Little Thompson Water District
Dry Creek Reservoir Feasibility Study

Prepared For: Colorado Water
Conservation Board Loan
Feasibility Grant

November 25, 2020

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1. Background

1.1 Purpose

Little Thompson Water District (the District) and Central Weld County Water District (CWCWD) evaluated the costs and benefits to increasing the storage capacity of Dry Creek Reservoir by different amounts. Both Districts rely heavily on Colorado-Big Thompson Project water and have concerns about drought storage. Additionally, the District was evaluating the delivery of native waters to Dry Creek Reservoir and the impact on yield the additional storage would provide to its water supplies. The District requested funding from the Colorado Water Conservation Board for the evaluation and cost analysis of the Dry Creek Reservoir enlargement.

1.2 Study Area Description

Dry Creek Reservoir is an offline Reservoir located approximately 10 miles west of Berthoud, Colorado in Larimer County and jointly owned by the District and CWCWD. It acts as a municipal water storage reservoir to provide drought protection and operational flexibility for the District and CWCWD. The reservoir was constructed in 2006 in response to the 2002 drought and stores approximately 9,500 acre-feet. The drought storage for the two districts serve a population in Larimer, Weld, and Boulder counties of nearly 80,000. Most of the service provided is for residential properties both in agricultural and municipal areas.

Figure 1-1: Little Thompson Water District Service Area

Figure 1-2: Central Weld County Water District Service Area

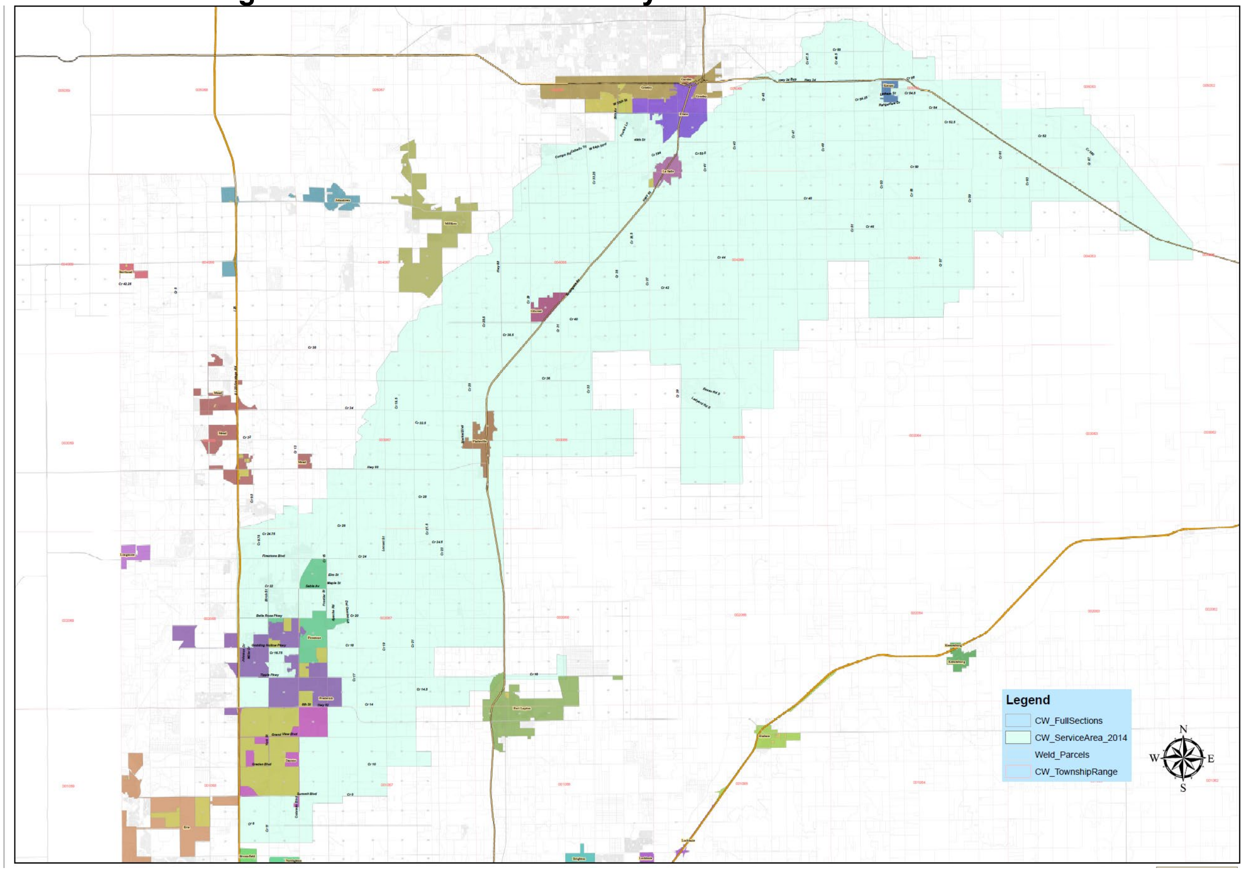


Figure 1-3: Aerial Photo of Dry Creek Reservoir

1.3 Previous Studies
N/A

2. Project Sponsor
2.1 Sponsoring Organization
The District and CWCWD are quasi-municipal corporations and political subdivisions of the State of Colorado formed by decree in 1961. The District's customers include homes, farms, commercial enterprises, and municipalities. The District serves approximately 7,500 residential customers and 300 non-residential business and commercial customers. Customer water usage for the 2020 water year was 6,744 acre-feet. The District's overall growth rate over the past 20 years has been approximately 2 percent but has been trending higher over the past several years. The District requires growth to pay its own way meaning developers are required to submit requests for service, purchase sufficient raw water for their development, and pay the cost of service through line improvements and fees for connecting to additional treatment and distribution facilities.

2.2 Brief History
The District and CWCWD were created in 1961 for the purpose of providing water facilities and services for the residents within each providers boundary. In 1962, the District began serving domestic water to a 250-square-mile area in Larimer, Weld and Boulder counties. CWCWD began service in the same manner and timing to customers in Weld County. The service area for the District is generally is bounded by the City of Loveland on the north, Longs Peak Water District on the south, the City of Greeley, the South Platte and St. Vrain Rivers on the east, and the foothills on the west. It expanded to include the former Arkins Water Association in 2000 and the Town of Mead in 2002.

CWCWD's service area is generally bound by the St. Vrain and South Platte Rivers on the north, follows Highway 85 to Greeley, and follows Highway 34 to the east approximately 10 miles east of Kersey. CWCWD also provides service to the Cities of Firestone, Fredrick, Dacono, and portions of Evans and the towns of Kersey, LaSalle, Gilcrest, and Platteville.

2.3 Identification of Revenue Sources
Revenue sources can be found in the Districts Rules and Regulations in the following sections:
- Section 1501.1 Schedule A – Tap Fees
- Section 1502.1 Schedule B – Water Rate Schedule
- Wholesale rates
- Section 1502.2 Schedule C – Miscellaneous Fees

These sections can be found in **Appendix A**.

2.4 Existing Water Supply Facilities
The District and CWCWD own and operate two water treatment plants at the south end of Carter Lake. The Carter Lake Filter Plant (CLFP) can deliver up to 50 million gallons per day of treated water. The North Plant, put into service in 1962, can deliver 30 million gallons per day. The South Plant, added in 1995, was originally rated at 10 million gallons per day. An

expansion in 2001 doubled its capacity to 20 million gallons. It draws its water from the outlet works of the St. Vrain Supply Canal and Northern Water's Carter Lake to Broomfield pipeline.

3. Water Rights

3.1 Water Availability

The District's water supply is comprised of Colorado-Big Thompson (C-BT) and Windy Gap units, Consolidated Home Supply and Handy Ditch shares which would use the proposed project, and a 2005 water right to fill Barefoot Lakes which would not utilize the proposed project. CWCWD's water supply is comprised of C-BT and Windy Gap units which would utilize the proposed project.

3.1.1 Colorado-Big Thompson (C-BT) Units

The C-BT Project collects and delivers on average more than 200,000 acre-feet of water each year. Most of this water is the result of melting snow in the upper Colorado River basin west of the Continental Divide. The Bureau of Reclamation project transports the water to the East Slope via the Adams Tunnel, a 13.1-mile tunnel beneath Rocky Mountain National Park.

There are 310,000 C-BT units. The District owns 10,487 units. **Figure 3-1** shows the District's average C-BT yields and **Table 3-1** shows average, minimum, and maximum yields. Each year the Northern Colorado Water Conservancy District (Northern) declares the yield (quota) for each unit. The maximum quota of 100% yield equals one acre-foot per unit. The quota has historically varied from 50% to 100% based upon water availability in the C-BT system and the water needs on the East Slope. Once the quota is declared, the number of units multiplied by the annual quota for the model period provides the annual yield of District's C-BT water for each year. C-BT water is a supplemental water supply. The quota may be reduced in years when there is a surplus of water on the East Slope. In the 70-year history of the project, Northern has never issued a quota less than 50%. However, in a historic prolonged drought or a call on the Colorado River, the inflow to the C-BT system may not be sufficient to support a 50% quota. Historic quota is illustrated in **Figure 3-2** and shown in **Table 3-2**.

Figure 3-1: Colorado-Big Thompson District Yields

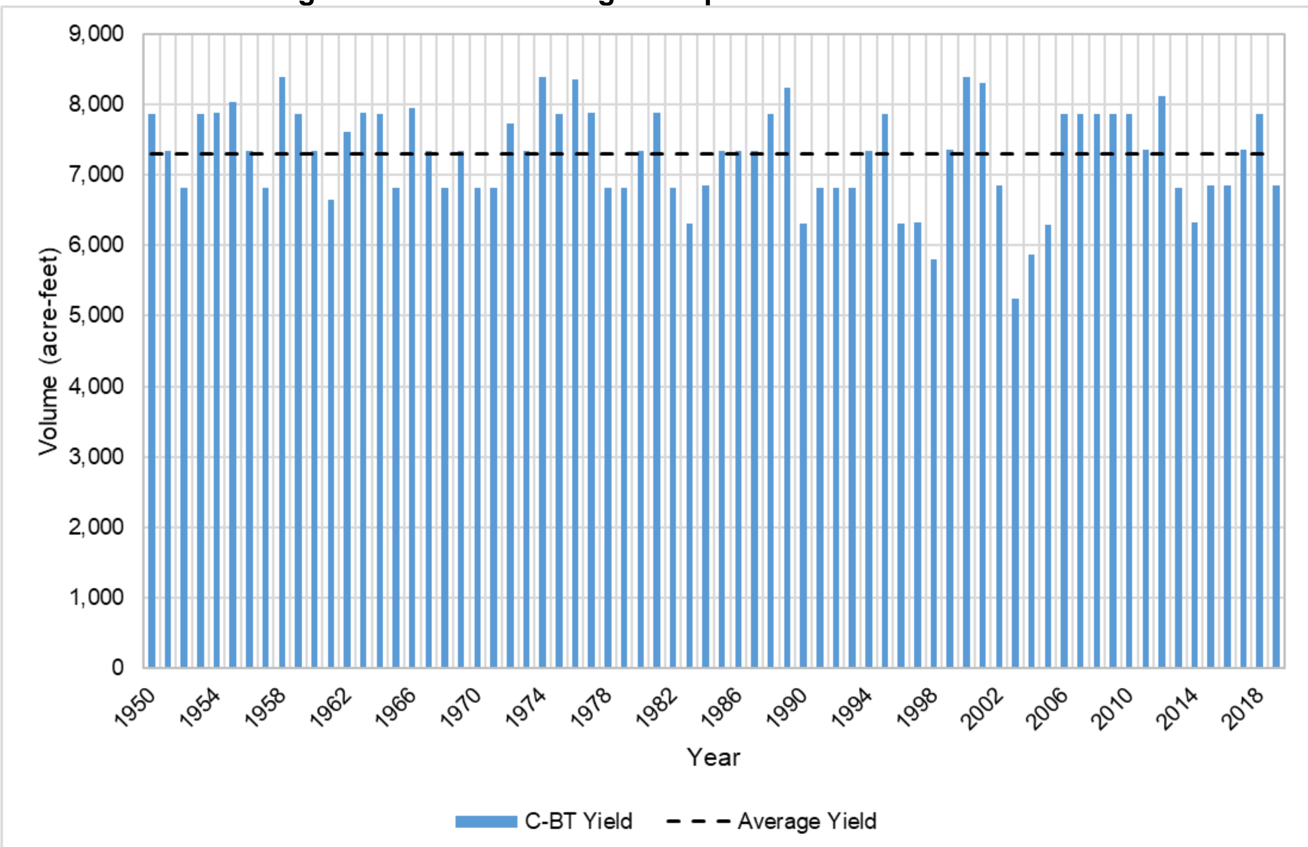


Table 3-1: Yields of C-BT Units

Minimum Yield	Average Yield	Maximum Yield
5,226 acre-feet	7,370 acre-feet	7,826 acre-feet

Figure 3-2: Colorado-Big Thompson Project Historic Quota

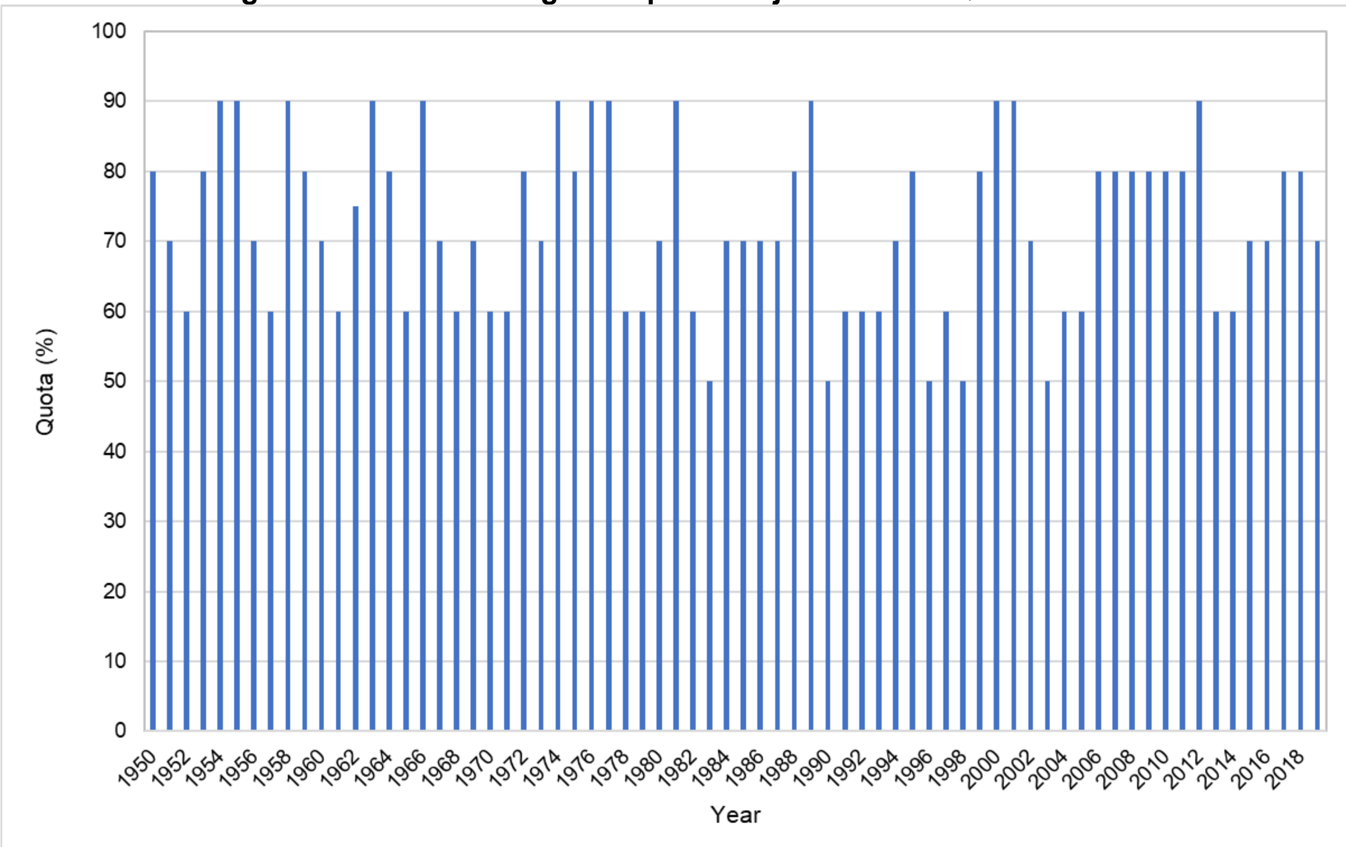


Table 3-2: Colorado-Big Thompson Quota and the District's Yields

Year	C-BT Quota (%)	C-BT Yield (acre-feet)	Year	C-BT Quota (%)	C-BT Yield (acre-feet)
1950	80%	7,862	1985	70%	7,341
1951	70%	7,341	1986	70%	7,341
1952	60%	6,820	1987	70%	7,341
1953	80%	7,862	1988	80%	7,862
1954	90%	7,884	1989	90%	8,228
1955	90%	8,036	1990	50%	6,298
1956	70%	7,341	1991	60%	6,820
1957	60%	6,820	1992	60%	6,820
1958	90%	8,384	1993	60%	6,820
1959	80%	7,862	1994	70%	7,341
1960	70%	7,341	1995	80%	7,862
1961	60%	6,641	1996	50%	6,298
1962	75%	7,602	1997	60%	6,320
1963	90%	7,884	1998	50%	5,798
1964	80%	7,862	1999	80%	7,362
1965	60%	6,820	2000	90%	8,384
1966	90%	7,945	2001	90%	8,302

Year	C-BT Quota (%)	C-BT Yield (acre-feet)	Year	C-BT Quota (%)	C-BT Yield (acre-feet)
1967	70%	7,341	2002	70%	6,841
1968	60%	6,820	2003	50%	5,244
1969	70%	7,341	2004	60%	5,868
1970	60%	6,820	2005	60%	6,292
1971	60%	6,820	2006	80%	7,862
1972	80%	7,718	2007	80%	7,862
1973	70%	7,341	2008	80%	7,862
1974	90%	8,384	2009	80%	7,862
1975	80%	7,862	2010	80%	7,862
1976	90%	8,347	2011	80%	7,362
1977	90%	7,884	2012	90%	8,112
1978	60%	6,820	2013	60%	6,820
1979	60%	6,820	2014	60%	6,320
1980	70%	7,341	2015	70%	6,841
1981	90%	7,884	2016	70%	6,841
1982	60%	6,820	2017	80%	7,362
1983	50%	6,298	2018	80%	7,862
1984	70%	6,841	2019	70%	6,841

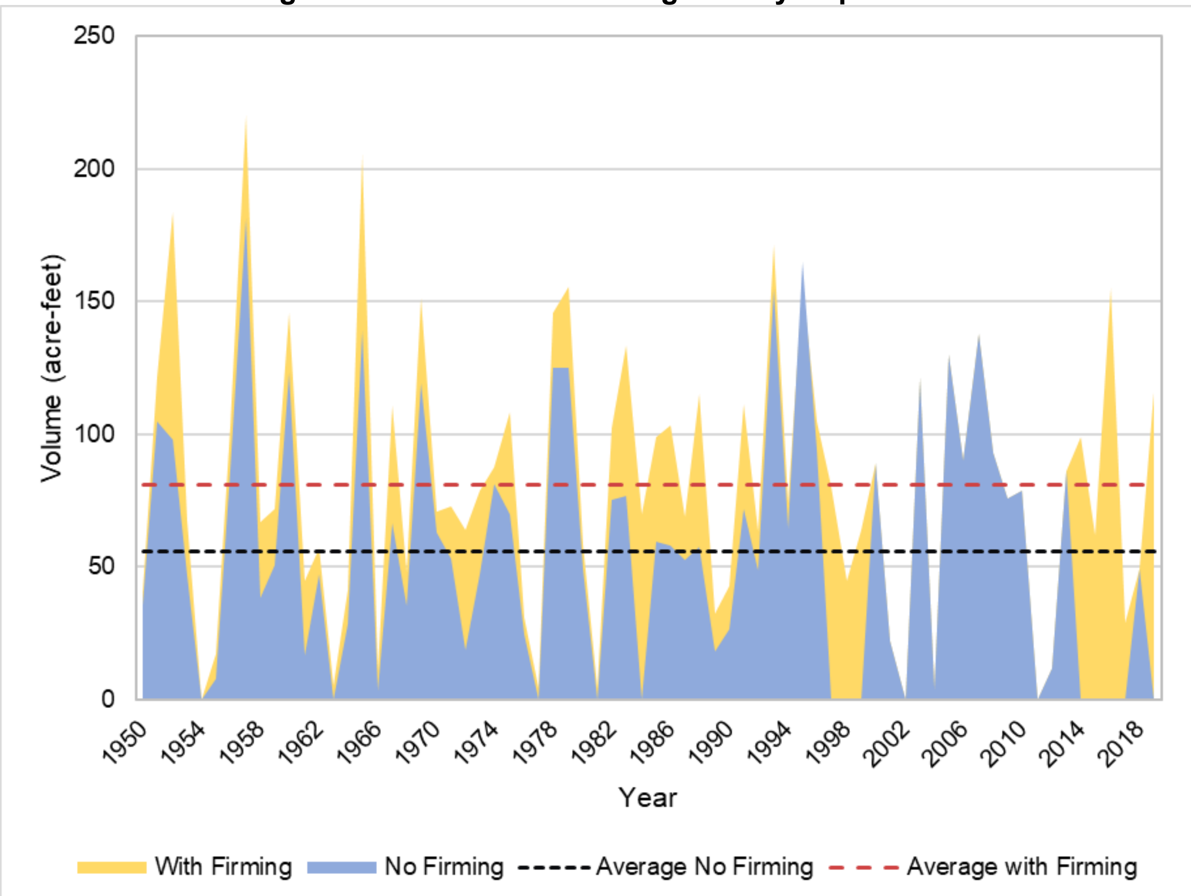
3.1.2 Windy Gap Units

The Windy Gap Project consists of a diversion dam on the Colorado River, a 445-acre-foot reservoir, a pumping plant, and a six-mile pipeline to Lake Granby. Windy Gap water is pumped and stored in Lake Granby before it is delivered to water users via the Colorado-Big Thompson Project's East Slope distribution system.

Windy Gap water can be delivered to the Carter Lake Filter Plant (CLFP) or Dry Creek Reservoir through the St. Vrain Supply Canal from the Carter Lake system. The water right has constraints. In wet years, Granby Reservoir might be full, so there would not be room to store or deliver Windy Gap water to the East Slope and in dry years the Windy Gap water right might not provide any water.

The District and CWCWD have joined with nine municipalities, one other water district and one power provider to establish the Windy Gap Firming Project (WGFP) to build Chimney Hollow Reservoir. Northern is managing the construction and operation of the 90,000 acre-foot reservoir, which when constructed, will be used to increase the yield of Windy Gap units by reducing spills from Grandy Reservoir and operational losses. The District currently owns 19 units and has contracted for 4,850 acre-feet of storage in Chimney Hollow Reservoir. **Figure 3-3** illustrates the yield of Windy Gap units without a built Chimney Hollow Reservoir (no firming) and with Chimney Hollow Reservoir built (firming).

Figure 3-3: Annual and Average Windy Gap Yields



3.1.3 Native Shares: Consolidated Home Supply and Handy

In 2003 the District made the decision to accept native water shares to diversify its water portfolio to meet growing demands and to provide drought protection. Home Supply and Handy headgates are located on the Big Thompson River. Streamflow data for the Big Thompson River is illustrated in **Figure 3-4** and can be found in tabular form in **Appendix B**.

Currently, the native water rights cannot be used by the District as it must obtain the legal authority to use agricultural water for municipal use. Furthermore, the District must build infrastructure to deliver the water to the CLFP. **Figure 3-5** illustrates the location of the ditch and reservoir system of the native supplies. **Table 3-3** shows the average, minimum, and maximum yields of all native shares currently owned by the District.

i. Consolidated Home Supply Company

The Consolidated Home Supply Ditch and Reservoir Company (Home Supply Ditch) diverts water out of the Big Thompson River and delivers it to approximately 16,500 irrigated acres north and east of the Town of

Berthoud. There are 2,001 shares of stock in the Home Supply Company. The District currently owns 70 shares.

The ditch relies upon the storage from three reservoirs for deliveries in the late irrigation season: Lone Tree, Mariano (Boedecker) and Lon Hagler. Releases from Mariano and Lon Hagler are made to the Big Thompson River and used to exchange to the Home Supply Ditch headgate to increase deliveries later in the irrigation season.

The District must convey its Home Supply water to a location where it can be treated and delivered into the District's treated water system.

ii. *The Handy Ditch Company*

The Handy Ditch diverts water out of the Big Thompson River and serves approximately 12,000 irrigated acres in the Berthoud area. There are 900 shares of stock in the Handy Ditch Company. The District owns 42 shares.

Storage associated with Handy Ditch is in Hertha and Welch Reservoirs. The Welch Reservoir is the largest reservoir of Handy Ditch and is the primary storage facility for the system and can release water into Handy Ditch downstream of the reservoir

Figure 3-4: Big Thompson River Average Monthly Volume above Canyon Gage

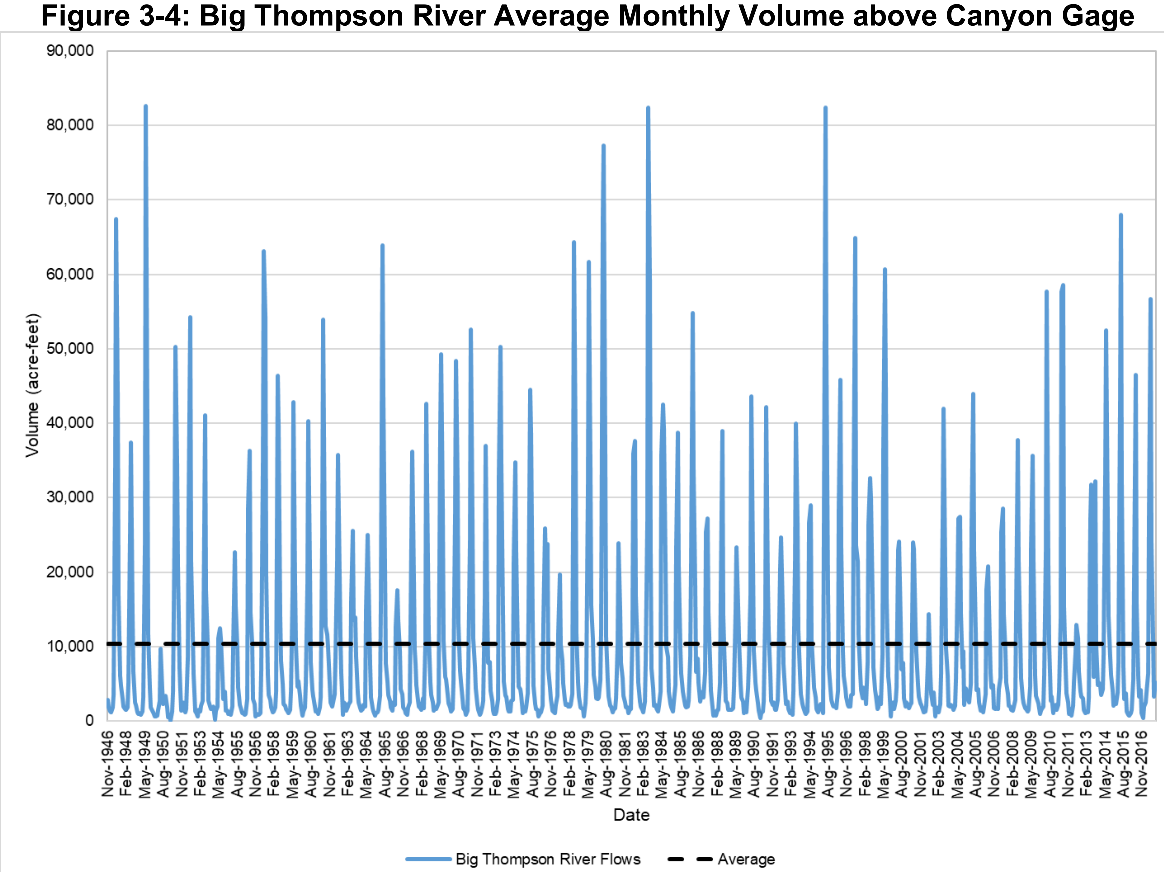


Figure 3-5: Native Shares

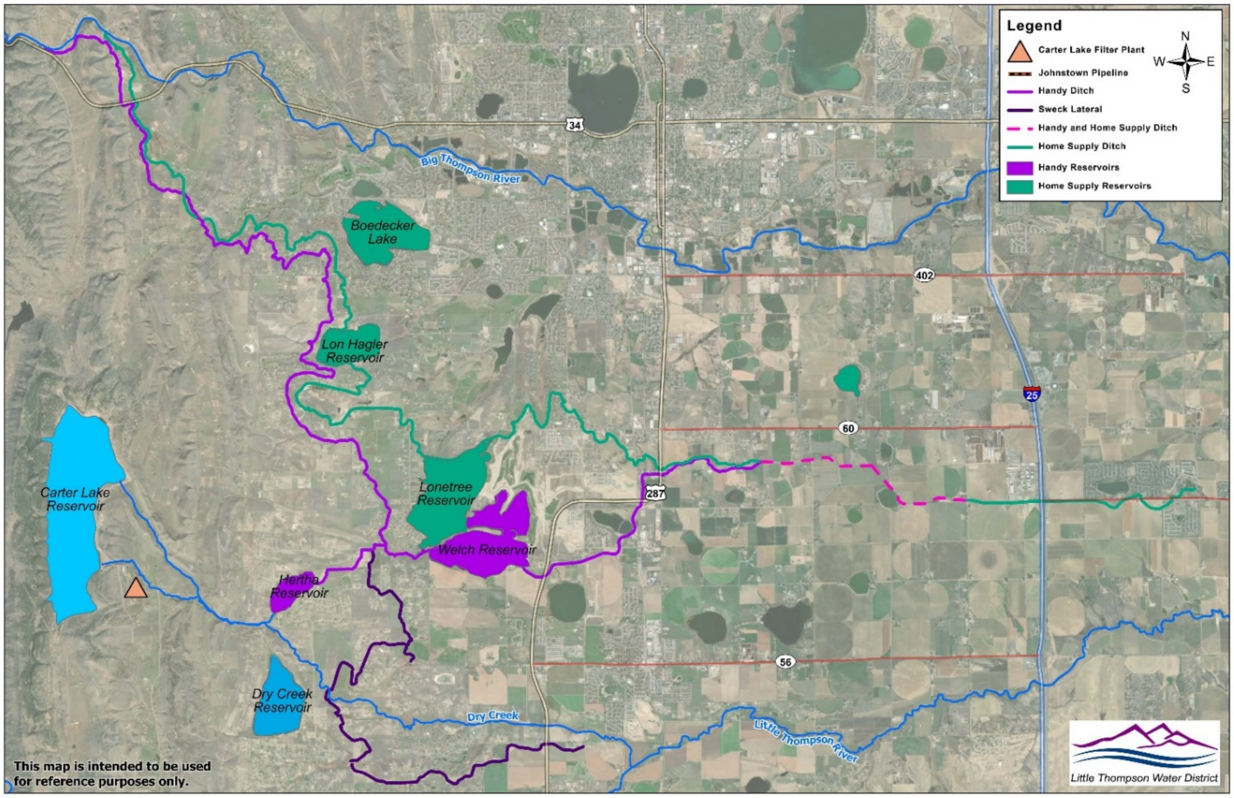


Table 3-3: Yields of Native Shares

Minimum Yield	Average Yield	Maximum Yield
659 Acre-Feet	993 Acre-Feet	1,365 Acre-Feet

3.2 Water Supply Demands

As the AECOM Dry Creek Expansion Feasilbility Study was being completed, the District was also developing a firm yield water supply model with Williams and Weiss Consulting, LLC. This was being developed to assist the District in determining whether the Dsitrict had the ability to meet future potable demands. The model incorporated data based upon observed hydrological conditions from 1950 to 2018, a 68-year period that includes wet, average, and dry years. A scenario-based approach was applied, allowing the yield to be quantified for different water supply portfolios. The Districts model was also used to determine the benefit of adding new water supplies and water treatment facilities. Enlarging Dry Creek Reservoir was one of those scnearios the the District and Williams and Weiss Consulting, LLC ran in the water supply model. Below summarizes the Districts existing demands, future demands, and the evaluation of enlarging Dry Creek Reservoir.

3.2.1 Existing Demand

The existing demand represents the District's annual demand in 2021 with no effect of weather. The existing demand includes water use through the meters, water losses, and bulk water. Water use through the meters was calculated for the District's 2019 Water Efficiency Report. Data was available for 2012-2018 which included wet and dry years. The average of the water demand through the meters for that period was used as an estimate of the water delivered to customers without the high use expected in dry years and the reduced use expected in wet years. **Table 3-4** shows the steps and cumulative volume to get the average demand of 5,789 acre-feet.

Table 3-4: Calculated Average Demand

Description	Increase (AF)	Cumulative Demand (AF)
2012-2018 Average Residential Use (2019 Water Efficiency Report)	3,782	3,782
2012-2018 Average Non-Residential Water Use (2019 Water Efficiency Report)	1,148	4,930
Non-Billed Water (2014-2018 AWWA M36 Report)[1]	204	5,134
Demand From 232 Urban Taps to be Added in 2020	81	5,215
11% losses (Average 2014-2018 AWWA M36 Report)	574	5,789

1. The American Water Work Association Water Loss Calculations. The District has completed a Water Loss Report from 2014-2018.

3.2.2 Future Demand

The tap projection is based upon the tap requests for all approved and proposed developments. The timing of the new demand is estimated by using weighting factors based on location, planning and zoning entities, whether water had been dedicated, who owns the development and infrastructure upgrades required. The number of taps added per year was then adjusted based on weighting factors for approved developments and proposed developments.

The tap average annual percent growth from 2021 to 2030 was 2.6% and 2031 to 2040 was 3.0%, **Table 3-5** shows the calculated 2030 demands, by using the tap average annual percent growth and the baseline demand of 5,789 acre-feet.

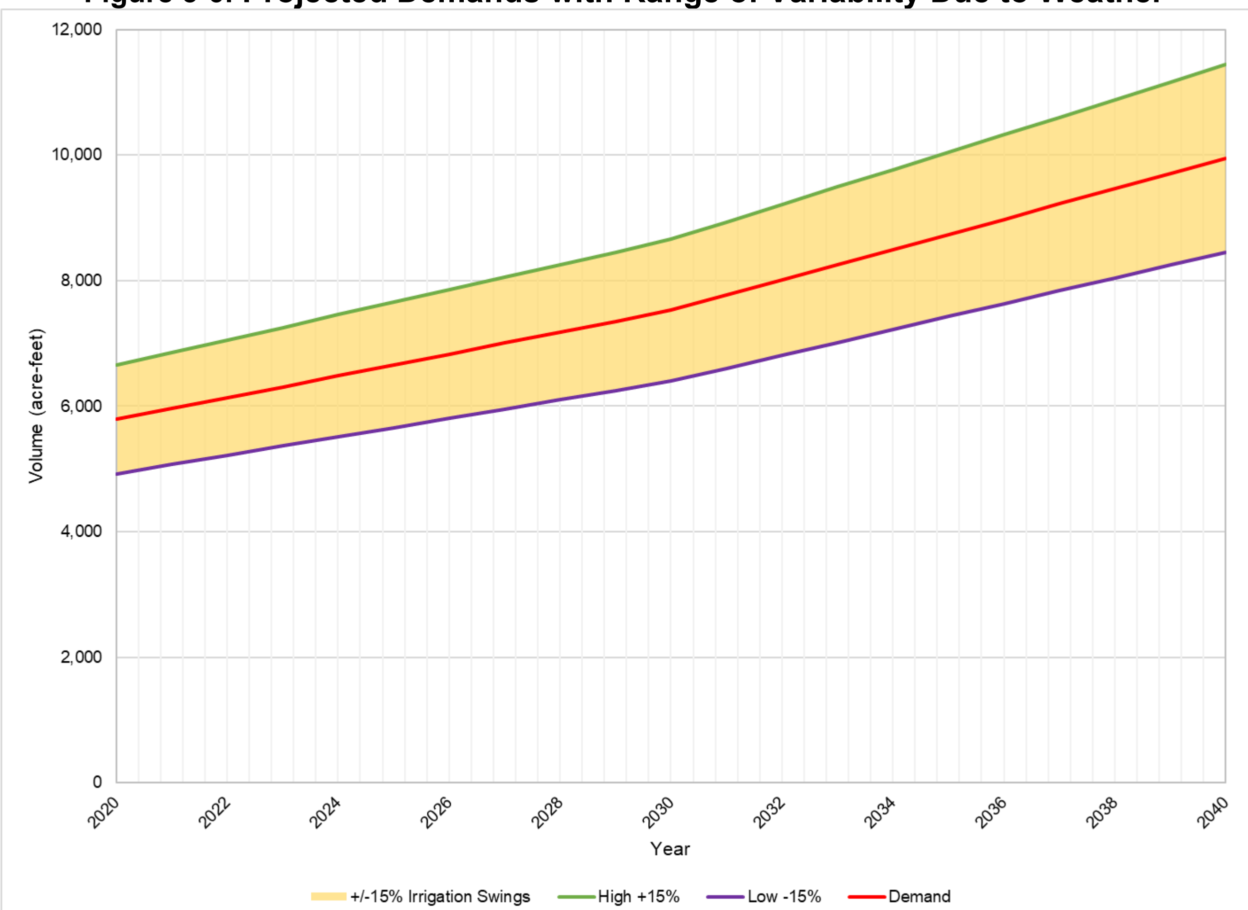
Table 3-5: Projected Demands

Year	Average Annual Percent (%) Growth	Demand Added over 10 years (acre-feet)	Number of Taps Added over 10 years	Demand Added per Year (acre-feet)	Number of Taps Added per Year	Demand (acre-feet)
2020						5,789
2030	2.6%	1,736	4,959	174	496	7,525
2040	3.0%	2,415	6,900	242	690	9,940

Annual weather patterns such as cool and rainy or hot and dry have a significant impact on that year's water demand. The cities of Fort Collins and Greeley conducted a study that determined annual water demand could vary 15% higher or lower than average demands depending on the weather.

Figure 3-8 illustrates the annual projected demand and the range of potential variability due to weather. The demand range will affect the annual demand and the timing adding additional water supplies

Figure 3-6: Projected Demands with Range of Variability Due to Weather



3.2.3 Obligated Demand

As discussed previously, raw water must be dedicated prior to development construction per the District's Rules and Regulations. The District accepts local native (ditch) shares, C-BT and Windy Gap units to meet the water dedication for taps within a new development. The native ditch shares will not yield physical, wet water for new District customers to use for several years due to the water court process and construction of delivery infrastructure. Additionally, C-BT and Windy Gap units were dedicated for developments not yet built out.

This pre-dedicated water is included in the District's existing wet water supply, creating an artificial water surplus.

New customers and new demand will come online as developments begin or continue with construction of homes. The District is obligated to serve this new demand with no new wet water supply (obligated demands). The District has 1,303 acre-feet of obligated water demand.

Table 3-5 shows that 1,736 acre-feet of additional demand would be brought online by 2030. The District assumed the 1,736 acre-feet of projected demand included the 1,303 obligated demand. Therefore only 433 acre-feet of new water supplies will be dedicated to the District by 2030.

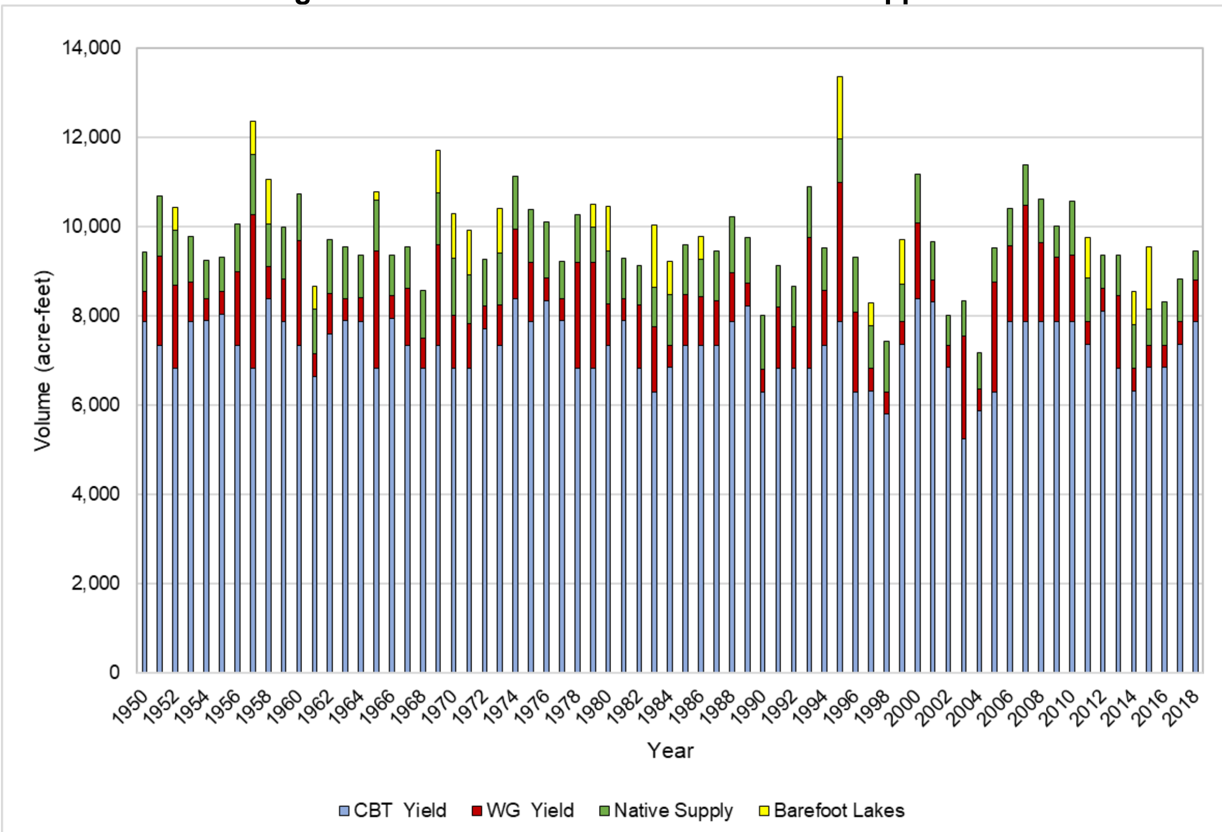
3.3 Dry Creek Reservoir Enlargement Evaluation

3.3.1 Evaluation Definition

According to the Dry Creek Enlargement Feasibility Report by AECOM, the dam could be raised by 5 feet, 10 feet, 15 feet, or 40 feet. The resulting storage increase would be 1,530 acre-feet, 3,150 acre-feet, 4,800 acre-feet, and 14,100 acre-feet respectively. Specifically, the District evaluated if and how much the firm yield of its current and projected water supplies would increase by additional storage in Dry Creek Reservoir. Storage can be used to carryover water in wet years to supplement supplies in dry years. The effectiveness of storage is dependent upon the composition of the utility's water supply portfolio.

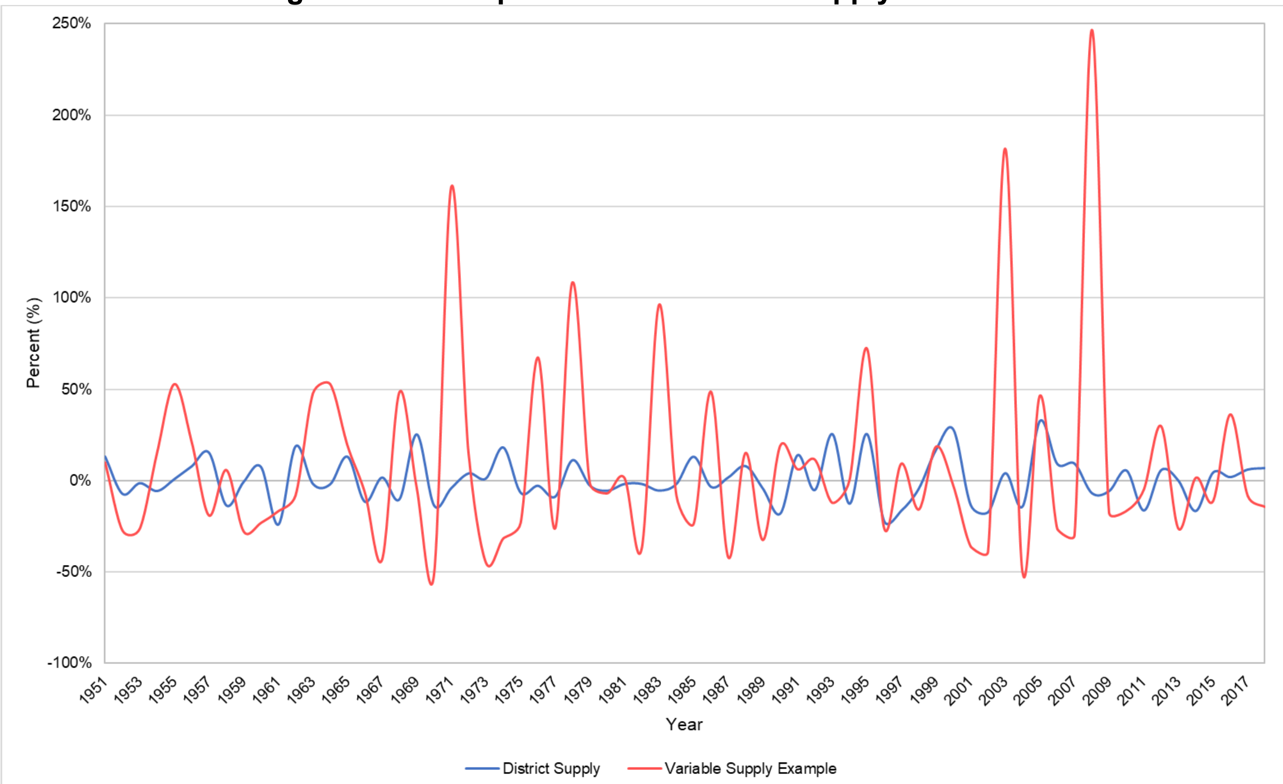
The District's water supply is based upon senior water rights. The yield of these water rights fluctuates from wet to dry years but does not have pronounced variations. Furthermore, C-BT and the native water reservoirs provide storage which helps maintain a consistent annual water yield**.** The Windy Gap Project will also have storage after Chimney Hollow Reservoir is constructed. **Figure 3-9** illustrates the consistency of the Districts total annual yield of each water source over the 68-year model period.

Figure 3-7: Annual Yield of District Water Supplies



Some water supply portfolios are variable**.** A substantial variation in annual yield is due to junior water (or flood) water rights that have high yields in time of free river. The junior water rights may not be priority at all in average or dry years. To maximize the yield of a junior water right, a water provider must have a large or an on-channel reservoir and a sizable conveyance capacity to capture the water when available. The comparison of the annual percentage variation of the District's water supplies and a variable water supply is illustrated in **Figure 3-10** and shows the relative opportunity and need for storage.

Figure 3-8: Example of Variable Water Supply

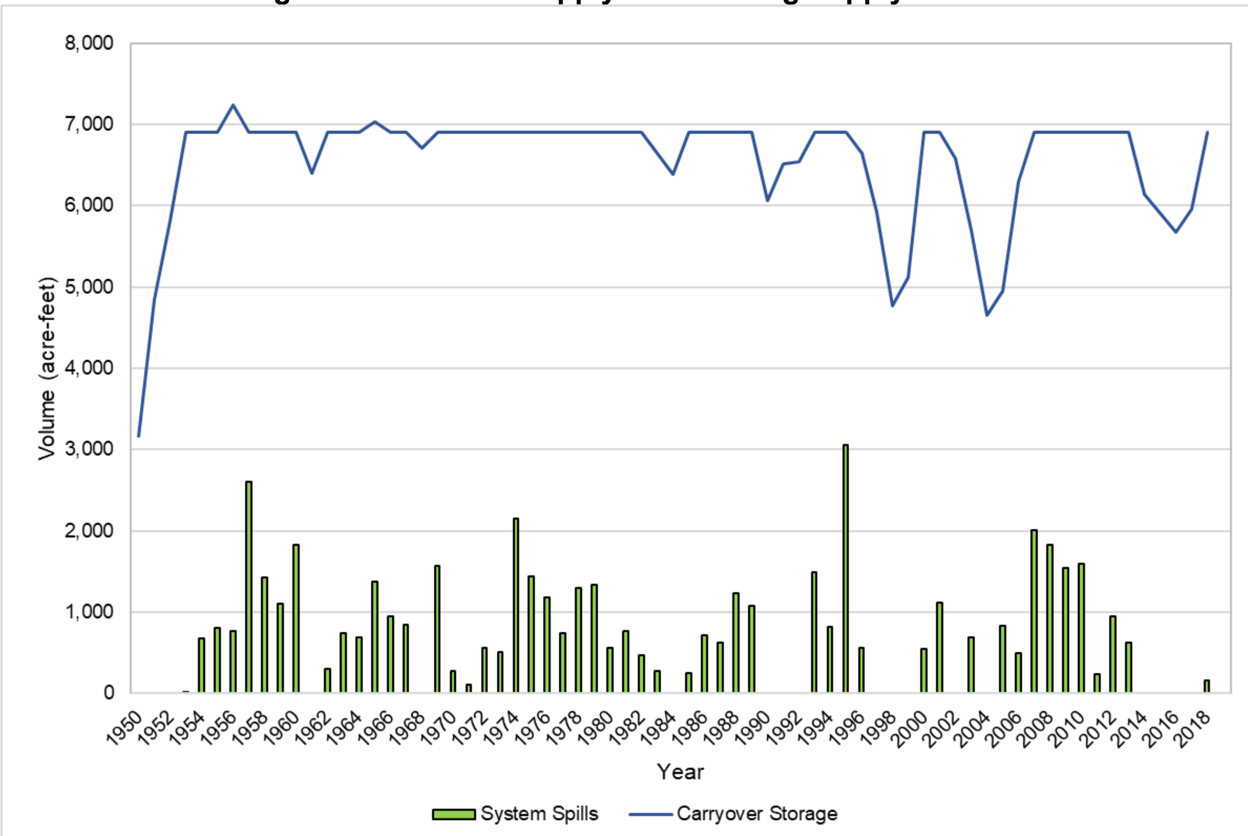


i. Dry Creek Reservoir Analysis Scenarios

Scenario 1

As discussed in Section 3.2.1, the existing average demand is 5,789 acre-feet which can increase or decrease 15% with annual weather conditions. The existing carryover storage in Dry Creek Reservoir and in the C-BT system is 6,897 acre-feet. The District used the model to determine if its existing available water supply (no native water) and existing storage could meet this demand every year of the model period. Additionally, the model was used to define the volume of water stored each year. **Figure 3-11** shows that the District's current water supply can meet the existing demand every year and still consistently spill water from the system. Even in dry years, the District's carryover storage does not drop below 4,800 acre-feet, which is Dry Creek Reservoir's capacity. Additional storage from an enlarged Dry Creek Reservoir would not increase the District's firm yield as it is not needed.

Figure 3-9: Current Supply and Existing Supply

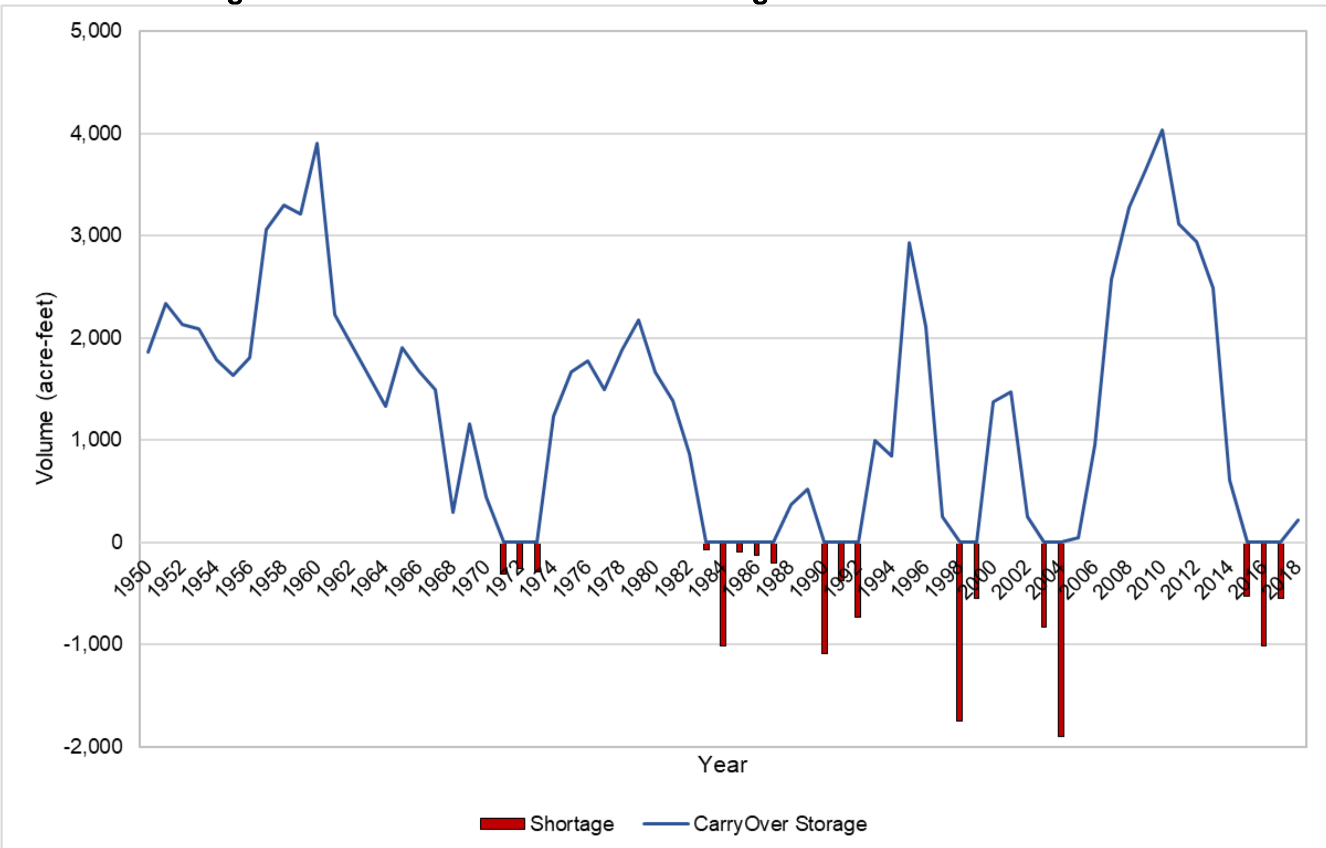


Scenario 2

The District evaluated if the firm yield would be increased if additional storage was available in scenarios where there are shortages. The obligated demand (1,303 acre-feet) is brought online but native water supplies are not available.

The existing water supplies and existing storage are not sufficient to meet the increased demand. The District's water sources do not generate a large surplus of water yield in a wet year. Therefore, the District will not have sufficient excess water to consistently fill the District's existing storage, much less any additional storage. Therefore, increasing storage by enlarging Dry Creek Reservoir would not increase the District's firm yield as there is not excess water to store. **Figure 3-12** illustrates the water shortages and carryover storage in this scenario.

Figure 3-10: Baseline Demand with Obligated Demand

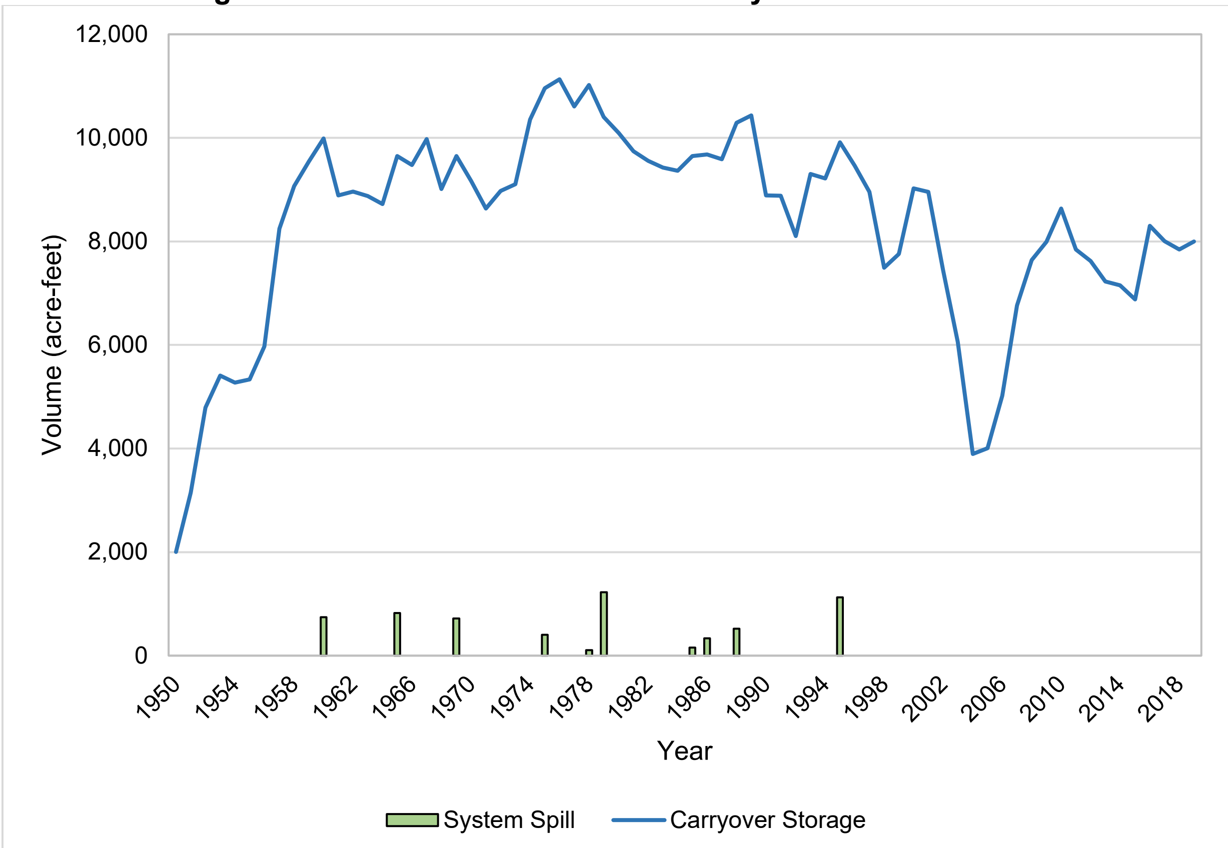


Scenario 3

The District is participating in the Windy Gap Firming Project which will provide approximately 4,850 acre-feet of new storage to manage Windy Gap and C-BT water supplies. In addition to the storage increase, the annual yield of the Windy Gap water is increased by pre-prepositioning C-BT water in Chimney Hollow Reservoir. Northern has all permits needed to construct the reservoir but is currently awaiting resolution of a federal lawsuit. The timeline for the reservoir to be online and full is a minimum of seven years. The time could increase due to legal challenges, low streamflow in the Colorado River, or water quality issues due to the recent impacts of the fires on the west slope.

Figure 3-13 shows that the District can meet 2030 demands if Chimney Hollow Reservoir is constructed. Relatively minor spills will occur. In this scenario the District does not fill its total system storage and the storage never drops below 4,000 acre-feet. Additional storage in Dry Creek Reservoir is not needed as there is not sufficient excess water to store.

Figure 3-11: 2030 Demands with Chimney Hollow Online



3.3.2 Dry Creek Reservoir Enlargement Conclusions

Enlarging Dry Creek Reservoir will not increase the firm yield of the District's water supplies. Adding water, not storage will allow the District to meet future demands. The District should reevaluate enlarging Dry Creek Reservoir if the District acquires new water sources.

4. Project Description – Analysis of Alternatives & Selected Alternative

4.1 Analysis of Alternative

AECOM evaluated several alternatives for increasing the capacity of Dry Creek Reservoir to establish the feasibility and costs with different levels of increased capacity and the relative impacts to The District and CWCWD facilities and adjacent properties. The attached report found in **Appendix C** evaluates impacts of dam raises of 5 feet, 10 feet, 15 feet, and 40 feet. The design alternatives summary found in **Appendix C**, **Table 4-1** lists the probable permit requirements and consultations that would be needed before construction for Alternatives 1, 2, and 3, the 5-foot, 10-foot, and 15-foot dam raises, respectively. It should be noted that Alternative 4, the 40-foot dam raise, would likely require a Clean Water Act Section 404 Individual Permit and associated documentation under the National Environmental Policy Act (NEPA). Additionally, Alterative 4 will require a Clean Water Act

Section 401 Water Quality Certification from the State prior to issuance of a 404 permit from the United States Army Corps of Engineers (USACE). **Appendix C**, **Table 5-1** includes probable project cost for each Alternative. **Appendix C**, **Table 7-1** includes yields, total cost, and impacts.

4.2 Selected Alternative

Since it was determined in the Districts water supply modeling that adding water and not storage will allow the District to meet future demands, The District has decided not to enlarge Dry Creek Reservoir at this time. Therefore, none of the alternatives provided will be chosen so a cost estimate, implementation schedule, impacts, and institutional feasibility will not be included in detail. The District should reevaluate enlarging Dry Creek Reservoir if the District acquires new water supply sources or if there is opportunity for regional cooperation that provides increased benefits.

5. Financial Feasibility Analysis

At this time, Dry Creek Reservoir will not be enlarged so the District will not need a loan, financing sources, or revenue and expenditure projections.

6. Conclusions and Recommendations

The AECOM report presented the four alternatives in **Appendix D, Table 7-1** noting that each alternative would present unique challenges with varying degrees of benefit. The water supply modeling that was completed concurrently with AECOM feasibility study concluded enlarging Dry Creek Reservoir will not increase the firm yield of the District's water supplies. Adding water, not storage will allow the District to meet future demands. The District should only revisit enlarging Dry Creek Reservoir if the District acquires new water sources or for a mutually beneficial regional cooperation project in the future.

7. Loan Request Submittals

No loan is being requested at this time due to conclusions and recommendations.

Appendix A: Revenue Sources

LITTLE THOMPSON WATER DISTRICT

Rules and Regulations

Section 1501.1 Schedule A – Tap Fees

Approved by the Board of Directors on May 14, 2020

Effective July 1, 2020

Residential Taps

Meter Size	Plant Investment Fee (PIF)	Installation Fee (1)	Cash-in-Lieu of Raw Water Dedication Requirement (2,3)	Total Cost of Tap
5/8” Inside Use	$6,000	$3,000	$14,400	$23,400
5/8” Urban (Conservation)	$7,000	$3,000	$28,000	$38,000
5/8" Standard	$11,000	$3,000	$56,000	$70,000

(1) If the service line and meter pit have already been installed by the developer, the installation fee is reduced to $450.

(2) If the water rights dedication has been made by the developer, the water rights dedication has been satisfied and there is no cash-in-lieu of water rights required. Not all lots are eligible to pay cash-in-lieu of dedicating water rights. See Section 1506.4 Schedule D for more raw water dedication information.

(3) The Cash-in-Lieu price is based on recent sale prices for water sources allowable for dedication, such that the District may purchase the raw water dedication requirement for lots allowed to utilize the Cash-in-Lieu option. The current price for Cash-in-Lieu is $80,000 per acre-foot.

Non-Residential Taps Meter Size	Plant Investment Fee (PIF)	Installation Fee District Supplied Materials	Installation Fee Developer Supplied Materials
5/8” Inside Use	$8,300	$3,000	$450
5/8” Urban (Conservation)	$7,000	$3,000	$450
5/8"	$11,000	$3,000	$450
3/4"	$16,500	$3,500	$600
1"	$27,500	$4,000	$1,000
1 1/2"	$55,000	Developer must install	$1,825
2"	$88,000	Developer must install	$2,920

Other Capital Fees

Fire Hydrant	$2,000 each
Residential Fire Sprinkler, 1-inch	$1,000
Non-Residential Fire Sprinkler up to 6-inch	$2,500

LITTLE THOMPSON WATER DISTRICT

Rules and Regulations

Section 1502.1 Schedule B – Water Rate Schedule

2020 Water Rate Structure – Updated April 9, 2020

Approved by the Board of Directors on May 14, 2020

Effective July 1, 2020

Tap Size	Base Fee	Gallons Used	Rate per 1,000 Gallons
5/8" Inside Use Only Res.+	$28.15	0-3,000 3,001-5,000 >5,000	$2.50 $3.14 $4.25
5/8” Urban Residential*	$28.15	0-6,000 6,001-15,000 >15,000	$2.50 $3.14 $4.25
5/8” Standard Residential	$28.15	0-6,000 6,001-25,000 25,001-50,000 >50,000	$2.50 $3.14 $3.70 $4.25
3/4” Standard Residential	$30.50	0-9,000 9,000-45,000 45,000-90,000 >90,000	$2.50 $3.14 $3.70 $4.25
5/8” Urban Non Res*	$28.15	0-6,000 6,001-15,000 >15,000	$2.50 $3.14 $4.25
5/8” Non Res	$28.15	0-6,000 6,000-30,000 30,000-60,000 >60,000	$2.44 $3.07 $3.38 $3.79
3/4” Non Res	$30.50	0-9,000 9,000-45,000 45,000-90,000 >90,000	$2.50 $3.14 $3.46 $3.79
1” Non Res	$38.93	0-15,000 15,000-75,000 75,000-150,000 >150,000	$2.50 $3.14 $3.46 $3.79
1.5” Non Res	$73.24	0-30,000 30,000-150,000 150,000-300,000 >300,000	$2.50 $3.14 $3.46 $3.79
2” Non Res	$88.69	0-48,000 48,000-240,000 240,000-480,000 >480,000	$2.50 $3.14 $3.46 $3.79
3” Non Res	$164.54	0-105,000 105,000-525,000 525,000-1,050,000 >1,050,000	$2.50 $3.14 $3.46 $3.79
4” Non Res	$240.45	0-189,000 189,000-945,000 945,000-1,890,000 >1,890,000	$2.50 $3.14 $3.46 $3.79

*The Urban Residential Tap rate allows for 114,000 gallons usage per year. Usage overage results in a surcharge of $20.00 per thousand gallons.

+ The Inside Use Only Residential Tap rate allows for 60,000 gallons usage per year. Usage overage results in a surcharge of $20.00 per thousand gallons.

Vacant Lot Base Fee = $8.75 per month

LITTLE THOMPSON WATER DISTRICT

Rules and Regulations

Section 1502.1 Schedule B – Water Rate Schedule

2019 Wholesale Rate Structure – Updated November 14, 2019

Effective January 1, 2020

	North Carter Lake	Longs Peak Water District		Berthoud		Johnstown	Loveland
		CR Rd 23	*Foster Ridge*	*Core Town*	*I-25*		
Wholesale Rate	$1.19	$1.56	$1.56	$1.28	$1.89	$1.39	$1.15

LITTLE THOMPSON WATER DISTRICT

Rules and Regulations

Section 1502.2 Schedule C – Miscellaneous Fees

Approved by the Board of Directors on November 14, 2019

Effective January 1, 2020

Transfer Fee	$ 25.00
Disconnect/Turn-on Fee	$ 50.00
Disconnect/Turn-on Fee After Hours	$ 25.00
Disconnect Letter Fee	$ 5.00
Final Read Fee	$ 25.00
Fire Sprinkler Annual Fee	$ 50.00
Dormant Tap Annual Fee	$ 60.00
Return Check/ACH Fee	$ 25.00/$10.00
Water Theft Violation Fee	$ 1,000.00
Past Due Penalty for Balances Over $15.00	1% of unpaid Balance
Fire Hydrant Rental:	
Backflow Device Deposit	$ 1,000.00
Meter Deposit	$ 1,000.00
Trip Charge	$ 50.00
Water (per 1,000 gals)	$ 10.00
Equipment Rental Per Day (each device)	$ 10.00
Fire Sprinkler Line (Commercial up to 6")	$ 2,500.00
Fire Sprinkler Tap (Residential Meter)	$ 1,000.00
Fire Hydrant (no materials or labor)	$ 2,000.00
Inspection Fee (after 5pm/Holiday/Weekends)	$ 100.00/per hour
*Residential/Non-Residential Commitment Letters:	
1 – 4 taps	$ 100.00/per tap
5 – 80 taps	$ 500.00
Over 80 taps (plus engineering fees)	$ 500.00
*Accessory Dwelling Commitment Letter	$ 100.00
Project Inspection & Test	$ 300.00
Plus, per lot	$ 100.00
Cross Connection Non-Compliance Fee	$ 50.00
Native Water Dedications Fee	$ 1,800.00/per acre-feet
Handy Water Dedication Fee	$ 7,500.00/per share

**Commitment Letters are good for two years.*

Appendix B: Streamflow Data

	Table 1: Big Thompson Native Flows (acre-feet)											
Water Year	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct
1947	2,862	1,841	1,303	1,208	1,831	3,554	34,008	67,441	44,203	16,777	6,013	4,681
1948	2,986	1,919	1,598	1,518	1,885	5,024	25,103	37,441	14,400	6,568	2,499	2,182
1949	1,183	967	1,114	800	1,292	3,182	23,615	82,630	39,215	11,555	4,418	1,877
1950	1,383	1,149	666	633	699	1,502	2,728	9,664	4,306	2,342	2,835	3,369
1951	1,895	476	622	49	1,274	3,903	26,122	50,284	34,668	20,645	7,042	4,078
1952	1,432	2,501	1,677	1,198	1,593	8,458	28,521	54,282	21,323	11,361	6,252	1,294
1953	1,160	634	1,508	1,294	2,051	2,769	11,980	41,060	17,494	10,698	2,727	1,945
1954	1,611	1,632	1,988	191	1,450	1,995	11,160	12,477	11,057	5,910	2,918	3,949
1955	1,429	1,419	914	1,229	905	1,989	9,859	22,680	15,390	10,090	4,507	2,173
1956	1,870	1,061	1,122	818	1,005	2,929	28,683	36,327	14,444	10,521	2,910	2,340
1957	610	981	817	831	1,112	6,690	34,618	63,067	54,338	19,456	6,208	3,492
1958	2,854	1,883	1,221	1,350	1,887	3,947	46,340	39,777	14,090	8,031	4,926	2,264
1959	2,037	1,652	1,244	1,108	1,516	4,010	17,512	42,826	18,232	10,189	4,572	5,400
1960	3,353	2,125	746	1,306	1,821	5,029	18,382	40,268	20,473	7,857	4,215	3,257
1961	1,925	1,349	1,416	980	1,895	3,216	24,553	53,907	22,326	12,737	11,595	9,811
1962	4,926	2,462	1,931	2,565	3,641	8,429	21,470	35,710	27,509	11,276	6,374	889
1963	2,470	2,343	1,388	1,927	2,300	2,679	16,163	25,569	13,621	13,938	8,582	3,741
1964	2,484	1,761	1,404	1,584	2,149	2,010	15,013	25,043	19,298	7,470	3,229	1,706
1965	1,280	761	1,074	1,156	1,558	3,442	16,044	63,860	43,544	20,316	7,715	5,335
1966	3,499	2,702	1,824	1,445	2,462	2,185	12,678	17,528	13,580	9,438	4,333	3,638
1967	1,835	1,488	1,122	839	1,818	2,481	12,839	36,178	27,784	9,560	7,678	4,868
1968	2,696	1,976	1,697	1,487	3,122	1,768	10,344	42,583	21,192	11,655	5,168	3,458
1969	2,459	1,408	1,698	1,634	2,236	2,481	39,128	49,220	28,591	10,751	5,994	5,603
1970	3,513	2,404	1,802	1,317	1,676	5,416	27,784	48,424	31,972	12,995	6,707	5,320
1971	2,984	1,777	1,354	797	1,416	7,174	24,223	52,550	27,101	11,012	7,261	4,363
1972	2,221	1,554	840	1,075	1,906	2,738	16,320	36,988	14,642	7,839	7,930	4,111
1973	2,745	1,416	1,013	930	1,312	2,922	33,018	50,314	34,556	14,227	5,292	3,451
1974	3,239	1,682	1,329	1,260	2,721	2,847	21,355	34,755	22,669	9,128	4,582	4,333

	Big Thompson Native Flows (acre-feet)											
Water Year	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct
1976	1,668	1,513	576	1,030	1,199	2,034	13,100	25,852	20,898	23,754	6,893	4,375
1977	2,940	1,393	1,293	1,118	2,205	3,381	11,865	19,687	10,318	8,111	5,117	2,836
1978	2,213	2,343	1,956	1,938	2,155	3,663	28,528	64,307	36,758	11,661	5,127	3,313
1979	1,859	1,692	1,679	595	2,401	5,190	31,772	61,690	34,108	15,456	10,892	6,224
1980	4,660	3,039	2,969	3,175	5,504	12,247	67,765	77,342	35,836	11,223	5,401	3,309
1981	2,122	1,937	1,140	1,528	1,752	3,013	10,356	23,892	14,975	7,876	5,778	3,387
1982	2,470	1,826	1,812	1,083	1,572	1,630	11,826	35,999	37,689	16,696	9,947	5,207
1983	2,645	2,008	1,468	1,212	2,657	8,024	26,817	82,389	59,372	22,436	7,038	4,384
1984	2,102	2,152	1,726	1,287	2,091	4,003	35,834	42,510	39,255	21,346	9,886	8,552
1985	3,982	2,288	1,878	1,344	2,524	4,875	23,617	38,691	20,701	9,705	6,377	3,983
1986	3,251	2,079	1,828	1,950	2,684	8,663	21,122	54,826	33,711	18,223	6,650	8,391
1987	5,143	2,579	3,274	3,928	3,153	6,601	25,454	27,272	14,515	8,162	4,069	1,836
1988	780	1,278	770	1,461	1,548	5,138	17,423	38,921	14,173	6,389	2,726	2,364
1989	1,499	1,571	1,536	1,537	1,718	4,657	14,959	23,387	15,377	11,135	4,943	3,141
1990	2,654	1,025	1,922	1,135	4,562	7,634	16,788	43,606	21,192	9,378	5,122	4,106
1991	2,400	1,448	429	1,068	1,245	2,594	14,968	42,146	18,268	11,938	6,533	2,688
1992	2,234	2,558	1,509	1,568	2,795	6,849	20,550	24,710	15,207	7,639	3,942	2,310
1993	2,677	1,628	1,051	1,303	883	3,963	21,408	39,934	26,667	12,178	6,332	3,656
1994	2,295	1,872	1,164	992	1,341	5,990	26,664	29,001	10,911	6,894	4,501	3,150
1995	1,630	1,144	1,873	2,330	2,048	1,095	26,556	82,428	49,190	16,878	7,149	4,195
1996	2,832	2,024	1,919	2,024	1,703	4,039	28,432	45,822	23,190	9,248	6,032	4,437
1997	3,182	2,232	2,001	1,920	3,467	3,629	30,009	64,841	23,548	21,410	11,559	6,431
1998	4,199	3,107	4,544	3,680	2,267	7,866	26,423	32,660	29,834	16,210	7,150	4,184
1999	3,387	1,626	1,870	3,313	2,310	8,783	36,655	60,710	44,885	16,311	5,978	4,816
2000	647	2,056	2,531	1,613	2,757	4,552	23,008	24,081	13,361	6,977	7,818	3,024
2001	1,966	2,470	2,134	1,685	2,347	2,404	24,050	23,105	12,563	9,265	4,794	3,333
2002	2,348	2,207	1,532	1,203	1,281	2,091	7,838	14,382	6,116	3,660	2,174	3,860
2003	651	1,886	1,791	1,206	2,251	6,325	27,099	42,007	20,639	9,736	6,070	2,073
2004	2,012	2,229	1,876	1,511	2,083	5,667	18,223	27,214	27,497	14,410	7,148	9,372

	Big Thompson Native Flows (acre-feet)											
Water Year	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct
2006	2,501	1,373	1,797	1,218	1,926	3,666	17,694	20,821	15,430	6,405	4,554	4,822
2007	1,720	1,636	1,730	1,672	4,278	5,828	25,504	28,574	14,252	9,430	5,150	3,634
2008	2,045	1,983	1,519	1,369	1,853	2,819	14,809	37,724	21,295	11,125	5,782	3,017
2009	2,392	1,692	1,634	1,281	1,519	4,580	23,267	35,651	21,325	6,092	3,422	2,691
2010	2,386	1,010	1,432	1,573	1,956	6,012	22,729	57,714	20,960	10,223	2,769	3,321
2011	1,111	1,960	2,154	1,529	2,156	4,191	13,710	57,674	58,541	15,281	6,912	3,677
2012	2,485	1,018	1,595	722	2,045	5,135	9,231	12,915	11,205	6,573	3,928	3,290
2013	3,082	1,500	1,101	1,186	1,176	3,049	27,341	31,817	14,618	5,984	32,177	10,192
2014	4,886	5,212	4,571	3,458	4,299	8,819	33,031	52,475	27,184	14,063	8,662	6,208
2015	4,025	2,037	2,876	2,325	3,860	7,670	42,961	67,947	31,714	7,119	2,969	3,781
2016	1,250	847	698	1,107	1,476	5,576	19,236	46,489	15,656	6,036	3,243	4,215
2017	1,041	399	2,011	2,460	3,794	6,359	27,602	56,688	23,923	11,034	3,306	5,157

*Flows measured at Big Thompson Native Flows Above Canyon Gage

Appendix C: AECOM Dry Creek Expansion Feasibility

Dry Creek Expansion Feasibility Study

Little Thompson Water District

Project number: 60595240

June, 17, 2020

Quality information

Prepared by	Checked by	Verified by	Approved by
Dan Swanson, P.E.	Ed Toms, P.E.	Ed Toms, P.E.	Dan Swanson, P.E.

Revision History

Revision	Revision date	Details	Authorized	Name	Position
Final	6/17/20			D. Swanson	PM

Distribution List

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Table of Contents

Figures

Tables

List of Acronyms and Abbreviations

AACE	Association for the Advancement Of Cost Engineering
ac-ft	Acre-Feet
APCD	Air Pollution Control Division
ASTM	American Society for Testing and Materials
BCC	Base Construction Cost
CCR	Code of Colorado Regulations
CDPHE	Colorado Department of Public, Health and Environment
CDPS	Colorado Discharge Permit System
CFR	Code of Federal Regulations
CH	High Plasticity Clay
CL	Low Plasticity Clay
CO	Colorado
CWCWD	Central Weld County Water District
CY	Cubic Yards
DWR	Department of Water Resources
El.	Elevation
ESA	Endangered Species Act
FS	Factor of Safety
ft	Feet
H:V	Horizontal to Vertical
IDF	Inflow Design Flood
LTWD	Little Thompson Water District
MBTA	Migratory Bird Treaty Act
MWS	Maximum Water Surface
NEPA	National Environmental Policy Act
NHWL	Normal High Water Line
NPDES	National Pollutant Discharge Elimination System
OPPC	Opinion Of Probable Project Cost
SEO	Office Of The State Engineer
RCC	Roller-Compacted Concrete
SWMP	Storm Water Management Plan
USACE	United States Army Corps of Engineer
USFWS	United States Fish and Wildlife Service
WQCD	Water Quality Control Division

Executive Summary

AECOM was commissioned to develop a feasibility-level study to evaluate four conceptual dam raises at Dry Creek Reservoir. The evaluation includes alternatives focused on raising the dam height to increase the storage capacity, and identifying potential fatal flaws and risks associated with constructing each of the alternatives. A desktop study was performed which included review of the original design documents, reports, and analyses, as part of the evaluation.

Dry Creek Reservoir is jointly owned and operated by LTWD and CWCWD, and is located in Larimer County, Colorado, approximately 10 miles west of Berthoud. The dam is an earthen embankment dam constructed in 2007. The dam is approximately 55 ft high at its maximum section, which includes 5 ft of freeboard and a crest elevation of 5,225. The upstream slope has a 3H:1V slope and the downstream slope is at a 2.5H:1V. The reservoir covers an area of approximately 315 acres and has an active storage capacity of approximately 8,862 ac-ft.

Conceptual Design

Three conceptual alternatives were developed. All three concepts are proposed to be constructed via a downstream raise to provide increased capacity and prevent the complete drainage of the reservoir. Alternative 1 includes a crest raise of 5 ft to El. 5,230 ft, Alternative 2 includes a crest raise of 10 ft to El. 5,235 ft, and Alternative 3 includes a crest raise of 15 ft to El. 5,240 ft.

The design assumptions that were made during this evaluation were consistent with the design of the original dam. A key design decision was to utilize material that was stockpiled west of the reservoir during the original construction. This material is likely clayey material, largely claystone bedrock that has weather into clay. It is assumed that this material, built to the existing dam slopes, will provide sufficient strength such that the slope stability meets the Colorado SEO criteria. The stockpile of material west of the reservoir was estimated to contain about 774,124 cubic yards of soil.

Another key design decision was to prevent inundation of neighboring private residences with the use of saddle dams. The saddle dams will be constructed similar to the existing dam, with a key trench and blanket drain in select locations, and to the same crest elevation as the proposed raise.

Alternative Development

Alternative 1 – Dam crest Elevation 5,230 ft

- Dam raise of 5 ft for a crest elevation of 5,230 ft.
- Crest Length: 5,150 ft.
- Storage Capacity: 10,400 ac-ft, an increase of about 1,530 ac-ft.
- Maximum Water Surface Elevation: 5,230 ft.
- Normal High Water Line: 5,225 ft.
- Existing toe drain could be re-used.
- Existing outlet works largely unaffected.

- Existing spillway and stilling basin would be re-used with alteration of the spillway sidewalls and existing labyrinth weir
- Saddle dam required near the southwest corner of the reservoir for about 250 ft.

Alternative 2 - Dam crest Elevation 5,235 ft

- Dam raise of 10 ft for a crest elevation of 5,235 ft.
- Crest Length: 6,000 ft.
- Storage Capacity: 12,000 ac-ft, an increase of about 3,150 ac-ft.
- Maximum Water Surface Elevation: 5,235 ft.
- Normal High Water Line: 5,230 ft.
- Existing toe drain would be removed and a new toe drain and conveyance system required.
- Existing outlet works would be extended downstream.
- Existing spillway would serve as the foundation for a raised spillway constructed of RCC.
- Existing stilling basin would be re-used with alteration of headwall and wing walls.
- Existing labyrinth weir would be removed and reconstructed at the new NHWL.
- Saddle dams required at both the southwest and northwest corners of the reservoir totaling about 2,600 ft in length.

Alternative 3 - Dam crest Elevation 5,240 ft

- Dam raise of 15 ft for a crest elevation of 5,240 ft.
- Crest Length: 6,400 ft.
- Storage Capacity: 13,700 ac-ft, an increase of about 4,850 ac-ft.
- Maximum Water Surface Elevation: 5,240 ft.
- Normal High Water Line: 5,235 ft.
- Existing toe drain would be removed and a new toe drain and conveyance system required.
- Existing outlet works would be extended downstream.
- Existing spillway would serve as the foundation for a raised spillway constructed of RCC.
- Existing stilling basin would be re-used with alteration headwall and wing walls.
- Existing labyrinth weir would be removed and reconstructed at the new NHWL.
- Saddle dams required at both the southwest and northwest corners of the reservoir totaling about 2,850 ft in length.

Alternative 4 – Dam crest Elevation 5,265 ft

- Dam raise of 40 ft for a crest elevation of 5,265 ft.
- Crest Length: 10,150 ft.

- Storage Capacity: 22,950 ac-ft, an increase of about 14,088 ac-ft.
- Maximum Water Surface Elevation: 5,265 ft.
- Normal High Water Line: 5,260 ft.
- Existing toe would be removed and a new drain and conveyance system required., including an additional vertical chimney drain.
- Existing outlet works would be extended downstream. The existing outlet structure and valve vault would be moved to the proposed downstream toe.
- Existing spillway would serve as the foundation for a raised spillway constructed of RCC.
- Existing labyrinth weir would be removed and reconstructed at the new NHWL.
- Saddle dams are not included in this raise. The purchase of 6 properties to the south of the reservoir and 11 properties on the northern half would be required.

Permitting Requirements

Permit requirements should be confirmed with the applicable regulatory agencies as the design progresses. The same permits and regulatory approvals will likely apply to all reservoir enlargement options. Permits are anticipated with the following agencies: U.S. Army Corps of Engineers; U.S. Fish and Wildlife Service; Colorado Department of Public Health and Environment; Colorado Department of Natural Resources, Division of Water Resources, Office of the State Engineer; and Larimer County.

Estimated Cost

The total OPCC for each alternative, using a contingency of 30 percent, is as follows:

Alternative 1 – Dam crest Elevation 5,230 ft

- Total Cost: $6,920,000
- Cost per ac-ft of storage gained: $4,523/ac-ft

Alternative 2 - Dam crest Elevation 5,235 ft

- Total Cost: $16,910,000
- Cost per ac-ft of storage gained: $5,377/ac-ft

Alternative 3 - Dam crest Elevation 5,240 ft

- Total Cost: $28,130,000
- Cost per ac-ft of storage gained: $5,854/ac-ft

Alternative 4 - Dam crest Elevation 5,265 ft

- Total Cost: $98,020,000
- Cost per ac-ft of storage gained: $6,957/ac-ft

Alternative Evaluation

The construction of Alternatives 1, 2, and 3 are similar, with the major differences being the extent of the saddle dams and the modifications to the spillway and outlet works. The larger dam raises include longer saddle dam alignments, as well as additional key trenches and blanket drains associated with the saddle dams. The larger dam raises will also include additional modifications to the spillway and outlet works. There appears to be enough material in the existing stock pile for Alternatives 1, 2, and 3.

Alternative 4 includes purchasing private property that would be inundated by the enlarged reservoir rather than control the pool surface area with the use of saddle dams. Alternative 4 also includes a new reinforced concrete spillway. Additional fill will be required, likely from the existing and proposed reservoir area.

Risks

The raises are not expected to modify the operation of the reservoir after construction; however the increased water level could increase existing seepage and cause potential additional seepage locations to develop.

Recommendations

Alternative 1, Crest El. of 5,230 ft, has been identified as the preferred alternative based on the District’s current water resources.

1. Introduction

1.1 Objectives

LTWD requires the development of a feasibility-level evaluation of the Dry Creek Reservoir dam to understand the technical feasibility of raising the dam to increase the active storage capacity of the reservoir. This evaluation includes alternatives focused on raising the dam height to increase the storage capacity, identifying potential fatal flaws or risks associated with constructing each of the alternatives, and potential encroachment on surrounding properties.

The work completed in this Feasibility Study includes:

- Development of design assumptions;
- Conceptual development of dam raise alternatives;
- Alternatives descriptions;
- Summary of potential permitting issues/requirements;
- Screening-level construction cost estimate;
- Alternative evaluation; and
- Conclusions and recommendations.

1.2 Background

Dry Creek Reservoir is located in Larimer County, Colorado, approximately 10 miles west of Berthoud. Jointly owned and operated by the LTWD and CWCWD, it acts as a municipal water storage reservoir to provide drought protection and operational flexibility within the District. The dam is an earthen embankment dam constructed in 2007. The dam is approximately 55 ft high at its maximum section, which includes 5 ft of freeboard and a crest elevation of 5,225. The upstream slope has a 3H:1V slope and the downstream slope is at a 2.5H:1V. The reservoir covers an area of approximately 315 acres and has an active storage capacity of approximately 8,862 ac-ft. Other appurtenant structures to the dam include a RCC spillway, outlet works, and a pump station.

2. Conceptual Design

2.1 Design Basis

The primary focus for this feasibility study was the technical feasibility (i.e. implementability and constructability) of each alternative, which includes identification of potential fatal flaws and the risks associated with the construction and operation for each alternative.

2.2 Design Assumptions

The following criteria and assumptions were used during the development and evaluation of the conceptual layouts:

- The dam expansion will be constructed via downstream construction methods.
- 5 ft of freeboard was selected based on review of the original design analyses which yielded a significant wave height of 2.1 ft and a freeboard of 2.5 ft, which is less than the SEO 5-foot minimum in accordance with the Colorado Rules and Regulations for Dam Safety and Dam Construction (CO DWR, 2007).
- The MWS is equal to the crest El.
- The existing chimney drain will be extended to NHWL. The existing chimney and blanket drains have enough capacity to handle the increased seepage flows for Alternatives 1, 2, and 3.
- The existing chimney drain and embankment material are filter compatible. The existing blanket drain is filter compatible with the embankment and foundation material.
- Constructing the embankment to similar slopes as the original design slopes will yield acceptable slope stability FS similar to the original analysis. The downstream dam expansion will not affect upstream rapid drawdown stability. The original design analyses utilized typical industry accepted practices, methods, and standard of care.
- The foundation of the existing RCC spillway has sufficient bearing capacity and will not settle excessively under the increased load of the additional RCC.
- Approximately 750,000 cubic yards CY of suitable embankment material is stockpiled outside of the reservoir area, on the west end between the reservoir and the hogback. The material consists of fat and lean clay which may have weathered from scraped claystone bedrock. The clay is strong enough to achieve the SEO stability criteria.
- The drainage basin and corresponding IDF will not increase. The updated Colorado SEO probable maximum precipitation criteria will not affect the design.
- The reservoir level will be lowered during construction, as required, to obtain borrow materials and construct potential saddle dams in the dry.
- A cutoff wall or downstream drain system to prevent or collect potential increased seepage from the additional water pressure head is not required.

- Private residences will not be purchased or inundated by the NHWL or the MWS for Alternatives 1, 2, and 3. Saddle dams will be used to protect existing residences from inundation. The saddle dam's crest El. will be set at the same El. as the enlarged embankment. The downstream toe of the saddle dam was set 20 ft from the property line.
- The purchase of 17 properties would be required for Alternative 4.
- The outlet works inlet is at El. 5,176.2, yielding 104 ac-ft of dead storage. This dead storage is sufficient to handle potential sediment deposits throughout the life of the structure given the small drainage basin.

2.3 Reference Documents

Boyle Engineering, 2005. *Dry Creek Dam Project Design Drawings*. Colorado.

Boyle Engineering, 2005. *Dry Creek Dam Project Final Design Report.* Colorado.

Boyle Engineering, 2005. *Dry Creek Dam Project Flood Hydrology Report.* Colorado.

Boyle Engineering, 2005. *Dry Creek Dam Project Geotechnical Report.* Colorado.

Colorado Department of Natural Resources, Dam Safety Branch, January, 2007. *Rules and Regulations for Dam Safety and Dam Construction.* Colorado.

3. Alternatives Development

Four conceptual design alternatives were developed for the Dry Creek Dam expansion feasibility study. The alternatives are relatively similar and were developed with the same assumptions, which were discussed in Section 2. Each alternative was developed to increase the reservoir storage capacity by raising the dam using downstream construction methods. The primary difference between the alternatives is the dam crest elevation. Alternative 1 has a crest El. of 5,230 ft, Alternative 2 5,235 ft, Alternative 3 5,240 ft, and Alternative 4 5,265 ft.

3.1 Alternative 1 – Dam Crest Elevation 5,230 Ft

Alternative 1 includes raising the dam such that the MWS matches the elevation of the existing access road near the northwest corner of the reservoir, which is estimated at El. 5,230 ft, a raise of 5 ft. The NHWL would increase from El. 5,220 ft to 5,225 ft and the storage capacity of the reservoir is expected to increase approximately 1,530 ac-ft for a total capacity of about 10,400 ac-ft at the NHWL. The crest length is expected to increase from about 4,900 ft to 5,150 ft. A plan and profile of the proposed dam modifications are shown on **Figures 3-1, 3-2, and 3-3**.

Raising the dam 5 ft using the existing slopes would extend the toe of the dam embankment approximately 27.5 ft downstream. The foundation in this area appears similar to the existing foundation and would require similar preparation to the existing downstream foundation. The top 3 ft of existing material would be removed and a 2 ft blanket drain of ASTM C33 sand placed prior to embankment fill. The extended blanket drain would be graded to drain into the existing toe drain.

The existing chimney drain extends vertically to El. 5,220 ft; Alternative 1 proposes to extend the chimney drain up to the NHWL of El. 5,225 ft. The existing chimney drain is vertical and 5 ft thick perpendicular to the direction of flow (vertical-parallel to the chimney drain). The chimney drain extension would match the upstream slope at 3H:1V and be reduced to 3 ft thick perpendicular to the direction of flow (parallel to the chimney drain extension) which yields a horizontal cross section length of 9 ft.

The remaining portions of the existing seepage collection system would not require modification beyond extending the toe drain manholes, cleanouts, and downstream monitoring wells 10 ft to reach the new ground surface.

A low hydraulic conductivity core, or zone of material, would be required upstream of the existing chimney drain. The remaining embankment fill could likely be a larger variety of materials.

The existing outlet works would be largely unaffected by the raise. A maximum height of about 5 ft of embankment fill would be placed above the existing valve vault and the toe of the fill would not reach the access hatch or manual operator. Alternatively, if it is desirable to avoid placing fill on the existing valve vault, a retaining wall could be constructed around the existing valve vault. Both options would allow the outlet works to be operated in the same manner as its current state.

The spillway stairs and stilling basin would be re-used as part of the raise. The spillway's labyrinth weir and the weir's sidewalls would need to be reinforced and raised 5 ft. Additional alteration of the spillway chute's sidewalls will be required to address the added load applied by the proposed embankment fill. A section showing the proposed embankment modifications laid overtop the existing spillway and outlet works facilities is included in **Figure 3-4**.

Alternative 1 would raise the MWS such that private residences would be partially inundated. Approximately 250 ft of saddle dam is required near the southwest corner of the reservoir to prevent private residences from inundation if the reservoir reaches the MWS. The saddle dam would be constructed similar to the main embankment, using the same fill with a 3H:1V downstream slope, a 2.5H:1V upstream slope, and a minimum crest width of 15 ft to meet SEO criteria (CO DWR, 2007) and provide an access road. The Alternative 1 saddle dam is designed to contain the reservoir when the water level reaches the MWS; the NHWL does not reach the downstream toe El. of the saddle dam. The saddle dam for Alternative 1 would not include a key trench and drainage system because the saddle dam does not continuously contain the reservoir under normal operating conditions (i.e. pool elevation at NHWL).

The upstream faces of the saddle dam and raised dam embankment would be lined with approximately 2 ft of riprap and a 9 inch thick riprap bedding layer, similar to the existing dam.

3.2 Alternative 2 – Dam Crest Elevation 5,235 Ft

Alternative 2 includes raising the dam such that the MWS is set at El. 5,235 ft, a raise of 10 ft. The NHWL would increase from El. 5,220 ft to 5,230 ft and the storage capacity of the reservoir is expected to increase approximately 3,150 ac-ft for a total capacity of about 12,000 ac-ft at the NHWL. The crest length is expected to increase from about 4,900 ft to 6,000 ft. A plan and profile of the proposed dam modifications are shown on **Figures 3-5, 3-6, and 3-7**.

Raising the dam 10 ft using the existing slopes would extend the toe of the dam embankment approximately 55 ft downstream. The foundation in this area appears similar to the existing foundation and would require similar preparation to the existing downstream foundation. The top 3 ft of existing material would be removed and a 3 ft blanket drain of filter sand placed prior to embankment fill. The blanket drain thickness would be increased from 2 ft at the toe of the existing embankment to 3 ft under the proposed embankment enlargement to account for the potential of additional water being conveyed by the drain further downstream. The existing toe drain and the associated facilities and structures would need to be removed and the excavations backfilled with embankment fill.

A new toe drain collection and conveyance system will need to be constructed at the new downstream toe location. The new toe drain would require new associated manholes, pumps, and clean-outs. The toe drain will be designed similar to the existing one, with a slotted collection pipe embedded in gravel at the downstream toe of the blanket drain.

Alternative 2 proposes to extend the existing chimney drain up to the NHWL of El. 5,230 ft. The existing chimney drain is vertical and 5 ft thick perpendicular to the direction of flow (vertical-parallel to the chimney drain). The chimney drain extension would match the upstream slope at 3H:1V and be reduced to 3 ft thick perpendicular to the direction of flow (parallel to the chimney drain extension) which yields a horizontal cross section length of 9 ft.

A low hydraulic conductivity core, or zone of material, would be required upstream of the existing chimney drain. The remaining embankment fill could likely be a larger variety of materials available on site.

The existing outlet works would need to be extended to the new downstream toe. A concrete culvert would extend from the proposed enlarged embankment toe to the existing outlet structure. The existing valve vault and outlet structure can be re-used, but will need to be reinforced to increase the capacity due to the maximum 20 ft of embankment fill that will be placed over top as part of Alternative 2. Access to the valve vault would be by the new concrete culvert.

Alternatively, the existing conduit could outlet into a larger pipe. The existing valve vault and outlet structure could be replaced with a new valve vault that is accessed via a vertical shaft. A new outlet structure would be required at the outlet of the extension pipe downstream of the proposed embankment toe. However, this alternative was not pursued as part of this feasibility study because it appeared conceptually to be more complex.

The 24-inch pipeline that is connected to the pump station at the valve vault would need to be embedded in reinforced concrete because it will become a pressurized conduit within the embankment.

Additional analyses would be required to verify that the existing outlet works are capable of lowering the top 5 ft of the reservoir in 5 days, in accordance with Colorado Rules and Regulations for Dam Safety and Dam Construction (CO DWR, 2007). If the existing outlet works are incapable of meeting this requirement, a variance could be submitted to the SEO stating that the existing outlet works were sized large enough to meet this requirement for the original dam; therefore they are large enough to allow for inspection.

The new NHWL would require a weir El. of 5,230 ft. The existing weir would need replaced; and the existing RCC would serve as a solid foundation. The new weir would be constructed in a similar position in relation to the proposed dam crest as the current weir is with the existing dam crest (i.e. the weir would be moved downstream of its current location to align with the proposed dam crest). The stilling basin and the bottom of the existing RCC spillway stairs could be re-used. The top of the proposed spillway stairs would need to have a steeper slope such that the proposed stairway could intersect the existing stairway as far upstream as possible to limit the amount of additional RCC. The spillway walls would need to be raised and reinforced to handle the additional load applied by the increased embankment height and higher water height splashing in the stairway. A section showing the proposed embankment modifications laid overtop the existing spillway and outlet works facilities is included in **Figure 3-4.**

Alternatively, the embankment could be raised in an upstream fashion at the spillway location. This would allow for the complete re-use of the existing stairway and reduce the amount of additional RCC. The weir would be moved upstream of its current location (as opposed to downstream) and the stairway would be extended up at the same slope (2.5H:1V). However, this alternative was not pursued as part of this feasibility study because it would require the reservoir to be drained down to the dead pool, require the removal and replacement of slope protection, and reduce storage.

Alternative 2 would raise the NHWL and MWS such that private residences would be partially inundated. Approximately 2,600 ft of saddle dam is required near the southwest and northwest corners of the reservoir to prevent private residences from inundation. The saddle dams would be constructed similar to the main embankment, using the same fill with a 3H:1V downstream slope, a 2.5H:1V upstream slope, and a minimum crest width of 15 ft to meet SEO criteria (CO DWR, 2007) and provide an access road. A portion of the saddle dams will require a key trench and drainage system similar to the existing dam depending on the water level that the specific section of saddle dam is designed to contain. If the saddle dam is designed to contain the NHWL, then a key trench and drain system would be included; if the saddle dam is designed to contain only the MWS, then no key trench or drainage system would be required.

The key trench and drainage system would be similar to the existing dam's layout. The drain system would be required for approximately 1,625 ft of the saddle dam alignment and the key trench for approximately 250 ft. Some portions of the saddle dam that include a chimney drain do not include a key trench based on the downstream topography. The key trench would be excavated approximately 10 ft into the existing ground, or a minimum of 3 ft into fine grained bedrock. The key trench would be 10 ft wide at the base with 1H:1V slopes.

The drainage system would consist of a chimney drain sloped to match the dam's downstream slope and would connect to a toe drain. The toe drain would be a two-staged filter drain with a slotted drain pipe embedded in gravel that is surrounded by filter sand. Manholes with sump pumps will be required at low points in the collection pipe. The saddle dam sections are shown on **Figure 3-7**.

Foundation preparation for the saddle dams would be similar to the main embankment. 5 ft of material would be stripped upstream of the key trench and 3 ft downstream of the key trench.

The proposed saddle dams may prevent surface water from the drainage upstream of the saddle dams from discharging into the reservoir and may cause ponding at the downstream toe of the saddle dams. A valve through the saddle dams, or diversion channel at the downstream toe of each saddle dam, may be required to prevent ponding and allow surface water to discharge into the reservoir.

The upstream faces of the saddle dams and raised dam embankment would be lined with approximately 2 ft of riprap and a 9 inch thick riprap bedding layer, similar to the existing dam.

3.3 Alternative 3 – Dam Crest Elevation 5,240 Ft

Alternative 3 includes raising the dam such that the MWS is set at El. 5,240 ft, a raise of 15 ft. The NHWL would increase from El. 5,220 to 5,235 ft and the storage capacity of the reservoir is expected to increase approximately 4,850 ac-ft for a total capacity of about 13,700 ac-ft at the NHWL. The crest length is expected increase from about 4,900 to 6,400 ft. A plan and profile of the proposed dam modifications are shown on **Figures 3-8, 3-9, and 3-10**.

Raising the dam 15 ft using the existing slopes would extend the toe of the dam embankment approximately 82.5 ft downstream. The foundation in this area appears similar to the existing foundation and would require similar preparation to the existing downstream foundation. The top 3 ft of existing material would be removed and a 3 ft blanket drain of filter sand placed prior to embankment fill. The blanket drain thickness would be increased from 2 ft at the toe of the existing embankment to 3 ft under the proposed embankment enlargement to account for the potential of additional water being conveyed by the drain further downstream. The existing toe drain and the associated facilities and structures would need to be removed and the excavations backfilled with embankment fill.

A new toe drain collection and conveyance system will need to be constructed at the new downstream toe location. The new toe drain would require new associated manholes, pumps, and clean-outs. The toe drain will be designed similar to the existing one, with a slotted collection pipe embedded in gravel at the downstream toe of the blanket drain.

Alternative 3 proposes to extend the existing chimney drain up to the NHWL of El. 5,235. The existing chimney drain is vertical and 5 ft thick perpendicular to the direction of flow (vertical-parallel to the chimney drain). The chimney drain extension would match the upstream slope at 3H:1V and be reduced to 3 ft thick perpendicular to the direction of flow (parallel to the chimney drain extension) which yields a horizontal cross section length of 9 ft.

A low hydraulic conductivity core, or zone of material, would be required upstream of the existing chimney drain. The remaining embankment fill could likely be a larger variety of materials available on site.

The existing outlet works would need to be extended to the new downstream toe. A concrete culvert would extend from the proposed enlarged embankment toe to the existing outlet structure. The existing valve vault and outlet structure can be re-used, but will need to be reinforced to increase the capacity due to the maximum 30 ft of embankment fill that will be placed over top as part of Alternative 3. Access to the valve vault would be by the new concrete culvert.

Alternatively, the existing conduit could outlet into a larger pipe. The existing valve vault and outlet structure could be replaced with a new valve vault that is accessed via a vertical shaft. A new outlet structure would be required at the outlet of the extension pipe downstream of the proposed embankment toe. However, this alternative was not pursued as part of this feasibility study because it appeared conceptually to be more complex.

The 24-inch pipeline that is connected to the pump station at the valve vault would need to be embedded in reinforced concrete because it will become a pressurized conduit within the embankment.

Additional analyses would be required to verify that the existing outlet works are capable of lowering the top 5 ft of the reservoir in 5 days, in accordance with Colorado Rules and Regulations for Dam Safety and Dam Construction (CO DWR, 2007). If the existing outlet works are incapable of meeting this requirement, a variance could be submitted to the SEO stating that the existing outlet works were sized large enough to meet this requirement for the original dam; therefore they are large enough to allow for inspection.

The new NHWL would require a weir El. of 5,235 ft. The existing weir would need replaced; and the existing RCC would serve as a solid foundation. The new weir would be constructed in a similar position in relation to the proposed dam crest as the current weir is with the existing dam crest (i.e. the weir would be moved downstream of its current location to align with the dam crest). The stilling basin and the bottom of the existing RCC spillway stairs could be re-used. The top of the proposed spillway stairs would need to have a steeper slope such that the proposed stairway could intersect the existing stairway as far upstream as possible to limit the amount of additional RCC. The spillway walls would need to be raised and reinforced to handle the additional load applied by the increased embankment height and higher water height splashing in the stairway. A section showing the proposed embankment modifications laid overtop the existing spillway and outlet works facilities is included in **Figure 3-4**.

Alternatively, the embankment could be raised in an upstream fashion at the spillway location. This would allow for the complete re-use of the existing stairway and reduce the amount of additional RCC. The weir would be moved upstream of its current location (as opposed to downstream) and the stairway would be extended up at the same slope (2.5H:1V). However, this alternative was not pursued as part of this feasibility study because it would require the reservoir to be drained down to the dead pool, require the removal and replacement of slope protection, and reduce storage.

Alternative 3 would raise the NHWL and MWS such that private residences would be partially inundated. Approximately 2,850 ft of saddle dam is required near the southwest and northwest corners of the reservoir to prevent private residences from inundation. The saddle dams would be constructed similar to the main embankment, using the same fill with a 3H:1V downstream slope, a 2.5H:1V upstream slope, and a minimum crest width of 15 ft to meet SEO criteria (CO DWR, 2007) and provide an access road. A portion of the saddle dams will require a key trench and drainage system similar to the existing dam depending on the water level that the specific section of saddle dam is designed to contain. If the saddle dam is designed to contain the NHWL, then a key trench and drain system would be included; if the saddle dam is designed to contain only the MWS, then no key trench or drainage system would be required.

The key trench and drainage system would be similar to the existing dam's layout and would be required for approximately 2,200 ft of the saddle dam alignment. The key trench would be excavated approximately 10 ft into the existing ground, or a minimum of 3 ft into fine grained bedrock. The key trench would be 10 ft wide at the base with 1H:1V slopes.

The drainage system would consist of a chimney drain sloped to match the dam's downstream slope and would connect to a toe drain. The toe drain would be a two-staged filter drain with a slotted drain pipe embedded in gravel that is surrounded by filter sand. Manholes with sump pumps will be required at low points in the collection pipe. The saddle dam sections are shown on **Figure 3-10**.

Foundation preparation for the saddle dams would be similar to the main embankment. 5 ft of material would be stripped upstream of the key trench and 3 ft downstream of the key trench.

The proposed saddle dams may prevent surface water from the drainage upstream of the saddle dams from discharging into the reservoir and may cause ponding at the downstream toe of the saddle dams. A valve through the saddle dams, or diversion channel at the downstream toe of each saddle dam, may be required to prevent ponding and allow surface water to discharge into the reservoir.

The upstream faces of the saddle dams and raise embankment would be lined with approximately 2 ft of riprap and a 9 inch thick riprap bedding layer, similar to the existing dam.

3.4 Alternative 4 – Dam Crest Elevation 5,265 Ft

Alternative 4 includes raising the dam such that the MWS is set at El. 5,265 ft, a raise of 40 ft. The NHWL would increase from El. 5,220 to 5,260 ft and the storage capacity of the reservoir is expected to increase approximately 14,091 ac-ft for a total capacity of about 22,953 ac-ft at the NHWL. The crest length is expected increase from about 4,900 to 10,150 ft. A plan and profile of the proposed dam modifications are shown on **Figures 3-11, 3-12, and 3-13**.

Raising the dam 40 ft using the existing slopes would extend the toe of the dam embankment approximately 225 ft downstream. The foundation in this area appears similar to the existing foundation, however initial steady-state drained stability analyses show that the existing downstream alluvium would need to be cut down to bedrock to meet SEO stability criteria for Alternative 4. The cut will extend from the existing downstream toe to approximately 20 ft beyond the proposed downstream toe. The depth to bedrock was assumed to be 10 ft based on the original design drawings.

Embankment fill will be placed from the bottom of the cut up 7 ft to a 3 ft blanket drain of filter sand. The blanket drain thickness would be increased from 2 ft at the toe of the existing embankment to 3 ft under the proposed embankment enlargement to account for the potential of additional water being conveyed by the drain further downstream. The existing toe drain and the associated facilities and structures would need to be removed and the excavations backfilled with embankment fill. The existing blanket drain will be connected to the proposed drain.

A new toe drain collection and conveyance system will need to be constructed at the new downstream toe location. The new toe drain would require new associated manholes, pumps, and clean-outs. The toe drain will be designed similar to the existing one, with a slotted collection pipe embedded in gravel at the downstream toe of the blanket drain.

Alternative 4 proposes to leave the existing chimney drain in place and construct a new vertical chimney drain just downstream of the embankment centerline to the NHWL of El. 5,265. The proposed chimney drain and blanket drain layout is similar to the existing layout.

A low hydraulic conductivity core, or zone of material, would be required upstream of the existing chimney drain. The remaining embankment fill could likely be a larger variety of materials available on site.

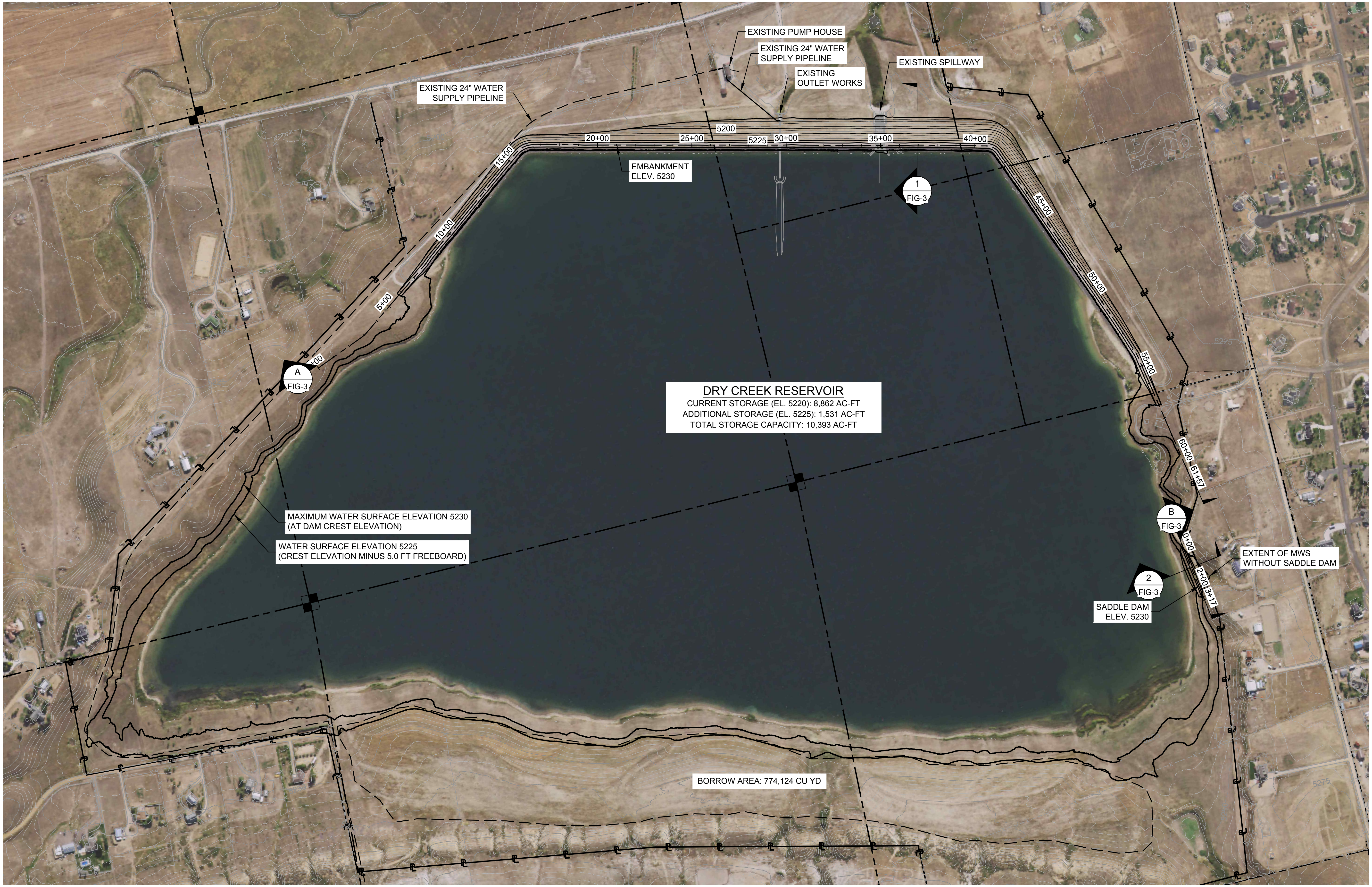
The existing outlet works would need to be extended to the new downstream toe. Unlike Alternatives 1, 2, and 3, Alternative 4 will require the relocation of the valve vault house and the outlet structure. Therefore, the outlet works will be extended via a concrete encased steel pipe to the new valve vault house and outlet structure near the proposed downstream toe. The existing 24 inch pipeline from the vault house to the pump station will require proper abandonment via grout or concrete.

Additional analyses would be required to verify that the existing outlet works are capable of lowering the top 5 ft of the reservoir in 5 days, in accordance with Colorado Rules and Regulations for Dam Safety and Dam Construction (CO DWR, 2007). If the existing outlet works are incapable of meeting this requirement, a variance could be submitted to the SEO stating that the existing outlet works were sized large enough to meet this requirement for the original dam; therefore they are large enough to allow for inspection.

The new NHWL would require a weir El. of 5,260 ft. The Alternative 4 raise is large enough that the existing spillway and stilling basin would not be re-used, but rather serve as a foundation for the proposed RCC spillway. The new spillway would have a design slope of 1:1 to reduce the quantity of RCC. Additional RCC would be required for a new stilling basin, which will be founded on bedrock similar to the existing structures. The bedrock that serves as the foundation of the existing RCC will require further evaluation for strength and settlement.

Alternatively, a cast-in-place reinforced concrete spillway could be founded in the left abutment. The left abutment is preferable because of the natural Dry Creek drainage and absence of county roads. Improvement to the existing channel may be required as well as the purchasing of additional property. The RCC spillway was evaluated for the cost estimate for comparison purposes.

Alternative 4 would raise the NHWL and MWS such that 17 private residences would be inundated. Alternative 4 does not include saddle dams to protect these properties; however the estimated cost to purchase these properties has been included in the cost estimate. The cost



PLAN

0 300 600

1" = 300'

NOTE:

1. ALL EXISTING CONDITIONS AND INTERNAL GEOMETRY SHOWN ARE APPROXIMATE AND ESTIMATED FROM THE 2005 DESIGN DRAWINGS BY BOYLE ENGINEERING CORPORATION. LOCATIONS OF FEATURES SHOULD BE CONFIRMED PRIOR TO CONSTRUCTION.

Issue Status: FINAL

AECOM

Figure: 3-1

EMBANKMENT CREST ELEVATION 5230
PLAN

DRY CREEK RESERVOIR
EXPANSION FEASIBILITY STUDY
Little Thompson Water District
Project No.: 60595240

Last saved by: BRYCE.TENNANT(2019-02-20) Last Plotted: 2019-02-20
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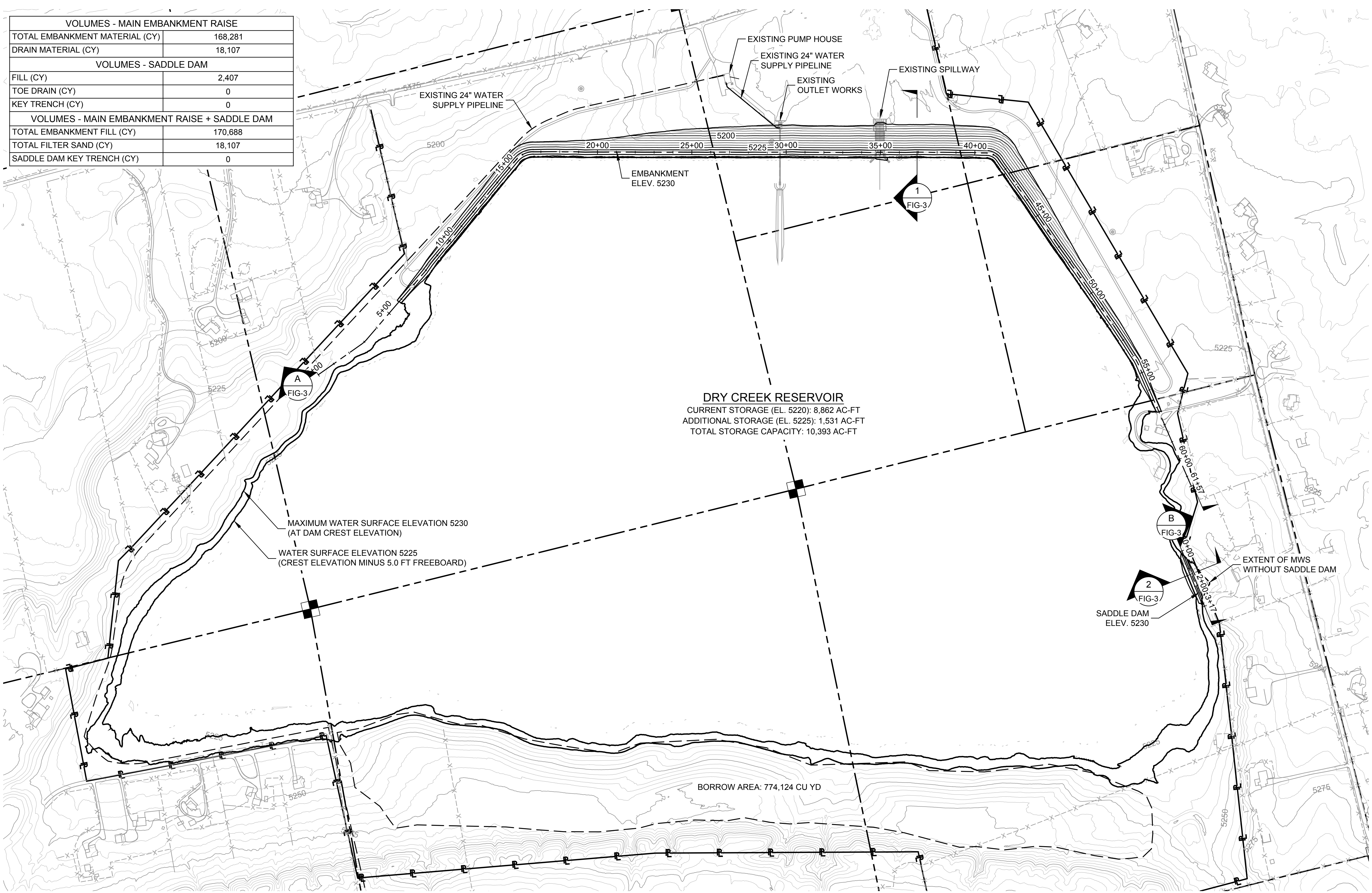
Project Management Initials: Designer: Checked: Approved: ANSI D 22" x 34"

VOLUMES - MAIN EMBANKMENT RAISE	
TOTAL EMBANKMENT MATERIAL (CY)	168,281
DRAIN MATERIAL (CY)	18,107
VOLUMES - SADDLE DAM	
FILL (CY)	2,407
TOE DRAIN (CY)	0
KEY TRENCH (CY)	0
VOLUMES - MAIN EMBANKMENT RAISE + SADDLE DAM	
TOTAL EMBANKMENT FILL (CY)	170,688
TOTAL FILTER SAND (CY)	18,107
SADDLE DAM KEY TRENCH (CY)	0



PLAN

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1" = 300'

NOTE:

1. ALL EXISTING CONDITIONS AND INTERNAL GEOMETRY SHOWN ARE APPROXIMATE AND ESTIMATED FROM THE 2005 DESIGN DRAWINGS BY BOYLE ENGINEERING CORPORATION. LOCATIONS OF FEATURES SHOULD BE CONFIRMED PRIOR TO CONSTRUCTION.

Issue Status: FINAL

AECOM

Figure: 3-2

EMBANKMENT CREST ELEVATION 5230
PLAN

DRY CREEK RESERVOIR
EXPANSION FEASIBILITY STUDY
Little Thompson Water District
Project No.: 60595240

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Last saved by: JAMES.KIRCH(2019-03-11) Last Plotted: 2019-03-11
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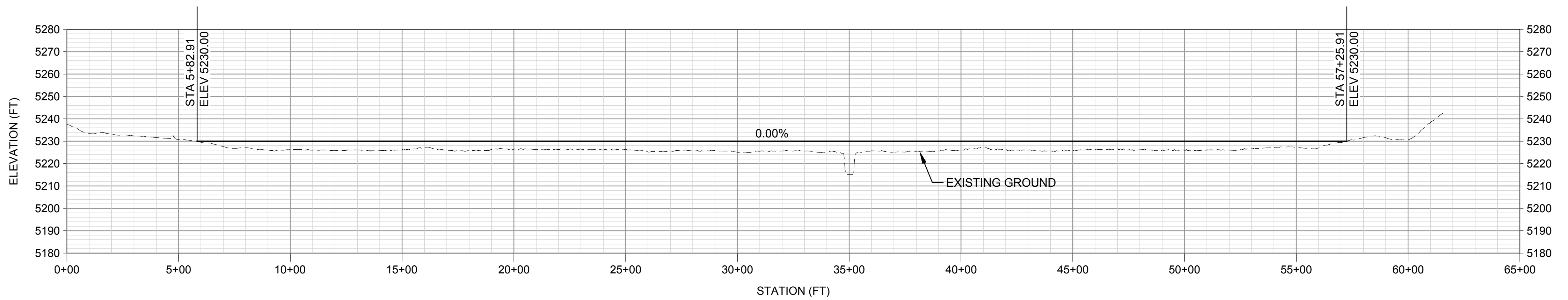
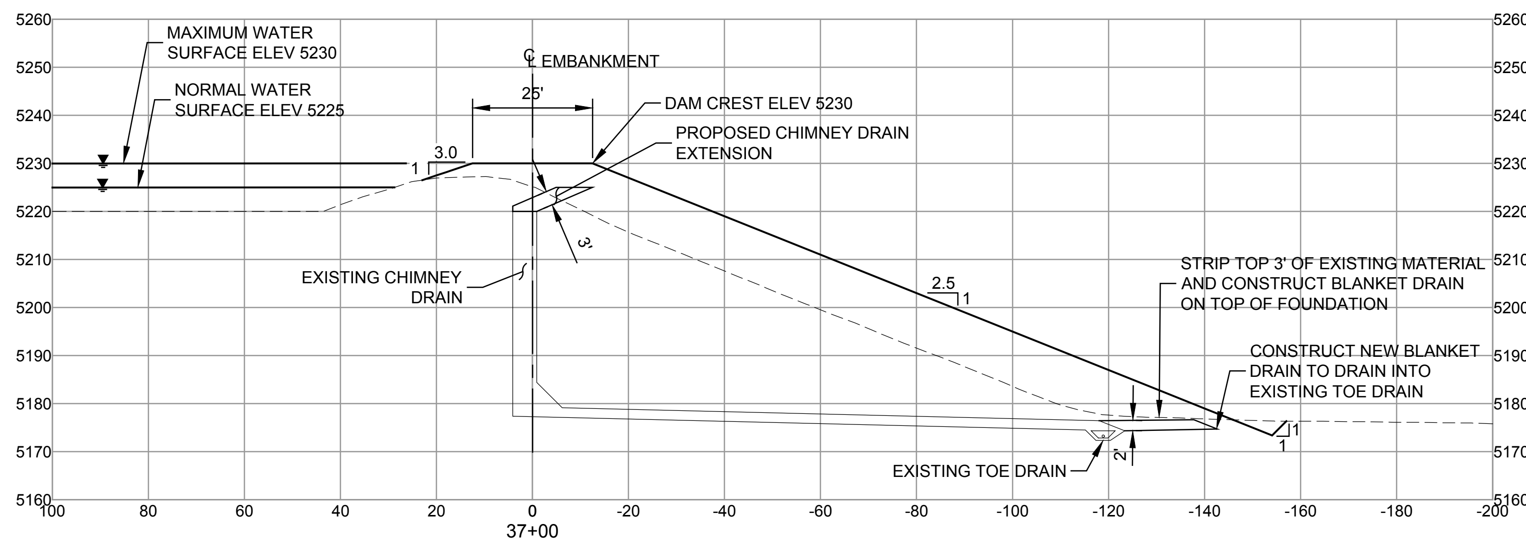
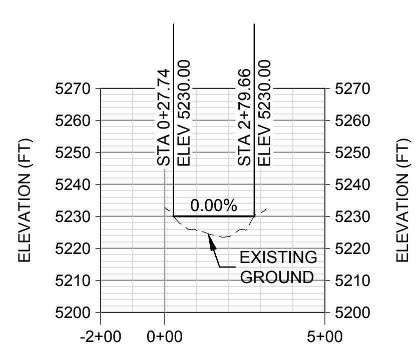


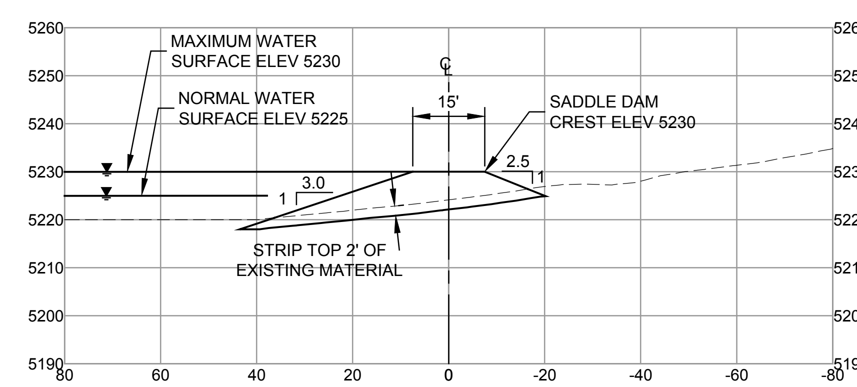
DAM CENTERLINE PROFILE (A / FIG-2)
SCALE: H: 1"=300' V: 1"=30'



SECTION (1 / FIG-2)
SCALE: 1" = 20'



SADDLE DAM CENTERLINE PROFILE (B / FIG-2)
SCALE: H: 1"=300' V: 1"=30'



SECTION (2 / FIG-2)
SCALE: 1" = 20'

NOTE:
1. ALL EXISTING CONDITIONS AND INTERNAL GEOMETRY SHOWN ARE APPROXIMATE AND ESTIMATED FROM THE 2005 DESIGN DRAWINGS BY BOYLE ENGINEERING CORPORATION. LOCATIONS OF FEATURES SHOULD BE CONFIRMED PRIOR TO CONSTRUCTION.

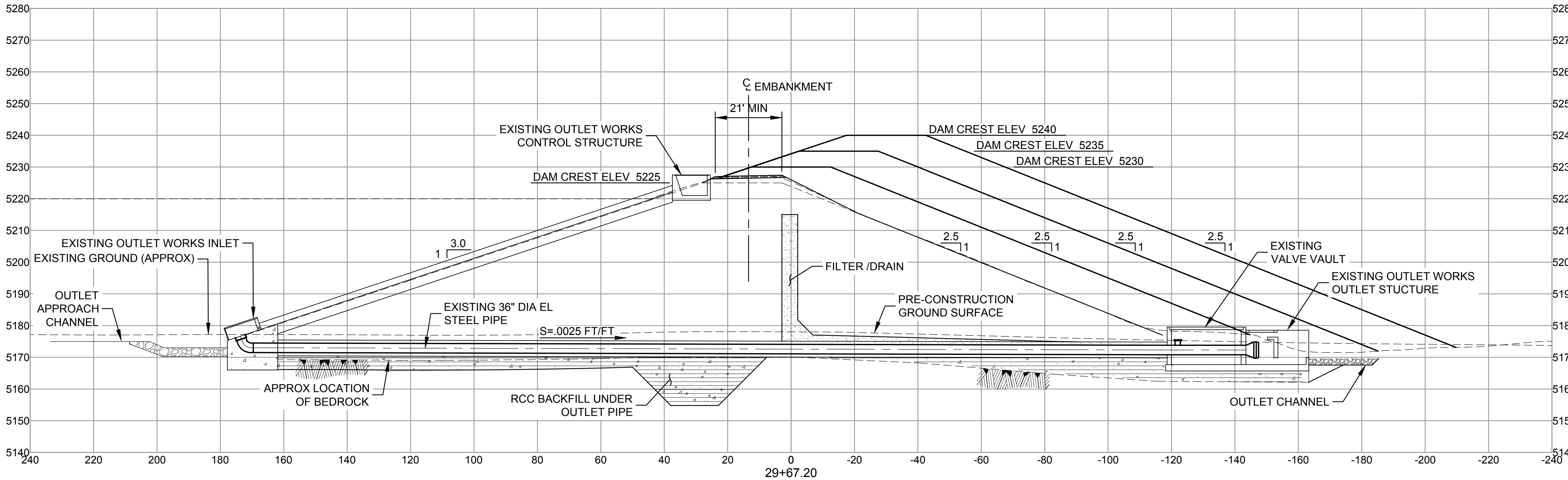
Issue Status: FINAL

AECOM

Figure: 3-3

EMBANKMENT CREST ELEVATION 5230
PROFILE AND SECTION

DRY CREEK RESERVOIR
EXPANSION FEASIBILITY STUDY
Little Thompson Water District
Project No.: 60595240



OUTLET WORKS SECTION (9 / -)

SCALE: 1" = 20'

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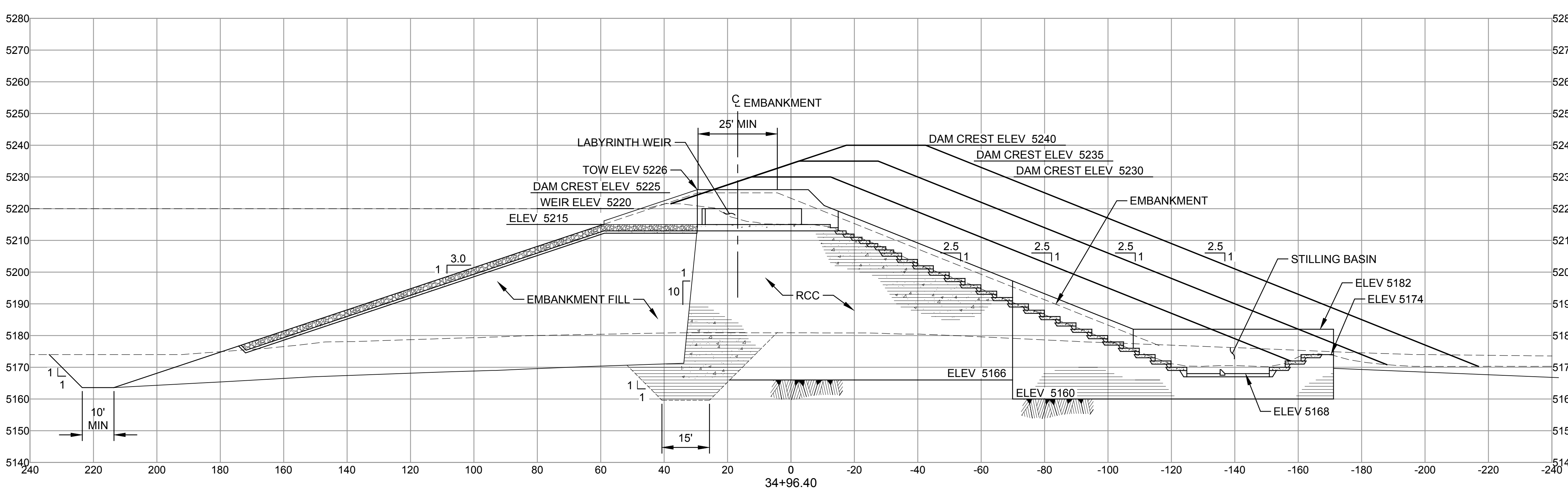

SPILLWAY (10 / -)

SCALE: 1" = 20'

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NOTE:

1. ALL EXISTING CONDITIONS AND INTERNAL GEOMETRY SHOWN ARE APPROXIMATE AND ESTIMATED FROM THE 2005 DESIGN DRAWINGS BY BOYLE ENGINEERING CORPORATION. LOCATIONS OF FEATURES SHOULD BE CONFIRMED PRIOR TO CONSTRUCTION.

Issue Status: FINAL

Figure: 3-4

OUTLET WORKS AND SPILLWAY SECTION

DRY CREEK RESERVOIR EXPANSION FEASIBILITY STUDY

Little Thompson Water District

Project No.: 60595240

ANSI D 22" x 34"
Approved:
Checked:
Designer:
Project Management Initials:
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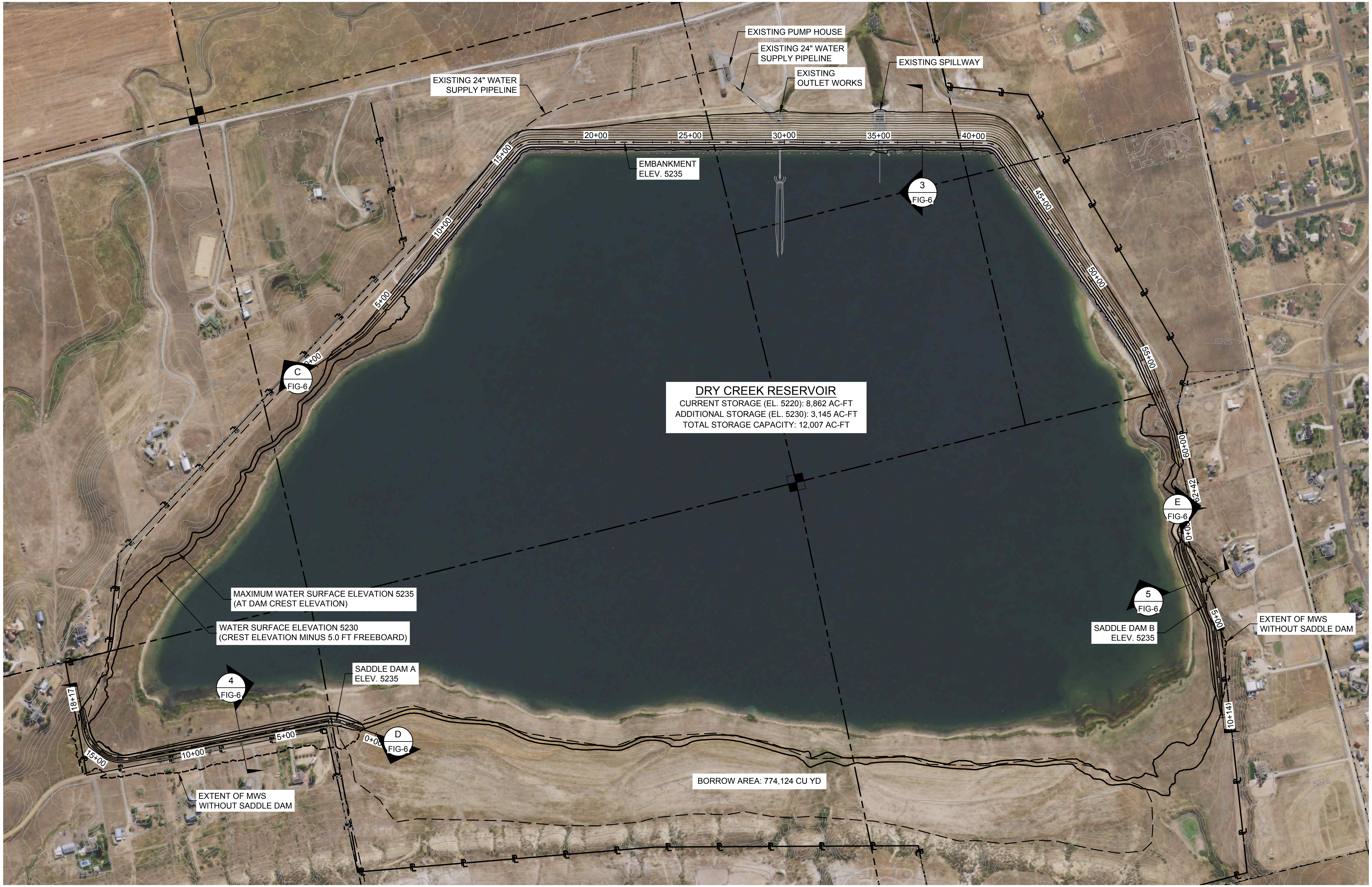


PLAN

0 300 600

1" = 300'

NOTE:

1. ALL EXISTING CONDITIONS AND INTERNAL GEOMETRY SHOWN ARE APPROXIMATE AND ESTIMATED FROM THE 2005 DESIGN DRAWINGS BY BOYLE ENGINEERING CORPORATION. LOCATIONS OF FEATURES SHOULD BE CONFIRMED PRIOR TO CONSTRUCTION.

Issue Status: FINAL

AECOM

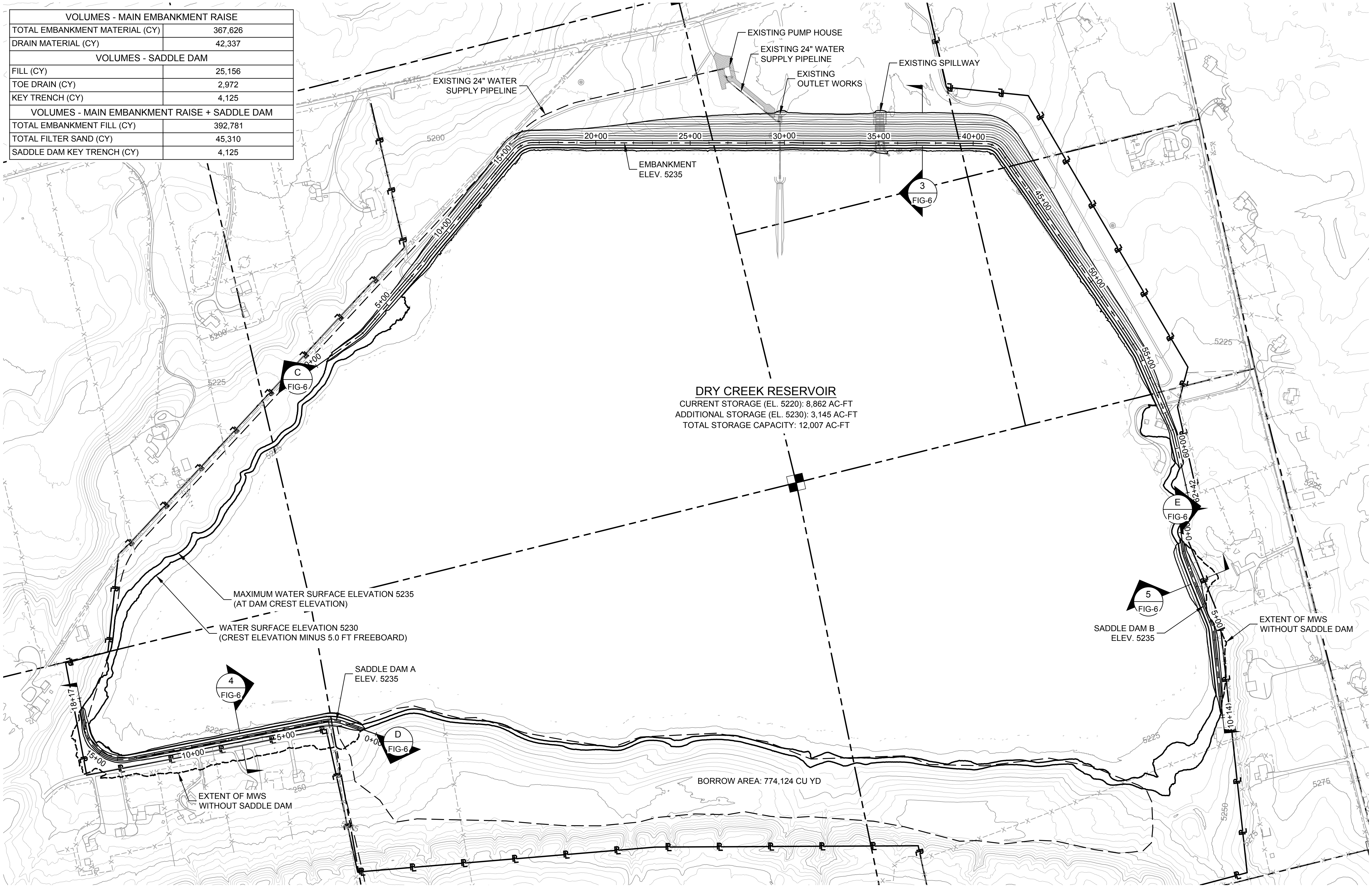
Figure: 3-5

EMBANKMENT CREST ELEVATION 5235
PLAN

DRY CREEK RESERVOIR
EXPANSION FEASIBILITY STUDY
Little Thompson Water District
Project No.: 60595240

ANSI D 22" x 34"
Approved:
Checked:
Designer:
Project Management Initials:
Last saved by: BRYCE.TENNANT(2019-02-20) Last Plotted: 2019-02-20
Filename: M:\DCS\PROJECTS\WTR\60595240_DRYCRKRFS\900_CAD_GIS\910_CAD\25-SKETCHES\EMBANK ALT 2.DWG

VOLUMES - MAIN EMBANKMENT RAISE	
TOTAL EMBANKMENT MATERIAL (CY)	367,626
DRAIN MATERIAL (CY)	42,337
VOLUMES - SADDLE DAM	
FILL (CY)	25,156
TOE DRAIN (CY)	2,972
KEY TRENCH (CY)	4,125
VOLUMES - MAIN EMBANKMENT RAISE + SADDLE DAM	
TOTAL EMBANKMENT FILL (CY)	392,781
TOTAL FILTER SAND (CY)	45,310
SADDLE DAM KEY TRENCH (CY)	4,125



PLAN

0 300 600
1" = 300'

NOTE:

1. ALL EXISTING CONDITIONS AND INTERNAL GEOMETRY SHOWN ARE APPROXIMATE AND ESTIMATED FROM THE 2005 DESIGN DRAWINGS BY BOYLE ENGINEERING CORPORATION. LOCATIONS OF FEATURES SHOULD BE CONFIRMED PRIOR TO CONSTRUCTION.

Issue Status: FINAL

AECOM

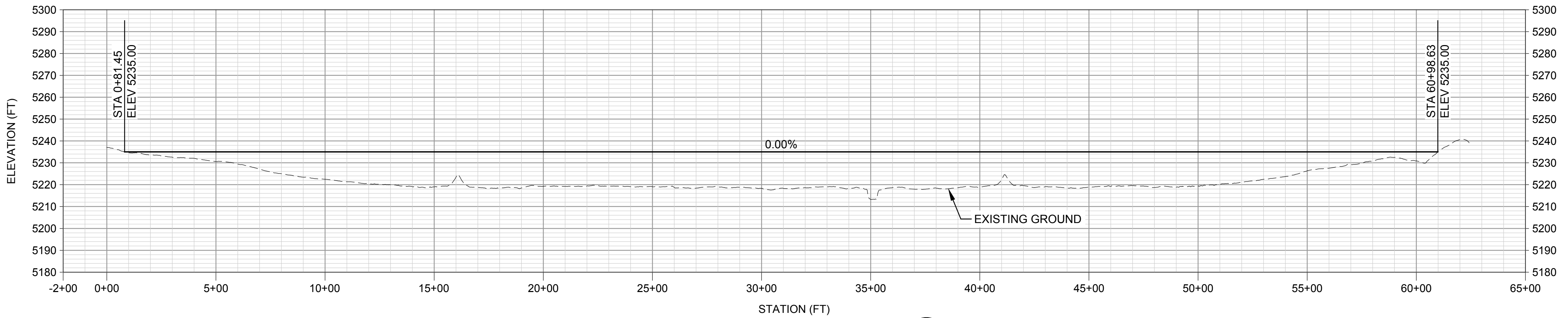
Figure: 3-6

EMBANKMENT CREST ELEVATION 5235
PLAN

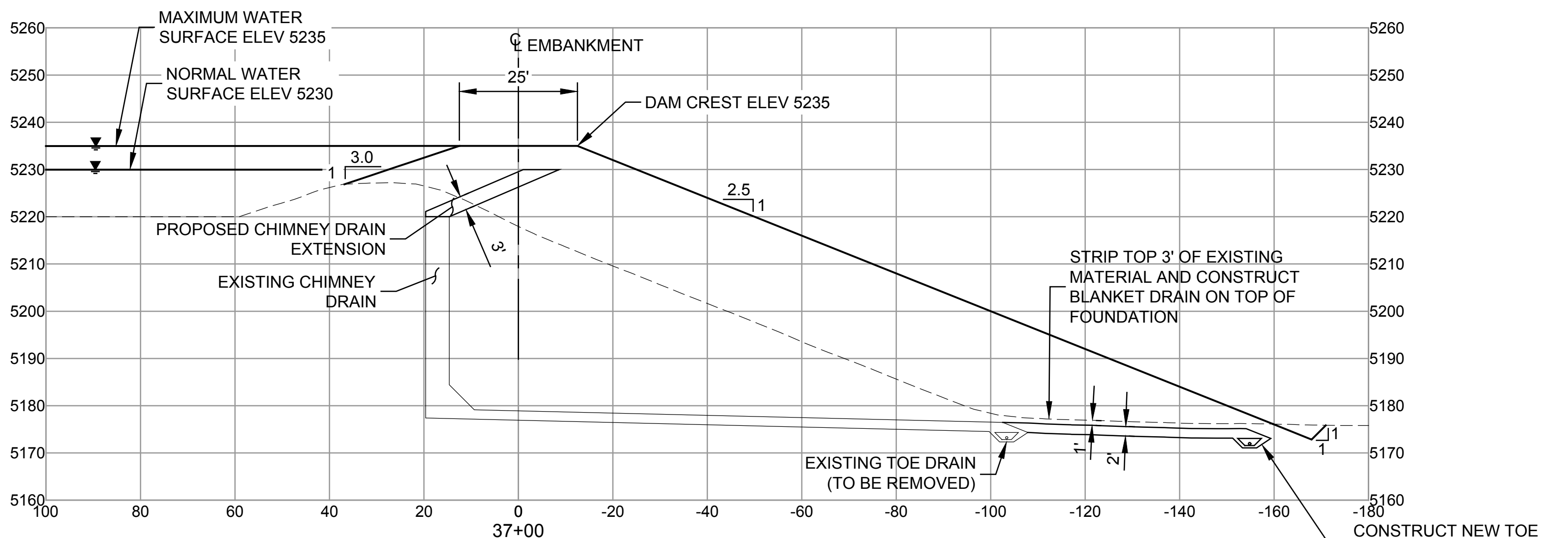
DRY CREEK RESERVOIR
EXPANSION FEASIBILITY STUDY
Little Thompson Water District
Project No.: 60595240

ANSI D 22" x 34"
Approved: ____ Checked: ____ Designer: ____ Project Management Initials:

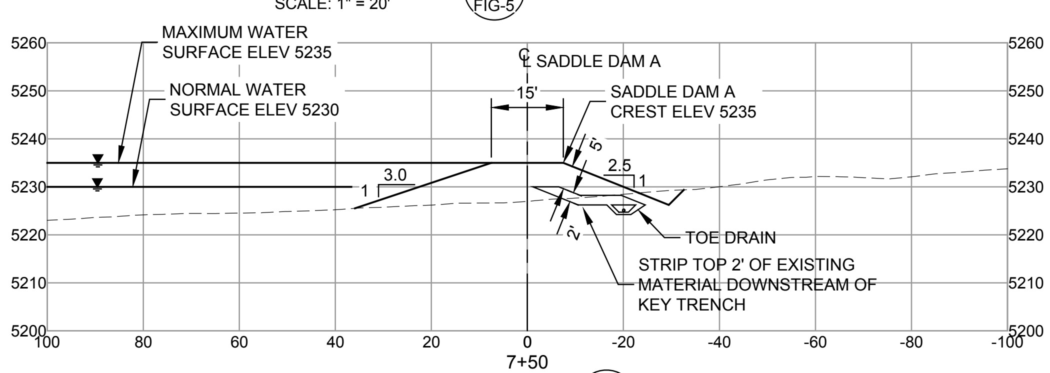
Last saved by: BRYCE.TENNANT(2019-02-20) Last Plotted: 2019-02-20
Filename: M:\DCS\PROJECTS\WTR\60595240_DRYCRKRFS\900_CAD_GIS\910_CAD\25-SKETCHES\EMBANK ALT 2.DWG



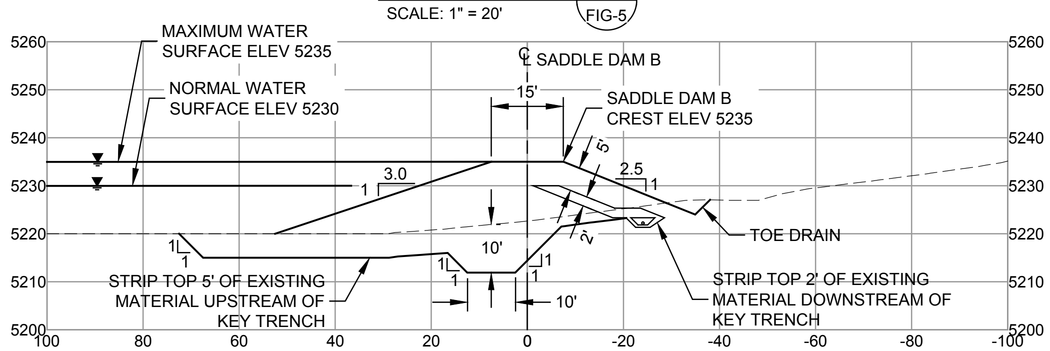
DAM CENTERLINE PROFILE (C / FIG-5)
SCALE: H: 1"=300' V: 1"=30'



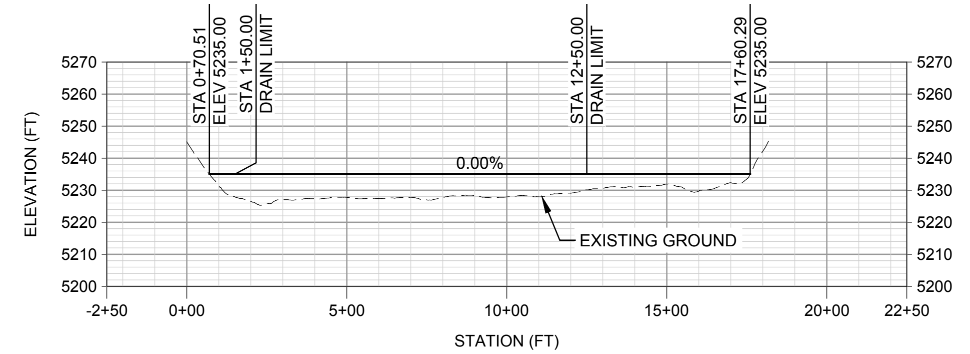
SECTION (3 / FIG-5)
SCALE: 1" = 20'



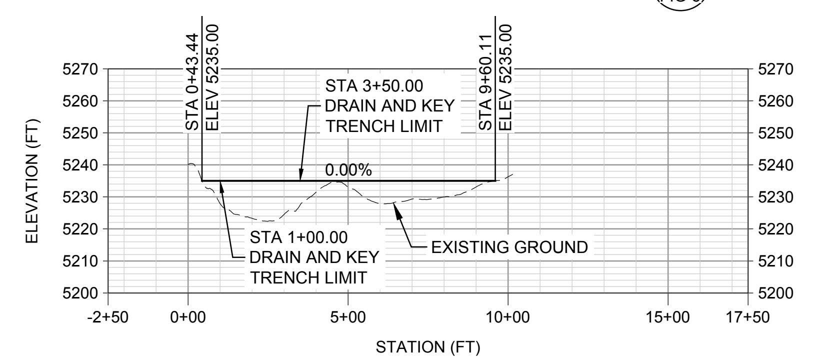
SECTION (4 / FIG-5)
SCALE: 1" = 20'



SECTION (5 / FIG-5)
SCALE: 1" = 20'



SADDLE DAM A CENTERLINE PROFILE (D / FIG-5)
SCALE: H: 1"=300' V: 1"=30'



SADDLE DAM B CENTERLINE PROFILE (E / FIG-5)
SCALE: H: 1"=300' V: 1"=30'

NOTE:
1. ALL EXISTING CONDITIONS AND INTERNAL GEOMETRY SHOWN ARE APPROXIMATE AND ESTIMATED FROM THE 2005 DESIGN DRAWINGS BY BOYLE ENGINEERING CORPORATION. LOCATIONS OF FEATURES SHOULD BE CONFIRMED PRIOR TO CONSTRUCTION.

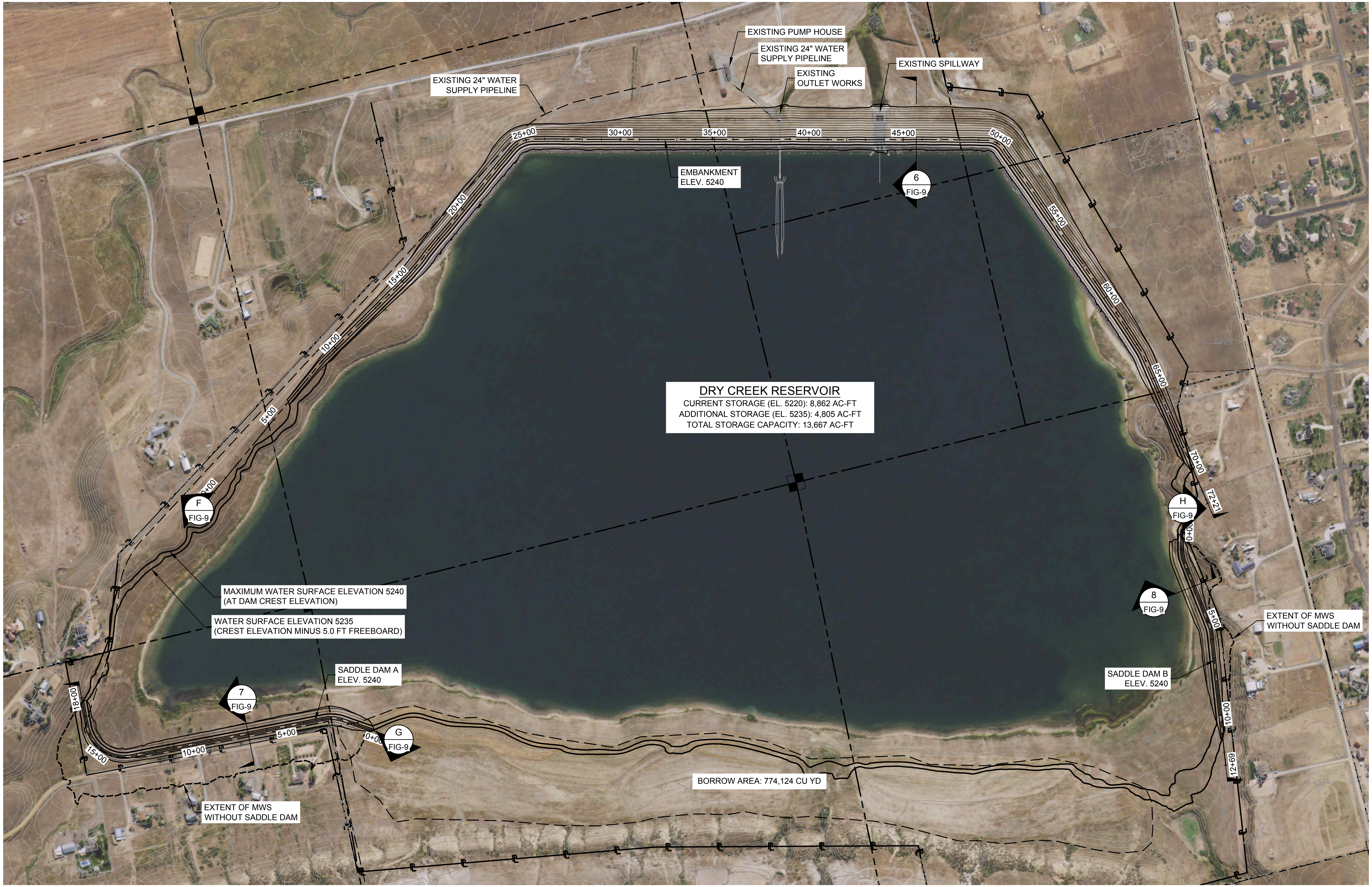
Issue Status: FINAL

AECOM

Figure: 3-7

EMBANKMENT CREST ELEVATION 5235
PROFILE AND SECTION

DRY CREEK RESERVOIR
EXPANSION FEASIBILITY STUDY
Little Thompson Water District
Project No.: 60595240



PLAN

0 300 600
1" = 300'

NOTE:
1. ALL EXISTING CONDITIONS AND INTERNAL GEOMETRY SHOWN ARE APPROXIMATE AND ESTIMATED FROM THE 2005 DESIGN DRAWINGS BY BOYLE ENGINEERING CORPORATION. LOCATIONS OF FEATURES SHOULD BE CONFIRMED PRIOR TO CONSTRUCTION.

Issue Status: FINAL

AECOM

Figure: 3-8

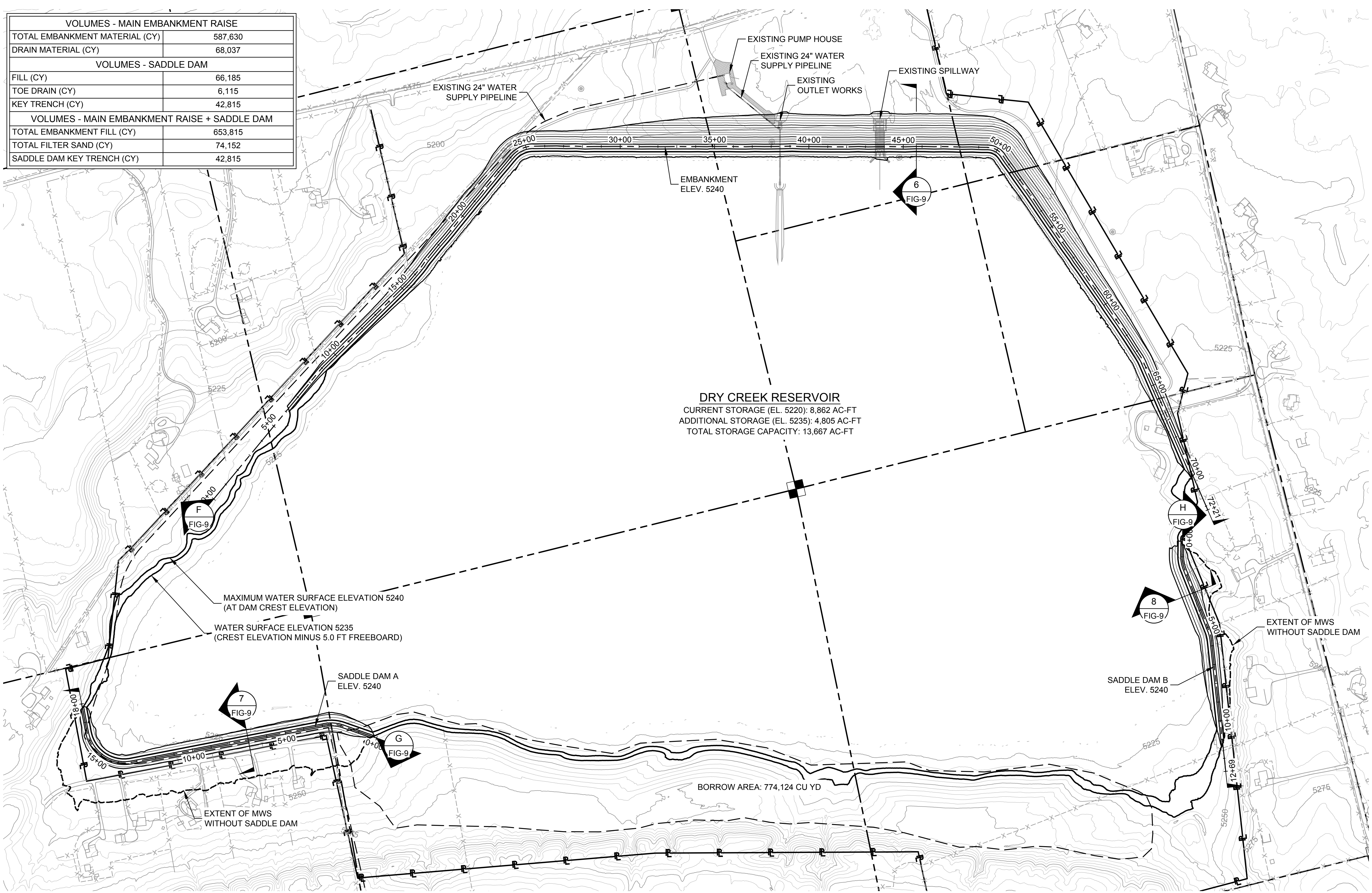
EMBANKMENT CREST ELEVATION 5240
PLAN

DRY CREEK RESERVOIR
EXPANSION FEASIBILITY STUDY
Little Thompson Water District
Project No.: 60595240

ANSI D 22" x 34" Approved: Checked: Designer: Project Management Initials:

Last saved by: BRYCE.TENNANT(2019-02-20) Last Plotted: 2019-02-20
Filename: M:\DCS\PROJECTS\WTR\60595240_DRYCRKRFS\900_CAD_GIS\910_CAD\25-SKETCHES\EMBANK ALT 3.DWG

VOLUMES - MAIN EMBANKMENT RAISE	
TOTAL EMBANKMENT MATERIAL (CY)	587,630
DRAIN MATERIAL (CY)	68,037
VOLUMES - SADDLE DAM	
FILL (CY)	66,185
TOE DRAIN (CY)	6,115
KEY TRENCH (CY)	42,815
VOLUMES - MAIN EMBANKMENT RAISE + SADDLE DAM	
TOTAL EMBANKMENT FILL (CY)	653,815
TOTAL FILTER SAND (CY)	74,152
SADDLE DAM KEY TRENCH (CY)	42,815



PLAN

0 300 600
1" = 300'

NOTE:
1. ALL EXISTING CONDITIONS AND INTERNAL GEOMETRY SHOWN ARE APPROXIMATE AND ESTIMATED FROM THE 2005 DESIGN DRAWINGS BY BOYLE ENGINEERING CORPORATION. LOCATIONS OF FEATURES SHOULD BE CONFIRMED PRIOR TO CONSTRUCTION.

Issue Status: FINAL

AECOM

Figure: 3-9

EMBANKMENT CREST ELEVATION 5240
PLAN

DRY CREEK RESERVOIR
EXPANSION FEASIBILITY STUDY
Little Thompson Water District
Project No.: 60595240

Project Management Initials: Designer: Checked: Approved: ANSI D 22" x 34"

Last saved by: BRYCE.TENNANT(2019-02-20) Last Plotted: 2019-02-20
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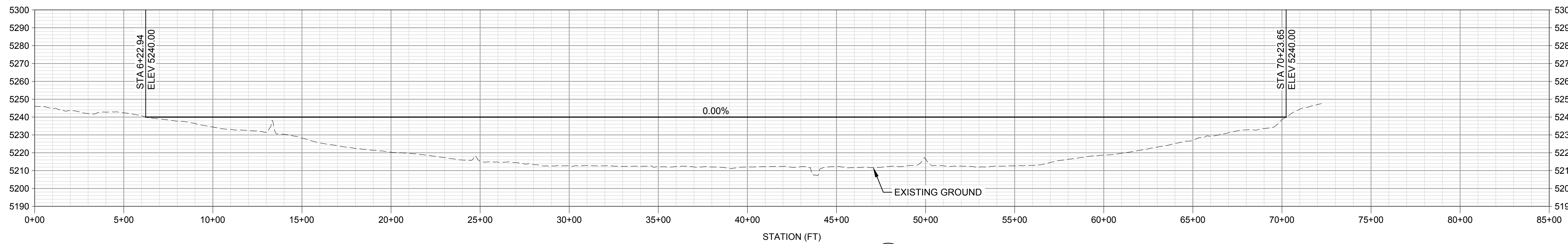
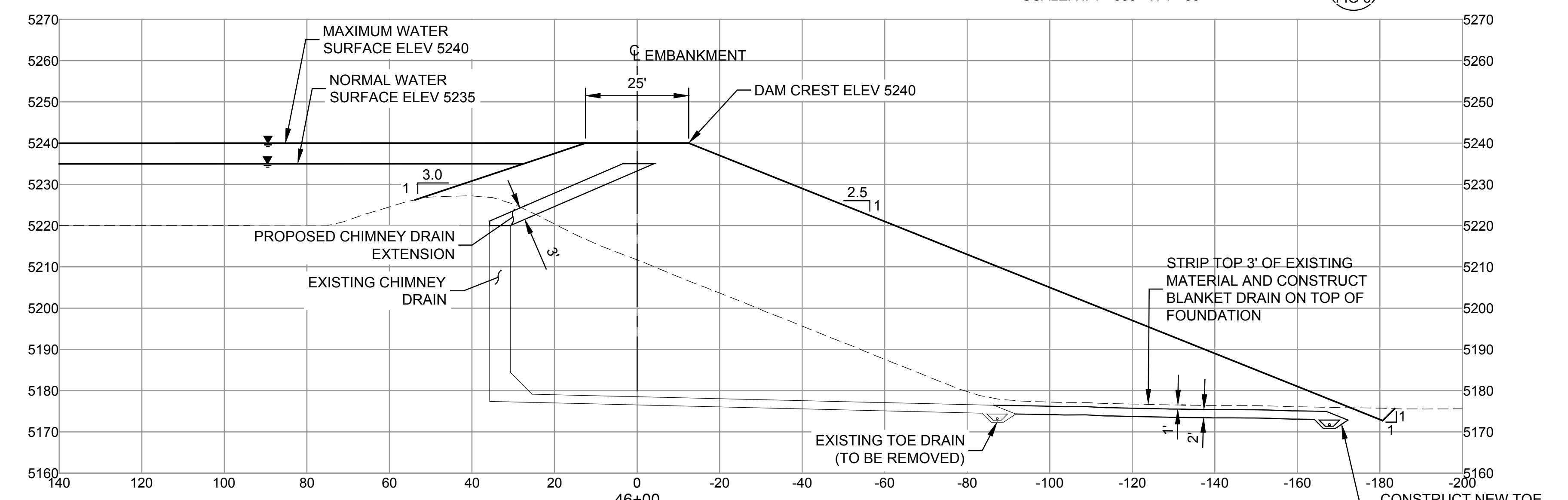


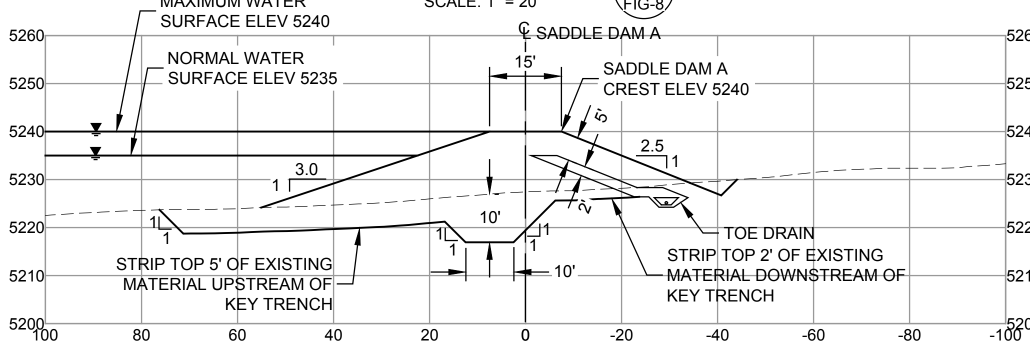
DAM CENTERLINE PROFILE (F / FIG-8)

SCALE: H: 1"=300' V: 1"=30'



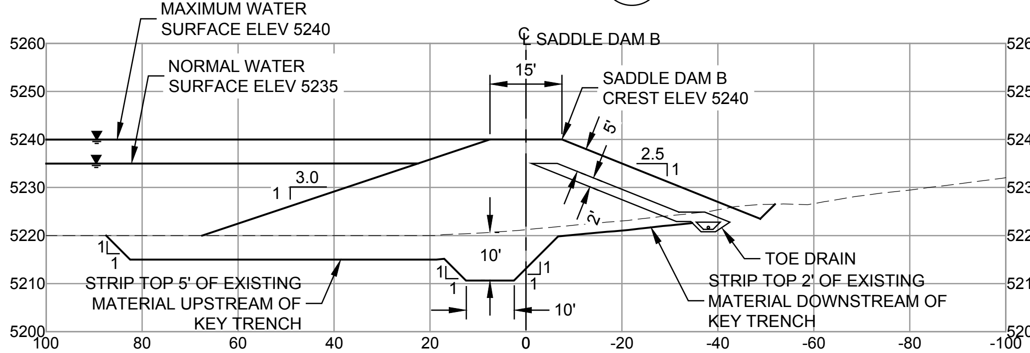
SECTION (6 / FIG-8)

SCALE: 1" = 20'



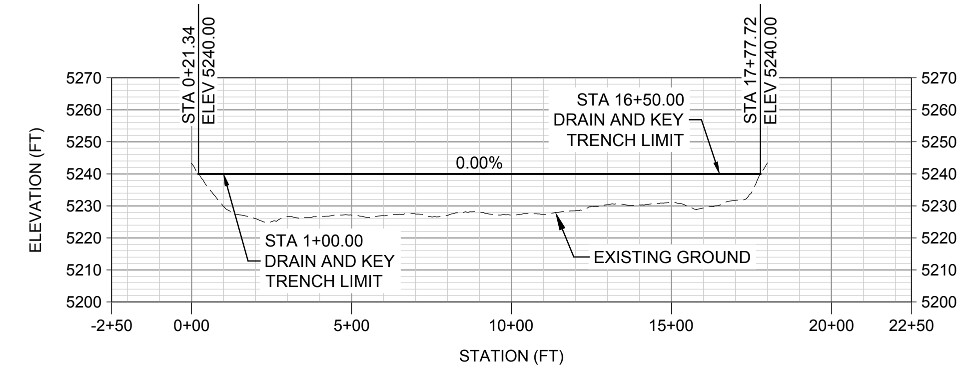
SECTION (7 / FIG-8)

SCALE: 1" = 20'



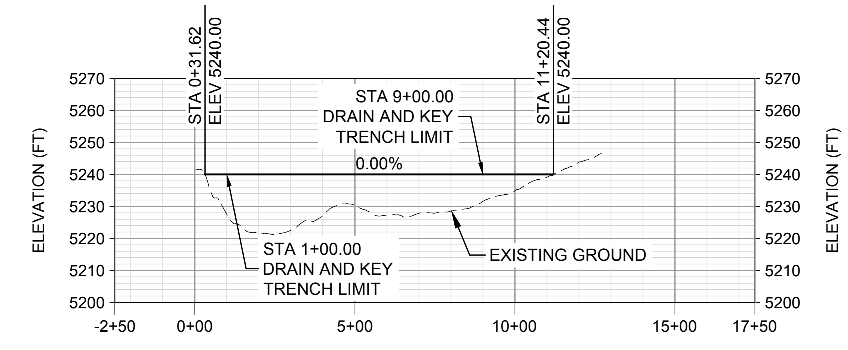
SECTION (8 / FIG-8)

SCALE: 1" = 20'



SADDLE DAM A CENTERLINE PROFILE (G / FIG-8)

SCALE: H: 1"=300' V: 1"=30'



SADDLE DAM B CENTERLINE PROFILE (H / FIG-8)

SCALE: H: 1"=300' V: 1"=30'

NOTE:

1. ALL EXISTING CONDITIONS AND INTERNAL GEOMETRY SHOWN ARE APPROXIMATE AND ESTIMATED FROM THE 2005 DESIGN DRAWINGS BY BOYLE ENGINEERING CORPORATION. LOCATIONS OF FEATURES SHOULD BE CONFIRMED PRIOR TO CONSTRUCTION.

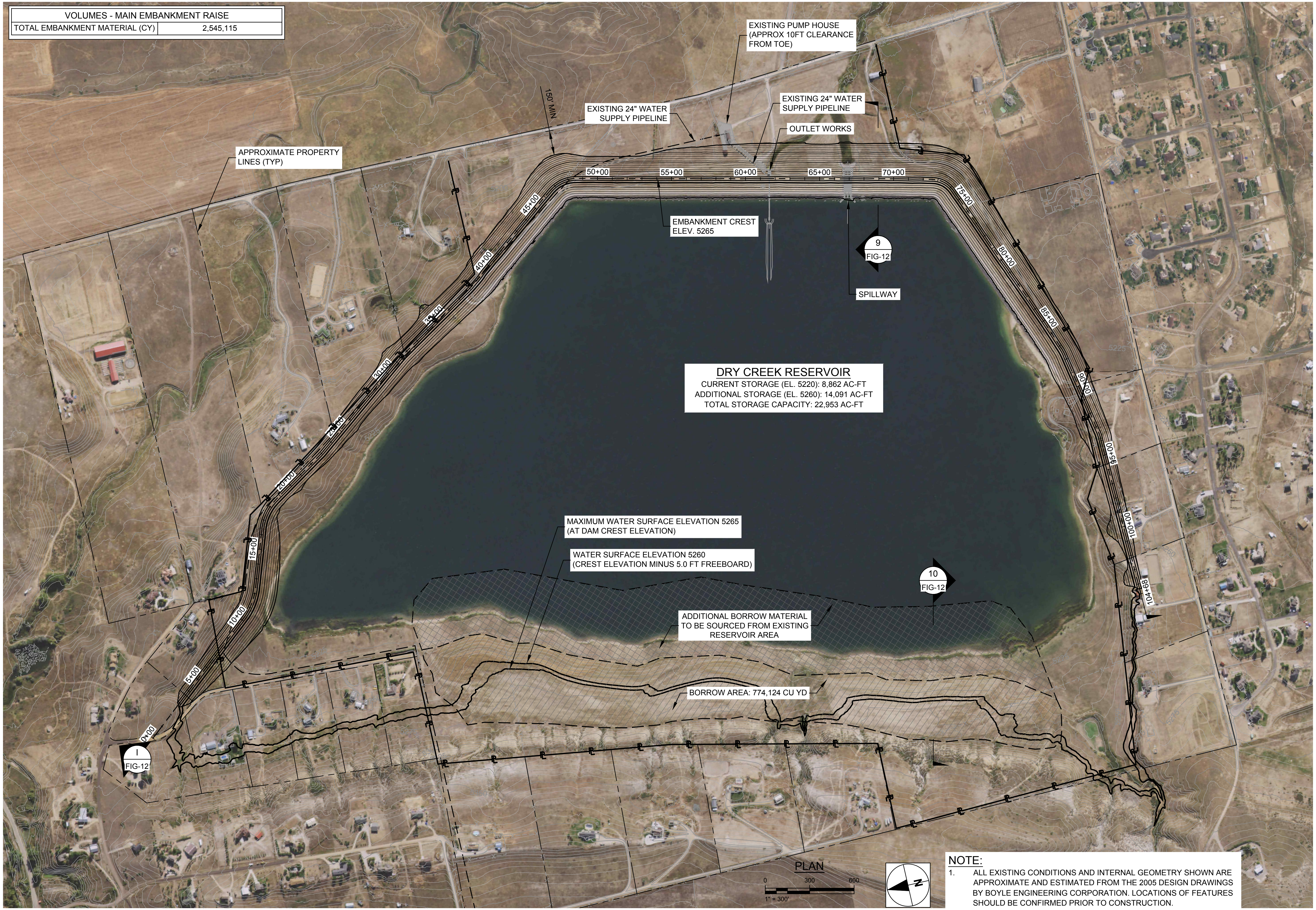
Issue Status: FINAL

AECOM

Figure: 3-10

EMBANKMENT CREST ELEVATION 5240
PROFILE AND SECTION

DRY CREEK RESERVOIR
EXPANSION FEASIBILITY STUDY
Little Thompson Water District
Project No.: 60595240



Issue Status: FINAL

AECOM

Figure: 3-11

EMBANKMENT CREST ELEVATION 5265-MAX RAISE
PLAN

DRY CREEK RESERVOIR
EXPANSION FEASIBILITY STUDY
Little Thompson Water District
Project No.: 60595240

ANSI D 22" x 34"

Project Management Initials: Designer: Checked: Approved:

Last saved by: BRYCE.TENNANT(2019-07-09) Last Plotted: 2019-07-09
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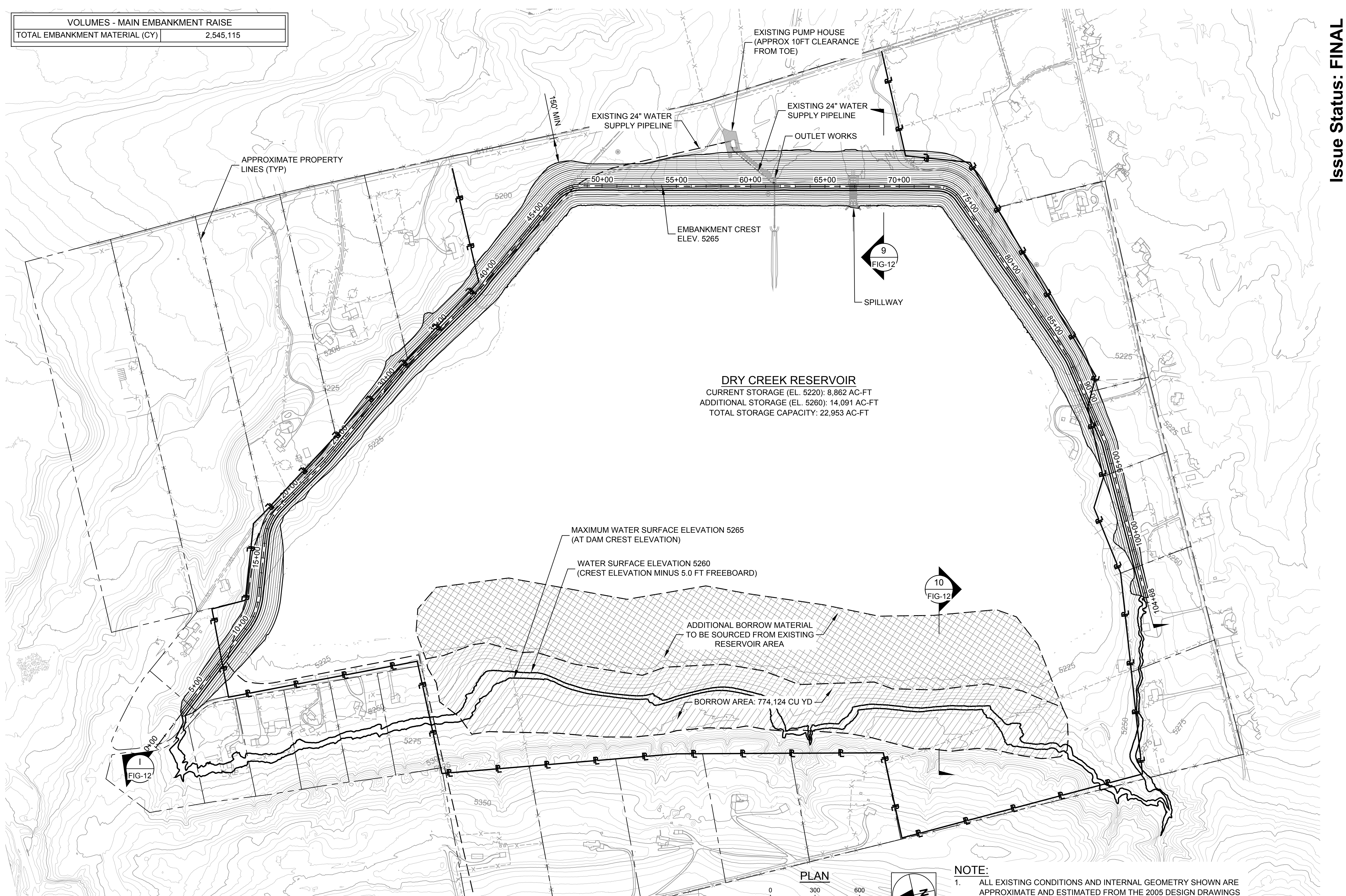

NOTE:

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Issue Status: FINAL

AECOM

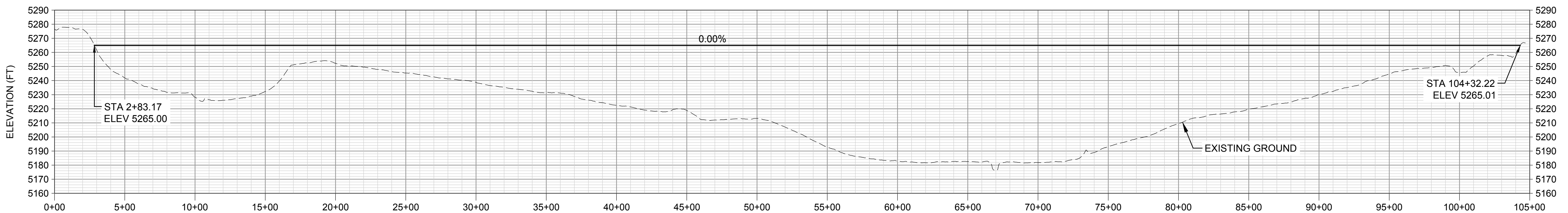
Figure: 3-12

EMBANKMENT CREST ELEVATION 5265-MAX RAISE
PLAN

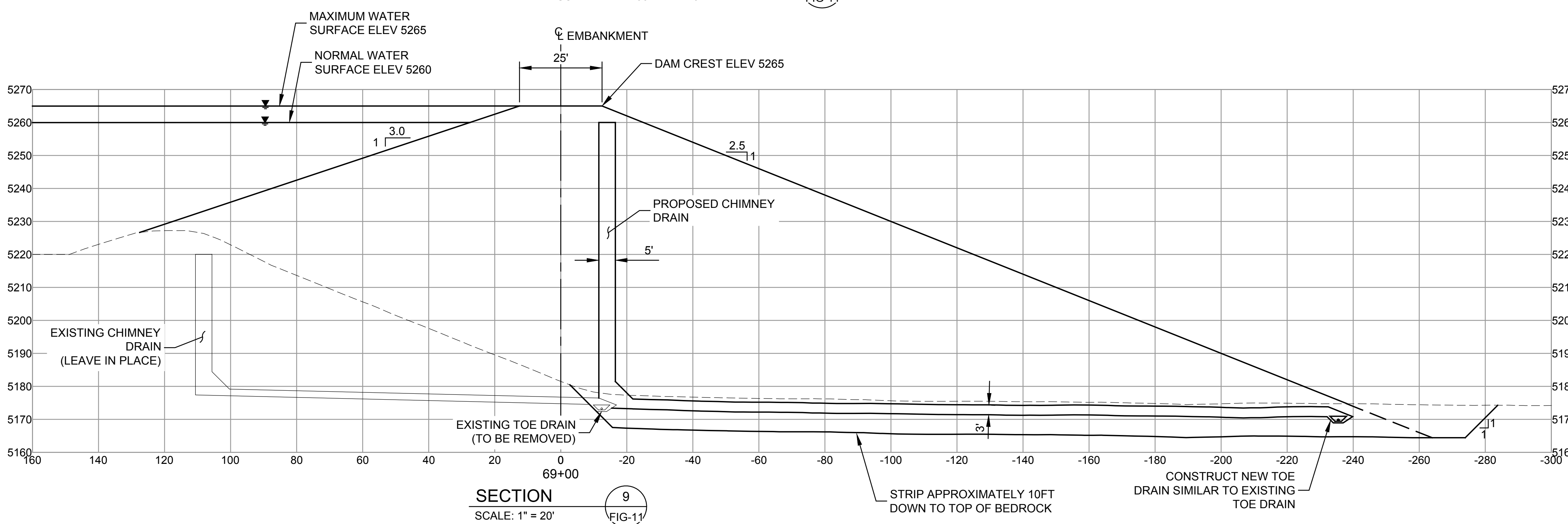
DRY CREEK RESERVOIR
EXPANSION FEASIBILITY STUDY
Little Thompson Water District
Project No.: 60595240

Last saved by: BRYCE.TENNANT(2019-07-09) Last Plotted: 2019-07-09
Filename: M:\DCS\PROJECTS\WTR\60595240_DRYCRKRFS\900_CAD_GIS\910_CAD\25-SKETCHES\EMBANK-MAX RAISE.DWG

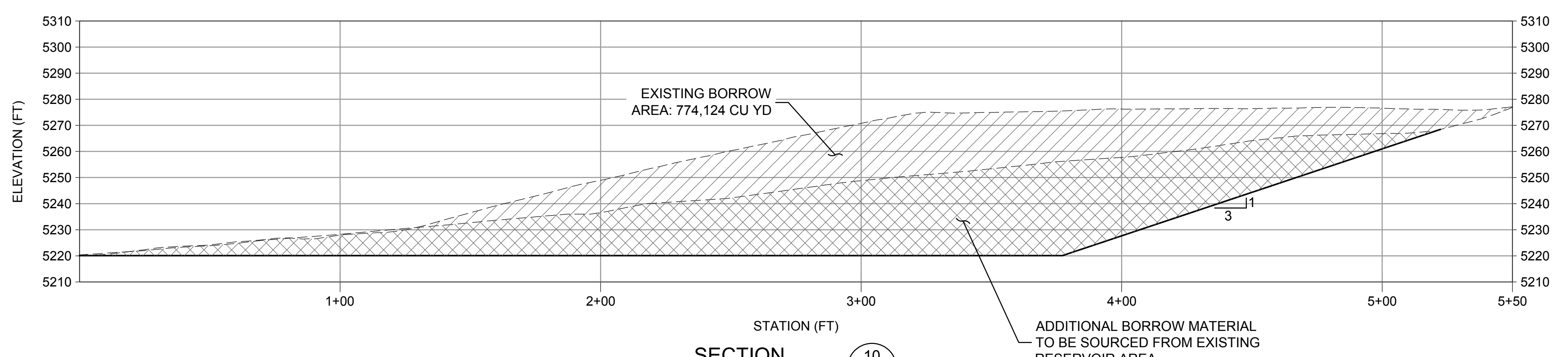
Project Management Initials: Designer:____ Checked:____ Approved:____ ANSI D 22" x 34"



DAM CENTERLINE PROFILE (I / FIG-11)
SCALE: H: 1"=400' V: 1"=40'



SECTION (9 / FIG-11)
SCALE: 1" = 20'



SECTION (10 / FIG-11)
SCALE: 1" = 30'

NOTE:

1. ALL EXISTING CONDITIONS AND INTERNAL GEOMETRY SHOWN ARE APPROXIMATE AND ESTIMATED FROM THE 2005 DESIGN DRAWINGS BY BOYLE ENGINEERING CORPORATION. LOCATIONS OF FEATURES SHOULD BE CONFIRMED PRIOR TO CONSTRUCTION.

Issue Status: FINAL

Figure: 3-13

EMBANKMENT CREST ELEVATION 5265-MAX RAISE
PROFILE AND SECTION

DRY CREEK RESERVOIR
EXPANSION FEASIBILITY STUDY
Little Thompson Water District
Project No.: 60595240

4. Permitting Requirements

LTWD requested permitting services to identify environmental regulatory approvals required for construction of an enlarged Dry Creek Reservoir. This section describes the anticipated permits and regulatory approvals that were evaluated based on AECOM's current understanding of the proposed Project. Permit requirements should be confirmed with the applicable regulatory agencies as the design progresses. The permits are organized by the organization responsible for obtaining the permit (i.e., LTWD versus the Construction Contractor). **Table 4-1** presents a summarized compilation of anticipated permitting requirements and regulatory consultation that will be needed prior to constructing the Project. The same permits and regulatory approvals will likely apply to Alternatives 1, 2, and 3 reservoir enlargement options.

Alternative 4 will likely also require a Clean Water Act Section 404 Individual Permit and associated documentation under the National Environmental Policy Act (NEPA). Additionally, Alterative 4 will require a Clean Water Act Section 401 Water Quality Certification from the State prior to issuance of a 404 permit from the USACE

Table 4-1: Anticipated Permit Requirements

Agency	Permit and/or Regulation	Trigger/Action	Preparation/Processing Time	Fees	Agency Contact	Notes
OWNER RESPONSIBILITY						
U.S. Army Corps of Engineers, (USACE)	Clean Water Act Section 404 Individual Permit National Environmental Policy Act (NEPA) USACE regulations for implementing NEPA - 33 Code of Federal Regulations [CFR] 325, Appendix B	404 Placement of fill into jurisdictional wetlands and waters of the U.S. As of June 18, 2019, the 2015 definition of waters of the U.S. is applicable in Colorado. This table only addresses potential permits for the maximum reservoir enlargement. Actions associated with ancillary facilities (e.g. canals and head gates) may trigger additional 404 permit requirements. NEPA Enlarged reservoir is a federal action that requires a permit from the USACE, thus NEPA is required. Based on our current understanding of the project, an Environmental Assessment (EA) level of analysis.	2-3 years	No Fee	Kiel Downing Chief Denver Regulatory Office 9307 S. Wadsworth Blvd. Littleton, CO 80128-6901 (303) 979-4120	*Evaluation of 404 and NEPA permitting requirements will continue as the dam design progresses. Delineation of wetlands, other aquatic features and documentation of cultural/historic resources will be prior to initiating permitting. - NEPA documentation is required; verify with USACE if an Environmental Assessment (EA) or Environmental Impact Statement (EIS) level of analysis will be required - There is no floodplain permitting requirement for the max raise dam enlargement because there are no delineated floodplains on the Larimer County FIRM and the enlargement does not impact the Zone A floodplain along Dry Creek. The floodplain information will be noted in the 404 permit application. - Assessment of cultural and historic resources in the project area will need to be documented for 404 and NEPA - Although LTWD obtains the Section 404 permit, the Construction Contractor is required to implement applicable permit conditions. - Shoreline Wetlands: Desktop analysis shows two potential wetlands on the perimeter of the reservoir (NW corner about 1.25 acre, and SW corner about 1.1 acre). These estimates are from Google Earth, National Wetland Inventory (NWI) mapping does not show the reservoir or adjacent wetlands. The reservoir was constructed in an upland area and wetlands within its basin were previously determined to be non-jurisdictional by the USACE. It is unknown at this time if the shoreline wetlands would be jurisdictional under the 2015 definition. -Wetlands Below the Dam (outlet works and spillway): Approximately 0.3 acres of wetlands appear to be within the project footprint. These wetlands are anticipated to be jurisdictional under the Clean Water Act and will likely trigger a 404 Individual Permit.

Agency	Permit and/or Regulation	Trigger/Action	Preparation/Processing Time	Fees	Agency Contact	Notes
U.S. Fish and Wildlife Service (USFWS)	Section 7 of the Endangered Species Act (ESA) 50 CFR 402	Any activity that may adversely affect federally-listed, proposed, or candidate endangered species or their designated critical habitat	Section 7considerations will be addressed during the 404 permitting process	No fee	USFWS Colorado Field Office Ecological Services Drue DeBerry P.O. Box 25486 DFC (MS 65412) Denver, Colorado 80225-0486 (303) 236-4773 coloradoes@fws.gov	*Field surveys to assess sensitive species habitat will be required prior to initiating 404 permitting. - Does not appear that suitable Preble's Meadow Jumping Mouse habitat occurs in the project area, but should be field-verified. -South Platte River protected species – may be a potential issue that should be verified with the USFWS. The water to be stored in the enlarged Dry Creek Reservoir has already been through Section 7 consultation (C-BT and Windy Gap transbasin diversions). LTWD not part of SPWRAP.
USFWS	Migratory Bird Treaty Act 50 CFR 10, 13 and 21 Department of Interior M-Opinion 37050, December 22 2017	Incidental take of migratory birds and nest contents during construction	Not applicable	No fee	U.S. Fish and Wildlife Service Migratory Bird Permit Office Region 6 – Mountain Prairie Region Jeremy Warner 134 Union Blvd #400 Lakewood, CO 80228 303-236-8171 jeremy_w_warner@fws.gov	-Incidental take (the unintentional take of migratory birds that results from an activity, but is not the purpose of the activity) of migratory birds and/or their active nest contents is allowable under the MBTA (Department of Interior M-Opinion 37050, December 22 2017). Apply BMPs to prior to construction to make nesting at the site less desirable. -An osprey nest exists near the reservoir that was established as part of wildlife enhancement opportunities by LTWD. The nest has been used every year since it was established. The nest would be temporarily relocated during the non-breeding season to avoid impacts during construction.
CDPHE, Water Quality Control Division (WQCD)	Clean Water Act Section 401 Water Quality Certification • 33 U.S.C. Section • Regulation #82:5 CCR 1002-82	Project requires permitting under the Clean Water Act	Up to a year	CDPHE charges hourly for preparing 401Certifications. Verify fees with the CDPHE.	Scott Garncarz CDPHE 4300 Cherry Creek Drive South WCDS-WSP-EDU-B2 Denver, CO 80246 303-692-2374 scott.garncarz@state.co.us	- The USACE will require that the proponent obtains a 401 Water Quality Certification prior to issuing a 404 Individual Permit. - Although LTWD obtains the Section 401 Certification, the Construction Contractor is required to implement applicable permit conditions.

Agency	Permit and/or Regulation	Trigger/Action	Preparation/Processing Time	Fees	Agency Contact	Notes
Department of Natural Resources (DNR), Division of Water Resources, Office of the State Engineer (SEO)	Office of the State Engineer Rules and Regulations for Dam Safety And Dam Construction, 2 CCR 420-1. The regulations are specifically covered under: Rule 5. Requirements for Construction or Enlargement of Jurisdictional Size Dams or Reservoirs.	State approval process for regulating dam safety.	By State statutes, the SEO has up to 6 months to review and respond to an application.	Per Colorado House Bill HB 15-1247: $6 per $1,000 of construction cost for a project Minimum fee is $100 Maximum fee is $30,000	Division 1: South Platte River Basin Dam Safety Engineer John Batka (970) 352-8712 John.Batka@state.co.us Dam Safety Engineer Kallie Bauer (970) 352-8712 Kallie.Bauer@state.co.us	SEO will initiate review upon receipt of signed and sealed drawings and specifications.
Larimer County	State House Bill 1041 Activities of State Interest Larimer County Land Use Code 14.4 (K)	Expansion of an existing water storage reservoir resulting in a surface area at high water line in excess of 50 acres, natural or manmade, used for the storage, regulation and/or control of water for human consumption or domestic use	6-12 months (minimum)	Determined at the Pre-Application Meeting	Larimer County Planning Department 200 West Oak Street, Suite 300 Fort Collins, CO 80521 970-498-7679 (On Call Planner) planningoncall@co.larimer.co.us	-A pre-application conference with Larimer County Planning Department is required before submitting a permit application -An associated Land Use Permit is required by the County - To the extent possible, document County requirements in NEPA documentation so that it can be utilized for 1041 permitting purposes
CONSTRUCTION CONTRACTOR RESPONSIBILITY						
Colorado Department of Public, Health and Environment (CDPHE)	Section 402 of the Clean Water Act - National Pollutant Discharge Elimination System (NPDES). The Colorado program is referred to as the Colorado Discharge Permit System, or CDPS, instead of NPDES. Construction Stormwater General Permit (COR030000)	State approval process for regulating stormwater runoff from projects impacting >1 acre. Regulates the quality of stormwater runoff from construction areas that discharge into waterways.	Submit application at least 30 days prior to the date anticipated discharge with a complete Stormwater Management Plan (SWMP)	Based on acres disturbed: Based on acres disturbed: • < 1 acre ($83 initial fee, $165 annual fee) • 1-30 acres ($175 initial fee, $350 annual fee) • > 30 acres ($270 initial fee, $540 annual fee)	Lisa Knerr CDPHE Water Quality Control Division 4300 Cherry Creek Drive South Denver, CO 80246 303-692-3004 lisa.knerr@state.co.us	-Develop SWMP to comply with Larimer County Stormwater Design Standards -CDPHE prefers electronic application submission -Submit Discharge Monitoring Reports through the Electronic Reporting (eReporting) platform

Agency	Permit and/or Regulation	Trigger/Action	Preparation/Processing Time	Fees	Agency Contact	Notes
CDPHE, WQCD	Colorado Water Quality Control Act, (25-8-101 et seq., CRS, 1973 as amended) and the Federal Water Pollution Control Act, as amended (33 U.S.C. 1251 General Permit for Construction Dewatering Activities (COG-070000)	State approval process for regulating discharges of groundwater from construction dewatering	Submit application at least 30 days prior to the date of anticipated discharge	$500 permit annual application fee (prorated when terminated)	Lisa Knerr CDPHE Water Quality Control Division 4300 Cherry Creek Drive South Denver, CO 80246 303-692-3004 lisa.knerr@state.co.us	Apply online through the Colorado Environmental Online Services (CEOS) www.colorado.gov/cdphe/ceos
CDPHE, Air Pollution Control Division (APCD)	Land Development APEN General Construction Permit for Land Development Projects (GP03)	Regulates the emission of fugitive dust from land development activities during construction State approval process for air pollution emissions for projects >25 acres or >6 months construction	2 months	$202.90 ($152.90 APEN fee + $50.00 General Permit fee) $95.56/hr fee for permit review and processing	CDPHE Air Pollution Control Division 4300 Cherry Creek Drive South Denver, CO 80246-1530 303-692-3150 APEN Hotline: 303-692-3210	A Fugitive Dust Control Plan should be implemented by construction contractor
Larimer County	Access Permit	Upgrading of existing access from the County roads adjacent to the project site	10 days (assuming Larimer County insurance requirements are met)	Varies, confirm with the County	Attn Permits Larimer County Engineering Department 200 West Oak Street, Third Floor Fort Collins, CO 80521 970-498-5709 Eng-Permits@larimer.org	An associated Traffic Control Plan must be submitted to County

****Note**** Permitting information was obtained from correspondence with the District. Other regulatory information was obtained from readily available information and permitting experience on similar projects. The information contained in this table should be periodically reviewed and verified with regulatory agencies in future phases of the project.

5. Alternative Cost Estimate

5.1 Assumptions

The cost opinion is based on the feasibility-level layouts presented in this report and estimated quantities of the major construction items.

Lump sum item prices are based on qualitative estimates of the work required and the corresponding cost. Estimated unit prices and costs for the work items were derived from the following sources: 1) published and non-published bid price data for similar work from the Team's database, 2) quotes from local vendors, and 3) the Team's experience on similar construction work.

The sum of the work items is defined for this study as the BCC. We also included an allowance to account for contingencies and unlisted items. This allowance was taken as 30 percent of the BCC. This allowance will decrease as Project development progresses toward more detailed levels of design. These costs do not include allowances to purchase permits, legal fees, or owner administration.

The estimated cost to purchase private residencies affected by the proposed enlargement includes the entire parcel. An average price was estimated using available market data. This cost is not typically included in the BCC, was included for cost comparison purposes across the four alternatives.

The OPPC is based on professional opinions and will change as more design details are developed. Also, actual costs would be affected by a number of factors beyond control, such as supply and demand for the types of construction required at the time of bidding and in the Project vicinity, changes in material supplier costs, changes in labor rates, changes in fuel costs, competitiveness of contractors and suppliers, availability of qualified bidding contractors, changes in applicable regulatory requirements, and changes in design standards. Therefore, conditions and factors that arise as Project development proceeds through design, bidding, and construction will likely result in construction costs that differ from the estimate provided in this memorandum.

For some items, a separate unit cost was developed for Alternative 4 due to the much larger volumes than the previous three alternatives.

The OPPC was developed as a Class 5 estimate in general accordance with the AACE. This level is appropriate for a study phase where the design engineering is between 1 and 15 percent complete. This classification is defined as a screening-level estimate with a plus 50% and minus 30% range of accuracy, when all costs are compared to 2019 dollars. Our OPPC is presented in **Table 5-1**.

Table 5-1: Opinion of Probable Project Cost

Feature No.	Task No.	Description	Unit	Alt 1 Quantity	Alt 2 Quantity	Alt 3 Quantity	Alt 4 Quantity	Alt 1-3 Unit Price ($)	Alt 4 Unit Price ($)	Alt 1 Amount ($)	Alt 2 Amount ($)	Alt 3 Amount ($)	Alt 4 Amount ($)
1	**Mobilization/Demobilization**									**350,000**	**800,000**	**1,400,000**	**4,000,000**
	1.1	Mobilization/Demobilization	lump sum	1	1	1	1			350,000	800,000	1,400,000	4,000,000
2	**Site Preparation**									**423,968**	**556,323**	**711,928**	**1,406,000**
	2.1	Sediment and Erosion Control	lump sum	1	1	1	1	$25,000.00	$25,000.00	25,000	25,000	25,000	25,000
	2.2	Clearing	acre	16	20	23	36	$2,500.00	$2,500.00	40,448	49,198	58,593	90,000
	2.3	Stripping Topsoil	cubic yard	23,704	48,425	77,667	210,200	$5.00	$5.00	118,520	242,125	388,335	1,051,000
	2.4	Temporary Construction Haul Roads	lineal foot	16,000	16,000	16,000	16,000	$15.00	$15.00	240,000	240,000	240,000	240,000
3	**Embankment Dam Raise**									**3,845,070**	**8,820,961**	**14,214,830**	**51,357,000**
	3.1	Foundation Removal	cubic yard	0	0	0	114,000		$5.00	0	0	0	570,000
	3.2	Unclassified Earthwork	cubic yard	168,281	367,626	587,630	2,751,000	$8.00	$7.00	1,346,248	2,941,008	4,701,040	19,257,000
	3.3	Drain and Filter Material	cubic yard	18,107	42,337	68,037	200,000	$101.00	$101.00	1,828,807	4,276,037	6,871,737	20,200,000
	3.4	Riprap and Bedding	cubic yard	6,505	15,572	25,651	110,000	$103.00	$103.00	670,015	1,603,916	2,642,053	11,330,000
4	**Saddle Dam**									**87,236**	**1,255,636**	**2,967,805**	**0**
	4.1	Key Trench	cubic yard	0	4,125	42,815	0	$10.00		0	41,250	428,150	0
	4.2	Unclassified Earthwork	cubic yard	2,407	25,156	66,185	0	$8.00		19,256	201,248	529,480	0
	4.3	Drain and Filter Material	cubic yard	0	2,972	6,115	0	$101.00		0	300,172	617,615	0
	4.3	Riprap and Bedding	cubic yard	660	6,922	13,520	0	$103.00		67,980	712,966	1,392,560	0
5	**Spillway**									**195,800**	**696,750**	**1,209,850**	**3,983,000**
	5.1	Cut and Fill Earthwork	cubic yard	0	500	925	2,350	$20.00	$20.00	0	10,000	18,500	47,000
	5.2	Concrete Structural	cubic yard	178	435	671	1,050	$1,100.00	$1,100.00	195,800	478,500	738,100	1,155,000
	5.3	Concrete RCC	cubic yard	0	833	1,813	13,500	$250.00	$206.00	0	208,250	453,250	2,781,000
6	**Outlet Works**									**53,525**	**197,775**	**255,815**	**1,063,108**
	6.1	Structure Concrete 10' x 10' Culvert	cubic yard	0	73	110	0	$1,200.00	$1,200.00	0	87,600	132,000	0
	6.2	Culvert and Reinforce Existing Structures	cubic yard	50	94	94	94	$900.00	$900.00	45,000	84,600	84,600	84,600
	6.3	Concrete Encase existing 24" steel pipe	cubic yard	14	41	63	0	$620.00		8,525	25,575	39,215	0
	6.4	New 36" steel concrete encased OW pipe	ft	0	0	0	220	$0.00	$1,680.00	0	0	0	369,600
	6.5	New 24" steel concrete encased pipe	ft	0	0	0	280	$0.00	$1,120.00	0	0	0	313,600
	6.6	Abandon existing 24" pipe w/ concrete	cubic yard	0	0	0	41	$0.00	$520.00	0	0	0	21,177
7	**Water Supply Pipeline Reinforcement**									**0**	**170,500**	**341,000**	**1,705,000**
	7.1	24" Pipe Concrete Encasement	cubic yard	0	275	550	2,750	$620.00	$620.00	0	170,500	341,000	1,705,000
8	**Instrumentation**									**260,400**	**375,000**	**377,400**	**579,600**
	8.1	Survey Marker	each	17	25	27	33	$1,200.00	$1,200.00	20,400	30,000	32,400	39,600
	8.2	Piezometer	each	32	46	46	72	$7,500.00	$7,500.00	240,000	345,000	345,000	540,000
9	**Site Reclamation**									**110,040**	**135,450**	**157,400**	**257,500**
	9.1	Topsoil	cubic yard	10,808	13,090	15,380	26,300	$5.00	$5.00	54,040	65,450	76,900	131,500
	9.2	Revegetation	acre	16	20	23	36	$3,500.00	$3,500.00	56,000	70,000	80,500	126,000
10	**Private Property Purchase**									**0**	**0**	**0**	**11,050,000**
	10.1	Purchase private properties within reservoir and embankment plan	each property	0	0	0	17	-	$650,000.00	0	0	0	11,050,000
		Base Construction Cost - Features 1 - 10								**$5,326,039**	**$13,008,395**	**$21,636,028**	**$75,401,208**
		Contingency Allowance for Unidentified Items, Quantities, Pricing (30%)								$1,597,812	$3,902,519	$6,490,808	$22,620,362
		Total								**$6,923,850**	**$16,910,914**	**$28,126,836**	**$98,021,570**

6. Alternative Evaluation

6.1 Technical Feasibility

Each of the alternatives is technically feasible and constructible. There are unique challenges associated with each of the alternatives that are discussed further below.

6.1.1 Reservoir Water Level Control and Borrow Material

The water level will need to be lowered enough such that foundations and potential key trenches (Alternatives 2 and 3) of the proposed saddle dams are not saturated. The lowest anticipated elevation for the saddle dam’s foundation is approximately El. 5,220 ft for Alternative 1. Alternative 2 and 3 may require key trenches that extend to El. 5,210 ft. The water level should be lowered to a minimum of 5 ft below these elevations at least three months ahead of the planned construction. Additional de-watering may be required if the reservoir is not lowered below these minimum elevations in advance.

Lowering the reservoir in advance of construction would allow for potential fill material to be borrowed from within the limits of the proposed expanded reservoir, thereby increasing storage. Reducing the reservoir elevation 6 to 12 months in advance of construction, would allow the material the opportunity to dry resulting in cost savings in processing and handling prior to placement. Advanced reservoir lowering may be required for Alternative 4 where a large portion of the fill would likely be sourced from below the current reservoir pool.

During the original construction, a large amount of clayey fill - roughly 750,000 CY – was removed from the bottom of the reservoir and stockpiled outside of the reservoir area, on the west side. Based on test pits and laboratory testing performed by GEI Consultants for the Northern Colorado Water Conservancy District’s Chimney Hollow Reservoir, the stock piled material consists of claystone bedrock that has degraded to lean and fat clays (CL and CH). One test pit encountered siltstone bedrock at 19 ft, one encountered a pocket of coarser material at 19 ft, and one terminated in fat clay at 17.5 ft. This material is similar to the fill used to construct the original embankment, would likely be appropriate as embankment fill for the proposed enlargement (although additional analysis of the material and the stability would be required), and require minimal moisture conditioning. There appears to be sufficient material in the stock pile to construct Alternatives 1, 2, and 3.

Alternative 4 will require about 2 million CY of embankment fill material in addition to the estimated 750,000 CY that is available in the existing stockpile. The majority of this fill may be sourced from the proposed expanded, and within the existing, reservoir pool. A conceptual cross section that includes a cut for additional borrow material can be seen in **Figure 3-12.**

6.1.2 Stability

The original stability analysis met the existing and current SEO requirements. However, the original stability analysis made available to AECOM during our data review did not include the as-constructed geometry. The analyzed section included a 4H:1V upstream slope that broke to 3H:1V about half way up the dam. The assumed phreatic surface during rapid drawdown was also a few ft below the upstream embankment fill surface. These inputs led to a FS of 1.22, just above the SEO requirement of 1.2 for rapid drawdown. Therefore a steady-state drained stability analysis was performed for the Alternative 4 raise.

The AECOM analysis used the same material properties as the original analysis, per the documents made available to AECOM. The original stability analysis documentation provided did not include material properties for undrained conditions, therefore undrained conditions were not evaluated as part of this study. The AECOM analysis used similar geometry as the original and the section evaluated was the maximum section.

The initial stability analysis performed for Alternative 4 was below the SEO requirement of 1.5. Removing the downstream foundation alluvium and replacing with embankment fill increased the FS to meet SEO criteria for steady-state drained conditions. Due to the low result of the Alternative 4 analysis, a separate analysis was performed for the existing geometry of the dam at the maximum section. The results met SEO criteria.

Further stability analyses should be performed for the End of Construction and Rapid Draw Down conditions to confirm that the current dam meets SEO criteria and that the proposed enlargements, using the existing material properties, also meet SEO criteria.

6.1.3 Water Supply Pipeline and Diversion During Construction

The existing 24-inch water supply pipeline that provides water to the pump station is located parallel to the downstream toe of the dam along the north side of the reservoir, as shown on **Figures 3-1, 3-4, 3-7, and 3-10**. The pipeline is within about 10 ft of the proposed toe of Alternative 1, and within the footprint of approximately 500 ft, 1,000 ft, and 5,000 ft of the proposed toes of Alternatives 2, 3, and 4, respectively. The pipeline becomes pressurized when water is pumped up from the Dry Creek Reservoir pumping station to the water treatment plant near Carter Lake. The portion of the pipeline under the proposed footprints would need relocated or embedded in reinforced concrete.

The reservoir is an off-stream reservoir; therefore diversion requirements are not anticipated. However, the drainage basin will produce some runoff during precipitation events or from snowmelt. Storm water and snowmelt runoff would likely not require diversion as the reservoir will be lowered during construction and the drainage basin is very small. In addition, the outlet works will likely be operational during the majority of the construction. However, prior to the modifications to the outlet works outlined in Alternative 2, 3, and 4, the reservoir level should be lowered incase an extreme event occurs. Some of the upstream drainages would require diversion during construction of the saddle dams.

6.2 Implementability

The enlarged reservoir could be operated in a similar manner to its current state. None of the alternatives require a modification to the operation of the dam and reservoir. The following changes would be expected form the modifications:

- Alternative 1 would make access to the existing toe drain sumps more difficult by extending the manholes 10 ft;
- Alternative 2, 3, and 4, would require a new toe drain;
- Alternative 2, 3, and 4, would require additional sumps and pumps as part of the drain system for the saddle dams;
- Alternative 2 and 3 would require modified access to the valve vault and outlet structure;

- Alternative 2 and 3 may require a gate or valve within the proposed saddle dams to drain the area downstream of the saddle dam after precipitation events.

6.3 Construction Risks

Based on our review of the original design and construction documents, and our evaluation during the development of the conceptual Alternatives, we have identified the following risks that could occur during construction:

- The amount of suitable stock piled material may be less than anticipated;
- Precipitation events could flood and saturate excavations and haul routes;
- The existing chimney drain may not have been constructed as shown in the design drawings and additional excavation could be required;
- Alternative 1 requires raising the existing manholes, cleanouts, and monitoring wells. Special care will be required during construction to limit damage to these existing structures and to achieve proper compaction without introducing potential preferential seepage paths;
- Alternative 2, 3, and 4 requires modifications to the existing water supply pipeline and the outlet works. A stop block will be required to prevent accidental pressurization of these conduits.

6.4 Operational Risks

We have identified the following risks associated with operation of the enlarged reservoirs:

- Increased water pressure head will increase seepage, and new seepage locations could develop;
- Alternative 2, and 3 include an additional pressurized conduit within the dam in the form of the 24-inch pipeline from the valve vault to the pump station;
- The proposed embankment would encroach on the existing 24-inch water supply pipeline from Carter Lake to the pump station.

7. Conclusions

As part of this feasibility evaluation we have reviewed the original design and construction documents, evaluated potential permitting requirements, and conceptually laid out four embankment enlargement alternatives based on the crest heights and the existing topography. Each of the alternatives presents unique challenges and provides varying degrees of benefit. **Table 7-1** provides a side-by-side comparison of each of the alternatives presented herein:

Table 7-1: Design Alternatives Summary

Item	Alternative 1	Alternative 2	Alternative 3	Alternate 4
Concept Crest El.	5,230	5,235	5,240	5,265
Crest Raise (ft)	5	10	15	40
Downstream Extension (ft)	27.5	55	82.5	225
Crest Sta (ft)	6,157	6,241	7,221	10,468
Crest Length (ft)	5,143	6,016	6,401	10,149
Additional Capacity (AF)	1,531	3,145	4,805	14,091
Total Capacity (AF)	10,393	12,007	13,667	22,953
Embankment Fill (CY)	150,174	325,288	519,593	2,750,933
Filter Sand (CY)	18,107	42,337	68,037	196,334
Riprap and Bedding (CY)	7,164	22,495	39,172	110,326
Saddle Dams (ft)	250	2,600	2,850	0
Outlet Works	Construct wall around existing outlet works vault and backfill against.	Extend existing outlet works downstream via a reinforced concrete culvert. Reinforce 24-inch water supply pipeline out of existing valve vault.	Extend existing outlet works downstream via a reinforced concrete culvert. Reinforce 24-inch water supply pipeline out of existing valve vault.	Extend existing outlet works downstream via concrete embedded steel pipe. Valve vault house and outlet structure will be re-located to the new downstream toe.
Spillway	Raise weir and sidewalls and use existing spillway.	A new weir and the top of the spillway will be constructed on top of the existing spillway. The modified spillway will into the existing spillway approximately 1/3 down the stairs.	A new weir and the top of the spillway will be constructed on top of the existing spillway. The modified spillway will into the existing spillway approximately 2/3 down the stairs.	A new weir, spillway, and stilling basin will be constructed of RCC. The spillway will be at 1H:1V.
Toe Drain	Extend manholes 10 ft to new surface. Grade new blanket drain into existing toe drain.	Remove existing toe drain and re-build at the new toe location.	Remove existing toe drain and re-build at the new toe location.	Remove existing toe drain and re-build at the new toe location.
Chimney Drain	Extend at 3H:1V for 5 vertical ft.	Extend at 3H:1V for 10 vertical ft.	Extend at 3H:1V for 15 vertical ft.	Construct new vertical chimney drain.
24-inch Water Supply Pipeline	Re-location not required.	Re-locate or reinforce approximately 500 ft of pipeline.	Re-locate or reinforce approximately 1,000 ft of pipeline.	Re-locate or reinforce approximately 5,000 ft of pipeline.
Maximum Construction Water El.	5,215	5,205	5,205	5,200 pending borrow material availability
Total Cost ($)	6,920,000	16,910,000	28,130,000	98,020,000
Cost ($/additional ac-ft)	4,523	5,377	5,854	6,957

Based on the reviewed data, our evaluations, and our experience as dam engineers, we offer the following conclusions:

- All four Alternatives are technically feasible and there is enough stockpiled material to construct Alternative 1, 2, and 3. Alternative 4 will require additional fill sourced from the existing reservoir pool.
- There are no major operational changes associated with either Alternative.
- Additional research and analyses are required to confirm assumptions made in this feasibility report.
- Groundwater and potential seepage from the reservoir should be considered when evaluating alternatives.
- The OPPC and cost per ac-ft is summarized in **Table 5-1**.

8. General Information

This report was prepared by AECOM and is intended for the sole use by the LTWD. The scope of services performed for this study may not be appropriate to satisfy the needs of other users, and any use or re-use of this document or of the findings, conclusions, or recommendations presented herein is at the sole risk of said user.

Professional judgments, analyses, and evaluations presented in this report are based in part on team discussions, discussion with third parties, file information, information or reports prepared by others and provided by LTWD, and analyses conducted by AECOM and documented in this memorandum and in part by AECOM's experience on similar projects.

The condition of a dam is evolutionary in nature and depends on numerous and constantly changing internal and external conditions. It would be incorrect to assume the present condition of a dam will continue to represent the condition of that dam at some point in the future. Only through periodic, updated inspections and ongoing monitoring can unsafe conditions be detected so that corrective action can be taken. Likewise, continued care and maintenance are necessary to minimize the risk of unsafe conditions.

AECOM represents that our services were performed within the limits prescribed by the client, in a manner consistent with the level of care and skill ordinarily exercised by other professional consultants under similar circumstances. No other representation to the client, expressed or implied, and no other warranty or guarantee is included or intended.

9. References

Boyle Engineering, 2005. *Dry Creek Dam Project Design Drawings.* Colorado.

Boyle Engineering, 2005. *Dry Creek Dam Project Final Design Report*. Colorado.

Boyle Engineering, 2005. *Dry Creek Dam Project Flood Hydrology Report*. Colorado.

Boyle Engineering, 2005. *Dry Creek Dam Project Geotechnical Report*. Colorado.

Colorado Department of Natural Resources, Dam Safety Branch, January, 2007. *Rules and Regulations for Dam Safety and Dam Construction*. Colorado