5.0 ALTERNATIVES ANALYSIS

5.1 Reservoir Enlargements

Three reservoir enlargement sizes were evaluated, a small enlargement raising the water surface five feet, a mid-size enlargement raising the water surface 13 feet, and a maximum enlargement raising the water surface 19 feet. We also considered two options for each enlargement size, a baseline case and a shoreline case. The baseline option utilizes the best topographic alignment for a future dam and minimizes dam embankment volumes. The shoreline option keeps the dam embankment located on Union Reservoir Company property and minimizes the land required for acquisition along the western side of the reservoir. Thus, a total of six dam raise alternatives were evaluated in our studies.

As mentioned in Section 2.2, the five-foot, 13-foot, and 19-foot raises described in this section are relative to elevation 4957, the full reservoir water surface elevation presented in the 1986 RMC report. However, with the conclusion that the existing reservoir high water line is at elevation 4955.87, the raises described in this section are actually 1.13 feet higher than presented. Likewise, the incremental storage increase for each raise option would be approximately 846 acre-feet more than the storage increases discussed later in this section. Finally, the cost per acre-foot of increased storage would be less than what is presented in this section.

5.2 Dam Type

Given the topography and geology of the site, an earth dam is considered the most appropriate dam type. Any size enlargement requires a very long main dam, between 6,000 feet long for the five-foot raise and 12,000 feet long for the 19-foot raise. An earth dam is the most economical method to construct a dam of this length. Abundant borrow soils are available on-site for an earth dam. Foundation conditions also strongly favor earth dam construction because they consist of soft to stiff clayey soils with some settlement potential that would be compatible with a flexible earth dam. An earth dam is also easily enlarged if planned for ahead of time. Thus, the City could build a smaller raise first and enlarge it further in the future.

Other dam types, such as roller compacted concrete (RCC) could be considered for say a 1,000-foot section of the dam. RCC is overtoppable forming an emergency spillway during the design flood event. Thus, some cost savings might be effected by reducing the required size of a service spillway. This was evaluated and proposed by RMC in their 1986 study and should be considered during design.

Since a primary purpose of this study was to perform a comparative evaluation of various enlargement alternatives, an earth dam was used consistently for each alternative. All earth dam alternatives assumed five feet of freeboard to pass the design flood with one-foot of residual freeboard. Thus, the dam crest would be five feet above the reservoir enlargement height. A 400-foot wide concrete labyrinth spillway and similar outlet improvements were also used throughout all the alternatives.

5.3 Dam Section

5.3.1 Borrow

Abundant sandy clay overburden soils are available on City owned property both south and southwest of the reservoir. Approximately 600,000 cubic yards of clay soil could be borrowed south of the reservoir. This could be done in conjunction with spillway channel construction (**Figure 5.1, Borrow Area A**). By excavating the channel down to near the groundwater level, approximately 12 acres of wetlands would form that could be used to mitigate wetland impacts from the project.

Deep clay soils east of the reservoir provide large quantities of borrow, and excavation work could be done in conjunction with grading for a potential future City park. This is shown as Area B on **Figure 5.1**. Bedrock could also be used for borrow from the reservoir bottom if the lake is lowered.

Borrow Area C, a small City owned parcel to the west of the reservoir, would yield 180,000 cubic yards of eolian soils and bedrock if excavated to a depth of 10 feet.

5.3.2 Typical Section

A homogeneous dam section is suitable given the available borrow, sandy clay, and the maximum dam heights. A typical section for the 13-foot enlargement is shown on **Figure 5.2**. This section shows a 3:1 (horizontal to vertical) upstream slope and 3:1 downstream slope with an 18-foot wide crest. The upstream slope would contain 18-inch thick riprap placed on 12-inch thick gravel bedding. A toe drain consisting of slotted PVC pipe surrounded in graded filter sand would also be included to collect seepage.

In order to reduce underseepage through the sand and gravel, a soil-bentonite slurry wall extending to bedrock was assumed throughout the alternatives. This is shown on **Figure 5.2**.

The bottom drawing on **Figure 5.2** illustrates a staged construction for a five-foot reservoir enlargement to a 13-foot reservoir enlargement. This could be accomplished with a simple downstream raise of the dam.

5.3.3 Stability Analysis

The slope stability for the proposed maximum embankment section (station 59+74) for the 13-foot raise option was evaluated under several anticipated and required loading conditions. Both the upstream and downstream embankment slopes were analyzed. The loading conditions analyzed included:

1. Reservoir at the Normal High Water Line (NHWL):   The stability analysis was performed under the modeled condition of a full design reservoir with the water at the NHWL elevation of 4970 feet above sea level.

2. Reservoir at the NHWL with a design earthquake: The stability analysis was performed assuming the reservoir was full to the NHWL of 4970 feet and a design earthquake loading was applied to the model. The design earthquake was modeled to apply a horizontal loading of 0.1 times the force of gravity to the embankment.

3. Rapid Drawdown of the Reservoir: The stability analysis was performed assuming the reservoir was rapidly lowered 17 feet from the NHWL elevation of 4970 feet.

The computer program SLOPE/W was used to model all of the slope stability analyses. The program allows the operator to modify the search parameters to find the most critical failure surface out of several hundred failure planes over a range of entry and exit locations along the surface of the embankment. For this analysis, 2,816 different failure planes were analyzed using the Spencer Method, which satisfies both movement and force, to find the most critical failure surface. The assumed material properties for each soil layer are shown on the table below:

Unit	***Moist Unit Weight (pcf)***	***Cohesion C' (psf)***	***Friction Angle Φ' °***
Bedrock	110	0	26
Sand and Gravel	120	0	35
Overburden	106	50	26
Embankment	106	200	27
Slurry Wall	115	0	22

The cross-section, shown on **Figure 5.3**, represents the maximum embankment cross-section at station 59+74 for the NHWL loading condition. The calculated factors of safety for the various loading conditions are summarized in the following table:

Failure Surface Location	***Condition Analyzed***	***Calculated Factor of Safety***	***State Engineer Criteria Minimum Factor of Safety***
Upstream Dam Slope	Full Reservoir Full Reservoir w/ Earthquake (.1 g) Rapid Drawdown	2.5 1.5 1.2	1.5 1.0 1.2
Downstream Dam Slope	Full Reservoir Full Reservoir w/ Earthquake (.1 g)	1.7 1.2	1.5 1.0

All of the slope stability analysis figures can be found in **Appendix D**.

5.3.4 Seepage Analysis

A seepage analysis was performed on a cross-section at station 42+20 to evaluate the potential loss of water due to the permeability of the subsurface geology. This cross-section, as shown on **Figure 5.4**, was selected because of the presence of a thick (approximately 10-foot) layer of sand and gravel was found during our geotechnical investigation. The finite-element program SEEP/W was used to model the embankment at the normal high water line elevation of 4970 feet. A constant head, steady state seepage model using the hydraulic conductivities for each geologic unit shown below was developed to perform the analysis. The model was run with and without a slurry wall and with and without the 10-foot thick gravel layer found near station 42+20 to allow the approximation of water seepage out of the reservoir.

Material Hydraulic Conductivities

Material	***Hydraulic Conductivity***
Bedrock	7.99e-06 cm/sec
Sand and Gravel	1.40e-02 cm/sec
Overburden	3.29e-05 cm/sec
Embankment	3.29e-07 cm/sec
Slurry Wall	1.00e-07 cm/sec

From our analysis we estimate the seepage losses from the reservoir to be approximately 100 acre-feet per year with the construction of the proposed slurry wall and 200 acre-feet per year without the construction of the proposed slurry wall.

All of the seepage analysis figures can be found in **Appendix E**.

5.4 <u>Outlet Works</u>

As part of any enlargement, renovation or replacement of the 100 year old outlet works is warranted to ensure reliable water delivery. A municipal reservoir of this size commonly contains multi-level outlets (2 or 3) to allow selective discharge from distinct temperature (or water quality) stratifications in the reservoir.

We assumed for all alternatives in this study that twin 36-inch diameter steel outlet pipes would be constructed. This could be constructed using micro-tunneling technology and installed while the reservoir is fully operational. This could be accomplished by jacking the pipe from the existing outlet channel and tunneling in bedrock. This type of outlet replacement was done at both Standley Lake for Westminster in 2004 and at McClellan Reservoir for Centennial Water and Sanitation District in 2000. The cost of replacing the outlet works is estimated at approximately $2,000,000.

5.5 <u>Union Reservoir Inlet Modifications</u>

Increasing the storage at Union Reservoir, and thereby raising the normal high waterline elevation, will require modification of the inlet. Union is now filled from the Oligarchy Ditch through a diversion located at 9th Avenue and County Line Road and an open earth canal from County Line Road to Union Reservoir. The existing inlet is capable of filling the reservoir to its normal high waterline elevation of 4957 feet. To contain the raised reservoir water surface, a dam embankment will be built across the existing inlet canal.

Filling the enlarged reservoir would utilize a piped inlet through the embankment. The piped inlet could be constructed at the existing inlet canal location for the 5-foot reservoir raise, or along an alternate route paralleling County Line Road, the existing Great Western Rail Road right-of-way, and the reservoir outlet channel for the 13-foot and 19-foot enlargements. The Oligarchy Ditch through Longmont has been enlarged along most of its length to carry up to 500 cfs. Thus, the new inlet configurations described herein are sized for 500 cfs.

The 5-foot reservoir raise will store water to an elevation of 4962. Filling the reservoir to this level at a rate of 500 cfs by gravity will require a 108-inch diameter pipeline approximately 2,600 feet long placed at the location of the current inlet canal. The estimated cost of this inlet is approximately $1,275,000 including rebuilding the existing diversion structure at the Oligarchy Ditch to accommodate the new pipe.

Raising the reservoir 13 feet will require that a new diversion be constructed at a higher elevation (farther south) on the Oligarchy Ditch. The proposed diversion location would be approximately 0.7 miles south of 9th Avenue and just west of County Line Road. At this location, the ditch elevation is high enough to fill the reservoir by gravity at a rate of 500 cfs to an elevation of 4,970 using a 126-inch diameter pipe approximately 6,100 feet long. The estimated cost of this inlet, including diversion structure and pipeline, is approximately $3,325,000.

Filling Union Reservoir to an elevation of 4976 (the 19-foot raise) can use the same inlet structure as described above for the 13-foot raise, except that a lift station would be required to lift the water the final 6 feet. The cost of this inlet, including the diversion structure, the pipeline and a 525 horsepower pump station, is estimated at approximately $4,375,000.

5.6 Spillway Design

Several spillway designs were considered to safely pass the PMP inflow design flood. All configurations were designed to provide 5 feet of freeboard above the spillway crest, with one-foot of residual freeboard above the maximum water surface during the design flood. Each spillway configuration was designed to safely convey IDF flows for all three dam raise conditions.

The first option was a paved broad crested weir spillway. Because the spillway was limited to four feet of operating head, the broad crested spillway required a length of approximately 1,200 feet in order to maintain one foot of residual freeboard.

An ogee weir was also considered as a spillway crest. While the ogee weir is more efficient than the broad crested weir, a length of 900 feet was necessary to safely convey the design storm.

Because of the physical limitations of the site, neither the broad crested weir nor the ogee weir were practical. In order to reduce the length of the spillway, a labyrinth weir design was considered. The labyrinth spillway configuration is capable of safely passing the design storm flood with a length of 400 feet. A second advantage of the labyrinth spillway configuration is that it is easily modified to accommodate future dam raises. For example, the original dam raise may be 5 feet, but later modified to the 13-foot raise option. The original labyrinth walls would be 5.6 feet high. These walls could be designed with the proper concrete thickness and steel reinforcement to support an addition of 8 vertical feet. Hydraulic information for the spillway design is included in **Appendix F**.

5.7 Storm Drain Line

All alternatives include a storm drainage line along the western side of the reservoir. The purpose of this drain is two-fold. First, the 48-inch diameter pipe would carry low flows for the unnamed gulch that flows into the reservoir on the northwest around the reservoir. This would enhance the water quality of the reservoir. Secondly, the storm drain would carry storm flows that would have originally flowed easterly into the reservoir which would now be impounded by the dams.

5.8 Five-Foot Enlargement Alternative

The general plan for the five-foot baseline enlargement is shown on **Figure 5.5**. This option would result in 4,090 acre-feet of additional storage. The plan for the five-foot shoreline option is presented on **Figure 5.6**. A total of 3,870 acre-feet would be grained under this scenario. The figures show the required hydraulic improvements in red and required earthwork in orange. The normal high water line is shown in solid blue and the flood stage (four feet higher) is shown with a dashed blue line. A small berm is shown in the northeast part of the reservoir that would prevent the existing houses from future inundation. Also shown are the drainage improvements that will collect storm water north of the reservoir and carry it east away from the reservoir.

5.9 Thirteen-Foot Enlargement Alternative

The 13-foot raise options are shown on **Figures 5.7 and 5.8**. These options provide 12,280 acre-feet of additional storage under the baseline option and 11,420 acre-feet under the shoreline option.

These options have similar required improvements as the five-foot alternative, except: 1) no berm is constructed on the northeast side of the reservoir and the existing houses are inundated, 2) a small saddle dam is required on the far western part of the reservoir, and 3) the current City park and recreation area would need to be located to the southwestern shoreline area (Section C-C').

5.10 Nineteen-Foot Enlargement Alternative

The 19-foot raise option is shown in plan view on **Figure 5.9 and 5.10**. This alternative has similar improvements required for the lower raises, except: 1) the saddle dam on the west becomes larger and extends over 2,000 feet to the north, and 2) complete filling of the reservoir would require pumping from the Oligarchy Ditch.

5.11 Reservoir Deepening and Filling of Properties West of the Reservoir

In order to reduce inundation of lands proposed for future development west of the reservoir, filling could be performed. Material could be borrowed from along the shoreline below the proposed future high water line providing reservoir storage. For example, much of the acreage that would be inundated under the 13-foot baseline alignment west of the reservoir could be raised above the flood line by placing 1.6 million cubic yards of material and would yield an additional 1,000 acre-feet of storage.

Most of the fill material would be derived from Pierre Shale bedrock, but is excavatable with heavy equipment. The fill would provide satisfactory fill for development if properly compacted.

This type of reservoir enlargement was performed at Windsor Reservoir in Windsor, Colorado. A total of 5 million cubic yards of material was excavated from the reservoir bottom and much of it was placed adjacent to the reservoir shoreline for use in overlot grading for future development.

There are several issues that need to be studied further, such as slope stability of finished cut and fill slopes, etc., prior to pursuing this option. We recommend that additional geotechnical investigations be conducted in order to study this option in more detail.

5.12 Cost Estimates

Cost estimates for each alternative were prepared and are presented on **Tables 5.1 through 5.6**. **Table 5.**7 presents a cost estimate summary of all six alternatives. The costs range from $19,751,000 for the five-foot baseline raise alternative which provides 4,090 acre-feet ($4,829 per acre-foot) of new storage to $37,090,500 for the 19-foot shoreline raise alternative which provides 17,000 additional acre-feet of storage ($2,182 per acre-foot). The costs per acre-foot are much higher for the small raise due to the infrastructure improvements (spillway, inlet and outlet pipes, and storm drainage work) required for each enlargement regardless of size. The enlargement costs for the 13 and 19-foot raises are favorable when compared to other Front Range water storage project costs. Total costs and costs per acre-foot of added storage are shown on **Figures 5.11 through 5.14**. **Figures 5.11 and 5.12** show costs for construction and engineering only, while **Figures 5.13 and 5.14** show construction, engineering, and land acquisition costs. **Figure 5.15** shows the storage gain for each raise option.

These estimates present the required volumes for the improvements and unit costs based on our experience with Colorado construction were applied. Filling of the properties west of the reservoir would generate storage at a cost of about $2,800 per acre-foot assuming a cost of soil excavation and placement of $1.75 per cubic yard.

TABLE 5.1

Union Reservoir Cost Estimate

5' Base

Alternative: 5' Base

Storage: 16,890 acre-feet
Gained Storage: 4,090 acre-feet
Land to Acquire: 42 acres
Flood Easements: 33 acres

Based on file: Union Reservoir Dam Feasibility.dwg Layer 5 Base

Description: 5' low raise to NHWL 4962' , dam crest 4967'
Labyrinth weir spillway, Dam west of shoreline, no East embankment

Primary (South) Embankment

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	10.5	Ac	$ 2,000	$ 21,000
Excavate Key Trench	12,089	cy	$ 4	$ 48,356
Embankment Fill	101,700	cy	$ 2	$ 203,400
Slurry Cut Off Wall	73,800	sf	$ 3.5	$ 258,300
Riprap Bedding	7,097	cy	$ 21	$ 149,031
Riprap	14,193	cy	$ 35	$ 496,769
Toe Drain Excavation	4,740	cy	$ 4	$ 18,960
Toe Drain Gravel Fill	4,740	cy	$ 8	$ 37,920
Toe Drain 6" Pipe	6,320	LF	$ 4	$ 25,280
Toe Drain 4" Pipe	6,320	LF	$ 3	$ 18,960
			Subtotal:	**$ 1,277,976**

Principal Spillway Construction

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Labyrinth Weir Concrete	4,000	cy	$ 415	$ 1,660,000
Lab Foundation Anchors	400	Ea	$ 630	$ 252,000
Labyrinth Drain Material	2,200	cy	$ 8	$ 17,600
Stilling Basin	1	LS	$ 2,000,000	$ 2,000,000
Approach Excavation	12,300	cy	$ 4	$ 49,200
			Subtotal:	**$ 3,978,800**

North Embankment & Road

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	6.5	Ac	$ 2,000	$ 13,000
Embankment Fill	27,790	cy	$ 2	$ 55,580
Riprap Bedding	1,963	cy	$ 21	$ 41,222
Riprap	3,926	cy	$ 35	$ 137,407
Storm ditch/sump	53,250	cy	$ 4	$ 213,000
Culverts across stream	3	Ea	$ 70,000	$ 210,000
Roadway on berm	5680	LF	$ 80	$ 454,400
			Subtotal:	**$ 1,124,610**

Northeast Embankment

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	7.5	Ac	$ 2,000	$ 15,000
Embankment Fill	71,285	cy	$ 2	$ 142,570
Riprap Bedding	4,982	cy	$ 21	$ 104,623
Riprap	9,964	cy	$ 35	$ 348,743
			Subtotal:	**$ 610,935**

Outlet

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
New Outlet Works	1	LS	$ 2,000,000	$ 2,000,000
			Subtotal:	**$ 2,000,000**

TABLE 5.1

Union Reservoir Cost Estimate

5' Base

Alternative: 5' Base   Storage: 16,890 acre-feet

Inlet: 500 cfs

	Quantity	Unit	Unit Cost	Estimated Cost
Ditch Structure	1	Ea	$ 150,000	$ 150,000
Install 108" Pipe	2,600	LF	$ 432	$ 1,123,200
			Subtotal:	**$ 1,273,200**

West Storm Drain

	Quantity	Unit	Unit Cost	Estimated Cost
Manhole (60")	23	Ea	$ 1,500	$ 34,500
Install 48" Pipe	11,567	LF	$ 115	$ 1,330,205
			Subtotal:	**$ 1,364,705**

Rebuild Wetlands

	Quantity	Unit	Unit Cost	Estimated Cost
Wetlands Construction	1	ea	$ 500,000	$ 500,000
			Subtotal:	**$ 500,000**

Purchase/Relocate Gas Well

	Quantity	Unit	Unit Cost	Estimated Cost
Acquire/move Gas Well	1	ea	$ 250,000	$ 250,000
			Subtotal:	**$ 250,000**

Subtotal of all Items		**$ 12,380,226**
Mobilization	3%	**$ 371,407**
Construction Subtotal		***$ 12,751,632***
Design, Construction Engineering, and Permitting	20%	**$ 2,550,326**
Construction and Engineering Subtotal		***$ 15,301,959***
Contingencies	20%	**$ 3,060,392**
Total Estimated Cost		***$ 18,362,351***
Total Estimated Cost Rounded to Nearest $1000		**$ 18,362,000**

TABLE 5.2

Union Reservoir Cost Estimate

5' Shore

Alternative: 5' Shore

Storage:	16,670	acre-feet
Gained Storage:	3,870	acre-feet
Land to Acquire:	14	acres
Flood Easements:	13	acres

Based on file: Union Reservoir Dam Feasibility.dwg Layer 5 Shore

Description: 5' low raise to NHWL 4962' , dam crest 4967'
Labyrinth weir spillway, Dam along shoreline, no East embankment

Primary (South) Embankment

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	20.4	Ac	$ 2,000	$ 40,800
Excavate Key Trench	34,933	cy	$ 4	$ 139,733
Embankment Fill	228,570	cy	$ 2	$ 457,140
Slurry Cut Off Wall	73,800	sf	$ 3.5	$ 258,300
Riprap Bedding	13,881	cy	$ 21	$ 291,504
Riprap	27,762	cy	$ 35	$ 971,680
Toe Drain Excavation	8,595	cy	$ 4	$ 34,380
Toe Drain Gravel Fill	8,595	cy	$ 8	$ 68,760
Toe Drain 6" Pipe	11,460	LF	$ 4	$ 45,840
Toe Drain 4" Pipe	11,460	LF	$ 3	$ 34,380
			Subtotal:	**$ 2,342,518**

Principal Spillway Construction

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Labyrinth Weir Concrete	4,000	cy	$ 415	$ 1,660,000
Lab Foundation Anchors	400	Ea	$ 630	$ 252,000
Labyrinth Drain Material	2,200	cy	$ 8	$ 17,600
Stilling Basin	1	LS	$ 2,000,000	$ 2,000,000
Approach Excavation	12,300	cy	$ 4	$ 49,200
			Subtotal:	**$ 3,978,800**

North Embankment & Road

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	6.5	Ac	$ 2,000	$ 13,000
Embankment Fill	27,790	cy	$ 2	$ 55,580
Riprap Bedding	1,963	cy	$ 21	$ 41,222
Riprap	3,926	cy	$ 35	$ 137,407
Storm ditch/sump	53,250	cy	$ 4	$ 213,000
Culverts across stream	3	Ea	$ 70,000	$ 210,000
Roadway on berm	5680	LF	$ 80	$ 454,400
			Subtotal:	**$ 1,124,610**

Northeast Embankment

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	7.5	Ac	$ 2,000	$ 15,000
Embankment Fill	71,285	cy	$ 2	$ 142,570
Riprap Bedding	4,982	cy	$ 21	$ 104,623
Riprap	9,964	cy	$ 35	$ 348,743
			Subtotal:	**$ 610,935**

Outlet

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
New Outlet Works	1	LS	$ 2,000,000	$ 2,000,000
			Subtotal:	**$ 2,000,000**

TABLE 5.2

Union Reservoir Cost Estimate

5' Shore

Alternative: 5' Shore   Storage: 16,670 acre-feet

Inlet: 500 cfs

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Ditch Structure	1	Ea	$ 150,000	$ 150,000
Install 108" Pipe	2,600	LF	$ 432	$ 1,123,200
			Subtotal:	**$ 1,273,200**

West Storm Drain

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Manhole (60")	24	Ea	$ 1,500	$ 36,000
Install 48" Pipe	11,910	LF	$ 115	$ 1,369,650
			Subtotal:	**$ 1,405,650**

Rebuild Wetlands

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Wetlands Construction	1	ea	$ 1,000,000	$ 1,000,000
			Subtotal:	**$ 1,000,000**

Purchase/Relocate Gas Well

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Acquire/move Gas Well	0	ea	$ 250,000	$ -
			Subtotal:	**$ -**

Subtotal of all Items		**$ 13,735,713**
Mobilization	3%	**$ 412,071**
Construction Subtotal		***$ 14,147,784***
Design, Construction Engineering, and Permitting	20%	**$ 2,829,557**
Construction and Engineering Subtotal		***$ 16,977,341***
Contingencies	20%	**$ 3,395,468**
Total Estimated Cost		***$ 20,372,809***
Total Estimated Cost Rounded to Nearest $1000		**$ 20,373,000**

TABLE 5.3

Union Reservoir Cost Estimate

13' Base

Alternative: 13' Base

Storage: 25,080 acre-feet
Gained Storage: 12,280 acre-feet
Land to Acquire: 150 acres
Flood Easements: 41 acres

Based on file: Union Reservoir Dam Feasibility.dwg Layer Set 13 Base

Description: 13' medium raise to NHWL 4970' , dam crest 4975'
Labyrinth weir spillway, Dam west of shoreline

Primary (South) Embankment

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	23	Ac	$ 2,000	$ 46,000
Excavate Key Trench	20,293	cy	$ 4	$ 81,173
Embankment Fill	368,665	cy	$ 2	$ 737,330
Slurry Cut Off Wall	73,800	sf	$ 3.5	$ 258,300
Riprap Bedding	16,055	cy	$ 21	$ 337,151
Riprap	32,110	cy	$ 35	$ 1,123,837
Toe Drain Excavation	6,125	cy	$ 4	$ 24,498
Toe Drain Gravel Fill	6,125	cy	$ 8	$ 48,996
Toe Drain 6" Pipe	8,166	LF	$ 4	$ 32,664
Toe Drain 4" Pipe	8,166	LF	$ 3	$ 24,498
			Subtotal:	**$ 2,714,447**

Principal Spillway Construction

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Labyrinth Weir Concrete	4,000	cy	$ 415	$ 1,660,000
Lab Foundation Anchors	400	Ea	$ 630	$ 252,000
Labyrinth Drain Material	2,200	cy	$ 8	$ 17,600
Stilling Basin	1	LS	$ 2,000,000	$ 2,000,000
Approach Excavation	12,300	cy	$ 4	$ 49,200
			Subtotal:	**$ 3,978,800**

Northeast Embankment & Road

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	15.7	Ac	$ 2,000	$ 31,400
Embankment Fill	135,080	cy	$ 2	$ 270,160
Riprap Bedding	7,535	cy	$ 21	$ 158,231
Riprap	15,070	cy	$ 35	$ 527,437
Detention pond	60,000	cy	$ 4	$ 240,000
Storm sewer	1,740	LF	$ 115	$ 200,100
Culverts across stream	3	Ea	$ 70,000	$ 210,000
Roadway on berm	5500	LF	$ 80	$ 440,000
			Subtotal:	**$ 2,077,328**

East Embankment Construction

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	3.4	Ac	$ 2,000	$ 6,800
Embankment Fill	18,750	cy	$ 2	$ 37,500
Riprap Bedding	4,446	cy	$ 21	$ 93,372
Riprap	8,893	cy	$ 35	$ 311,241
			Subtotal:	**$ 448,913**

Outlet

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
New Outlet Works	1	LS	$ 2,000,000	$ 2,000,000
			Subtotal:	**$ 2,000,000**

TABLE 5.3

Union Reservoir Cost Estimate

13' Base

Alternative: 13' Base   Storage: 25,080 acre-feet

Inlet: 500 cfs

	Quantity	Unit	Unit Cost	Estimated Cost
Ditch Structure	1	Ea	$ 250,000	$ 250,000
Install 126" Pipe	6,100	LF	$ 504	$ 3,074,400
			Subtotal:	**$ 3,324,400**

West Storm Drain

	Quantity	Unit	Unit Cost	Estimated Cost
Manhole (60")	23	Ea	$ 1,500	$ 34,500
Install 48" Pipe	11,586	LF	$ 115	$ 1,332,390
			Subtotal:	**$ 1,366,890**

Rebuild Wetlands

	Quantity	Unit	Unit Cost	Estimated Cost
Wetlands Construction	1	ea	$ 500,000	$ 500,000
			Subtotal:	**$ 500,000**

Purchase/Relocate Gas Well

	Quantity	Unit	Unit Cost	Estimated Cost
Acquire/move Gas Well	1	ea	$ 250,000	$ 250,000
			Subtotal:	**$ 250,000**

Subtotal of all Items		**$ 16,660,779**
Mobilization	3%	**$ 499,823**
Construction Subtotal		***$ 17,160,602***
Design, Construction Engineering, and Permitting	20%	**$ 3,432,120**
Construction and Engineering Subtotal		***$ 20,592,722***
Contingencies	20%	**$ 4,118,544**
Total Estimated Cost		***$ 24,711,267***
Total Estimated Cost Rounded to Nearest $1000		**$ 24,711,000**

TABLE 5.4

Union Reservoir Cost Estimate

13' Shore

Alternative: 13' Shore

Storage:	24,220	acre-feet
Gained Storage:	11,420	acre-feet
Land to Acquire:	90	acres
Flood Easements:	29	acres

Based on file: Union Reservoir Dam Feasibility.dwg Layer Set 13 Shore

Description: 13' medium raise to NHWL 4970' , dam crest 4975'
Labyrinth weir spillway, Dam along shoreline

Primary (South) Embankment

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	36	Ac	$ 2,000	$ 72,000
Excavate Key Trench	38,360	cy	$ 4	$ 153,440
Embankment Fill	658,500	cy	$ 2	$ 1,317,000
Slurry Cut Off Wall	73,800	sf	$ 3.5	$ 258,300
Riprap Bedding	26,221	cy	$ 21	$ 550,651
Riprap	52,443	cy	$ 35	$ 1,835,504
Toe Drain Excavation	9,173	cy	$ 4	$ 36,693
Toe Drain Gravel Fill	9,173	cy	$ 8	$ 73,386
Toe Drain 6" Pipe	12,231	LF	$ 4	$ 48,924
Toe Drain 4" Pipe	12,231	LF	$ 3	$ 36,693
			Subtotal:	**$ 4,382,591**

Principal Spillway Construction

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Labyrinth Weir Concrete	4,000	cy	$ 415	$ 1,660,000
Lab Foundation Anchors	400	Ea	$ 630	$ 252,000
Labyrinth Drain Material	2,200	cy	$ 8	$ 17,600
Stilling Basin	1	LS	$ 2,000,000	$ 2,000,000
Approach Excavation	12,300	cy	$ 4	$ 49,200
			Subtotal:	**$ 3,978,800**

Northeast Embankment & Road

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	15.7	Ac	$ 2,000	$ 31,400
Embankment Fill	135,080	cy	$ 2	$ 270,160
Riprap Bedding	7,535	cy	$ 21	$ 158,231
Riprap	15,070	cy	$ 35	$ 527,437
Detention pond	60,000	cy	$ 4	$ 240,000
Storm sewer	1,740	LF	$ 115	$ 200,100
Culverts across stream	3	Ea	$ 70,000	$ 210,000
Roadway on berm	5500	LF	$ 80	$ 440,000
			Subtotal:	**$ 2,077,328**

East Embankment Construction

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	3.4	Ac	$ 2,000	$ 6,800
Embankment Fill	18,750	cy	$ 2	$ 37,500
Riprap Bedding	4,446	cy	$ 21	$ 93,372
Riprap	8,893	cy	$ 35	$ 311,241
			Subtotal:	**$ 448,913**

Outlet

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
New Outlet Works	1	LS	$ 2,000,000	$ 2,000,000
			Subtotal:	**$ 2,000,000**

TABLE 5.4

Union Reservoir Cost Estimate

13' Shore

Alternative: 13' Shore   Storage: 24,220 acre-feet

Inlet: 500 cfs

Item	Quantity	Unit	Unit Cost	Estimated Cost
Ditch Structure	1	Ea	$ 250,000	$ 250,000
Install 126" Pipe	6,100	LF	$ 504	$ 3,074,400
			Subtotal:	**$ 3,324,400**

West Storm Drain

Item	Quantity	Unit	Unit Cost	Estimated Cost
Manhole (60")	26	Ea	$ 1,500	$ 39,000
Install 48" Pipe	13,085	LF	$ 115	$ 1,504,775
			Subtotal:	**$ 1,543,775**

Rebuild Wetlands

Item	Quantity	Unit	Unit Cost	Estimated Cost
Wetlands Construction	1	ea	$ 1,500,000	$ 1,500,000
			Subtotal:	**$ 1,500,000**

Purchase/Relocate Gas Well

Item	Quantity	Unit	Unit Cost	Estimated Cost
Acquire/move Gas Well	0	ea	$ 250,000	$ -
			Subtotal:	**$ -**

Subtotal of all Items		**$ 19,255,807**
Mobilization	3%	**$ 577,674**
Construction Subtotal		***$ 19,833,481***
Design, Construction Engineering, and Permitting	20%	**$ 3,966,696**
Construction and Engineering Subtotal		***$ 23,800,177***
Contingencies	20%	**$ 4,760,035**
Total Estimated Cost		***$ 28,560,213***

Total Estimated Cost Rounded to Nearest $1000 **$ 28,560,000**

TABLE 5.5

Union Reservoir Cost Estimate

19' Base

Alternative: 19' Base

Storage:	31,760	acre-feet
Gained Storage:	18,960	acre-feet
Land to Acquire:	207	acres
Flood Easements:	117	acres

Based on file: Union Reservoir Dam Feasibility.dwg Layer Set 19 Base

Description: 19' high raise to NHWL 4976' , dam crest 4981'
Labyrinth weir spillway, Dam west of shoreline, no North embankment, much property acquisition

Primary (South) Embankment

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	29.1	Ac	$ 2,000	$ 58,200
Excavate Key Trench	22,222	cy	$ 4	$ 88,889
Embankment Fill	605,119	cy	$ 2	$ 1,210,238
Slurry Cut Off Wall	73,800	sf	$ 3.5	$ 258,300
Riprap Bedding	21,810	cy	$ 21	$ 458,018
Riprap	43,621	cy	$ 35	$ 1,526,726
Toe Drain Excavation	6,450	cy	$ 4	$ 25,800
Toe Drain Gravel Fill	6,450	cy	$ 8	$ 51,600
Toe Drain 6" Pipe	8,600	LF	$ 4	$ 34,400
Toe Drain 4" Pipe	8,600	LF	$ 3	$ 25,800
			Subtotal:	**$ 3,737,971**

Principal Spillway Construction

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Labyrinth Weir Concrete	4,000	cy	$ 415	$ 1,660,000
Lab Foundation Anchors	400	Ea	$ 630	$ 252,000
Labyrinth Drain Material	2,200	cy	$ 8	$ 17,600
Stilling Basin	1	LS	$ 2,000,000	$ 2,000,000
Approach Excavation	12,300	cy	$ 4	$ 49,200
			Subtotal:	**$ 3,978,800**

North Embankment & Road

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	12.9	Ac	$ 2,000	$ 25,800
Embankment Fill	115,800	cy	$ 2	$ 231,600
Riprap Bedding	5,305	cy	$ 21	$ 111,401
Riprap	10,610	cy	$ 35	$ 371,337
Storm sewer	-	LF	$ 115	$ -
Culverts across stream	3	Ea	$ 70,000	$ 210,000
Roadway on berm	9210	LF	$ 80	$ 736,800
			Subtotal:	**$ 1,686,938**

East Embankment Construction

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	6.4	Ac	$ 2,000	$ 12,800
Embankment Fill	57,035	cy	$ 2	$ 114,070
Riprap Bedding	4,174	cy	$ 21	$ 87,663
Riprap	8,349	cy	$ 35	$ 292,211
			Subtotal:	**$ 506,744**

Outlet

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
New Outlet Works	1	LS	$ 2,000,000	$ 2,000,000
			Subtotal:	**$ 2,000,000**

TABLE 5.5

Union Reservoir Cost Estimate

19' Base

Alternative: 19' Base   Storage: 31,760 acre-feet

Inlet: 500 cfs

	Quantity	Unit	Unit Cost	Estimated Cost
Ditch Structure	1	Ea	$ 250,000	$ 250,000
Install 126" Pipe	6,100	LF	$ 504	$ 3,074,400
Pump Station	1	Ea	$ 1,050,000	$ 1,050,000
			Subtotal:	**$ 4,374,400**

West Storm Drain

	Quantity	Unit	Unit Cost	Estimated Cost
Manhole (60")	23	Ea	$ 1,500	$ 34,500
Install 48" Pipe	11,496	LF	$ 115	$ 1,322,040
			Subtotal:	**$ 1,356,540**

Rebuild Wetlands

	Quantity	Unit	Unit Cost	Estimated Cost
Wetlands Construction	1	ea	$ 500,000	$ 500,000
			Subtotal:	**$ 500,000**

Purchase/Relocate Gas Well

	Quantity	Unit	Unit Cost	Estimated Cost
Acquire/move Gas Well	1	ea	$ 250,000	$ 250,000
			Subtotal:	**$ 250,000**

Subtotal of all Items		**$ 18,391,393**
Mobilization	3%	**$ 551,742**
Construction Subtotal		***$ 18,943,135***
Design, Construction Engineering, and Permitting	20%	**$ 3,788,627**
Construction and Engineering Subtotal		***$ 22,731,762***
Contingencies	20%	**$ 4,546,352**
Total Estimated Cost		***$ 27,278,114***
Total Estimated Cost Rounded to Nearest $1000		**$ 27,278,000**

TABLE 5.6

Union Reservoir Cost Estimate

19' Shore

Alternative: 19' Shore

Storage:	29,800	acre-feet
Gained Storage:	17,000	acre-feet
Land to Acquire:	119	acres
Flood Easements:	105	acres

Based on file: Union Reservoir Dam Feasibility.dwg Layer Set 19 Shore

Description: 19' high raise to NHWL 4976' , dam crest 4981'
Labyrinth weir spillway, Dam along shoreline, no North embankment, much property acquisition

Primary (South) Embankment

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	49.9	Ac	$ 2,000	$ 99,800
Excavate Key Trench	43,111	cy	$ 4	$ 172,444
Embankment Fill	1,105,170	cy	$ 2	$ 2,210,340
Slurry Cut Off Wall	73,800	sf	$ 3.5	$ 258,300
Riprap Bedding	36,605	cy	$ 21	$ 768,698
Riprap	73,209	cy	$ 35	$ 2,562,327
Toe Drain Excavation	9,975	cy	$ 4	$ 39,900
Toe Drain Gravel Fill	9,975	cy	$ 8	$ 79,800
Toe Drain 6" Pipe	13,300	LF	$ 4	$ 53,200
Toe Drain 4" Pipe	13,300	LF	$ 3	$ 39,900
			Subtotal:	**$ 6,284,709**

Principal Spillway Construction

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Labyrinth Weir Concrete	4,000	cy	$ 415	$ 1,660,000
Lab Foundation Anchors	400	Ea	$ 630	$ 252,000
Labyrinth Drain Material	2,200	cy	$ 8	$ 17,600
Stilling Basin	1	LS	$ 2,000,000	$ 2,000,000
Approach Excavation	12,300	cy	$ 4	$ 49,200
			Subtotal:	**$ 3,978,800**

North Embankment & Road

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	12.9	Ac	$ 2,000	$ 25,800
Embankment Fill	115,800	cy	$ 2	$ 231,600
Riprap Bedding	5,305	cy	$ 21	$ 111,401
Riprap	10,610	cy	$ 35	$ 371,337
Storm sewer	-	LF	$ 115	$ -
Culverts across stream	3	Ea	$ 70,000	$ 210,000
Roadway on berm	9210	LF	$ 80	$ 736,800
			Subtotal:	**$ 1,686,938**

East Embankment Construction

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
Stripping	6.4	Ac	$ 2,000	$ 12,800
Embankment Fill	57,035	cy	$ 2	$ 114,070
Riprap Bedding	4,174	cy	$ 21	$ 87,663
Riprap	8,349	cy	$ 35	$ 292,211
			Subtotal:	**$ 506,744**

Outlet

	Quantity	*Unit*	*Unit Cost*	*Estimated Cost*
New Outlet Works	1	LS	$ 2,000,000	$ 2,000,000
			Subtotal:	**$ 2,000,000**

TABLE 5.6

Union Reservoir Cost Estimate

19' Shore

Alternative: 19' Shore   Storage: 29,800 acre-feet

Inlet: 500 cfs	Quantity	Unit	Unit Cost	Estimated Cost
Ditch Structure	1	Ea	$ 250,000	$ 250,000
Install 126" Pipe	6,100	LF	$ 504	$ 3,074,400
Pump Station	1	Ea	$ 1,050,000	$ 1,050,000
			Subtotal:	**$ 4,374,400**

West Storm Drain	Quantity	Unit	Unit Cost	Estimated Cost
Manhole (60")	28	Ea	$ 1,500	$ 42,000
Install 48" Pipe	12,430	LF	$ 115	$ 1,429,450
			Subtotal:	**$ 1,471,450**

Rebuild Wetlands	Quantity	Unit	Unit Cost	Estimated Cost
Wetlands Construction	1	ea	$ 2,000,000	$ 2,000,000
			Subtotal:	**$ 2,000,000**

Purchase/Relocate Gas Well	Quantity	Unit	Unit Cost	Estimated Cost
Acquire/move Gas Well	0	ea	$ 250,000	$ -
			Subtotal:	**$ -**

Subtotal of all Items		**$ 22,303,042**
Mobilization	3%	**$ 669,091**
Construction Subtotal		***$ 22,972,133***
Design, Construction Engineering, and Permitting	20%	**$ 4,594,427**
Construction and Engineering Subtotal		***$ 27,566,560***
Contingencies	20%	**$ 5,513,312**
Total Estimated Cost		***$ 33,079,871***
Total Estimated Cost Rounded to Nearest $1000		$ 33,080,000

TABLE 5.7

CITY OF LONGMONT, UNION RESERVOIR FEASIBILITY STUDY
UNION RESERVOIR COST ESTIMATE SUMMARY

Alternative	NHWL	Total Water Storage (ac-ft)	Gained Water Storage (ac-ft)	Estimated C&E Cost	Cost per Acre-foot Gained	Land to Acquire (acres)	Flood Easements to Purchase (acres)	Estimated Cost w/ Land[a]	Cost w/ Land per Acre-Foot Gained[b]
5' Base	4962	16,890	4,090	$ 18,362,000	$ 4,489	42.2	33.4	$ 19,751,000	$ 4,829
5' Shore	4962	16,670	3,870	$ 20,373,000	$ 5,264	13.8	12.8	$ 20,846,000	$ 5,387
13' Base	4970	25,080	12,280	$ 24,711,000	$ 2,012	149.6	40.9	$ 28,860,000	$ 2,350
13' Shore	4970	24,220	11,420	$ 28,560,000	$ 2,501	89.6	28.5	$ 31,085,000	$ 2,722
19' Base	4976	31,760	18,960	$ 27,278,000	$ 1,439	207	116.9	$ 33,622,000	$ 1,773
19' Shore	4976	29,800	17,000	$ 33,080,000	$ 1,946	118.5	104.8	$ 37,090,500	$ 2,182

a. Land acquisition cost estimated at $25,000 per acre.
b. Flood easement acquisition cost estimated at $10,000 per acre.