



COLORADO

**Colorado Water
Conservation Board**

Department of Natural Resources

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TO: Colorado Water Conservation Board Members

FROM: Lauren Ris, Deputy Director
Erik Skeie, Interstate, Federal & Water Information Section

DATE: November 16-17, 2021

AGENDA ITEM: 12. Bear Creek Lake Reallocation

Staff Recommendation:

This is an informational item only.

Background:

The Bear Creek Dam and Reservoir Project (aka "Bear Creek Lake") was completed in 1977 by the U.S. Army Corps of Engineers (Corps) and is located on Bear Creek at its confluence with Turkey Creek, approximately 10 miles southwest of Denver, Colorado in Jefferson County. The reservoir was authorized for the purposes of flood control, recreation, and fish and wildlife enhancement with a majority of the reservoir being used for flood control. The project's active capacity is 57,678 AF (at the spillway crest) and is currently operated at a maximum priority storage volume of 2,000 AF. The CWCB currently holds existing water rights for Bear Creek Lake decreed for piscatorial, recreational, municipal, domestic, industrial, and irrigation under case Nos. 79CW306 (1989 acre-ft) and 84CW167 (2,000 acre-ft).

In May of 2015, the Corps provided the CWCB with a draft Reconnaissance Study¹ evaluating the potential of reallocating up to 20,000 AF of space from flood control to multi-purpose storage. Based on the initial conclusions of the Reconnaissance Study, the Corps proposed initiating a feasibility study with the CWCB as the local sponsor. Feasibility study costs are split 50/50 between the Corps and the project sponsor.

At its November 2015 meeting, the CWCB Board approved including a request for up to \$2,500,000 from the Severance Tax Perpetual Base Fund in the annual Projects Bill for the Bear Creek Reallocation of Storage Study. These funds were officially appropriated in Section 7 of SB16-174.

¹ Also known as a Section 905(b) Analysis, these studies are preliminary assessments of potential reallocation of storage space in Corps dams.

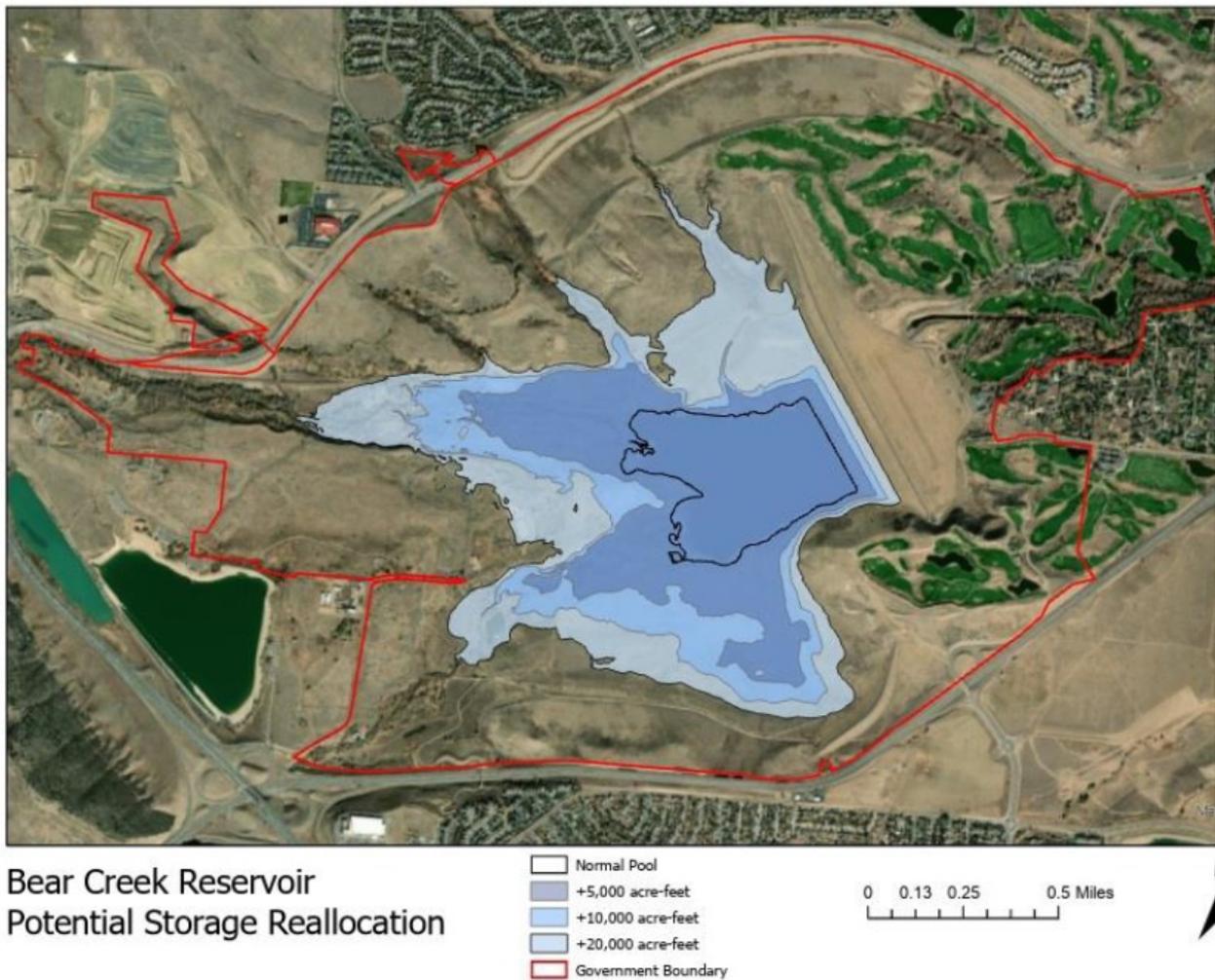


Currently, there are two active aspects of the reallocation process discussed in this memo:

- 1) Reallocation Feasibility Study with the Army Corps Engineers
- 2) Potential Water Rights Issues

Reallocation Feasibility Study

Figure 1: Bear Creek Reservoir with current storage and additional reallocation levels to be investigated as presented by the Corps at the October 14th Public Scoping Meeting (Attachment 1).



On August 30th, 2019 CWCB and the Corps entered into a cost share agreement on a \$3 million Reallocation Feasibility Study. The following timeline provides key decision points and milestones during this three-year process (Figure 2).



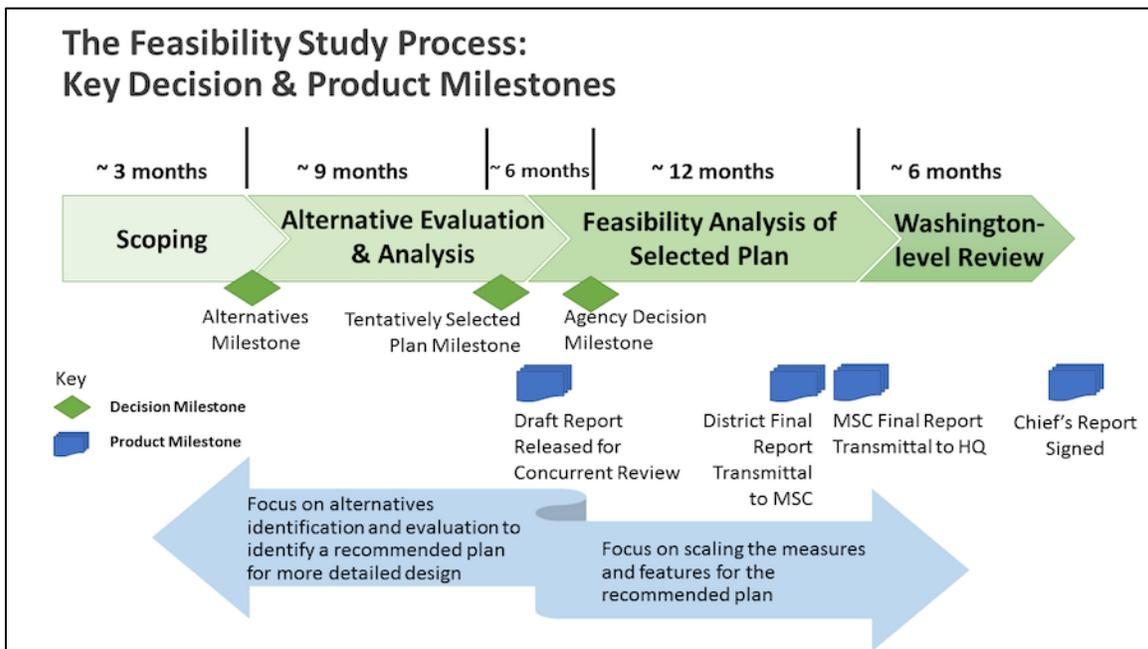


Figure 2: Timeline for the Corps' Feasibility Study Process under the Bear Creek Reservoir Project Management Plan

After signing the Cost Share Agreement with the Army Corps of Engineers, CWCB and Corps staff held the first Scoping Team meeting with key project stakeholders in October 2019. Scoping Team members include CWCB, City of Lakewood, the State Engineer's Office, and the Bear Creek Watershed Association.

CWCB suspended the work on the study after two issues came to light during that initial scoping meeting. First, the Corps needed to conduct a Risk Assessment before moving forward on a feasibility study. Army Corps staff completed this preliminary Risk Assessment in late September 2020 and concluded that the Reallocation Feasibility Study could proceed. Second, the State Engineer's Office (SEO) advised CWCB staff to work with the Corps on updating hydrology methods for the study. SEO, CWCB, and the Corps came to agreement on the hydrology in June of 2021, and the study resumed.

The Scoping Team Reconvened in August of 2021 and the first Public Scoping Meeting was held virtually on October 14th, 2021. There were over 200 participants, most of whom were local residents in Lakewood. The purpose of the meeting was to gather feedback on the proposed study alternatives. The Corps' presentation is attached to this memo, and a recording of the meeting can be found [here](#).



The Corps proposed five study alternatives:

1. No Change
2. Increase Reservoir Capacity & Normal Operating Pool (up to 20,000 AF)
 - a. Structural modifications to dam (e.g. dam raise and spillway raise) to increase reservoir storage for water supply.
 - b. Excavate reservoir (remove accumulated sediment or deepen reservoir) to increase in-pool storage for water supply.
 - c. Excavate forebays upstream of reservoir to increase storage capacity for water supply.
3. Reallocation of Existing Capacity (up to 20,000 AF)
 - a. Reallocation of reservoir storage from flood control and/or flood surcharge zones to conservation zone for water supply.
 - b. Reallocation of reservoir storage from multipurpose zone to conservation zone for water supply.
4. Operational Changes (Release More Water/Release Water Sooner)/Increase Normal Operating Pool
 - a. Structural modifications to dam (e.g. lower spillway, widen spillway, raise spillway with fuse plug, modify outlet works) to increase dam freeboard.
 - b. Modify reservoir Water Control Plan and Tri-Lakes System Regulation Plan to release more water sooner to increase dam freeboard.
5. Nonstructural
 - a. Nonstructural measures downstream of dam (e.g. floodproofing or relocation of structures) to decrease consequences.

Public comment during the meeting was largely in opposition to the study, citing recreation and environmental mitigation concerns related to any increase in water elevation.

The Corps is currently working on preliminary investigations of these alternatives, and should reach their alternative milestone by the end of November 2021. CWCB Staff will continue to work with the Corps and the public as the study moves forward.



Water Rights

In anticipation that the feasibility study may confirm that an additional 20,000 AF may be stored in Bear Creek Lake, the CWCB Board declared its intent to appropriate 20,000 AF of storage in Bear Creek Lake in March of 2016.

It was determined that partners be identified before an application was filed, and to that end Staff conducted several outreach efforts to build partnerships with local water users and determine interest in the project (Attachment 2). Through these efforts the following entities have been identified as potential partners: City of Brighton, Evergreen Metropolitan District, Hidden Valley Water District, City of Berthoud, City of Dacono, and Foothills Parks and Recreation District.

CWCB hired Brown and Caldwell to conduct the engineering required for a water rights application. Preliminary results are available (Attachment 2). Though the Corps will not include these results in the Feasibility Study, they have received Brown and Caldwell's results and methodology for consideration in their hydrologic analysis.

There are several legal issues to work through regarding water storage rights in Bear Creek Lake. Staff will continue to work with the Attorney General's Office.

Attachments:

1. October 14th, 2021 Presentation from the Army Corps of Engineers
2. Preliminary Future Operational Analysis by Brown and Caldwell



BEAR CREEK DAM & RESERVOIR WATER SUPPLY REALLOCATION STUDY

Agency/Public Scoping Meeting
14 October 2021



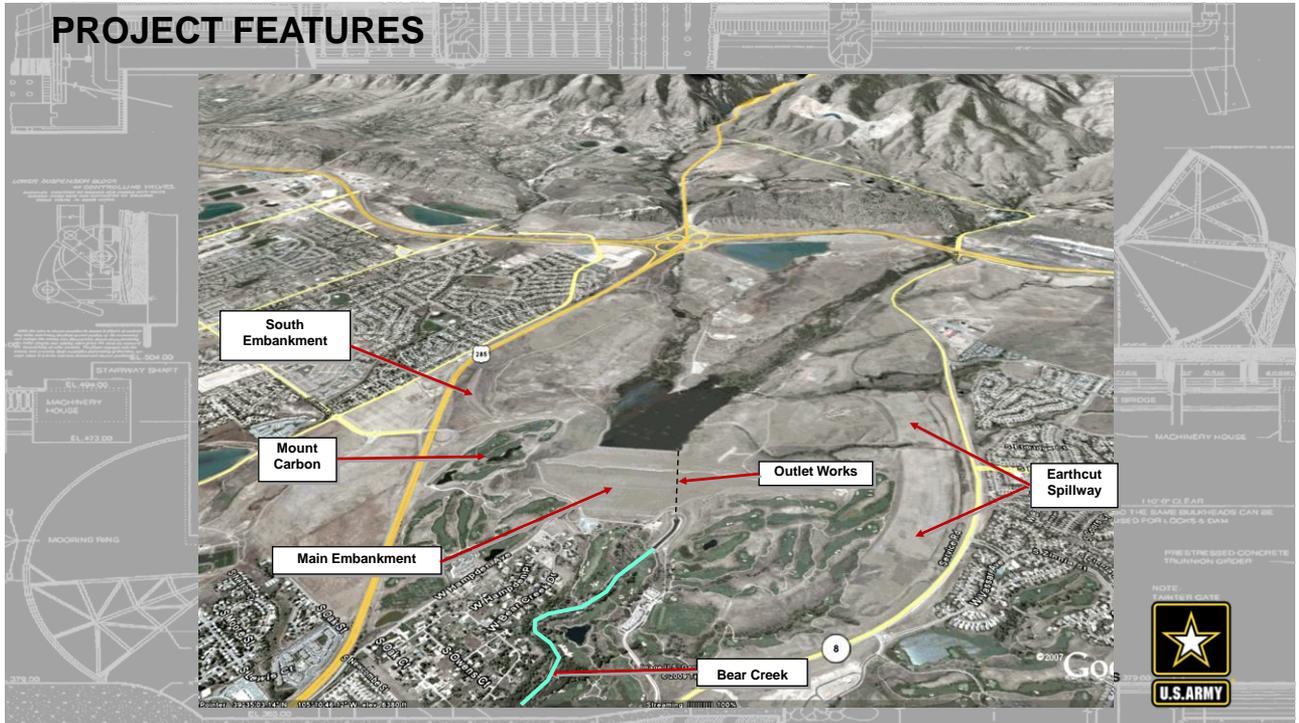
US Army Corps of Engineers
Omaha District

The views, opinions and findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other official documentation.

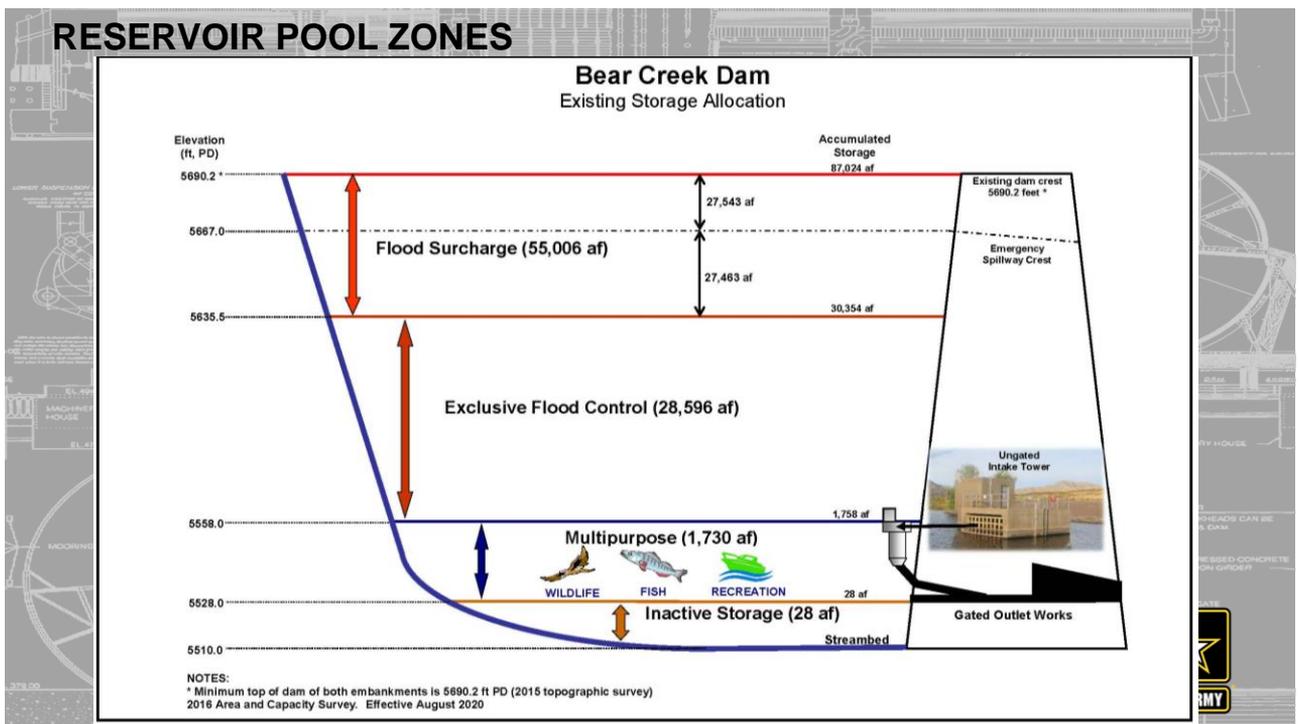


PROJECT LOCATION





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STUDY PURPOSE & NEED

- Problem: State of Colorado has identified significant water supply shortfall statewide – 400K ac-ft by 2050.
- Colorado Water Conservation Board (CWCB) requested study to determine whether storage in Bear Creek Reservoir can be reallocated to water supply.
- Bear Creek Dam is Dam Safety Action Classification (DSAC) 3 dam; current authorized purposes are flood risk management, fish and wildlife enhancement, and recreation.
- Due to DSAC 3 classification, USACE was required to request exception from ER 1110-2-1156, Safety of Dams – Policy and Procedures, which restricts reallocation studies at dams with DSAC 1, 2, or 3 ratings. Exception was granted 23 May 2018.



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STUDY BACKGROUND

- Feasibility Cost Sharing Agreement for study executed between USACE and CWCB on 30 August 2019.
- 1st Iteration Planning Meeting held with CWCB, Colorado State Engineer, and City of Lakewood on 07 October 2019.
- Study suspended at CWCB's request from November 2019 to June 2021 to address concerns regarding dam safety considerations related to reallocation and questions regarding estimation of probable maximum precipitation and Inflow Design Flood (IDF).
- 2nd Iteration Planning Meeting held with CWCB, Colorado State Engineer, and City of Lakewood on 31 August 2021.



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PUBLIC SCOPING MEETING

This Public Scoping Meeting is being conducted to solicit public input prior to establishment of initial array of alternatives for consideration in study.

USACE requests public input regarding:

- Potential benefits of reallocation.
- Potential impacts of reallocation.
- Potential study outcomes you would like to see realized or avoided.
- Any other aspects of study.

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STUDY OPPORTUNITIES

- May be opportunity to reallocate storage in Bear Creek Reservoir to water supply, helping reduce risk of future water supply shortfall.
- May be opportunity to store agricultural augmentation water in Bear Creek Reservoir for future use.
- May be opportunity to improve reservoir water quality and/or prevent Bear Creek downstream of Bear Creek Dam from running dry in drought periods by incorporating environmental considerations.
- IDF can be updated to better understand dam safety risk and allow for more accurate analysis of alternatives.
- Bear Creek Reservoir's location directly on Bear Creek and Turkey Creek allows for immediate capture of all available flows that may legally be stored.
- Bear Creek Reservoir's location at relatively high elevation within basin affords opportunity to deliver any stored water by gravity flow.

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STUDY OBJECTIVES

- Evaluate availability of existing storage in Bear Creek Reservoir, including consideration of potential for updated hydrologic analysis to change IDF.
- Determine whether there is Bear Creek Reservoir storage available that can be reallocated to water supply and/or whether it may be technically and economically feasible to modify Bear Creek Project to create additional storage for water supply. Note that project modifications could include physical modifications (e.g. raise dam) or operational modifications (e.g. modify Water Control Plan).



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STUDY CONSTRAINTS

- Bear Creek Dam's current DSAC 3 rating may limit opportunities for water supply reallocation. Reallocation may require measures to address dam safety issues.
- Bear Creek Dam's primary authorized purpose is Flood Risk Management (FRM), and any impacts of water supply reallocation on FRM, including transfer of flood risk to other dams or basins (e.g. Chatfield or Cherry Creek), must be carefully considered.
- Any potential increase to overall project risk (e.g. increased loading of Bear Creek Dam due to higher reservoir pool) must be carefully considered. Updated risk assessment will be required to ensure that any changes in overall project risk are acceptable.
- Any water supply reallocation alternative must comply with all applicable laws and policy requirements, including requirements to mitigate any environmental, cultural, or recreational resource impacts.



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STUDY CONSIDERATIONS

- Impacts to recreational resources could significantly affect character of Bear Creek Lake Park. Although impacts must be mitigated, maintaining park's overall character (e.g. land-based vs. water based) may be difficult.
- Water supply reallocation could result in increased reservoir hypolimnetic volume, which could adversely impact reservoir water quality. Increased reservoir use by waterfowl could result in increased E. coli/fecal coliform bacteria contamination.
- Existing sewer pipe crossing over Bear Creek downstream of Bear Creek Dam constrains flows to approximately 500 cfs, especially with debris blockages, limiting current release capacity of dam.
- Harriman Ditch pipe that runs under Turkey creek could be impacted by water supply reallocation, depending on whether/how much reallocation raises normal reservoir pool level.



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POTENTIAL WATER SUPPLY REALLOCATION MEASURES

Retained for Further Consideration

No Change

1. No action.

Increase Reservoir Capacity & Normal Operating Pool (up to 20,000 ac-ft)

2. Structural modifications to dam (e.g. dam raise and spillway raise) to increase reservoir storage for water supply.
3. Excavate reservoir (remove accumulated sediment or deepen reservoir) to increase in-pool storage for water supply.
4. Excavate forebays upstream of reservoir to increase storage capacity for water supply.



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POTENTIAL WATER SUPPLY REALLOCATION MEASURES

Retained for Further Consideration

Trade-off Purposes/Increase Normal Operating Pool (up to 20,000 ac-ft)

5. Reallocation of reservoir storage from flood control and/or flood surcharge zones to conservation zone for water supply.

Trade-off Purposes/Do Not Increase Normal Operating Pool

6. Reallocation of reservoir storage from multipurpose zone to conservation zone for water supply.

Operational Changes (Release More Water/Release Water Sooner)/Increase Normal Operating Pool

7. Structural modifications to dam (e.g. lower spillway, widen spillway, raise spillway with fuse plug, modify outlet works) to increase dam freeboard.
8. Modify reservoir Water Control Plan and Tri-Lakes System Regulation Plan to release more water sooner to increase dam freeboard.



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POTENTIAL WATER SUPPLY REALLOCATION MEASURES

Retained for Further Consideration

Nonstructural

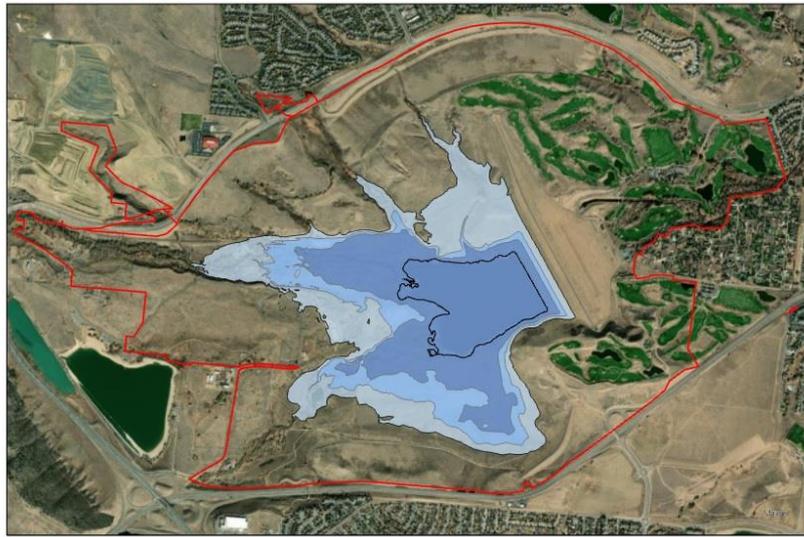
9. Nonstructural measures downstream of dam (e.g. floodproofing or relocation of structures) to decrease consequences.



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POTENTIAL INUNDATION AREAS FOR REALLOCATION



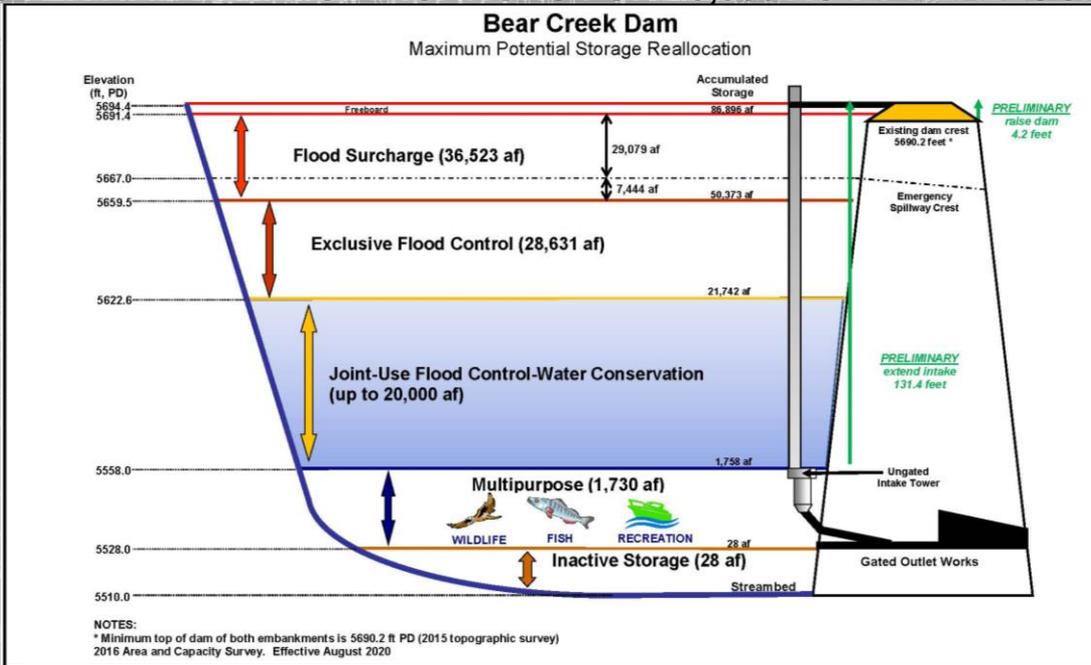
Bear Creek Reservoir
Potential Storage Reallocation

- Normal Pool
- +5,000 acre-feet
- +10,000 acre-feet
- +20,000 acre-feet
- Government Boundary

0 0.13 0.25 0.5 Miles



POTENTIAL DAM MODIFICATIONS FOR 20,000 AC-FT REALLOCATION



REALLOCATION STUDY & QRA EXPECTED OUTCOMES

- Reallocation Study:
 - Determine availability of water to reallocate (storage-yield analysis, etc.);
 - Determine cost of storage and any required mitigation measures;
 - Compare to cost of other water supply alternatives to evaluate economic feasibility;
 - Analyze environmental, recreational, and cultural resource impacts;
 - Determine whether reallocation can be recommended.
- Quantitative Risk Assessment (QRA):
 - Update hydrologic analysis to support QRA;
 - Update Potential Failure Modes Analysis (PFMA);
 - Perform QRA to better characterize existing conditions dam safety risk;
 - Perform QRA to evaluate potential dam safety risk of alternative reallocation plans;
 - Determine whether reallocation can be recommended.



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ENVIRONMENTAL RESOURCES

- Reference Information:
 - USFWS Information for Planning & Consultation (IPaC) Report
 - No critical threatened/endangered (T/E) species habitat in directly affected area.
 - Six known T/E species may be in directly affected area.
 - At least 14 migratory birds with varying breeding seasons may be in directly affected area.
 - Downstream extent of effect under consideration.
 - National Wetlands Inventory indicates at least eight different types of wetlands in directly affected area.
- Geographic Information System (Desktop) Analysis:
 - Used data from USFWS, imagery from USDA, and approximate inundation extents.
 - No Action alternative has no impacts as nothing would be done to address purpose and need of project.

Alternative	550 ac-ft	10,000 ac-ft	20,000 ac-ft
Stream Length	721 ft	3,886 ft	5,813 ft
Wetlands	2.55 acres	50.59 acres	72.29 acres



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RECREATIONAL RESOURCES

- City of Lakewood provided detailed assessment of potential recreational resource impacts by reallocation alternative.
- Analysis of recreational resource impacts will be performed in coordination with City of Lakewood.



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STUDY SCHEDULE

- September 2019 – Study start
- October 2019 – First Iteration Planning Meeting
- November 2019 – June 2021 – Study suspension requested by CWCB
- August 2021 – Second Iteration Planning Meeting
- October 2021 – Public Scoping Meeting
- November 2021 – Alternatives Milestone Meeting
- Schedule beyond November is to be determined, but study is expected to take approximately three years to complete.



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PUBLIC INVOLVEMENT

Provide your feedback regarding water supply reallocation, including:

- Potential benefits of reallocation.
- Potential impacts of reallocation.
- Potential study outcomes you would like to see realized or avoided.
- Any other aspects of study.

Mail or E-Mail Comments or Questions

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Technical Memorandum

Prepared for: Colorado Water Conservation Board

Project Title: Bear Creek Lake Water Rights

Project No.: 154220.002

Technical Memorandum

Subject: PRELIMINARY Future Operations Analysis

Date: September 21, 2021

To: Mr. Erik Skeie, Project Manager, Colorado Water Conservation Board

From: Meg Frantz, Modeling Task Manager
Zach Wengrovius, Project Engineer
Beth Albrecht, Project Engineer
Matt Lindburg, Project Manager

Copy to: Chris Fessaro, Rachel Schulz, Kathryn Seefus, U.S. Army Corps of Engineers (USACE)

Section 1: Introduction

The U.S. Army Corps of Engineers (USACE) is conducting a general investigation into feasibility of reallocating flood control space in Bear Creek Lake to other purposes. The Colorado Water Conservation Board (CWCB) is pursuing a junior water storage right that will utilize this space in Bear Creek Lake. The water right will serve multiple participants. In the analysis of the water right, each participant was assigned a portion of the water right according to their stated needs.

This memo describes a reservoir modeling effort by Brown and Caldwell to understand performance of individual storage pools with respect to participants' objectives, and to predict total reservoir content fluctuations. Brown and Caldwell and CWCB met with interested parties in the fall of 2018 to discuss their needs, the size of pool they were interested in, and to solicit operational information to incorporate into the model. The magnitude and rate of content fluctuation is of interest to the USACE as well as the City of Lakewood and its park managers. In addition, the model demonstrates pool size required to meet a minimum downstream flow requirement that is anticipated as a project mitigation requirement. Note that a specific, minimum downstream flow requirement has not yet been determined, and the required downstream flow rates used for the purposes of this analysis are likely conservative and are subject to future revision.

The purpose of this memo is to summarize and present model results for the total content of Bear Creek Lake. Operation and performance of individual participant pools is considered confidential information, so is not discussed in detail. Furthermore, USACE's interest is in overall operating levels and fluctuation rather than individual pool fluctuations.

Section 2: Description of Model

The model is a daily time step reservoir mass balance model implemented in Excel. The model includes historical inflows, downstream call records, evaporation losses, and lake levels, and it accounts for deliveries to downstream water rights and the current stage-storage-area relationship. The study period for the model is January 1986 through December 2016. The period includes both wet years (1995, 2015) and dry years, including the multi-year dry sequence 2000 through 2003. The period was selected based on availability of gage records used to estimate time series of total reservoir inflow.

Based on interest conveyed by potential partners, Bear Creek Lake was modeled with the operating pools listed in Table 1. The total amount of storage modeled for potential partners (including the Environmental Pool) is 16,965 AF. The model allows the participant pools to be used for storing senior water rights from sources outside of Bear Creek Lake and for storing unappropriated inflows to Bear Creek Lake under a new, junior storage water right.



Table 1. Bear Creek Lake Operating Pools	
Pool	Pool Size (AF)
Berthoud	3,000
Brighton	6,200
Dacono	3,000
Evergreen Metropolitan District	100
Foothills Park and Rec	65
Hidden Valley	50
Environmental Pool	4,550
Total of Participant Pools:	16,965
Historical Pool	varies

The Historical Pool refers to the combined historical contents in Bear Creek Lake, meaning water owned by CWCB, Lakewood, the dead pool, and at times, the flood pool. In the model, the Historical Pool is operated as it did historically, with all new participant operations added “on top” of the existing pool. The inflow that was stored in the reservoir during runoff events (i.e., when historical change in storage was positive) was not available to fill participant accounts. Sections below describe the logic applied by the model to place water in storage, release water from storage, and account for evaporation.

2.1 Storage of Participants’ Senior Water

Some participants own senior water rights from other sources that they wish to store and manage using Bear Creek Lake. At least one participant is planning on using reallocated space in Bear Creek Lake without participating in the new water right. Participants with senior water provided year-by-month estimates of yield that they would store in Bear Creek Lake.

Senior water right yield was added to each applicable owner’s storage account at the beginning of the time step, before junior water was allocated, subject to capacity of the account at that time. Storing a participant’s senior water diminished that participant’s remaining capacity in their account, but it did not reduce the total available inflow to be allocated among participants.

2.2 Allocation of Unappropriated Inflow

Unappropriated flow was developed outside the model from inflow time series (partially synthesized, particularly on Turkey Creek), bypass records and requirements, and daily call records. The model distributed the unappropriated inflow to participants with the objective of exercising the CWCB right to the fullest extent within volumetric limits of a fill and refill right and distributing water to participants in proportion to their ownership in the right. These two objectives are at times at odds with one another because the participant pools are depleted under different rates and patterns. If one participant pool has less available capacity than the participant’s pro-rata portion of the inflow, that participant’s excess portion of the water right should be available to other participants.

The model observed an annual fill limit of 16,900 AF and a refill limit of 16,900 AF for the junior right. November 1 was the beginning of the administrative year at which time available total storage volume was computed as the fill limit volume less the combined contents of participants’ accounts. This value was



decremented each day by the available inflow, whether or not it was stored, to simulate paper fill¹ of the decree when water is available but not appropriated.

The modeling logic for the annual fill limit counts all November 1 content as carryover, which is not correct to the extent that the accounts hold senior water on that day. Because Brown and Caldwell did not have enough information to operate (release) senior and junior water differently on behalf of participants, separate senior and junior accounts were not maintained in the model. The simplification may introduce error into a yield analysis, but error may be limited to the moderately wet year following a dry year or years. As participants develop more information about when and how they would use their various sources, the model can be refined.

It should be noted that some existing water rights decrees identify Bear Creek Lake as an alternate location to store senior water rights. However, to Brown and Caldwell's knowledge, only one water user (outside of the CWCB) currently has a contract with USACE for storing senior water in the reservoir. Operations of that water right would be reflected in the historical pool incorporated into the model. Other water rights that could be stored in Bear Creek Lake via their decrees were not represented in the model, because it is unknown whether contracts with USACE to store those rights will ever be sought. In addition, the CWCB has a water right for storage in Bear Creek Lake. This water right was not specifically operated in the model, because its operation is reflected in the historical pool.

2.3 Net Evaporation

Evaporation was computed based on Bear Creek Lake's surface area and daily net loss rates that CWCB currently uses for accounting pursuant to their water right (Colorado water court case no. 14CW3127). The net loss rate is calculated from gross monthly evaporation specified in a document entitled *Memorandum of Understanding Between the United States and the State of Colorado On Regulation of Bear Creek Dam and Reservoir (revised March 1988)* and average monthly precipitation, converted to daily values.

The area-capacity table used to calculate surface area was from the USACE Water Control Manual Bear Creek Dam and Reservoir (February 2018). At each time step, the model assigned a portion of total reservoir evaporation to each pool, in accordance with the pool content's portion of total reservoir storage at the time. Exception to this rule occurs when there is water in the historical flood pool, in which case evaporation is attributed entirely to the flood pool.

2.4 Reservoir Releases

At each time step, each pool released the lesser of available pool content and pre-determined demand, as provided by the participant. Demand at the reservoir for downstream users included the transit losses administered by the Water Commissioner, in addition to the contemplated delivery at the downstream diversion.

The historical pool was assumed to operate as it has in the past. Outflow was computed as the residual term in the mass balance of historical inflow, outflow, change in storage, and evaporation. After participant pool and historical releases and bypasses were determined or estimated, the model checked to see whether a minimum fish flow was met below Bear Creek dam. Colorado Parks and Wildlife (CPW) suggested that for the initial modeling, an instream flow demand of 15 cfs from April 1 through October 15 and 7 cfs from October 16 through March 31 be incorporated. This demand is subject to revision after additional fieldwork. When total outflows for all other purposes were below the minimum, the model allowed additional release from the

¹ When the owner of a storage right foregoes in priority water, the Division of Water Resources administrators typically count foregone water against the fill limit. This is referred to as a "paper fill".

environmental pool. The operation was included in this study to determine the pool size needed to meet the downstream flow rates suggested by CPW throughout the study period. The model was run iteratively to determine that a 4,550 AF pool was needed.

Section 3: Results

3.1 Model Results

Figure 1 shows the time series of inflow stored historically in orange, superimposed on total inflow stored in Bear Creek Lake. Accordingly, the indigo represents inflow stored in the reallocated pool for all participants in aggregate. This stored inflow includes water stored pursuant to the junior right as well as senior rights described in Section 2.1. Storage under senior rights represents a very small portion of the total amount stored. Monthly total inflow to storage is given in Table 2.

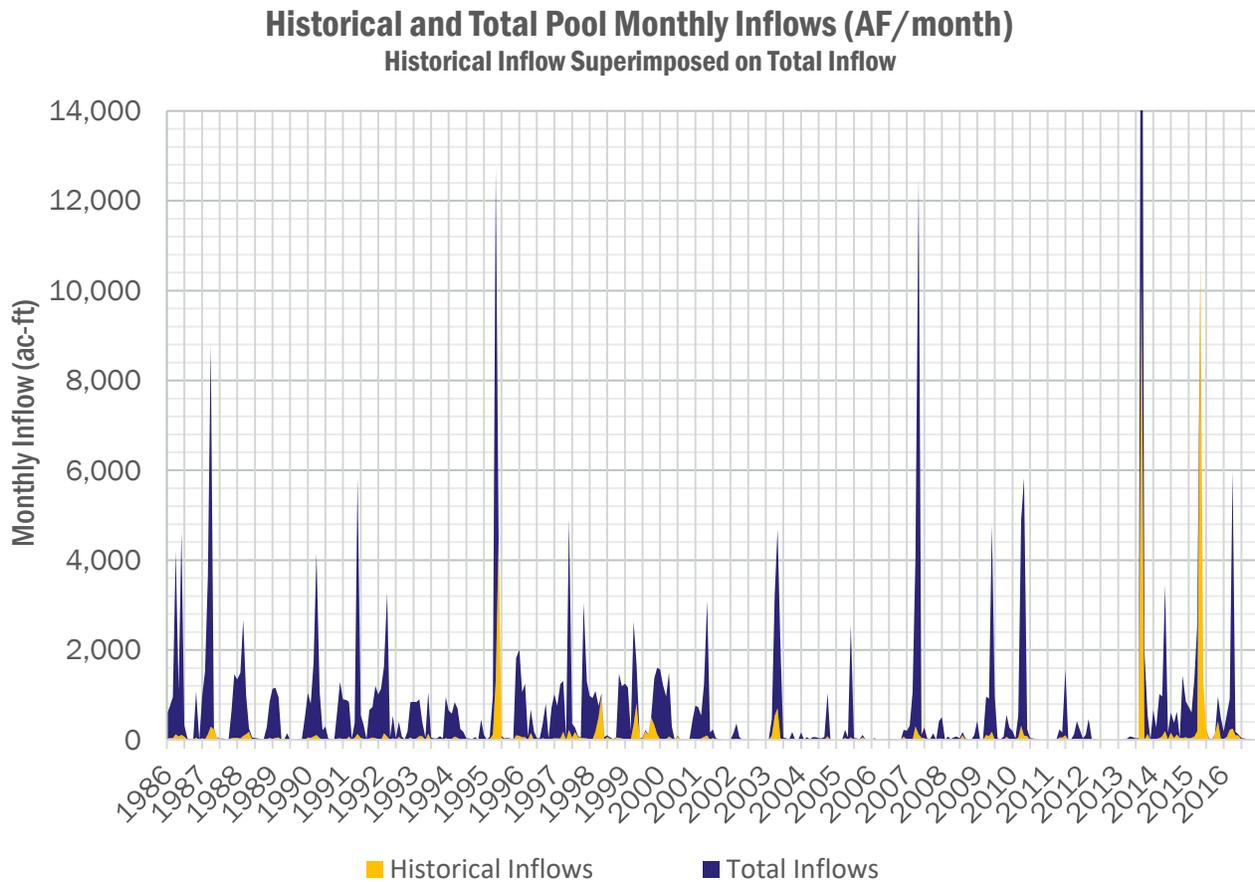


Figure 1. Monthly Inflow to Storage

Table 2. Monthly Total Inflow to Storage (AF)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1986	581	734	955	4,205	1,094	4,620	317	32	19	9	1,071	0	13,638
1987	976	1,523	3,637	8,813	251	64	28	31	18	9	631	1,461	17,443
1988	1,345	1,494	2,671	1,003	262	53	37	32	18	9	288	852	8,063
1989	1,134	1,160	946	19	12	149	3	8	2	18	17	524	3,993
1990	1,043	805	1,733	4,155	1,072	218	293	32	18	9	631	1,295	11,304
1991	903	888	844	30	379	5,819	548	338	18	664	732	1,202	12,365
1992	1,009	1,142	1,635	3,270	48	537	37	403	74	9	187	841	9,191
1993	845	844	905	409	53	1,058	53	31	30	81	31	951	5,291
1994	656	586	843	695	235	185	36	32	18	64	6	449	3,804
1995	110	6	71	980	12,710	4,503	81	36	49	34	15	1,821	20,415
1996	2,012	1,058	1,249	84	678	191	37	31	341	804	35	715	7,236
1997	1,017	764	1,243	1,306	50	4,923	357	276	87	56	3,050	1,305	14,434
1998	982	935	1,088	759	1,029	60	106	56	18	62	1,471	1,191	7,758
1999	1,248	1,165	206	2,630	1,698	57	39	217	127	510	1,378	1,603	10,878
2000	1,571	1,228	965	1,489	295	4	90	1	14	1	0	441	6,100
2001	759	729	544	1,235	3,091	168	230	39	19	9	1	0	6,822
2002	0	163	368	59	13	5	3	15	9	4	0	0	639
2003	0	2	466	3,217	4,692	2,115	56	31	21	171	5	0	10,777
2004	167	0	63	18	59	59	36	33	66	1,042	20	0	1,564
2005	0	0	4	222	58	2,548	38	32	19	112	1	0	3,034
2006	0	39	4	8	14	5	23	14	15	8	1	227	356
2007	203	317	1,053	4,024	12,515	118	274	31	18	143	1	415	19,112
2008	507	0	73	18	57	72	36	177	31	15	0	109	1,096
2009	425	0	4	958	915	4,778	977	31	19	74	554	272	9,008
2010	197	34	551	4,898	5,827	239	37	32	17	8	0	0	11,841
2011	0	0	5	8	229	165	1,563	14	14	127	418	213	2,755
2012	36	119	463	13	20	5	3	2	2	1	0	0	665
2013	0	2	4	23	75	60	36	43	24,319	1,990	567	2	27,121
2014	663	270	1,015	966	3,449	157	605	378	627	54	1,428	864	10,475
2015	731	603	1,362	2,545	10,619	1,292	246	30	18	141	968	494	19,049
2016	185	571	910	5,990	183	118	36	31	17	8	0	10	8,062
Avg	623	554	835	1,744	1,990	1,108	202	80	841	201	436	557	9,171

Figure 2 is a pool hydrograph for the historical pool superimposed on a hydrograph of the entire reservoir content. The reservoir critical period is from May of 1999 to May of 2007, during which content ranges from approximately 19,700 AF to 2,400 AF before returning to over 19,000 AF in storage.



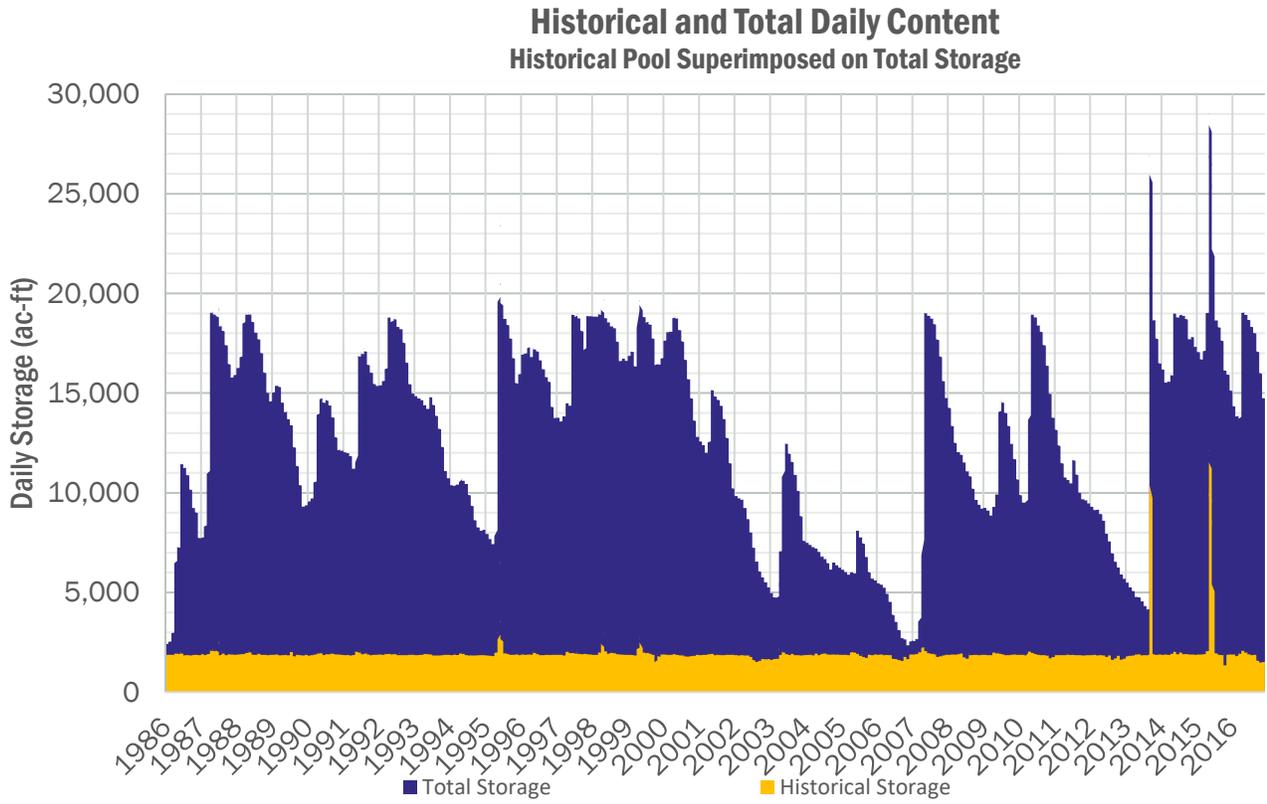


Figure 2. Daily Content

Figure 3 shows daily reservoir elevation:

Total Reservoir Daily Elevation

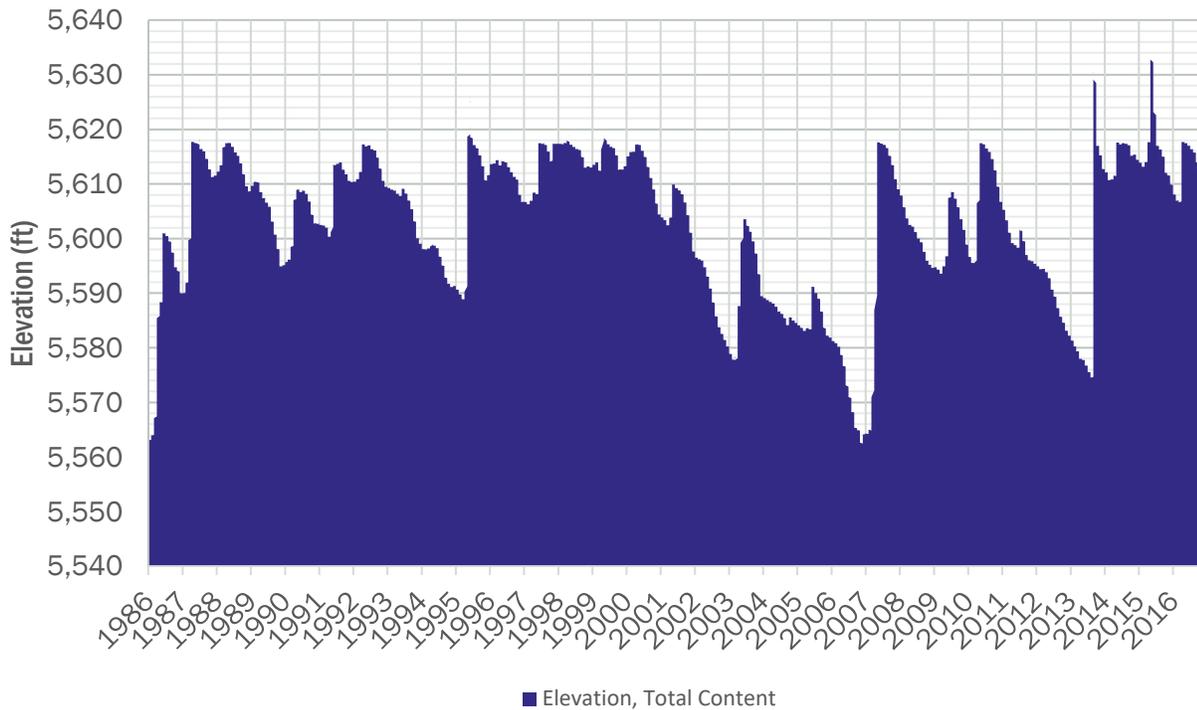


Figure 3. Daily Reservoir Elevation

3.2 Comments

- Water is available and stored generally between November and April or May. Storage is limited in summer months by lack of physical flow and downstream senior water rights.
- The model suggests a storage to yield ratio of 4.9:1 for the reallocated space.
- Storage to yield ratio and firm yield reflect not only variability but also sequential properties of both inflow to and outflow from a reservoir. If the inflow time series in this model was re-ordered, the yield would be affected. Said another way, a different set of inflows with the same mean and standard deviation as the modeled inflows would result in a different yield.
- Minimum total water in storage over the modeling period was approximately 2,340 AF.
- Within-year fluctuations are typically 10 feet or less, but when unappropriated winter and spring inflow is minimal, these 10-foot changes become additive. Water level fluctuations are frequently multi-year rather than seasonal.

References

- U.S. Army Corp of Engineers, Omaha, Nebraska. Water Control Manual Bear Creek Dam and Reservoir, South Platte River Basin Colorado. February 2018.
- Case No. 14CW3127. Findings of Fact, Conclusions of Law, Judgment and Decree of the Water Court. December 4, 2017.
- Memorandum of Understanding Between United States of America and the State of Colorado on Regulation for Bear Creek Dan and Reservoir. March 1988.