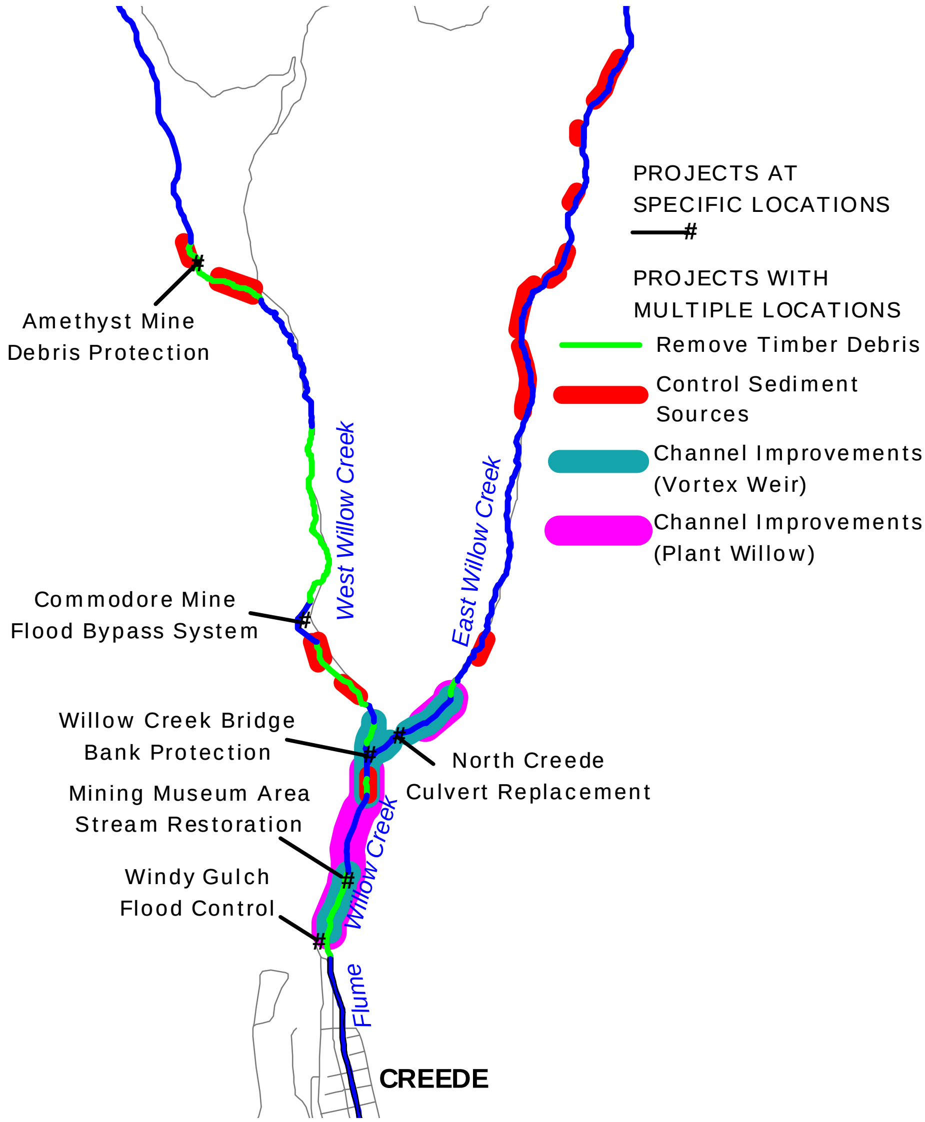
Section 3 – Alternate Mitigation Strategies

3.1 Overview

This section presents alternate mitigation strategies to address problems that were identified in the study of the Upper Willow Creek watershed. Figure 3.1.1 shows the location of potential projects. Preliminary designs and approximate cost estimates were developed for a number of projects. It should be stressed that the designs presented here are only preliminary and are meant to initiate a process of project consideration and prioritization. Designs are not meant for construction purposes.

Approximate cost estimates were developed using the 2002 Construction Cost Data manuals published by the RSMeans Company (RSMeans 2002). Material, labor, and equipment costs were adjusted to costs more appropriate to southwestern Colorado using procedures recommended in the manuals. It should also be stressed that costs are very approximate and meant only to help initiate the process of project consideration and prioritization.

Figure 3.1.1. Locations of Potential Mitigation Projects



A contingency of 20% was added to each project cost to account for unforeseen costs and changes during final design and construction but still provide as accurate of an overall cost estimate as possible. However, it should be noted that many conceptual level studies use a contingency rate as high as 50%. The WCRC may want to consider higher contingency rates if these approximate cost estimates area are used to apply for grants prior to final design.

Eleven categories of specific projects are examined in Section 3.2 through 3.12 as follows:

3.2 Windy Gulch Culvert
3.3 Mining Museum Area Flood Protection
3.4 North Creede Culvert
3.5 Commodore Mine Flood Bypass System
3.6 Commodore Mine Debris Protection
3.7 Amethyst Mine Debris Protection
3.8 Timber Debris
3.9 Timber Debris below Commodore Mine
3.10 Bank Protection below West Willow Bridge
3.11 Channel Improvements
3.12 Sediment Source Controls

3.2 Windy Gulch Culvert

As discussed in Section 2.2.2 of this report, the hydrologic information available for Windy Gulch is somewhat uncertain. A simple watershed area ratio using hydrology determined for the much larger West Willow Creek suggests a 100-year flood level of 57cfs. A recent study for the Homestake Mining Company's Bulldog Mine Reclamation Project by Water Management Consultants used an SCS curve number and rainfall/runoff model approach to estimate flood levels in the Windy Gulch watershed. This study suggested a 100-year flood level of 239cfs. In section 2.2.2, it was suggested that the rainfall/runoff approach may better represent a possible large thunderstorm event that could be able to cover nearly the entire watershed. Therefore, the rainfall / runoff approach is considered to be the more appropriate of the two procedures. However, additional study of the hydrology of Windy Gulch is needed to determine accurate flood flow levels.

But, in any case, the 2.5 ft by 4 ft metal culvert that conveys flow from Windy Gulch, under the Bachelor Loop road, to Willow Creek just above the flume approach levees is severely undersized. Using either hydrologic analysis approach, the culvert cannot pass the 10-year flood. The 100-year flood from the ratio method, and the 10-year flood from the rainfall/runoff method will cause flooding of the Fire Department Tunnel and direct some flow down the road into downtown Creede.

As the Windy Gulch watershed has the potential to flood downtown Creede, it may be important for flood insurance and flood protection reasons to ensure that the 100-year flood can be passed safely. In order to pass the 100-year flow indicated by the ratio method (10-year flow from the rainfall/runoff method), a 6-foot wide by 2-foot tall culvert would be required. However, to pass the 100-year flood predicted by the rainfall-runoff hydrologic analysis, a 12-foot wide by 12-foot tall culvert would be required. Obviously, the two different methods of hydrologic analysis indicate quite different measures necessary to protect Creede from a 100-year flood of Windy Gulch. Due to these differences, conceptual designs for both levels of flooding follow. Before further consideration is given to structural work at the Windy Gulch road crossing, it is strongly recommended that the questions about flood hydrology be resolved.

3.2.1 Option 1: Protection of 57cfs Flood

Replacement of the current Windy Gulch culvert with a larger culvert would allow conveyance of the 57cfs flood (100-yr ratio method / 10-yr rainfall/runoff method). The current elevation of the asphalted roadway restricts headroom for circular or elliptical culverts. Therefore, a concrete box culvert may be the best solution. The 57cfs flood can be conveyed by a 6-foot wide by 2-foot high concrete box culvert with bottom inverts placed at the current inverts of the metal culvert and concrete wing-walls placed at 30 to 75 degrees to the flow line. The following figure displays a plan view schematic of the box culvert.

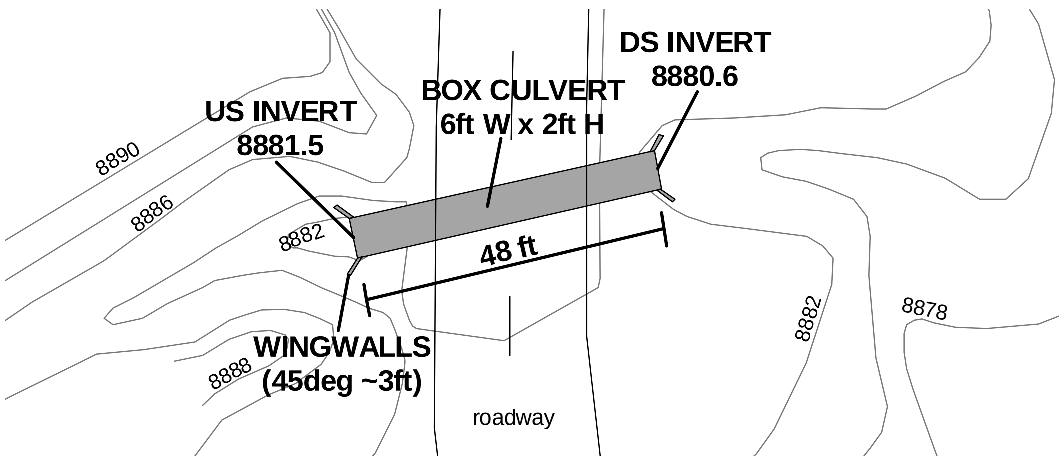


Figure 3.2.1. Windy Gulch 57cfs box culvert plan view

The current metal culvert is 43 feet long. A 48-foot culvert length was used to develop a rough cost estimate. 45 to 75 degree angled headwalls were assumed in the hydraulic calculations to ensure relatively low entrance and exit hydraulic losses, and should be used in construction in order to maximize flood conveyance. The following table includes approximate costs for installation of the box culvert. The total cost would be approximately $25,000.

Table 3.2.1. Approximate box culvert costs for 57cfs flood at Windy Gulch

Item	Quantity	Unit	Cost
R.C. Box Culvert, 6' x 3' (8' section)	48	L.F.	$9,495
Box Culvert set up charge at plant	1	each	$3,240
R.C. Wingwalls, 3' long, 2' foundation	4	each	$6,774
Trench Excavation / Backfill, 1:1 slope	48	L.F.	$1,011
Pipe Bedding, compacted sand	48	L.F.	$662
Remove Asphalt	28	S.Y.	$116
Asphalt Patch	250	S.F.	$542
Total Cost			$21,841
Total Cost (Subtotal*20%) Rounded			$25,000

3.2.2 Option 2: Protection of 239cfs Flood

As previously mentioned, a 12-foot wide by 12-foot tall culvert would be required to pass the 100-year flood of Windy Gulch predicted by the rainfall-runoff hydrologic analysis. This size culvert is obviously not feasible at this location given area and roadway constraints. The only feasible option may be to re-design a system to pass floods over the top of the roadway without allowing water to flow south towards downtown Creede or north towards the Fire Department Tunnel.

The following figure shows a possible cross-section view of the road centerline designed to pass the 239cfs flood. The vertical scale in the figure is exaggerated. At least a 2' high ridge is required to contain flood flows. Unfortunately, this dip will create an awkward road design. A steep 20% slope will be created over a 10-foot length. The road up to the culvert level will have to be increased from the current 5.5% slope to an 8% slope for about 90 feet. Vehicles should be able to maneuver satisfactorily over these steep but short slopes. However, the slopes may exceed county road standards, and further design consideration will be warranted. The 6ft by 2ft box culvert as designed in Option 1 could also be installed to effectively pass small floods and avoid blocking the Bachelor Loop road except during exceptionally high floods.

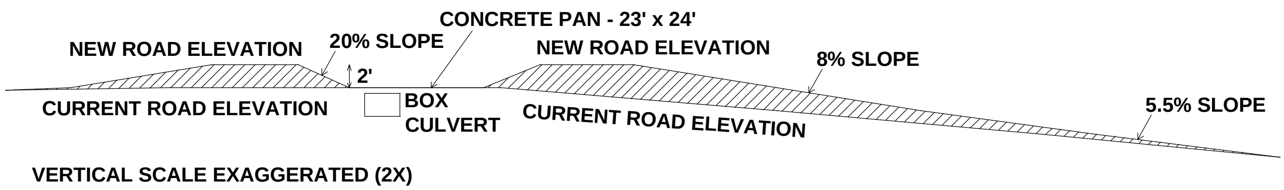


Figure 3.2.2. Roadway centerline plan view of Windy Gulch flood overflow

Figure 3.2.3 shows results of a HEC-RAS analysis of the proposed configuration at the entrance to the culvert using the rainfall/runoff hydrology. Water surface elevations for Windy Gulch at this location show that the levee on the south side of the channel bed must be raised from the current elevation of about 8884 to an elevation of at least 8886 to direct flood waters from the 100 year flood to the concrete pan.

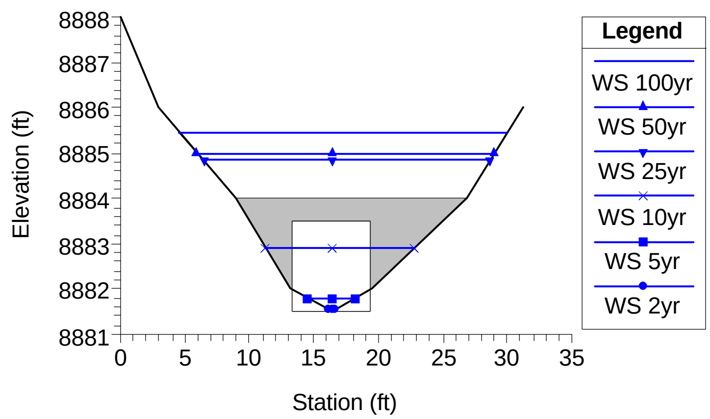


Figure 3.2.3. Water surface elevations at US section of Windy Gulch box culvert / pan

The figure on the following page shows a plan view of the possible floodway design. Current topographic elevations are indicated with light gray lines, and dark black lines indicate re-designed topographic contours. The re-designed topography would contain flooding to the north and the south and direct waters from Windy Gulch into the flume forebay. The roadway must be elevated above its current level for about 220 feet. Concrete pavement with a thick upstream footer should be placed within the floodway area itself.

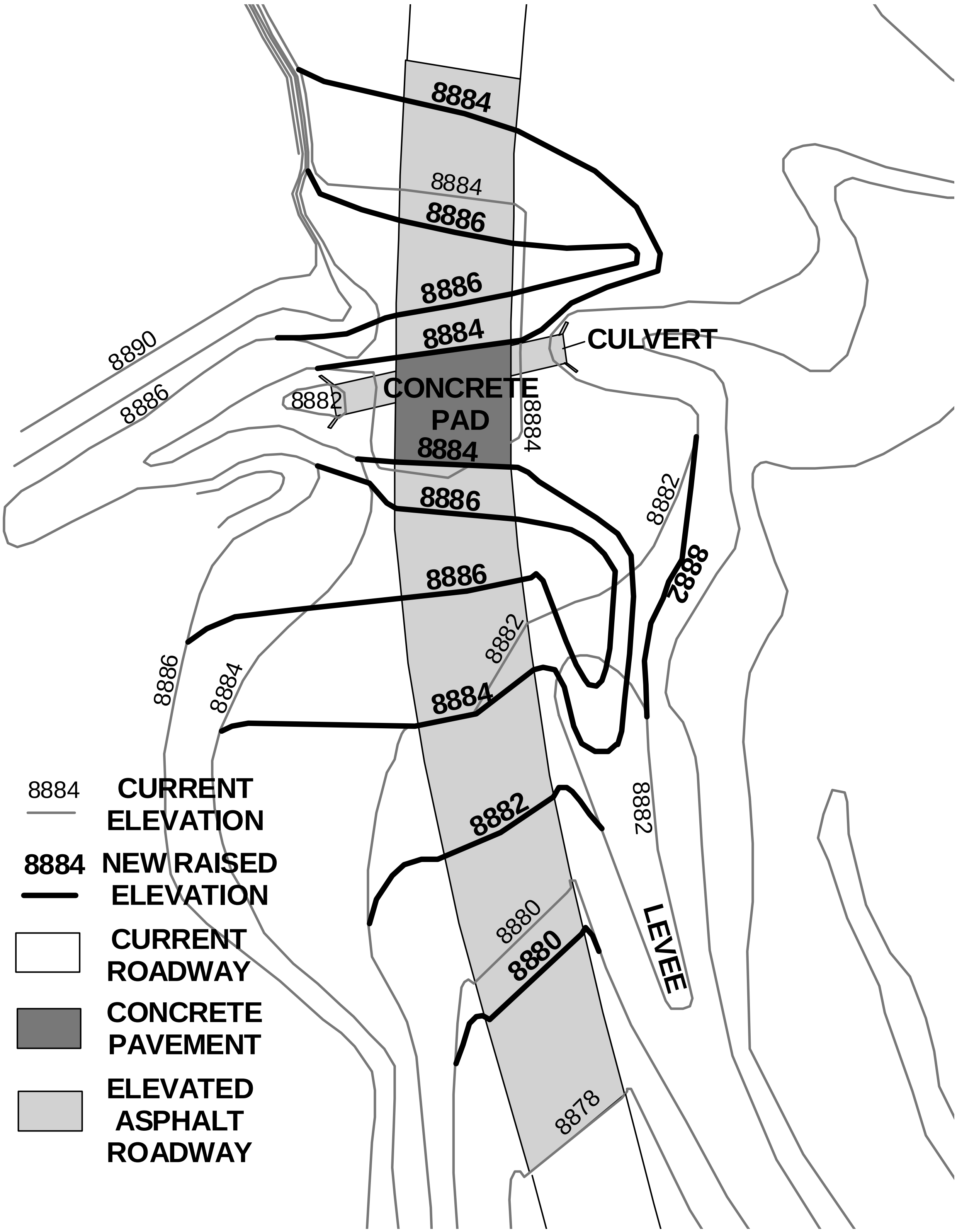


Figure 3.2.4. Plan view of Windy Gulch flood overflow

The topographic re-design would also allow for a short raising and continuation of the Army Corps levees for the flume entrance. This will allow the freeboard of the 100-year flood in Willow Creek to be raised from less than 3 feet at the tip of the levees to more than 3 feet at all locations within the flume forebay. In essence, a similarly designed project should protect downtown Creede from upstream flooding by Windy Gulch at the 100-year level and should also help meet the Army Corps 100-year flood 3-foot freeboard requirements in Willow Creek. As the study by Yochum (2002) found that the concrete flume should be able to pass the 100-year flood level, this should help satisfy the requirements necessary to remove downtown Creede from the 100-year floodplain delineation.

The following table presents a cost estimate of the Windy Gulch flood overflow passage for a 239cfs flood. The project should cost roughly $60,000.

Table 3.2.2. Approximate cost of Windy Gulch culvert flood overflow

Item	Quantity	Unit	Cost
Asphalt Roadway, 4" thick, 12" gravel base, 24' wide	220	L.F.	$18,939
Concrete Pavement, 6" thick	61	S.Y.	$1,310
Excavate / Haul Fill	587	C.Y.	$3,791
Place / Compact Fill	587	C.Y.	$2,535
Grading, Roadway	1389	S.Y.	$3,893
R.C. Box Culvert, 6' x 3' (8' section)	48	L.F.	$9,495
Box Culvert set up charge at plant	1	each	$3,240
R.C. Wingwalls, 3' long, 2' foundation	4	each	$6,774
Trench Excavation / Backfill, 1:1 slope	48	L.F.	$1,011
Bedding, compacted sand	48	L.F.	$662
Remove Asphalt	28	S.Y.	$116
Total Cost			$51,766
Total Cost (Subtotal*20%) Rounded			$60,000

3.3 Mining Museum Area Flood Protection

Flow at the 25-year return flood return level will overtop the wood and earthen weir at cross-section 14. The push-up levees holding the stream against the east side of the canyon will actually keep floodwaters from re-entering the stream channel, and the overtopping flow will flow down a long depression, through the small pond, and into the parking area in front of the mining museum. The 100-year flood should come just to the edge of the Bachelor Loop road. A slightly larger flood close to the flume capacity will cause flooding of the Mining Museum and the fire department tunnel.

These calculations assume that the weir will not fail during overtopping. Failure of the earthen weir during overtopping may cause flooding of the Mining Museum and fire department at floods close to the 25-year return level. In addition, the hydraulic analysis assumes that the earthen pushup levees containing the stream channel along most of the reach will not fail during high flows. These levees are about 20 feet wide on the south end of the reach and 30 feet wide towards the north end of the reach. They consist of local gravels and cobbles and are not constructed to typical levee construction standards. During high flow events, the levees must be watched periodically and often "re-pushed" up. Therefore, it could be quite likely that the levees will fail and the Mining Museum and fire department tunnel will be flooded at flood levels much smaller than suggested by the hydraulic analysis.

Finally, although channel slope decreases somewhat in this reach in comparison to upper reaches, there still exists a potential to transport large volumes of sediments through the reach and into the concrete flume. Some sediment will deposit in the areas above cross-sections 3 and 14. However, the capacity of these areas is limited, as a large amount of sediments has already accumulated. To protect the "sinuous channel" that has been designed downstream of the flume, and to protect the flume itself, it may be important to take measures to decrease the potential to transport sediments through the Mining Museum reach into the flume.

The potential reconstruction of the channel reach also presents the opportunity to improve the aesthetics and health of the stream reach and increase both recreational and habitat values. Aesthetically, the stream in this reach does appear to be degraded by both past mining activities and by the current containment to the far east side of the canyon to maximize parking area. In contrast, the canyon walls around the stream are breathtaking. The area is visited by a large number of "tourists", and could potentially be restored to a more beautiful and functional state that could even draw additional tourism. Improvements in upstream water quality may someday allow fish to return to this area, and fish habitat could be improved in the reach.

Two options were considered to address problems within this reach. First, the simplest and cheapest option to fix only the weir-overtopping problem at cross-section 14 was considered. This option will not address the other problems listed above. Secondly, a more comprehensive approach to restore the entire stream reach from the flume entrance to cross-section 15 was considered. This second approach will address all of the problems (and opportunities) listed above. The proposed design was intended to begin a consideration of the restoration of the reach. However, further exploration of the priorities and needs of the community as well as available funding may be needed in order to design the most appropriate restoration.

3.3.1 Option 1: Widening of XS14 Weir

The mouth of the weir at cross-section 14 could be widened to pass high flood levels. This would be the simplest and cheapest option to deal with potential flooding problems due to the weir.

The following figure shows a plan view of a potential widening of the weir. The timber low flow opening of the weir could be left at its current width. However, at a height of about 2 feet above the wooden weir (8908), the earthen weir could be widened about 30 feet to the west and 12 feet to the east (to the cliff bank). The levee would also have to be moved west and reshaped to match the widening. This configuration would allow high flows to overtop the weir and flow back into the main channel area.

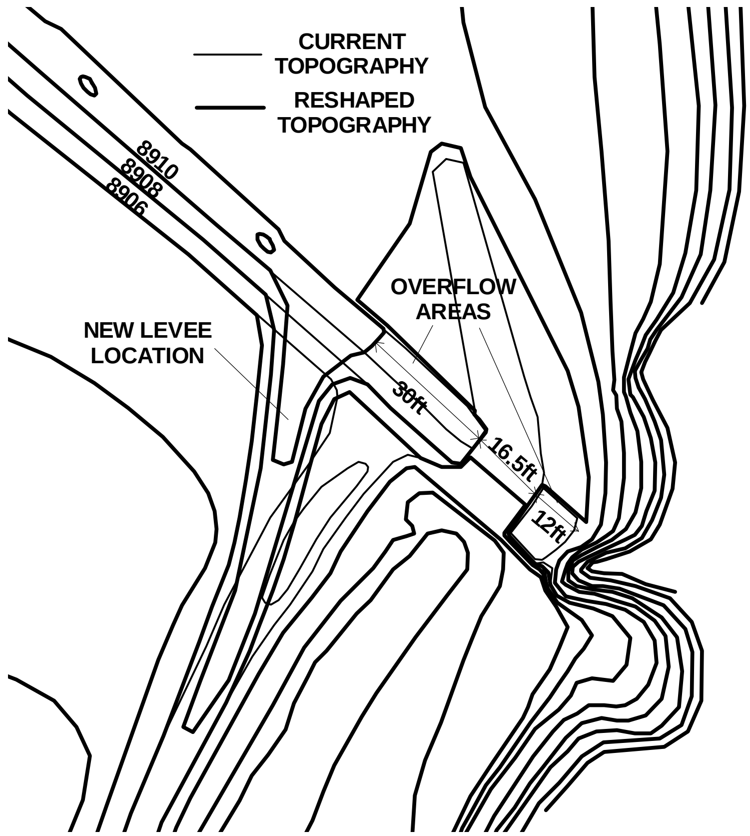


Figure 3.3.1. Widening of XS14 weir

The next figure shows results from a hydraulic analysis of the widened weir configuration. Overtopping into the overflow areas will initiate at the 1.25-year flood, but even the 1800 cfs flood should be contained within the widened area. The depth at flood stage should encourage deposition of large sediments in the current sedimentation area behind the weir.

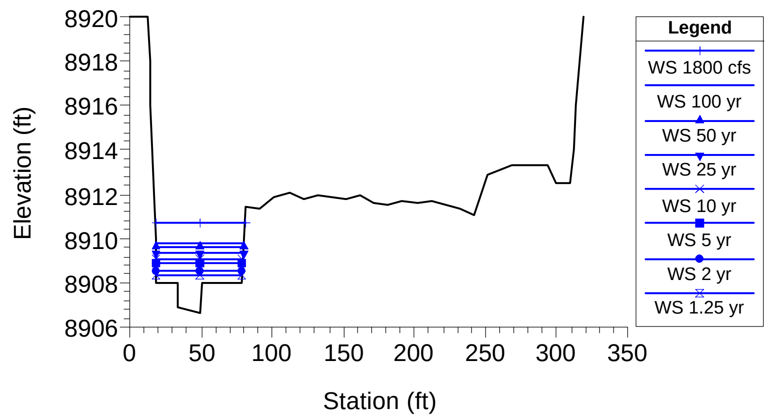


Figure 3.3.2. HEC-RAS analysis of widened XS14 weir

The overflow areas will act similarly to dam spillways at high flow. As such, the overflow areas should be faced with a material that will resist erosion. Concrete would be the most effective facing material. However, timber or boulder facing may be more appropriate to match the character of the area. The following table lists approximate costs to widen the weir at XS14. The construction should cost approximately $15,000.

Table 3.3.1. Approximate cost to widen XS14 weir

Item	Quantity	Unit	Cost
Excavation and ReSpread - Backhoe	348	C.Y.	$2,046
Compaction	348	C.Y.	$360
Grading	156	S.Y.	$436
Boulder facing	67	S.Y.	$10,067
Total Cost			$12,909
Total Cost (Subtotal*20%) Rounded			$15,000

3.3.2 Option 2: Stream Restoration from Flume to XS15

A more comprehensive approach than Option 1 is needed to address the range of problems discussed in the beginning of this section. Rather than focusing on only one problem, a "restoration" of this stream reach could improve stream function, flood control, and aesthetics together. An example of a stream restoration approach was designed to address the problems detailed in the reach. The goals considered in the design include:

- Stop flooding outside channel area at flume capacity flood level
- Reduce reliance on push up levees for flood containment
- Reduce downstream sediment transport (using sedimentation basins)
- Reduce downstream sediment transport (by reducing shear stress)
- Improve stream aesthetics
- Improve recreational access to stream
- Retain maximum area for parking
- Retain "hockey rink" pond

The proposed design was intended to be a first step to a final restoration design of the reach. Further exploration of the priorities and needs of the community as well as available funding may be needed in order to design the most appropriate solution.

The following figure presents an overall plan schematic of the proposed stream design. The inundation of the 100-year flood from HEC-RAS analysis is also shown on the map. The 100-year flood should be contained within the channel area and flow from Willow Creek should not affect the Mining Museum or fire department tunnel. The design should also pass a larger flood flow (1800cfs) at the maximum flume capacity.

Push-up levees will not be needed to retain flood flows at the north and south ends of the reach as they are now. A small levee area will be needed to keep flow from entering the small pond currently used as a community "hockey rink" in the winter.

The stream reach has been designed to have a 2% channel slope. This is within the slope range for a Rosgen B3 type channel that is probably most appropriate in this location. The stream course would be reshaped to have a gently meandering flowline. A possible bike trail / walking path is also designed and passes within a wider floodplain within the channel area that will lower shear stress at high flows above bankfull depth. Small areas of willow could be planted at several points along the channel edge.

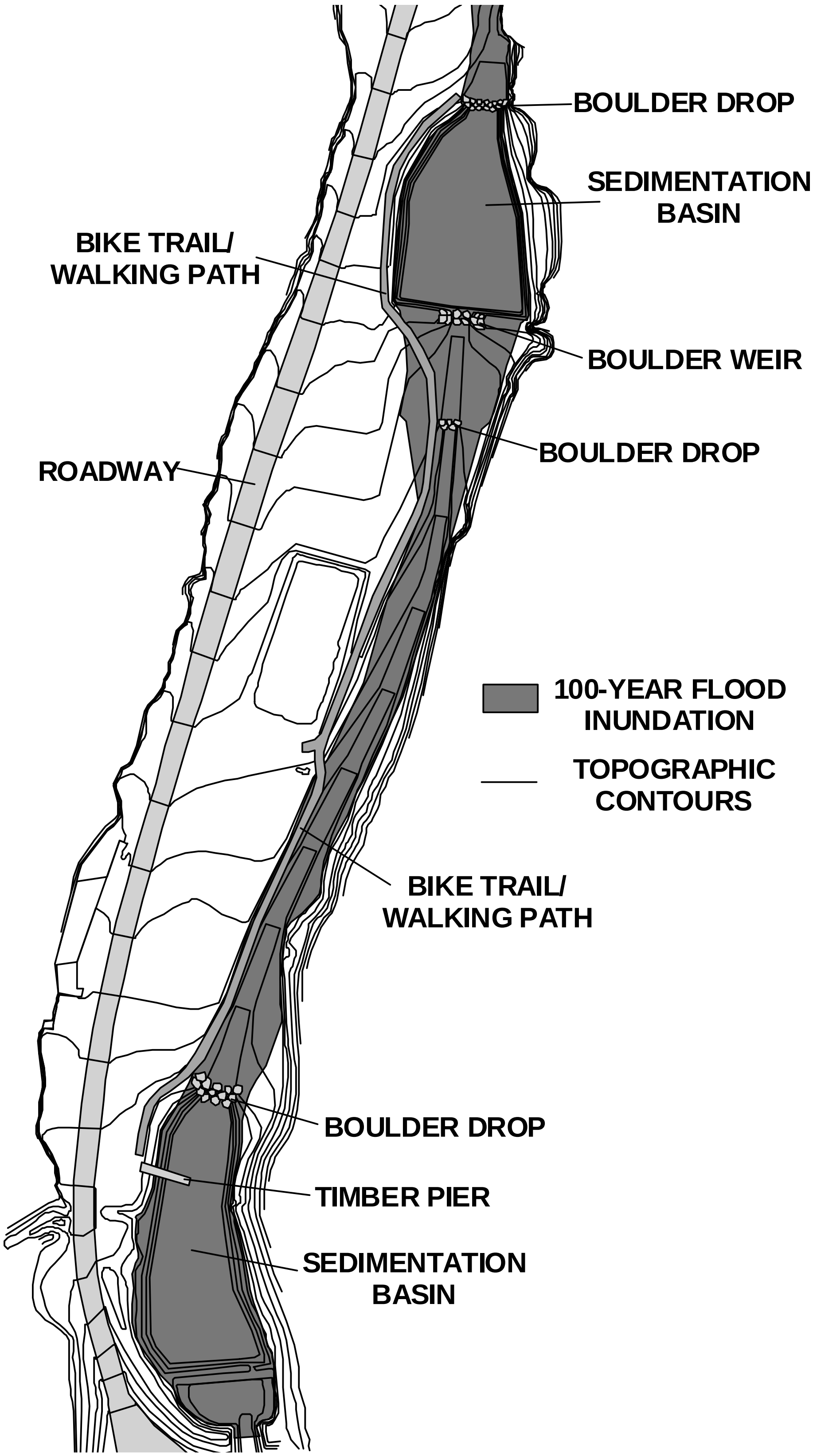
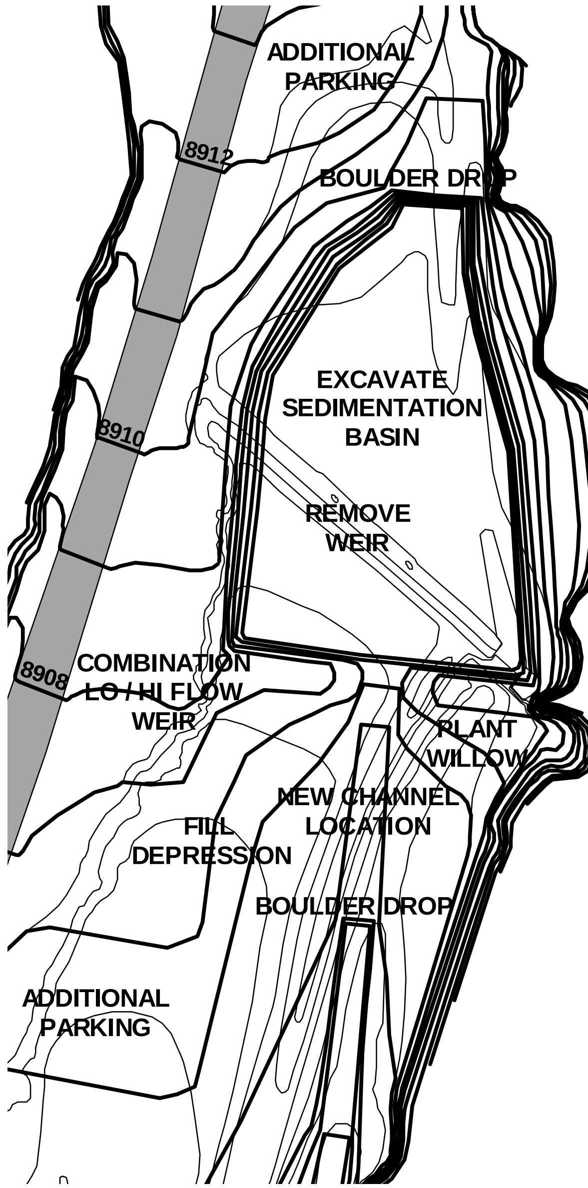


Figure 3.3.3. Overall plan view of XS1 to XS15 stream restoration

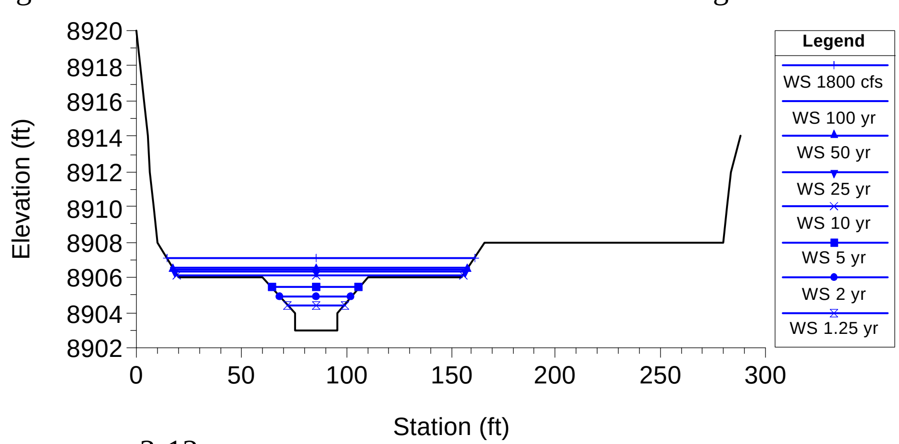
The following figure shows a closer view of the north end of the reach. Reshaped topographic contours are shown as dark lines, while current topographic contours to be changed are showed as light lines. To retain clarity, flood inundation levels and the bike trail alignment are not shown.



The design would remove the angled earthen weir and replace it with a shorter weir that would be more perpendicular to flow lines. Behind the weir, a sedimentation basin would be excavated that would have a permanent water level. Most sediments traveling into the reach would be deposited in the basin. This basin will accumulate sediments faster than a dry sedimentation basin like the current basin, and will, therefore, require re-excavation more often, but the permanent level “pond” will be more attractive than a large dry area of gravels.

The combination weir design would maintain flow depth at low flows, and would also be able to pass large flood flows. The next figure shows a cross-section of the weir looking downstream and flood levels from HEC-RAS. Low flows would flow through a 20-foot wide by 1-foot tall area. Floods up to the 10-year level would be passed through a sloping weir area with a top width of 50 foot and a depth of 3 foot. Larger floods would be passed over a flat portion on top of the weir. The floodplain area below the weir could be shaped to direct flows that overtop the weir back into the main channel.

(above) Figure 3.3.4. Plan view north end of stream restoration
(below) Figure 3.3.5. Flood levels over combination weir looking D/S



The low and mid flow levels of the weir could be built with large boulders to create a cascading natural “waterfall” drop out of the pond. The upper portion of the weir will act similarly to a dam spillway at high flow and, therefore, should be constructed to resist erosion. If the bike trail is constructed of asphalt, this asphalt could be continued on the weir top. Alternatively, boulders or heavy timbers could be used to face the top and sides.

The current weir forces the stream against the far east side of the valley. The proposed design would reshape the main channel to exit at the center of the weir. This would create a more natural flow line and meander for the stream. The small space to the east would be contoured for weir overflow, so large obstructions should not be placed in the area. However, this may be an opportune spot to plant small willows. The current large depression to the east of the roadway would be filled to create the channel contouring and could also provide a large area of additional parking. The filling of the area would remove the need for push up levees. The parking area could be used for access to the bike trail and restored stream area as well as access to the "hockey rink" pond and the Mining Museum. Some additional parking could also be gained at the northwest end of the sedimentation basin.

A large boulder wall is designed to drop water into the sedimentation basin, and a boulder drop (vortex weir) could be used to drop grade 2 foot about 110 feet downstream of the weir. Large boulders will be needed for the construction of the drops (3-4 foot diameter), but they can be arranged to create natural looking cascades.

The following two figures show closer views of the mid and south sections of the stream design.

In order to eliminate the push up levees and control the channel overtopping that will currently occur during high flows at cross-section 8.5, it is envisioned that the old timber weir at this location (XS8.5 – XS9) will be removed, the 2% channel bed slope will be extended, and the channel bed above this location will be deepened. As this may lower the elevation of the local water table in the immediate area, the nearby "hockey rink" pond may also have to be deepened.

It is also proposed to create a wider floodplain shelf within the channel overbanks of at least 20 foot. A relatively small main channel should be designed to maintain depth at low flows. However, high flows above about the 2-year flood level should spill into a wider floodplain area. In addition to increasing flood capacity of the main channel, this will decrease shear stress at high flows and therefore decrease sediment transport, mobilization of cobbles within the channel bed, and bank erosion.

Currently in the south section of the reach, a small "peninsula" separates a basin above the flume and a small pond. Water from the Mining Museum tunnels drains into this pond before flowing into the stream. An old timber weir and the peninsula will cause backwater during high floods to flow across a depression in the road to the entrance of the fire department tunnel. The proposed design calls for excavation of the main basin as well as the peninsula and small pond to form one large sedimentation basin that will stay filled with water. This basin should stop sediments from entering the flume, and the configuration will prevent backwater flooding of the fire department tunnel.

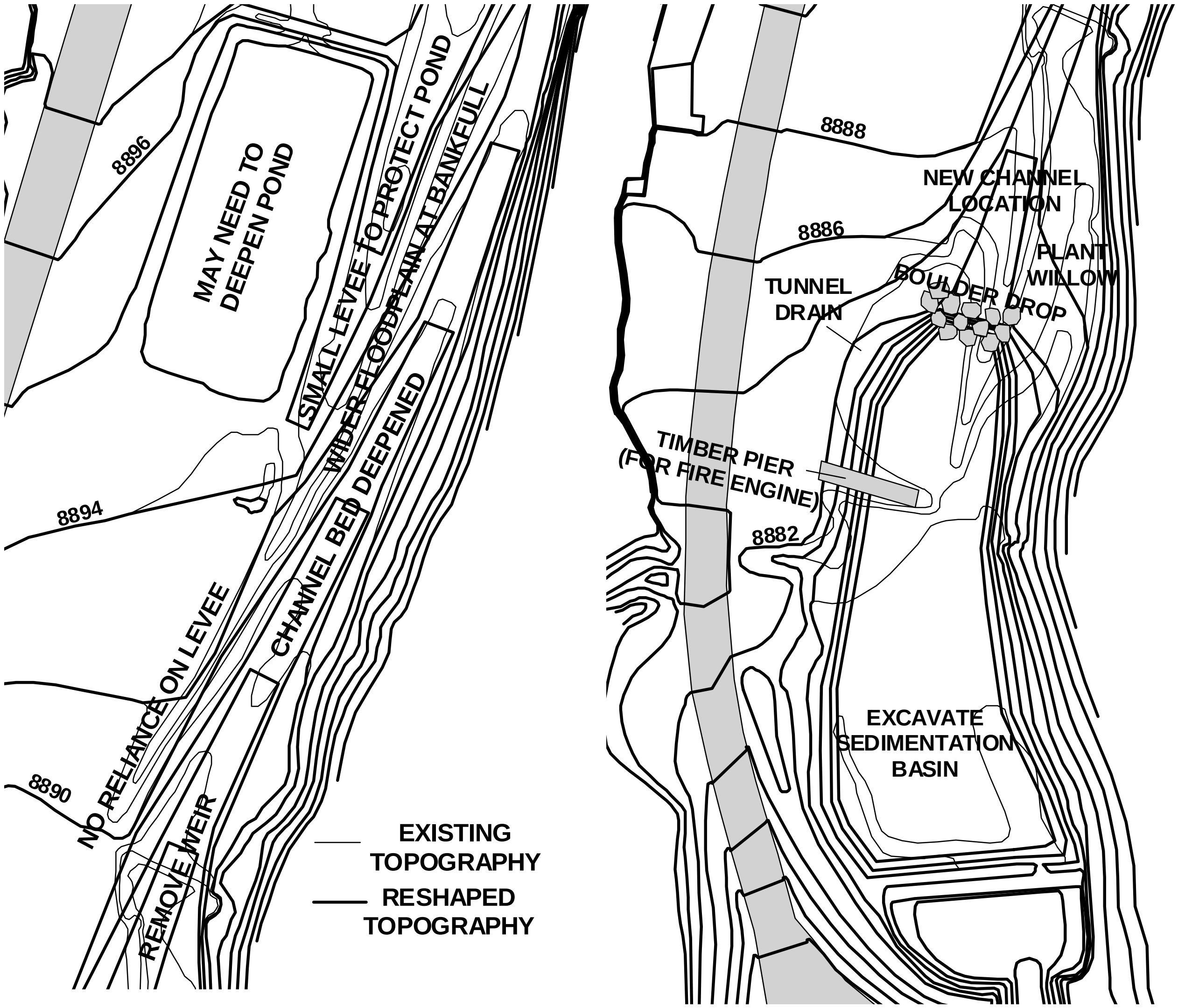


Figure 3.3.6. Plan view of mid section (left) and south end (right) of stream restoration

The current channel from cross-sections 6 through 9 could be realigned to form a more gradual curve through the reach. The reshaping would remove a small portion of the current parking area. The area to the east of the new channel alignment could function as additional floodplain space, and could also be planted with willows. A large boulder drop could be built to create a waterfall that would cascade into the basin.

The peninsula is currently used to help park fire department vehicles in the tunnel. If this area is still needed, a pier capable of supporting heavy vehicles could be designed. A pier could also be a recreational amenity where visitors could look over the lake, waterfall, and restored stream area. Construction of the pier with heavy timbers would match Creede’s mining character.

As mentioned before, this design may be just an initial suggestion for a stream restoration design. Therefore, it was not necessary to develop an extremely detailed cost estimation at this time. However, the following table shows very approximate costs for the design as detailed here. A stream restoration of this type would cost approximate $350,000.

Table 3.3.2. Approximate cost for XS1 to XS15 stream restoration

Item	Quantity	Unit	Cost
Cut - Bulk Excavation / 1 C.Y. Crawler mtd. Backhoe	32622	C.Y.	$53,037
Fill - Spread Dump by Dozer	16785	C.Y.	$29,123
Hauling	15837	C.Y.	$43,751
Grading	66667	S.Y.	$51,026
Bike Trail / Walking Path - 5' width, 1.5" Asphalt, 6" gravel	1440	L.F.	$16,049
Boulder Drop	4	each	$39,450
Timber Pier	600	S.F.	$39,887
Replace river cobble, top 1'	1630	C.Y.	$22,402
Total Cost			$294,725
Total Cost (Subtotal*20%) Rounded			$350,000

3.4 North Creede Culvert

The culvert on East Willow Creek at the community of North Creede is severely undersized for flood flows. Overtopping of the culvert initiates at about the 1.25-year flood level, and flooding of structures could occur during a 5-year flood. A bend in the culvert and its small size makes it extremely susceptible to debris plugging. The culvert exists to allow access to one log cabin on the south side of East Willow Creek. Flooding periodically causes damage to the roadway, and large floods will damage at least two surrounding structures.

Hydraulic analyses highlighted the severe constriction from the current 5.5-foot diameter metal culvert. In order to safely pass the 100-year flood, a space of about 24 foot wide by 6 foot tall is required. Installation of a culvert or bridge of this size that would be able to pass a 100-year flood would be quite expensive. Considering that damage at North Creede should not increase damage to downtown Creede and that road culverts further upstream are also undersized to pass a 100-year flood, perhaps consideration of 100-year flood protection only is not justified. The town council, interested citizens, property owners in North Creede, and possible funding agencies will need to weigh project cost versus risk of damage and the desired level of flood protection. Therefore, various levels of flood protection were analyzed to facilitate this decision making process.

Several basic options could be considered to increase flood protection including installation of a larger culvert or a bridge to still allow vehicular access to the cabin, construction of retaining walls and a small foot bridge to allow continued access to the cabin but not support vehicles, or removal of the cabin structure and restoration of the stream to a more natural width and course.

Construction of a reinforced vehicular concrete bridge was considered. However, due to the long retaining walls that would still be required in addition to the bridge construction cost, a concrete bridge solution did not appear as cost effective as a culvert solution.

Several configurations of culverts were considered. Circular corrugated metal pipes are typically the cheapest solution for a road culvert and are used extensively. However, the circular design often limits capacity to available headroom. A double circular pipe configuration would be required to pass even the 5-year flood at North Creede given headroom limitations. Multiple pipe configurations are quite susceptible to debris plugging at large flows. Corrugated pipe can be distorted into an elliptical or arched shaped to increase flow capacity somewhat given headroom limitations. Both circular and arched corrugated metal pipes are susceptible to rust when constantly in contact with water (particularly acidic water such as in Willow Creek), and, although inverts can be protected with bituminous or cement coatings, use for higher levels of flood protection may be inappropriate given limited design life. The top half of a corrugated metal arch can be “keyed” into a concrete foundation with a bed of natural stream materials that may help pass any resident fish populations. This open bottom arch can convey larger flood levels than pipe culverts given headroom limits, and is less susceptible to rust damage. A pre-cast concrete arch such as the pre-designed CONSPAN systems could also be used. Concrete arches can be quite attractive, and their design life is longer than corrugated metal. However, higher cost may limit its use to the highest flood protection levels. Finally, concrete box culverts can also be used. Box culverts are often an effective solution to deliver higher capacities with relatively low headroom, are designed to support vehicular loads, and have a high design life.

The following table details culvert size and culvert and excavation cost per lineal foot for different culvert types given various flood protection levels. A suggestion for the most effective option for each flood return level is indicated with gray shading. At the 5-year level, corrugated pipe options are most cost effective. Although slightly more expensive, one 10.9ft by 7ft pipe arch was considered more desirable than two 6ft circular pipes as the two circular pipes would be much more susceptible to debris plugging. The 10.9ft by 7ft pipe may push headroom limits somewhat and force the roadbed to be raised by about a foot near the culvert inlet. For the 10 to 50 year flood levels, a corrugated metal open bottom arch was considered to be the most desirable option, as it is much cheaper than the concrete box or arch options and more hydraulically efficient and attractive than double or triple pipe options. At the 100-year flood protection level, a 24ft by 6ft pre-cast concrete open bottom arch may be the most desirable option. Although double concrete box culverts would be slightly cheaper, a concrete arch would be much more aesthetically pleasing and better restore stream functionality given the large expense of this level of protection.

Table 3.4.1. Comparison of culvert option costs per lineal foot

Flood Level	Concrete Box Culvert		Concrete Open Bottom Arch		Corrugated Metal Open Bottom Arch		Corrugated Metal Pipe Arch		Corrugated Metal Pipe	
	Size	$/L.F.	Size	$/L.F.	Size	$/L.F.	Size	$/L.F.	Size	$/L.F.
100yr	2 - 12' x 6'	$1,092	24' x 6'	$1,153						
50yr	2 - 10' x 6'	$934	20' x 6'	$995	20' x 6'	$454	2 - 10.9' x 7'	$540		
25yr	2 - 8' x 6'	$629	16' x 6'	$690	18' x 6'	$417	2 - 8.8' x 6'	$428	3 - 6'	$390
10yr	12' x 6'	$547	12 x 6'	$609	14' x 6'	$342			2 - 7'	$318
5yr	10' x 6'	$469			12' x 6'	$305	10.9' x 7'	$272	2 - 6'	$261

The following figures provide plan view schematics of the culvert solutions indicated above for various flood return intervals. One schematic displays the 5-yr to 50-yr solutions as differing shades of gray. For all of these options, it is most cost effective to extend the culvert length to about 88 foot similarly to the current length rather that use longer retaining walls. About 40 foot of retaining wall will need to be replaced / extended on both sides upstream of the culvert, and an additional retaining wall should also be used to protect the roadway downstream of the culvert on the north side. A schematic is also included for the 100-year protection option. In this case, longer retaining walls are cheaper than extending the length of the concrete arch. A length of 40 foot was chosen. A large rock exists on the north side of the roadway near the middle of the culvert that forces the roadway south. The culvert should probably be located across from this rock to avoid road width constriction as much as possible.

The following table estimates total project costs for the “most effective” culvert solution for each of the return intervals. Culvert sizes, lengths, and headwall lengths that were considered are detailed. The retaining walls were priced as a wooden tie wall. The wall will vary between 5 and 10 foot; averaging about 8 foot tall. The wall is designed with ½ inch treaded rod on , “deadman” timbers placed every 6 foot, and crushed gravel and drainage pipe placed behind the wall. Different mine cribbing construction techniques could be considered, although walls must be designed to resist large floods. Pressure treated wood was priced. Local wood sources with wood preservative treatments may be more cost effective.

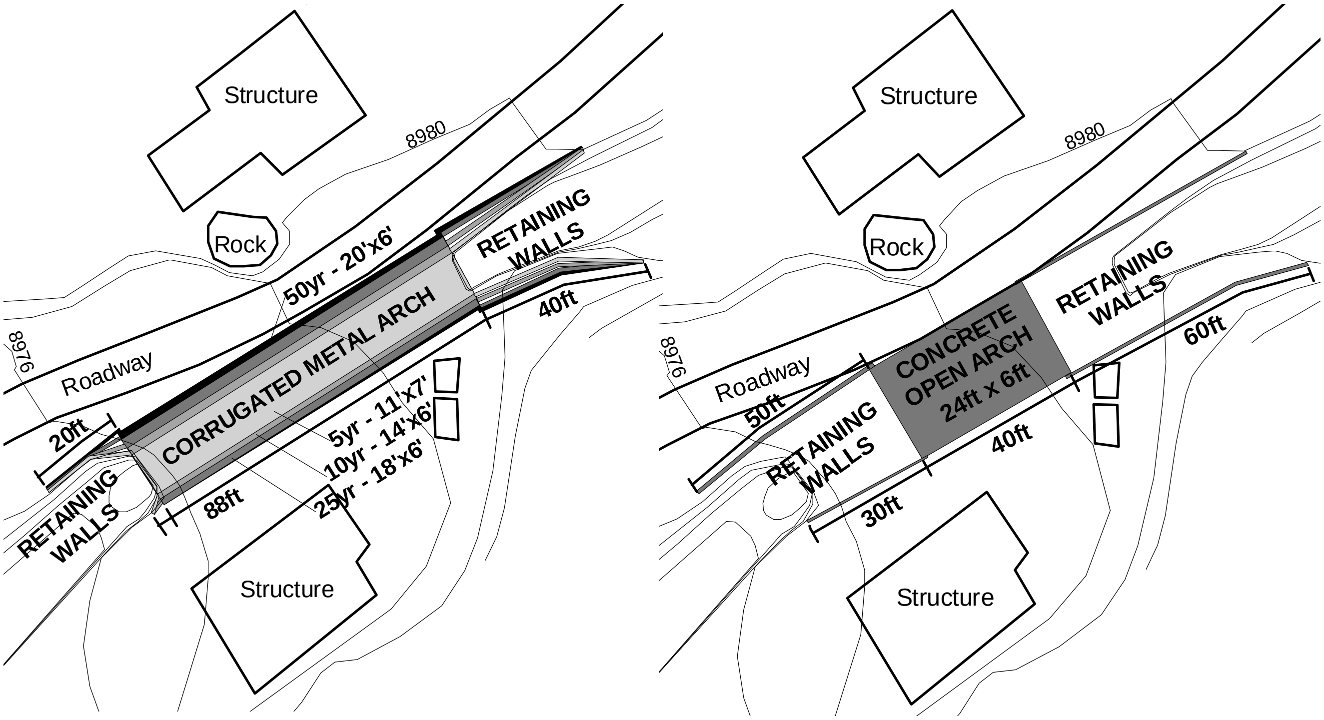


Figure 3.4.1. North Creede culvert replacement options, 5-50yr(left) and 100yr (right)

Table 3.4.2. Approximate cost of North Creede culvert replacement options

Flood Level Protection	100yr	50yr	25yr	10yr	5yr
Culvert Type	Concrete Arch	Corrugated Metal Open Bottom Arch			Corrugated Pipe Arch
Size	24' x 6'	20' x 6'	18' x 6'	14' x 6'	10.9' x 7'
Culvert Length	40	88	88	88	88
Retaining Wall Length	200	100	100	100	100
Culvert + Excavation/Backfill Cost	$46,113	$39,961	$36,710	$30,129	$22,966
Retaining Wall Cost	$27,375	$10,304	$10,304	$10,304	$10,304
Headwall	$8,212	$8,212	$8,212	$6,570	$5,338
Total Cost	$81,700	$58,478	$55,226	$47,003	$38,608
Total Cost (Subtotal*20%)	$100,000	$70,000	$65,000	$55,000	$45,000

Total project costs using different culvert types would range from about $45,000 for the 5year flood protection option to about $100,000 for the 100-yr flood protection option. Fairly cheap construction methods were considered for these estimates. Possible relocation of any buried utilities (sewer, water, electric) may add significantly to this cost. Also, the bend of the current culvert may indicate that a large rock or buried obstacle may be present, and rock removal may also add to this cost.

In comparison to the culvert options that will allow passage of vehicles to the cabin, a footbridge could also be constructed that would allow continued access to the cabin by foot but would not support heavy vehicles. The bridge could also be designed to carry light vehicles. Use of timber retaining walls and a timber bridge designed to match the historical "flavor" of the area could enhance aesthetics of the area. Constriction of the roadway shoulder and parking space available for the cabin resident would be somewhat problematic.

The following schematic shows a plan view of a footbridge option. To pass the 100-year flood, the constricted area of the retaining walls needs to be at least 17ft wide, with a gradual opening starting at about 24ft wide. The following table lists the approximate cost of the footbridge. The approximate $70,000 cost for 100-year flood protection with a footbridge type design is cheaper than the equivalent 100-year culvert option. A footbridge with an opening designed to pass a flood smaller than the 100-year flood would only be a small amount cheaper as the majority of the cost is related to the long retaining walls. However, a smaller bridge could more easily be designed to pass light vehicles.

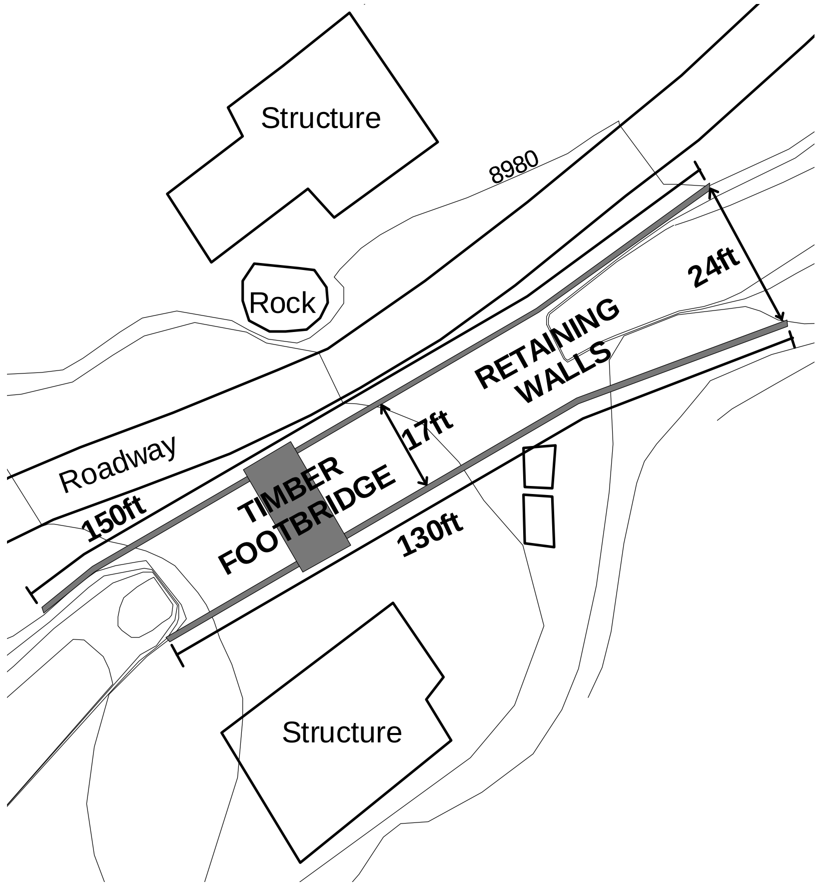


Figure 3.4.2. Plan view of North Creede footbridge

Table 3.4.3. Approximate cost of North Creede footbridge

Item	Quantity	Unit	Cost
Excavation	1236	C.Y.	$6,954
Wood Tie Wall, pressure treated, 8' high	280	L.F.	$38,325
Pedestrian Bridge, Wood	230	S.F.	$12,742
Replacement of Stream Material	133	C.Y.	$1,501
Total Cost			$59,521
Total Cost (Subtotal*20%)			$70,000

The final option to resolve the culvert problem at North Creede would be to remove the cabin structure and restore the section to an open more natural stream course. As mentioned in the previous section, the cabin is made of chinked log and may be of historical value. It is unsure if the cabin could be moved to an alternate location. The following table attempts to provide a very approximate cost estimate of this option, although this cost is quite difficult to estimate without contact with the property owner. The real cost of removing or moving the cabin and restoring the channel may be around $300,000.

Table 3.4.4. Approximate cost of structure removal and stream restoration at North Creede

Item	Quantity	Unit	Cost
Purchase / Removal of Cabin Property	1	each	$250,000
Excavation, 3/4 CY Backhoe, 3 CY dump trucks	889	C.Y.	$5,003
Restoration of Stream Channel / Banks	1	each	$20,000
Total Cost	0	0	$275,003
Total Cost (Subtotal*20%) Rounded	0	0	$300,000

3.5 Commodore Mine Flood Bypass System

Currently, an arrangement of a wooden and metal flume, along with concrete and steel pipes, conveys West Willow Creek over and through the Commodore tailings pile. The conveyance system presents a number of potential problems, and related issues include:

- The flume and pipes are not able to convey large flood flows. An area of the tailings will be inundated at a 10-year flood return interval, and the 25-year flood will cause overtopping of the tailings pile.
- Flooding at the 25-year level could cause severe erosion of Commodore Mine tailings pile. This could wash tons of mine tailings into West Willow Creek that could even be carried to the Rio Grande and cause fish kills. The erosion may also wash an enormous amount of old mine timbers and cribbings into the stream which could plug the West Willow Culvert and potentially cause plugging of the flume entrance and flooding in downtown Creede.
- High flows could cause saturation of the tailings piles, possibly increasing acid or metal pollution in West Willow Creek. Saturation during a sustained large snowmelt flood could cause increased erosion or sloughing of the tailings piles or even mud type flows.
- Current stream flow may be infiltrating at the top of the tailings pile and leading to increased pollution in West Willow Creek. Also, water now drops from the flume to a basin in the tailings pile before entering the pipe. This may also cause added infiltration into the pile.
- The current wooden/metal flume is in poor condition and may soon fail. High flood flows may severely damage the flume and flume debris could plug the pipe entrance below. In this case, flood damage to the tailings pile could occur at less than the 25-year flood level.
- It has been reported that the existing steel sections of the Commodore pipe were not welded together and large gaps are said to exist between some sections. Some of the pipe may be collapsed somewhat, and diameters may vary between the pipe sections. Therefore, high pipe velocities under flood flows may cause failure of the pipe and severe damage. The current useful life of the pipe setup, even in the absence of flooding, may be limited. In additional, the timber cribbing wall supporting the pipe may also be unstable.
- Flow out of the current pipe is attractive and is of value to tourism and historical preservation in the area. Continuation of pipe flow should be valued in alternatives. However, in order to preserve this pipe, it may be important to limit pipe flows so that higher flood flows do not further damage the pipe and its ability to carry some flow.

Two general options seem to be available to address the Commodore pipe problems. The first option may be to remove the wooden flume and extend a more adequate pipe from the stream through the upper tailings pile to the entrance of the existing concrete pipe. This option would use the existing pipe system to convey large floods. This option could potentially solve the flood control problem from a hydraulic perspective. However, as mentioned above, conveyance of a large flood through the existing steel pipe sections could potentially cause pipe failure or severe damage, and it would end up causing flood waters to again overtop the tailings piles.

The second option may be to continue to use all or part of the entire existing flume and pipe setup to convey low stream flows, but use a separate conveyance system for large flood flows. In this case, a conveyance system would have to be installed down the tall and very steep slopes of the lower Commodore tailings piles. Heavy equipment operation on these slopes may be extremely difficult. The installation would also be clearly visible from the Bachelor Loop road and may alter the historic character of the area. However, this option could help protect the existing pipe and would be required to fully ensure flood protection for the tailings piles.

Potential “preliminary” designs considering the two general options follow.

3.5.1 Option 1: Extension of Existing Pipe System

As there are serious structural concerns about the existing steel pipe, Option 1 is not recommended. However, because the actual construction of Option 1 is much more feasible than the construction of Option 2, it is briefly presented here for cost comparison. If Option 1 is considered further, it may be advisable to scope the existing steel pipe with a sewer type video camera to examine the actual stability and capacity of the pipe.

Hydraulically, the problem with both the current flume and pipe is entrance losses. A possible solution seems to be to pass the flood flows from the stream channel through a larger diameter pipe, and “force” the flow into the smaller pipe through a smooth transition at a lower location where the pipe could actually pressurize and “pile up” a significant headwater. This is a rather unconventional design and may be problematic. However, it would reduce the current risk of flooding and may be more feasible than other options.

An 8-foot diameter pipe with a very efficient entrance transition could pass the 100-year flood, but only by submerging the inlet with several feet of head and having an extremely hydraulically efficient entrance. Therefore, the entrance invert will have to be buried fairly deep with the top of the concrete headwall at least five foot above the top of the pipe and a smooth concavely rounded entrance. The uncertainty of this design may warrant a larger size pipe or box culvert. The following figure shows a plan view of a conceptual design alternative to extend flow through a pipe from the stream to the current concrete pipe. The following table lists approximate costs to construct the Commodore pipe extension alternative. The option as designed would cost approximately $400,000.

Table 3.5.1. Approximate cost to extend existing Commodore pipe system

Item	Quantity	Unit	Cost
8' dia. prestressed concrete pipe (water distribution), 150PSI, 24'L	216	L.F.	$110,680
8' dia. Black steel pipe, 3/4" wall	24	L.F.	$15,700
5.5' dia. Black steel pipe, 3/4" wall	48	L.F.	$24,785
5.5' dia. prestressed concrete pipe, 150PSI, 8'L	8	L.F.	$2,241
5.5' dia. Welded Steel Elbow, 3/4" wall	2	each	$9,529
8' to 5.5' dia. Welded Steel Smooth Transition, 3/4" wall, 8'L	1	each	$16,353
10' dia x 16ft deep Concrete Manhole, Cast in Place	1	each	$16,100
6' dia x 8ft deep Concrete Manhole, Cast in Place	1	each	$8,975
Concrete thrust blocks, 3000 psi cast in place	35	C.Y.	$5,231
Excavation, compaction, backfill, 10' wide by 15' deep, 1:1slope	310	L.F.	$77,670
Headwall, wingwalls, and concave transition	1	each	$28,930
Upstream debris protection / gratings	1	each	$24,149
Total Cost			$316,192
Total Cost (Subtotal*20%) Rounded			$400,000

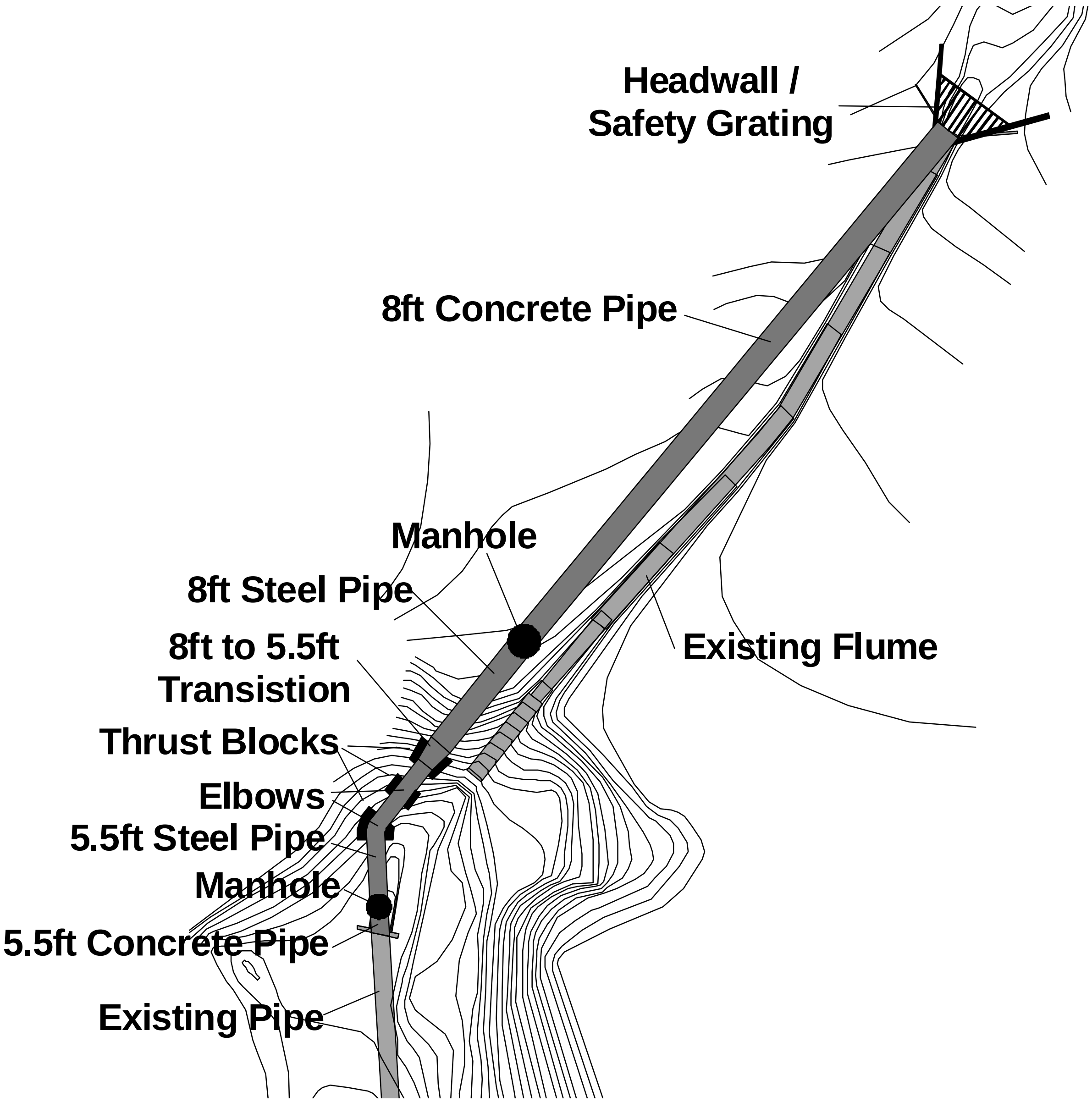


Figure 3.5.1. Plan View of Commodore pipe alternative

3.5.2 Option 2: New flood Conveyance System over Commodore

Many options were considered to form a "preliminary" design to pass floods over the Commodore tailings pile. Due to the deep depression at the current concrete pipe entrance, it would be most effective to pass water to the east of the current system alignment over the upper level of the tailings pile. A concrete lined open channel could be used, but precast concrete or metal culverts or pipes would probably be cheaper, less prone to cracking and leakage, and would have less public safety and access concerns. Directing a channel or pipe toward the current pipe outfall location would probably not be feasible, as this slope is extremely steep and the timber cribbing at the base of the slope may be unstable. Apart from the road access, the gentlest and most uniform slope seems to be located on the southwestern side of the lower tailings pile. This may be the most feasible location to drop from the mid-level of the tailings pile to the creek bed.

The following figure shows a plan view of possible "preliminary" flood bypass design. As designed, flow will first pass from the stream into a 12-foot wide by 5-foot tall concrete box culvert. The width of the culvert is needed in order to pass the 100-year flood into the culvert entrance. However, this is also dependent on the construction of a hydraulically efficient entrance. Large wingwalls of less than 45 degrees are required with the headwall beveled at 45 degrees. The box culverts will convey the water across the large flat area of the upper tailings pile with one horizontal angle change and manhole. The box culvert will be placed in a trench and backfilled so that the culvert does not pose an aesthetic or access problem. At the edge of the flat area, a smooth concrete transition will be used to warp the rectangular concrete culvert shape to the circular shape of an 8-foot diameter pipe.

A steel pipe will be used to drop down the steep slope to the mid-level of the tailings. The pipe will be supported by support blocks and a thrust block at the slope change. It is envisioned to place the pipe in a trench, although special means will be needed to excavate, form concrete supports, and place pipe on such a steep slope. After the thrust block and a vertical elbow, an 8-foot corrugated metal pipe will convey water to an additional thrust block near the southwestern edge of the tailings. Here, an 8-foot to 6-foot pipe transition and elbow will direct flood flows down a 6-foot diameter corrugated metal pipe towards the creek bottom. This pipe will be quite a challenge to install. Special measures will again be needed to excavate a trench, pour concrete pipe supports, and lay the pipe. It may be possible to nearly hide the pipe by burying it in a trench and backfilling. However, this may be nearly impossible on such a steep slope of loose scree. If burying is not possible, the pipe may have to be installed above ground which will be much more visible to visitors of the Commodore area.

As shown in the plan, it may be best to direct the 6-foot pipe across slope somewhat. This may make the excavation easier, and will direct the discharge from the pipe into a more direct line with the channel bed. A concrete stilling basin should be installed below the pipe and outlet headwall to allow the formation of a hydraulic jump and dissipation of energy on a concrete surface before entering the channel.

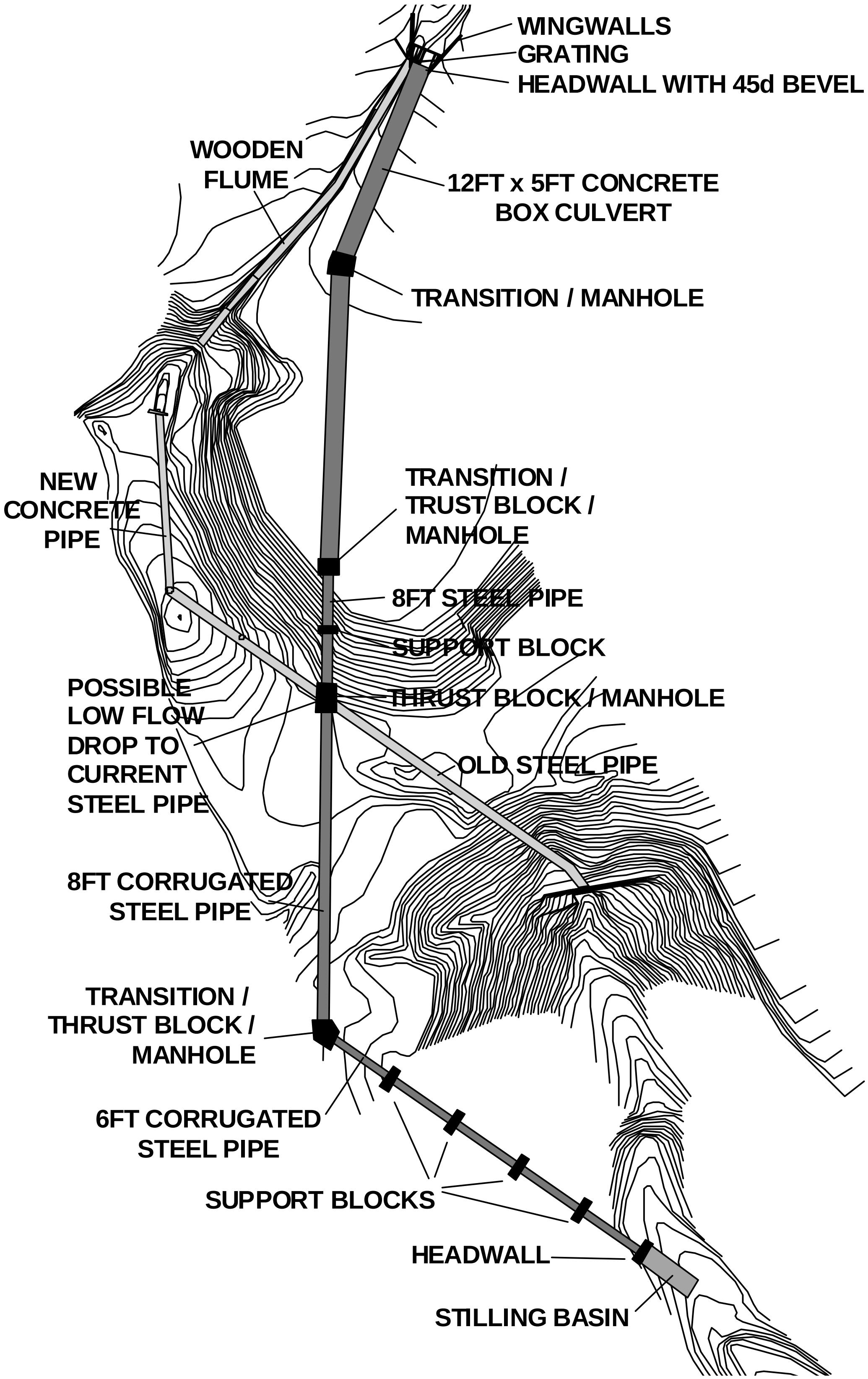


Figure 3.5.2. Plan view of Commodore flood bypass “preliminary” design

The “preliminary” design shown in the figure would direct all flow from West Willow Creek into the new conveyance system. Small “tees” could be welded into the new and existing steel pipes to pass low stream flows from the new pipe to the existing pipe and outfall. The tee in the new pipe would be sized not to pass a large flow, and flood flows would continue past the tee to the corrugated metal flood bypass. Therefore, normal low flows would still flow from the existing pipe outfall as an aesthetic feature, but the pipe would be protected from high flood flows. This option would discontinue use of the wooden flume, and allow for its removal. This was considered favorable as the flume may be a public safety concern if public visitation of the commodore tunnel is expanded, the flume is deteriorating and may soon be unusable, and water may currently be infiltrating into the tailings between the flume drop and the pipe entrance. A table of very approximate costs to build the “preliminary” design follows. Construction of this design would cost approximately $900,000.

Table 3.5.2. Approximate cost for Commodore flood bypass “preliminary” design

Item	Quantity	Unit	Cost
12' x 5' concrete box culvert	360	L.F.	$184,715
Box Culvert set up charge at plant	1	each	$3,240
8' dia. Black steel pipe, 3/4" wall	100	L.F.	$65,415
8' dia. Corrugated metal pipe, bituminous coat paved invert, 8ga	220	L.F.	$58,749
6' dia. Corrugated metal pipe, bituminous coat paved invert, 8ga	260	L.F.	$40,416
8' dia. Corrugated metal pipe coupling	10	each	$1,921
6' dia. Corrugated metal pipe coupling	12	each	$1,486
8' dia. Black steel pipe elbow	2	each	$8,666
8' dia. Black steel pipe tee	2	each	$11,203
8' dia. Corrugated metal pipe elbow	1	each	$1,694
8' to 6' dia. Corrugated metal pipe reduction	1	each	$1,694
Concrete Manhole with size transition, Cast in Place	4	each	$64,399
Concrete thrust/support blocks, 3000 psi cast in place	483	C.Y.	$72,319
Concrete stilling basin, 3000 psi cast in place	44	C.Y.	$13,300
Excavation, compaction, backfill, 15' wide by 8' deep, 1:1slope	360	L.F.	$40,359
Excavation, compaction, backfill, 12' wide by 10' deep, 1:1slope, steep	100	L.F.	$16,816
Excavation, compaction, backfill, 12' wide by 10' deep, 1:1slope	220	L.F.	$24,664
Excavation, compaction, backfill, 10' wide by 8' deep, 1:1slope, steep	260	L.F.	$43,722
Excavation, pit to connect to existing pipe	296	C.Y.	$20,864
Pipe bedding, crushed 3/4" gravel x 12"	1253	S.Y.	$9,855
Headwall, wingwalls, and grating	1	each	$23,144
Upstream debris protection / gratings	1	each	$24,149
Total Cost			$732,789
Total Cost (Subtotal*20%) Rounded			$900,000

Although there are several reasons to replace the wooden flume, some may express a desire to preserve the wooden flume and continue its use as a historic feature. In this case, the large headwall installed for the box culverts could include a small cutout to pass flows to the wooden flume. This cutout would be designed as a weir or orifice to limit flows into the wooden flume and pass flood flows into the box culvert. In effect, the new culvert would act only as a flood bypass and not normally convey water. The previous design called for black steel pipe to be used in the portion of the system that would constantly be conveying flow and into which the low flow tee would be welded, while corrugated metal (bituminous coated with paved invert) pipe was envisioned for the area that would only convey flood flows. However, in this second design option, corrugated metal could potentially be used in place of the black steel pipe in the drop from the upper to mid level of the tailings pile. This would reduce the cost of the project by approximately $70,000.

Large timber debris or boulders could potentially plug the flood bypass system and cause reduced capacity or damage. Therefore, it would be very important to take measures to prevent timbers and large sediments from entering the bypass. Section 3.6 separately details the construction of a series of gratings above the bypass entrance to restrict the entry of debris. The installation of these gratings would be necessary if the flood bypass is constructed and should probably be considered as part of a potential flood bypass project for planning and funding purposes. The cost of these gratings was included in the cost table for the flood bypass designs.

The construction of a flood bypass over the Commodore tailings pile will be a difficult challenge given the steep and unstable slopes and the need for historic preservation at the site. The designs here should only be considered "preliminary". Following further investigation of community priorities, appropriate configurations, design needs, and available funding; more effort will be needed to determine the most appropriate materials, pipe sizes, thrust block sizes, and determine construction methods that will work in such a challenging area. A qualified geotechnical engineer should also be consulted to examine feasible project options and design criteria.

3.5.3 Option 3: Micro-hydro Power Generation

There was interest in the WCRC to investigate hydro-power generation related to the Commodore flood bypass system. In the case that West Willow Creek could be conveyed over the Commodore site within a closed pipe system, it would seem reasonable to use the energy of the falling water to generate electricity. A small-scale water treatment system may someday be installed on the Commodore tailings piles to treat polluted water from the Nelson tunnel, and could possibly employ an electrolytic type treatment process. The electricity produced by a turbine could potentially provide cheap power for the treatment plant.

The following graph shows the average monthly streamflow in West Willow Creek. Streamflow was approximated by compiling all available monthly data from the Willow Creek gage and prorating it to the expected flow in West Willow Creek. The graph shows the large difference in streamflow in Willow Creek between winter months and spring and early summer.

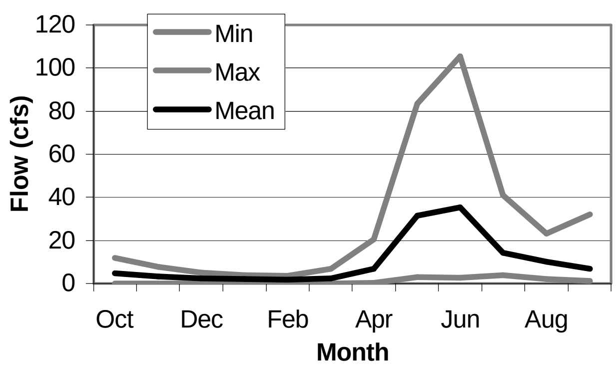
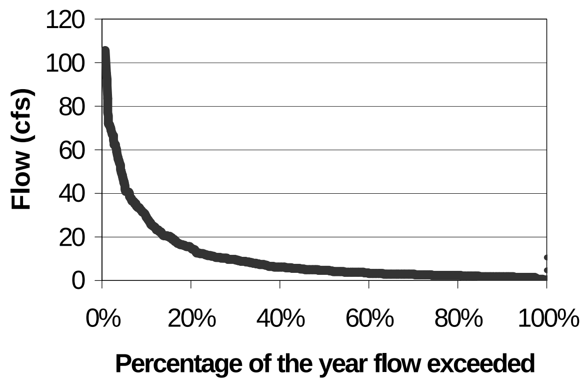


Figure 3.5.3. Average monthly streamflow in West Willow Creek

Figure 3.5.4 shows a flow duration curve for this same streamflow data for West Willow Creek. The average monthly flow in West Willow Creek is about 10.4cfs while the median flow (50% of the year exceeded) is 4.6cfs.



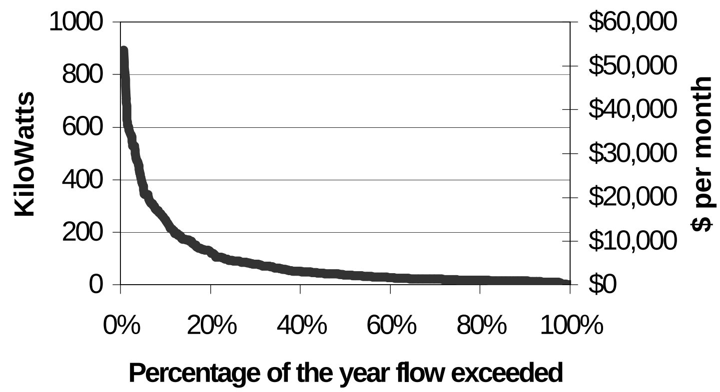


Figure 3.5.4. Flow duration curve (left) and potential power generation (right) at Commodore

These flow values can be used to approximate the Kilowatts of power and the revenue that could be generated from this water as shown. A head of 200 feet and a power cost of 7.8 cents per Kilowatt hour were assumed. The 7.8-cent value is typical of a consumer electric cost rather than the purchase price for raw power. However, this is the amount that could potentially be saved if the power was used on site for water treatment processes. An overall system efficiency (including penstocks) of 50% was also assumed. This value is typical to small-scale (micro) power generation facilities (Harvey 1993).

The generation facility would be designed given an optimization of the increased cost for system capacity versus the potential for increased power generation. It would obviously not be cost effective to design high pressure penstocks at the capacity desired for the flood bypass system (532cfs). Multiple turbines and generators, or turbines than can operate efficiently over a large flow range such as multi-jet Pelton turbines, could be installed. However, experience indicates that small-scale hydro-power projects typically need to operate at their full design capacity for at least 50% of the year in order to be cost effective (Harvey 1993). Therefore, a turbine project for West Willow Creek may be most cost effective designed at about a 4.6cfs capacity. Without any storage but with turbines that could operative efficiently at lower flows, this capacity would generate about $20,000 per year on average in electricity. As the addition of the turbine system to the flood bypass system could potentially cost on the order of $500,000, this does not appear to be cost effective.

Water storage could potentially be used to increase the capacity for power generation. The average flow of 10.4cfs could potentially be maintained throughout an average year – generating $60,000 per year. However, this would require the storage of about 3500 acre-feet of water. Obviously, this amount of storage is infeasible given the space limitations of the area and potential effects on downstream water rights in the Rio Grande.

Therefore, unfortunately, it appears that power generation in conjunction with a flood bypass system over the Commodore tailings pile would not be cost effective or feasible.

3.6 Commodore Mine Debris Protection

The stream reach above the Commodore Mine is extremely steep. During a flood flow, extremely high shear stresses in the reach will have the potential to mobilize large boulders on the order of 2 feet in diameter. The channel bed has a base of larger, relatively immobile boulders, and previous high flows have removed most small cobbles from the reach. However, disturbances and slides from the surrounding steep slopes have left a large amount of scattered large cobbles and boulders within the channel area that could be transported downstream in a large flood.

Timber debris or large boulders could potentially plug the current wooden flume and pipe conveyance system, or the proposed box culvert and pipe flood bypass. Plugging of this system would be a very serious problem that could cause or exacerbate overtopping and erosion of the Commodore Mine tailings pile into Willow Creek. Large boulders could also damage the flume or pipe systems. Therefore, it is very important that large sediments or debris are demobilized above the entrance to the Commodore flume/pipe system and are not allowed to enter.

Two "grizzly" gratings are currently located above the existing wooden flume. The grizzlies are somewhat "makeshift" and consist of railroad irons leaned against a large timber. The lower grizzly is about 12 feet wide. This grizzly once protected the flume as a large amount of sediment has accumulated and filled the area above the grizzly. However, the stream has since eroded around the grizzly to the east and the grizzly now provides little protection. The stream still flows through the upper grizzly, but a significant amount of sediments has also accumulated.

Sediment transport calculations indicated that a tremendous amount of sediment could be transported into this area. Unfortunately, space isn't available to construct a large sedimentation basin, and the steep slope of the stream reach would make it difficult to construct a constant level pond. A small pond could potentially be constructed just above the flume entrance in the area around the lower existing grizzly. However, a pond at this location could possibly increase water infiltration into the tailings pile. Therefore, the best option may be to construct gratings similar to a "grizzly" to trap large sediments and debris. As large areas for sediment and debris storage will not be available, periodic maintenance and excavation will be required.

The following figure (Fig. 3.6.1) shows a plan view of area above the Commodore flume entrance and possible locations for new grating structures. The two existing grizzlies as well as accumulated sediments should be removed. As much material as possible could be excavated from the area above the lower grizzly and shaped to create as large of a sediment storage area as possible. It is proposed to install 3 gratings in the area. The first, with a spacing of 16 inches, would remove large boulders and timber debris. The second, with a spacing of 10 inches would remove large boulders and cobbles. The third, with a spacing of 3 inches would remove all remaining cobbles. The three grizzlies were placed so that the west sides could be placed against large rocks. The constructed gratings would be wider than the current grizzlies, and the east side should be keyed into the channel banks so that the stream will not erode around the gratings. The top of the gratings should be placed below the top level of the bank so that, if the gratings became completely plugged, floods would flow over the top of the gratings but remain within the channel.

An additional figure (Fig. 3.6.2) follows that shows a plan view of the second grating. The gratings could be welded from heavy structural square tubing with posts placed in large concrete blocks. The upstream grating would be similar to the second, although it is proposed to install a middle post and additional central concrete block on the third, downstream grating, similar to the grating proposed above the Amethyst Mine (Section 3.7). An access road will need to be constructed on the channel bank to facilitate periodic removal of debris from the gratings and excavation of accumulated sediments using a backhoe and dump truck.

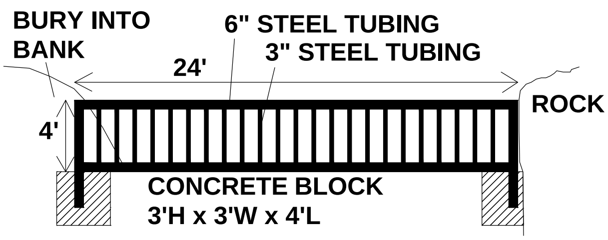


Figure 3.6.2. Profile view of second proposed grating above Commodore flume entrance

The following table shows approximate costs to construct the proposed "grizzly" gratings to ensure that sediments will not enter the existing flume or proposed flood bypass over the Commodore tailings piles. The project would cost approximately $30,000. The annual cost to periodically remove sediments and debris from the grating may be approximately $500 per year.

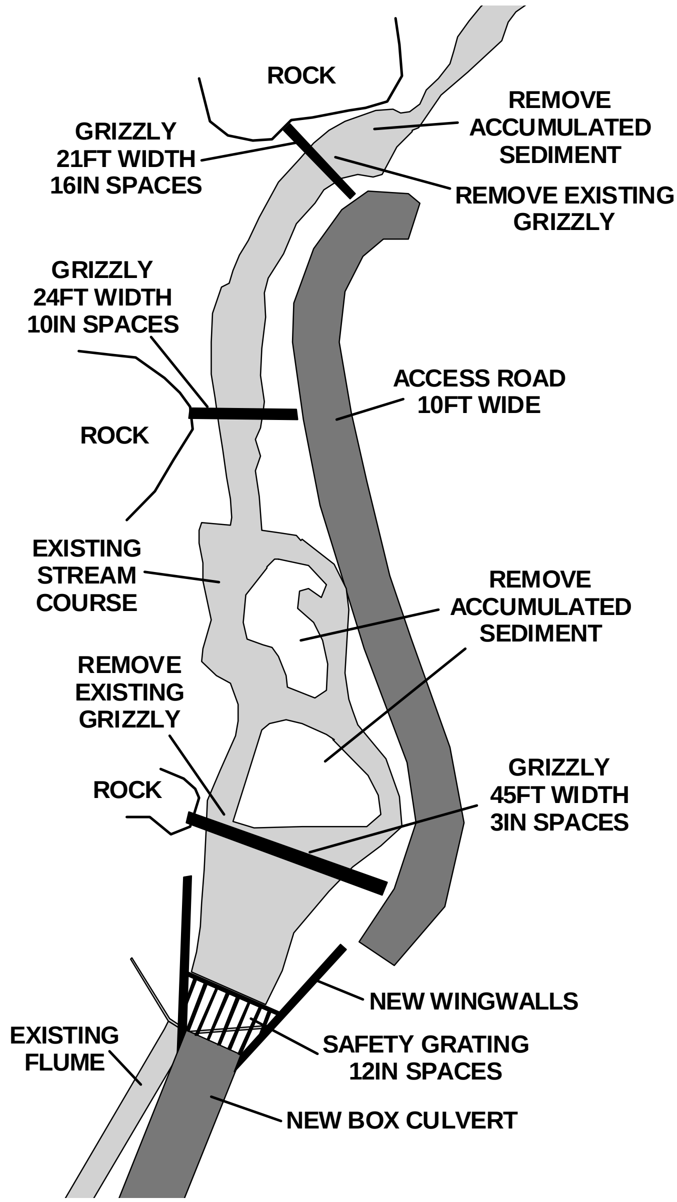


Figure 3.6.1. Plan view of proposed gratings above Commodore flume entrance

Table 3.6.1. Approximate cost of gratings above Commodore flume entrance

Item	Quantity	Unit	Cost
6"x6"x1/4" square structural steel tubing	192	L.F.	$3,935
3"x3"x1/4" square structural steel tubing	512	L.F.	$7,159
Welding, 1/4"	270	L.F.	$3,648
Concrete footings	7	each	$4,823
Excavation, 3/4 CY Backhoe, 3 CY dump trucks	647	C.Y.	$3,643
Grading of Access Road	200	S.Y.	$942
Total Cost			$24,149
Total Cost (Subtotal*20%) Rounded			$30,000

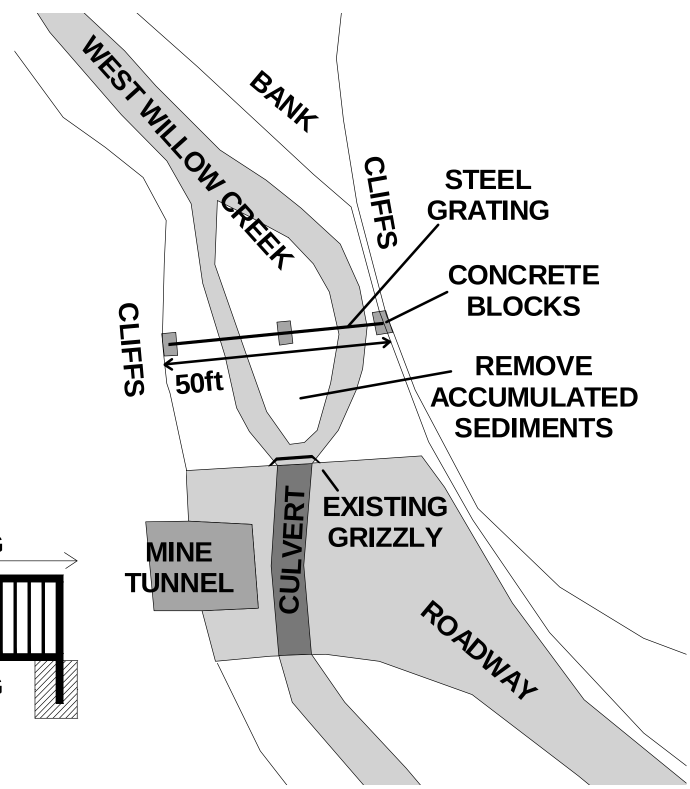
3.7 Amethyst Mine Debris Protection

A large amount of both natural and mine related timber debris collects on the grizzly protecting the culvert near the entrance of the Amethyst Mine tunnel. Almost yearly maintenance is required to remove this debris. Collection of the debris on the grizzly during flood flows will probably cause flood damage to the roadway and the Amethyst Mine tunnel entrance. A large pile of gravel and cobble sediments has also accumulated above the grizzly.

Manual removal of timber debris upstream of the Amethyst culvert could significantly improve the debris problem in the short term. However, installation of a debris control structure could remove the need for nearly yearly periodic maintenance. Maintenance and removal of debris collected by the new structure would be needed on a much longer term – perhaps every 25 years.

The grizzly currently installed above the culvert effectively collects debris to avoid plugging of the culvert. However, the effective surface area and "detention area" of the grizzly is easily overwhelmed by the debris load during high flows. The channel upstream of the Amethyst culvert is bounded on the east and west by large vertical rock cliffs about 50 feet across. A large "grizzly" grating structure could be placed between these cliffs. This 50-foot grizzly would have sufficient surface area to handle large debris flows over many years, and would be able to contain debris and sediments in this restricted "basin". If the entire grizzly plugged with debris, flow would overtop the grizzly without causing damage, and the grizzly at the culvert would provide secondary protection.

The following figures display plan and profile views of the possible debris control structure. Sediments that have currently accumulated upstream of the culvert could be removed prior to construction of the structure. 6" square steel tubing could be set in large 4 foot deep by 5 foot long and 3 foot wide concrete foundation blocks. Two 6" beams could be welded to the posts to span the 50ft width horizontally, and smaller (~3" square) steel ties could be welded vertically to the beams on 1-foot centers. A table of approximate costs to install the debris control structure also follows. It will cost approximately $15,000 to install the structure.



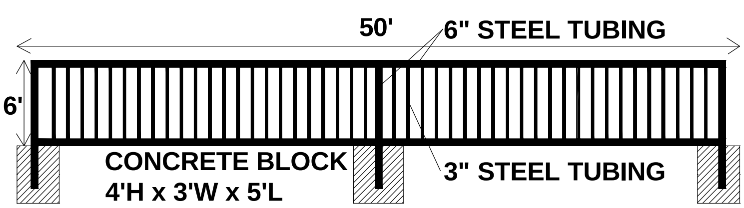


Figure 3.7.1. Plan (right) and profile (left) views of Amethyst debris control structure

Table 3.7.1. Approximate cost of Amethyst debris control structure

Item	Quantity	Unit	Cost
6"x6"x1/4" square structural steel tubing	130	L.F.	$2,664
3"x3"x1/4" square structural steel tubing	300	L.F.	$4,195
Welding, 1/4"	133	L.F.	$1,792
Concrete footings	3	each	$2,069
Excavation, 3/4 CY Backhoe, 3 CY dump trucks	278	C.Y.	$1,563
Total Cost			$12,284
Total Cost (Subtotal*20%) Rounded			$15,000

Timber debris and large sediments will slowly accumulate and eventually fill much of the area behind the structure. At this time, maintenance will be required to remove the accumulated debris. It is expected that a backhoe or excavator could enter the area just behind the structure and reach behind the structure to remove debris. Alternatively, a temporary or permanent road could be constructed against the cliffs on the east side of the canyon to allow passage of heavy equipment over the top of the structure.

3.8 Timber Debris

A large amount of large timber debris is located within the Willow Creek channel. Much of this timber is related to historic mining activities; old mine timbers, refuse, or deteriorated timber cribbings. Some amount of natural timber debris is also present. This timber debris has the potential to be a significant cause of flood damage. Even in smaller flood events, these timbers may float downstream and plug structures such as culverts, bridges, or flumes. As much of the stream study reach will flow "super-critical" during flood events, channel blockage by timber debris may cause flow transitions and overtopping of channel banks or significant bank erosion.

Removal of timber debris may be one of the easiest and most cost effective ways to reduce flood risk within the study area. A volunteer community effort could be organized by the Willow Creek Reclamation Committee to provide the manual labor for this cleanup. Much of the timber could be removed by hand, while larger timbers could be cut up by chainsaw and removed. Except for the area below the Commodore Mine, road access follows the stream throughout the study area and timbers could be placed by hand into dump trucks. Dump trucks could possibly be borrowed from cooperating agencies such as Mineral County or the Forest Service. In this case, the cleanup may require very little funding.

The historical value of deteriorated timber cribbings may need to be addressed before their removal. Some may also feel that the presence of timber debris may be valuable to the historical "character" of the stream. However, removal of this debris should greatly improve the natural aesthetics of the stream, and may make the stream area less hazardous to public access.

Small amounts of timber debris are located throughout Willow Creek. However, the following figure notes areas of high and moderate timber debris concentration that were noted by field studies. A clean-up effort could concentrate on these areas first, and then a reconnaissance of the other stream reaches could remove remaining timber debris.

The largest single source of timber debris and possibly the most important area for timber debris removal exists below the Commodore Mine. Quite large timbers are located here, and many are partially buried or are supporting earthen debris. Therefore, heavy equipment may be needed to facilitate timber debris removal. Unfortunately, access is much more difficult. The following section (Section 3.9) describes timber debris removal specifically below the Commodore Mine.

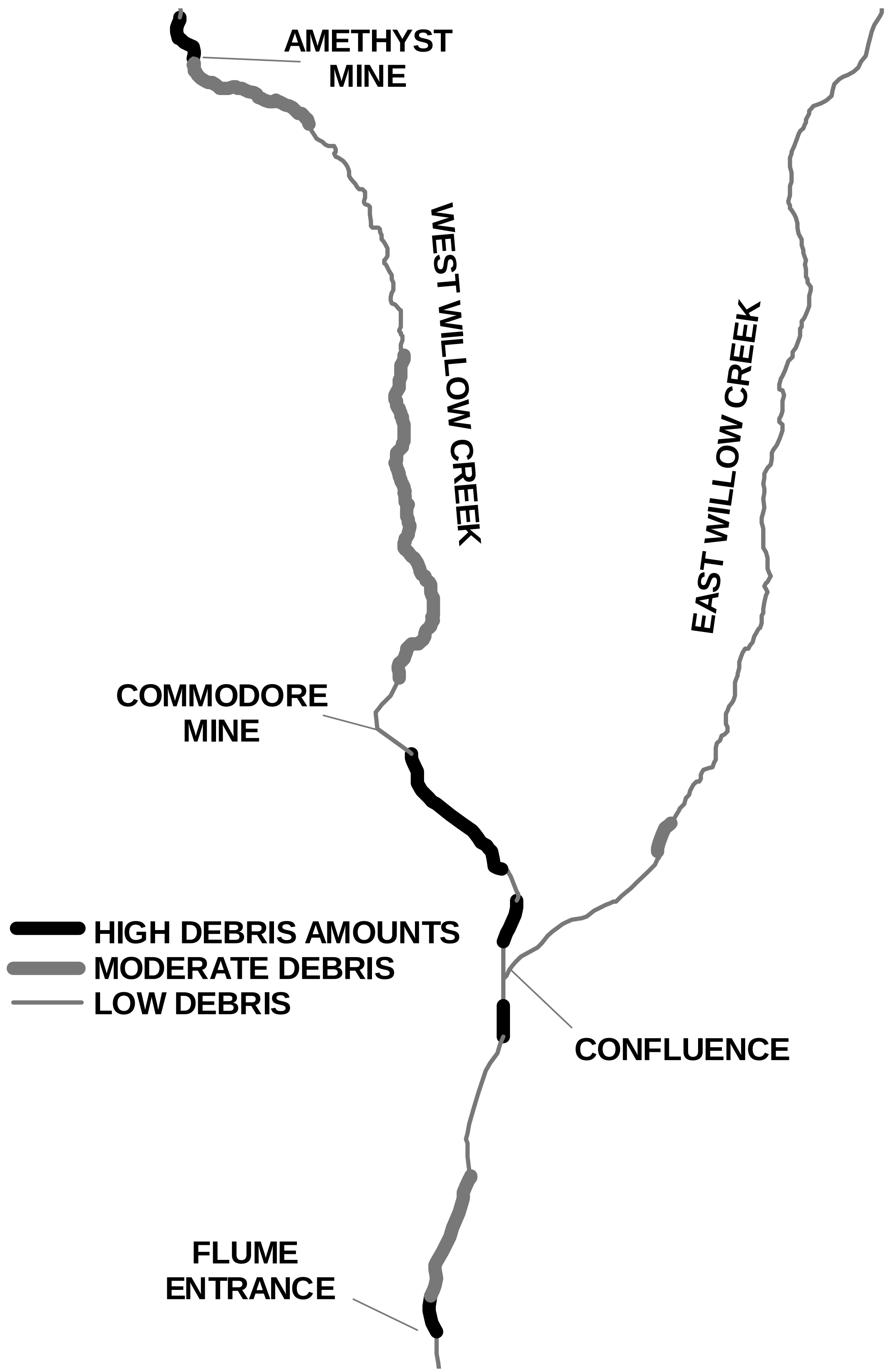


Figure 3.8.1. Timber debris locations within study area.

3.9 *Timber Debris below Commodore Mine*

The largest single source of timber debris in the stream system is concentrated below the Commodore tailings pile area. The debris is a result of deteriorated timber cribbing and refuse timbers from mine workings. Much of this timber debris is located directly in the channel, is quite mobile, is of large size, and could easily block flood flows and greatly increase flooding downstream. Removal of this debris may be one of the most cost effective methods to decrease flooding risks to downstream areas including downtown Creede. Debris removal may also improve the natural aesthetics of the stream in the area.

Steep canyon walls surrounding the creek at this point make access to the area and removal of debris quite difficult. The entry of dump trucks to a location as close to the debris as possible may be the most critical effort to facilitate the removal of the debris. An old access road to the stream bed area below the tailings pile could possibly be improved sufficiently to allow entry of dump trucks and other heavy equipment.

The following figure shows a plan view of the access road and the potential to restore it temporarily for use. Sliding of the steep talus slopes has removed two sections of the road. Although further investigation of the stability of these two areas is required, a dozer could possibly restore the roadbed at these locations temporarily. Installation of a temporary bridge across West Willow Creek would allow access near to the level of the stream on the West side. A small bridge similar to the bridge recently built to allow temporary access to the Commodore tunnel could be installed using welded steel I-beams and heavy planking without the need for permanent headwalls. Alternatively, an area could possibly be cleared of boulders and rubble sufficiently to allow crossing of the stream during low flow. In this case, measures should be taken to protect stream water quality. The need for access may need to be weighed against possible effects that the road restoration may have on the historical character of the area

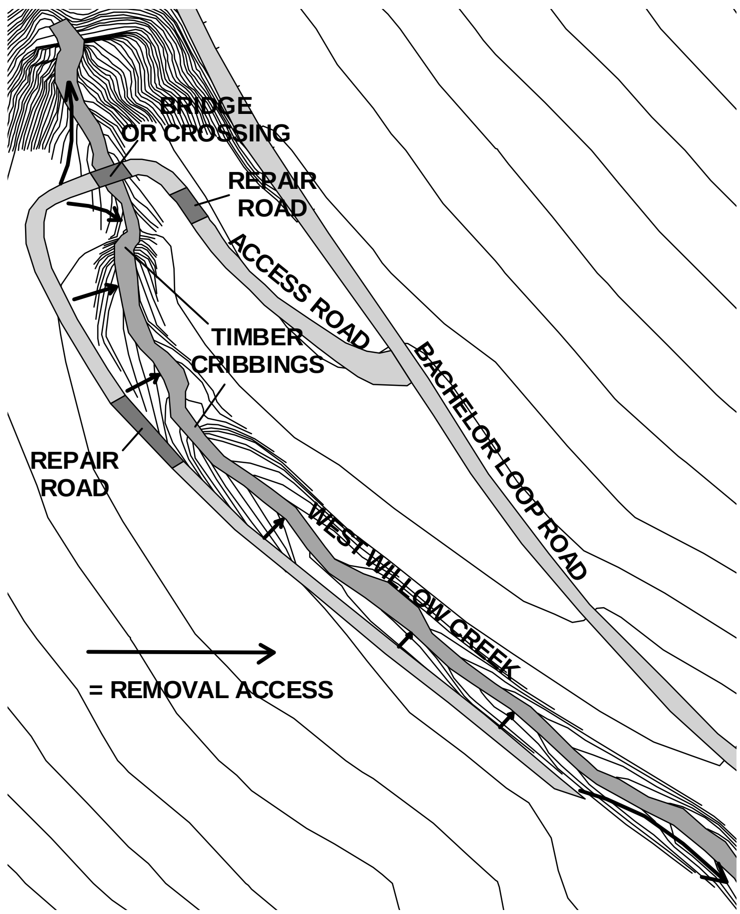


Figure 3.9.1. Restoration of access road below Commodore Mine

In addition to dump trucks, restoration of the access road could also allow entry of backhoe type equipment. Backhoes or longer armed excavators could possible be used near the stream crossing and near the bottom of the access road to directly remove large timber debris. Unfortunately, elevation of the access road above the creek bed throughout the remainder of the area may necessitate other means of removal. Heavy winch equipment could possibly be used to pull timbers from the creek bottom. Probably, cutting of the large timbers with chainsaws and manual removal to a location on the access road where timbers can be removed by dump truck will be required. A community effort could be organized to accomplish this work.

Two large timber cribbing retaining walls are also indicated on the schematic. These cribbings may have been constructed in an attempt to lower channel slopes and stabilize the stream below the mine. Currently, the walls have deteriorated significantly and are not only a large source of debris but are also unstable and hazardous. The second wall could possibly be removed. However, removal of the first and largest wall may destabilize the surrounding area and cause movement of a large amount of cobble and earthen debris into the stream system. The stability of the wall should be examined further and care should be taken in removing timbers at this point. The historical character of these cribbings should also be examined. Several cribbing areas may still be in good enough shape to retain or could be restored.

The cost to remove timber debris may depend on many factors including the degree of restoration of the access road, installation of a bridge or direct crossing of the stream, and the use of heavy equipment versus manual labor. A very approximate cost estimate may be about $25,000, depending on these factors.

3.10 Bank Protection below West Willow Bridge

Significant erosion has occurred on the east bank of Willow Creek just downstream from the reinforced concrete bridge over West Willow Creek. High flows will exit the bridge at very high, supercritical velocities. The exposed bank is composed of relatively fine materials, and flood flows could potentially erode many tons of sediment from the area and transport it downstream.

The bank should be protected before additional damage occurs. More natural protection measures, such as willow plantings, would probably not be effective here. Therefore, the best alternative may be rock riprap protection. The following figure shows a plan view of the protection area.

The bank should be pulled back to a 2:1 (H:V) slope or gentler. The point that has been eroded significantly should be filled and re-contoured to create a straighter flow-line. Rocks weighing at least 200 pounds should be used to resist the extreme hydraulic stresses that will be present at high flows at this point. It was considered that a source of rock could be located within several miles of the area. The rock should be "keyed" into the bed to resist undercutting with a foundation of about 3 foot. The following table details approximate costs to protect the slope. The project should cost approximately $8000. Perhaps the county could assist with construction. A timber retaining wall could also be considered to protect the bank and match the character of the area.

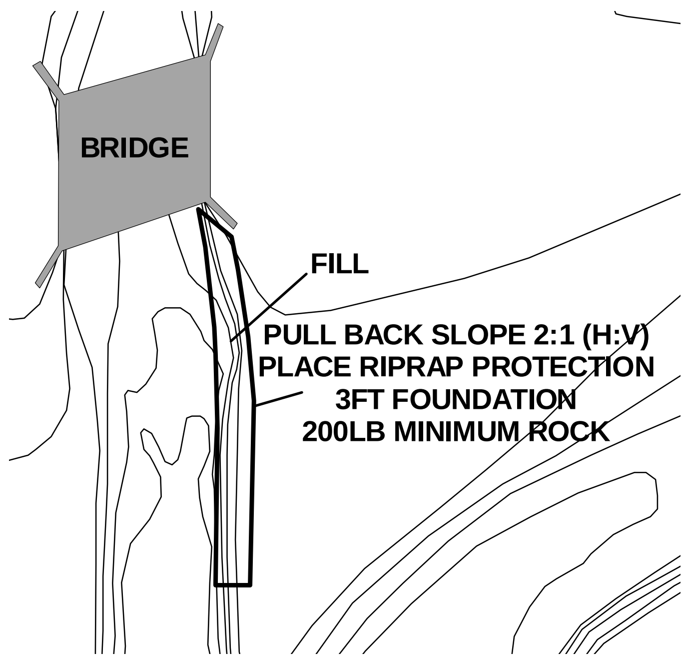


Figure 3.10.1. Plan view of West Willow bridge bank protection

Table 3.10.1. Approximate cost of West Willow bridge bank protection

Item	Quantity	Unit	Cost
Rock riprap, 200lb minimum, machine placed	71	C.Y.	$2,015
Hauling, 6C.Y. truck, 4mile round trip	71	C.Y.	$547
Excavation	53	C.Y.	$509
Rock, purchase	71	C.Y.	$3,292
Total Cost			$6,363
Total Cost (Subtotal*20%) Rounded			$8,000

3.11 Channel Improvements

Within the study area, Willow Creek is typified by steep slopes and high potential sediment transport rates. Transport of large sediments during flood flows may cause damage to hydraulic structures important for flood control – particularly the concrete flume through downtown Creede. Deposition of sediments and debris may cause blockage of structures or reduction of flood capacity.

Many stream areas have been disturbed by mining or road building activities. A population of trout is surviving in portions of East Willow Creek. Improved habitat within Willow Creek could improve further improve fish population and may eventually facilitate the population of Willow Creek below the confluence with West Willow Creek with fish. Increased fishing opportunities may have a positive economic impact on the area. Restoration techniques are available that could both decrease sediment transport rates and improve fish habitat and stream health that should be considered.

In **Applied River Morphology**, Dave Rosgen generalizes the success of fish habitat and river restoration structures using an index he refers to as "Rosgen" stream type. As detailed in Chapter 2, most of Upper Willow Creek can be classified as a "Rosgen" type G3, A3, or A2 stream within the study area. The reach near the Mining Museum may have naturally been a B3 stream, but it is currently kept entrenched by the push-up levees. Success is not listed for the A2 type stream, as structures are usually not installed on this type of stream. Many commonly used structures including check dams, random boulder placement, single and double wing deflectors, log covers, submerged shelters, v-shaped and log sill gravel traps, and "W" weirs have proven to have fair to poor results on A3 and G3 type streams like upper Willow Creek. On this type of stream, many of these structures will tend to increase lateral erosion and increased width to depth ratio. Only vortex rock weirs, re-vegetation of banks, and bank placed boulders or root wads are listed as generally successful on both A3 and G3 streams. Rock or log spurs are listed as successful on A3 streams types but not G3 streams.

Re-vegetation of stream banks with willows in areas that have been disturbed could greatly improve potential fish habitat along Willow Creek and help stabilize stream banks. Willow are quite easy to transplant successfully. Live willow sticks from well established areas can be buried or driven into banks near the water line and will form roots and grow. Lack of soil in disturbed areas may pose a problem, but small amounts of topsoil could also be placed around the willow above the bankfull stage. Although currently unsuitable for fish due to water quality from West Willow, habitat conditions in the stream reach downstream from the confluence of East and West Willow Creeks to XS15 could be improved with willow re-vegetation. Existing fish populations could benefit immediately from re-vegetation with willows in smaller disturbed areas up East Willow Creek.

Placement of boulders along bank lines could help maintain adequate water depths and provide additional habitat for fish. Boulder placement along banks in conjunction with placement of topsoil and willow sticks above the boulders could be a successful means of re-vegetation and habitat improvement. Unfortunately, placement of boulders could create a problem if the boulders where not of sufficient size and were themselves transported downstream. Many areas of Willow Creek can transport two-foot boulders at high flows. At least 3-foot diameter boulders would probably be required.

The most effective and successful means to both improve fish habitat and decrease sediment transport rates in Willow Creek may be installation of vortex weirs. Large boulders are used to form a "V" across the entire channel bed with the middle of the "V" pointing upstream. The "V" tends to focus the main channel flow or "thalwag" to remain in the center of the channel rather than causing bank erosion. The small cascade caused by the weir aerates water, and the pool caused by vortex provides shelter for fish. The vertical step of the weir will help decrease channel slope slightly and stabilize the grade of the channel bed; helping to decrease channel sediment transport rates.

A picture of a natural vortex weir follows. Large hydraulic stresses will warrant the use of very large boulders that would not move in a large flood. Boulders of at least 4-foot diameter would probably be required in Willow Creek, but an engineering analysis should be used to evaluate minimum boulder size at each site. A "foundation" of boulders should be buried to eliminate undercutting and erosion under and around the boulders, and top boulders should be "keyed" into the foundation and the stream bed. Undercutting is one of the most common failure mechanisms of placed boulder structures used for river restoration. The upstream center area should dip 4 to 18 inches below the tops of the other boulders. In other river restoration projects, it is noted that vortex weirs have been placed at spacings up to 0.3 to 0.6 times the channel width. Rosgen notes that the natural pool spacing for "A" type streams is normally on the order of 3.5 to 4 times the bankfull width. This rule of thumb could be used to approximate the minimum spacing of the vortex weirs for a more natural appearance.

Further study is needed to determine where stream conditions could be improved with vortex weirs. High velocities and bank erosion could be reduced between cross-section 20 (below the confluence) and cross-section 25 on West Willow Creek using vortex weirs. Vortex weirs could also be beneficial in the mining museum area upstream of the flume (as described in Section 3.3.2). East Willow Creek from the confluence through North Creede could also be improved with vortex weirs, although channel reshaping may also be beneficial between cross-sections 12 and 14. Upstream sediment sources (Section 3.12) could also be protected with vortex weirs.

Figure 3.11.1. Photo of natural vortex weir looking upstream (adapted from Rosgen 1996)

3.12 Sediment Source Controls

Production of sediment that can be transported downstream by Willow Creek is obviously an active natural process. However, human disturbances such as mining and road building activities have increased the supply of mobile sediment in Upper Willow Creek. The large alluvial fan downstream of Creede is a testimony to high sediment loads probably increased greatly by human activity. This increased sediment can decrease channel flood capacities and require periodic maintenance and removal. In comparison to relatively coarse natural sediments, fine sediments, particularly mine tailings, caused by human disturbance can also degrade water quality and fish habitat.

Mine tailings, disturbed areas, mobile talus/scree, and roadway watershed sediment sources are mapped in Figure 2.2.2 in Chapter 2. Figure 2.2.3 classifies the potential of areas to produce mobile sediments that could enter Willow Creek given the slope, cover, disturbance, and distance from the channel. Many of the sediment sources throughout the watershed indicated in these figures could eventually be protected by re-vegetation, removal, or stabilization.

However, the first sediment sources that should be addressed are probably those of mine tailings or fine sediment sources that are in direct contact with the creek. Additional field investigation is required to identify these sources and prioritize the risk of sediment or contaminant production from these sources. However, the sediment potential mapping identified several obvious sources which have a potential to directly contribute sediments to Willow Creek. The following figure indicates these sediment sources.

The highest priority locations for sediment control measures are indicated with a dark black line. On West Willow Creek, these locations include the sliding tailings just upstream of the Amethyst tunnel, the mine tailings located to each side of the stream below the Amethyst tunnel, the steep banks of the Commodore Mine tailings pile just downstream from the pipe outlet, and the sliding area of fine sediments a short distance downstream. Other high priority locations include the small pile of fine sediments and debris being eroded just downstream from the confluence, and the tailings of the Outlet Mine on East Willow Creek.

Additional lower priority candidates for source protections on East Willow Creek are indicated on the figure with a gray line. These locations include the Solomon, Ridge, and the Holy Moses Mines that have exposed areas of mine tailings close to the stream but are separated from the creek by the roadway. This separation should lower the immediate potential to contribute sediments. Three areas of sliding scree that are entering the creek are also indicated as lower priority sources.

Sediment sources, particularly mine tailings, directly in the flow of the stream could be removed using a backhoe or excavator. The main flow of the stream channel could be directed away from sediment sources using the vortex weirs described in Section 3.11. For high banks or steep slides, timber or concrete retaining walls could be placed to stop sediment movement. Lower or less steep banks could be re-vegetated with willow or protected with large boulder (>2 foot) or riprap protection. Additional field investigation is required in order to design site-specific sediment controls.

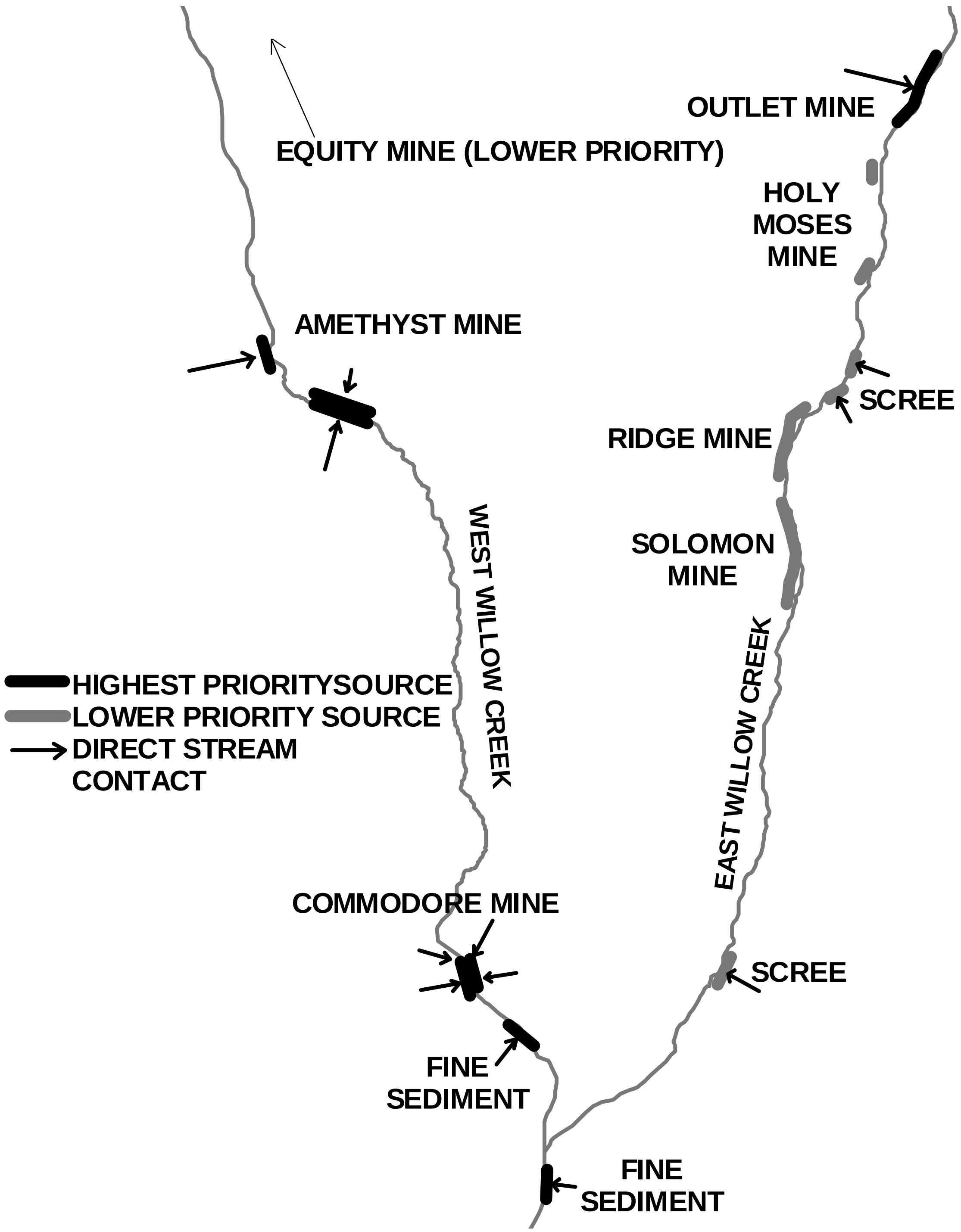


Figure 3.12.1. High priority locations for sediment source control

Section 4 – Project Prioritization and Implementation

4.1 Prioritization of Mitigation Strategies

A wide variety of possible projects was identified to mitigate problems in Willow Creek. These projects vary in the degree to which they meet project goals and feasibility for funding and construction. Table 4.1.1 lists the proposed projects and the approximate project costs. Projects have been arranged geographically from downstream to upstream. For projects with multiple options, the option that is currently considered most favorable by the WCRC based on discussions at WCRC meetings is indicated in bold.

An indication is given of the degree to which proposed project alternatives benefit the adopted goals of the WCRC. For each WCRC goal, a score of 1.0 was given if the project would be "beneficial" to the goal, and a 0.5 was given if the project would be "somewhat beneficial". The sum of these scores for each project indicates the number of different types of benefits the project may have in conformance with WCRC goals, but does not give an absolute ranking of the effectiveness or priority of the project. Of the proposed projects, the planting of willow to stabilize banks benefited the most WCRC goals, while the Commodore Mine flood bypass system, the Mining Museum area steam restoration, installation of vortex weirs, and sediment source control projects ranked the next highest.

The WCRC discussed project alternatives in depth. The table lists a "priority" ranking for each general project location that was developed by the WCRC during the September 4, 2002 meeting. The WCRC noted that priority rankings were based primarily on the perceived risk or urgency of each problem.

The WCRC felt that a new flood bypass system at the Commodore Mine was the highest priority of the potential projects on Upper Willow Creek. The project was given the highest priority rating by the WCRC because it was considered that a flood failure at the site could have the most catastrophic impacts on Willow Creek, Creede, and the Rio Grande of any of the projects. It was felt that the risks of flood damage and degradation of water quality warranted at least 100-year flood protection at the site. However, an appropriate flow bypass will be very expensive over such a steep and instable site. The project could cost more that all of the other potential projects combined. A flow bypass system may also have negative impacts on the historical character of the area.

The replacement of the culvert at North Creede was given second priority due to the time sensitive nature of current opportunities. The City of Creede and the owner of the property on the south side of the stream are currently considering the replacement and may be willing to act quickly. A range of flood protection levels could be considered at North Creede given decreased risks of flood damage versus cost, and 100-year flood protection may not necessarily be warranted. The WCRC felt that the greatest flood protection value was offered by the 50-year flood option, and recommended this option to the mayor of Creede.

Table 4.1.1. Conformance with WCRC goals, approximate costs, and prioritization of proposed mitigation strategies

Location	Priority	Description	1 Reduce Potential Fish Kills	2 Improve Visual and Aesthetics	3 Stabilize Nonpoint Sources	4 Protect Structures (Flooding)	6 Improve Water & Habitat	Score	Approximate Cost
Windy Gulch		Option1: Culvert replacement for 57cfs flood				□		0.5	$25,000
	3	**Option2: Flood overflow for 239cfs flood**				■		1.0	$40,000
Mining Museum Area		Option1: Widening of wooden weir				□		0.5	$15,000
	5	**Option2: Restoration of stream reach**		■	□	■		2.5	$350,000
North Creede		Option1a: Culvert replacement (5yr flood)				□		0.5	$45,000
		Option1b: Culvert replacement (10yr flood)				□		0.5	$55,000
		Option1c: Culvert replacement (25yr flood)				□		0.5	$65,000
	2	**Option1d: Culvert replacement (50yr flood)**				■		1.0	$70,000
		Option1e: Culvert replacement (100yr flood)		□		■		1.5	$100,000
		Option2: Footbridge for 100-year flood		■		■		2.0	$70,000
		Option3: Remove structure and Restore Stream		■		■		2.0	$300,000
Below Concrete Bridge	7	**Bank Protection**		□	■			1.5	$8,000
Commodore Mine		Option1: Extend current pipe system	□		□	□		1.5	$400,000
	1	**Option2: New flood flow bypass system**	■		□	■		2.5	$900,000
Above Amethyst Mine	4	**Debris Protection**				■		1.0	$15,000
Upper Willow Creek	6	**Remove Timber Debris**		■		■		2.0	$25,000
		Plant Willow on Banks		■	■		■	3.0	
		Install Vortex Weir Drops		■	□		■	2.5	
		Sediment Source Controls	□	□	■		□	2.5	

■ = beneficial to project goal (score=1), □ = somewhat beneficial to project goal (score=0.5)

The Windy Gulch culvert project was given the third priority due to the high risk of flooding to downtown Creede. The historic and economic value of downtown Creede definitely warrants 100-year flood protection. A project to install a larger culvert and flood overflow "pan" at Windy Gulch and reinforce the upper end of the flume approach levees should ensure 100-year protection to downtown Creede as long as debris blockage is not a problem on Willow Creek during flooding. However, the priority of Windy Gulch is based on uncertain hydrology that should be examined further.

Debris protection at the Amethyst mine entrance culvert was given the fourth priority due to the regular maintenance requirement to remove debris from the grizzly grating and the feeling that a moderately small flood flow could plug the grizzly and cause flood damage. Installation of a more effective grating would be a fairly cheap project. However, removal of timber debris above the area may lessen the need for the project in the short term.

The restoration of the stream reach in the mining museum area offers many benefits including reducing flood risks to the mining museum and fire department tunnel, stabilizing the stream reach, and improving the aesthetics and recreational resources of the area. The WCRC recognized the value of this project, but ranked it fifth priority, as the problems in the area may not be as urgent as the higher ranked projects.

Priorities were given to general project locations. The timber debris, willow planting, vortex weir, and sediment source controls were assigned to a more general project location of Upper Willow Creek. These generalized project types would consist of many small individual projects, and individual small projects were not considered as high of priority as the previously mentioned large projects. However, it was recognized that the removal of timber debris from Willow Creek may be one of the easiest projects to implement while being one of the most beneficial projects for generally reducing flooding risks. The control of sediment sources may generally be the primary project to address goal #3 of the WCRC (stabilization measures for non-point sources). Planting of Willow and installation of vortex weirs may be the most direct ways to improve fish habitat in Willow Creek (part of goal #6 of the WCRC).

The bank protection below the concrete bridge was given the lowest priority of the proposed projects. The project would be beneficial, cheap, and relatively easy to implement. But the WCRC felt that project was not as important as the other proposed projects.

In considering project priorities, the Willow Creek Reclamation Committee has felt that all of these projects are important. It may be that, in general, what can be done first should be done first. Cost, potential funding partners, and many other factors may affect the order in which projects are pursued.

4.2 Potential Implementation Partners and Funding Sources

This section provides information on organizations that may be potential implementation and funding partners for Willow Creek enhancement projects.

Natural Resources Conservation Service
The local NRCS office in Monte Vista has been actively involved with the Willow Creek Reclamation Committee and protection and restoration efforts in the Rio Grande Corridor and Creede areas. The NRCS can assist with stream bank stabilization and habitat improvement projects, and has several cost-share programs available for different types of land conservation practices. Many of the NRCS programs are oriented towards agricultural and ranching land, but may also be applicable in the Willow Creek watershed.

<u>Resource Conservation and Development (RC&D)</u> – The USDA has established RC&D areas to promote conservation development and use of natural resources; to improve the general level of economic activities; and to enhance the environmental and standard of living in communities. Six RC&D areas have been established in Colorado, including the San Luis Valley RC&D. Obviously, as the Willow Creek Reclamation Committee operates under the San Luis Valley RC&D, the two have an intimate connection. The SLV RC&D also secured $52,000 to form the San Luis Valley Environmental Conservation Education Council whose purpose is to provide environmental conservation education to youth.

<u>Small Watershed Program (PL-566)</u> - The Small Watershed Program is administered through the Watershed Protection and Flood Prevention Act (PL-566), which authorizes the Secretary of Agriculture to provide technical and financial assistance in planning and development of watershed projects. Thus far, no projects have been implemented in the Upper Rio Grande corridor through this program.

<u>Wildlife Habitat Incentives Program (WHIP)</u> - The WHIP program is a wildlife habitat improvement and restoration program which offers landowners up to 75 percent cost-share for wildlife habitat improvement projects. The Colorado WHIP program objectives are to improve habitat for declining or at-risk species; to improve habitat and increase the population of economically important species, and to reduce significant agriculture/wildlife conflicts.

U.S. Army Corps of Engineers
The Army Corps can participate in flood control and environmental restoration projects that meet certain benefit/cost and national economic development criteria. Reconnaissance studies can be completed with federal funds, but major design and construction projects require a significant local cost-share.

Partners for Fish and Wildlife
Sponsored by the U.S. Fish and Wildlife Service, the Partners for Fish and Wildlife program is designed to provide funding and technical assistance for habitat improvement projects to private landowners. The San Luis Valley has been and remains the area of greatest emphasis due to its high value for migrating waterbirds and extensive interest.

U.S. Environmental Protection Agency (EPA)
The EPA provides the majority of the funding for the WCRC. The EPA has been highly involved in the WCRC and its efforts and is very interested in the success of water quality and ecosystem improvements in Willow Creek.

Regional Geographic Initiative Program
The WCRC has already received one grant from the Regional Geographic Initiative (RGI) program. The program may also be a good fit for future funding. The purpose of the RGI program is to provide grants for projects which have been identified as high priority by an EPA region, state, or locality. These projects generally pose a high human or ecosystem risk and have significant potential for risk reduction. The problems are defined geographically rather than by pollutant or sector. All of the initiatives support one or more of the seven EPA guiding principles: ecosystem management, environmental justice, partnerships, sound science and data, pollution prevention, reinventing EPA management, and environmental accountability (www.epa.gov/regional/rgi.htm).

Funding for regional initiatives is generally considered to be "seed" money. RGI projects generally expect funding for four years, including one year of project development and partnering and three years of project implementation. The general timeline for the process is October through January.

Watershed Initiative Program
The Watershed Initiative is a new competitive program that may be a one time opportunity. Although the program has not yet received congressional funding, the EPA is optimistic that President Bush's request for the funding will be approved. A total of $21 million has been requested to support up to 20 projects throughout the country with $300,000 to $1,300,000 awards. Project nominations must be submitted by the Governor, and each governor can nominate two projects.

The program encourages innovative or unique approaches to improve water quality and water resources. The program is aimed to help successful watershed coalitions with broad community support just like the WCRC. The grant application should present a watershed characterization and restoration plan. The difficulty with this funding source may be the deadline requirements. The governors must submit their nominations no later than November 21, 2002. The funding may be available in future years, but this is not certain.

Colorado Water Conservation Board (CWCB) / Department of Natural Resources
As the CWCB funded part of the current study, the CWCB is obviously willing to cooperate with the Willow Creek Reclamation Committee and is interested in flood control in Willow Creek. The CWCB provides funding for flood hazard mitigation plans. Funding for demonstration restoration projects could also be provided, similar to support currently being provided for the Alamosa River restoration project. CWCB makes loans available for flood mitigation and erosion control projects through its Construction Fund.

Great Outdoors Colorado Trust Fund (GOCO)
The Great Outdoors Colorado Trust Fund program receives a portion of Colorado Lottery proceeds to award grants that preserve, protect, and enhance Colorado's wildlife, parks, rivers, trails, and open spaces. There are five competitive grant programs: Legacy, Open Space, Local Government Parks, Outdoor Recreation & Environmental Education Facilities, Trails, and Planning/Capacity Building. Local governments (counties, municipalities, special districts), non-profit land conservation organizations, the Colorado Division of Wildlife and Colorado State Parks are eligible to receive GOCO grants. The program has awarded $290 million in grants for 1700 projects in the state. Natural resources related projects within the area include an inventory of Native Species project by the Colorado Division of Wildlife, the Medano/Zapata Ranch project by the Nature Conservancy, the San Luis Valley Community-Based Conservation Project, San Luis Valley GIS Development/Smart Growth, a Wetland Development and Enhancement Project, and many others. Grant amounts ranged from $10,000 to $2,000,000. (www.goco.org)

Grant cycles vary based on project type. Grant requests typically take 6 to 9 months from application distribution to grant award.

San Luis Valley Wetland Focus Area Committee
This group represents the local link to national funding organizations interested in supporting wetland preservation and enhancement projects. This group has been successful in attracting money for previous projects in the San Luis Valley.

River Network
River Network is a national non-profit organization with a mission to "help people understand, protect, and restore rivers and their watersheds." The organization helps to build citizen groups and works with private land owners and public agencies to acquire and conserve critical riverlands. (www.rivernetwork.org)

The River Network has teamed with the EPA to institute the Watershed Assistance Grants (WAG) program. This program is a component of the Clean Water Action Plan. The grants range from $1,500 to $30,000 and are primarily used as seed money intended to initiate grass-roots watershed protection groups. Recipients include watershed groups, planning commissions, universities, water districts, and municipalities. Projects included development of GIS databases, funding for meetings/conferences, hire coordinators, and conduct studies. The grants cannot be used for on-the-ground restoration projects.

Proposals are normally due in mid-August, with final grant recipients announced no later than November. All funds must be used within the River Network's fiscal year, which ends on September 30.

Private Organizations
Private organizations such as Ducks Unlimited and Trout Unlimited offer assistance through consultations and funding projects to enhance wildlife habitat.

Rio Grande Water Conservation District
The Rio Grande Water Conservation District may be interested in Willow Creek projects; particularly those that effect water quality on the Rio Grande.

U.S. Forest Service
The majority of the Willow Creek watershed is the property of the U.S. Forest Service. The Forest Service, through its regional office in Monte Vista, has been actively involved in the Willow Creek Reclamation Committee and has provided some funding. The Forest Service is interested in protecting sediment sources within the watershed.

Colorado Department of Health (CDHP)
The Colorado Department of Health has been actively involved with the WCRC and is very interested in reducing risks to public health posed by mine wastes. The agency can assist with cleanup of watershed and "brownfield" areas.

Mineral County
Mineral County is responsible for the Bachelor Loop roadway within the study area and may be able to assist in repairing flood damage associated with the road or decreasing the risk of flood damage. The county may be able to complete some projects such as culvert installations or cooperate with heavy equipment.

City of Creede
The city of Creede has an interest both in decreasing the risk of flood damage near downtown Creede or North Creede and in supporting and increasing tourism to the area. The city may be able to help fund projects or provide matching funds for projects funding by state or federal organizations.

4.3 *Project Implementation*

The next task for implementation of potential projects may be for the Willow Creek Reclamation Committee to further investigate potential partnerships and funding opportunities. The following table matches a preliminary list of potential implementation partners or funding sources to each potential project.

Table 4.3.1. Potential implementation partners or funding sources for each project

Potential Project	Potential Implementation Partner or Funding Source
Windy Gulch Flood Control	Colorado Water Conservation Board (CWCB) U.S. Army Corps of Engineers (Army Corps) Mineral County City of Creede
Restoration of Mining Museum Area Reach	Great Outdoors Colorado Trust Fund (GOCO) Colorado Water Conservation Board (CWCB) EPA Watershed Initiative Program
North Creede Culvert Replacement	Private Land Owner City of Creede Mineral County
Willow Creek Bridge Bank Protection	Mineral County
Removal of Timber Debris	Willow Creek Reclamation Committee Mineral County
Commodore Mine Flood Bypass System	EPA Regional Geographic Initiative Program EPA Watershed Initiative Program
Amethyst Mine Debris Protection	Willow Creek Reclamation Committee City of Creede
Plant Willow, Install Vortex Weir Drops	SLV Environmental Conservation Education Council NRCS Wildlife Habitat Incentives Program U.S. FWS Partners for Fish and Wildlife Trout Unlimited
Sediment Source Controls	U.S. Forest Service NRCS Small Watersheds Program Colorado Department of Health (CDHP)

The following sections discuss short-term implementation activities by project.

Commodore Mine Flood Bypass System

A very large amount of funding will be needed to design and build a flood bypass system over the Commodore tailings pile. Due to the risk of catastrophic damage to water quality of both Willow Creek and the Rio Grande, the EPA should be very interested in the project. The EPA's Regional Geographic Initiative Program may be a very appropriate fit to fund the project, as this project does pose a high risk to the ecosystem and has a significant potential for risk reduction.

The project will need to be identified as a high priority by an EPA region, state, or locality. The representatives of the EPA directly involved with the WCRC could help to initiate steps for participation in this program. The EPA's Watershed Initiative program may also be another potential source of funding.

The Commodore Flood Bypass system still requires a significant design effort prior to implementation phases. A qualified geotechnical engineer should be consulted to examine project feasibility and design. System layout, material specifications, and construction methods appropriate for the steep slopes of the tailings pile need to be considered. The Creede community will need to be involved extensively to consider affects to the visual and historical character of the area. The EPA program often funds project planning, although other partner funding sources may be needed.

The project could also be considered jointly with a project to treat water from the Nelson Tunnel. The flood bypass system could allow easier separation of the Nelson water from West Willow Creek. This may also facilitate the installation of a small-scale treatment system for Nelson water.

North Creede Culvert Replacement

Efforts have already been initiated between the City of Creede and the owner of the affected property in North Creede to replace the culvert on East Willow Creek. The mayor of Creede did consult the WCRC on recommendations for the culvert, and the WCRC recommended installing a culvert with at least a 50-year flood capacity. However, additional funding sources may need to be located to install this size of culvert. The engineers for the City of Creede (McLaughlin Water Engineers) may be able to provide final design services and accurate cost estimation for the project.

Windy Gulch Flood Control

Better hydrologic estimates are needed on Windy Gulch. The CWCB, NRCS, or Army Corps could be approached by the WCRC to help refine hydrologic estimates. The hydrology of the gulch is unique due to sub-surface flow conditions, and sophisticated methodologies may be needed. Proposed improvements to the waste dumps of the Bulldog Mine may also change the hydrology of Windy Gulch.

For the Windy Gulch flood overflow project, the CWCB could possibly provide a flood mitigation loan through its construction fund. The City of Creede or Mineral County may be able to assist with loan repayment. The Army Corps could also be approached about the project as the Gulch influences the effectiveness of the flume and flume levees and the project could help raise the end of the flume levees. The Army Corps would probably require a local cost share. Mineral County could also help with road reconstruction. The Windy Gulch project could possibly be combined with the restoration of the Mining Museum area.

Amethyst Mine Debris Protection

Implementation partners may be a little more difficult to locate for the Amethyst Mine debris protection project. The WCRC could possibly fund the project directly in the interest of maintaining long-term access to mine tunnel. The City of Creede or others may also be interested in this objective. A local welder could possibly install the grating. Removal of timber debris upstream of the culvert may help the problem in the short term.

Restoration of Mining Museum Area Reach

The Mining Museum area restoration could be combined with other projects to make an attractive large-scale project for funding agencies. The stream reach between the Mining Museum area and the confluence of East and West Willow Creek may be highly visible area to install stream channel improvements as "demonstration projects", and willow plantings and vortex weir drops could help decrease the transport of sediments into the Mining Museum area and decrease maintenance needs for the proposed sedimentation basins. The proposed bike/walking trail could also be extended into this area. The Windy Gulch culvert replacement could also be considered with the project as it is in the same area and may facilitate reshaping of the flume levees. An even larger scale restoration effort could be envisioned by combining the project with the restoration of the Willow Creek floodplain below the flume. The Mining Museum area restoration may be important to ensure the long term viability of the proposed "sinuous" channel by lowering sediment transport into the flume. The number of elements that are included with the project may be dependent on the funding source and potential partners.

GOCO may be an ideal fit for the comprehensive restoration of the stream reach near the Mining Museum. The project fits perfectly with GOCO's primary objective to enhance Colorado's wildlife, parks, rivers, trails, and open spaces. If a bike/walking trail was included in the design of the project, the project could be funded through its public trails program. GOCO's Open Space or Outdoor Recreation and Environmental Education Facilities programs may also be applicable. The EPA's new Watershed Initiative program may also be able to fund such a large-scale project. The CWCB may also be interested in portions of the project as a demonstration project. A final design process will be needed before phases of project implementation. The WCRC should further consider the project, investigate funding possibilities, and submit a grant application.

Removal of Timber Debris

The WCRC should organize a community volunteer effort to remove timber debris from the Willow Creek channel. Some community members may be able to donate the use of chain saws or small winches to aid in the manual removal of debris. Mineral County could possibly lend a dump truck to help remove this debris or additional heavy equipment to restore the access road below the Commodore Mine. The effort could first concentrate on easy but effective areas such as the reaches above the flume entrance, the Commodore Mine, and the Amethyst Mine. Crews could walk other stream stretches and remove more scattered debris. Later, a more intensive effort could be organized to remove the large timber debris piles below the Commodore Mine.

Channel Improvements - Willow / Vortex Weir Drops

The NRCS Wildlife Habitat Incentives Program, U.S. Fish and Wildlife Partners for Fish and Wildlife, Trout Unlimited, or other environmental or habitat related organizations could help fund the planting of willow on stream banks or the installation of vortex weir drops. The SLV Environmental Conservation Education Council or local schools could use the projects as educational tools.

Possible locations for planting willow and installing vortex weirs need to be further evaluated. Then, a project plan needs to be developed. Restoration of the area upstream of the Mining Museum area to the confluence of East and West Willow Creeks could be combined with the Mining Museum area restoration plan.

Sediment Source Controls

Potential sources of sediment erosion need to be further identified and prioritized by the WCRC. The U.S. Forest Service may be able to fund protection of sources located on Forest Service property. The WCRC could apply for a grant from the NRCS Small Watersheds Program of the Colorado Department of Health to help protect other sediment sources within the Willow Creek watershed.

Willow Creek Bridge Bank Protection

Finally, the project to protect the bank below the Willow Creek Bridge is small and relatively inexpensive. Mineral County could possibly complete this project to protect the bridge and roadway areas.

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APPENDIX