Colorado Division of Water Resources
State Engineers Office
Dam Safety Branch

COLORADO
Division of Water Resources
Department of Natural Resources

MEMORANDUM

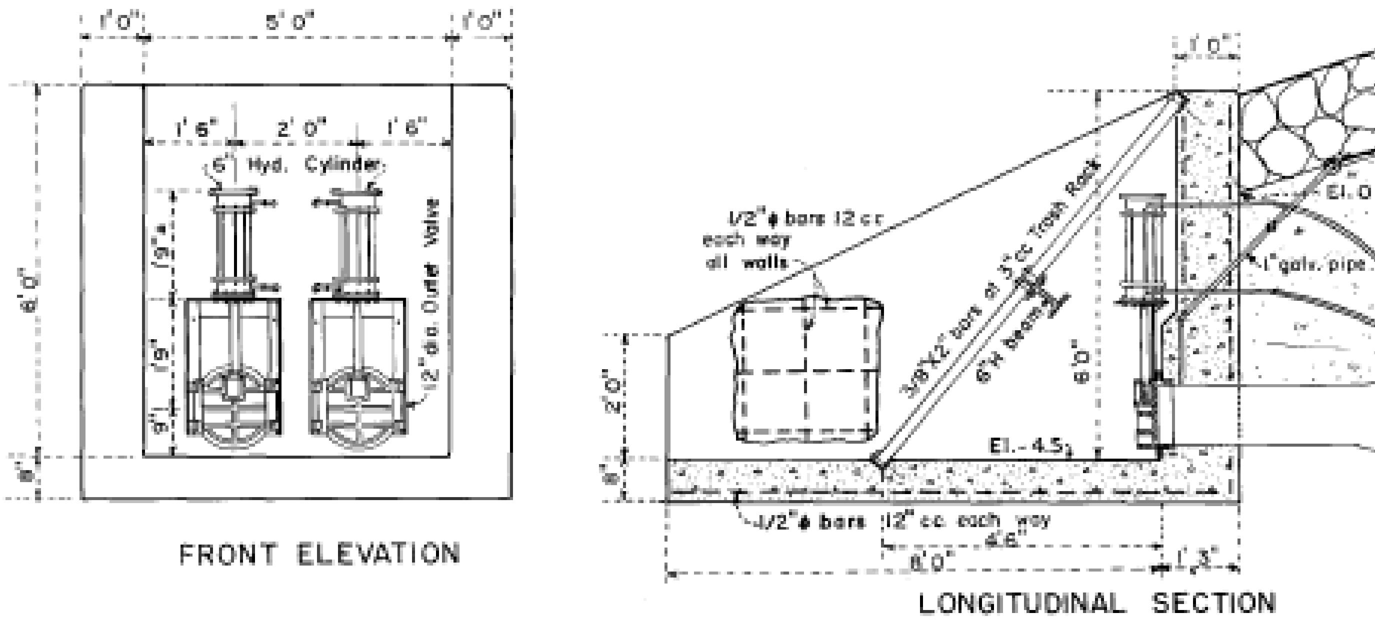
To:	Randi Kim, Mark Ritterbush and Slade Connell - City of Grand Junction
CC:	Jason Ward - Design Review Engineer
	John Hunyadi - Chief, Dam Safety Branch
From:	Jackie Blumberg - Dam Safety Engineer
Date:	March 20, 2023
Dam Name:	Juniata
DAMID:	420128
Subject:	Low Level Outlet File Review

Juniata Dam is a high hazard structure located at 38.967457° latitude, -108.285497° longitude in Mesa County, Colorado. The dam was constructed circa 1940 and subsequently enlarged in 1954 and 1978. Additional construction affecting the outlet occurred in 1987, followed by minor projects in 2002, 2019 and 2021. The low level outlet is known to be a bifurcated system, equipped with two identical upstream gates. The dam is presently 98-feet high and stores 7281 acre-feet at the spillway crest. Recent attempts to inspect the low level outlet have revealed a leak into the conduit, prohibiting rover entry and meaningful video capture. The source of the leak is unknown but it is posited to be originating from the upstream end. This memorandum presents a summary of the low level outlet following review of the digital archive with the intent to aid future inspection and discussion.

Below is a summary of construction efforts as they pertain to the low level outlet:

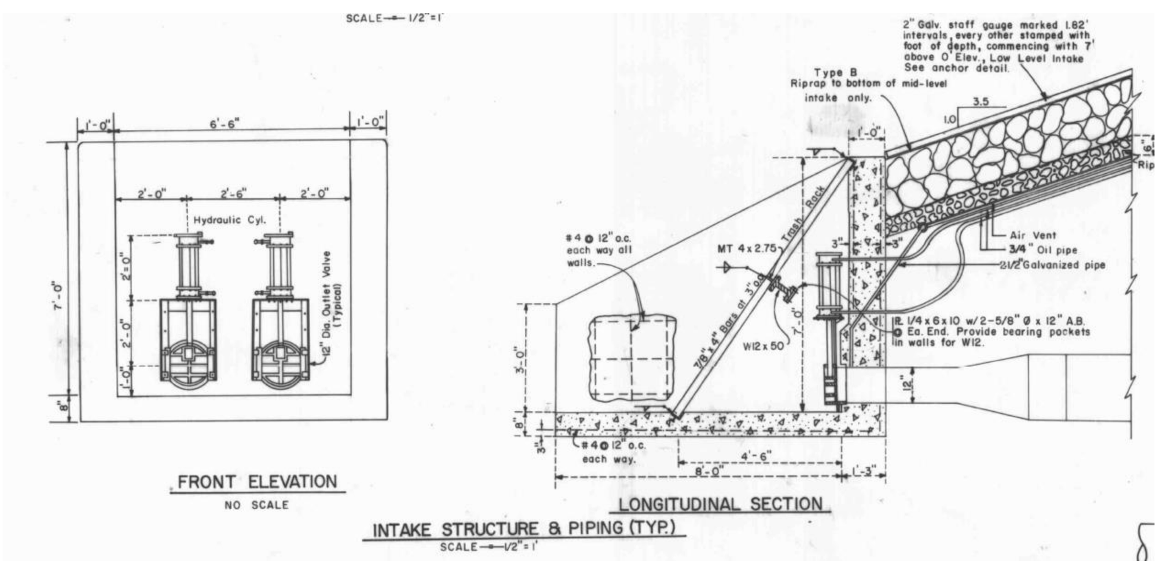
1. **1940** original construction (no C#, no construction documents) – low level outlet comprised of 10-inch dia. VCP
2. **1954** first raise (C-0661) – VCP plugged, abandoned, and replaced with 24-inch dia. CMP (asbestos bonded). The plans show the control house at the downstream toe.
3. **1978** second raise (C-0661A) – pipe was lined with cement mortar (reducing ID to 22-inch) and extended on upstream and downstream ends with 24-inch dia. bell and spigot RCP. Control moves to the crest.
4. **1986** internal inspection – conducted by City of Grand Junction revealed cracking and deterioration of upstream extension, resulting in a recommendation to slipline the pipe with steel or HDPE
5. **1987** North Fork diversion and outlet lining (C-0661B, completion report only addresses diversion, as-constructed plans show lining) – low and mid-level outlets are lined with HDPE. Existing concrete intake structure to remain in place
6. **1990** correspondence discusses known leak from the low level outlet and leakage from the hydraulic system that controls the low level gates. Installing a butterfly valve on the downstream end is proposed, acknowledging the measure as being temporary until the upstream issues can be investigated further and addressed.
7. **2002** bypass and outlet reconfiguration above stilling basin(C-0661C) – work is performed primarily on the downstream end and/or specific to the mid-level outlet
8. **2019** new trash rack installed under [2007] Rule 12 (Maintenance)
9. **2021** outlet valves replaced under [2020] Rule 11 (Maintenance) with 12-inch VSI Waterworks gates equipped with hydraulic actuators – divers observe valves open & close.

1954 intake details show air vent connection to conduit is encased by the concrete headwall.

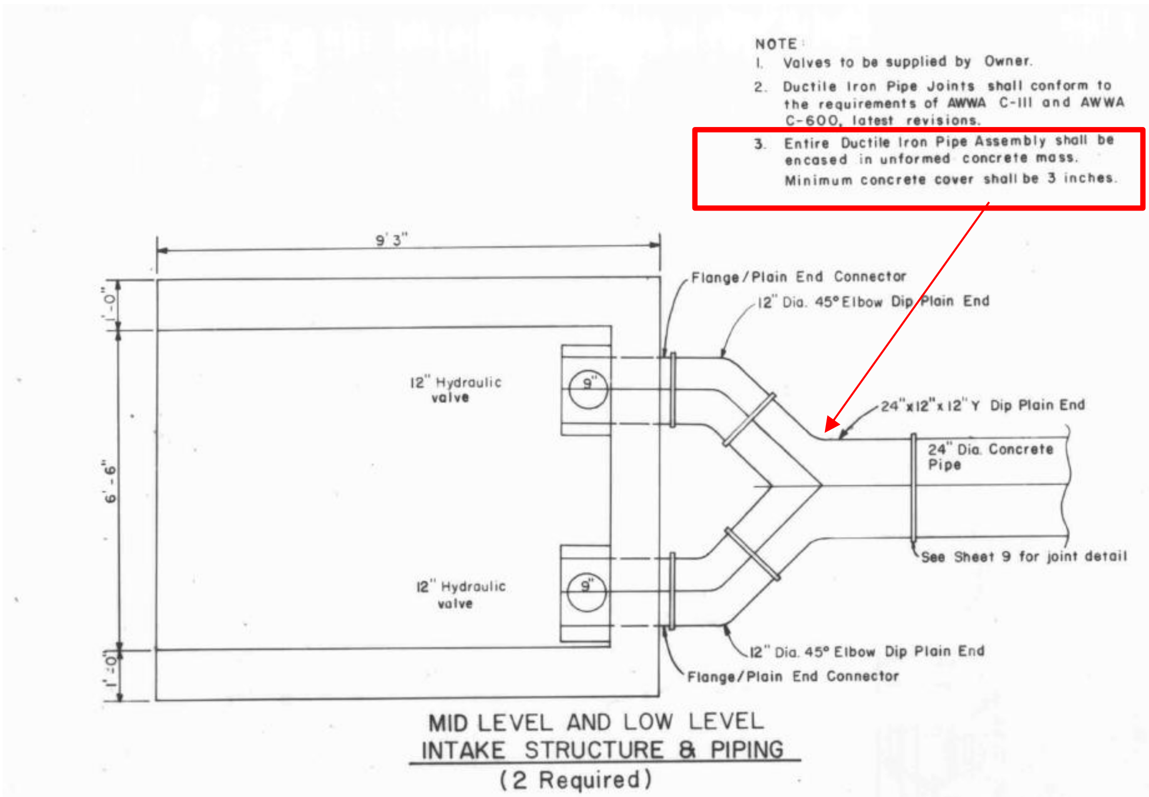


OUTLET VALVES
Scale 1/2" = 1'

1978 raise shows a nearly identical intake detail, one where the air vent connection to the conduit is encased by the concrete headwall. The plans show the 24-inch dia. bell and spigot RCP transitioning to 12-inch ductile iron (the original bifurcated inlet and gates). Although the detail is nearly identical, <u>the intake structure is entirely rebuilt to accommodate the second dam raise and attendant outlet extension.</u>



The existing CMP segment remains in place and is extended by RCP at upstream (195-feet) and downstream ends (160-feet). Notes on plans state, “Existing CMP to be excavated to first joint, cleaned, banded and extended to the limits noted with RCP”. The plans also show the ductile iron bifurcated intake to be encased in unformed concrete.



Review process internal comments expressed concern over using a cement liner for the low level outlet CSP, citing lower structural integrity. However, since the decision was made to allow the CSP to remain in place and if the pipe was not expected to corrode, the ability to resist the load applied by overburden would be acceptable. Last, it was stated that the lining would reduce potential for corrosion from the inside and add to structural strength.

Review comments recommend against steel pipe [CMP] within earthen embankments due to deterioration leading to pipe failure or collapse, concluding with the recommendation to line the existing steel pipe [CMP] with HDPE (or other suitable plastic pipe).

Response to comments indicated a change from CMP [CSP] to RCP, plus the addition of an alternate bid item to provide additional protection for the existing CMP in the event it was discovered that the pipe was structurally inadequate during video inspection prior to construction.

The plans note: “Prior to mortar lining, the Contractor shall inspect the existing CSP in order to locate holes in the CSP and voids under and around the CSP which have been caused by deterioration of the CSP. The Contractor shall fill all existing voids under and around the bottom of the CSP with cement mortar.” The length of CMP [CSP] exposed for Contractor evaluation is unclear. However, a subsequent video inspection conducted in 1986 stated that in 1978, the 24-inch CMP was “lined with cement mortar which reduced the diameter to 22-inches”.

Construction inspection on April 17, 1979 revealed pockets associated with the grouted beam at the intake for both upper and lower level gates. The Contractor indicated the pocket was due to soil within the forms and not poor quality concrete.

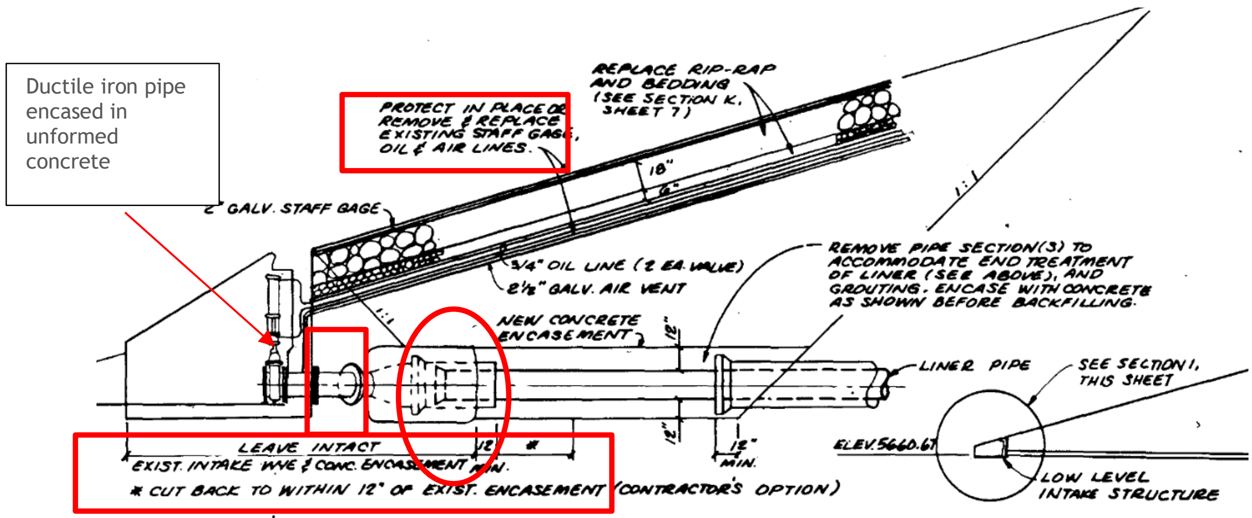
LOW LEVEL GATES
↙ POCKET CAUSED BY DIRT IN FORMS

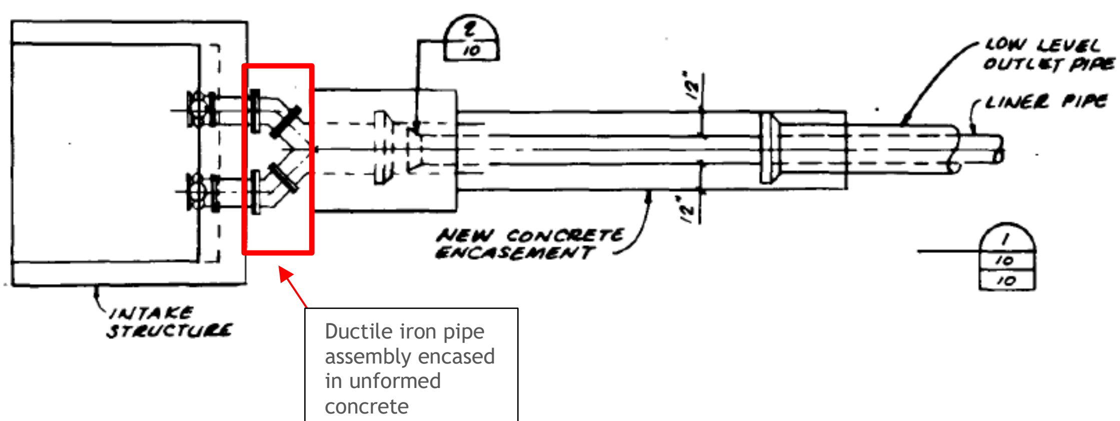
POORLY GROUTED BEAM POCKET
ON UPPER LEVEL INTAKE.

An inspection was conducted on September 26, 1979 by request due to leakage observed above the downstream end of the outlet (whether upper or lower is unclear). It was posited that the leakage was due to a damaged joint.

Comments for the 1987 work included concern over grout pumping pressures, “Can this be a problem for cracked pipe? The possibility for crushing the liner pipe is only half the problem. I believe the proposed pressure is too high”.

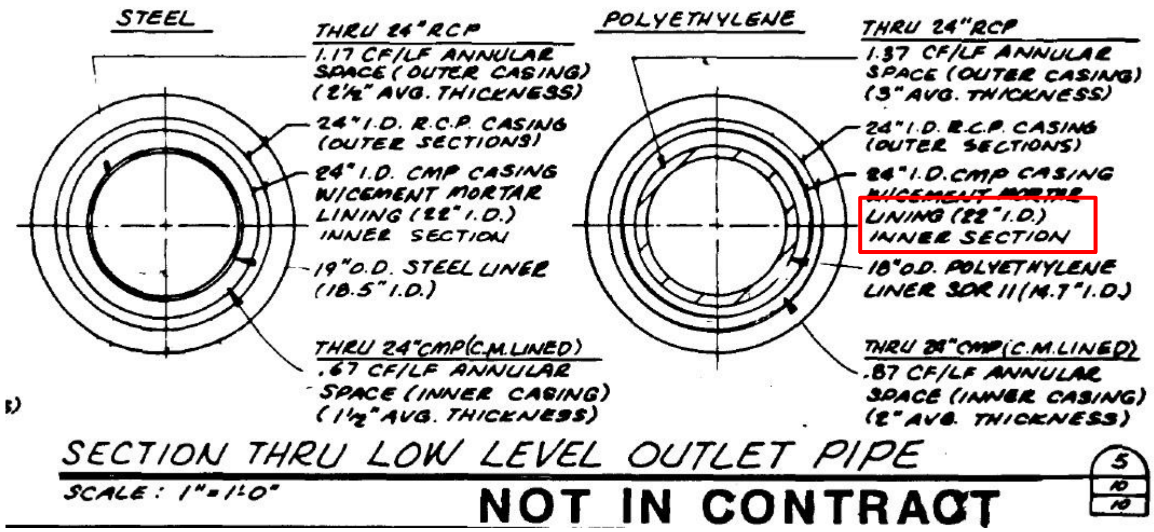
1987 details are shown below for the HDPE sliplining work. The existing concrete headwall at the intake to remain in place. Ductile iron bifurcated segment (encased in unformed concrete) also to remain in place. Refer to end of this memorandum for 1986 video inspection discussion that prompted the work. Structural calculations showing load resistance were provided.

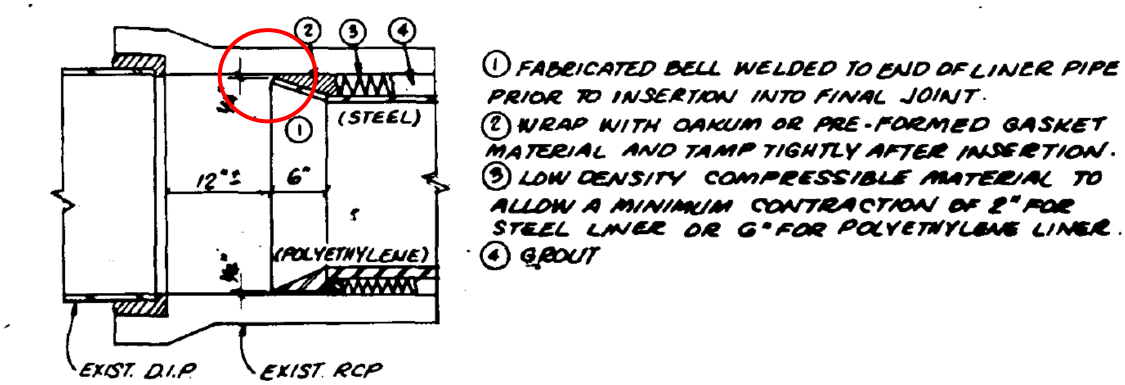




INTAKE STRUCTURE PLAN
SCALE: 1/4" = 1'-0"

Below shows the section view for pipe lining. Ultimately, HDPE was selected as the liner pipe that would be pulled through the host pipe and the annular space grouted. Based on construction drawings, the segment through the longitudinal center of the dam would be comprised of (extending outward from center): HDPE (14.7-inch ID/18-inch OD), grout, cement mortar (22-inch ID), CMP (24-inch) with asbestos coating (assuming host pipe is intact). The extended end segments would be: HDPE (18-inch ID), grout, RCP (24-inch), discrete concrete encasement at ends (appears as 48-inch OD on plans, assuming host pipe is intact).





Specifications state, “Grout shall be injected by means of multiple grout tubes, permanently anchored to either the casing pipe or the liner pipe and grouted in place or a single grout tube to be withdrawn progressively as grout is injected.” According to phone records, 2-inch diameter lines were proposed for the low-level outlet. Specifications also require Type III HDPE, grade p34 as defined by (now obsolete) ASTM D-1248 (Driscoplex 1000 or equivalent) with SDR of 11 (indicating a wall thickness of 1.65-inches).

Phone conversation records indicate the challenge in not only pulling the liner pipe through, but installing “a grout line into the CM lined portion of the low-level outlet”. Correspondence from April 2, 1987 indicates ID found to be as low as 20-inch in some CMP and mortar segments, resulting in minimal annular space attained in those areas. Timing for grout pumping of low level was documented on April 22, 1987.

1986 video inspection report concluded sliplining would be needed, particularly for the upstream RCP extension which had cracked – the driver for the 1987 lining work

No seepage was observed entering the downstream extension through any of the exposed joints and/or circumferential cracks. However, since about 1 inch of water was flowing in the pipe invert, detection of seepage there would have been difficult. (Nearly all of this water entered through two cracks in the crown of the pipe near the upstream face of the embankment - discussion later.)

3. Upstream RCP extension. - The condition of the pipe sections and joints in the upstream extension is generally similar to the downstream extension, with two exceptions:

a. Several thin diagonal cracks were observed in the haunches of the RCP pipe near the connection with the CMP (in addition to the circumferential cracking mentioned previously).

b. The entire extension was wet, with water entering through any structural flaws. The upstream extension passes through saturated fill under hydrostatic pressure.

Two 1/8-inch-wide (estimated) circumferential cracks are present in the extension (from spring line to spring line) about 50 feet downstream from the intake structure. One crack is about 14 inches downstream from a pipe joint and the other is about 12 inches upstream from the same joint. About 2 gal/min of seepage was entering the pipe through the cracks. A total flow of 2-1/2 gal/min was measured at the downstream end of the outlet. The chemistry of the seepage, including sulfate content, is unknown.

Most of the seepage dropped into the outlet pipe from the crown, where the cracks are widest (photo 2); however, some seepage was also spraying across the pipe in fine streams emerging from the haunches, where the cracks are thinnest. The head of water on the pipe was about 70 feet. Although the seepage inflow appeared to be clear, the cracks in the upstream extension, in conjunction with the external hydrostatic pressure, appear to offer a present potential for embankment fill to "pipe" into the conduit. Also, the cracks allow water and air to contact the pipe reinforcement, which can cause the reinforcement to rust and deteriorate.

Because the conduit cracks are close to the upstream face, any piping through them should remove only a relatively small quantity of fill; and based upon existing reservoir conditions, complete breaching of the dam would not be expected.

1990 upstream outlet valve leakage leads to placement of butterfly valve on d/s end – it is deemed as a "temporary measure" in light of problems being on the u/s end (resolved in 2021 see further below)

As you are aware the lower level outlet on Juniata Reservoir continues to leak at the approximate rate of .28 cfs. A leak has also developed in the hydraulic system that controls the low level discharge gates. In light of this situation we are proposing to install a butterfly valve on the discharge end of the lower level outlet to control flow in the case of an emergency and also to control flow through the lower level until the gate leakage and the hydraulic problem can be remedied.

We have reviewed your plan to install a butterfly valve on the downstream end of the low level outlet. We understand the remedial action is a temporary measure until the problems with the upstream hydraulic valve can be investigated and necessary repairs performed.

Because the outlet pipe has been relined and pressure tested, the use of a downstream valve would not appear to create a loading the system cannot withstand; therefore, we hereby approve your proposal. The upstream valve should be placed in a full open position once the downstream valve is operational. This will provide means to make releases through the low level outlet without the concern that the upstream valve may completely cease to function.

The low-level and mid-level outlets had been lined with high density polyethylene pipe prior to this project. The reconfigured outlet works are connected to the HDPE by use of Smith Blair stainless steel couplings that incorporate internal stiffeners enabling connection to the new C-905 PVC pipe and DI fittings. The new valves and connections to the existing HDPE are located within two concrete vaults that allows for annual inspection of the connections, and easy access for future maintenance as needed.

2002 excavation pictures revealed that the crown of the RCP was indeed broken in some places.

Marine Diving Solutions (MDS) provided a marked-up/redlined copy of the C-0661A plans with notes about hydraulic line housing and gate dimensions when the repairs to the hydraulic lines/replacement of the gates were made under Rule 11 Maintenance. MDS informed the City that video inspection of the low-level outlet could not be achieved due to flows entering the conduit with the upstream gate closed. MDS attributed the leakage to a broken air vent.

An excerpt from an email from MDS to the City describes the conditions encountered when replacing the hydraulic lines, installing housing and setting up to replace the valves (shown below). Highlight emphasis placed on discussion of broken air vent repair. It should be noted the repair discussed within the email was made to the mid-level vent.

From: Ian Stephens <ian@marinedivingsolutions.com>
Sent: Sunday, October 10, 2021 11:15 AM
To: Lee Cooper <leec@gjcity.org>
Subject: Juniata Progress for Week Oct 4th-8th and Look Ahead for Week Oct 11th-15th

Hi Lee,

I wanted to give you an update on what we completed for this past week, and also a look ahead for this coming week.

For the week of October 4th to the 8th, MDS was able to mobilize our staff and equipment to the job site. We started by opening up the rip rap and soil part of the dams embankment with an excavator. We noticed that the existing hydraulic lines were scattered throughout our dig and that they did not match the existing drawings. With the lines encountered, we ended up having our hole for the new encasement pipes being anywhere from 4' to 1' from the existing rip rap elevation. We noted that we should bring in approximately 1 to 2 yards of soil (class 6) to cover the encasement pipes in areas and also bring in 6 yards of rip rap (natural rock) approximately 18" diameter to fill in low spots where the encasement pipe will be. Once we dug the hole, we dove and marked the mid intake structure. The team then fed the new encasement pipe to the mid location. Once the mid was sent, the team then dove and marked the lower intake structure and fed and sent the encasement pipe to that location. The team noted that at both the mid and lower structures, there was significant sized boulders just upstream of each structure. With that notation, the team decided to terminate each encasement pipe approximately 2' from the left side wing wall and position the pipe on mid center of the head wall (this will be noted on our final as-builts once we are finished for the City's records). The team then ended by drilling and setting 2 all thread anchors on each head wall that will have unistrut and pipe clamps on them to hold the encasement pipe. The studs are Hilti epoxy in and take approximately 24 hours to cure. The team also set a 3'X3'X1'thick pad of concrete at the current mid location in the embankment of the dam. The pad will be used to set clamps in it that will secure the encasement pipe at the upper elevation during normal water levels. Our welder Evan, was also able to expose the vent pipe that was broken and weld it back together. This was the completion of week one of the project.

A site visit was conducted on November 28, 2022, to determine if the low level conduit could be video inspected with the pipe conveying water. The DSE and City staff decided it would not be feasible due to the volume of water exiting the pipe. The pipe conveyed a notable flow of clear water (image below). Sediments from within the impact basin mixed with flows exiting the pipe, causing the basin water to be visually cloudy, but flows exiting the pipe were noted to be clear. The DSE and City staff observed that the volumetric flow rate exiting the low level conduit appeared greater than would be expected from a 2.5-inch diameter air vent. Reservoir storage was high as pressure reservoirs from on top of the Grand Mesa were released into Juniata for the winter. However, a staff gauge reading was not collected the day of the site visit.

The City of Grand Junction provided diver audio from the August 18, 2022 post-installation inspection dive following valve replacement in 2021. A rough transcribing of the audio is as follows:

- Diver feels entire valve with his fingers - 360-degrees, confirms valve is shut…no jams, no ripping of the seals, no flow

- Diver feels the flange/outside, notes sediments on concrete, feels backside of flange…nothing

- At 1:44 diver asks are there any other holes in the headwall? Terrestrial crew responds there is only the air vent. Diver asks, is that the air vent I am hearing? Diver states there is no gushing, only a “water hum”. It is not coming from the gate, the seal or the flange. After discussion with terrestrial crew, diver states, “that is probably what I hear, I’ve touched the gates all over.” Diver encounters silt, but no debris. Hoses feel good. Diver thinks it’s the vent pipe, “It makes sense, the way they’ve been opening the gates.” Diver wants to weed out the sound he is hearing, doesn’t think it’s a leak, thinks it’s the vent pipe.

- Terrestrial crew informs diver that the vent pipe is located on the backside of the valve, 6-inches away and encased in concrete. Diver reconfirms the above, states the first diver of the day confirmed feeling no leaks. Diver reiterates he has felt the valves all over. Everything feels new, the bolt to the blind flange is checked and the hardware is tight. The valve is 100% closed. Sediment accumulation is 2- to 3-inches of fluffy material. No foreign objects or debris encountered. No pulling sensation through the valve.

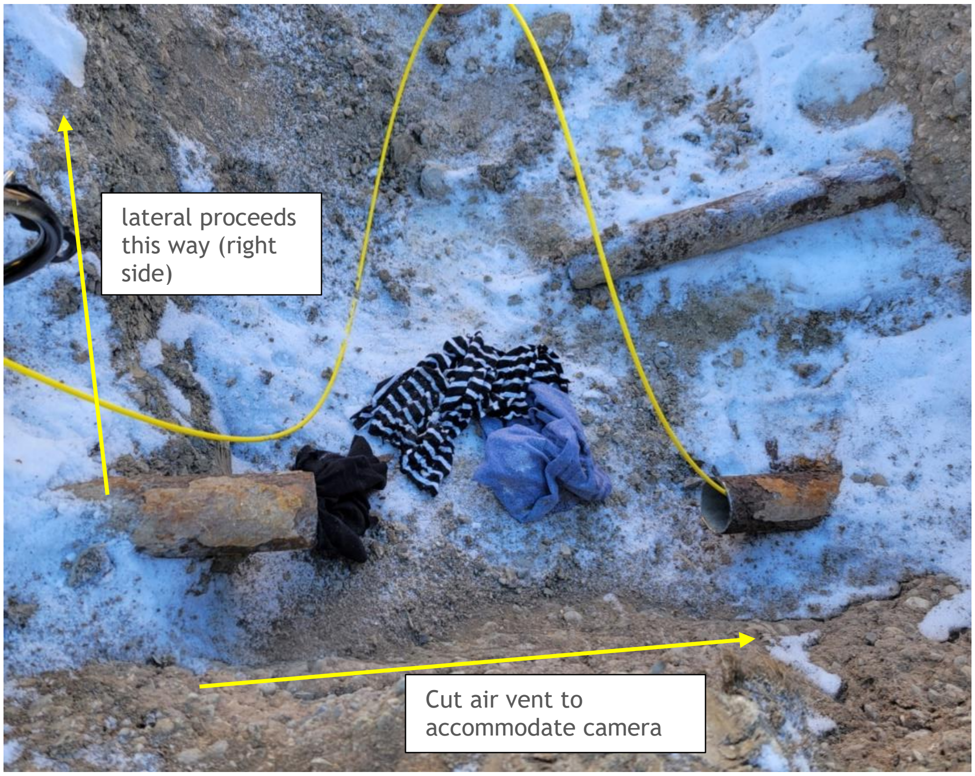
After review of digital archive and considering observations from the November 28, 2022 site visit and the diver audio, leakage into/from the pipe may be attributed to the following:

- High likelihood (Strong Confidence) - Broken air vent - penetration/connection to the conduit is encased and 2.5-inch dia. air vent is covered by about 2-feet of soil running up the slope.
- Moderate Likelihood (Low Confidence) - Defect at the upstream grouted/bell connection (identified by red circle on page 6 profile view) coupled with degradation of host RCP bell. This PFM requires two defects to occur.
- Low Likelihood (Strong Confidence) - Upstream valve leakage. See discussion directly above and below following two independent dive inspections.
- Not Evaluated - Internal pressure damage to the pipe resulting from water hammer following rapid closure of downstream butterfly valve – leakage appeared prior to installation of butterfly valve on downstream end.
- Low-likelihood (Strong Confidence) - Structural defect in HDPE where host pipe no longer exists, allowing a direct open path into/through the HDPE liner pipe defect. **Structural calculations show resistance to wall crushing and wall buckling[1] for maximum water or soil loading condition.** Joint damage from pulling liner through was evaluated on April 2, 1987 correspondence. It appears a nose cone pulling head may have been used to pull the liner pipe.

On December 19, 2022, the City scheduled a dive inspection to be conducted by Potable Divers, including camera entry into the low-level air vent and dive inspection of the upstream intake structure. The downstream valve was opened during the inspection and City staff estimated (by weir) the outflow from the low-level outlet as 466 gpm (0.96 cfs).

The City located and cut the low-level air vent just below a 90-degree lateral on the crest of the dam, on the reservoir side of the control shed, to accommodate the small camera. City staff stated the air vent alignment contained at least four, and possibly up to six 90-degree bends. The camera encountered water within the vent pipe at about the same level as the reservoir, indicating a break. Further, the camera revealed minor deposition but otherwise acceptable condition of pipe and joints until it reached a 90-degree that it could not surmount at about 150-feet. The downstream valve had been open for about an hour before the camera inspection and the City staff were surprised the air vent had not drained.

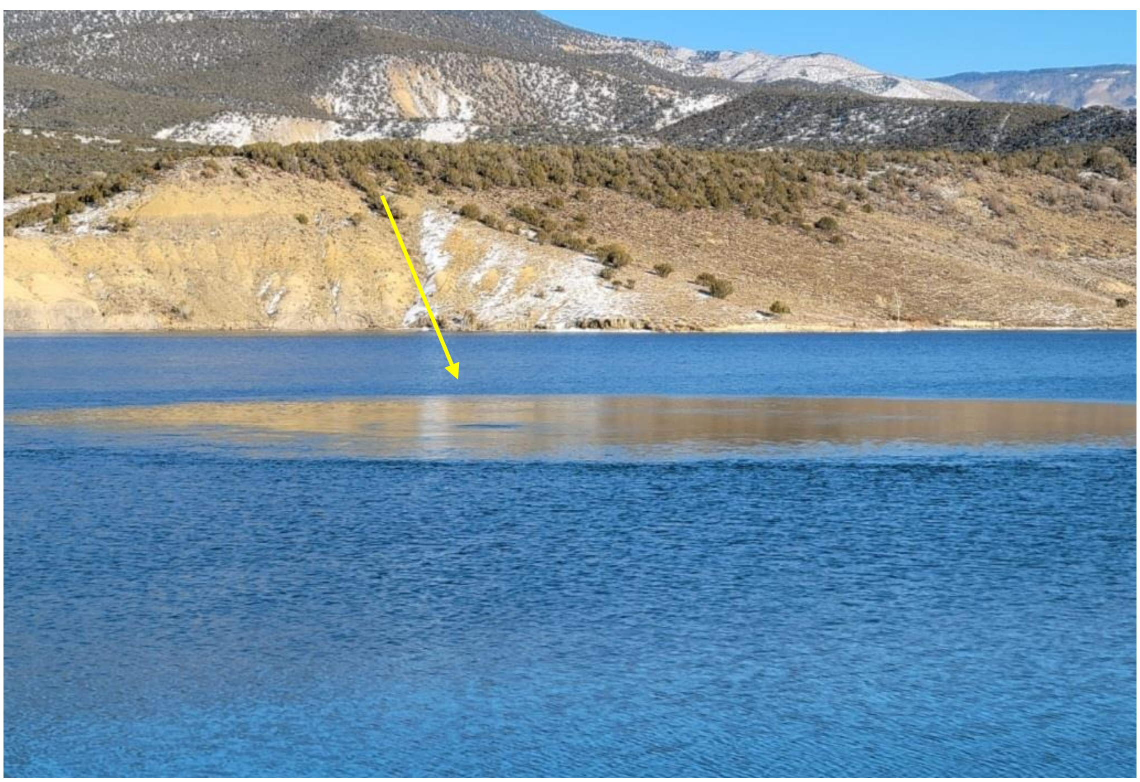
[1] Driscoplex 1000 allowable stress rating (HDB) of 1600 psi (Driscoplex data sheet), compared to a calculated maximum allowable compressive stress of 204 psi (water) and 371 psi (soil); buckling calculations show 404-foot allowable column of water or 641 allowable column of soil (compared to dimensions shown for maximum reservoir cover at the upstream end and maximum soil cover in line with the crest). Calculations assume SDR of 11 (provided in specifications). Reference for equations: Plastic Pipe Design Manual by Vylon Pipe.



The City also tested the integrity of a butterfly valve that joined the mid- and low-level outlets just upstream from the downstream valve. The City typically sends water via the mid-level valve to the City of Grand Junction. City staff temporarily closed the mid-level upstream valve, cutting the flow to town. The discharge rate at the downstream end did not appear to change, indicating that the butterfly valve was not the source of the leakage into the low-level outlet.

The dive inspection proceeded generally the same as for MDS. Potable Divers could not visually see the gate, flange, trash rack or intake structure, rather, the inspection was done by feel. The diver noted no pull or other sign of intake of flow around the gate but did report he heard a sound like ice popping or microphone static on the right side of the structure. The sound became more pronounced when he placed his head very near the right side of the concrete. No spalling of concrete was detected when the diver felt the intake structure.

At the conclusion of the dive inspection, City staff closed the downstream valve. Water was expunged through the air vent on the top of the control shed and later through the cut section on the crest. Interestingly, air bubbles were seen out in the reservoir, at the approximate location of the intake structure, which would support a break in the air vent line.

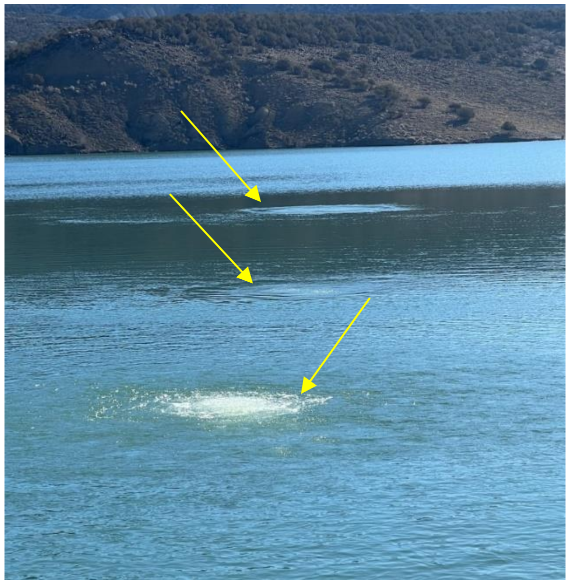


If the break in the air vent occurred at the intake structure as observations during the dive indicate, an 88-foot column of water, or 40 psi would pressurize the air vent at the break. Comparing the estimated outflow from the low-level outlet of 466 gpm, and applying the Bernoulli equation provides a flow depth similar to observations[2]. Review of prevailing Manufacturer data indicates a 2.5-inch diameter pipe is capable of conveying 466 gpm under pressurized conditions.

The City provided historic photos below (unlabeled, undated).

[2] Calculations indicate a flow depth of about an inch exiting the low-level outlet

Applying pressurized air within the line on March 30, 2023, revealed two additional breaks in the galvanized line, occurring between the upstream intake structure and the crest.



Moving forward, the City plans to replace the galvanized line. Following replacement, the low-level outlet may be video inspected as normal. The City will maintain the low-level outlet valve in a closed configuration until repairs can be made.