CARBON CANAL COMPANY
ASSESSMENT OF CANAL STRUCTURES

Prepared for

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BACKGROUND

The Carbon Canal (Figure 1) was constructed between 1906 and 1909 to deliver 125 cubic feet per second (cfs) of irrigation water to 7,973.46 acres of land. The main canal is an unlined earthen canal that has not changed in design since its original construction. There were six wooden flumes – Gordon Creek, Garley Wash, Pinnacle Wash, Drunkard's Wash, Miller Creek and Olsen's Wash and a 265 ft tunnel (Figure 1) included in the original construction. The flume at Olsen's Wash was later replaced with an undershot culvert, replacing the deteriorating flume.

All of the remaining flumes have been replaced once and some have been repaired following replacement. Drunkard's wash flume was replaced in 1926 and again in about 1944 or 1945[1]. In 1968 drunkard's wash was lined with fiberglass due to leaks in the steel liner.

The original Miller Creek flume was apparently replaced in 1937 and other replacement work occurred primarily in the 1940's. While not specified in the record, the current Garley Wash, Gordon Creek and Pinnacle Wash flumes where likely either replaced or rebuilt during the late 1930's through the 1940's. The Pinnacle Wash flume was rebuilt in 1957.

This study was undertaken to:

- evaluate the current condition of the tunnel and each of the flumes
- rank them in terms of condition and risk of failure
- Determine repair/replacement options and cost

EVALUATION

The following structures are included in this evaluation and are shown in Figure 1:

- Garley Wash Flume
- Tunnel
- Gordon Creek Flume
- Pinnacle Wash Flume
- Drunkard's Wash Flume
- Olsen's Wash Undershot
- Miller Creek Flume

Originally the Gordon Creek dump gate was also included. However, this facility was addressed in Carbon County emergency watershed program (EWP) projects and will be replaced in 2019. The Olsen's Wash undershot was also included in the EWP funds but was only partially funded by NRCS. Carbon Canal Company was required to provide the culverts for this project as NRCS will not supply culverts under EWP funding.

Each of these structures was inspected twice (once in July 2018 and again in November 2018 after the water was out). The condition assessment of each structure is based on these site visits.

[1] Carbon Canal History, Sheri Murray Ellis, November 27, 2017. This source is used extensively for the history of the canal structures, but likely does not document all the work performed.

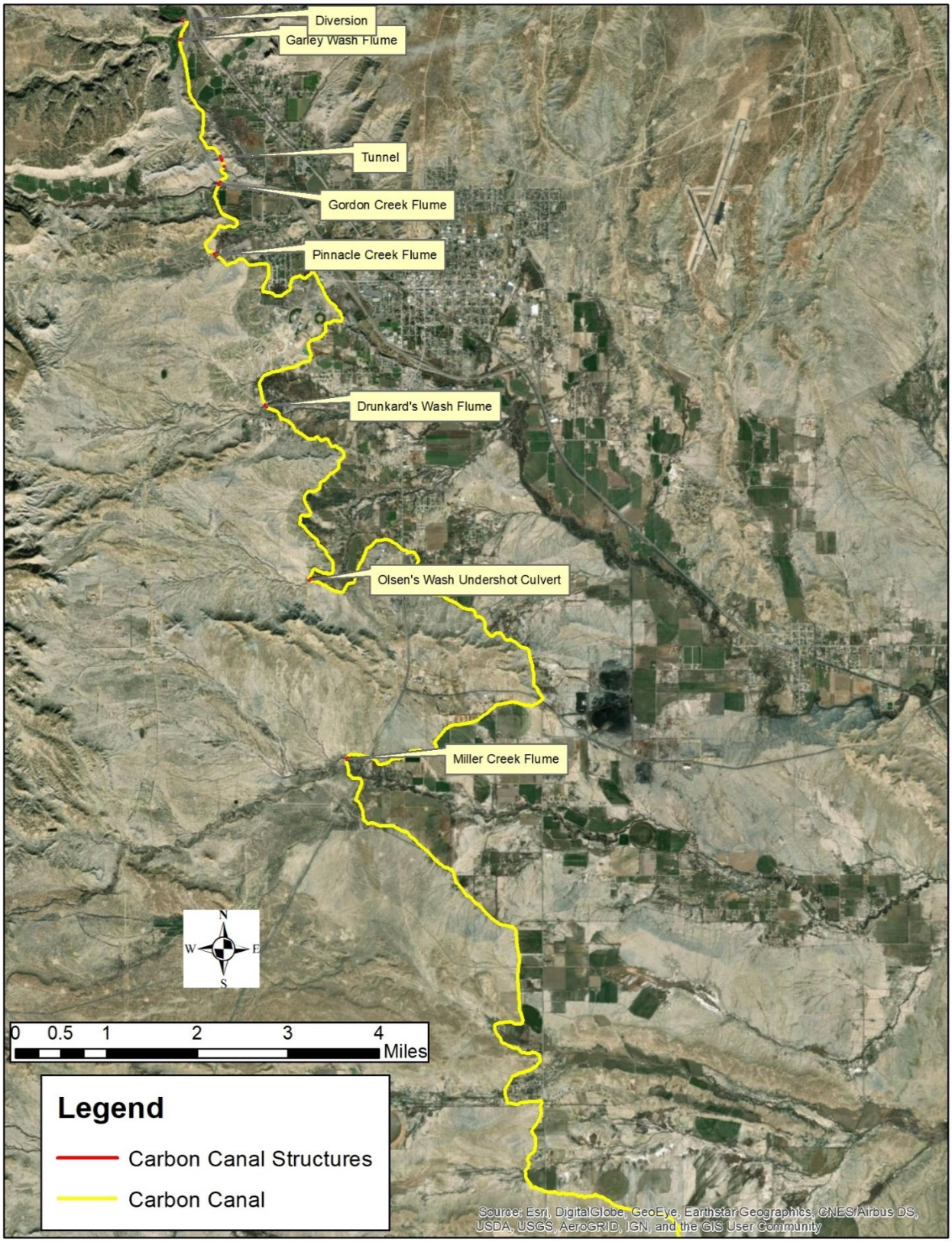

Figure 1. Carbon Canal Map

Garley Wash Flume

The Garley Wash flume is a 50-ft long semi-circular wood-stave flume with a 6.5 ft radius (Figures 2 and 3). It is suspended from a steel girder that spans the wash. The girder and concrete structures that support it are in excellent condition, although there is a good deal of surface rust on the steel.

The wood-stave flume is tensioned with 5/8-inch steel rods that pass through 3.5-inch by 5-inch wooden cross-members. The tension rods and cross-members are mostly in good condition. The leaking water has caused some rusting of the rods, but it is not severe. We identified three cross-members and rods that should be replaced.

There are 5 locations in the flume where the boards have warped, partially displaced or are broken. Otherwise, the wooden flume is in amazingly good condition for its age.

The biggest concern with this flume is the leakage. If the leakage continues, the tensioning rods will rust and eventually fail. We believe the best solution is to perform the repairs and line the flume with a 40-mil woven engineered geomembrane liner[2] with 8-oz geotextile backing or a 100 mil EPDM rubber liner. The budgets use the geomembrane liner as it is less expensive and is guaranteed for 20 years.

The first task is to remove the 6 to 12-inches of sediment from the bottom of the flume. We recommend using a slip scraper and cable with a skid-steer loader to pull it through the flume. The flume would be pressure washed, especially at the connection points on the ends, to assure good bonding of the liner. After completing all repairs, the liner would be installed and fastened with stainless steel battens. The ends would be fastened to the concrete abutments with a gasket or sealant and stainless-steel bolts in concrete anchors. The sides would be bolted through the wood-stave flume to hold the lining in place.

The last recommended repair activity for this site is the excavation of the remaining sediment under the upstream end of the flume to increase the channel capacity under the flume. With these repairs, the flume is expected to last at least 20 more years. The total cost of the repair is estimated at about $17,000 (rounded). The details of the cost estimate appear in Table 1. This is less than 10% of the replacement cost of the flume.

Tunnel

The 265-ft long tunnel was constructed in 1906 by excavation through Mancos shale (Figure 4). It is unlined and has likely eroded in width since construction due to weathering of the shale that was in contact with the water as it is now 22 to 27 ft wide and from 6 to 7 ft high (Figure 5). We could find no original dimensions, but it is unlikely that is was excavated that wide and there is evidence of shale slaking off the top as the tunnel has widened. There is adequate capacity and the top of the tunnel is not in contact with the water. The rock is competent in the ceiling, but the ceiling of the tunnel is very wide and flat, placing it at risk of further ceiling collapse. As it is located above all irrigation, a full tunnel collapse would cut off all water supply to the irrigated lands. The tunnel has up to 40 ft of over-burden and could take some time to clear if it collapsed during the irrigation season. A full collapse is not eminent, but continued slaking and partial blockage is a strong possibility. An earthquake would likely result in a total collapse.

[2] Aquamaster Armorliner 40L or approved equal

Figure 2. Garley Wash flume outside view

Figure 3. Garley Wash Flume inside view

Table 1. Cost estimate for reconditioning Garley Wash flume

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
1	Clean and muck out sediment inside the flume	11	CY	$136.00	$1,496
2	Pressure wash flume including inlet and outlet	2658	SF	$0.22	$585
3	Repair lifted boards (2-3/8" x 5-1/2") and holes	5	ea	$295.00	$1,475
4	Replace Broken Wooden Cross Beams 3.5"x5" x 15-ft	3	ea	$115.00	$345
5	Replace broken 5/8" diameter x 24-ft steel rods	3	ea	$189.00	$567
6	Geomembrane liner 40 mil with 8-oz nonwoven geotextile one side 20-ft wide x 60-ft long	1155	SF	$0.86	$993
7	Geomembrane liner installation	1155	SF	$2.24	$2,583
8	Batten Strip (Stainless Steel 1/4" x 2" Flat Bar w/ 1/2" hole on 6" centers) 3/8" bolts and socket	150	LF	$15.00	$2,250
9	Clean channel under the upstream end of the flume for more capacity	190	CY	$5.00	$950
	Subtotal				**$11,244**
10	Mobilization			6%	$675
11	Engineering & Project Management			25%	$2,980
12	Contingencies			20%	$2,249
	Total Implementation Cost			**(rounded)**	**$17,000**

Figure 4. Tunnel alignment

Figure 5. Interior view of tunnel looking upstream. November 15, 2018

Three possible repair options were examined: (1) Open cut; (2) Multiplate steel arch; (3) Multiple pipes.

Open Cut Tunnel Option

The over-burden has not been drilled to examine the material, but we estimate from the exposed material on the inlet and outlet that there is approximately 20 ft of shale and then up to 20 ft of soil over the shale in the center of the tunnel. The soil over-burden would require a final slope of 2:1(horizontal:vertical) with an 8-ft step at the top of the rock. We have assumed that the rock could be excavated at 1:3 (horizontal:vertical) and would be stable at that slope, although no geotechnical investigation has been completed. The 8-ft step at the top of the rock would allow the placement of a drainage ditch to intercept runoff from the soil above. The cut would be 33 ft wide at the top of the shale, 49 ft wide at the beginning of the soil and average 129 ft wide (range 90-160 ft) at the top of the cut. There would be over 2,500 cubic yards of rock excavation and 17,000 yards of soil.

There is an existing road over the top of the tunnel. If access is required on the east side of the tunnel, the canal road would be the only access. Disposal of the excavated material may be an issue as the tunnel passes through private property. We have estimated right-of-way cost at $25,000 per acre for the open cut and the disposal area (2 acres total), but it may be more.

The total cost of this open cut solution is estimated at about $412,000 (rounded). The details of the cost estimate appear in Table 2.

Table 2. Cost estimate for open cut tunnel solution.

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
1	Excavate Tunnel 1:3 Slope in Shale then 8-ft step and cut-off ditch then 2:1 Loose Soil with 12-ft Road on East Side	16,000	CY	$7.80	$124,800
2	Haul and Dispose of Excavated Material	16,000	CY	$3.18	$50,900
3	Drill, Blast, load & haul Rock	2,528	CY	$19.56	$49,500
4	Right-of-way for open cut and disposal	2	AC	$25,000	$50,000
	Subtotal				**$275,200**
5	Surveying and Soil Testing	1	LS	$5,000	$5,000
6	Mobilization			6%	$16,500
7	Engineering & Project Management			25%	$74,200
8	Contingencies			15%	$41,300
	Total Implementation Cost				**$412,200**

Multiplate Steel Arch Option

Installation of a multiplate steel arch (Figure 6) inside the tunnel and then grouting the annular space between the tunnel and the arch is a common solution to tunnel lining. We anticipated extending the liner outside the existing tunnel for end protection with a total length of 280 ft.

The tunnel would first be cleaned and a concrete footing installed on each side of the tunnel to support the arch (Figure 7). The arch would be constructed one section at a time and pulled or pushed into the tunnel until the entire liner is assembled and installed. The arch would have 2-in bungs installed at approximately 10 ft intervals. Bulkheads would be constructed at each end and low-strength grout or sand-cement slurry pumped into the annular space through the bungs. The cost for this solution is estimated to be $395,000 (rounded). The detailed cost estimate is in Table 3.

The advantage of this option is that it allows full capacity with no restrictions in the channel and does not change the impact to local land-owners. It is also less expensive than the open cut option and is not subject to erosion nor increased risk to the public.

Piped Option

There is space to install two 6-ft diameter HDPE Type S culverts in the existing tunnel and then grout them in place. The combined capacity at normal canal depth is 140 cfs, with a maximum capacity of 230 cfs, exceeding the canal maximum capacity of 200 cfs at this location.

The floor of the tunnel would be cleaned along the pipe alignment and the pipes assembled and pushed into place. We have planned for 280 ft of pipe to allow protection of the ends after installation in the 265-ft long tunnel. After installation, bracing would be installed on top of the pipe to prevent the pipe from floating when the grout is pumped in.

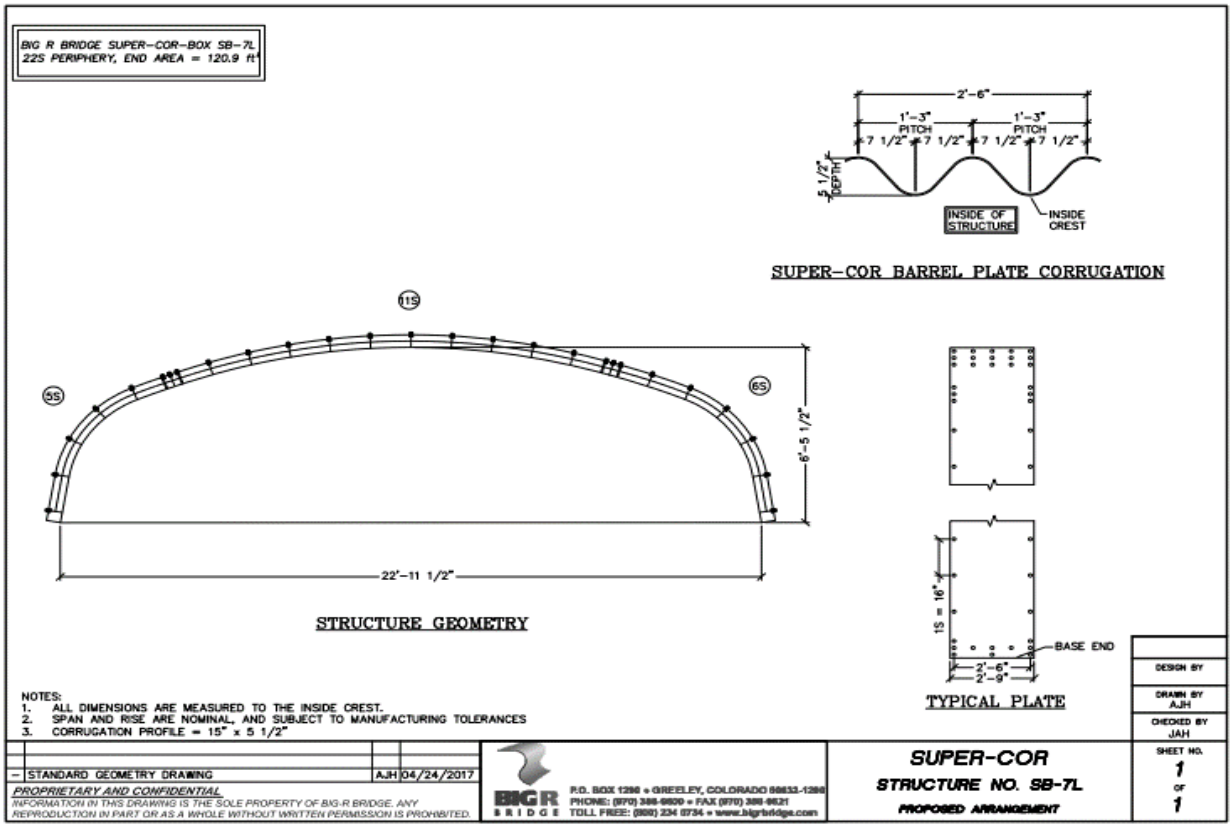

Figure 6. Multiplate steel arch tunnel option

Figure 7. Typical footing cross-section for installation of tunnel liner

Table 3. Cost estimate for multi-plate steel tunnel liner

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
1	Structural Plate Single Arch Inside Span 22-ft x Inside Rise 6.5-ft with grouted annular space	280	FT	$690.7	$193,400
2	Excavate and prep for concrete footings	213	CY	$12.5	$2,700
3	Concrete Footing with Notch for Structural Plate 24" wide by 12" deep (Excavated and Poured)	560	LF	$41.0	$23,000
4	Grout Annular Space with Soil Cement	141	CY	$160.0	$22,500
5	Structural Plate Assembly and Installation	1	LS	$21,600	$21,600
	Subtotal				**$263,200**
6	Surveying and Soil Testing	1	LS	$5,000	$5,000
7	Mobilization			6%	$15,800
8	Engineering & Project Management			25%	$71,000
9	Contingencies			15%	$39,500
	Total Implementation Cost				**$394,500**

2-inch diameter grout pipelines would be installed and withdrawn as the grout is pumped in. Each end would include a bulkhead to retain the grouy. Low-strength grout or sand-cement slurry would be pumped into the annual space to provide the necessary strength to allow the pipes to support the overburden.

The total estimated cost of this option is $321,000 (rounded). The detailed cost estimate is given in Table 4. The largest single cost is grouting the annular space as the volume is large.

This is the least-cost option. It has adequate capacity to handle the full flow of the canal and maintains the same impact to local land-owners. The only downside to this option is that the twin pipes will be subject to trash accumulation at the inlet between the two pipes, requiring periodic cleaning. An access trail and catwalk along the top of the pipes would be provided to allow access for cleaning.

Table 4. Cost estimate for piped tunnel option

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
1	Two 72" HDPE Type S Pipe	560	FT	$150.0	$84,000
2	Excavate and prep for pipe lining	207	CY	$12.5	$2,600
3	Supply and Install Grout Application Tube (i.e. 2" PVC) and Skids to Prevent Floating Pipe	1120	FT	$4.7	$5,300
4	Grout Annular Space with Soil Cement	639	CY	$160.0	$102,300
5	HDPE Assembly and Installation	1	LS	$14,400.0	$14,400
6	Headwall catwalk and access trail	1	LS	$5,000.0	$5,000
	Subtotal				**$213,600**
7	Surveying and Soil Testing	1	LS	$5,000	$5,000
8	Mobilization			6%	$12,800
9	Engineering & Project Management			25%	$57,900
10	Contingencies			15%	$32,000
	Total Implementation Cost				**$321,300**

Tunnel Recommendation

The least cost option is to line the tunnel with two 6-ft diameter HDPE Type S culverts, grouted in place. At $321,000, it is $73,000 or 18.5% less expensive than the multi-plate arch option. It has capacity to handle the maximum canal flow and is not subject to corrosion. The only down-side for this option is the potential for trash accumulation at its inlet. No trash racks are required on these large pipes, but trash could become trapped between the two pipes, requiring periodic cleaning.

The multi-plate tunnel option has the best operational conditions with an expected life in excess of 60 years, but it still subject to corrosion with time. The corrosion can be mitigated by cleaning re-coating the exposed steel at 25-year intervals, extending the life to 100 years. At $395,000 it is more expensive than the pipe option but does not have the limitation of trash accumulation at the entrance. If funding is available, it is the recommended option. If funding is limited, the piped option is an excellent second choice.

Because of the high cost, impact to local land owners, the human risk due to the very tall slopes and the possibility of erosion bringing material into the canal, the open cut option is not recommended.

Gordon Creek Flume

The 200-ft long flume at Gordon Creek is similar in design to the Garley wash flume with the same cross-section. The steel girder support structure is larger because of the longer length, but the same wood-stave semi-circular flume is used (Figures 8, 9, 10). Figure 9 shows the presence of surface rust on the steel girders and Figure 10 shows the rusting condition of the tensioning rods as a result of leakage from the flume.

Figure 8. Aerial view of Gordon Creek flume

Figure 9. Gordon Creek flume showing girders and cross-braces

Figure 10. Closeup of wood-stave condition of Gordon Creek flume

The Gordon Creek flume is the same vintage (likely early 1940's) as the Garley wash flume, but it shows more deterioration. About 50% of the cross-braces are badly deteriorated and two were broken. Some of the tensioning rods have lost 50% of their thickness due to corrosion.

The concrete structures are in good condition, except stream erosion near the downstream pier risks undercutting the footings (Figure 11). Bank protection is needed in this area to prevent further erosion that could compromise the integrity of the structure.

The condition of the overall structure is sufficient to warrant repair rather than replacement. The repair approach is the same as for Garley wash, only more of the cross members and tensioning rods require replacement. Sediment removal, cleaning, flume repair and lining would proceed as described for the Garley wash flume. In addition, we have added an estimate for placing grouted riprap along the south-side of Gordon Creek to protect the south pier.

Table 5 lists the items of repair that we anticipate, together with the estimated cost. We estimate the total cost of repair at $110,000 (rounded). This work is expected to extend the life of the flume by 20 years at a cost of about 20% of the replacement cost, making this the most economical solution. Bank protection accounts for nearly 30% of the total cost and would be needed for any solution.

Figure 11. Gordon Creek flume south pier showing stream channel erosion

Table 5. Cost estimate for rehabilitating Gordon Creek flume

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
1	Clean and muck out sediment inside the flume	37	CY	$135.14	$5,000
2	Pressure wash flume including inlet and outlet	6489	SF	$0.22	$1,400
3	Repair lifted boards (2-3/8" x 5-1/2") and holes	20	ea	$295.00	$5,900
4	Replace Wooden Cross Beams 3.5"x5" x 15-ft	67	ea	$115.40	$7,700
5	Replace broken 5/8" diameter x 24-ft steel rods	67	ea	$189.40	$12,700
6	Geomembrane liner 40 mil with 8-oz nonwoven geotextile one side 20-ft wide x 210-ft long	4305	SF	$0.86	$3,700
7	Geomembrane liner installation	4305	SF	$2.24	$9,600
8	Batten Strip (Stainless Steel 1/4" x 2" Flat Bar w/ 1/2" hole on 6" centers) 3/8" bolts and socket	450	LF	$15.00	$6,800
9	Grouted rip/rap under flume on south side	56	CY	$350.00	$19,600
	Subtotal				**$72,400**
10	Mobilization			6%	$4,300
11	Engineering & Project Management			25%	$19,200
12	Contingencies			20%	$14,500
	Total Implementation Cost				**$110,400**

Pinnacle Wash Flume

The Pinnacle wash flume is a 200-ft long rectangular wooden flume set on steel I-beams that are supported by concrete piers (Figure 12). The rectangular box is 13 ft wide with 3 ft sides. It has been replaced at least once. Records show that $4,000 was borrowed in 1957 to raise the flume and replace abutments. There is evidence of other repairs, but it is not known when they were made.

This flume is in much worse condition than the Garley Wash or Gordon Creek flumes. The wooden flume has deteriorated and is leaking. Some of the steel I-beams are rusted completely through in the web. The concrete piers are deteriorating and the I-beams rest on wooden beams that are blocked up on one of the piers (Figure 12, left).

The sides of the flume have been lined in the past as some of the lining is still in place (Figure 13). The integrity of the liner is lost now. Given the overall condition of this flume, it is not expected to continue to function more than one more year without failure. By cleaning and lining the flume to stop the leakage and performing some remedial work on the piers, we believe the life could be extended up to 5 years while funds are sought to replace it. We estimate $17,000 for the remedial work and lining as shown in Table 6. The flume should be monitored closely following repair and replaced within 5 years.

Pinnacle Wash Pipe Flume Option

The preferred replacement option is a suspended pipe flume using an 8-ft diameter x 0.375-inch wall steel pipe (Figure 14). The detail of the connection to the canal is shown in Figure 15. The flume would be installed about 1- 1.5 ft below the invert of the canal to allow more of the pipe diameter to be available for flow at normal canal depth. At normal canal depth, the pipe flume has a capacity of 130 cfs. At bank-full, the pipe flume can carry 200 cfs, exceeding the canal capacity at this location.

The pipe would be polyurethane coated for long life and can be recoated to prevent corrosion in the future if the lining is damaged. With proper maintenance, suspended pipe flumes have an operational life of 60 plus years and with regular maintenance can remain serviceable for 100 years.

The 8-ft diameter is sufficiently large that it will pass trash typical to this size canal so no trash rack or regular cleaning is needed. The estimated cost to replace Pinnacle Wash flume with an 8-ft diameter pipe flume is $356,000 (rounded). The detailed cost estimate is given in Table 7.

Pinnacle Wash Inverted Siphon Option

The traditional method of crossing streams like Pinnacle Wash is with an inverted siphon whereby a buried pipeline carries the water under the wash. To prevent sediment accumulation, the design velocity must be 3.0 fps or more. This requires some head loss and would require enlarging the canal upstream for about ½ mile to maintain the same overall capacity.

The inverted siphon would use 6-ft diameter reinforced concrete pipe, buried with 3 ft of cover. An inlet and outlet structure would be included to allow smooth transition from the canal to the pipe, similar to the structures for the pipe flume. A cleanout and drain would be included in the low elevation portion of the siphon near the stream. Grouted riprap would be placed in the stream downstream of the pipe crossing to protect the pipe from channel erosion.

Figure 12. Pinnacle Wash flume

Figure 13. Inside condition of Pinnacle Wash flume

Table 6. Cost estimate for remedial repair to Pinnacle Wash flume

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
1	Clean and muck out sediment inside the flume	1	LS	$500.00	$500
2	Repair lifted boards and holes, prep for liner	1	LS	$1,000.00	$1,000
3	Geomebrane liner 40 mil with 8-oz nonwoven geotextile one side, 20-ft wide x 210-ft long	3990	SF	$0.86	$3,400
4	Geomembrane liner installation	3990	SF	$1.34	$5,300
5	Batten Strip (Treated 2x4) screwed to the flume sides	410	LF	$1.00	$400
6	Batten Strip (Stainless Steel 1/4" x 2" Flat Bar w/ 1/2" hole on 6" centers) 3/8" bolts and socket at (inlet/outlet transitions)	60	LF	$15.00	$900
	Subtotal				**$11,500**
7	Mobilization			6%	$700
8	Engineering & Project Management			25%	$3,100
9	Contingencies			15%	$1,700
	Total Implementation Cost				**$17,000**

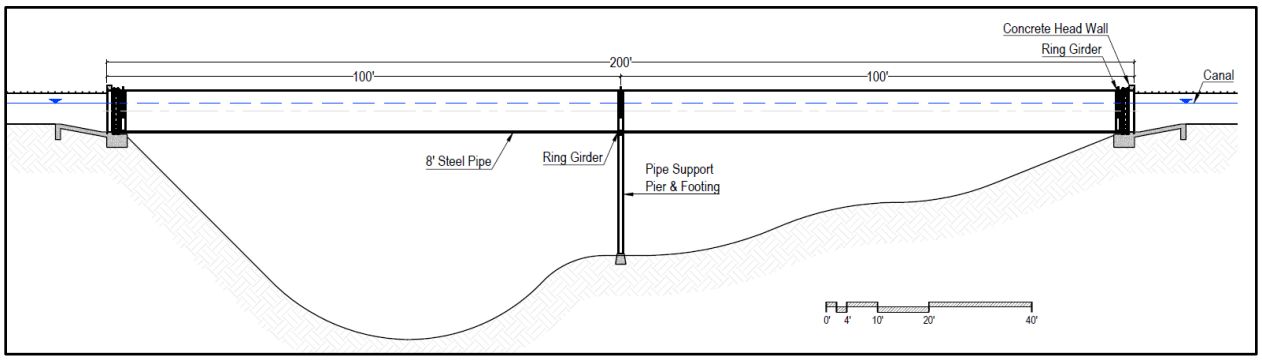

Figure 14. Pinnacle Wash pipe flume

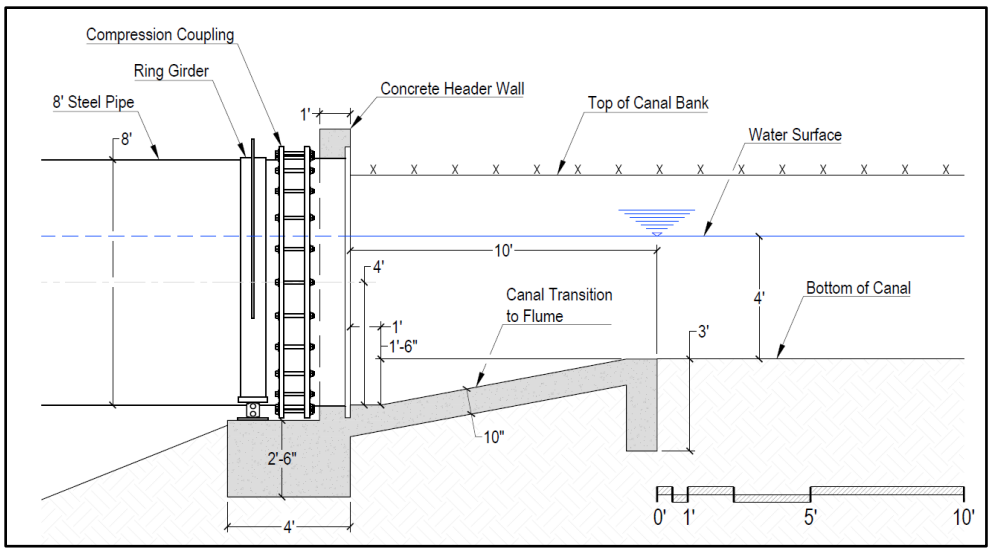

Figure 15. Pipe flume end detail

Table 7. Cost estimate for Pinnacle Wash pipe flume

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
1	Removal/disposal of existing concrete structures	5	days	$3,000.00	$15,000
2	Removal/disposal of steel I-beams and wood	13,650	CF	$0.38	$5,200
3	Form and pour siphon inlet transition	9.1	CY	$1,450.00	$13,200
4	Form and pour siphon outlet transition	9.1	CY	$1,450.00	$13,200
5	96" diameter x .375" wall steel pipe flume with ring-girders	200	LF	$838.00	$167,600
6	Crane rental	1	LS	$2,000.00	$2,000
7	Pier & steel support structure	1	LS	$10,000.00	$10,000
8	Expansion joints and seals	1	LS	$5,000.00	$5,000
9	Pipe flume installation	1	LS	$10,000.00	$10,000
	Subtotal				**$241,200**
10	Mobilization			6%	$14,500
11	Engineering & Project Management			25%	$63,900
12	Contingencies			15%	$36,200
	Total Implementation Cost				**$355,800**

Because of the smaller diameter pipe and the problem with trash and safety, a trash rack is included. To protect the canal in case the trash rack plugs, three Waterman over-top siphons are included along with a return channel to convey excess flow to the wash. The total cost is estimated at $336,000 (rounded). The detailed cost estimate is shown in Table 8.

Table 8. Cost estimate for Pinnacle Wash inverted siphon

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
1	Removal/disposal of existing concrete structures	5	days	$3,000.00	$15,000
2	Removal/disposal of steel I-beams and wood	13,650	CF	$0.38	$5,200
3	Form and pour siphon inlet transition	9.1	CY	$1,450.00	$13,200
4	Form and pour siphon outlet transition	9.1	CY	$1,450.00	$13,200
5	72" Reinforced Concrete Siphon Pipe	243	SF	$430.00	$104,500
6	Siphon Pipe Installation, Compaction & Backfill	243	LF	$46.00	$11,200
7	Steel Trash Rack on Inlet	1	EA	$1,000.00	$1,000
8	Cleanout and drain structure	1	LS	$6,000.00	$6,000
9	Waterman Automatic Siphon S5/50 Overflow (3 devices 50 cfs each), concrete headwall, rip/rap return channel	1	LS	$26,000.00	$26,000
10	Enlarge channel upstream to maintain capacity	1180	CY	$3.00	$3,500
11	Bank Protection under flume on south side, Grouted Rip/Rap	83	CY	$350.00	$29,200
	Subtotal				**$228,000**
12	Mobilization			6%	$13,700
13	Engineering & Project Management			25%	$60,400
14	Contingencies			15%	$34,200
	Total Implementation Cost				**$336,300**

Pinnacle Wash Recommendation

Unless funding can be identified for replacement in the winter of 2019-2020, we recommend performing the remedial repair and lining as soon as possible. The expenditure of $17,000 will extend the life of the flume up to 5 years at 5% of the cost of replacement and protect the flume from failing.

Even though the estimated cost of the pipe flume options is $20,000 (5%) more than the inverted siphon, it is the recommended solution. It is not subject to plugging with trash or sediment accumulation, has a long life and is simple to maintain.

Drunkard's Wash Flume

The Drunkard's wash flume was originally constructed in 1926 during realignment of the canal in this area. It was replaced or rebuilt in 1944 or 1945 with the present-day flume, consisting of a 5-ft radius semicircular Armco steel panel flume suspended from a steel I-beam support structure using tension rods and cross-members similar to a wood-stave flumes (Figure 16, 17). By 1968 the steel panels were rusting through and the flume was lined with fiberglass. About 3 or 4 years ago a portion of the flume was covered with a membrane liner because of excessive leakage near the downstream abutment. The remaining fiberglass liner is brittle and leaking and the membrane liner is developing some small holes.

Figure 16. Drunkard's Wash flume side view

Figure 17. Drunkard's Wash flume top views

The concrete piers and abutment and the steel structure is in very good condition. The steel panels, cross-ties and support rods are in poor condition and must be replaced. We have examined two options for this location: (1) rehabilitation and (2) pipe flume replacement. An inverted siphon option would be difficult because of the steep slopes.

Drunkard's Wash Rehabilitation Option

The rehabilitation option retains the concrete inlet and outlet structures, the concrete piers and the steel structures. As Figure 17 shows, the cross-ties must be replaced along with the Armco steel panels and many of the support rods. The best solution for replacement is to use multiplate semi-circular polymer-coated galvanized steel panels to replace the existing Armco panels. They would be suspended using 5/8" galvanized steel suspension rods bolted through the top flange of the steel I-beam supports with angle-iron cross ties for rigidity. The corrugated steel panels are inherently stronger than the flat-panel plates with less pressure on the steel rods. Salvagable rods will be reused.

After installation, the panel seams will be polymer-coated and any damage to the polymer coating on the panels repaired to seal the seams and protect the steel from corrosion. At each end, the transition from the steel panels to the concrete structures will be completed with geomembrane sheets attached with stainless-steel battens and gaskets or flexible sealant. This will allow the steel to expand and contract without leakage.

The total cost for this rehabilitation is estimated to be $111,000 (rounded). The detailed cost estimate is in Table 9. It is expected that this reconstruction will last for 50 plus years, with 2 replacements of the geomembrane seals and 2 seam seal applications.

Drunkard's Wash Pipe Flume Option

Drunkard's Wash flume could be replaced with a single-span 8-ft diameter steel pipe flume, similar to the Pinnacle Wash option, but with just one span and no center support (Figure 18). This would require total removal of the existing flume and replacement of the concrete abutments.

The total cost for the pipe flume option is estimated to be $205,000 (rounded). The detailed cost estimate is in Table 11. The expected life is between 60 and 100 years.

Drunkard's Wash Recommendation

Because the rehabilitation option is ½ the cost of the replacement option and will last nearly as long, it is the recommended option. The maintenance will be somewhat higher, but the total annual cost will still be substantially less than the replacement option.

Table 9. Cost estimate for reconstruction of Drunkard's Wash flume

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
1	Remove and dispose of existing Armco panels (salvage good 1/2" rods and cross beams)	34	Panel	$360.00	$12,200
2	Structural plate (galvanized & polymer coated) single arch inside span 10-ft x inside rise 5.2-ft 10 gauge	100	FT	$293.00	$29,300
3	Structural plate installation	100	FT	$73.25	$7,300
4	angle iron cross beams 3" x 3" x 15-ft	67	EA	$115.40	$7,700
5	Replace broken 1/2" diameter x 22-ft steel rods	67	EA	$145.00	$9,700
6	Geomembrane liner 40 mil with bonded 8-oz nonwoven geotextile one side 16-ft wide x 4-ft long for inlet/outlet transitions	128	SF	$0.86	$100
7	Geomembrane liner installation inlet/outet at concrete/steel transition	128	SF	$2.24	$300
8	Batten Strip (Stainless Steel 1/4" x 2" Flat Bar w/ 1/2" hole on 6" centers) 3/8" bolts and socket	80	LF	$15.00	$1,200
9	Seam coating, cleaning and painting structural steel	1	LS	$5,000	$5,000
	Subtotal				$72,800
10	Mobilization			6%	$4,400
11	Engineering & Project Management			25%	$19,300
12	Contingencies			20%	$14,600
	Total Implementation Cost				$111,100

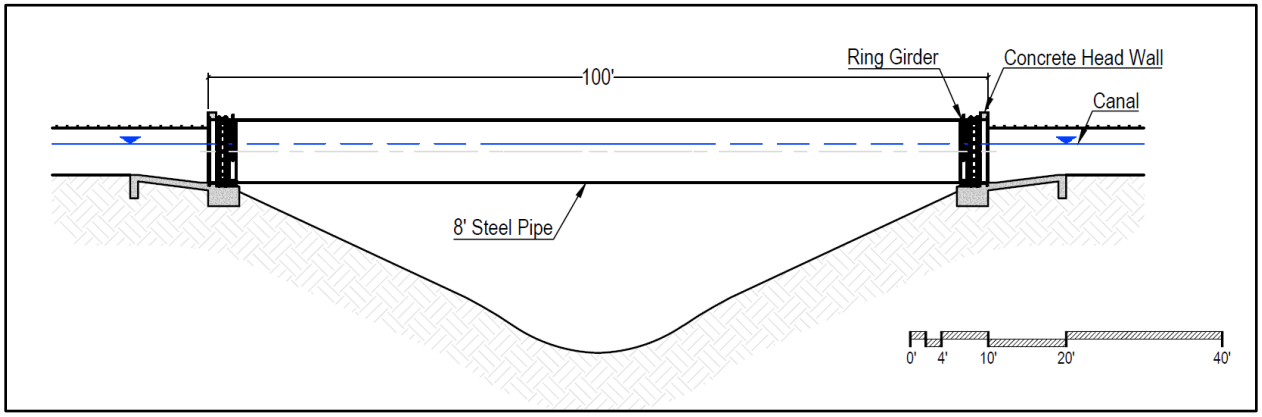

Figure 18. Drunkard's Wash pipe flume options

Table 10. Cost estimate for Drunkard's Wash pipe flume option

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
1	Removal/disposal of existing concrete structures	5	days	$3,000.00	$15,000
2	Form and pour siphon inlet transition	9.1	CY	$1,450.00	$13,200
3	Form and pour siphon outlet transition	9.1	CY	$1,450.00	$13,200
4	96" diameter x .375" wall steel pipe flume with ring-girders	100	LF	$838.00	$83,800
5	Crane rental	1	LS	$2,000	$2,000
6	Expansion joints and seals	1	LS	$5,000	$5,000
7	Pipe flume installation	1	LS	$7,000	$7,000
	Subtotal				**$139,200**
8	Mobilization			6%	$8,400
9	Engineering & Project Management			25%	$36,900
10	Contingencies			15%	$20,900
	Total Implementation Cost				**$205,400**

Olsen's Wash Undershot

The undershot at Olsen's Wash (sometimes referred to as Robinson's Wash) is being rebuilt under an NRCS Emergency Watershed Protection project administered by Carbon County. Although the existing site has not been fully dewatered and examined, the best estimate is that the existing undershot consists of one 6-ft diameter culvert that is deeply submerged and partially filled with sediment. Downstream sedimentation of the channel prevents the site from fully draining and has reduced the capacity. The culvert is too short and severe erosion at the discharge end is threatening the canal road and the canal.

Because of the depth of the existing pipe relative to the downstream channel elevation and resistance by a downstream land tenant to excavating the wash downstream of the undershot, the best solution is to replace the existing culvert that is at least 60 years old with two new 5 ft diameter culverts placed above it. The existing culvert will be either removed or grouted full to prevent future failure of the embankment above. The downstream channel will be excavated to daylight the downstream end of the culverts. Jones and DeMille Engineering is completing the design at this site (Figure 19). The WSP program in NRCS cannot buy culverts. At this site, WSP funding will do all other work except provide the culverts.

The cost of the two 5-ft diameter HDPE Type S culverts is $30,800. Without this expenditure, the repair cannot proceed, putting a large portion of the irrigated lands at risk as a result of a canal failure. It is recommended that these pipes be purchased to allow the project to move forward, protecting the canal, downstream water users and down-slope land owners that could be damaged if the canal fails at this location.

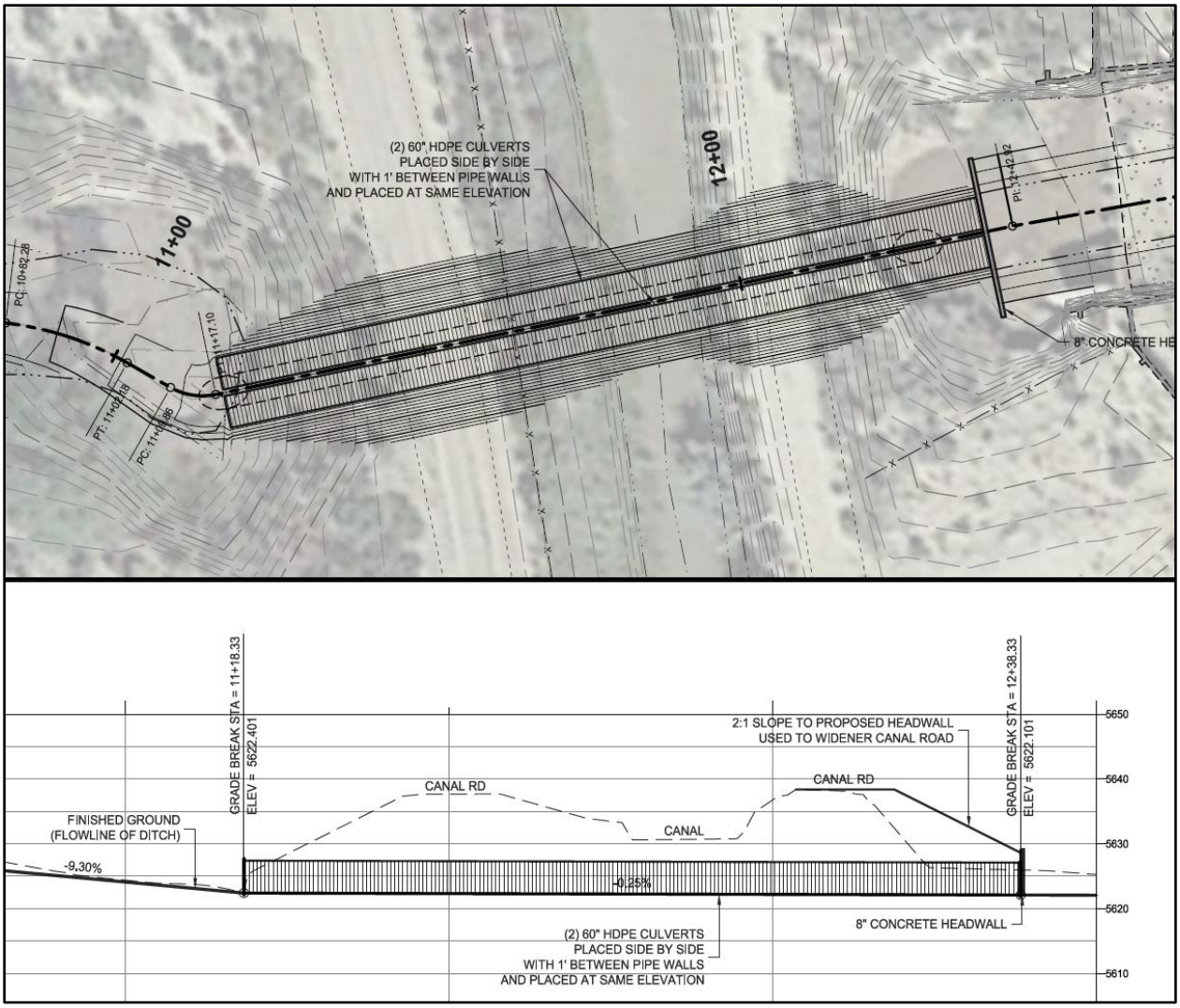

Figure 19. Preliminary plan and profile of new undershot (Jones & DeMille)

Miller Creek Flume

The existing 100 ft long Miller Creek Flume (124 ft long counting the two suspended concrete abutments) is the second flume at this location. It was constructed in 1937, just a few years before Garley Wash and Gordon Creek flumes. It consists of a 6.5-ft radius semi-circular wood-stave flume resting on wooden cribs (Figure 20). The cribs are supported by steel I-beams resting on concrete pillars. The entire structure is in poor condition. The greatest risk is a severely eroded concrete pillar on the downstream end (Figure 21). The erosion is caused by leakage and winter freeze-thaw damage. There is also leakage on the upstream abutment with eroded concrete and exposed and corroded rebar (Figure 22). The center concrete pillar is cracked with exposed and corroded rebar. The northern pillar is also cracked. The wooden structure is in reasonable condition, although it is leaking.

We have explored two options at this site: (1) rehabilitate and (2) replace with pipe flume.

Figure 20. Miller Creek Flume looking west

Figure 21. Miller Creek flume south pier showing concrete erosion

Figure 22. Miller Creek flume center pier with exposed and corroded rebar

Miller Creek Flume Rehabilitation Option

After careful examination of this structure, we believe it can be rehabilitated for an additional life of approximately 20 years. The flume would be rehabilitated in the same manner as Garley Wash and Gordon Creek flumes by cleaning, repairing and lining with 40 mil woven geomembrane liner with an 8 oz geotextile back. The damaged cross-braces and tension rods would be replaced also. The wooden cribs are in excellent condition and do not require replacement.

The larger work involves rebuilding the concrete piers. In each instance, this would be accomplished by encasing the piers in a new steel rebar gage and pouring a new concrete case around the existing pier.

We estimate the cost of this rehabilitation at about $112,000 with an extension of useful life of 20 years. The detailed costs are presented in Table 11. The rehabilitated piers are expected to last up to 40 more years, If the wooden components are in good condition at the end of 20 years, the lining could be replaced for additional 20-year life with an investment of an additional $15,000.

Miller Creek Pipe Flume Replacement Option

The best replacement option at this site is to use an 8-ft diameter steel flume as previously described (Figure 23). Since this is a 124 ft span, 0.50-inch thick steel pipe would be used to support the additional load. The cost of this option is estimated to be $310,000 (rounded). The detailed costs are shown in Table 12.

Miller Creek Recommendation

Since the rehabilitation cost is only 1/3 of the replacement cost and has nearly half the life, it is the recommended option. The annualized capital cost of the rehabilitation at 5% interest over 20 years is $8,947 per year. The annualized capital cost of the pipe flume replacement option is $16,970, twice the annual cost of the rehabilitation option. The rehabilitation option is the most economical. If the wood is in good condition after 20 years, it could be relined for an additional 20 years.

Table 11. Cost estimate for Miller Creek flume rehabilitation option

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
1	Clean and muck out sediment inside the flume	13	CY	$135.14	$1,800
2	Pressure wash flume including inlet and outlet	3945	SF	$0.22	$900
3	Repair lifted boards (2-3/8" x 5-1/2") and holes	10	ea	$295.00	$3,000
4	Replace Broken Wooden Cross Beams 3.5"x5" x 15-ft	34	ea	$115.40	$3,900
5	Replace broken 5/8" diameter x 24-ft steel rods	34	ea	$189.40	$6,400
6	Geomembrane liner 40 mil with 8-oz nonwoven geotextile one side 20-ft wide x 110-ft long	2200	SF	$0.86	$1,900
7	Geomembrane liner installation	2200	SF	$2.24	$4,900
8	Batten Strip (Stainless Steel 1/4" x 2" Flat Bar w/ 1/2" hole on 6" centers) 3/8" bolts and socket	250	LF	$15.00	$3,800
9	Center pier repair, cage with #4 rebar 12" O.C. form and pour 6" thick 4000 psi concrete encasement around existing pier.	11	CY	$1,450.00	$15,700
10	South pier repair, cage with #4 rebar 12" O.C. form and pour 6" thick 4000 psi concrete encasement around existing pier.	9	CY	$1,450.00	$13,500
11	North pier repair, cage with #4 rebar 12" O.C. form and pour 6" thick 4000 psi concrete encasement around existing pier.	8	CY	$1,450.00	$11,300
12	Concrete and steel repair under north abutment	1	LS	$6,000.00	$6,000
	Subtotal				**$73,100**
13	Mobilization			6%	$4,400
14	Engineering & Project Management			25%	$19,400
15	Contingencies			20%	$14,600
	Total Implementation Cost				**$111,500**

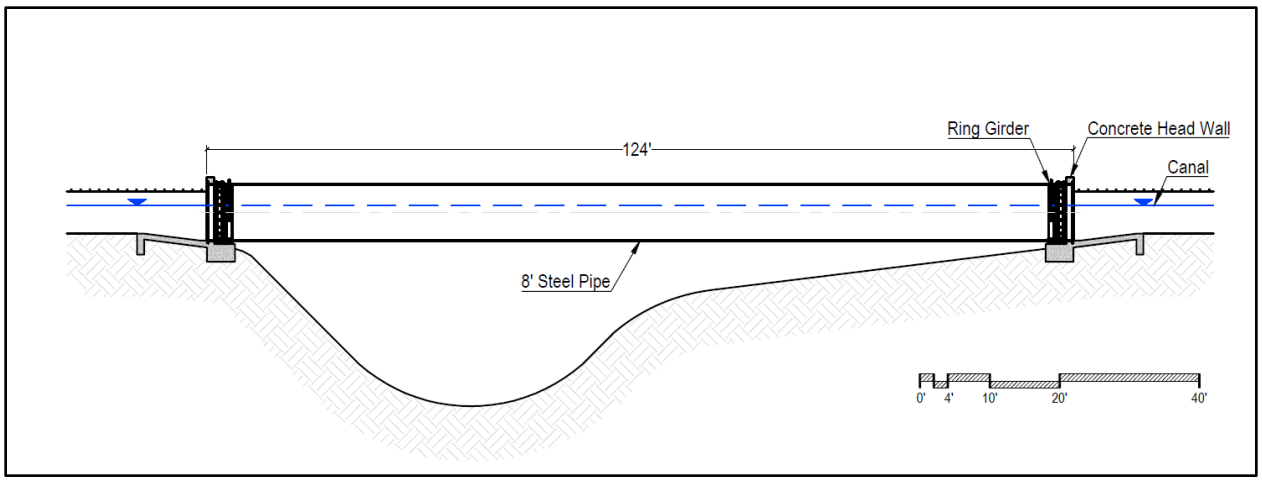

Figure 23. Miller Creek Pipe Flume Option

Table 12. Cost estimate for Miller Creek pipe flume replacement option

Item	Description	Quantity	Unit	Unit Cost ($/unit)	Total
1	Removal/disposal of existing concrete structures	7	days	$3,000.00	$21,000
2	Form and pour siphon inlet transition	9.1	CY	$1,450.00	$13,200
3	Form and pour siphon outlet transition	9.1	CY	$1,450.00	$13,200
4	96" diameter x .5" wall steel pipe flume with ring-girders	124	LF	$1,118.00	$138,600
5	Crane rental	1	LS	$4,000	$4,000
6	Expansion joints and seals	1	LS	$5,000	$5,000
7	Pipe flume installation	1	LS	$15,000	$15,000
	Subtotal				**$210,000**
8	Mobilization			6%	$12,600
9	Engineering & Project Management			25%	$55,700
10	Contingencies			15%	$31,500
	Total Implementation Cost				**$309,800**

SUMMARY AND CONCLUSIONS

We have examined seven structures on the Carbon Canal, assessed their condition and developed costs for repair or replacement. The costs of the recommended options appear in Table 13. The costs total $1,149,000 if the recommended options are selected.

It is not necessary to complete all projects simultaneously, but some structures are at higher risk of failure. Following is a priority list of projects:

1. The Olsen's Wash undershot is critical and should be funded in 2019 to utilize the EWP funding for installation.
2. Pinnacle Wash flume is at high risk of failure. If funding is not available by fall 2019 for replacement, it should be repaired before the 2020 irrigation season. With the repair its replacement could be postponed to as late as 2024 or 2025.
3. The Miller Creek southern pier could fail within 2 years if not repaired. Ideally its full rehabilitation should be funded in 2020 or 2021. At the very least the southern pier should be rebuilt no later than the fall of 2020. The entire reconstruction should not be extended past 2022.
4. Drunkard's wash fiberglass liner is failing. Leakage will increase in 2019. Rehabilitation should be considered by 2021 or 2022.
5. Garley Wash and Gordon Creek flumes are not under immediate risk of failure but the leakage will continue to deteriorate the structure. The Gordon Creek foundation is at risk and should be closely monitored. A large storm event in Gordon Creek could worsen the erosion and threaten the south pier. Lining of these structures should be scheduled as early as funding is available to avoid further damage, but they are not at risk of failure.
6. The tunnel will likely sustain for some time without failure unless there is an earthquake. The potential damage from failure is high, but the probability of failure in the next few years is relatively low. Lining the tunnel within the next 5-6 years would be advisable.

Table 13. Summary of costs for rehabilitation or replacement of seven structures on the Carbon Canal

Project	Construction	Mobilization	Engineering and Project Management	Contingency	Total Estimated Cost
Garley Wash Flume	$11,244	$675	$2,980	$2,249	$17,000
Tunnel	$268,200	$15,800	$71,000	$39,500	$395,000
Gordon Creek Flume	$72,400	$4,300	$19,200	$14,500	$110,000
Pinnacle Wash Repair	$11,500	$700	$3,100	$1,700	$17,000
Pinnacle Wash Replace	$241,200	$14,500	$63,900	$36,200	$356,000
Drunkard's Wash Flume	$72,800	$4,400	$19,300	$14,600	$111,000
Olsen Undershot	$30,700				$31,000
Miller Creek Flume	$73,100	$4,400	$19,400	$14,600	$112,000
Total	$781,144	$44,775	$198,880	$123,349	$1,149,000