

Clear Creek Water Bank

Water Storage Reservoir Feasibility Study

9-Sites Evaluation

Clear Creek County, Colorado



October 2008

AG File No. 07-133

Prepared for:



401 Argentine Street
PO Box 2000
Georgetown, CO 80444


Prepared by:



Water Resource Advisors for the West
1499 W. 120th Ave., Suite 200
Denver, CO 80234
Phone: 303-452-6611
Fax: 303-452-2759
www.applegategroup.com

CERTIFICATION

I hereby certify this Water Storage Reservoir Feasibility Study for the Clear Creek County 9-Sites Evaluation prepared for Clear Creek County, Colorado was prepared by me or under my direct supervision.


Mike Applegate, PE
Registered Professional Engineer
State of Colorado No. 15791



FUNDING

This study was made possible from 1177 funding provided through the South Platte Basin Roundtable and approved by the Colorado Water Conservation Board.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
INTRODUCTION	3
GENERAL SITE INFORMATION.....	4
Environmental Due Diligence	5
Geologic Hazards.....	6
Permits and Regulations Applying to the Property	7
Dam Construction Options.....	9
Reservoir and Dam Sizing Summary	11
SITE SPECIFIC INFORMATION	12
(Lower) Bakerville Reservoir No. 1.....	12
(Upper) Bakerville Reservoir No. 2	13
Ball Placer	14
Clear Creek County Reservoir #2.....	15
Clear Creek County Reservoir #3.....	16
Clear Creek County Reservoir #4.....	17
Grizzly Gulch Reservoir.....	18
(Upper) Leavenworth Reservoir No. 1.....	19
(Lower) Leavenworth Reservoir No. 2	20
OPINION OF PROBABLE COST	21
Construction.....	21
Engineering	22
RANKING COMPARISON ANALYSIS	23
Criteria and Weights.....	23
Data.....	24
Scoring.....	25
Results	25
Discussion	27
Environmental Scenario.....	27
Construction-Conscious Scenario	27
CONCLUSIONS AND RECOMMENDATIONS.....	28
Ranking Observations.....	28
Recommendations	29

TABLE OF FIGURES

Appendix A: Bakerville #1

Vicinity map	Fig 1 of 5
Soils map	Fig 2 of 5
Wetland map	Fig 3 of 5
Floodplain map	Fig 4 of 5
Reservoir evaluation map	Fig 5 of 5

Appendix B: Bakerville #2

Vicinity map	Fig 1 of 5
Soils map	Fig 2 of 5
Wetland map	Fig 3 of 5
Floodplain map	Fig 4 of 5
Reservoir evaluation map	Fig 5 of 5

Appendix C: Ball Placer

Vicinity map	Fig 1 of 5
Soils map	Fig 2 of 5
Floodplain map	Fig 3 of 5
Geology map	Fig 4 of 5
Reservoir evaluation map	Fig 5 of 5

Appendix D: Clear Creek County #2:

Vicinity map	Fig 1 of 4
Soils map	Fig 2 of 4
Geology map	Fig 3 of 4
Reservoir evaluation map	Fig 4 of 4

Appendix E: Clear Creek County #3 & #4

Vicinity map	Fig 1 of 5
Soils map	Fig 2 of 5
Geology map	Fig 3 of 5
Reservoir evaluation map CCC #3	Fig 4 of 5
Reservoir evaluation map CCC #4	Fig 5 of 5

Appendix F: Grizzly Gulch

Vicinity map	Fig 1 of 5
Soils map	Fig 2 of 5
Wetland map	Fig 3 of 5
Floodplain map	Fig 4 of 5
Reservoir evaluation map	Fig 5 of 5

Appendix G: Leavenworth #1

Vicinity map	Fig 1 of 6
Soils map	Fig 2 of 6
Wetland map	Fig 3 of 6
Floodplain map	Fig 4 of 6
Geology map	Fig 5 of 6
Reservoir evaluation map	Fig 6 of 6

Appendix H: Leavenworth #2:

Vicinity map	Fig 1 of 6
Soils map	Fig 2 of 6
Wetland map	Fig 3 of 6
Floodplain map	Fig 4 of 6
Geology map	Fig 5 of 6
Reservoir evaluation map	Fig 6 of 6

Appendix I: MCDA Data tables

Appendix J: Supporting Documents

EXECUTIVE SUMMARY

Nine alternate water storage reservoir locations within Clear Creek County were evaluated as a part of the Basinwide Augmentation project (See Figure 1 County-wide Vicinity Map). This report is intended to provide Clear Creek County with an analysis of each specific location. In addition, the report also includes a multiple criteria decision analysis (MCDA) in order to rank the overall feasibility of each of the sites compared with one another. The findings in this report are preliminary in nature, requiring further study and fieldwork to confirm assumptions used. The comparison of the nine sites can be used to prioritize future phases of the project.

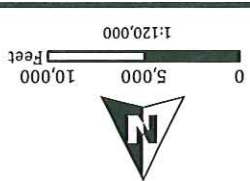
This study involved an analysis of each site for environmental risks, geologic hazards, permitting requirements, and engineering hurdles or design considerations. Site visits were performed to identify potential construction constraints. Generally, all sites appeared to have cobbly soils available with small rock outcrops and minimal topsoil. Aspects such as mapped soils, wetlands, threatened and endangered species, faults, land ownership, and access roads were investigated. Satellite topography was used to develop 2-foot contours of each site for dam layout, sizing and quantity estimates.

Two types of dam construction were considered: earthen dam with a clay core and roller compacted concrete (RCC). In future studies additional designs such as a rock fill geometry may be added if better information warrants consideration. Three of the sites appeared to have clay available from the soils maps and both dam options were considered. Preliminary opinions of probable cost were prepared to include dam and infrastructure design and construction. For the MCDA analysis tool, main and sub criteria were established with varying associated weighting factors. The results were compiled to give an overall ranking for the nine sites. The data used in the comparison analysis and corresponding results are included in Appendix I.

Bakerville Reservoir #1 was determined to be the most feasible site based on the results generated by the MCDA. This site ranked first numerous times under various weighting options. Clear Creek County Reservoir #3 was also determined to be a feasible site but one fatal flaw may be that a motor vehicle tunnel is currently proposed that may render the site unusable. Clear Creek County #4 was also determined to be a viable alternative as it could likely be constructed by possibly avoiding conflict with the tunnel.

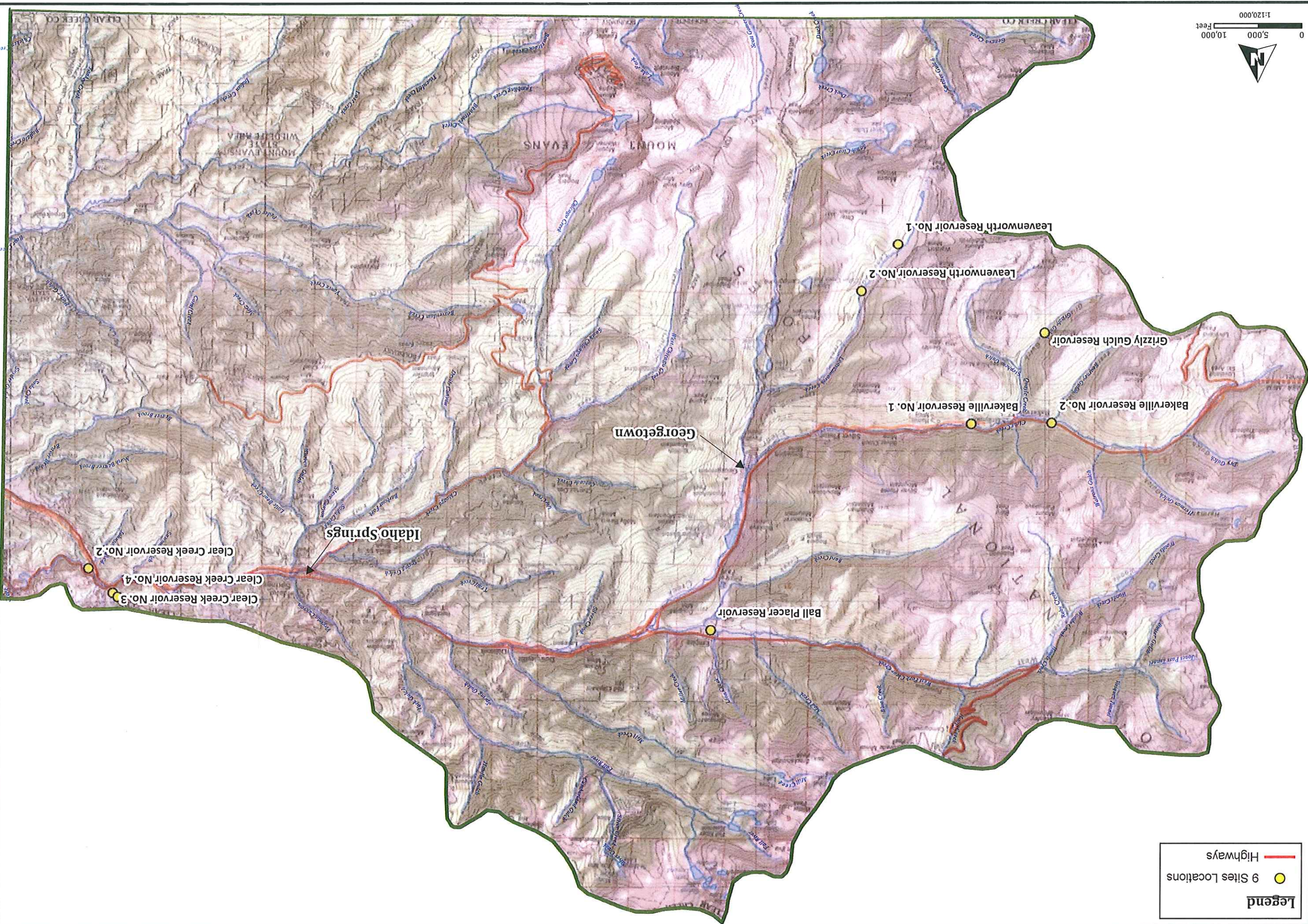
Some of the factors that eliminated the other sites from a better ranking were extent of permitting, land ownership, wetlands, and construction considerations such as access road, utility line relocations, and cost per acre-foot. Land ownership and wetland issues were two of the more negative items that caused sites to receive a lower ranking.

The next phase of this project should include initial discussions with regulating agencies to more formally identify the site-specific potential environmental impacts and necessary permits. Obtaining survey and geotechnical information would also be recommended for preliminary design. If multiple sites are selected by the County for further study, obtaining survey information or performing geotechnical testing for several sites at one time would likely result in a cost savings.



Legend

- 9 Sites Locations
- Highways



9 Sites Evaluation
Clear Creek County
County-wide Vicinity Map

Applegate Group, Inc.
Water Resource Advisors for the West
1499 West 120th Ave, Ste 200
Denver, CO 80234-2728
Phone: (303) 452-6611
Fax: (303) 452-2759
e-mail: info@applegategroup.com

Figure:

Date: 05-05-2008				
Job #: 07-133				
Drawn By: KNS				
No.	Rev. Date	Revision Description		

INTRODUCTION

This feasibility study is intended to provide a broad overview of potential issues related to developing future water storage reservoirs for 9 specific sites in Clear Creek County, Colorado. These reservoirs are being considered for incorporation into the Basinwide Augmentation plan that is being proposed by the County. The study areas for the proposed future reservoirs are referred to as Bakerville 1, Bakerville 2, Ball Placer, Grizzly Gulch, Leavenworth 1, Leavenworth 2, and Clear Creek County Reservoirs 2, 3 and 4. All of these potential reservoir sites are within Clear Creek County and are generally located in the northeast, north-central and southwest areas of the county. Specific site locations will be addressed in each site's detailed summary later in the report. It is our understanding that Clear Creek County would ideally like to use all 9 of the sites as future water storage reservoirs.

Clear Creek County has conditional water rights decreed and pending for the 9 sites to be used in the County's Basinwide Augmentation Plan. To date, the County has met the standards for initiating conditional water rights and the next step is to refine and focus the evaluation process. This work is part of the due diligence for development of the conditional water rights. The purpose of this study is to analyze each site for environmental risks, geologic hazards, engineering hurdles or design considerations, and rank each site to identify the most cost-effective alternatives.

Eight of the nine sites (all but Grizzly Gulch) were originally identified during a Reservoir Siting Analysis performed by WRC Engineering in 2002. All nine sites however were preliminarily analyzed based on 40-ft contours from the United States Geological Survey (USGS) Quadrangle maps. A more-detailed feasibility was later performed on the Ball Placer site by WRC Engineering in 2004. This included a 3-sheet preliminary plan set with site grading and a stage-storage curve for their proposed dam design. This current comparison study utilized satellite imagery to generate one-foot contours for each site to develop better site data for proposed dam alignments and dimensions.

This report outlines and discusses existing soil conditions, required permits and regulations applying to the site, environmental issues, possible reservoir configurations based on satellite topography, and an opinion of probable construction cost associated with creating a water storage reservoir at each site. Existing information was compiled from several sources including the United States Geological Survey (USGS), Colorado Geologic Survey (CGS), National Wetlands Inventory (NWI) Map, National Floodplain Insurance Program (NFIP) floodplain map, State Division of Wildlife (DOW), Natural Resources Conservation Service (NRCS), Environmental Protection Agency (EPA), and Clear Creek County supplied reports and GIS information. Meetings were held with the County to discuss issues that were considered critical. A conceptual site plan was prepared for each potential site to depict its approximate reservoir configuration.

Preliminary opinions of probable cost were formulated for each site to include dam construction, infrastructure, foundation preparation, access road, survey, geotechnical testing, and engineering. These estimates are preliminary in nature and were prepared using similar RCC and earth

embankment dams overall project cost per acre-foot or height of dam. The estimates prepared resulted in a cost/acre-foot which facilitated in the comparison analysis of the nine sites.

This report will apply a Multi Criteria Decision Analysis (MCDA) using the information gathered for this feasibility report. Meetings were held with the County in order to determine the most important issues and criteria weighting factors to be used in the MCDA model. The model will provide a numerical method of comparing each of the 9 site's feasibility against the other sites.

GENERAL SITE INFORMATION

The general site information section of this report will cover topics that apply to more than one of the sites. Site visits were performed for each of the 9 proposed reservoir locations as a part of this feasibility study. The site visits were used to identify potential issues like site constraints, site geology, possible wetlands, and other site specific conditions that should be considered. One of the possible issues found during the visits was that a number of the sites had power lines that ran in the vicinity of the proposed dam alignment. The visits also helped during the investigation of land ownership by verifying the actual locations of each site with the GIS land ownership information provided by Clear Creek County.

Table 1 – Land Ownership Information

Reservoir	Owner Information
Bakerville Reservoir No. 1	CLEAR CREEK COUNTY PO BOX 2000 GEORGETOWN, CO 80444
Bakerville Reservoir No. 2	USFS
Ball Placer	TOWN OF EMPIRE PO BOX 100 EMPIRE, CO 80438
Clear Creek County Reservoir No. 2	CLEAR CREEK COUNTY PO BOX 2000 GEORGETOWN, CO 80444
Clear Creek County Reservoir No. 3	CLEAR CREEK COUNTY PO BOX 2000 GEORGETOWN, CO 80444
Clear Creek County Reservoir No. 4	CLEAR CREEK COUNTY PO BOX 2000 GEORGETOWN, CO 80444
Grizzly Gulch	USFS
Leavenworth Reservoir No. 1	USFS
Leavenworth Reservoir No. 2	USFS

Much of the information found during the due diligence of the 9 sites environmental issues, such as required permits and regulations, and the modeling of each reservoir's material quantities and potential storage volumes, involves overlapping information of a more general nature. This section

will cover these topics in relation to all of the sites while more detailed, site-specific information will be covered in a later section.

ENVIRONMENTAL DUE DILIGENCE

Our environmental evaluation of the 9 sites included a site visit to each of the potential reservoir vicinities and review of available publications and mapped resources applicable to the project area. The work performed was not intended for use as a Phase I Audit. We reviewed existing information from the National Wetlands Inventory (NWI) maps, NRCS, and DOW to determine the potential environmental and ecological resources that may be affected by each project. Our review focused on Federal environmental requirements and applicable issues anticipated with the project.

A preliminary meeting with Jacobs Carter Burgess was held to discuss the Environmental Impact Statement for the proposed Gaming Area Access. Excerpts of their report were provided to us and the information within applied to the Clear Creek County Reservoirs No. 2, 3, & 4. This previous study reviewed existing soils, geologic information, hazardous materials, floodplains, wetlands, and wildlife. This report was reviewed and the results were consistent with our findings. The excerpts of this report are included in Appendix D.

WETLANDS

The NWI has mapped all of the areas surrounding each of the 9 proposed reservoir locations. Clear Creek County Reservoirs 2, 3 and 4 have no wetland designations related to any of the three locations and their surrounding areas (See Figure 3 in Appendices D and E). Bakerville Reservoirs 1 and 2 are both classified as R30WZ: Riverine Upper Perennial, Open Water Class, with Intermittently Exposed/Permanent water regimes (See Figure 3 in Appendices A and B). With this classification, we would not anticipate extensive wetlands impacts.

The areas within and surrounding Ball Placer Reservoir and Grizzly Gulch Reservoir are classified as P SS/EM C: Paulustrine, Scrub/Shrub and Emergent Class, with Seasonal water regimes (See Figure 3 in Appendices C and F). Leavenworth Reservoirs 1 and 2 are classified as P SS/EM B: Paulustrine, Scrub/Shrub and Emergent Class, with a saturated water regime (See Figure 3 in Appendices G and H). With the exception of Ball Placer, it is likely that the Army Corps of Engineers (Corps) would consider these wetlands jurisdictional.

The current decreed status of jurisdictional wetlands existing on each site would likely be determined through a wetlands survey and site visit accompanied by the Corps. They would be involved in determining if any isolated wetlands are present and would determine whether an Individual or Nationwide permit would be required. If wetlands issues do occur, the Nationwide Permit process would be preferred over the Individual.

FLOODPLAINS

Floodplains in relation to the proposed reservoir sites were investigated using both the FEMA Flood Insurance Rate Maps (FIRM) and Clear Creek County GIS data.

Four of the 9 proposed reservoir sites are within the floodplain. Leavenworth Reservoirs 1 and 2 are located within the Leavenworth creek floodplain (See Figure 4 in Appendices G and H). Bakerville Reservoirs 1 and 2 are located within the Clear Creek floodplain (See Figure 4 in

Appendices A and B). Neither floodplain is part of a detailed study, each floodplain is designated Zone A. Grizzly Gulch is also proposed as an on-channel dam and would likely have a floodplain associated with the gulch; however, this area is unmapped and floodplain delineation would likely be necessary.

THREATENED AND ENDANGERED SPECIES

Our review focused on federally listed species, since these are the main species that will be reviewed during Federal permitting processes (if necessary), and impacts to Federal species can trigger their own permitting requirements in certain situations. We have reviewed the list for threatened and endangered species at the state level listing Federal and State status¹ and the list of known or likely species in Clear Creek County².

Federally affected species were evaluated in cross-referencing these two lists. The species known to occur in the County (and their abundance) are as follows: Boreal Toad (Locally Common), Southwestern Willow Flycatcher (Rare), Greater Sandhill Crane (Unknown), American Perigran Falcon (Unknown), Lynx (Very Rare), Wolverine (Extirpated), Townsend's Big Eared Bat (Uncommon), Northern Pocket Gopher (Common), Midget Faded Rattlesnake (Rare).

It should be noted that both the Boreal Toad and the Northern Pocket Gopher are listed as Common species for the County. However, no indication of these species were noted in any of the information that was found for each site or during any of the site visits and we do not anticipate threatened and endangered species to be a fatal flaw to this project. We recommend verification with the Division of Wildlife and further investigation in the next phase to verify this assumption.

Membership with the South Platte Water Related Activities Program (SPWRAP) is recommended to develop any of these reservoir projects. SPWRAP represents water users' interests and is partnering with the State of Colorado to implement the Platte River Recovery Implementation Program (PRRIP) in central Nebraska. The Platte River Recovery Implementation Program allows streamlining of Endangered Species Act Section 7 compliance procedures. The PRRIP also provides an alternative to some of the requirements for historic and future water related activities and one for one replacement of depletions.

GEOLOGIC HAZARDS

Clear Creek County has a large amount of information concerning the history of the mines and other geological studies in the county. The County provided us with the GIS information and applicable reports that were very helpful in the review of the geological hazards on and surrounding the proposed reservoir locations. The Colorado Geological Survey Open-File Report 03-02 Geologic Hazards of the Georgetown, Idaho Springs, and Squaw Pass Quadrangles was obtained and reviewed. The information in this report was consistent in content and extent with the GIS information obtained from the County. A copy of this report and the two accompanying geologic maps are included in Appendix J. Although the information provided did not entirely encompass all of the sites, information can likely be extrapolated for any sites that are outside the study areas. Some of the potential geologic hazards slightly affecting the sites include debris flow areas, flood

¹ <http://wildlife.state.co.us/WildlifeSpecies/SpeciesOfConcern/ThreatenedEndangeredList/>

² <http://ndis.nrel.colostate.edu/>

areas, and rockfall areas and are discussed in the site-specific sections. Other more general hazards such as faults and unstable slopes are discussed in the following sections.

FAULTS

Faults that are located within the proximity of the proposed reservoir locations were researched using data from both Clear Creek County and the Colorado Geological Survey. The sites that appear to be within proximity of a fault, based on the information shown in Figure 5 of appendices D, G, E and H are Clear Creek County Reservoirs 1, 2 and 3, and Leavenworth Reservoir 2. It could also be inferred based on the locations and alignment of the faults shown on the information provided by Clear Creek County that the Ball Placer and Upper Leavenworth Reservoir No. 1 are likely to be located within the proximity of these faults. The classifications of the faults in the proximity of the reservoirs are identified as inferred, concealed and certain. The proposed Grizzly Gulch Reservoir site and both proposed Bakerville Reservoir sites are not located within the information provided by Clear Creek County. However, based on the trending for the locations of the faults shown in the Clear Creek County Data, it must also be noted that these three proposed sites could be located within the proximity of a fault.

UNSTABLE SLOPES

Only four of the proposed reservoir locations are within the Clear Creek County GIS information concerning unstable slopes. Of those four, only the proposed Clear Creek County Reservoir No. 2 site is located in an area that is specifically noted to have potentially unstable slopes. The proposed Ball Placer Reservoir location is in an area identified as a debris fan and the proposed Clear Creek County Reservoir No. 3 and No. 4 are located in an area with no indicated geological hazard.

PERMITS AND REGULATIONS APPLYING TO THE PROPERTY

COMPATIBILITY WITH SURROUNDING USES

With the exception of the Ball Placer Reservoir site, each of the nine proposed site locations is compatible with surrounding uses and no rezoning issues are anticipated. The Ball Placer Reservoir site lies within the boundaries of the Town of Empire. Based on research and discussions with the Town of Empire staff, the Ball Placer Reservoir site location may be intended for a different use (i.e. a park or similar use) upon reclamation of the Ball Placer mining operations. The Town of Empire staff was not aware of any permitting process for this type of land use and referred all questions regarding planning, zoning, and permitting directly to the Mayor. It is possible that the Town of Empire could default permitting issues to the County, or they may need to develop a process for reservoir permitting within the Town limits.

UNITED STATES FOREST SERVICE

Five of the proposed sites are located on USFS land: Leavenworth #1, Leavenworth #2, Grizzly Gulch Reservoir, Bakerville #1 and Bakerville #2. As a result, the USFS requires the project to undergo the County's special use review and authorization process. Part of this process requires coordination between USFS representatives and the applicant to determine site-specific permitting requirements and limitations. Although water storage and transmission guidance lies partially within Forest Service Manual (FSM) 7500, the FSM does not clearly define the permitting requirements and guidelines for water storage on USFS land (see FSM 7500 – Water Storage and Transmission Chapter 7520 – Dam Planning, Investigation, and Design). Therefore, the special use

permitting process will require increased communication and coordination between USFS staff and the applicant.

Typically water storage facilities located on Forest Service land either obtain a 30 year easement or a special use permit. Special use permits are issued in 20 year increments. The downside to these processes is that the conditions of the agreements can be modified during the renewal process after the 20 or 30 year time period has expired. Another option that has been used in other locations is a land exchange between the USFS and Clear Creek County. The uncertainty to this process is that it takes at least 3-5 years to complete (some land swaps can drag on for decades) and there is not a definite outcome.

WATERSHED PROTECTION ORDINANCE (WPO) BOUNDARY

Individual municipalities within Clear Creek County have enforced WPO boundaries to protect the town's water source. These municipalities include Idaho Springs, Georgetown, and Empire. The boundaries are established to include the watershed within 5 miles upstream of the city's intake structures. The Ball Placer site is downstream of the Town of Empire's intake structure and is therefore not affected by this permit. The WPO boundary established by Georgetown affects the Leavenworth No. 2 site and it will be necessary to obtain a permit through Georgetown for this site.

CLEAR CREEK COUNTY SPECIAL USE PERMIT (SUP)

A Clear Creek County Special Use Permit is required for long-term or permanent changes to the use of the land for all proposed sites in unincorporated Clear Creek County. Therefore, a Special Use Permit would not initially be required for the Ball Placer Reservoir because the site generally lies within the jurisdiction of the Town of Empire. It is possible that the Town of Empire could default permitting issues to the County, thereby enforcing a Special Use Permit. The remaining eight proposed sites would all be required to apply for a Clear Creek County Special Use Permit.

CLEAR CREEK COUNTY "1041 REGULATIONS"

"Clear Creek County Guidelines and Regulations for Matters of State Interest" apply to activities and areas located in the unincorporated areas of the county. Since the Ball Placer Reservoir site is generally located within the jurisdiction of the Town of Empire, these regulations may not apply. It is possible that the Town of Empire could default permitting issues to the County, thereby enabling 1041 Regulations to be applied. The remaining proposed sites are subject to this regulation. "1041 Regulations" require a pre-application conference with county staff. Based on the guidance set forth in the pre-application conference, the applicant is required to submit an application for review and public hearing. The "1041 Regulations" permitting process usually is processed concurrently with the Clear Creek County Special Use Permit process.

STATE ENGINEER'S OFFICE (SEO)

This agency regulates the use of surface and groundwaters of the state. A permit is required to expose groundwater to evaporation/consumption and a plan for the replacement of the evaporative loss or use of the groundwater is needed. Four of the nine sites are proposed to be off channel dams with an inlet structure from a predetermined diversion point. If any of these four dams (Clear Creek County Reservoirs 2, 3, and 4, and Ball Placer) expose groundwater, they will be required to have a liner sealing the reservoir from the groundwater system and a 90-day leak test will be required.

Any extraction of potential aggregates from the site could expose any present groundwater to evaporation and drawdown the water table in the vicinity. A well permit and substitute water supply plan (SWSP) would then be required during construction. The SWSP will remain in effect until construction is complete and approved by the SEO. It will be necessary to show that any potential drawdown will not affect adjacent well owners.

This agency also regulates water storage reservoirs throughout the State of Colorado. Reservoirs that store water above the natural ground surface and exceed one of the following criteria are under the SEO's jurisdiction: water surface area greater than 20 acres; water storage greater than 100 acre-ft; or having a normal high water surface greater than 10 ft from lowest point of *natural* ground. The reservoirs evaluated in this study would all be considered jurisdictional per the rules and regulations of the SEO. The requirements for submittals to the SEO vary with the size and Hazard Classification of the proposed storage facility. These dams would likely be considered Small or Large Dams with a Significant to High hazard classification. The submittal to the SEO will require a Hydrology Report, Hazard Classification Report, Design Report, Construction Plans, and Specifications.

U.S. ARMY CORPS OF ENGINEERS (CORPS)

In general, if a project affects less than ½ acre of wetlands, a Nationwide Permit from the Corps could authorize the work. If a diversion structure is placed on channel, the impacts are more likely to require an Individual Corps permit, which takes longer to obtain and involves more environmental review than obtaining a Nationwide Permit authorization. Due to the unique issues and concerns presented at each proposed site, a pre-application consultation with the Corps may be required in order to determine permit requirements, including the need for a permit, exemption to permits and type of permit.

In addition to permitting, the Corps also drives the NEPA process. Since each of the proposed sites has its own unique environmental issues and concerns, it is difficult to compare the time and costs associated with the NEPA process relative to the other proposed sites. Nevertheless, it is likely that each of the proposed sites will require an Environmental Impact Statement since each may alter or significantly affect the environment.

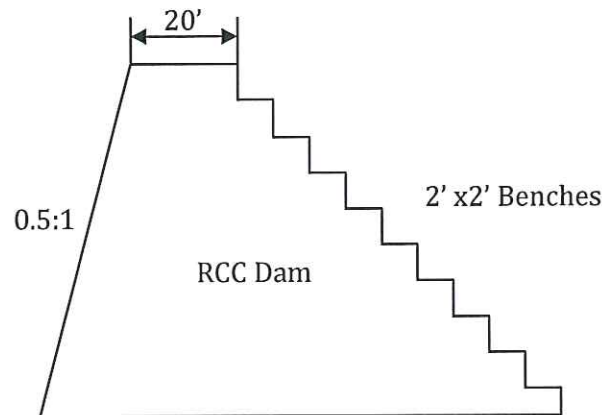
DAM CONSTRUCTION OPTIONS

From the site visits performed and the review of the soils maps, it is likely that construction of roller compacted concrete (RCC) dams on most sites is feasible. The soil types are generally gravels and sands with some cobbles, which were assumed to be suitable for the RCC aggregate (see Soil Tables located in each sites appendix). After the sites are prioritized and ranked based on the above information, the next phase of this project will include a recommendation for geotechnical testing to verify this assumption, among others.

RCC dams are essentially concrete dams that are constructed by compacting a very lean zero slump concrete mixture using a vibrating drum in 1 foot lifts. The structural qualities of an RCC dam are very similar to that of a standard concrete dam with a small number of differences. Most of the differences in design have to do with a reduction of shear and tensile strength at the location of each lift joint. As a result, the designs could require a greater minimum crest width of the gravity section. Another difference comes from using a concrete mix that has zero slump. This means that

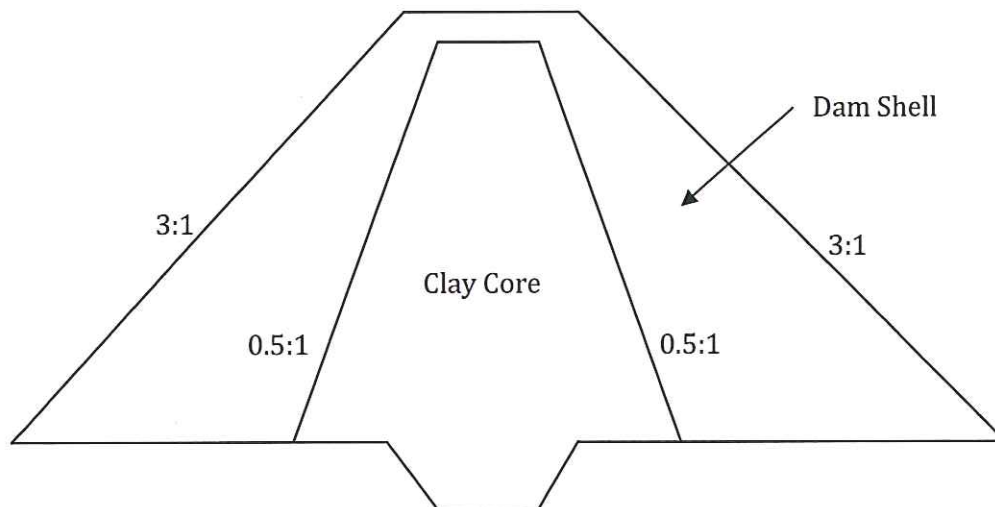
the concrete has low moisture content and provides less availability for shaping of small scale features and often have exposed, rough, and unformed surfaces. In some cases facing concrete can be used in combination with RCC to form a smoother and weather resistant surface.

An advantage of the RCC dams for these sites would be the ability to utilize on site materials via aggregate processing and potentially an onsite batch plant in order to produce the concrete and possibly reduce the cost (see RCC cross section below). The volume of material is a factor in the unit cost of RCC because of the costs involved in mobilizing a portable batch plant to a remote site.



Three of the sites had significant clay amounts listed in the mapped soils units. For these sites, a dam option for a clay core was also included. This option used the assumptions that the onsite clay quality was suitable for use in the clay core and that the remaining onsite soil quantity and quality was suitable for the shell of the dam. General cut and fill volumes were estimated for the clay core using an average depth of the clay within the inundation area.

For the Ball Placer site, we used the assumption that an earth embankment dam would be the best option. An RCC option would result in a large gravity dam which is rather long for its height. The previous study on Ball Placer suggested the use of a synthetic liner while using the mine tailings in the dam embankment. Although many options are available to build a dam and seal a reservoir, our past experience has resulted in some mixed reviews on the use of synthetic liners in jurisdictional dams. The State Engineer's Office Dam Safety branch does not generally accept the use of synthetic materials in a dam embankment such as geotextiles. Relying on a synthetic material as an impervious barrier could result in dam safety problems if a material tear and subsequent leak developed. Also, it is our professional opinion to recommend not using the mine tailings in the dam embankment as a structural element. For the purposes of this study, the assumption of the embankment dam allowed us to more accurately compare the Ball Placer site to the other eight options. Our assumptions included hauling the mine tailings material off site and importing clay material for use in a dam core. The mapped soils information listed a significant alluvial deposit on the Ball Placer site. For consistency in our comparison analysis we assumed that once the mine tailings were removed, this on site soil may be used for the dam shell (see clay core detail below).



RESERVOIR AND DAM SIZING SUMMARY

ArcGIS software was used to calculate the storage feasibility for 8 of the 9 proposed reservoir sites located in Clear Creek County. The general vicinity locations of the 9 sites are sourced from the water rights storage decree that was previously filed. Each location was then analyzed using aerial photography and two foot contours to determine that best dam location for maximizing the site-specific reservoir storage potential, within a couple hundred feet upstream or downstream. The contour information was generated from elevation data obtained from satellites that are administered by the United States Geological Survey (USGS). The generated contours generally lined up with the mapped USGS contours with the exception of the Ball Placer site. The accuracy in generating these contours is within ± 10 feet for vertical elevations, but also depends on the decade in which the satellite imagery was taken.

Shifting the location of the dam sites could potentially affect the current water court decrees slightly. The County may need to amend the location of the proposed dam in a diligence application.

Once the dam location was determined, an alignment was chosen with the goal of developing the most storage the site could economically hold. The reservoir stage storage curve was developed for a volumetric versus elevation comparison. The reservoir and dam sizing was then calculated to the decreed storage amount and a five-foot freeboard was added to the dam. The proposed dam heights were based on the GIS generated contours and were established from existing grade. The assumption of using the onsite material in the dam embankments was not tied into this volume calculation. No grading of excavated material was performed in the GIS analysis. The freeboard height estimate is based on typical dam safety requirements of the Colorado Division of Water Resources for jurisdictional dams.

Table 2 below summarizes the proposed dam dimensions based on this analysis utilizing refined topography. For comparison, the preliminary dam heights and lengths from previous studies based on USGS 40-ft contours are included in the table.

Table 2 – Revised Dam Dimensions

	Site	Stream	Location of Dam*	Previous Dam Height (ft)*	Previous Dam Length (ft)*	Previous Surface Acres*	Estimated Storage (AF)*	Proposed Dam Height (ft)	Proposed Dam Length (ft)	Proposed Surface Acres	Dam Crest Elevation
1	Bakerville Reservoir No. 1	Clear Creek	NW 1/4 NE 1/4 S21, T4S, R75W	30	470	5.3	70	18	534	7.1	9640
2	Bakerville Reservoir No. 2	Clear Creek	S19, T4S, R75W	40	480	5.9	80	23	557	7.6	9896
3	Ball Placer Reservoir	feeds West Fork Clear Creek	NE1/4 SW 1/4 S28, T3S, R74W	30	900	7.3	110	30**	900**	7.3	8573
4	CCC Reservoir No. 2	Johnson Gulch	NE 1/4 NE 1/4 S3, T4S, R72W	55	300	1.6	30	56	228	1.7	7326
5	CCC Reservoir No. 3	feeds Clear Creek	SW 1/4 NW 1/4 S34, T3S, R72W	70	400	3.5	65	56	268	2.9	7364
6	CCC Reservoir No. 4	feeds Clear Creek	SW 1/4 NW 1/4 S34, T3S, R72W	70	350	3	55	58	366	2.8	7468
7	Grizzly Gulch	Grizzly Gulch	NW 1/4 NW 1/4 S32, T4S, R75W	50	700	16	400	66	804	20.2	10776
8	Leavenworth No. 1	Leavenworth Creek	S2, T5S, R75W	45	1050	9.5	155	42	1070	10.4	11429
9	Leavenworth No. 2	Leavenworth Creek	SW 1/4 SW 1/4 S36, T4S, R75W	45	850	10.3	160	40	837	9.5	11056

* Taken from WRC Reservoir Siting Analysis

** Taken from Draft Feasibility Study by WRC February 2003

SITE SPECIFIC INFORMATION

(LOWER) BAKERVILLE RESERVOIR NO. 1

SITE DESCRIPTION

The proposed Bakerville Reservoir No. 1 site is approximately one mile east of the Bakerville exit on Interstate 70 (I-70), it is located along Clear Creek just south of I-70 between the Interstate and Silver Valley Road, which is also the I-70 frontage road. Clear Creek County is the landowner, although a portion of the site also falls within the I-70 Right of Way. The site is located in the NW¼ NE ¼ of Section 21, Township 4 South, Range 75 West of the 6th P.M. (See Figure 1, Appendix A) Site access is best via the frontage road and a short steep road will likely be needed for access off the frontage road. A portion of this reservoir lies within the CDOT Right-of-Way (ROW) and could be impacted by any future expansion of the interstate.

The site is a marshy area along Clear Creek with soft, organic earth on the surface on the southern shore. Dense forest exists along the southern shore of the stream and the streambed is very gravelly with cobbles. A site visit revealed a nearby gravelly ridge or bench between the creek and the frontage road which implies that hard rock could likely be found at shallow depths in this area.

DESIGN AND OPERATION CONSTRAINTS

Design constraints affecting this site include, but may not be limited to, the following:

- The Right of Way for the interstate and the frontage road limits the reservoir to a smaller size than the water rights decree.
- Any encroachment in a Federal right-of-way such as I-25 would likely require an Environmental assessment or impact statement to allow such use.
- Existing overhead power lines on both the interstate and the frontage road, no relocation anticipated.
- The density of the vegetation on site may cause problems for the survey equipment and therefore require an aerial survey.

DESIGN SPECIFICS

- Dam Crest Length: 534 Ft
- Dam Crest Elevation: 9640 Ft
- Reservoir Surface Area: 7.1 Acres
- Max Dam Height: 18 Ft
 - Does not include any freeboard
 - Including 5 feet of freeboard would limit the reservoir size by approximately 25% less than previously calculated
- Max Storage: 68 Ac-Ft
 - This does not reach the decreed storage target of 70 Ac-Ft

SOILS

There were three soil types shown on the NRCS map CO653 in the general area of the proposed reservoir (See Figure 2, Appendix A). Two of the soils are described as Rock Outcrop, these makes up the north and south side of the proposed site have a map symbol of 52 and 54. Likely, this is the area that was observed as the gravel ridge between the Creek and the Frontage Road during the site visit. The second soil type has a map symbol of 62 and is mostly made up of Loam, Clay, sand and some gravel. This soil is in the NRCS Hydrologic Group B/D, which is typically a more impervious soil type (See Table A-1, Appendix A, for detailed soil information).

(UPPER) BAKERVILLE RESERVOIR NO. 2

SITE DESCRIPTION

The proposed Bakerville Reservoir No. 2 site is approximately one mile west of the Graymont exit on Interstate 70 (I-70). The proposed site is located on Clear Creek just south of I-70 between the Interstate and a dirt bike path (See Figure 1, Appendix B). United States Forest (USFS) is the land owner, although the I-70 Right of Way is in close proximity. Access to the site is currently via the relatively new bike trail, no motorized vehicles are currently allowed on the trail and portions of it are located on Forest Service land.

A site visit revealed a piezometer field located on the south side of the creek approximately 500 ft downstream of the proposed reservoir site. The excavated mountainside to the south of the piezometers is gravelly and cobbly and appears to be an old borrow area that is eroding. The site visit also showed significant flows within Clear Creek and soft organic surface soils located in a dense forested cover. Improvements have been made to the channel in this area in the form of rock drops and armoring along the banks of the channel.

The bike trail also provides access to nearby dispersed campsites. The trail then continues along past the campsites and over a bridge that spans Kearney Gulch approximately 30 ft above Clear Creek.

DESIGN AND OPERATION CONSTRAINTS

Design constraints affecting this site include, but may not be limited to, the following:

- The Right of Way for the interstate and the frontage road results in sizing limitations.
- Existing overhead power lines on the interstate, relocation may be necessary.

- The density of the vegetation on site may cause problems for the survey equipment and require an aerial survey.
- Bike path and bridge would likely need relocated to obtain the entire decreed storage volume.

DESIGN SPECIFICS

- Dam Crest Length: 557 Ft
- Dam Crest Elevation: 9896 Ft
- Reservoir Surface Area: 7.6 Acres
- Max Dam Height: 23 Ft
 - Includes 5 feet of freeboard
- Max Storage: 80 Ac-Ft
- Portion of site falls within CDOT ROW for 1-70
 - Not as big of an issue as Bakerville No. 1
- Most likely could obtain decreed storage but would require relocation of pedestrian trail and bridge.

SOILS

There were two soil types shown on the NRCS map CO645 in the general area of the proposed reservoir (See Figure 2, Appendix B). One of the soils has a map symbol of 7103A, which is mostly made up of sands, loams and silts. This soil is in the NRCS Hydrologic Group D, which is typically a more impervious soil type. The second soil type has a map symbol of 7201B and is mostly made up of sand, gravel, loam and some boulders. The soil is in the NRCS Hydrologic Group A, which is typically a more pervious soil type (See Table B-1, Appendix B, for detailed soil information).

BALL PLACER

SITE DESCRIPTION

The proposed Ball Placer Reservoir site is located in the town of Empire, Colorado. This site has an extensive feasibility study that was completed by WRC Engineering in February 2003 (Feasibility Study for Ball Placer Reservoir). The WRC study has been included in Appendix C of this report for reference. This study was developed using more accurate site topography and proposed grading plans were prepared to include cut and fill quantities. Because of this level of detail, the GIS analysis of updating the site's reservoir volume, surface area, dam height and length was not performed. The parameters for Ball Placer were used from the previous feasibility study.

The following is a brief list of a portion of the information highlighted in the Ball Placer Report.

- The site has been previously disturbed and existing site conditions include mine tailings from an old gold mining operation.
- No significant wetland impacts are anticipated for this site.
- The potentially hazardous materials in the mine tailing could be cause for environmental concerns.
- The preliminary reservoir statistics in the Ball Placer study show a capacity of 110 acre-ft with a surface area of 7.3 acres and a 900 ft long dam with a maximum height of 30 ft.

The Town of Empire staff was not aware of any specific permitting process for this type of land use and referred all questions regarding planning, zoning, and permitting directly to the Mayor. It is possible that the Town of Empire could default permitting issues to the County, thereby enabling the use of 1041 Regulations and Special Use Permit, or they may need to develop a process for reservoir permitting within the Town limits.

DESIGN SPECIFICS

- Dam Crest Elevation: 8573 Ft
- Reservoir Surface Area: 6.6 Acres
- Max Dam Height: 32 Ft
 - Includes 5 feet of freeboard
- Max Storage: 110 Ac-Ft

SOILS

There were three soil types shown on the NRCS map CO653 in the general area of the proposed reservoir. The first soil makes up the majority of the reservoir area indicated on the Ball Placer Soil Map (See Figure 2, Appendix C). The soil has a map symbol of 1, which is defined as Mine Dumps consists of fragmented material. This was to be expected as the site visit showed a large amount of mine tailings in the vicinity of the proposed reservoir site. One of the soils has a map symbol of 27, which is mostly made up of Gravel, sand and loam. The second soil type has a map symbol of 28, which is mostly made up of Gravel, sand and loam. Both soils are in the NRCS Hydrologic Group A, which is typically a more pervious soil type (See Table C-1, Appendix C, for detailed soil information). Aside from the mapped soil units, the Ball Placer site also contains a significant amount of mine tailings. The previous studies on the Ball Placer site included testing of the tailings to identify depth and metal content. The depths ranged from 3-4 feet along the north and up to 25 feet in areas along the south.

CLEAR CREEK COUNTY RESERVOIR #2

SITE DESCRIPTION

The proposed Clear Creek County Reservoir No. 2 site is located approximately 1 mile southeast of the I-70 and Colorado State Highway 6 (HWY-6) overpass (see Figure 1, Appendix D). There is a concrete or asphalt business located at the confluence of Johnson Gulch and Clear Creek, which is directly below the proposed site and is likely the best option for access to the site.

For the purpose of the site visit, the guardrail of the frontage road for I-70 had to be crossed. The terrain east of the guardrail is steep, with 2:1 or 1:1 slopes. The area is heavily vegetated and there are a large number of cottonwood trees in the bottom of Johnson Gulch. Overhead power lines, with single wooden power poles, run down the Gulch just above the creek.

DESIGN AND OPERATION CONSTRAINTS

Design constraints affecting this site include, but may not be limited to, the following:

- Access to the site could be difficult unless an agreement can be reached with the land owner near the bottom of the gulch.
- The overhead power lines that run down Johnson Gulch will need to be relocated.

- The density of the vegetation and slope of the terrain suggest that survey will most likely need to be taken from the air.

DESIGN SPECIFICS

- Dam Crest Length: 228 Ft
- Dam Crest Elevation: 7326 Ft
- Reservoir Surface Area: 1.7 Acres
- Max Dam Height: 56 ft
 - Includes Freeboard
- Max Storage: 30 Ac-Ft
 - Meets Decree
- Other:
 - This site is close to maximum storage potential. Additional fill would be needed on the east abutment for increased storage capacity.
 - It is uncertain if there is sufficient flow on Johnson Gulch to fill this reservoir. A gravity diversion or pump station off of Clear Creek may be needed.

SOILS

There was one soil type shown on the NRCS map CO653 in the general area of the proposed reservoir (See Figure 2, Appendix D). The soil has a map symbol of 48 and is mostly made up of Loam, sand and weathered bedrock. This soil is in the NRCS Hydrologic Group D, which is typically a more impervious soil type (See Table D-1, Appendix D, for detailed soil information).

CLEAR CREEK COUNTY RESERVOIR #3

SITE DESCRIPTION

The proposed Clear Creek County Reservoir No. 3 site is located approximately 0.1 miles northeast of the I-70 and Colorado State Highway 6 (HWY-6) overpass (see Figure 1, Appendix E). There is a restaurant establishment called Kermit's located directly below the proposed site. Access to the site could be possible next to Kermit's but the establishments' building and property blocks the easiest access point. There is an old, re-vegetated road to the north of the site but it would need extended south to access the site.

A site visit revealed that the area above the proposed reservoir site appears to have undergone some reclamation and there is a small, maintained metal shack in this general area. It does not appear that this will have an impact on the proposed site. It was also noted that the valley between the east and west mountains is relatively steep with 1:1 or 0.5:1 side slopes.

DESIGN AND OPERATION CONSTRAINTS

Design constraints affecting this site include, but may not be limited to, the following:

- Access to the site would require extending the existing road south or constructing a new road around Kermit's.
- The density of the vegetation and slope of the terrain suggest that survey will most likely need to be taken from the air.
- This site is also the location of the proposed Black Hawk tunnel, currently in design phase.

DESIGN SPECIFICS

- Dam Crest Length: 268 Ft
- Dam Crest Elevation: 7364 Ft
- Reservoir Surface Area: 2.9 Acres
- Max Dam Height: 56 Ft
 - Includes Freeboard
- Max Storage: 65 Ac-Ft
 - Meets Decree
- Other:
 - Could double storage capacity by adding 16 feet to the dam height
 - Off channel reservoir; would likely require a pump station off of Clear Creek.

SOILS

There were two soil types shown on the NRCS map C0653 in the general area of the proposed reservoir (See Figure 2, Appendix E). One of the soils has a map symbol of 5 and is mostly made up of shallow deposits of gravel, sand and loam over unweathered bedrock. This soil classification also includes rock outcrops and is in the NRCS Hydrologic Group D, which is typically a more impervious soil type. The second soil type has a map symbol of 35 and is mostly made up of Loam, sand and gravel. This soil is in the NRCS Hydrologic Group B, which is typically a more impervious soil type (See Table E-1, Appendix E, for detailed soil information).

CLEAR CREEK COUNTY RESERVOIR #4

SITE DESCRIPTION

The proposed Clear Creek County Reservoir No. 4 site is located just up the western drainage from the proposed Clear Creek County Reservoir No. 3 site (see Figure 1, Appendix E). Access to the site could be possible via an old, re-vegetated road north of the site that used to extend relatively close to the proposed dam site. It was also noted that the valley between the east and west mountains is relatively steep with 1:1 or 0.5:1 side slopes.

DESIGN AND OPERATION CONSTRAINTS

Design constraints affecting this site include, but may not be limited to, the following:

- The density of the vegetation and slope of the terrain suggest that survey will most likely need to be taken from the air.
- This dam location could be slightly affected by the proposed Black Hawk tunnel.

DESIGN SPECIFICS

- Dam Crest Length: 366 Ft
- Dam Crest Elevation: 7468 Ft
- Reservoir Surface Area: 2.8 Acres
- Max Dam Height: 58 Ft
 - Includes Freeboard
- Max Storage: 55 Ac-Ft
 - Meets Decree

- Other:
 - Could double storage capacity by adding 16 feet to the dam height
 - Off channel reservoir; would likely require a pump station off of Clear Creek.

SOILS

There were two soil types shown on the NRCS map CO653 in the general area of the proposed reservoir (See Figure 2, Appendix E). One of the soils has a map symbol of 5 and is mostly made up of shallow deposits of gravel, sand and loam over unweathered bedrock. This soil classification also includes rock outcrops and is in the NRCS Hydrologic Group D, which is typically a more impervious soil type. The second soil type has a map symbol of 35 and is mostly made up of Loam, sand and gravel. This soil is in the NRCS Hydrologic Group B, which is typically a more impervious soil type (See Table E-2, Appendix E, for detailed soil information).

GRIZZLY GULCH RESERVOIR

SITE DESCRIPTION

The proposed Grizzly Gulch Reservoir site is located approximately 2 miles south of the Bakerville – I-70 exit on Stevens Gulch Road (see Figure 1, Appendix F). Stevens Gulch Road is the only likely candidate for access to the proposed reservoir site.

A site visit revealed that the road is wide enough for construction equipment most of the length. A few switchbacks may need improvement and the entire length would need 6" of road base (estimated) for construction equipment as well as some grading where erosion has damaged the road. Approximately 1 mile up the road, a turnoff to the west is taken and another access road, narrow in sections, is followed for 1.3 miles. Upgrades such as a bridge, widening and grading would be necessary for construction equipment in the upper lengths of the road. It was also determined that the site is on Forest Service and private land.

The road appears to pass through one or two tracts of private land. A house, along the upper portion of the road, appears well taken care of and probably used regularly. Past the proposed dam site, potentially within the inundation boundary, an existing building was identified on the quad map. This building was not seen on the site visit and appears to be gone although the jeep trail continued, eventually becoming a foot trail.

The flow in the gulch was estimated at approximately 4 cubic feet per second (cfs). The wide valley bed is bordered by dense forest on the east and west that will likely be inundated if a dam is built. Some dispersed campsites exist on site and a camping/fishing agreement could be investigated with the forest service. Also, many willows exist in the wide valley bed along Grizzly Gulch. These willows are likely to be a part of the P SS/EM C classification noted in the General Site Information section. With this classification, it is likely that there will be significant wetlands impacts for this site.

DESIGN AND OPERATION CONSTRAINTS

Design constraints affecting this site include, but may not be limited to, the following:

- Access to the site could be difficult and will require a significant amount of work.
- The density of the vegetation and slope of the terrain suggest that survey will most likely need to be taken from the air.

- Dense forest, a popular jeep trail, and dispersed campsites could likely be inundated by the proposed reservoir.
- Due to the high elevation of the site winter access would likely be restricted to snowmobiles.

DESIGN SPECIFICS

- Dam Crest Length: 804 Ft
- Dam Crest Elevation: 10776 Ft
- Reservoir Surface Area: 20.2 Acres
- Max Dam Height: 66 Ft
 - Includes Freeboard
- Max Storage: 400 Ac-Ft
 - Meets Decree
- Other:
 - Could double storage capacity by adding 20 feet to dam height
 - 100 ft tall dam could store up to 1500 ac-ft

SOILS

There were three soil types shown on the NRCS map CO645 in the general area of the proposed reservoir (See Figure 2, Appendix F). The first soil has a map symbol of 7201C and is mostly made up of loam, silt, sand and gravel. This soil is classified in the NRCS Hydrologic Group A, which is typically a more pervious soil type. The second soil type has a map symbol of 7103A and is mostly made up of loam, silt, sand and some gravel. This soil is classified in the NRCS Hydrologic Group D, which is typically a more impervious soil type. The third soil type has a map symbol of 7201B and is mostly made up of loam, sand and some gravel. This soil is classified in the NRCS Hydrologic Group A, which is typically a more pervious soil type (See Table F-1, Appendix F for detailed soil information).

(UPPER) LEAVENWORTH RESERVOIR NO. 1

SITE DESCRIPTION

The proposed Upper Leavenworth Reservoir No. 1 site is located approximately 6 miles south of Silver Plume, Colorado (See Figure 1, Appendix G). Access to the west side of the proposed site is via a single car wide rough road with tight switchbacks. There is an existing two track path that could potentially access the proposed reservoir site from the main road but it would need improved. The entire site is located on Forest Service land.

A site visit revealed mine tailings on the north and west of the site where the Waldorf Mine is illustrated on the quad map. A miner's cabin near the east abutment still looks somewhat maintained. During the site visit, it was also noted that the creek had significant flows and that many willows exist in the wide valley bed along Leavenworth Creek. These willows are likely to be a part of the P SS/EM B classification noted in the General Site Information section. With this classification, it is likely that there will be significant wetlands impacts for this site.

DESIGN AND OPERATION CONSTRAINTS

Design constraints affecting this site include, but may not be limited to, the following:

- Access to the site could be difficult and may require a significant amount of work.
- Large overhead power lines with three metal towers run through the site and are potentially in close proximity of the eastern abutment of the dam.
- Due to the high elevation of the site winter access would likely be restricted to snowmobiles.

DESIGN SPECIFICS

- Dam Crest Length: 1070 Ft
- Dam Crest Elevation: 11429 Ft
- Reservoir Surface Area: 10.4 Acres
- Max Dam Height: 42 Ft
 - Includes Freeboard
- Max Storage: 155 Ac-Ft
 - Meets Decree
- Other:
 - Could double storage by adding about 10 feet to the dam height
 - 100 ft tall dam could store up to 2100 ac-ft

SOILS

There were two soil types shown on the NRCS map C0645 in the general area of the proposed reservoir (See Figure 2, Appendix G). The first soil has a map symbol of 8101B and is mostly made up of loam, sand and cobble. This soil is classified in the NRCS Hydrologic Group D, which is typically a more impervious soil type. The second soil type has a map symbol of 7201B and is mostly made up of loam, sand and gravel. This soil is classified in the NRCS Hydrologic Group A, which is typically a more pervious soil type (See Table G-1, Appendix G, for detailed soil information).

(LOWER) LEAVENWORTH RESERVOIR NO. 2

SITE DESCRIPTION

The proposed Lower Leavenworth Reservoir No. 2 site is located approximately 4 miles south of Silver Plume, Colorado and would be just downstream of the proposed Leavenworth Reservoir No. 1 (See Figure 1, Appendix H). Access to the west side of the proposed site is via a single car wide, rough road with several tight switchbacks and a 4X4 side road off the main road. The entire site is located on Forest Service land.

Large overhead power lines with three towers are located along the access road and might be able to provide power to the site but should not be an issue with the height of the proposed dam.

During the site visit, it was also noted that the creek had flows of approximately 1 to 1.5 cubic feet per second (cfs) and that many willows exist in the wide valley bed along Leavenworth Creek. These willows are likely to be a part of the P SS/EM B classification noted in the General Site Information section. With this classification, it is likely that there will be significant wetlands impacts for this site.

DESIGN AND OPERATION CONSTRAINTS

Design constraints affecting this site include, but may not be limited to, the following:

- Access to the site could be difficult and may require a significant amount of work.
- Due to the high elevation of the site winter access would likely be restricted to snowmobiles.

DESIGN SPECIFICS

- Dam Crest Length: 837 Ft
- Dam Crest Elevation: 11056 Ft
- Reservoir Surface Area: 9.5 Acres
- Max Dam Height: 40 Ft
 - Includes Freeboard
- Max Storage: 160 Ac-Ft
 - Meets Decree
- Other:
 - Could double storage by adding 13 feet to the dam height
 - 100 ft tall dam could store up to 1500 ac-ft

SOILS

There was one soil type shown on the NRCS map CO645 in the general area of the proposed reservoir (See Figure 2, Appendix H). The soil has a map symbol of 7103A and is mostly made up of loam, silt, sand and some gravel. This soil is classified in the NRCS Hydrologic Group D, which is typically a more impervious soil type (See Table H-1, Appendix H, for detailed soil information).

OPINION OF PROBABLE COST

An Opinion of Probable Cost was calculated for each of the proposed sites. Each site was evaluated to determine the type of dam that might reasonably be constructed. The two dam types analyzed were earthen embankments and RCC. In the case of the Ball Placer reservoir, an earth dam was assumed to be the only type of dam this site could accommodate. The Bakerville #2, Grizzly Gulch, and Leavenworth #2 sites were analyzed for both embankment and RCC dams. The remainder of the proposed sites were analyzed for RCC construction only. An explanation of construction and engineering costs are described below. Permitting costs were not included in these opinions of cost due to the nature of permitting costs varying greatly in magnitude. There is great uncertainty, particularly in working with Federal agencies on cost, time schedule and outcome. Preliminary discussions with permitting agencies is recommended for the next phase of this project to further scope the magnitude of necessary permits, including costs and timeframes.

CONSTRUCTION

Construction costs consist of dam foundation preparation, placing material for an RCC dam or an earth dam with a clay core, infrastructure, access road costs, survey costs, geotechnical activities during construction, mobilization costs, and a construction contingency.

The costs associated with placing the dam materials are based on estimated volumes of material required. These estimates are based, in part, on the estimated cross-sectional area of the dam and

the proposed dam length. For the earth dams, the estimate of material needed for construction was broken out into clay core and shell quantities. Material import volumes were included for the clay core and were based on an estimate of available clay material on site. Earthfill dam geometries using a rockfill shell and earth core can vary.

Infrastructure costs including spillway, outlet structure, foundation cutoff, drains, and instrumentation, were estimated as a percentage of the dam structure cost. Each of the proposed earth dam infrastructure costs were estimated to be 15% of the cost associated with importing and placing the earth dam with a clay core. This percentage is based on past dam projects and comparing the relative costs of those related works to the dam embankment cost.

Access roads were based on the cost of building new access roads or upgrading roads that may already be in place. The costs for each proposed site vary depending on the length of each road and the estimated extent of road upgrades that may need to be performed in order for the road to be of acceptable configuration and condition for construction equipment.

Construction surveying was assumed to be approximately 2% of the cost associated with importing and placing the earth dam with clay core. This estimate is consistent with the survey costs for similar earth dam projects in the region.

Geotechnical costs during construction were estimated to account for 5% of the cost associated with importing and placing the earth dam with clay core. This estimate is consistent with geotechnical costs associated with construction for similar earth dam projects in the region.

Mobilization costs were estimated to be 10% of the cost associated with importing and placing the earth dam with clay core. This cost includes moving equipment to the site, providing bonds and insurance during construction and removing equipment after construction is completed. This estimate is consistent with mobilization costs associated with construction for similar earth dam projects in the region.

A construction contingency cost was estimated to be 30% of the cost of importing and placing the earth dam with clay core. This is a high figure that is justified because there are so many unknown factors and issues that may arise with further study.

ENGINEERING

The preliminary engineering cost is estimated to be 5% of the total estimated construction costs. This estimate is consistent with engineering costs for similar dam projects in the region.

Geotechnical testing, survey data collection, and SEO permitting activities are not assumed to vary from site to site. As a result, the costs associated with geotechnical testing, survey data collection, and SEO permitting are assumed to be constant for each of the proposed sites.

Final engineering costs are estimated to be 10% of the total estimated construction costs. This estimate is consistent with final engineering costs for similar dam projects in the region.

Construction observation costs are estimated to be 10% of the total estimated construction costs. This estimate is consistent with construction observation costs for similar earth dam projects in the region.

Table 3 below summarizes the construction, engineering, and final costs for each site and dam option, as well as the cost per acre-foot. Each site's opinion of cost table is included in the associated appendices.

Table 3 – Summary of Cost Opinions

Site	Dam Option	Dam Material Cost	Construction Cost	Engineering Cost	Total Cost	AF	Cost/AF
Bakerville #1	RCC	\$576,000	\$1,096,000	\$365,000	\$1,461,000	70	\$20,871
Bakerville #2	RCC	\$725,000	\$1,348,000	\$427,000	\$1,775,000	80	\$22,188
	Earth Dam	\$562,000	\$1,030,000	\$348,000	\$1,378,000	80	\$17,225
Ball Placer	Earth Dam	\$3,010,600	\$4,056,600	\$1,105,000	\$5,161,600	110	\$46,924
Clear Creek #2	RCC	\$1,073,000	\$2,030,000	\$598,000	\$2,628,000	30	\$87,600
Clear Creek #3	RCC	\$1,177,000	\$2,282,000	\$660,000	\$2,942,000	65	\$45,262
Clear Creek #4	RCC	\$1,538,000	\$2,900,000	\$815,000	\$3,715,000	55	\$67,545
Grizzly Gulch	RCC	\$3,279,000	\$6,614,000	\$1,743,000	\$8,357,000	400	\$20,893
	Earth Dam	\$2,905,000	\$5,840,000	\$1,550,000	\$7,390,000	400	\$18,475
Leavenworth #1	RCC	\$2,700,000	\$5,257,000	\$1,405,000	\$6,662,000	155	\$42,981
Leavenworth #2	RCC	\$2,140,000	\$4,154,000	\$1,128,000	\$5,282,000	160	\$33,013
	Earth Dam	\$2,056,000	\$3,937,000	\$1,075,000	\$5,012,000	160	\$31,325

RANKING COMPARISON ANALYSIS

CRITERIA AND WEIGHTS

The nine sites were compared based on a multiple criterion decision model. Main and sub criteria were established and identified for each site. The main criteria for potential dam construction at each site consisted of researching environmental risks, geologic hazards, permitting processes, and engineering considerations. Each main criterion was divided up into five to nine sub criteria. In addition to the main and sub criteria, weighting factors were also established. Five options for weighting the main criteria and two options for weighting the sub criteria were provided in this model. When all the weighted factors equal 1, each criterion is considered equally important. A weighting factor of 4 implies that the associated criterion is 4 times more important in the decision than a criterion with a weighting factor of 1. A summary table below illustrates the criteria and associated weighting options.

Main Criteria Weighting Factors

	<input checked="" type="radio"/> Option 1	<input type="radio"/> Option 2	<input type="radio"/> Option 3	<input type="radio"/> Option 4	<input type="radio"/> Option 5
Environmental Risks	1	2	4	2	1
Geologic Hazards	1	3	4	4	1
Permitting Process	1	4	3	3	3
Engineering Considerations	1	2	1	5	4

Main Criteria	Sub Criteria	Weighting Factors	
		Category 1	Category 2
Environmental Risks	wetlands	1	5
	floodplain	1	3
	dense forest	1	4
	mine tailings/hazardous materials	1	4
	forest thinning opportunity	1	2
Geologic Hazards	fault	1	5
	unstable slopes	1	4
	rockfall areas	1	3
	debris flow areas	1	2
	artificial fill	1	1
	side slopes	1	1
	estimated bedrock depth (ft)	1	3
Permitting Process	ownership	1	2
	wetlands	1	4
	No. of Municipal permits	1	4
	No. of County permits	1	6
	No. of Federal permits	1	8
	Magnitude of cost & timeframe	1	7
Engineering Considerations	Dam options	1	2
	Utility line relocations	1	5
	power availability modifications	1	3
	access road improvements	1	5
	inlet infrastructure	1	2
	ability to enlarge (AF/5-ft height)	1	4
	cost/AF	1	8
	other	1	9
	Percent of waterbank (1125AF total)	1	8

DATA

Once the criterion was established, the data for each sub criterion was then entered into a table (Included in Appendix I). The data was either entered in a quantitative format, where applicable, or a word-related scale of magnitude was used. In this case, the word scale was separately listed with associated values for use in alternatives' scoring. The data was scored by establishing the maximum and minimum values for each sub-criterion, and then interpolating the scores onto a 1 to 10 scale. Depending on the desired maximize or minimize goal for each criteria, the scores were interpolated to result in the "best" score of 10 and "worst" score of 1.

Weighting factors for the sub criterion were used to give each alternative (site) an overall score for each main criteria. The weighting factors for each main criterion were then used to give each alternative a final score, and ultimately a ranking. This was performed for each combination of the 5 sets of main criteria weighting factors and 2 sets of sub criteria weighting factors, resulting in 10 lists ranking the sites.

The purpose of this tool is to effectively compare the alternatives with consistency. The largest discrepancy in this comparison is identified geologically. As stated above, geologic information was researched utilizing the Colorado Geological Survey and other studies previously performed; however the most-detailed information was sourced from the County's GIS database. This information, however, did not physically extend to half of the sites. The sites with detailed information, Clear Creek County reservoirs #2, #3, and #4, and Leavenworth #2, were given "bad values" in the data table if geologic hazards exist on site or in the area. To account for a lack of geologic information, the remaining sites were assigned a value equal to "potential" geologic hazards.

SCORING

The scoring calculations were achieved through two methods: weighted average method (WAM) and discrete compromise programming method (DCP). The weighted average method directly interpolates each "data point" between the best and worst score onto a desired scale (1 to 10 was used for this comparison). The DCP method uses the WAM 1-10 score for each sub criterion and translates each score onto a 0 to 1 scale, 1 being the best, and raises the value to a power (see below). The exponent is normally taken to be 1.0, but can be varied slightly from 0.5 to 2.0. An exponent value of 0.5 gives slightly more weight to the lower-weighted factors; a value of 2.0 gives slightly more weight to the higher-weighted factors.

$$WAM = \frac{Actual - Minimum}{Maximum - Minimum} (Best - Worst) + Worst$$

$$DCP = \left(\frac{Actual - Worst}{Best - Worst} \right)^P$$

RESULTS

For both calculation methods, and varying the exponent, the 9 site alternatives were compared using each combination of main and sub criterion. Tables summarizing results of the 10 simulations are included in Appendix I of this report. Scores and ranks for each simulation are listed, along with which criteria weighting options and exponent values were used.

The final ranking was determined by counting how many times each site ranked first, second, etc. in the 10 scenarios. A weighted ranking average was calculated for each site to determine the final rank. For example, for the WAM method results shown in the table below, Clear Creek County Reservoir #3 ranked first seven times, ranked second twice, and ranked third once. The weighted ranking average for this site is 1.4. Alternately, the Leavenworth #1 site ranked ninth ten out of the ten times, resulting in a weighted ranking average of 9. This value was then used to establish the final rank based on all the results.

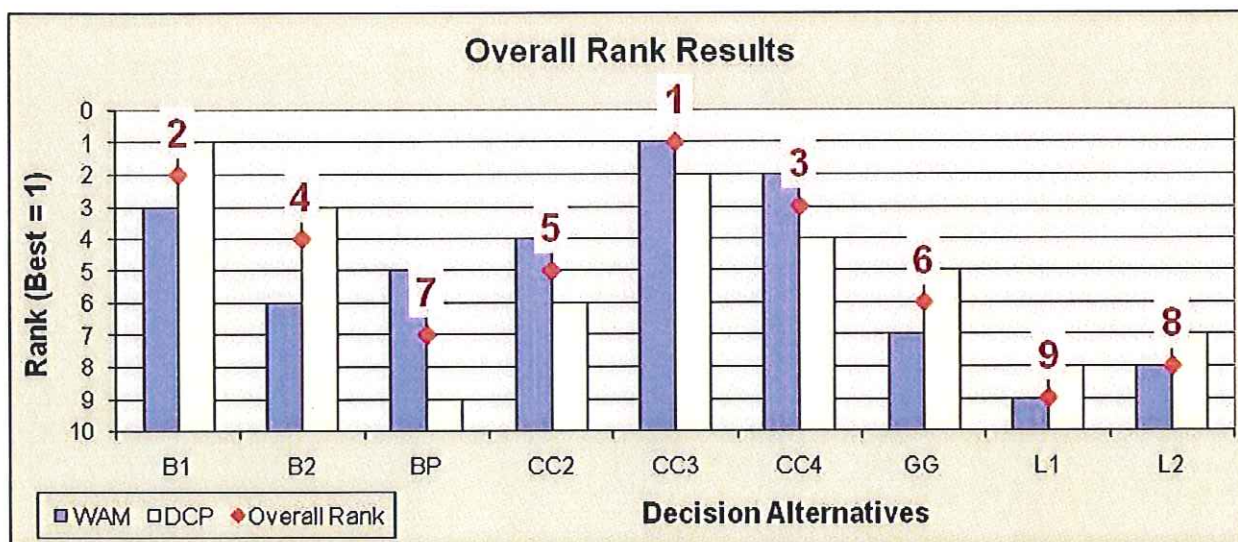
TOTALS - Weighted Average Method only

Rank	B1	B2	BP	CC2	CC3	CC4	GG	L1	L2
1	2		1		7				
2	1				2	7			
3	6			1	1	2			
4	1	1	2	5		1			
5		4	2	3					1
6		3	2				5		
7		1	2	1			5		1
8		1	1						8
9								10	
Weighted ranking average	2.6	5.7	5.3	4.5	1.4	2.4	6.5	9.0	7.6
Final Rank	3	6	5	4	1	2	7	9	8

The WAM method final ranks results show that all three Clear Creek County reservoirs rank in the top four, as well as the Bakerville #1 site. Both Leavenworth sites were the worst ranked reservoir alternatives.

The DCP method results did not vary greatly from changing the exponent from 1 to 0.5 or 2. Even with the exponent variances considered, Bakerville #1 and Clear Creek County Reservoir #3 remained the top two, and Clear Creek County Reservoir #4 and Bakerville #2 were consistently ranked third or fourth.

The final ranks for both the WAM and DCP calculation methods are shown in the graph below. The WAM results are shown with blue columns and the DCP are shown in yellow. An overall rank for each site, illustrated by the labeled red diamond, was established by averaging the two methods.



Clear Creek County #3 and Bakerville #1 ranked first in one calculation method or the other. Clear Creek County Reservoirs #3 and #4 ranked second in one method or the other. Bakerville #1 and #2 both ranked third in one of the calculation methods, and Clear Creek County Reservoirs #2 and #4 both ranked fourth in one of the calculation methods. The top four sites include Clear Creek County Reservoirs #3 and #4 and Bakerville Reservoirs #1 and #2. The Ball Placer and

Leavenworth #1 sites ranked last in one of the calculation methods. The two Leavenworth sites are ranked eighth and ninth in the overall standings.

DISCUSSION

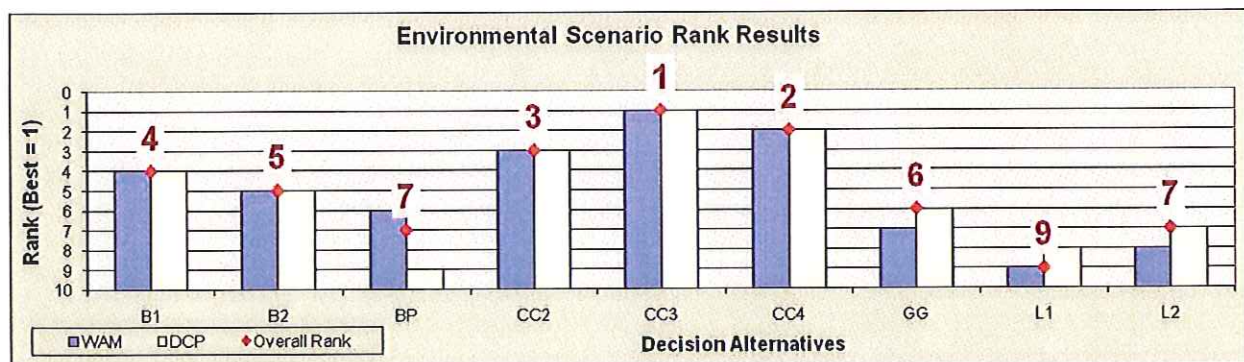
The comparison analysis results were compiled in multiple fashions. The results were broken down and compared regarding the sub criterion weighting factor categories. Category 1 made all sub criteria equal whereas category two gave more weight to specific aspects. The results comparing these two sub criteria weight categories varied slightly; each site ranking shifted by less than two. For the most part, the top four sites remained consistent with the overall results.

The results were also reviewed for two specific scenarios. The equal weighting factors for both the main and sub criterion is valuable to the model from a sensitivity analysis standpoint; however, the County's decision to move forward with the project may be swayed by one aspect over another. One scenario reviewed focused more on public influence and environmental impacts and will be referred to as the "Environmental" scenario. A second scenario focuses more on construction feasibility and overall costs/timeframe and will be referred to as the "Construction-Conscious" scenario.

ENVIRONMENTAL SCENARIO

This scenario included the combination of main criteria rating option 3 and sub criteria rating category 2, or Simulation #8 as listed in Appendix I. The decision in this scenario was weighted more towards environmental risks and geologic hazards. This scenario may focus more on public influence and environmental impacts.

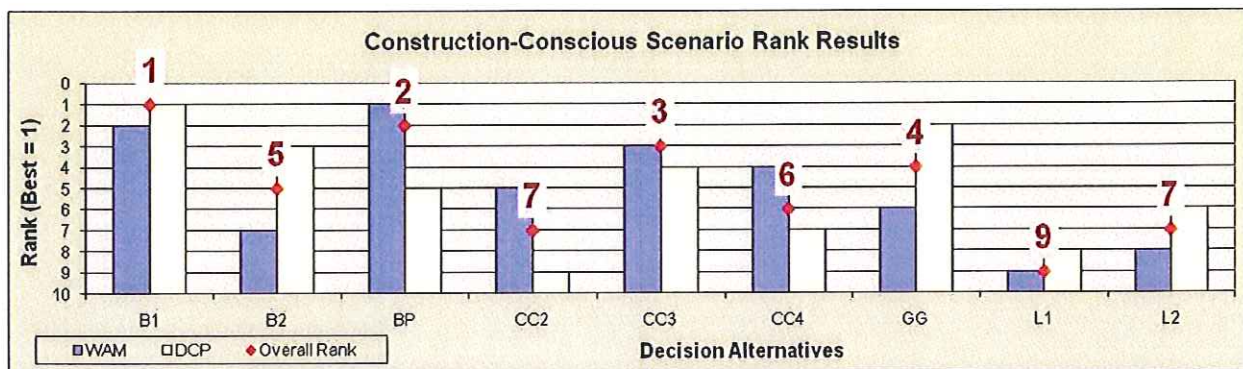
The Bakerville #1 site drops to fourth in the rankings when this scenario is analyzed. Bakerville #2 drops out of the top four; whereas Clear Creek County reservoir #2 is now included in the top four. These top four sites are all on County-owned land and do not have anticipated wetlands impacts.



CONSTRUCTION-CONSCIOUS SCENARIO

The second scenario included the combination of main criteria rating option 5 and sub criteria rating category 2 (Simulation #10). The decision in this scenario places more weight on permitting and engineering considerations, focusing more on construction feasibility and overall costs/timeframe.

In the analysis of this scenario, the Bakerville #1 site ranks first and the Clear Creek County Reservoir #3 site falls slightly to ranked third. Bakerville #2 and Clear Creek County Reservoir #4 both fall out of the top four alternatives, and Grizzly Gulch and Ball Placer move up to the top four. Assuming the Town of Empire will regulate the permitting for Ball Placer, the permitting cost and timeframe is expected to be considerably less than those sites on Forest Service land with significant wetlands. Although Grizzly Gulch is on Forest Service land with significant wetlands, the ability to enlarge, percent of water bank, and cost per acre-foot are comparatively better than the other 8 sites (see Data Table in Appendix I).



CONCLUSIONS AND RECOMMENDATIONS

The purpose of this study was to analyze and compare these nine sites for recommendation as to which sites to focus the County's efforts on. None of the nine sites, with the exception of Ball Placer, have survey information or have undergone geotechnical studies. Some site-specific fatal flaws may exist that could revise the findings of this comparison report. For example, the Clear Creek County Reservoir #3 site completely conflicts with the proposed Black Hawk tunnel undergoing preliminary design and approval. The comparison model took this into account under the engineering considerations criteria.

Another fatal flaw may exist regarding the Bakerville #1 site. It almost consistently ranks in the top three sites; however, it is in very close proximity to I-70, with the ROW encroaching on the site. This gives the site comparatively great access but coordination with CDOT will be necessary for dam design and was not included in this scope of work. Coordination with CDOT may be a significant negative impact to the project, and possibly a fatal flaw, since the issues of enlarging I-70 may conflict with an adjacent reservoir. Detailed geologic information was also not available for the Bakerville #1 site. The comparison model took this into account; however, some investigation should be done prior to final recommendations on which sites proceed to dam design.

RANKING OBSERVATIONS

- Only the Bakerville #1 and Clear Creek County Reservoir #3 sites ranked first in any of the simulations for both calculation methods. These two options are consistently in the top four alternatives no matter which scenario or simulation is analyzed.
- Three sites fall in ninth place at least once in all the simulations: Ball Placer, Clear Creek County Reservoir #2, and Leavenworth #1.

RECOMMENDATIONS

The next phase of this project should include initial discussions with regulating agencies to more formally scope the possible environmental impacts and any necessary permits; including but not limited to costs and timeframes. If multiple sites are being considered by the County, obtaining survey information or performing geotechnical testing for several sites at one time would likely result in a cost savings.

The rankings vary significantly between the environmental and construction-conscious scenarios. The direction taken will be totally dependent on the vision and goals that Clear Creek County has for future water supplies. If the County feels strongly toward one scenario over the other, our recommendations may be different than stated below.

Based on the results of the overall comparison analysis, and the snapshot look into two specific scenarios, we would recommend the following:

- The County should focus their efforts on the Bakerville #1 and Clear Creek County #3 sites.
 - Preliminary discussions with CDOT and those entities involved in the Black Hawk tunnel should be performed first to establish the existence of fatal flaws that may immediately impact the go/no-go decision.
 - Concerning the Clear Creek County Reservoir #3 site, the geologic fault shown in the area should be further investigated for extents and severity in regards to how it would impact the dam foundation.
 - Concerning the Bakerville #1 site, geologic information should be obtained if possible. This may entail subcontracting with a geologist before geotechnical testing is performed.
 - If the above mentioned discussions do not prohibit the potential dam construction at these sites, we would recommend performing a geotechnical investigation to obtain soil properties on both the overburden on site and underlying bedrock foundation.
 - A site-specific wetlands investigation should be completed for selected dams. We would also recommend preliminary discussions with the Army Corps of Engineers to identify the likely scenario involved in permitting should it be required.
 - We would also recommend preliminary discussions with the Colorado Division of Wildlife to identify site specific threatened and endangered species that may conflict with dam construction or permitting. There are some interstate T&E issues that will apply as well but should be adequately addressed through SPWRAP.
- The County should consider Clear Creek County Reservoir #4. The location of the Black Hawk tunnel may not conflict with this site as much. The proposed dam location could likely be shifted slightly to avoid conflicts. The geology of this site is very similar to that of Clear Creek County Reservoir #3, although not entirely as detailed. The environmental risks and permitting are identical to that of County Reservoir #3. Although the cost per acre-foot is higher, this may be a good alternative if fatal flaws other than geology are found at the County Reservoir #3 site. Clear Creek County Reservoir #4 ranked third in the overall results.

- The County should also consider the weight of the percentage of their water bank that they will procure with the construction of each facility. This particular item was used in the comparison model of the 9 sites but the weight of the impact it has on the County's overall decision might hold influence over the overall positive aspects of Bakerville #1 and Clear Creek County #3 and #4. The site that should be considered based solely on size and contribution to the waterbank would be Grizzly Gulch. Though it was never ranked in the top three for any scenario, it would have the capacity to contain 36% of the overall water bank. The combined storage for the three other suggested sites is 17%. The cost per acre-foot to construct the Grizzly Gulch dam is approximately \$19,600. Our suggestion for this site would be to determine if the volume benefits for this site outweigh the negative aspects which caused its lower rating.

The purpose of this study was to prioritize the 9 potential reservoir sites for future construction of the County-wide water bank; this study was not intended to suggest that lower ranked sites should be dismissed from further consideration for construction for other water uses or purposes. For example, Ball Placer ranked 7th in the overall standings for the water bank comparison. This does not imply that the water decree for the Ball Placer site should be removed from the Court system.