FEASIBILITY STUDY

FOR THE

RECOMMISSIONING OF KLUG RESERVOIR WELD COUNTY, CO

PREPARED FOR:

Central Colorado Water Conservancy District
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1.0 INTRODUCTION

This report describes the feasibility of rehabilitating or enlarging Klug Reservoir No. 3 located near the northwest corner of Weld County Road (WCR) 22 and WCR 49 in unincorporated Weld County, Colorado. Civil Resources analyzed the site and are presenting two options to re-construct the dam and reservoir with varying operations, water storage volumes & construction costs.

1.1 Project Background

Klug Reservoir No. 3 has a 714.5 acre-foot storage decree with an appropriation date of July 6, 1918 as described in the decree and other supporting water rights documentation included in Appendix A. The dam was originally constructed in or around 1920 at a maximum height of 26 feet, length of 2,640 linear feet and 12-foot crest width. However, the reservoir was flooded resulting in dam breach in the 1930's and 1960's before the State Engineer's Office required the permanent breach in the 1980's. The reservoir has gone largely unmaintained since its decommissioning in the 1980's and therefore the embankment remains breached and is eroded resulting in over-steepening of the embankment and the potential for rodent tunnels is high. Further, the existing outlet pipe should be replaced in order to increase its capacity and extend the life of this facility. Based on these observable conditions, a nearly full-reconstructive effort would be recommended and likely required by the SEO.

Civil Resources completed four geotechnical borings on the Site within the reservoir and dam footprint as shown on Figure 3 of the Conceptual Design Plan set attached to this report. The borings were extended to bedrock with depths ranging from eleven to fifty one feet below ground surface and dipping from east to west across the Site. The overlying soils were predominantly sands with varying fines content from 4 to 45 percent. The underlying bedrock appears to be claystone based on collected samples and laboratory testing (refer Appendix B). The borings formed the basis for geologic profiles, slurry wall feasibility review and overall alternative feasibility analysis.

The existing site contains the historic reservoir footprint with steep slopes on the east side and gentle slopes to the west. Drainage flows from Box Elder Creek pass through the current reservoir with a minor amount being held due to pour grading/drainage in the old reservoir bottom. There is a large basin tributary to the property that stretches into Adams County and the City and County of Denver and also includes Barr Lake in the tributary basin along with smaller reservoirs (Meeks Reservoir #1, #2, Bowles Reservoir #1, #2, and Calhoun Reservoir). Support documentation provided by CCWCD indicates that the Bureau of Reclamation estimated the 100-year recurrence storm to produce approximately 35,000 cfs.

2.0 ALTERNATIVE ANALYSIS

Civil Resources considered several alternatives to determine which rehabilitation option provides the most economically viable option to recommission the reservoir. Environmental impacts are also important considerations in determining the District's preferred option. Following is a description of the alternatives considered and the expected pros and cons of each:

2.1 Alternative A – In-Line / Rehabilitation

Alternative A rehabilitates the existing dam and allows the Box Elder Creek flows to continue entering the reservoir. A large spillway would be required to pass the design storm flows safely downstream without breaching the dam. Further, the detained volume would have to be accounted and released by the Owner from the outlet when a more senior call is on downstream of the reservoir adding operational complexity and cost. The basic parameters of the proposed Alternative A are:

- Crest elevation: 4854.6 feet

- Spill Channel (existing) elevation: 4850.0 feet
- Reservoir Bottom elevation: 4930 feet
- Maximum water depth: 20 feet
- Water storage:

Elev. (ft)	Storage (ac-ft)
4830	0.0
4834	5.8
4838	44.5
4842	251.8
4846	490.8
4850	754.7

Alternative A assumes that the existing spill channel will be maintained which has approximately 400 cfs spill capacity and therefore the dam would be vulnerable to more frequent overtopping breach failures but represents the alternative with the lowest capital cost investment to recommission the reservoir. Attached Figures show the conceptual design concept(s) and the cost estimated for Alternative A is summarized below:

Site Preparation / Mobilization	$55,000
Site Work	$1,655,200
Control Structures	$177,600
Total Construction Cost Estimate =	*$1,887,800*
Total Engineering Cost Estimate =	*$186,000*
Total Project Cost Estimate =	***$2,073,800***

2.2 Alternative B – Bypass / Rehabilitation

Alternative B presents a design that diverts Box Elder creek base flows and moderate storm flows around the reservoir by constructing an upstream check dam on the Box Elder Creek and a diversion channel along the west side of the reservoir with an estimated maximum capacity of approximately 4,000 cfs. An emergency spillway is also proposed on the northwest corner of the reservoir/dam that would approximately double the flood conveyance capacity to 8,000 cfs. A controlled inflow location near the upstream end of the reservoir could be constructed to allow the reservoir to fill without full breaching the dam and allow the larger storms to essentially flow "over" the west reservoir containment embankment. The basic parameters of the proposed Alternative B are:

- Crest elevation: 4854.6 feet
- Spillway elevation: 4850.0 feet
- Reservoir Bottom elevation: 4930 feet
- Maximum water depth: 20 feet
- Water storage:

Elev. (ft)	Storage (ac-ft)
4830	0.0
4834	5.8
4838	44.5
4842	251.8
4846	490.8
4850	754.7

Attached Figures show the conceptual design concept(s) and the cost estimated for Alternative B is summarized below:

Site Preparation / Mobilization	$80,000
Site Work	$2,155,200
Control Structures	$335,600
Total Construction Cost Estimate =	*$2,570,800*
Total Engineering Cost Estimate =	*$233,000*
Total Project Cost Estimate =	***$2,803,800***

2.3 Alternative C – Bypass / Enlargement

Alternative C presents a design that diverts Box Elder creek base flows and moderate storm flows around the reservoir by constructing an upstream check dam on the Box Elder Creek and a diversion channel along the west side of the reservoir along the property line similar to Alternative B but also includes excavation of soil materials down to the bedrock and expanded into the east bank. The basic parameters of the proposed Alternative C are:

- Crest elevation: 4854.6 feet
- Spillway elevation: 4850.0 feet
- Reservoir Bottom elevation: 4930 feet
- Maximum water depth: 49 feet
- Water storage:

Elev. (ft)	Storage (ac-ft)
4801	0.0
4810	64.8
4820	282
4830	683
4840	1,210
4850	1,794

Attached Figures show the conceptual design concept(s) and the cost estimated for Alternative C is summarized below:

Site Preparation / Mobilization	$105,000
Site Work	
- Mining	$2,155,200
- No Mining	$6,775,200
Control Structures	$335,600
Total Engineering Cost Estimate =	$429,000
Total Project Cost Estimate (Mining) =	***$3,024,800***
Total Project Cost Estimate (No Mining) =	***$7,215,800***

3.0 RECOMMENDED ALTERNATIVE

The Bypass / Enlargement alternative results in the lowest cost to storage ratio if the material proposed to be over-excavated is removed at no cost to CCWCD, however, the cost to excavate and haul to an adjacent spoil area makes this alterative far less practical. The following table summarizes the alternatives:

Table 1 - Engineer's Estimate of Cost Summary

Alternative	Crest Elev (ft)	Btm Elev (ft)	Construction Costs ($)	Water Storage (ac-ft)	Construction Cost per ac-ft ($)
A	4854.6	4830	$2,073,800	754.7	$2,748
B	4854.6	4830	$2,803,800	754.7	$3,715
C - Mine	4854.6	4800	$3,024,800	1,794	$1,686
C – No Mine	4854.6	4800	$7,215,800	1,794	$4,022

Notes:

1. 20-foot-wide embankment crest on all alternatives and 60'-wide cut bench on east side.

2. See attached Tables for detailed Opinion of Construction Costs.

Other Considerations

Following is a summary of considerations that support the bypass alternatives:

1. Flood Protection & SEO Approval

- The Bureau of Reclamation reviewed the Site for rehabilitation potential and estimated the 100-year flow to be in the order of 35,000 cfs and therefore constructing a spillway to convey the design storm flow would be very costly and may even require that the entire dam be constructed with Roller Compacted Concrete or other erosion resistant materials.

- Bypassing the maximum amount of flow prior to overtopping the dam would increase the likelihood that an Incremental Damage Analysis would be successful in demonstrating that breach of the reservoir would not significantly impact the peak flow and create likely loss of life which would allow the reservoir to be constructed with a lesser spillway and associated lower costs.

- Constructing a smaller spillway would result in more frequent dam failure and therefore the Owner would have to accept that reconstruction costs would be necessary in the future. Construction of a "fuse plug" in the dam embankment may also provide a mechanism for releasing the reservoir volume in a more controlled manner as to reduce flooding impacts (if any) downstream.

- Lowering the dam height to 10-feet and surface area to 20 acres would meet the State's criteria for a non-jurisdictional dam and simplify permitting requirements. Only approximately 150 acre-foot of storage would be available for Alternatives A and B, however, Alternative C would still allow up to 1210 acre-feet.

2. General

- Four on-site borings were completed and indicate that the site has limited clay and therefore a slurry wall lining would likely be the most cost effective liner option.

- A synthetic lining alternative is feasible for the alternatives that do not propose to excavate below maximum groundwater elevation(s). The anticipated cost for installing synthetic liner compared to slurry wall is significantly higher as presented in the detailed cost estimates for Alternatives A and B.

- Groundwater levels are based on drilling information.

- Possible acquisition of adjacent property to the west to allow further enlargement of the reservoir should be considered by CCWCD.

- Agreement with adjacent land owners to spoil excess material is very important to the financial feasibility of the project unless a sand mining operation is setup on the Site. The fines content of the natural material and limited mining volume may limit interest by most mining companies, however, the material would likely meet Class I or Class II structural fill per CDOT specifications which would make it valuable to roadway and oil/gas development and may make DRMS permitting unnecessary.

3. Permitting - The natural condition of the Box Elder Creek drainage is an incised steep bank drainage that maintains a baseflow and supports a narrow width of wetlands and biological corridor. The construction of Klug Reservoir originally intercepted the natural drainage flows thereby providing flood protection and a controlled downstream release of collected water. The reservoir provided additional habitat with as a sustained water source. Since the dam was breached, the Environmental impacts of the proposed project would be limited to short-term "disturbance" activities because the work proposed is associated with the repair of an existing structure and will not result in an increase in diversions from the river compared to historic operations. No social impacts are anticipated from the repair of the structure.

   The Klug Reservoir owner has a right to make repairs necessary to protect its property right represented by the associated court approved decrees. There appears to be jurisdictional wetlands on the site but no official determination has been made. Civil Resources recommends that CCWCD coordinate with an environmental consultant to delineate the wetlands and make suggestions on how to proceed from a permitting standpoint.Civil Resources anticipates that a Site Specific Permit may be required by the USACE for the repair of this existing dam structure and construction of the check dam that will both require fill in jurisdictional wetlands. The wetland impacts would be relatively minor and additional, higher quality wetlands would be created by constructing the bypass channel so it is likely that the project would be permitted. However, an Environmental impact Study may be necessary which would add time and cost to the project.

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TABLES

Opinion of Construction Cost
Klug Reservoir Recommissioning
Alternative A - In-line / Rehabilitation

Site Preparation / Mobilization

Item #	*Item*	*Qty*	*Unit*	*Unit Cost*	*Engineer Cost*	*Civil Resources' Cost Notes*
1	Mobilization	1	LS	$40,000	$40,000	
2	Surveying	1	LS	$15,000	$15,000	
				Subtotal =	*$55,000*	

Site Work

Item #	*Item*	*Qty*	*Unit*	*Unit Cost*	*Engineer Cost*	*Notes*
3	Dam Embankment					
	- Earthwork	1	LS	$60,000	$60,000	
	- Riprap	3,000	CY	$60	$180,000	
4	Dewatering & Water Control					
	- Construction Dewatering	1	LS	$18,000	$18,000	
	- Sfc Water Bypass	1	LS	$30,000	$30,000	
5	Revegetation / Erosion					
	- Seeding / Mulch	12	AC	$2,600	$31,200	
	- Erosion Blanket	30,000	SY	$1.20	$36,000	
6	Reservoir Liner					
	- Slurry Wall	260,000	SF	$5.00	$1,300,000	
	- Synthetic (Not incl. in Total Cost)	2,600,000	SF	$2.20	$5,720,000	Alternate / Not incl. in Total Cost
				Subtotal =	*$1,655,200*	

Control Stuctures

Item #	*Item*	*Qty*	*Unit*	*Unit Cost*	*Engineer Cost*	*Notes*
7	Gravity Outlet Replacement					
	- 36-inch DIP	180	LF	$300.00	$54,000	Concrete Encased
	- Upstream Control Gate	1	LS	$90,000	$90,000	
	- Downstream Baffle Structure	1	LS	$30,000	$30,000	
	- Riprap	60	CY	$60.00	$3,600	
				Subtotal =	*$177,600*	

Total Construction Cost Estimate

Site Preparation / Mobilization	$55,000
Site Work	$1,655,200
Control Stuctures	*$177,600*
Total Construction Cost Estimate =	*$1,887,800*
Survey & Engineering Design =	$110,000
Construction Engin. @ 4% =	$76,000
Subtotal =	*$186,000*
Total Project Cost =	*$2,073,800*

Opinion of Construction Cost
Klug Reservoir Recommissioning
Alternative B - Bypass / Rehabilitation

Site Preparation / Mobilization

Item #	*Item*	*Qty*	*Unit*	*Unit Cost*	*Engineer Cost*	*Civil Resources' Cost Notes*
1	Mobilization	1	LS	$60,000	$60,000	
2	Surveying	1	LS	$20,000	$20,000	
				Subtotal =	*$80,000*	

Site Work

Item #	*Item*	*Qty*	*Unit*	*Unit Cost*	*Engineer Cost*	*Notes*
3	Dam Embankment					
	- Earthwork	1	LS	$60,000	$60,000	
	- Riprap	3,000	CY	$60	$180,000	
4	Bypass Channel					
	- Riprap	3,000	CY	$60	$180,000	
	- Earthwork	100,000	CY	$3.20	$320,000	
5	Dewatering & Water Control					
	- Construction Dewatering	1	LS	$18,000	$18,000	
	- Sfc Water Bypass	1	LS	$30,000	$30,000	
6	Revegetation / Erosion					
	- Seeding / Mulch	12	AC	$2,600	$31,200	
	- Erosion Blanket	30,000	SY	$1.20	$36,000	
7	Reservoir Liner					
	- Slurry Wall	260,000	SF	$5.00	$1,300,000	
	- Synthetic (Not incl. in Total Cost)	2,600,000	SF	$2.20	$5,720,000	Alternate / Not incl. in Total Cost
				Subtotal =	*$2,155,200*	

Control Stuctures

Item #	*Item*	*Qty*	*Unit*	*Unit Cost*	*Engineer Cost*	*Notes*
8	Emergency Spillway (West Abutment)					
	- Riprap	800	CY	$60.00	$48,000	
	- Reinforced Concrete	200	CY	$550.00	$110,000	
9	Gravity Outlet Replacement					
	- 36-inch DIP	180	LF	$300.00	$54,000	Concrete Encased
	- Upstream Control Gate	1	LS	$90,000	$90,000	
	- Downstream Baffle Structure	1	LS	$30,000	$30,000	
	- Riprap	60	CY	$60.00	$3,600	
				Subtotal =	*$335,600*	

Total Construction Cost Estimate

Site Preparation / Mobilization	$80,000
Site Work	$2,155,200
Control Stuctures	*$335,600*
Total Construction Cost Estimate =	*$2,570,800*
Survey & Engineering Design =	$130,000
Construction Engin. @ 4% =	$103,000
Subtotal =	*$233,000*
Total Project Cost =	*$2,803,800*

Opinion of Construction Cost

Klug Reservoir Recommissioning

Alternative C - Bypass / Enlargement

Site Preparation / Mobilization

Item #	*Item*	*Qty*	*Unit*	*Unit Cost*	*Engineer Cost*	*Civil Resources' Cost Notes*
1	Mobilization	1	LS	$80,000	$80,000	
2	Surveying	1	LS	$25,000	$25,000	
				Subtotal =	*$105,000*	

Site Work

Item #	*Item*	*Qty*	*Unit*	*Unit Cost*	*Engineer Cost*	*Notes*
3	Earthwork					
	- Dam Embankment	1	LS	$60,000	$60,000	
	- Below Grade Excavation	2,100,000	CY	$2.20	$4,620,000	
	- Dam Riprap	3,000	LS	$60	$180,000	
4	Bypass Channel					
	- Riprap	3,000	CY	$60	$180,000	
	- Earthwork	100,000	CY	$3.20	$320,000	
5	Dewatering & Water Control					
	- Construction Dewatering	1	LS	$18,000	$18,000	
	- Sfc Water Bypass	1	LS	$30,000	$30,000	
6	Revegetation / Erosion					
	- Seeding / Mulch	12	AC	$2,600	$31,200	
	- Erosion Blanket	30,000	SY	$1.20	$36,000	
7	Reservoir Liner					
	- Slurry Wall	260,000	SF	$5.00	$1,300,000	
				Subtotal =	*$6,775,200*	

Control Stuctures

Item #	*Item*	*Qty*	*Unit*	*Unit Cost*	*Engineer Cost*	*Notes*
8	Emergency Spillway (Right Abutment)					
	- Riprap	800	CY	$60.00	$48,000	
	- Reinforced Concrete	200	CY	$550.00	$110,000	
9	Gravity Outlet/Pump Station					
	- 36-inch DIP	180	LF	$300.00	$54,000	Concrete Encased
	- Upstream Control Gate	1	LS	$90,000	$90,000	
	- Downstream Baffle Structure	1	LS	$30,000	$30,000	
	- Riprap	60	CY	$60.00	$3,600	
				Subtotal =	*$335,600*	

Total Construction Cost Estimate

				Site Preparation / Mobilization	$105,000	
				Site Work	$6,775,200	
				Control Stuctures	*$335,600*	
				Total Construction Cost Estimate =	*$7,215,800*	
				Survey & Engineering Design =	$140,000	
				Construction Engin. @ 4% =	$289,000	
				Subtotal =	*$429,000*	
				Total Project Cost =	*$7,644,800*	