow and reserves. LMWD debt service payments dropping off provided additional cash flow to complete project.

Two items pushed the capitalized costs higher, the unbudgeted replacement and upgrade of the 4 flumes, of which 3 were done while the expert concrete contractor was on site. This saved money in the long run. Overall, the savings from Zak Dirt's bid on the RCC dam allowed the District to deal with the higher costs on the UBB outlet works.

In the spring of 2024, the 4th flume was built, and the final SCADA instruments were integrated into the system. Programming and fine tuning continues, but the system is working with operator interaction.

The lining of the outlet pipe and gate replacement bids were beyond our expectations, some unexpected issues also increased the costs beyond the bids. Though we have learned from this experience, we know the final product will serve the district well for many years.

In addition to having eliminated a great deal of the risk posed by the old Lower Beaver Brook dam, LMWD now has two very functional reservoirs, a water management plan and a SCADA system to maximize the water generated under our water rights. Through much of 2024, Upper Beaver Brook reservoir was spilling, meaning it was holding near 400 acre feet of water. This spring was the first time that had happened since the reservoir was expanded in 2017. We hope our systems will help make that a more common occurrence.

Thank you to the CWCB for its support and patience with LMWD during the multiple phases of this project. This would not have gotten done without your help.

Best regards,

Kyle J. Schroeder
Treasurer
Lookout Mountain Water District

Attachments: pdf photos

Original spillway LBB dam

LBB Dam prior to demolition

Outlet Pipe from man tunnel

Temporary feed for WTP so reservoir can be drained

Demolition of LBB Dam

Wood timbers and concrete from 1903 construction

Working to dry out sediment

Find solid rock to interface with new dam

Bypass pipe to carry flow of Beaver Brook through site

Original outlet and WTP plant pipe in man tunnel

Original 1903 reservoir outlet, pipe with cement in a barrel

The xcel high pressure gas line running through the job site

Prep work to the dam site took about 2 months

Rock crusher arrives

Many Zac workers cleaning and grouting by hand

Starting 2nd pour of leveling floor for dam

Grout curtain drilling

Establishing position of concrete headwall that ties into new dam

Drilling holes and injecting grout

Testing grout mix

Rock crusher on site making RCC materal from old dam rubble

RCC batch plant on site

RCC test patch is laid and rolled to compact it

Dental concrete is laid all rock face for dam to seal

Dental Concrete being spread

Another pour of leveling concrete

Test patch is cut to be eveluated by engineers, it was good to go

Work in the man tunnel

Dental concrete on outer upper edges of dam site

First placement of RCC underway

Outer downstream edge will carry this set angle

Conventional concrete face is placed with each lift

Conventional concrete being pumped into place while RCC rolled

Each lift need considerable finish work

Ramp keeps getting steeper

Additional shifts for RCC lifts allowed Zac to push ahead of schedule

Last RCC lift getting finishing work

Rebar for conventional concrete cap

Concrete cap went on in layers

Working to fill and seal the man tunnel

Bed is laid on downstream face for rip rap to be placed

Dean Snyder watching conventional concrete final levels being placed

Upstream forms start to come down

Outlet base getting ready to be poured

New outlet pipes in man tunnel

New spillway being finished

New Beaver Brook confluence flume

Man tunnel being inspected

New Lower Beaver Brook inlet flume

New Lower Beaver Brook dam before first fill

New trash rack over outlet valves

Lower Beaver Brook dam, outlet flume being worked on by HydroLogik

Remaining photos are from Upper Beaver Brook Outlet works. They were taken by GEI and provided in weekly reports.

Weekly Photographs:

Photo 1: Excavator staged at dam toe

Photo 2: Fill material placed along access road to provide more even travel surface.

Photo 3: Completed clearing / grubbing near outlet.

Photo 4: Reservoir level has been draw down below spillway crest elevation due to operation of the outlet works.

Photo 5: Bypass hoses setup along spillway.

Photo 6: 6-inch trash pump setup with inline flow meter.

Photo 7: McElroy 18” HDPE fusion machine staged on-site.

Photo 8: HDPE staged at dam crest.

Photo 9: Crawler-carrier delivered on-site for equipment transport between dam crest and toe.

Photo 10: Loading crawler-carrier with HDPE fusion equipment.

Photo 11: HDPE pushing machine staged near access gate.

Photo 12: Outlet closed in preparation for conduit jetting / sliplining operations.

Photo 13: Site layout for HDPE fusion operations. Excavator on left is used to transport HDPE sections to the work area, excavator on left is used to pull HDPE string back as sections are fused.

Photo 14: Hydraulic press used to perform reverse back-bend test on HDPE test weld.

Photos 15 & 16: Performing reverse back bend test. Hydraulic press used to bend HDPE test section to 120°.

Photo 17: Result of reverse back bend test. Weld is shown to be intact and free of defects. Test was performed on four separate test sections with same result.

Photo 18: MDS deconstructing v-notch weir to drain outlet structure and facilitate conduit access.

Photo 19: V-notch weir removed at outlet.

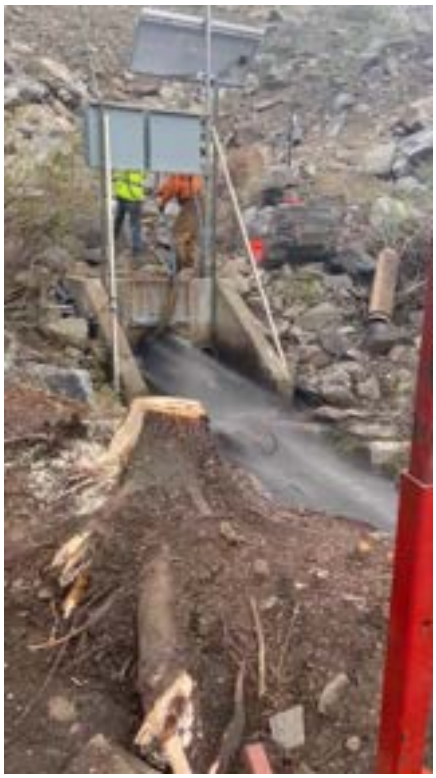
Photo 20: Excavator transfering HDPE section to prep for fusion.

Photo 21: HDPE sections in place for surfacing/fusion

Photo 21: Pipe surfacing and welding performed using McElroy 18” HDPE Fusion Machine.

Photo 23: Downstream end has temporary cap to allow pressure testing upon completion of welding.

Photo 24: Vac truck used to collect water for jetting operations. 600-ft hose reel is affixed to front of vac truck.



Photos 25 & 26: Jetting outlet works conduit. Multiple passes were made until debris and dirty water were no longer observed to be discharging from conduit.

Photos 27 & 28: Lime scaling, corroded iron, and water with high suspended solids observed during jetting.

Photo 29: 80-ft string of fused 18” HDPE.

Weekly Photographs:

6/28/2023 - Grouting

Photo 1: Downstream bulkhead and grout injection / vent pipe assembly.

Photo 2: Downstream bulkhead anchoring and sealing.

Photos 11: Downstream pressure gauge and flow control.

Photo 12: Grout pour into concrete hopper. Some doughballs observed in mix, as shown on strainer.

Photo 13: Grout hose connected to grout injection pipe.

Photo 14: Grout return observed at 25% and 50% pipe lengths. Grout return also observed at 75% pipe length (not shown).

Photo 15: Partial grout return observed at 100% vent pipe lengths, as indicated by dried grout collected in pipe valve.

Photo 16: Contractor performing final line cleanout following completion of grouting.

6/29/2023-6/30/2023 – Barge Setup

Photo 1: Barge setup and launch area. Crane staged for transferring barge segments to launch area.

Photo 2: Hyperbaric chamber and boat staged at laydown area.

Photo 3: Truck turnaround area near launch site.

Photo 4: Barge segments being delivered to site.

Photo 5: Crane picking Flexifloat barge segment from delivery truck.

Photo 5: Transferring Flexifloat barge segment.

Photo 6: Placing Flexifloat barge segment at launch area.

Photo 7: Contractor working on assembly of barge segments.

Weekly Photographs:

Diving and Demolition

Photo 1: One of two 4'x4' steel plates placed against downstream headwall to brace hydraulic ram and push of tee at bell and spigot.

Photo 2: HSS section placed between steel plate and hydraulic ram.

Photo 3: Hydraulic pump and ram with 2-inch stroke.

Photo 4: Hydraulic rams with 6-inch stroke

Photo 4: Existing equipment fully removed from HPU building pad.

Photo 5: Water free flowing through grout vent pipes (approx 95% of pipe length) indicating grout is not placed up to the crown of the pipe at the full length.

Photo 6: Temporary valve placed on downstream end of pipe.

Photo 7: Diving operations continue.

Photo 8: Left side of tee broken off and removed from structure.

Photo 9: Left side of tee broken off and removed from structure.

Photo 10: Condition of left-side gate.

Photo 11: Grout placement within tee (approximately 50% full).

Photo 12: Right side of tee and gate broken off and removed from structure.