City of Boulder, CO

Source Water Quality Planning Study – Phase I

April 2003

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Black & Veatch Corporation

Boulder, Colorado
Colorado Source Water
Quality Planning Study

B&V Project 132441.100
B&V File A
April 29, 2003

Ms. Anne Noble
Department of Public Works/
Utilities Division
City of Boulder
P. O. Box 791
Boulder, CO 80306

Dear Annie:

Enclosed are 10 copies of the Phase 1 Source Water Quality Planning Study. Based on the comments we received from the City on the January 2003 draft of this document, we have expanded the document, added chapters, and rearranged others. The result is a document that is easier to follow and more accessible to readers that did not participate in the planning process. In addition, we have incorporated the water quality information received from Dr. Frey.

Based on the results of the Phase 1 work, the City should be positioned to further refine the selected alternatives and formulate a definitive plan to implement both near-term and long-term source water quality strategies. Obviously, a number of questions remain to be answered and another well organized planning effort will be required to take the City to the next stage of the process.

We greatly appreciate the opportunity to be able work with the City and the knowledgeable staff that was assembled for this project. Please call if Black & Veatch can provide any additional assistance towards helping the City reach its water quality goals.

Very truly yours,

Lela S. Parsons

for Kerry C. Heidel, P.E.

LSP:alh
Enclosures

cc: Dr. Michelle Frey

City of Boulder, CO

Source Water Quality Planning Study – Phase 1

April 2003

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EXECUTIVE SUMMARY

The purpose of the Phase 1 Source Water Quality Planning Study (Phase 1 Study) is to provide the City of Boulder (City) with an overview of alternative approaches available to improve and protect Boulder Reservoir Water Treatment Facility (BRWTF) source water quality. This Phase 1 Study identifies those alternatives that provide the best value to the City for future implementation.

The Phase 1 Study was conducted within the context of the City's on-going efforts to establish definitive drinking water quality and quantity goals. As part of the strategy, the City desires to employ a multiple barrier approach to preventing pathogens and other contaminants from reaching the drinking water customer. Source water improvement and protection is the first barrier in this approach.

A. Overview

The primary source of BRWTF raw water is Carter Lake. Raw water is delivered through a 21 mile open canal known as the Boulder Feeder Canal (BFC). The BFC discharges water either directly to the BRWTF or to Boulder Reservoir for later pumping to the BRWTF.

The Phase 1 Study focused on *Cryptosporidium* as a primary indicator for water quality. Based on historical monitoring of raw water entering the BRWTF, additional removal treatment will be required under the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) if the City continues its current operational mode.

B. Source Water Quality Management Alternatives

The source water quality management alternatives investigated as part of the Phase 1 Study were identified through discussions with the City staff during the initial stages of the project. These alternatives are briefly described below.

- ***Existing Source Water System.*** The existing source water delivery system is considered the baseline condition for the alternative evaluation. This alternative represents the current seasonal operation of the BFC and Boulder Reservoir as source water supplies.

- ***Boulder Reservoir Management.*** This alternative is based on using Boulder Reservoir as a year-around terminal reservoir. Raw water will be pumped from the reservoir to the BRWTF throughout the year.

- ***Full Containment from Carter Lake to the BRWTF.*** The full containment alternative is based on the construction of a new 21-mile raw water pipeline that would contain, protect, and deliver CBT source water from Carter Lake directly to the BRWTF on a year-around basis using gravity flow.

- ***Partial Containment from Nelson Road to the BRWTF.*** The partial containment alternative is similar to the full containment alternative with a pipeline being constructed through the more highly developed areas to the north of the BRWTF. Above Nelson Road, the BFC would remain in service as an open canal. Under this approach the pipeline would only be in operation during the months when the BFC was in operation. During the remainder of the year, raw water would have to be pumped from Boulder Reservoir, as is the current practice.

- ***New Terminal Reservoir.*** This alternative includes the construction of a new earthen terminal reservoir upstream of the Boulder Reservoir and the BRWTF. This approach would avoid the water quality conflicts inherent in using Boulder Reservoir for both recreation activities and a drinking water supply.

- ***New Forebay.*** Similar to the new terminal reservoir alternative, this alternative is based on the construction of a new earthen forebay upstream of the Boulder Reservoir and the BRWTF. This approach would provide some amount of dilution and settling to reduce the contaminant load entering the BRWTF.

C. Alternative Evaluation

The alternative evaluation was performed collectively by the study participants. Each alternative was ranked in relation to each of the following criteria:

- Predicted water quality with respect to pathogens.
- Treatability issues including turbidity, manganese, TDS and algae.
- Capital cost to implement each alternative.
- Operational impacts including reliability and security.
- Potential impacts to water rights or the ability to supply water to the BRWTF.
- Community impacts including environmental and public acceptance issues.
- Potential impacts on the City's water quantity and water quality goals.
- Implementation timeframe.

D. Recommendations

As a result of the alternative evaluation, the Boulder Reservoir Management and the Full Containment alternatives were recommended to be carried forward for further investigation. The selection of these two alternatives provides the City with both near-term and long-term solutions to their source water quality issues.

Facilities are in place to allow the full-time use of Boulder Reservoir as a terminal reservoir for the BRWTF. Based on the historical BRWTF raw water data, this strategy can provide immediate reductions in the occurrence of microbial pathogens in the BRWTF raw water and compliance with the LT2ESWTR. Additional management strategies could be implemented at the reservoir over time to further enhance source water quality. However, to implement this alternative, the City will have to take steps to address the seasonal uptake of manganese.

The Full Containment alternative would reliably deliver raw water from Carter Lake and assure that the source water quality will not be degraded in the BFC. Based on historical *Cryptosporidium* concentrations for other entities that deliver Carter Lake water through a pipeline, no additional treatment would be

required under the LT2ESWTR if this alternative was implemented. However, implementation of a full containment pipeline will involve a major commitment of capital funds by the City.

To date, the City has been engaged in two separate planning efforts; one to investigate alternatives for improvements to the BRWTF source water supply system and a second to investigate alternatives for improvements to the BRWTF treatment facilities. It is important for the City to consolidate the findings of these two efforts in a Phase 2 Study to develop a multi-barrier approach that provides the most cost effective means of achieving the City's water quality and quantity goals. The Phase 2 work should encompass the following tasks:

- Consider the preferred source water management alternatives identified in this Phase 1 Study in conjunction with potential BRWTF treatment alternatives.
- Further define the scope and cost of source water and treatment alternatives as necessary to perform final evaluation.
- Develop recommended long-term plan and prioritize implementation of key elements.
- Perform utility cash flow scenarios and develop a capital improvements program (CIP) based on projected financial conditions.
- Develop facility planning documents as required to guide the implementation of improvements for both the BRWTF source water supply and treatment facilities.

The Phase 2 work will be more comprehensive in nature by considering both source water quality and treatment at the BRWTF. The relationship of source water protection measures in combination with treatment requirements and their overall impact on the requirements of the LT2ESWTR will need to be considered. This analysis will define the scope of combined alternatives, which will include both source water and treatment process elements.

Chapter 1

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CHAPTER 1
INTRODUCTION

This chapter describes the purpose, background, and approach of the Phase 1 Source Water Quality Planning Study (Phase 1 Study). In addition, this chapter includes a discussion of drinking water regulations and the City's water quality goals as they relate to this study.

A. Purpose

The purpose of the Phase 1 Study is to examine the existing source water supply system for the Boulder Reservoir Water Treatment Facility (BRWTF) and to evaluate several alternative source water quality management strategies for improving and protecting source water quality. The alternatives have been evaluated based on select criteria to determine the most beneficial and cost-effective means of delivering source water to the BRWTF in the near-term as well as in the future.

The Phase 1 Study was performed within the context of an ongoing effort by the City to establish definitive drinking water quality and quantity goals as a framework for planning and implementing future improvements throughout their treated water system. One central strategy for achieving the City's water quality goals is a to implement multiple barrier approach to pathogen protection.

By providing multiple barriers to the introduction or passage of pathogens throughout the system, the drinking water customer is afforded the highest levels of protection. This approach is the motivation for source water quality planning since source water storage and delivery provides the first opportunities to implement barriers to contamination.

B. Background

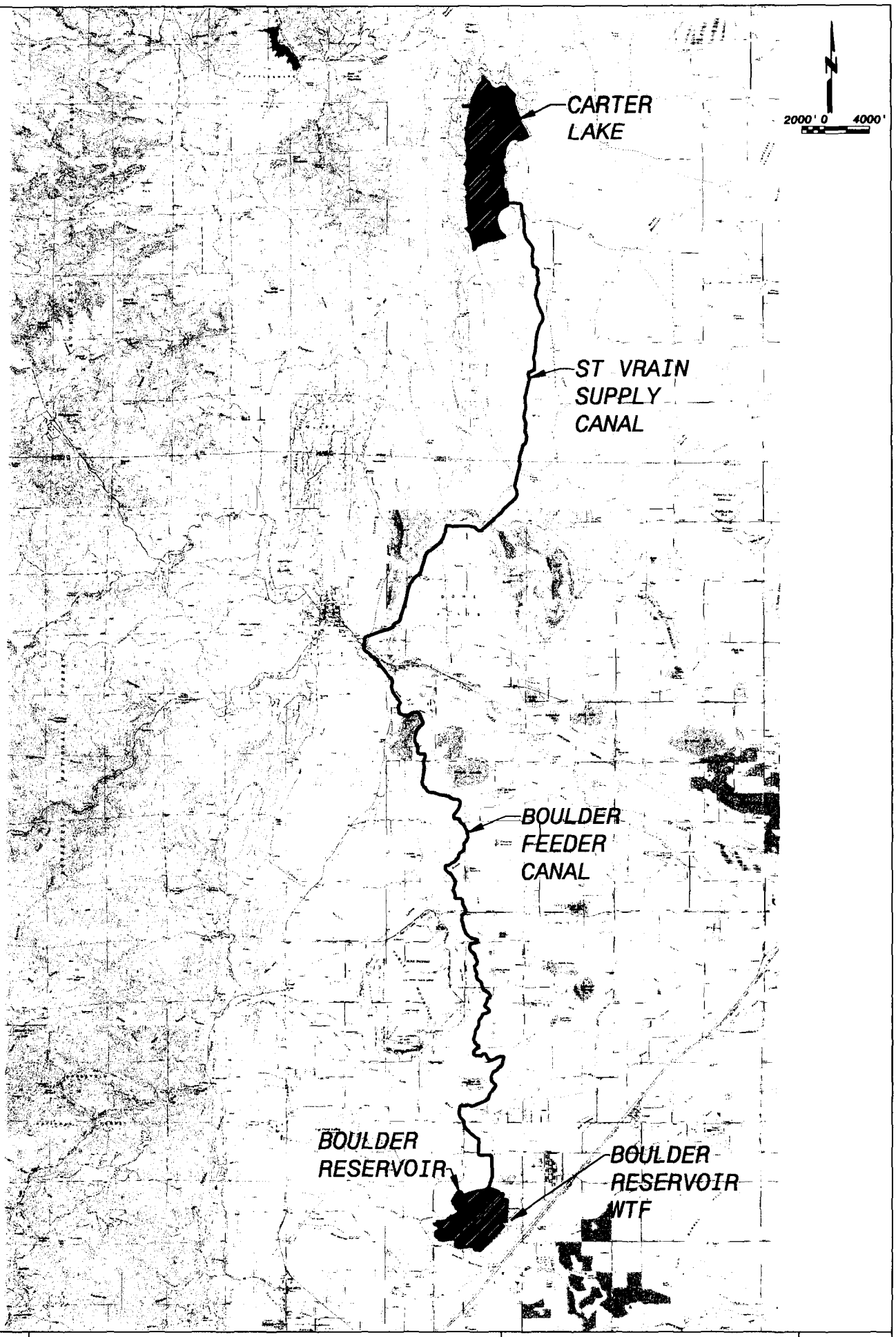
Raw water is primarily delivered to the BRWTF through the Colorado-Big Thompson (CBT) project, which is administered and operated by the Northern Colorado Water Conservancy District (NCWCD). The CBT project diverts both Colorado River water from the west slope and Big Thompson River water from the east slope into storage to sustain supplies of water for irrigation and municipal water systems.

Currently, the City's portion of CBT water is stored approximately 20 miles north of Boulder in Carter Lake and is transferred to the City through a 21 mile long, open, unlined, earthen canal that discharges into Boulder Reservoir. Figure 1-1 shows the existing raw water delivery system for the BRWTF. The upper portion of the canal is known as the Saint Vrain Supply Canal (SVSC) and the lower portion is known as the Boulder Feeder Canal (BFC). For the purposes of this study the entire length of the canal will be referred to as the BFC.

Any consideration of source water management alternatives must account for water storage rights that the City currently possesses in Boulder Reservoir. These rights may be impacted by operational changes which could potentially reduce the City's ability to deliver water during prolonged periods of regional drought. The City's current storage rights account for 3,143 acre-feet of long-term drought or emergency storage capacity in Boulder Reservoir. Of this, 2,143 acre-feet can be taken into the BRWTF or exchanged to Boulder Creek. The remaining 1,000 acre-feet can only be utilized at the BRWTF. In addition, the City uses 5,357 acre-feet of winter storage in Boulder Reservoir. This storage is only available in the winter as it is being used by NCWCD in the summer. This 5,357 acre-feet is delivered via the BFC before November and is used to meet the City's winter treated water demands by pumping to the BRWTF. Presently, the City is also entitled to fill Boulder Reservoir with 2,000 acre-feet of non-CBT water delivered through the Farmers Ditch that must then be used for treatment at the BRWTF between May 1 and July 31.

C. Drinking Water Regulations and City Water Goals

Source water improvement and protection is directly linked to the City's ongoing efforts to assure the delivery of high quality drinking water that not only satisfies the standards established by federal and Colorado regulations, but that surpasses these standards in specific target areas for which the City has established goals. The Safe Drinking Water Act (SDWA) was first promulgated by the Environmental Protection Agency (EPA) in 1974. The SDWA has been amended numerous times and currently addresses a wide range of water quality issues that includes microbial contamination, disinfection byproducts, metals, arsenic, radionuclides, as well as a long list of biological and chemical contaminants that are currently unregulated, but under consideration for regulation.



RV	CITY OF BOULDER, CO SOURCE WATER QUALITY PLANNING STUDY	BRWTF RAW WATER SUPPLY ROUTE	FIGURE 1-1

Because there are specific microbial pathogens, such as *Cryptosporidium*, that have been found to resist traditional disinfection practices, special attention has been focused on reducing the potential for their occurrence in water systems. In recent years, EPA has issued the Interim Enhanced Surface Water Treatment Rule (IESWTR) and will soon issue the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) specifically to address *Cryptosporidium* in surface water and groundwater under the direct influence (GWUDI) of surface water systems.

As a result, a good deal of the City's attention in the area of source water quality is focused on the requirements of LT2ESWTR. The requirements of LT2ESWTR include a program of source water monitoring for *Cryptosporidium, E. coli*, and turbidity. On the basis of the resulting *Cryptosporidium* concentrations, bin classifications have been established that dictate additional treatment requirements. Table 1-1 lists the *Cryptosporidium* concentrations and resulting bin classifications.

Table 1-1

Treatment Requirements for *Cryptosporidium* Bin Designations

Average Raw Water *Cryptosporidium* Concentration (Number/Liter)	Additional Treatment Requirements
<0.075	No action.
0.075 - 1.0	1-log treatment.
1.0 - 3.0	2.0-log treatment.[1]
>3.0	2.5-log treatment.[1]

[1]At least 1-log inactivation must come from UV, ozone, chlorine dioxide, membranes, bag filters, or riverbank filtration.

The City has a source water monitoring program in place, which provides historical source water quality data. That program was expanded in the last several years to comply with LT2ESWTR requirements. All sampling is currently

performed on a monthly basis. Samples are drawn at the BRWTF from the intake piping as it enters the facility. For the raw water source that is not in use, either the BFC or Boulder Reservoir, the operators go out to the field to retrieve the monthly samples in order that a complete record of both sources can be maintained.

Table 1-2 presents the regulatory requirements that will be applicable under the LT2ESWTR along with the City's goals with respect to pathogen removal/inactivation. In general, the City's goals are 1.0-log more stringent than the regulatory requirements. The LT2ESWTR removal requirements for *Cryptosporidium* are based on the average historical concentration found in each source as discussed in Chapter 2 and the resulting bin classification as discussed above. The removal/inactivation credit that the City receives for its existing processes are also listed in Table 1-2.

Table 1-2

Pathogen Removal/Inactivation Requirements

Pathogen	Regulatory Requirement Under the LT2ESWTR	City's Goal	Credit for Existing Processes
Viruses	4.0 log	5.0 log	>4.0 log
Giardia	3.0 log	4.0 log	3.0 log
Cryptosporidium	3.0 log (Boulder Reservoir) 4.0 log (BFC)	5.0 log	3.0 log

D. Study Approach

The City intends to accomplish the overall source water quality planning process in two phases described in the following paragraphs. The overall goal of the Phase 1 and Phase 2 studies was to optimize a combination of source water management and water treatment process barriers to provide the most cost effective means of achieving the City's water quality and quantity goals. The Phase 1 work has been completed and the Phase 2 work will be initiated in the Spring 2003.

1. Phase 1

The Phase 1 work was facilitated by a series of three meetings held at the BRWTF as follows:

Meeting	Meeting date
Kick-off	October 30, 2002
Workshop No. 1	December 5, 2002
Workshop No. 2	January 7, 2003

The meeting participants included City staff members representing the departments of Water Quality, Water Resources, Operations, and Engineering. Also participating were representatives of three of the City's consultants; Black & Veatch, McGuire Environmental, and Dr. Bill Lewis from the University of Colorado. The meetings were generally conducted to provide information through presentations made by the consultants and free discussion by the participants. Meeting minutes were prepared to document the proceedings and are included in the Appendix.

The Phase 1 Study concentrated on the following tasks:

- Identify conceptual alternative approaches to improve and protect BRWTF source water quality.
- Identify criteria by which to evaluate alternatives and investigate the advantages and disadvantages of each alternative in relation to each of the evaluation criteria. Document the findings in technical memoranda.
- Perform an evaluation to rank the alternative source water management strategies and identify those alternatives with the highest overall potential for improving and protecting source water quality.
- Document the Phase 1 process and results. Carry the preferred alternatives forward to Phase 2.

2. Phase 2

In keeping with the multiple barrier approach to achieving the City's water quality goals, the City is engaged in preliminary planning for facility

improvements at the BRWTF in addition to the Phase 1 Study. The BRWTF study includes the evaluation of alternative treatment technologies. The Phase 1 Study and BRWTF facility planning effort are closely related in finding ways to satisfy the City's stated water quality and quantity goals.

The upcoming Phase 2 Source Water Quality Planning Study (Phase 2 Study) will consider the results of both the Phase 1 Study and BRWTF facility planning to develop an overall approach to achieving the City's water quality and quantity goals. The Phase 2 Study will likely include the following major tasks:

- Consider the preferred source water management alternatives identified in Phase 1 in conjunction with potential BRWTF treatment alternatives.
- Further define the scope and cost of source water and treatment alternatives as necessary to perform final evaluation.
- Develop recommended long-term plan and prioritize implementation of key elements.
- Perform utility cash flow scenarios and develop a capital improvements program (CIP) based on projected financial conditions.
- Document the Phase 2 Study results in a facility plan document that can be used to implement source water improvements.

E. Source Water Quality Management Alternatives

The source water quality management alternatives included in the Phase 1 Study were identified by the participants from City staff. These alternatives were developed based largely on discussions that took place during the Kick-off Meeting. The source water quality management alternatives are described as follows:

1. Existing Source Water System

The existing source water system served as the baseline condition for the alternative evaluation and as such is included in the Phase 1 Study as an alternative. This alternative represents the current seasonal operation of the

BFC and Boulder Reservoir as source water supplies. The available source water quality monitoring data is representative of this alternative.

2. *Boulder Reservoir Management*

This alternative is based on using Boulder Reservoir as a year-around terminal reservoir. All raw water will be pumped from the reservoir to the BRWTF throughout the year. This alternative appears to offer an advantage for near-term implementation since source water can already be delivered using this operational mode and a number of watershed management practices could be implemented to mitigate water quality degradation.

3. *Full Containment from Carter Lake to the BRWTF*

The full containment alternative is based on the construction of a new 23-mile raw water pipeline that would contain, protect, and deliver CBT source water from Carter Lake directly to the BRWTF on a year-around basis using gravity flow.

4. *Partial Containment from Nelson Road to the BRWTF*

The partial containment alternative is similar to the full containment alternative with a pipeline being constructed through the more highly developed areas to the north of the BRWTF. However, above Nelson Road, the BFC would remain in service as an open canal. Under this approach the pipeline would only be in operation during the months when the BFC was in operation. During the remainder of the year, raw water would have to be pumped from Boulder Reservoir, as is the current practice.

5. *New Terminal Reservoir*

This alternative is based on the construction of a new earthen terminal reservoir upstream of the Boulder Reservoir and the BRWTF. This approach would avoid the water quality conflicts inherent in using Boulder Reservoir for both recreation activities and a drinking water supply. The reservoir, as proposed, is sited to provide gravity flow from the BFC into the reservoir and gravity flow out of the reservoir directly to the BRWTF. The new reservoir is sized to provide enough year-round storage for the City's needs during a normal year.

6. New Forebay

Similar to the new terminal reservoir alternative, this alternative is based on the construction of a new earthen forebay upstream of the Boulder Reservoir and the BRWTF. This approach would provide some amount of dilution and settling to reduce the contaminant load entering the BRWTF. During the winter, the BRWTF would have to pump raw water from Boulder Reservoir, as is the current practice.

The following chapters discuss each of these source water quality management alternatives in turn.

Chapter 2

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CHAPTER 2
EXISTING SOURCE WATER SYSTEM

This chapter provides an overview of the existing source water system including the available source water quality data from both the BFC and Boulder Reservoir. This chapter also represents an evaluation of the expected source water quality if no additional source water protection was implemented and the City continued with its current operation. Potential alternatives to enhance the existing source water supply system, such as implementing better management practices or constructing additional facilities, are addressed in Chapters 3 through 7.

A. Description of the BFC

Normal operation of the BRWTF from April through October has historically utilized the BFC delivery system for raw water supply. Raw water is diverted from the BFC at a location upstream from Boulder Reservoir and delivered through a pipeline to the BRWTF for treatment. Any remaining flow continues in the BFC for a short distance and discharges to Boulder Reservoir where it is stored for water exchanges, downstream irrigation or as a reserve raw water supply for treatment at the BRWTF.

The open channel BFC generally follows a north to south route traversing the lower slopes of the foothills. As such, it tends to capture a significant amount of surface runoff that originates uphill and to the west. Although a riparian habitat along the canal could, to some extent, naturally attenuate contamination, the channel bottom and banks are regularly maintained by NCWCD to prevent growth of vegetation. Therefore, although the raw water at its source in Carter Lake is of a very high quality, significant degradation generally occurs as the water travels the length of the BFC.

The resulting variable water quality delivered to the BRWTF and/or Boulder Reservoir can pose significant treatment challenges to the City. The BRWTF staff must frequently adjust treatment operations in response to raw water quality changes from weather and human or animal activities. Operational changes in treatment are also required each time the raw water supply is switched between the BFC and Boulder Reservoir. Unfortunately, the existing

BRWTF monitoring and treatment technologies do not always provide the ability to react to quickly enough to these changes and there have been times when the facilities have been taken off-line to avoid the possibility of violating treated water quality requirements.

B. Description of Boulder Reservoir

Boulder Reservoir is a low volume, shallow, Class 1 warm water fishery owned by the City of Boulder and operated by NCWCD. The reservoir has a surface area of approximately 700 acres and a capacity of about 13,270 acre-feet. Historically, the BRWTF has primarily used the Boulder Reservoir supply only during the winter months when the BFC is not in service. Water from Boulder Reservoir must be delivered by pumping from the BRWTF Raw Water Pumping Station.

Boulder Reservoir is a multipurpose reservoir and is used year round for a variety of recreational activities including special events that bring in large numbers of people for short durations. As a result, the reservoir is subject to water quality degradation resulting from both body contact recreation and non-body recreational activities such as swimming and boating. These activities contribute to general water quality degradation and an increase in the BRWTF raw water supply pathogen load.

Flows from the BFC have in the past been as high as 2.5 times the reservoir volume of Boulder Reservoir. These flows are significant in that the high flows tend to improve water quality by keeping the reservoir water mixed and fresh, which helps reduce stratification that occurs in the summer. However, the City has no control over these flows, which can vary significantly from year to year. In addition, the reservoir provides a degree of dilution, settling, and natural processes to break down contaminants before the raw water reaches the BRWTF.

During the late summer, a natural temperature stratification occurs in the reservoir and a hypolimnetic layer low in dissolved oxygen forms at the bottom of the reservoir. This condition results in the uptake of soluble manganese from the reservoir sediment into the water and causes taste and odor treatment concerns at the BRWTF.

The water in the reservoir is also high in total dissolved solids (TDS) including sodium, sulfate, and hardness. The turbidity in the reservoir is

generally low, but wind action can increase the turbidity from 10 to 150 nephelometric turbidity units (ntu). Additional water quality concerns include taste and odor, which may be a byproduct of anoxia.

C. Source Water System Vulnerabilities

Currently, both the BFC and Boulder Reservoir contain a number of features that make them vulnerable to source water quality degradation. These features are described below:

Boulder Feeder Canal Source Features

- The BFC is a 21-mile long earthen open channel.
- Copper sulfate and herbicides are routinely applied along the length of the BFC to control algae and native vegetation.
- The BFC has 51 outfalls along its length where overland flow is directed into the canal.
- Land use in the drainage areas adjacent to the BFC include undeveloped publicly owned open space, residential development, agricultural, and industrial/commercial development.
- There are 11 street crossings over the BFC along throughout its length.

Boulder Reservoir Source Features

- The reservoir is open to recreational uses, including swimming and motorized boating.
- Overland flow drainage enters the reservoir from four uncontrolled sources beside the BFC, one of which is influenced by secondary treated wastewater and irrigation drainage.
- Naturally occurring manganese is released into the water during the summer months when the reservoir undergoes stratification and reservoir bottom conditions become anoxic.
- Algal blooms can occur in the reservoir throughout the year.

- Public trails for biking and hiking activities public follow the perimeter of the reservoir.

Contaminants of concern to the City come primarily from non-point sources and include pathogens, algae, pesticides, herbicides, TDS, turbidity, volatile organics, manganese, and nutrients. Besides surface runoff, these contaminants can be introduced from illegal dumping, canal maintenance activities, recreational activities, or groundwater seepage.

D. Source Water Quality

As discussed in Chapter 1, the raw water quality monitoring program at the BRWTF is performed on a monthly basis. Samples are taken as the flow enters the facility. Although monthly sampling does not provide a complete picture, Table 2-1 provides an overview of the results obtained over the last several years.

Even though the Boulder Reservoir is replenished by the flows from the BFC, the water quality between the two supplies can vary substantially. Table 2-1 demonstrates that there are distinctions between the BFC and Boulder Reservoir supplies. Increased mineralization of the Boulder Reservoir supply occurs during the stagnant winter period when concentrations of alkalinity and sulfate tend to increase.

As discussed previously, the reservoir is also susceptible to manganese release during the summer when the reservoir bottom conditions become anoxic. These results are not evident from Table 2-1, since the reservoir is not normally used as a raw water supply in the summer. Therefore, sampling from the BRWTF inlet piping in the summer would only be representative of the conditions in the BFC.

Table 2-1

Recent Raw Water Quality Data

Water Quality Parameter	Boulder Feeder Canal	Boulder Reservoir
Alkalinity, mg/L	34.7	75.1
Chlorophyll-a, counts/mL	1.6	3.5
Conductivity, µS/cm	90.5	324.0
Dissolved Oxygen, mg/L	9.5	8.9
Fecal Coliform, cfu/mL	28.0	5.9
Hardness, mg/L	38.4	141.3
Iron, mg/L	0.0	0.0
Manganese, mg/L	0.0	0.1
Nitrate/Nitrite, mg/L	0.04	0.02
pH, s.u.	8.1	8.0
Phosphorus, µg/L	6.7	6.5
Sodium, mg/L	2.9	11.2
Sulfate, mg/L	7.8	87.4
Temperature, °C	13.3	9.9
TOC, mg/L	3.6	3.7
Turbidity, ntu	4.6	11.1
UV-254	0.078	0.065

In addition to the parameters sampled and presented in Table 2-1, the City has also sampled for pathogens in response to the LT2ESWTR requirements. Table 2-2 presents the results of this sampling program. Samples were drawn from the BRWTF inlet piping on a monthly basis.

Table 2-2 shows that the Boulder Reservoir supply has, for the period of the sampling program, contained lower levels of pathogens than found in the BFC.

Table 2-2

Protozoa Quality for BRWTF Sources of Supply

Statistical Endpoint	BFC		Boulder Reservoir	
	Giardia	*Cryptosporidium*	*Giardia*	*Cryptosporidium*
Number of Samples	31	31	37	37
Average, (oo)cysts/L	0.49	0.16	< 0.001	0.01
Maximum, (oo)cysts/L	2.00	3.04	< 0.001	0.20
Maximum:Average Ratio	4.1	19.7	NA	19.3
Detection Frequency	68%	23%	0%	8%

E. Water Quality Evaluation with Respect to Pathogens

Due to the multiple delivery systems, the City's existing raw water pathogen data was compared to similar water sources in order to determine whether the sources had characteristics similar to reservoirs and lakes or flowing streams. Data for the similar water sources was collected from the Information Collection Rule (ICR) database. This comparison is shown in Table 2-3.

Table 2-3

Benchmark of Pathogen Quality for the BRWTF Raw Water Supplies

Pathogen of Concern	BFC			Boulder Reservoir		
	Average Concentration	Equivalent Percentile Among ICR Systems		Average Concentration	Equivalent Percentile Among ICR Systems	
		Reservoir or Lake Supplies	Flowing Stream Supplies		Reservoir or Lake Supplies	Flowing Stream Supplies
Giardia, cysts/L	0.49	97%	58%	< 0.001	50%	16%
Cryptosporidium, oocysts/L	0.16	97%	75%	0.01	84%	50%
Fecal Coliform, cfu/mL	28	85%	30%	5.9	53%	10%

Table 2-3 indicates that the BFC and Boulder Reservoir raw water supplies represent water resources with clear pathogen removal challenges based on their comparative quality to similar water resources nationally.

The requirements of the LT2ESWTR are driven by a particular concern about the presence and magnitude of *Cryptosporidium* oocyst levels in drinking water supplies due to the unique public health challenge represented by this protozoa organism. As shown by Table 2-3, the level of *Cryptosporidium* in the BFC is at the 97th percentile of U.S. river supplies while the level in the Boulder Reservoir is at the 84th percentile of national lake or reservoir supplies.

Without consideration of future contamination potential, the water quality represented in the BFC indicates that the City would exceed the LT2ESWTR threshold for *Cryptosporidium*. These thresholds were discussed in Chapter 1. Therefore, at least 1-log of additional *Cryptosporidium* control will be required for the BRWTF to meet the LT2ESWTR requirements. No additional treatment will be required based on the samples collected for the Boulder Reservoir source of supply.

With respect to meeting the City's goals, 2-logs of additional removal treatment would be needed for the BFC supply and 1-log additional removal treatment would be needed for the Boulder Reservoir supply.

Chapter 3

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CHAPTER 3
BOULDER RESERVOIR MANAGEMENT

During the initial stages of the Phase 1 Study, there was a good deal of discussion about management strategies that might be applied at both the BFC and Boulder Reservoir to improve and protect source water quality. There was general agreement that significant water quality degradation was occurring along the length of the BFC, and therefore, the initial emphasis was on management strategies that might be applied to the BFC to improve and protect source water quality.

The City has identified 41 outfalls discharging to the BFC along its 21 mile length. Unfortunately, there is no historical water quality monitoring data available for the BFC upstream of the BRWTF intake with the exception of data collected from a fecal coliform study during the spring and summer of 2002.

At the Kick-off Meeting in October 2002, it was determined that significantly more BFC monitoring and mapping data would be required in order to perform a meaningful assessment or develop a realistic management strategy for improving and protecting the BFC source water. Based on this, the City decided to focus on management of Boulder Reservoir as a more viable alternative for improving and protecting source water upstream of the BRWTF.

A. Description of Alternative

This alternative is based upon using Boulder Reservoir as a year-round terminal reservoir for the BRWTF. The reservoir provides dilution, settling, and natural biological processes that reduce the contaminant load before raw water is pumped to the BRWTF. A principal advantage of this alternative is that it is conducive to near-term implementation since the major facilities are in place including the reservoir and raw water pumping station.

In addition to the implementation of strategies to improve or protect water quality within the reservoir, certain modifications or rehabilitation of existing facilities may also be required. An example of this would be the BRWTF Raw Water Pumping Station. Given that it was constructed in 1981, new pumps and controls may be required to increase capacity and improve reliability for year-round pumping to the BRWTF.

The Boulder Reservoir Management alternative is a multi-tiered approach incorporating strategies to mitigate impacts from the following three causes of water quality degradation:

- Reservoir processes
- Watershed sources
- Human sources

Strategies to mitigate the effects of these causes are discussed in detail below.

1. Reservoir Processes

These strategies involve modifications within the reservoir to alter the natural physical and chemical processes that impact raw water quality. The proposed modifications would be engineered construction projects designed to improve the raw water quality specifically at the point where the BRWTF intake structure is located. Some of the existing raw water quality issues and the strategies that might be used to mitigate them are as follows:

a. Naturally Occurring Manganese. Temperature stratification of the reservoir along with anoxic reservoir bottom (hypolimnion) conditions occurs during the summer months, resulting in the release of manganese from the underlying soils and sediments. During late summer when the anoxic conditions are most extreme, raw water containing high concentrations of manganese is drawn into the BRWTF Raw Water Pumping Station Intake (Pumping Station Intake). This intake is located at the bottom in one of the deepest points in the reservoir. To overcome this condition, three strategies have been proposed.

- Modify the Pumping Station Intake to provide a multi-level structure that would allow raw water to be drawn in from a level above the anoxic zone where manganese concentrations would be lower. This option could increase the chance that the BRWTF would receive a higher pathogen concentration from the warmer BFC and contributing watershed flows that will remain in the upper strata waters.

- Implement in-situ manganese control treatment by installing an aeration system. The goal of the hypolimnetic aeration process is would be to raise the dissolved oxygen (DO) in the reservoir to above 5 milligrams per liter (mg/L). The increased DO will cause manganese and other compounds to attach to sediment and settle out of the water column.

  The aeration could optionally be configured to either increase the level of dissolved oxygen throughout the reservoir by aerating and mixing or increase the level of dissolved oxygen only in the hypolimnion while maintaining the thermal stratification of the reservoir. While there may be some associated benefits such as reductions in algal growth and anoxia, the first scenario would likely mix the flow from the BFC throughout the water column which could keep pathogens in suspension instead of settling into the lower strata.

- Manage BFC flow into and out of the reservoir to promote turnover and promote oxidation. It's been shown that with a constant flow of 75 cubic feet per second (cfs) over a two week period, oxidation of the bottom anoxic zone can be achieved. However, the City does not control flows into and out of the reservoir, so without a change in responsibility for reservoir flow management, this strategy could not be relied upon on a continuing basis.

Of the control strategies discussed above, the installation of an aeration system to raise the DO concentration to 5 mg/l in the hypolimnion layer of the reservoir appears to be the most viable and effective. The resulting oxygenated water would essentially eliminate the taste and odor problems associated with uptake of soluble manganese and, depending on how the system is configured, may provide other benefits such as reductions in algal growth and anoxia.

b. Wind Generated Sediment. During times of sustained winds in the winter, the sediment in the lake is churned by the wind and is mixed throughout the entire depth of the reservoir since there is no thermal stratification. As a result sediment is drawn into the Pumping Station Intake and becomes a serious treatment issue. It has been proposed that a multi-level intake structure would be beneficial under these conditions because it would allow the operators to draw water from a level containing the least amount of settlement load.

c. **Flow Pattern of Discharge from BFC.** During periods when the BFC is in operation, the currents in the reservoir may be such that a relatively undiluted discharge from the BFC might reach the existing Pumping Station Intake with a high contaminant load (i.e. short circuiting). Possible solutions include relocating the Pumping Station Intake or inducing a different flow pattern in the reservoir to assure that the BFC flow receives the benefits of dilution and settling in the reservoir prior to being drawn into the BRWTF for treatment.

2. Watershed Sources

Watershed source control is based on managing storm water before it enters Boulder Reservoir by reducing surface water runoff at its source or providing treatment before it enters the reservoir. This type of control strategy can help reduce nutrient and metals concentrations in the Boulder Reservoir.

Stormwater pollution can be mitigated using landscape based and/or structural based solutions. Landscape-based solutions use a combination of bioretention and nutrient uptake from wetland plants. These solutions include grass lined swales, detention and retention ponds, and treatment wetlands. Structural-based solutions include hydrodynamic separators, catch basin inserts, oil and water separators, and chemical flocculants for removal of sediment.

Bioretention is a soil and plant-based storm water management practice employed to filter runoff and usually consists of a porous soil covered with mulch and various grasses, shrubs and small trees. Studies at the University of Maryland completed in 1997 & 1998 have shown that the use of storm water bioretention reduced total phosphorus, ammonium, and nitrate levels by 65, 92, and 16 percent, respectively. In addition, lead, total copper, and zinc levels were reduced by 90, 70 and 64 percent, respectively. Locally, bioretention techniques employed at the Environmental Center of the Rockies site at the southwest corner of Baseline Road and Broadway in Boulder have proved to be very successful.

Hydrodynamic separators force storm water passing through the unit to slow down allowing debris and pollutants to separate out. Heavier particles settle into a sump where they can be removed by regular maintenance. Floatable pollutants are skimmed out of the storm water. Some of the separator systems have components that cause the water to swirl, increasing the amount of settling particles. Because these units are installed underground they require less space

than aboveground treatment facilities. Maintenance on these structural systems needs to be preformed three to four times a year.

The following is a brief description of recommendation to address watershed source control:

- Construct bioretention facilities at all creek confluences with the reservoir including Dry Creek, Little Dry Creek, and the Unknown Ditch entering the reservoir from the west.
- Install structural storm water treatment systems on all storm water pipe outfalls leading into the reservoir.
- Use a combination of structural and landscape-based treatment facilities to treat the runoff from the Lake Valley development area.
- Use landscape-based treatment systems to treat runoff from the golf course that is in close proximity to the reservoir.
- Construct a combination structural and landscape-based treatment facility to filter and treat the irrigation canal start-up flows to reduce initial spring pollution into the reservoir.
- Begin a program of planting riparian vegetation, using drip irrigation, along the banks of the reservoir and creeks draining into the reservoir.

These control methods have up to 80 percent effectiveness in controlling contaminants in the source water.

3. Human Sources

Human source control recommendations are based on California Department of Health Services (DHS) guidelines for recreational use of domestic water supply reservoirs. California standards were chosen for several reasons. First, the State of Colorado does not maintain any similar guidelines and second, the California guidelines are written to be applicable to a variety of conditions including those similar to the area around the Boulder Reservoir. The guidelines are broken into the following five categories: developing reservoir and watershed information, protecting the reservoir outlet, inventory of recreational activities, developing a control program and performing a biological risk assessment. A

discussion of each category and its applicability to the Boulder Reservoir is described in the following paragraphs.

a. Develop Reservoir and Watershed Information. DHS recommends that a map showing the reservoir and its surrounding areas be developed that includes the following information:

- Location of water works facilities (i.e., reservoir inlets or tributaries, reservoir outlets, controls, treatment works, etc.).
- Topography of the reservoir (including subsurface) and its immediate watershed (i.e., within approximately 1 mile of shoreline).
- Location of the shoreline at anticipated high and low water levels.
- Prevailing currents in the lake.
- Areas to be open for different types of recreational use.
- Location of any intakes used to supply water for recreational use areas.
- Location of activities and/or facilities that have the potential to contaminate the water supply (e.g., horse stables).
- Location of wastewater collection, treatment, or disposal facilities in the proximity of the reservoir, including information on the degree of treatment provided and any reliability features.
- Locations of toilets to be provided for the public.
- Information on the quality of the water in the reservoir (i.e., results of any microbiological, chemical, turbidity, and radiological monitoring.

The following data on the reservoir should also be documented:

- Physical dimensions of the reservoir, including the range of water level fluctuations.

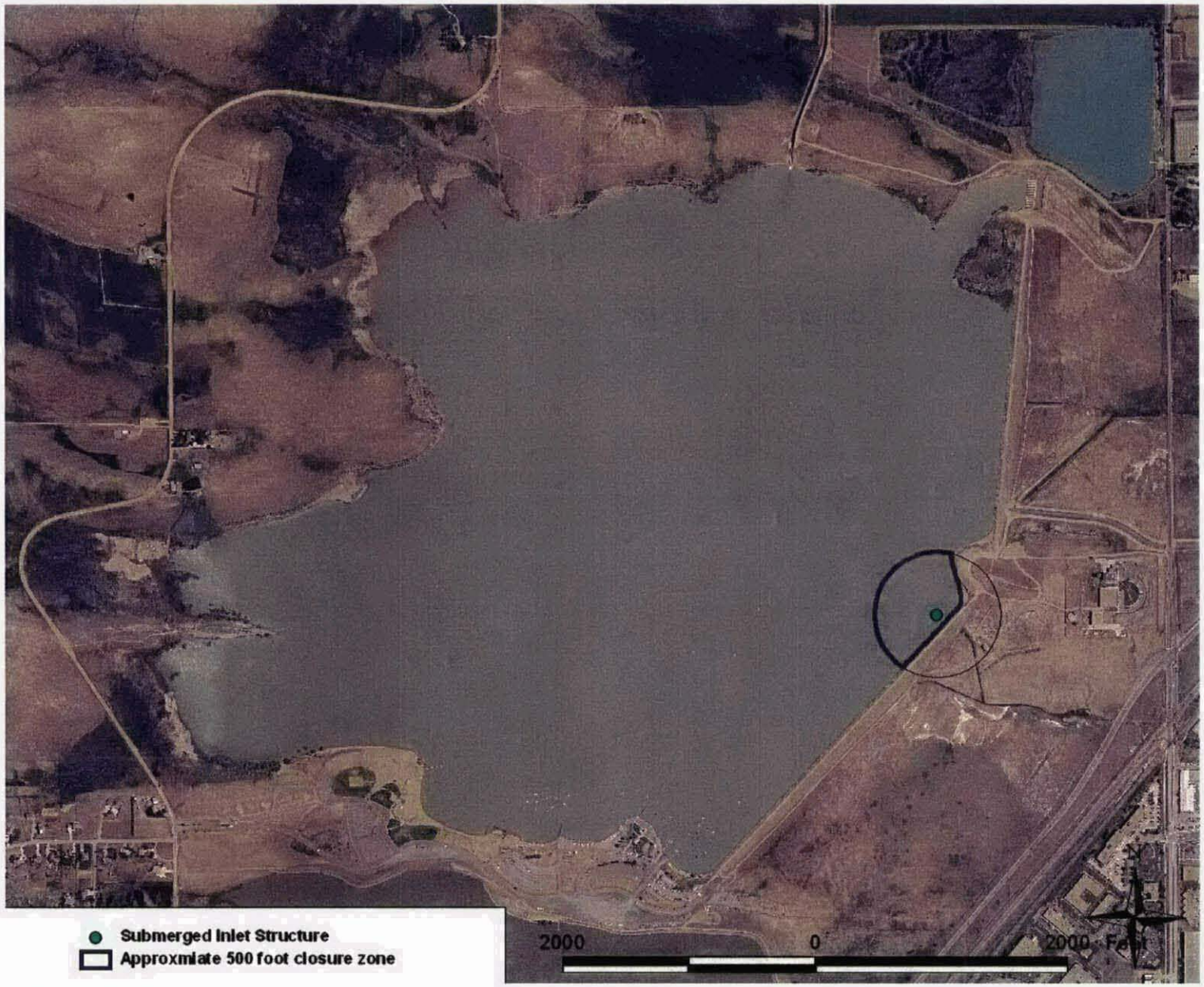
- Reservoir storage capacity and shoreline length at anticipated high and low water levels.
- Residence time for water stored in the reservoir at anticipated high and low water levels.
- Occurrence of wind-induced currents, natural or man-induced turbulence, thermal gradients, a thermocline, or other factors that may affect the quality of the stored water and movement of possible contaminants to the water intake from various points in the reservoir.

The City currently has a map that includes a large portion of the data required. The remaining data would require minimal effort to develop.

b. Protecting the Reservoir Outlet. In California a protective zone must be established around the intake to the treatment plant intake. The zone is an area around the inlet in which all recreational use is prohibited. The zone should be marked with buoys and a cable line and patrolled to prevent boats from entering. The area should be a minimum of 500 feet from the reservoir inlet. A site specific study of flow dynamics may be undertaken to determine whether the 500-foot setback is adequate. Figure 3-1 shows the proposed protective zone.

c. Inventory of Recreational Activities. A detailed inventory of the recreational activities allowed on and around the reservoir should be completed.

d. Prepare a Control Program. Using the inventory of recreational activities, prepare a control program to establish appropriate guidelines for recreational activities such as boating, swimming, and equestrian activities. In addition, the control program should identify specific requirements for toilets, trailer sanitation stations, onsite sewage disposal systems, sewerage systems, refuse disposal, visitor limitation, water quality monitoring, reservoir area closure, reservoir patrol, emergency plan, public health surveillance and public notification.



BLACK & VEATCH	CITY OF BOULDER, CO SOURCE WATER QUALITY PLANNING STUDY	BOULDER RESERVOIR PROPOSED INTAKE CLOSURE ZONE	FIGURE 3-1

(1) Boating Activities. A program to control boating activities should be implemented with the following requirements:

- Vessels with any form of portable toilet capable of being emptied into the reservoir must be prohibited. In some cases, all boats with any form of toilet or sink should be excluded from the reservoir.
- The reservoir must be open to boating only when the operating agency can maintain an adequate patrol and enforce the provisions of all applicable regulations.
- Boat-washing facilities should be provided for rental and private boats. All waste from such facilities must be removed to an on-shore disposal system.
- A responsible person must be on duty at all times at the launching ramps when the ramps are in operation to inspect all boats being launched to ensure compliance with applicable regulations.
- Containment features must be provided at all fuel-loading facilities to prevent fuel spillage into the reservoir. Storing fuel in containers over the water must be prohibited.
- Floating restaurants, snack bars, or other similar types of facilities that require disposal of sewage or other waste should be prohibited.
- Fish cleaning facilities with adequate water supply and waste disposal systems must be provided.

(2) Swimming. Swimming areas should be located as far as possible from drinking water inlets. In order to reduce the introduction of fecal matter into the reservoir, diaper wearing infants, dogs and domestic animals should be prohibited from water contact. As an alternative, swimming in the reservoir could be prohibited. A swimming pool or isolated lagoon could be constructed for swimming.

(3) Equestrian Activities. Horse activity in the area around the reservoir must be carefully regulated. In general, horses should be prohibited from entering the reservoir or any tributary stream within 200 feet of the reservoir

shoreline. All trails should be set back 100 feet from the reservoir high water level and horses should be bagged.

(4) Toilets. Toilets must be sufficient in number, conveniently located, readily accessible to the public, and maintained in a clean, sanitary fashion at all times. The following requirements should be met:

- Toilet facilities must be convenient and available to the public in all areas of the reservoir that are open to recreation. Only parts of the shoreline where toilet facilities are available within a 5-minute walk (or, alternatively, within 500 feet) should be open for recreation.
- Toilet facilities must be available within two miles of any point of the reservoir, and provided with a dock for easy access.
- Toilets must be emptied and cleaned daily in developed areas during the recreation season. At other times, and in remote areas, toilets must be emptied and cleaned at least once a week.

DHS recommends either conducting a study to determine the appropriate number of toilets or assume 50 persons per toilet at picnic areas, playgrounds, beaches, and other general use areas and 70 persons per toilet for designated shore-fishing areas. There is currently only one permanent public restroom facility in the area around Boulder Reservoir. Based on DHS guidance, two additional restrooms should be added in the area near the first one. Additionally, new restrooms should be developed in the area between the two dams, on the west side of the reservoir, and in the area near Coot Lake. A map of possible toilet locations is shown in Figure 3-2.

(5) Trailer Sanitation Stations. Trailer sanitation stations are not necessary because camping is not allowed at the reservoir.

(6) Individual, On-Site Sewage Disposal Systems. Onsite sewage disposal systems are not used in the area around the reservoir. Continuing this policy will ensure the reservoir is not contaminated by these systems.

BLACK & VEATCH	CITY OF BOULDER, CO SOURCE WATER QUALITY PLANNING STUDY	BOULDER RESERVOIR RESTROOM FACILITIES	FIGURE 3-2

(7) Sewerage Systems. A variety of controls are recommended for areas using integrated collection and disposal systems including:

- Sewers and appurtenances must be at least 10 feet above and over 200 feet away from the high water line of the reservoir.
- Sewerage facilities must be designed and built to prevent overflow or leakage.
- Sewage pumping stations and force mains must be designed on a fail-safe basis.
- All failure alarms on the various portions of the sewerage system must have an independent power source.
- All portions of the sewerage system must be outside the closed zone at the reservoir outlet.

Although the location of existing sanitary sewers was not established as part of this study, it seems unlikely that the existing sewer line is 200 feet from the high level water level.

(8) Refuse Disposal. Dumping of refuse must be prohibited. Conveniently located, covered, and anchored refuse containers must be provided in all areas open for recreation. A sufficient number of such containers must be provided to accommodate refuse generated during peak use periods. An approved waste collection and disposal entity must transport refuse off the watershed for disposal.

(9) Visitor Limitation. In order to prevent overuse of the area and creation of health or safety hazards, the number of persons, boats and trailers allowed to use a recreation area must be limited to avoid exceeding the capacity of sanitation and other support facilities. DHS recommends 2.1 visitors per acre-foot of water above the thermocline during peak visitation periods. A detailed study of reservoir conditions is needed to accurately determine the appropriate number of visitors allowed to swim in the reservoir at any one time.

(10) Water Quality Monitoring. The reservoir should be monitored for microbial quality. At a minimum, samples should be collected for total and fecal coliform bacteria. Samples for *E. Coli*, enterococcus bacteria, *Giardia* and *Cryptosporidium* are also recommended. Bacteriological samples should be collected at least weekly during peak usage periods. At least one sample should be collected from each swimming or dock area, and from the reservoir inlet(s) and outlet(s). Protozoa samples should be collected at least monthly from the reservoir outlet.

Special studies are recommended to determine microbial load during heavy use events such long holiday weekends or special events attracting large numbers of visitors to the reservoir.

(11) Reservoir Area Closure. The recreation administrator or manager must be authorized to close a reservoir to recreation. DHS recommends that a recreation area be closed when water quality monitoring indicate that levels of indicator organisms exceed any of the values listed in Table 3-1.

Table 3-1

Reservoir Closure Cutoff Values

Parameter	Single Sample	30-day Average
Total coliform	10,000/100 ml	1,000/100 ml
Fecal coliform	400/100 ml	200/100 ml
E. coli	235/100 ml	126/100 ml
Enterococcus	61/100 ml	33/100 ml

(12) Reservoir Patrol. Full-time patrol personnel must be provided. In general, one patrol personnel should be provided if there are less than 200 visitors and two patrol personnel should be provided for up to 1,000 visitors. Additional personnel should be provided for larger crowds. One additional full-time patrol personnel should be provided for each additional 500 visitors.

Boat patrols must also be provided. The number of patrols should be sufficient to police the entire reservoir at least twice daily.

(13) Emergency Plan. An emergency plan should be developed to respond to an actual or threatened water contamination incident.

(14) Public Health Surveillance. At least monthly, a registered Environmental Health Specialist should inspect the reservoir and provide recommendations for future reservoir protection.

(15) Public Notification. Visitors must be effectively informed that the reservoir is used for drinking water. A public information program should have the following elements:

- Indicate on all informational bulletins that the reservoir is a source of domestic water supply and shall not be polluted.
- Provide all persons entering the recreation area with copies of ordinances or similar informational material relating to the protection of the water supply.
- Locate large permanent signs throughout the recreation area indicating that the reservoir is a source of domestic water supply. Signs in swimming areas should also indicate that domestic animals are not allowed, and that diaper-wearing infants must be kept out of the water.
- Provide decals for posting inside all rental and all private boats indicating the need for protection of the stored water supply.

e. Biological Risk Assessment. In cases where the annual number of visitors exceeds recommended guidelines, a numerical estimate of the anticipated densities of critical pathogenic organisms at the reservoir outlet, and how these concentrations vary with recreational use patterns, reservoir levels and flow conditions must be completed. Sufficient information is not available to determine if a risk assessment for the Boulder Reservoir is necessary.

B. Water Quality Impacts

The difficulty with the aforementioned management strategies for Boulder Reservoir is determining which strategies will provide the most. Because the City

does not have the resources to implement all strategies, some form of cost-benefit analysis will be necessary to establish which strategies should be implemented. After implementation, the benefits, in terms of water quality improvement or protection, should be quantified to justify continued expenditures.

The City currently maintains a regular, monthly, monitoring program in Boulder Reservoir throughout the year. This historical data should provide a useful baseline by which the success of particular control strategies can be assessed over time. Of course, if a number of strategies are implemented simultaneously, there will likely be difficulties in arriving at a complete understanding of the relative benefits of each.

Because the City currently performs water quality monitoring on a monthly basis, the development of a statistically significant database could potentially take years. Depending upon the strategy under consideration, the City may want to consider customizing certain aspects of the monitoring program to accelerate the development of a database and facilitate an assessment of the value derived from particular strategies.

The following section identifies the impacts to water quality that can be expected from implementing a reservoir management alternative.

1. Pathogens

Human source controls should significantly reduce the risk from pathogens in the reservoir. However, quantitative values cannot be easily developed. Watershed source control may be eligible for additional ½ log removal credit under LT2ESWTR. Additional credit may be obtained through demonstration.

2. Treatability

Aeration should help reduce algae concentrations in the raw water, which may result in lower DBP precursors, depending on what treatment system is used at the BRWTF. Manganese and algae should be reduced through the in-reservoir management processes discussed. This alternative will not have a significant effect on TDS concentrations.

C. Cost Opinion

The Phase 1 Study provided only a conceptual level of design for each of the source water management alternatives. Although a number of different strategies for source water improvement and protection were presented and discussed in relation to the Boulder Reservoir Management alternative, a specific project was never defined. Consequently, the cost opinion for this alternative does not represent an actual project, but instead provides an overview of the range of possible elements that might be included in a multi-tiered project at Boulder Reservoir.

1. Capital Costs

The capital cost opinion presented in Table 3-2 represents the conceptual nature of the Phase 1 Study and as such, are based on a general understanding of the components and experience with projects of a similar nature. The costs are intended to provide a picture of the relative costs of different source water management strategies that can be compared to one another.

2. Operation and Maintenance

Sufficient data is not available to determine O&M costs at this time, since a specific project has not been defined. A specific project should be defined and O&M costs developed as part of the Phase 2 Study including number of required personnel. It is important to note that proper maintenance of all facilities is essential to project success.

Table 3-2

Capital Cost Opinion for Reservoir Management

Solution Component	Description	Requirements	Estimated Cost
Reservoir Processes	Design and install reservoir aeration system		$300,000
Human Sources	Reservoir and watershed information	Develop reservoir topography data	$5,000
		Expansion of existing GIS data	$5,000
		Development of Reservoir Model	$100,000
	Outlet protection	Mark zone with protective buoys and cables	$20,000
		Fence appropriate areas	$22,000
	Recreational activities	Develop detailed inventory of current recreational activities	$10,000
	Fishing	Fish cleaning facilities	$40,000
	Toilets	Install a minimum of 2 toilets immediately and additional toilets as necessary	$250,000
	Water Quality Monitoring	Complete required water quality testing	$5,000
	Emergency Plan	Develop emergency plan	$5,000
	Public Notification	Develop public education materials	$20,000
Watershed Sources	Bioretention facilities		$240,000
	Structural storm water treatment systems		$80,000
	Treatment of runoff from Lake Valley development		$100,000
	Treatment of runoff from golf courses		$150,000
	Treatment facility for irrigation canal start-up flows		$150,000
	Planting and drip irrigation		$200,000
		Subtotal	**$1,702,000**
		Engineering and Administration (15%)	$255,000
		Contingencies (15%)	$294,000
		Total	**$2,251,000**

D. Operational Impacts

Operational impacts are key criteria in the evaluation and selection of an alternative. Issues associated with operations include reliability, security, and potential impacts to water rights or the ability to supply water to the BRWTF.

1. *Water Supply/Water Rights*

Under the reservoir management alternative, water will be pumped from the Boulder Reservoir year-round. This will be a change from the current practice of using water directly from the BFC in the summer months and pumping from Boulder Reservoir in the winter months. However, this alternative will have no impact on the water rights currently held by the City.

2. *Reliability*

The human source control aspect of this alternative will require continued City attention and effort in order to remain effective. However, as public knowledge and awareness is increased, reliability should also be increased.

It is important to note that one advantage of utilizing Boulder Reservoir year-round is that plug flow of any contaminant directly into the BRWTF is avoided, due to the large dilution volume.

3. *Security*

The human source control aspect of this alternative is built around measures that will improve the security in the reservoir. Increased patrols, personnel, buffer zones, and fences will all substantially increase the security of the reservoir.

Public education will increase knowledge on intake location and operation, and thus increase the risk of intentional contamination. However, increased public vigilance will result in increased protection.

E. Community Impacts

The following describes the potential community impacts associated with the reservoir management alternative.

1. *Environmental*

The reservoir option is built around actions that will improve the environment. Improving raw water quality is improving the environment.

2. *Public Acceptance*

Generally it is anticipated that the public will approve of the improvements associated with the reservoir alternative. However, potential closures and other

restrictions associated with the alternative may not be popular with the affected public.

F. Impact on City's Water Goals

The City has set pathogen removal/inactivation goals that are more stringent than the regulatory requirement. In addition, the City has also set water quantity and aesthetic water quality goals. These goals are discussed in Chapter 1. The reservoir solution will help the City meet its water quality goals. However, it is not possible to determine the extent of the improvement without substantially more investigation. This alternative will not significantly help the City obtain its goal of providing similar finished water quality to all of its customers.

G. Implementation Timeframe

Most control measures can be implemented in a relatively short timeframe. With appropriate budget and City support, most measures can be fully implemented within less than two years.

Chapter 4

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CHAPTER 4
FULL CONTAINMENT FROM CARTER LAKE TO THE BRWTF

This chapter addresses the potential impacts associated with a full containment alternative.

A. Description of Alternative

The full containment alternative is based on construction of a new raw water pipeline to contain and protect source water delivered from Carter Lake to the BRWTF. This alternative assumes that the City would participate with several other municipal agencies having a similar interest in a pipeline that would transport Windy Gap Project water, as administered by NCWCD, from Carter Lake to the individual municipal localities for treatment.

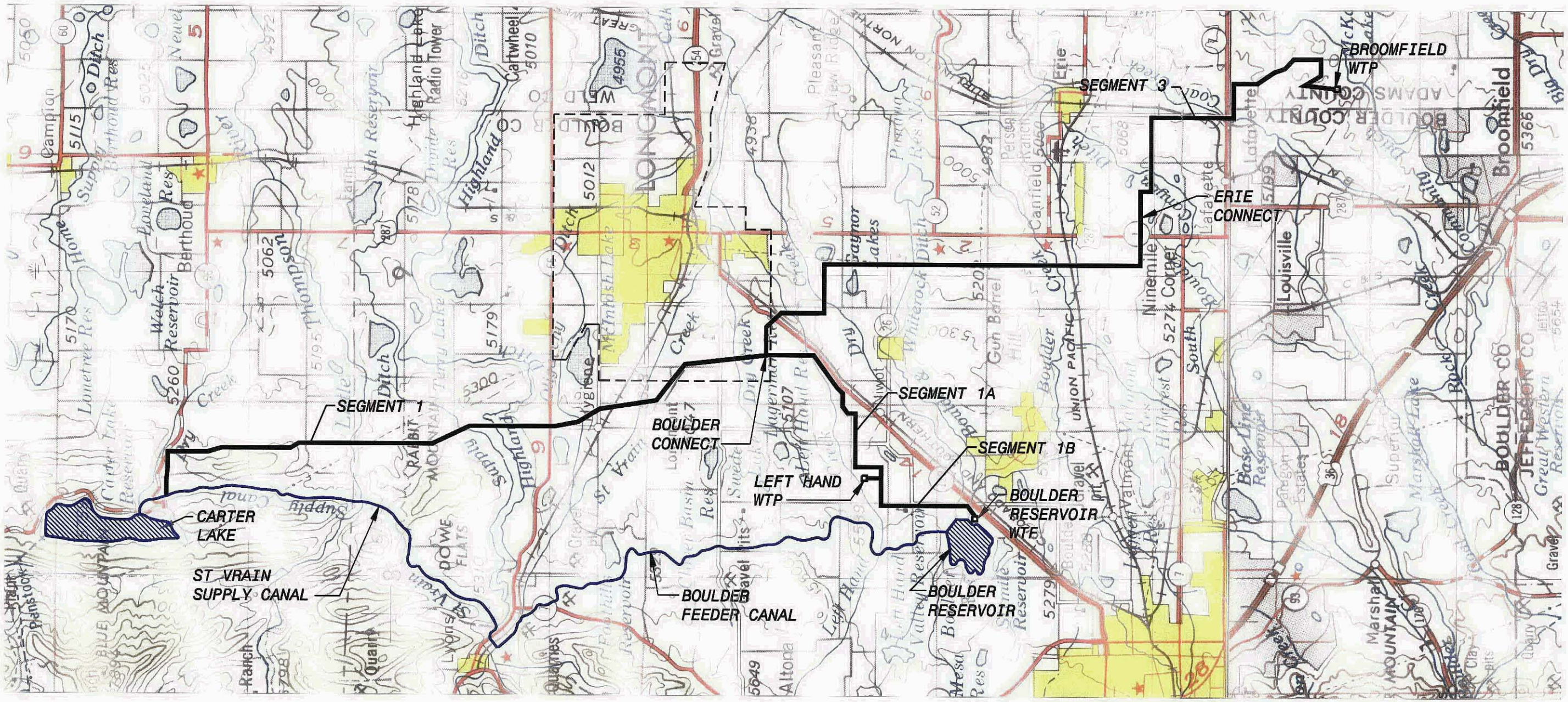
To provide a basis for comparison with other source water alternatives, a conceptual full containment alternative has been developed. To date, there have been no discussions between the City of Boulder and municipal agencies regarding such a project. However, Black & Veatch has discussed this concept with NCWCD and has performed evaluations for several other agencies that use CBT water. The agencies that have considered participation in a pipeline as a future possibility are identified in Table 4-1, which also lists their preliminary design flows.

Table 4-1

Potential Participants for Shared Pipeline from Carter Lake

Potential Participant	Preliminary Design Flow (mgd)
City of Boulder	20.0
City of Broomfield	20.0
Town of Erie	6.0
Left Hand Water District	14.0

A reconnaissance level evaluation of alternative pipeline routes was prepared by Black & Veatch in March 2002 for the City of Broomfield. The



LONGMONT CITY LIMITS

PROPOSED PIPELINE ROUTE

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CITY OF BOULDER, CO
SOURCE WATER QUALITY PLANNING STUDY

FULL CONTAINMENT
PROPOSED PIPELINE ALIGNMENT

FIGURE
4-1

evaluation determined that the least expensive of the alternative routes was the alignment that followed the existing NCWCD pipeline all the way from Carter Lake to Broomfield. For the purposes of this evaluation, it will be assumed that the new pipeline for the full containment project will follow this alignment. As it crosses the Diagonal Highway, a western branch would convey flow to Left Hand Water District and the City of Boulder. Figure 4-1 shows the conceptual alignment of the pipeline.

Table 4-2 presents a preliminary design for the full containment alternative based on the maximum design flows estimated for each of the project participants. On the basis of the maximum flow requirements, the available elevation head, pipeline headloss, and pipe diameters were established to provide gravity flow to the maximum extent possible. As a result, all participants can be served by gravity flow except for Broomfield where a booster pumping station will be required to convey the flow the last few miles to the Broomfield Water Treatment Plant (WTP).

Table 4-2

Preliminary Pipeline Design

Description	Segment 1	Segment 1A	Segment 1B	Segment 2	Segment 3
	Carter Lake to Boulder Connect	Boulder Connect to Left Hand Dodd WTP	Left Hand Dodd WTP to BRWTF	Boulder Connect to Erie Connect	Erie Connect to Broomfield WTP
Flow Contribution					
Boulder, mgd	20.0	20.0	20.0	-	-
Left Hand, mgd	14.0	14.0	-	-	-
Erie, mgd	6.0	-	-	6.0	-
Broomfield, mgd	20.0	-	-	20.0	20.0
Total Flow, mgd	60.0	34.0	20.0	26.0	20.0
Beginning Elevation, ft	5,580	5,010	5,130	5,010	5,190
Ending Elevation, ft	5,010	5,130	5,170	5,190	5,390
Length, ft	84,900	22,200	14,300	55,600	37,200
Diameter, inches	54	36	30	42	42
C value	120	120	120	120	120
Velocity, ft/second	5.9	7.4	6.3	4.2	Pressurized
Headloss, ft	165	109	64	78	Pressurized

B. Water Quality Impacts

The following section identifies the impacts to water quality that can be expected from implementing the full containment alternative outlined above.

1. Pathogens

With the full containment alternative, the raw water from Carter Lake will not be exposed to the BFC. This should result in a large reduction in bacteriological organisms such as fecal coliforms, viruses, *Giardia* and *Cryptosporidium*.

Construction of a pipeline from Carter Lake to the BRWTF should enable the City to meet all of the regulatory requirements with respect to pathogen removal/inactivation. Discussions were held with the Town of Erie, Colorado, which utilizes a pipeline to deliver Carter Lake water to their WTP. Since 1998, no *Cryptosporidium* or *Giardia* has been detected in the raw water entering their treatment plant. Therefore, no additional treatment should be necessary to meet the requirements of the LT2ESWTR under this alternative.

2. Treatability

The sediment in Carter Lake does not contain large amounts of naturally occurring manganese, and therefore, release of manganese would not be a concern, since raw water would be delivered directly from Carter Lake, instead of into Boulder Reservoir. In addition, algae blooms are not prevalent in Carter Lake, due to the large volume and depth of the lake, and therefore, would not be a major concern under this alternative.

In general, the turbidity of the raw water in the BFC has been relatively low and has not been an issue during treatment. None the less, some reduction in turbidity should be realized from the full containment alternative, since turbidity levels in Carter Lake are generally less than those in the BFC and Boulder Reservoir.

C. Cost Opinion

This section includes a preliminary estimate of the costs associated with the full containment alternative.

1. *Capital*

Capital costs have been developed based on the major components of the pipeline. Table 4-3 presents the cost opinions for the individual pipeline segments. The following assumptions were used for the development of capital costs:

- Costs for the pipeline itself are based on unit pricing per diameter inch of one foot of pipe length. A unit price of $6.00 was used for open country, $7.00 for areas requiring asphalt replacement, and $8.00 for areas within the City of Longmont.

- Segments 1, 2, and 3 of the pipeline will follow the route of the existing pipeline and therefore no additional permanent easement will be required. However, costs have been included for obtaining an additional 20 feet of temporary construction easement. Cost estimates for Segments 1A and 1B assume that a 50 foot permanent easement will be obtained.

- The tie-in at Carter Lake will be made at the existing outlet structure by cutting through the concrete wall and stubbing in the new pipe.

- During the original pipeline construction, the upper reaches of the Feeder Canal at Carter Lake were improved in association with the construction of the outlet structure. To offset the earlier costs, NCWCD has established a progressive connection fee to be charged to additional customers connecting to the existing outlet structure. According to NCWCD, this fee is currently in the range of $91,000 per cubic foot of pipeline capacity. Dependent upon the particular participants and configuration of the new pipeline, this fee may be negotiable.

Table 4-3

Capital Cost Opinion for Pipeline from Carter Lake to the BRWTF

Description	Segment 1	Segment 1A	Segment 1B	Segment 2	Segment 3
Metering Vault and Tie-in	$437,000	-	-	-	-
Outlet Works Tie-in Fee	$6,825,000	-	-	-	-
Pipeline and Appurtenances	$28,760,000	$5,288,000	$2,892,000	$14,011,000	$9,374,000
Easements	$195,000	$128,000	$82,000	$128,000	$86,000
Flow Control Vault	-	$325,000	$325,000	-	-
Pump Station	-	-	-	-	$3,000,000
Subtotal	**$36,217,000**	**$5,741,000**	**$3,299,000**	**$14,139,000**	**$12,460,000**
Engineering and Administration (15%)	$5,432,000	$861,000	$495,000	$2,121,000	$1,869,000
Contingencies (15%)	$6,248,000	$990,000	$569,000	$2,439,000	$2,149,000
Total	**$47,897,000**	**$7,592,000**	**$4,363,000**	**$18,699,000**	**$16,478,000**

Table 4-4 presents a cost breakdown among the participating agencies that is in direct proportion to the pipeline capacity allocation for each entity within each segment.

Table 4-4

Pipeline Cost Allocation Based on Flow

Description	City of Boulder	Left Hand Water District	Town of Erie	City and County of Broomfield	Total Segment Cost
Segment 1	$15,966,000	$11,176,000	$4,790,000	$15,966,000	$47,898,000
Segment 1A	$4,466,000	$3,126,000	-	-	$7,592,000
Segment 1B	$4,363,000	-	-	-	$4,363,000
Segment 2	-	-	$4,315,000	$14,384,000	$18,699,000
Segment 3	-	-	-	$16,478,000	$16,478,000
Total Allotted Cost	**$24,795,000**	**$14,302,000**	**$9,105,000**	**$46,828,000**	**$95,030,000**

2. *Operation and Maintenance*

If the full containment project were to be developed jointly by several municipal entities, it is likely that NCWCD would be the contracting authority and would own and maintain the mainline of the pipeline when complete. Whether this ownership would extend to the branch serving Left Hand Water District and the City is uncertain at this time.

D. Operational Impacts

Operational impacts are key criteria in the evaluation and selection of an alternative. Issues associated with operations include reliability, security, and any potential impacts to water rights or the ability to supply water to the BRWTF.

1. *Water Supply/Water Rights*

Under this alternative, water will flow directly from Carter Lake to the BRWTF during most of the year. As a CBT allottee, the City is entitled to draw its annual quota of CBT water from any of the CBT project facilities and a pipeline would not affect the City's ability to access its annual quota of CBT water. However, the City cannot carryover CBT water specifically designated for Boulder's use without paying an annual shrinkage fee of 10 percent. Presently, the City can carryover water long-term in Boulder Reservoir without an annual shrinkage fee. Therefore, this alternative will still require that the City maintain 3,143 acre-feet of water in Boulder Reservoir as long-term storage that could be used for drought or emergency supplies for treatment at the BRWTF and/or for exchange. However, 1,000 acre-feet of this water can only be taken at the BRWTF and is not available for exchange.

In addition, the BRWTF may continue to need to treat up to 2,000 acre-feet of non-CBT water delivered through Boulder Reservoir from the Farmers Ditch between May 1 and July 31 in order to maintain this water right. Therefore, it may be necessary to pump raw water from Boulder Reservoir for a period of time. However, the length of time that this pumping would occur would be much less than the current practice.

The City could also continue to use the Boulder Reservoir as an on-going annual supply source for the BRWTF by storing additional CBT water in Boulder Reservoir for winter use. Use of this water, possibly by mixing it with water from the pipeline, could increase the city's overall water yields.

2. *Reliability*

Of the alternatives under consideration, a full containment pipeline will provide the highest degree of reliability for source water protection from Carter Lake to the BRWTF. This reliability can be achieved with minimal expenditures of operational or management effort, once the pipeline is in place.

3. *Security*

The full containment alternative is the best option for protection against contamination events. The only potential intrusion points would be either Carter Lake, which offers enormous dilution, or direct taps to the pipeline which would require a substantial intentional-based threat condition. Although it would be nearly impossible to secure the entire length of the pipeline, the buried pipeline would be difficult to access and the vault structures, where it would be most vulnerable, could be alarmed if necessary. The City's vulnerability assessment should assess the level of concern for such a threat condition, and if reasonable, actions to protect the infrastructure of the delivery system would need to be coordinated with NCWCD.

E. Community Impacts

The following describes the potential community impacts associated with the full containment alternative.

1. *Environmental*

Overall the environmental impacts of the full containment project will be minimal. The mainline of the pipeline will follow an existing pipeline so once the pipeline is installed and the area revegitated, there should be no adverse impacts to the environment. The branch of the pipeline that would serve Left Hand Water District and the City will be a new pipeline route, but again, once in the ground and vegetated, there should be no long-term environmental impacts.

The project will have to undergo the Boulder County 1041 permitting process. Although the City is not increasing the quantity of raw water being supplied, the other potential participants will be increasing their raw water quantity. This increase will support additional growth within Boulder County and thus, this alternative will likely encounter opposition from the public opposed to growth. The improvement in water quality for the City of Boulder should mitigate

some of these concerns, but a full environmental assessment should be anticipated to permit this project.

2. *Public Acceptance*

It is anticipated that public acceptance issues related to the buried pipeline will be limited to a very small segment of the public that may be impacted during the pipeline construction. Because the pipeline will be buried and will be installed adjacent to an existing pipeline or in an existing right-of-way (R.O.W.), there will be no visual impact after the construction is completed.

F. Impact on City's Water Goals

The City has set pathogen removal/inactivation goals that are more stringent than the regulatory requirement. In addition, the City has also set water quantity and aesthetic water quality goals. These goals are discussed in Chapter 1. Construction of this alternative will go a long way toward allowing the City to meet its water quality goals. Based on the water quality that is routinely observed from similar, existing conduit systems, the City can reliably plan for consistent high quality raw water.

Utilizing the full containment alternative will allow the City to obtain its goal of providing similar finished water quality to all of its customers, including TDS concentrations.

G. Implementation Timeframe

By constructing the full containment project in the existing easement adjacent to the existing NCWCD pipeline, only temporary construction easements would need to be purchased, which would save some time over having to identify and purchase new easements for an alternative route. It is anticipated that the 1041 Permit for Boulder County could take 6 to 12 months to obtain. Survey and design could be accomplished in approximately 10 to 15 months. Pipe fabrication would take approximately 2 years to complete depending on manufacturers backlog and construction would require approximately 8 to 10 months. Although some of these tasks can be completed simultaneously, the overall schedule should allow approximately 3 years after the engineer's notice to proceed.

Timing of the project will likely be determined by the availability of funds, both from the City and the other participants in the pipeline project. NCWCD has indicated that their planning horizon for this project is 2010 – 2015.

CHAPTER 5
PARTIAL CONTAINMENT FROM NELSON ROAD TO THE BRWTF

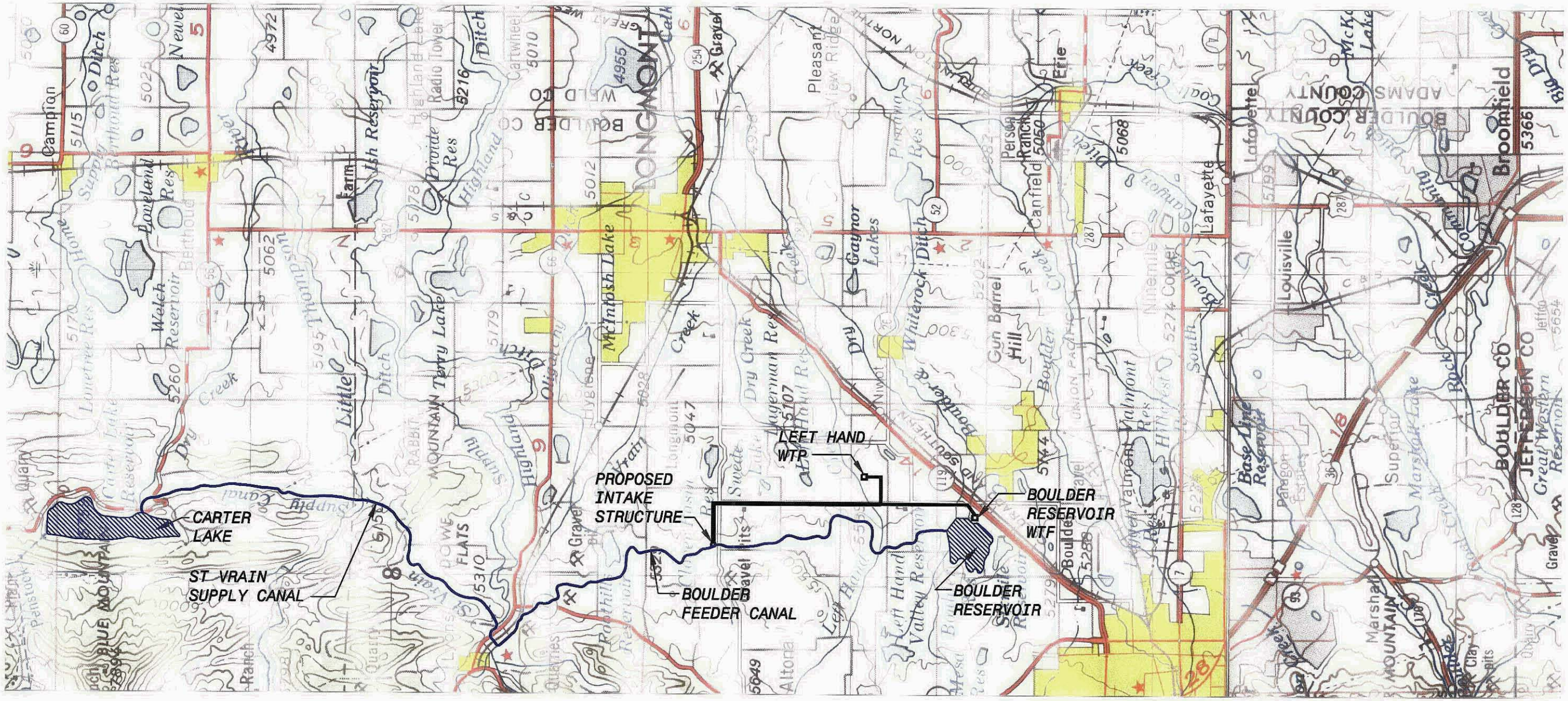
This chapter addresses the potential impacts associated with a partial containment alternative.

A. Description of Alternative

This partial containment alternative is based on delivering raw water from Carter Lake by way of the BFC to a point just upstream of Nelson Road, approximately 5 miles north of the BRWTF. From this point, raw water would be diverted from the BFC at a new intake structure and delivered to the BRWTF in a new buried pipeline to provide containment and protection of the source water. The pipeline would only be operation during the summer months when the BFC was operating. The remainder of the year, raw water would be pumped from Boulder Reservoir, as is the current practice.

This alternative would eliminate the potential for degradation and contamination of the raw water from point and non-point sources along the more highly developed areas between Nelson Road and the Boulder Reservoir. In addition, the pipeline will eliminate the historical problems experienced when high flows in Left Hand Creek intermingle with the flows in the BFC. This alternative may also provide some potential for sharing cost with Left Hand Water District.

Figure 5-1 shows the conceptual alignment of the pipeline. Table 5-1 presents a preliminary design for the partial containment alternative. The table details two potential scenarios. The first is based on the City undertaking the project alone. The second was developed on the basis of maximum design flows estimated in Chapter 4 for both the City and Left Hand Water District. Raw water would be delivered to both the City and Left Hand by gravity flow.



PROPOSED PIPELINE ROUTE

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SOURCE WATER QUALITY PLANNING STUDY

PARTIAL CONTAINMENT
PROPOSED PIPELINE ALIGNMENT

FIGURE
5-1

Table 5-1

Potential Pipeline Design Scenarios

Description	Boulder Only	Boulder and Left Hand	
	Segment 1	Segment 1	Segment 2
	Nelson Road to BRWTF	Nelson Road to Left Hand Connect	Left Hand Connect to BRWTF
Flow Contribution			
Boulder, mgd	20.0	20.0	20.0
Left Hand, mgd	-	14.0	-
Total Flow, mgd	20.0	34.0	20.0
Beginning Elevation, ft	5,245	5,245	5,170
Ending Elevation, ft	5,170	5,170	5,170
Length, ft	33,400	20,700	12,700
Diameter, inches	36	48	36
C value	120	120	120
Velocity, ft/second	4.4	4.2	4.4
Headloss, ft	61	25	23

B. Water Quality Impacts

The following section identifies the impacts to water quality that can be expected from implementing the new forebay alternative outlined above.

1. Pathogens

The partial containment alternative should result in a reduction in bacteriological organisms such as fecal coliforms, *Giardia* and *Cryptosporidium*. However, the raw water will still be exposed for a large portion of the canal length, which increases the risk of pathogen contamination.

It is not known whether construction of a partial pipeline will enable the City to meet the requirements of the LT2ESWTR with respect to pathogen removal/inactivation. It is anticipated that this alternative will not have a significant impact on virus removal/inactivation from the current removal/inactivation.

2. *Treatability*

The release of naturally occurring manganese will continue to be a seasonal issue under this alternative since raw water will be pumped from Boulder Reservoir. There may be a slight decrease in the presence of algae, due to the raw water being in a pipeline and not exposed to sunlight for a portion of the time. However it is not expected that this decrease will be significant. The presence of algae can result in taste and odor problems, as well as increased total organic carbon (TOC) concentrations, which act as disinfection by-product precursors.

In general, the turbidity of the raw water in the BFC has been relatively low and has not been an issue during treatment. However, there are turbidity events that make the water untreatable. These occur during storm events and periods of canal maintenance. There should not be any change in turbidity levels under this alternative.

C. Cost Opinion

The following section is a preliminary estimate of the costs associated with the partial containment alternative.

1. *Capital*

Capital costs have been developed based on the major components of the pipeline. Table 5-2 presents the cost opinions for two alternative pipelines. The first alternative is for Boulder being the sole participant in the pipeline. The second includes Left Hand Water District participating in the project. The following assumptions were used for the development of the capital costs:

- Costs for the pipeline itself are based on unit pricing of $7.00 per diameter inch of one foot of pipe length. This assumes the piping will be located completely within existing roads and/or road R.O.W. and accounts for any required asphalt replacement.

- The only additional easements required for this alignment would be minimal and would be in the location adjacent to the BFC where the intake structure will be located and connecting piping would be installed out to Nelson Road.

Table 5-2

Capital Cost Opinion for Pipeline from Nelson Road to the BRWTF

Description	Boulder Only	Boulder and Left Hand	
	Segment 1	Segment 1	Segment 2
	Nelson Road to BRWTF	Nelson Road to Left Hand Connect	Left Hand Connect To BRWTF
Intake Structure	$200,000	$200,000	-
Pipeline and Appurtenances	$8,366,000	$6,955,000	$3,200,000
Subtotal	**$8,566,000**	**$7,155,000**	**$3,200,000**
Engineering and Administration (15%)	$1,285,000	$1,073,000	$480,000
Contingencies (15%)	$1,478,000	$1,234,000	$552,000
Total	**$11,329,000**	**$9,462,000**	**$4,232,000**

2. Operation and Maintenance

For the partial containment alternative, the City would own or share ownership of the pipeline and would therefore be responsible for operation and maintenance (O&M). Because the City already owns, operates, and maintains a large infrastructure of water distribution and wastewater collection piping, the additional O&M for the new piping can probably be considered insignificant in terms of the operating budget.

D. Operational Impacts

Operational impacts are key criteria in the evaluation and selection of an alternative. Issues associated with operations include reliability, security, and any potential impacts to water rights or the ability to supply water to the BRWTF.

1. Water Supply/Water Rights

This alternative will not impact on the City's current water rights, or how the water is supplied to the BRWTF. Boulder Reservoir would still store 3,143 acre-feet of water in long-term storage that could be used for drought or

emergency supplies to the BRWTF and/or exchange, and up to 5,357 acre-feet to meet winter delivery demands through the BRWTF. In addition, the City would still have the ability to treat up to 2,000 acre-feet of non-CBT water delivered through Boulder Reservoir from the Farmers Ditch between May 1 and July 31.

2. Reliability

A partial containment pipeline will provide reliable source water protection only from the point where the flow enters the pipeline. This reliability can be achieved with minimal expenditures of operational or management effort.

The remainder of the BFC from Carter Lake to the new intake would remain exposed to water quality degradation and contamination from point and non-point sources along its uncontained length to the degree that currently exists.

3. Security

The partial containment alternative would include approximately 6 miles of new pipeline to deliver water from the BFC to the BRWTF. The buried pipeline would be difficult to access and the vault structures, where it would be most vulnerable, could be alarmed if necessary. Therefore the pipeline would offer a higher level of security than would be available in the open canal or even a canal that was covered. However, there would be no change in the level of security for the portion of the canal that the raw water will travel down until it reaches the pipeline diversion.

In addition, since Boulder Reservoir will still be utilized in the winter when the BFC is not in operation, the City will also face the same security issues described in Chapter 2.

E. Community Impacts

The following describes the potential community impacts associated with the partial containment alternative.

1. Environmental

Overall the environmental impacts of the partial containment alternative will be minimal. Because the pipeline will be constructed within existing road

R.O.W., as long as proper measures are taken to control runoff from the construction sites, there should be no adverse impacts to the environment. The project will have to undergo the Boulder County 1041 permitting process.

In this alternative, there is no increase in water quantity, only an increase in water quality. Therefore, the public opposed to growth should not have an issue with this project. However, anything can happen during a public process and the extent of environmental analysis required for this project is difficult to predict.

2. Public Acceptance

It is anticipated that public acceptance issues related to the buried pipeline will be limited to a very small segment of the public that may be impacted during the pipeline construction. Because the pipeline will be buried and installed in existing R.O.W., there will be no visual impact after the construction is completed.

F. Impact on City's Water Goals

The City has set pathogen removal/inactivation goals that are more stringent than the regulatory requirement. These goals are discussed in Chapter 1. Construction of a partial pipeline will improve water quality during the irrigation season when water is drawn from the BFC directly into the BRWTF, and should help the City meet its water quality goals. However, this alternative will not help the City obtain its goal of providing similar finished water quality to all of its customers.

G. Implementation Timeframe

The partial containment alternative would not require extensive easement acquisition. A 1041 Permit for Boulder County would be required and may take 6 to 12 months to obtain. Survey and design could be accomplished in approximately 6 months. Pipe fabrication would take several months to complete depending on manufacturers backlog. Construction would require approximately 4 months. Although some of these tasks can be completed simultaneously, the overall schedule should allow approximately 2 years after the engineer's notice to proceed.

Chapter 6

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CHAPTER 6
CONSTRUCTION OF A NEW TERMINAL RESERVOIR

This chapter addresses the potential impacts associated with construction of a new terminal reservoir.

A. Description of Alternative

This alternative includes construction of a new terminal reservoir upstream of the Boulder Reservoir and the BRWTF. The reservoir will be sized for year-round raw water storage (approximately 4,000 acre-feet) and would be lined. The approximate usable depth of the reservoir would be 30 feet. This reservoir would be constructed as an "upland" reservoir, not located within the existing drainage.

Raw water from the BFC will flow by gravity through a pipeline into the reservoir during the summer months when the BFC is operating. The site of the new reservoir will be determined based on available land, hydraulic considerations, and water quality degredation along the BFC. Public access to the reservoir will not be permitted. Raw water will then flow by gravity from the new reservoir through a pipeline to the BRWTF for treatment.

Figure 6-1 shows a potential site for the new terminal reservoir as well as the proposed pipeline alignments into and out of the reservoir.

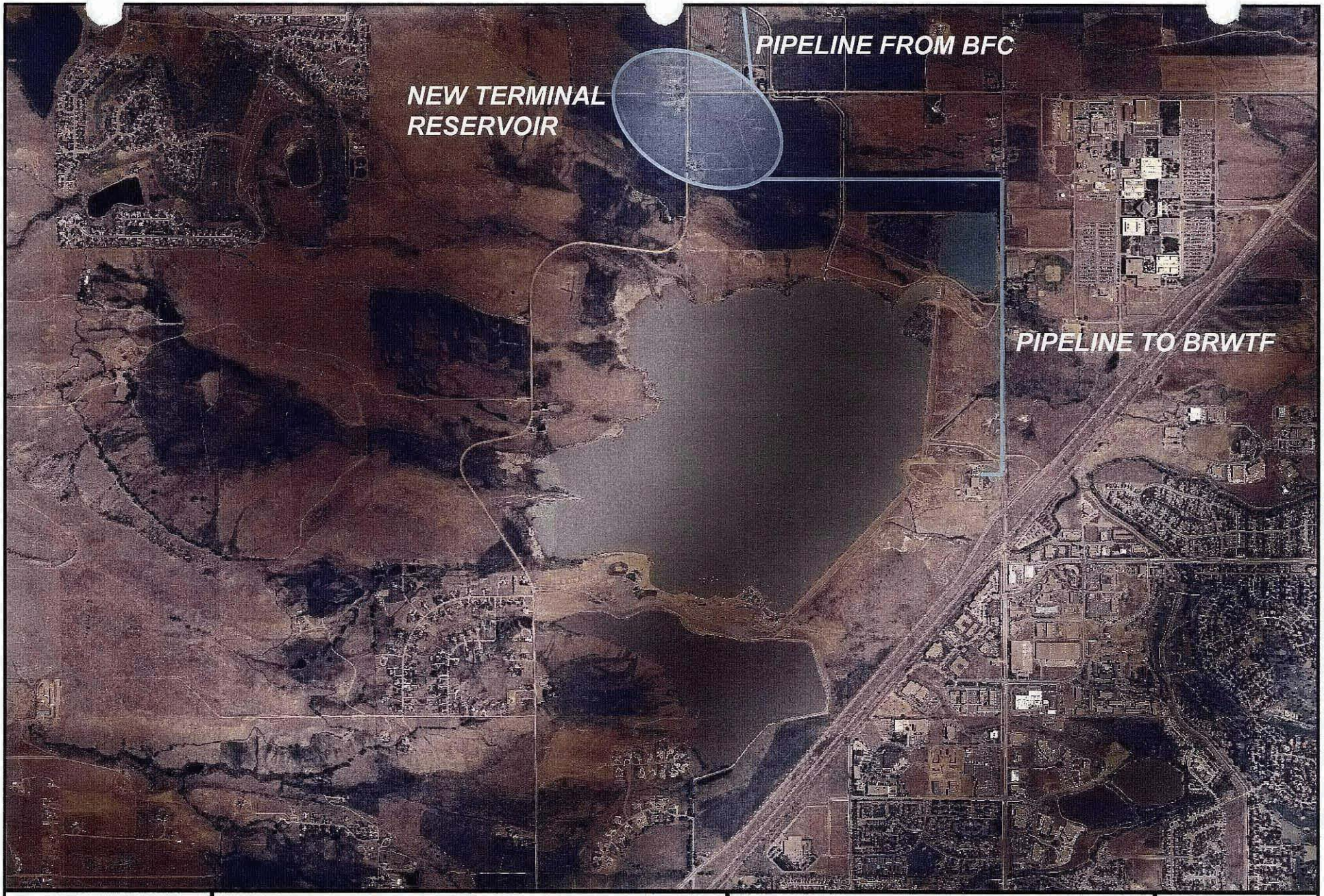
Watershed source control should be implemented as part of this alternative to reduce the amount of surface water runoff into the new reservoir. Landscape-based solutions such as grass lined swales, detention and retention ponds are potential watershed source control approaches. These solutions were discussed in Chapter 3.

B. Water Quality Impacts

The following section identifies the impacts to water quality that can be expected from implementing the new reservoir alternative outlined above.

1. Pathogens

The new reservoir should provide a substantial reduction in bacteriological organisms such as fecal coliforms, as compared to those found in the BFC, due



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to the large size and long detention time of the raw water. Since public access to the reservoir will not be permitted, the chance for fecal contamination from humans should be significantly reduced. However, fecal contamination from animals and waterfowl will not be eliminated since reservoirs with no human activity are very attractive to wildlife. In addition, pathogen concentrations such as *Giardia* and *Cryptosporidium* should be reduced due to settling. However, concentrations of these pathogens could fluctuate periodically due to wind action at the reservoir.

Giardia and *Cryptosporidium* data was reviewed from the City of Longmont, Colorado, which delivers raw water in a similar mode as proposed for this alternative. The City of Longmont utilizes the SVSC from Carter Lake to Carter Pond. Raw water from Carter Pond is delivered to the WTP via a pipeline. Since 2000, *Cryptosporidium* or *Giardia* has not been detected in the raw water entering their treatment plant. Therefore, no additional treatment should be necessary to meet the requirements of the LT2ESWTR under this alternative.

A new terminal reservoir should result in lower virus concentrations compared to levels found in the Boulder Reservoir and the BFC due to the long detention time and lack of public access to the site.

2. *Treatability*

Since the reservoir would be lined, release of naturally occurring manganese would not be a concern in the early years. However, over time, deposition of manganese and the resulting release of soluble manganese would occur.

In addition, it is likely that seasonal algae blooms will occur due to the shallow depth of the reservoir. These blooms can result in taste and odor problems, as well as increased TOC concentrations, which act as disinfection by-product precursors.

In general, the turbidity of the raw water in the BFC has been relatively low and has not been an issue during treatment. None the less, some reduction in turbidity should be realized from the construction of a new terminal reservoir. However, as with pathogen concentrations, turbidity levels could fluctuate periodically due to wind action at the reservoir.

C. Cost Opinion

The following section is a preliminary estimate of the costs associated with constructing and operating a new terminal reservoir.

1. Capital

Capital costs associated with the construction of a new terminal reservoir are listed in Table 6-1. These costs are based on the following assumptions:

- The usable depth of water in the reservoir is 30 feet.
- The height of the reservoir embankment is 40 feet.
- The slope ratio of the reservoir embankment is 1 foot vertical for every 3 feet horizontal.
- The slope of the existing land at the proposed site of the new terminal reservoir is approximately 1 foot vertical for every 87.5 feet horizontal.
- Permanent easements would need to be obtained for the portion of pipeline from the BFC to the new terminal reservoir and from the new terminal reservoir to 63rd Street. The pipeline would then run along 63rd Street and be completely located within existing roads and/or road R.O.W.

2. Operation and Maintenance

The pipelines from the BFC to the new reservoir and from the new reservoir to the BRWTF will be gravity-flow, and therefore, maintenance should be minimal. Maintenance around the reservoir will include weed and dust control. This alternative would require an on-call staff person who would be available to block off the incoming raw water during storm and other potential contamination events.

Sufficient data is not available to determine accurate O&M costs. These costs would be developed as part of a preliminary study and would include parameters such as additional staff requirements to patrol and maintain the new reservoir and pipeline facilities.

Table 6-1

Capital Cost Opinion for New Terminal Reservoir

Component	Quantity	Unit Cost	Estimated Cost
Permitting and geotechnical investigation	Lump Sum	$200,000	$200,000
Land acquisition	150 acres	$8,000/acre	$1,200,000
Easement acquisition	4,750 ft	$5.75/ft	$27,000
36-inch pipeline from BFC to new reservoir	1,750 ft	$5.00/ft/ diameter inch	$315,000
Excavation and berming	4,070,000 cu yd	$6.00/cu yd	$24,420,000
Slope preparation	1,188,000 sq ft	$0.50/sq ft	$594,000
HDPE synthetic liner	6,118,000 sq ft	$0.60/sq ft	$3,671,000
Geotextile	6,118,000 sq ft	$0.25/sq ft	$1,530,000
36-inch pipeline from new reservoir to 63rd Street	3,000 ft	$5.00/ft/ diameter inch	$540,000
36-inch pipeline from 63rd Street to BRWTF	6,000 ft	$7.00/ft/ diameter inch	$1,512,000
		Subtotal	**$34,009,000**
		Engineering and Administration (15%)	$5,101,000
		Contingencies (15%)	$5,867,000
		Total	**$44,977,000**

D. Operational Impacts

Operational impacts are key criteria in the evaluation and selection of an alternative. Issues associated with operations include reliability, security, and any potential impacts to water rights or the ability to supply water to the BRWTF.

1. Water Supply/Water Rights

Under this alternative, raw water will flow by gravity from the new terminal reservoir to the BRWTF during most of the year. The new terminal reservoir alternative would reduce the amount of Boulder Reservoir water delivered and treated through the BRWTF. However, it would not eliminate the need to deliver Boulder Reservoir water to the BRWTF completely unless the reservoir was sized and sited to receive an additional 2,000 acre-feet from the Farmers Ditch

and have the ability to return that water to Boulder Creek. If not, it would be necessary to pump this water from the Boulder Reservoir in order to maintain the water right. However, the length of time that this pumping would occur would be much less than the current practice. The City may also have to pump from Boulder Reservoir in the winter to maintain its winter water storage right.

The City would still maintain 3,143 acre-feet of water in Boulder Reservoir as long-term storage that could be used for drought or emergency supplies for treatment at the BRWTF and/or for exchange. However, 1,000 acre-feet of this water can only be taken at the BRWTF and is not available for exchange.

2. Reliability

Operationally, the reservoir and gravity flow pipelines will be very reliable. However, changes in the raw water quality may result in operational challenges at the BRWTF.

3. Security

Measures will need to be taken to ensure that public access to the reservoir is not permitted. This includes fencing off the perimeter and patrolling the area regularly.

New pipelines will deliver water from the BFC to the new reservoir and from the new reservoir to the BRWTF. The buried pipelines would be difficult to access and the vault structures, where it would be most vulnerable, could be alarmed if necessary. Therefore this alternative would offer a higher level of security than the current situation. However, there would be no increase in the level of security for the portion of the canal that the raw water will travel down until it reaches the pipeline diversion.

E. Community Impacts

Construction a new terminal reservoir will have a significant impact on the community. The following describes the potential community impacts associated with the new terminal reservoir alternative.

1. *Environmental*

This alternative would have significant impacts on the environment. One major environmental impact will be the changing land use. There could be a significant loss of upland habitat.

The construction of a new reservoir will include an extensive permitting and review process, including the Boulder County 1041 permitting process, a jurisdictional dam permit, a Federal 404 permit, and the development of an environmental impact statement (EIS).

2. *Public Acceptance*

Community involvement is paramount to the success of this alternative. Restricted access to the new reservoir may not be popular with the public. Therefore, it will be important to educate the public on the importance of protecting source water.

F. Impact on City's Water Goals

The City has set pathogen removal/inactivation goals that are more stringent than the regulatory requirement. These goals are discussed in Chapter 1. Construction of a new terminal reservoir will improve water quality and help the City meet its water quality goals. However, it is not possible to determine the extent of the improvement without substantially more investigation.

In addition, this alternative may or may not help the City obtain its goal of providing similar finished water quality to its customers, depending on the amount of water quality degredation that occurs before the raw water reaches the BRWTF.

G. Implementation Timeframe

Construction of a new reservoir is a lengthy process due to land and easement acquisition, local and State permitting requirements, and construction. It is anticipated that the environmental permitting process could take two to three years to obtain. Survey and design could be accomplished in approximately 12 months. Construction of the reservoir and pipelines could be completed simultaneously and could be accomplished in approximately two years. The City should expect the process to take approximately five years to implement.

Chapter 7

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BLACK & VEATCH	CITY OF BOULDER, CO SOURCE WATER QUALITY PLANNING STUDY	PROPOSED FOREBAY SITE AND PIPELINE ALIGNMENT	FIGURE 7-1

CHAPTER 7
CONSTRUCTION OF A NEW FOREBAY

This chapter addresses the potential impacts associated with construction of a new forebay.

A. Description of Alternative

This alternative includes construction of a new forebay upstream of the Boulder Reservoir and the BRWTF. The volume of the forebay would be approximately 200 acre-feet and the usable depth would be approximately 10 feet. This forebay would be constructed as an "upland" reservoir, not located within an existing drainage.

Raw water from the BFC will flow through a pipeline into the forebay. From the forebay, raw water will through a pipeline to the BRWTF for treatment. During the winter, raw water will be pumped from the Boulder Reservoir as is the current practice.

Figure 7-1 shows the proposed site for the new forebay as well as the proposed pipeline alignments into and out of the forebay.

B. Water Quality Impacts

The following section identifies the impacts to water quality that can be expected from implementing the new forebay alternative outlined above.

1. Pathogens

The new forebay will provide only slight reduction in bacteriological organisms such as fecal coliforms, as compared to those found in the BFC, due to the limited detention time of the raw water. Pathogen concentrations such as *Giardia* and *Cryptosporidium* may be reduced slightly due to settling. However, concentrations of these pathogens could fluctuate due to wind stirring up the water in the forebay.

The level of impact that a forebay will have on raw water *Giardia* and *Cryptosporidium* concentrations cannot be determined without substantially more investigation. Modeling and/or a literature search of similar installations could provide a better idea of the amount of pathogen reduction/inactivation that may

be achieved. It is unlikely that the forebay alternative will enable the City to meet the requirements of the LT2ESWTR. A forebay will have no significant effect on virus removal/inactivation.

2. Treatability

Since the forebay would be lined, release of naturally occurring manganese would not be a concern. However, it is likely that seasonal algae blooms will occur due to the shallow depth of the forebay. These blooms can result in taste and odor problems, as well as increased TOC concentrations, which act as disinfection by-product precursors.

In general, the turbidity of the raw water in the BFC has been relatively low and has not been an issue during treatment. None the less, some slight reduction in turbidity may be realized from the construction of a forebay. However, as with pathogen concentrations, turbidity levels could fluctuate due to wind stirring up the water in the forebay.

C. Cost Opinion

The following section is a preliminary estimate of the costs associated with constructing and operating a forebay.

1. Capital

Capital costs associated with the construction of a forebay are listed in Table 7-1. These costs are based on the following assumptions:

- The usable depth of water in the forebay is 10 feet.
- The height of the forebay embankment is 15 feet.
- The slope ratio of the forebay embankment is 1 foot vertical for every 3 feet horizontal.
- The slope of the existing land at the proposed site of the new forebay is approximately 1 foot vertical for every 87.5 feet horizontal.

- Permanent easements would need to be obtained for the portion of pipeline from the BFC to the new forebay and from the new forebay to 63rd Street. The pipeline would then run along 63rd Street and be completely located within existing roads and/or road right of ways (R.O.W).

Table 7-1

Capital Cost Opinion for New Forebay Alternative

Component	Quantity	Unit Cost	Estimated Cost
Permitting	Lump Sum	$150,000	$150,000
Land acquisition	25 acres	$8,000/acre	$200,000
Easement acquisition	5,000 ft	$5.75/ft	$29,000
36-inch pipeline from BFC to new reservoir	2,000 ft	$5.00/ft/ diameter inch	$360,000
Excavation and berming	233,000 cu yd	$6.00/cu yd	$1,398,000
Slope preparation	174,000 sq ft	$0.50/sq ft	$87,000
HDPE synthetic liner	931,000 sq ft	$0.60/sq ft	$559,000
Geotextile	931,000 sq ft	$0.25/sq ft	$233,000
36-inch pipeline from new reservoir to 63rd Street	3,000 ft	$5.00/ft/ diameter inch	$540,000
36-inch pipeline from 63rd Street to BRWTF	6,000 ft	$7.00/ft/ diameter inch	$1,512,000
		Subtotal	**$5,068,000**
		Engineering and Administration (15%)	$760,000
		Contingencies (15%)	$874,000
		Total	**$6,702,000**

2. *Operation and Maintenance*

The pipelines from the BFC to the forebay and from the forebay to the BRWTF will be gravity-flow, and therefore, maintenance should be minimal. Maintenance around the forebay will include weed and dust control. Sufficient data is not available to determine O&M costs. These costs would be developed as part of a preliminary study.

D. Operational Impacts

Operational impacts are key criteria in the evaluation and selection of an alternative. Issues associated with operations include reliability, security, and any potential impacts to water rights or the ability to supply water to the BRWTF.

1. Water Supply/Water Rights

Under this alternative, raw water will flow by gravity from the forebay to the BRWTF during the summer months when the BFC is in operation. During the remainder of the year, raw water will be pumped from Boulder Reservoir, as is the current practice. Therefore, this alternative will not impact on the City's current water rights, or how the water is supplied to the BRWTF.

Boulder Reservoir would still store 3,143 acre-feet of water in long-term storage that could be used for drought or emergency supplies to the BRWTF and/or exchange, and up to 5,357 acre-feet to meet winter delivery demands through the BRWTF. In addition, the City would still have the ability to treat up to 2,000 acre-feet of non-CBT water delivered through Boulder Reservoir from the Farmers Ditch between May 1 and July 31.

2. Reliability

Operationally, the forebay and gravity flow pipelines will be very reliable. However, changes in the raw water quality may result in operational challenges at the BRWTF.

3. Security

Measures will need to be taken to ensure that public access to the forebay is not permitted. This includes fencing off the perimeter and patrolling the area regularly.

New pipelines will deliver water from the BFC to the forebay and from the forebay to the BRWTF. The buried pipelines would be difficult to access and the vault structures, where it would be most vulnerable, could be alarmed if necessary. Therefore this alternative would offer a higher level of security than the current situation. However, there would be no increase in the level of security for the portion of the canal that the raw water will travel down until it reaches the pipeline diversion.

In addition, since Boulder Reservoir will still be utilized in the winter when the BFC is not in operation, the City will also face the same security issues described in Chapter 2.

E. Community Impacts

Construction a forebay will have a small impact on the community. The following describes the potential community impacts associated with the forebay alternative.

1. Environmental

This alternative would have impact the environment including the loss of land where the forebay is located and whatever purpose that land is currently utilized for, including loss of habitat.

The construction of a new reservoir will include an extensive permitting and review process, including the Boulder County 1041 permitting process, a minor jurisdictional dam permit, a Federal 404 permit, and most likely the development of an EIS.

2. Public Acceptance

It is anticipated that public acceptance issues related to the forebay alternative will be limited to a very small segment of the public that may be impacted in the immediate vicinity.

F. Impact on City's Water Goals

The City has set pathogen removal/inactivation goals that are more stringent than the regulatory requirement. These goals are discussed in Chapter 1. Construction of a new forebay will improve water quality and help the City meet its water quality goals. However, it is not possible to determine the extent of the improvement without substantially more investigation.

It is unlikely that this alternative will help the City obtain its goal of providing similar finished water quality to its customers based on the significantly different water quality characteristics of the BFC water as compared to other source waters currently utilized by the City.

G. Implementation Timeframe

Construction of a forebay is a lengthy process due to land acquisition and local and State permitting requirements, in addition to construction. It is anticipated that the permitting process could take approximately 12 months to obtain. Survey and design could be accomplished in approximately 12 months. Construction of the forebay and pipelines could be completed simultaneously and could be accomplished in approximately 12 months. The City should expect the process to take approximately three years to implement.

Chapter 8

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CHAPTER 8
SIMULATION MODELING FOR *CRYPTOSPORIDIUM*

Simulation modeling techniques were used to estimate expected *Cryptosporidium* concentrations in the BRWTF source waters based on improved analytical methods for detecting this organism. This chapter describes the simulation model and procedure used to predict *Cryptosporidium* concentrations for the existing system as well as each of the alternatives.

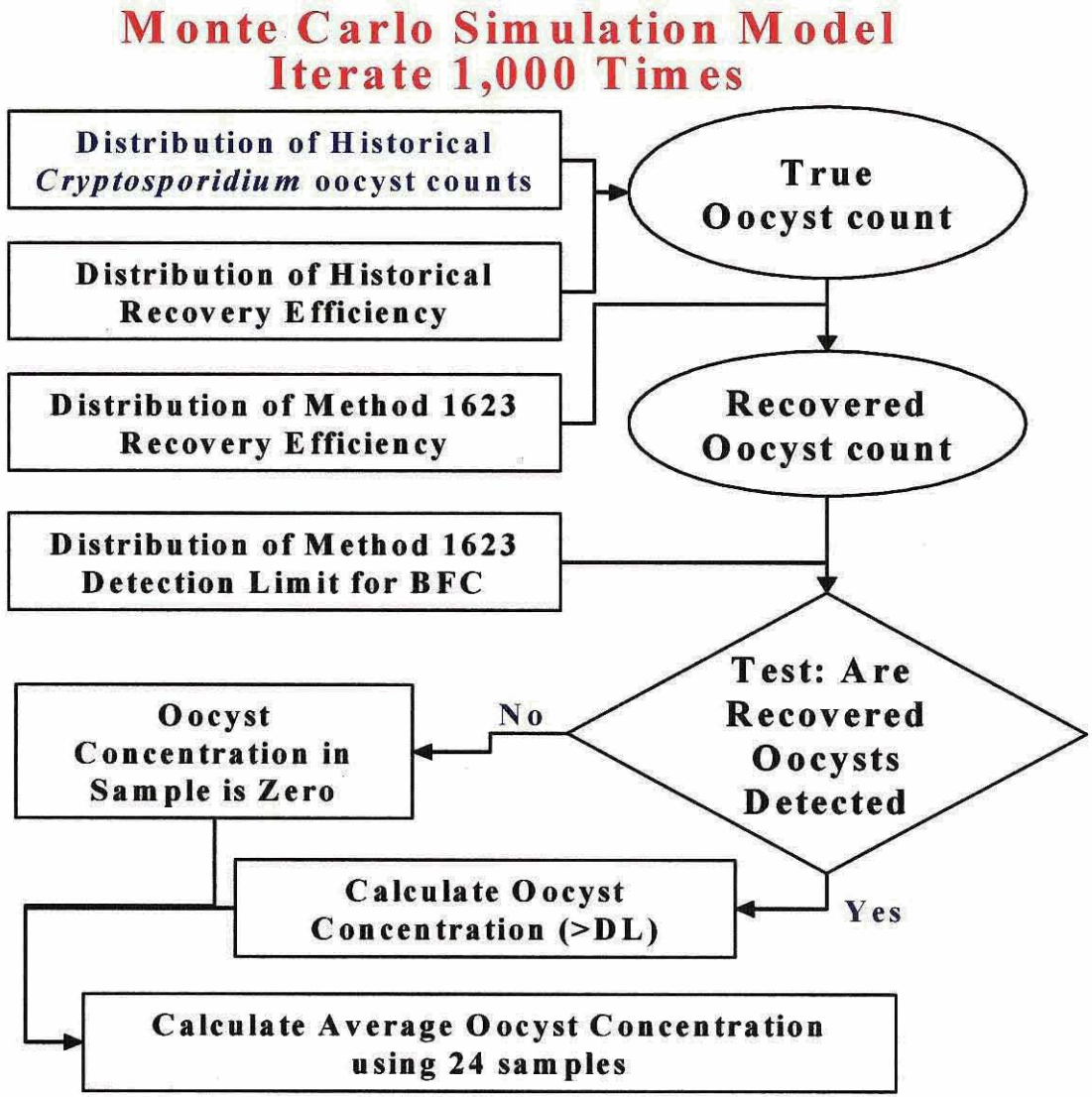
A. Determination of Baseline *Cryptosporidium* Concentrations

The simulation model relied upon historical monitoring data for *Cryptosporidium* for each source of supply and results from available research regarding the analytical method performance parameters for the old IFA method and the new Method 1623 approved by EPA for *Cryptosporidium* monitoring in the future. The algorithm for the Monte Carlo Simulation Model that was used estimate new baseline *Cryptosporidium* concentrations in each of the source water is shown in Figure 8-1. Table 8-1 provides the definition of all input distributions used in this model.

Table 8-1

Definition of Monte Carlo Simulation Model Input Distributions

Parameter	Distribution Type	Parameterization of the Distribution
BFC Observed Oocyst Counts	Custom fit distribution	0 count = 77%, 1 count = 13%, 2 count = 7%, 3 count = 3%
Boulder Reservoir Observed Oocyst Counts	Custom fit distribution	0 count = 91%, 1 count = 3%, 3 count = 3%, 5 count = 3%
Historical IFA Recovery Rate	Poisson distribution	Mean value = 11%
Method 1623 Recovery Rate	Weibull distribution	Location = -197.4 Scale = 279.2 Shape = 15
Method 1623 Detection Limit	Log-normal distribution	Mean = 19.2 oocysts/L Standard deviation = 17.1 oocysts/L



BLACK & VEATCH	CITY OF BOULDER, CO SOURCE WATER QUALITY PLANNING STUDY	ALGORITHM FOR THE MONTE CARLO SIMULATION MODEL	FIGURE 8-1

Using the simulation model, the predicted average concentration of *Cryptosporidium* showed a marginal increase in levels for the BFC as a result of using the new analytical method. A substantial increase in the estimated concentration for the Boulder Reservoir supply was found due to the increase method sensitivity for this supply. These results are illustrated in Figure 8-2.

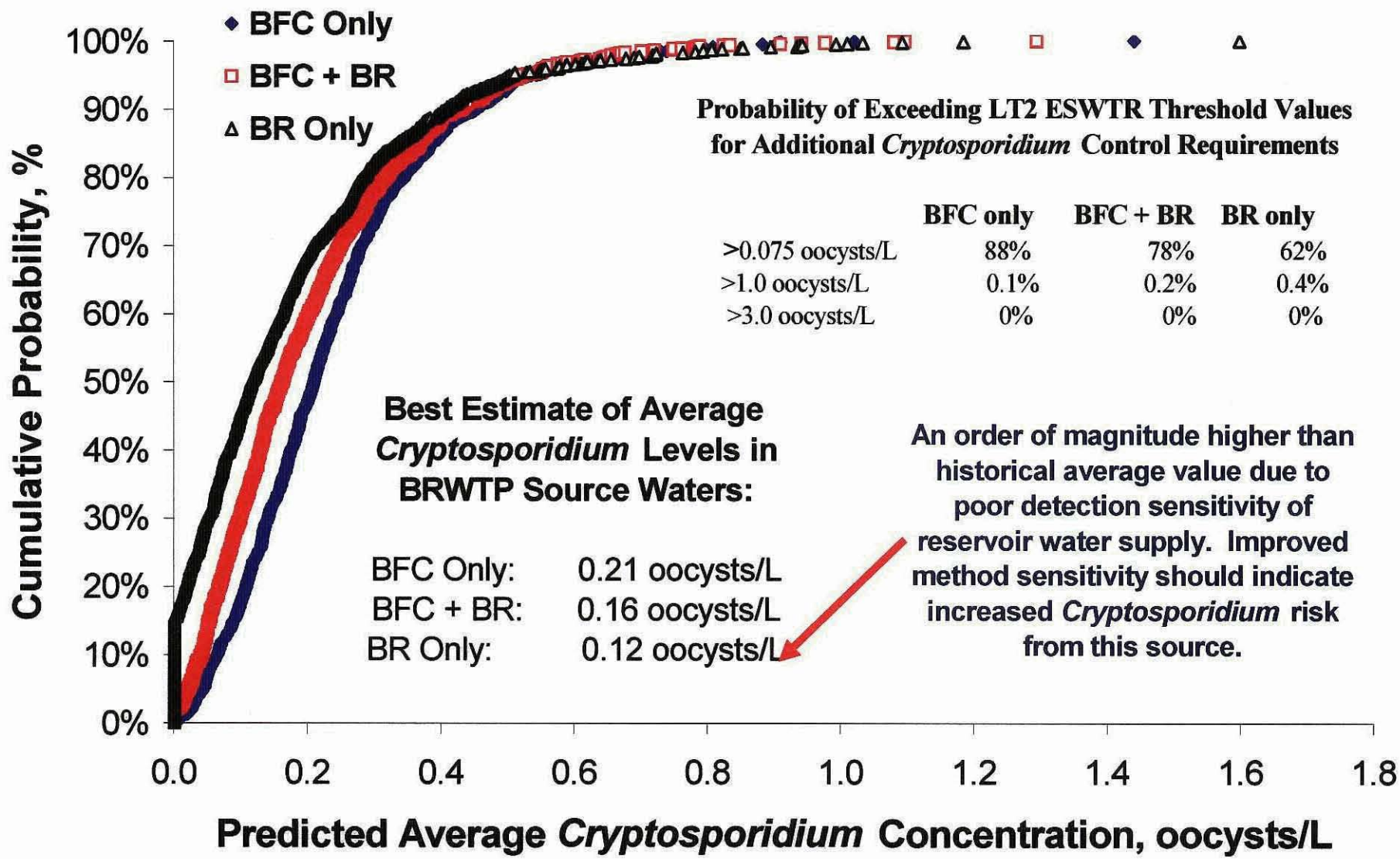
Figure 8-3 shows the distribution of method detection levels for the historical IFA method and the new Method 1623 performance. The detection sensitivity of Method 1623 will enable both the detection and quantification of peak concentrations that are significant in the reservoir supply. Note that the BFC supply only found counts of 3 oocysts in 3% of the sample events while the Boulder Reservoir supply found counts at or above 3 oocysts in a sample 6% of the time. These peak count sample events are leading to substantially higher predicted concentrations with the improved recovery and detection sensitivity than was possible with the historical IFA method (0.12 oocysts/L as compared to 0.01 oocysts/L).

Based on the predicted *Cryptosporidium* concentration in both the BFC and Boulder Reservoir, additional treatment barriers are likely to be required under the LT2ESWTR for the existing source water system. Further, the future water quality conditions in the existing system is expected to degrade due to continued development of the watershed and increased human and animal activities in proximity to both the BFC and Boulder Reservoir. The study of trail development impacts along the BFC, for example, indicated that trail use levels at or above 125,000 people per year could result in an order of magnitude increase in the BFC *Cryptosporidium* load from today's levels. These types of activities can lead to significant future concerns for effective control of pathogen water quality at the BRWTF.

B. Alternative Source Water Management Strategies

The alternative source water management strategies considered in this study were evaluated for their likely water quality impacts with respect to both pathogen quality and susceptibility to contamination events. Where possible, clear improvements in other water quality areas are also identified for each of the options considered.

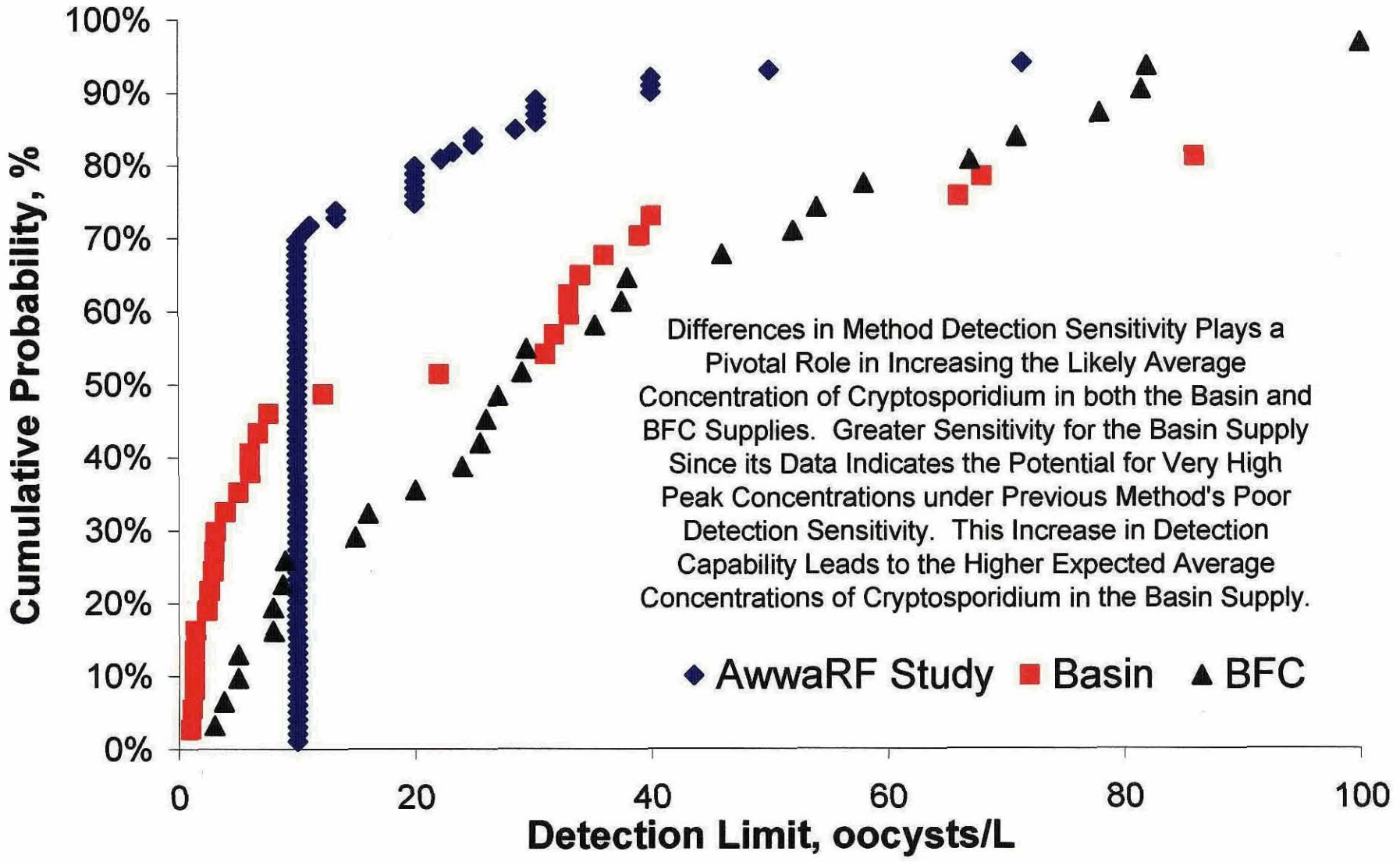
Each of the source water management options are strategically crafted to explicitly improve pathogen water quality as this is a critical area of public health



Probability of Exceeding LT2 ESWTR Threshold Values for Additional *Cryptosporidium* Control Requirements

	BFC only	BFC + BR	BR only
>0.075 oocysts/L	88%	78%	62%
>1.0 oocysts/L	0.1%	0.2%	0.4%
>3.0 oocysts/L	0%	0%	0%

BLACK & VEATCH	CITY OF BOULDER, CO SOURCE WATER QUALITY PLANNING STUDY	PREDICTED AVERAGE CRYPTO CONCENTRATIONS IN THE BFC AND BOULDER RESERVOIR	FIGURE 8-2



BLACK & VEATCH	CITY OF BOULDER, CO SOURCE WATER QUALITY PLANNING STUDY	DISTRIBUTION OF METHOD DETECTION LEVELS	FIGURE 8-3

protection for the City. As shown in Table 8-2, a range of improvements is expected for pathogen control given the distinct features of each option.

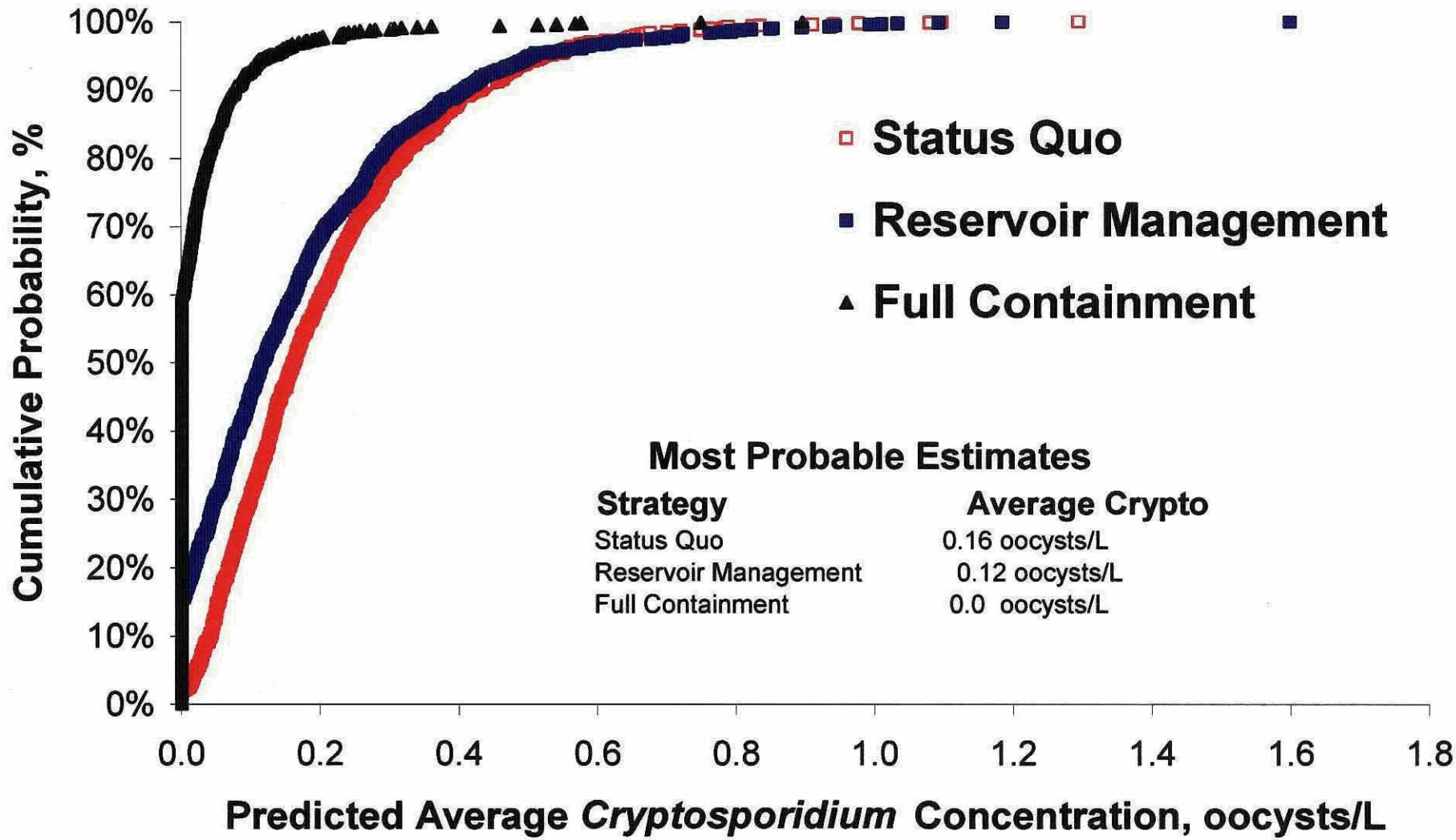
Table 8-2

Characterization of Pathogen Control Features for Alternative Source Water Management Strategies

Source Water Management Option	Key Pathogen Control Features
Boulder Reservoir Management	Public access controls and restrictions to mitigate human activity impacts on Boulder Reservoir; Implement stormwater runoff BMPs.
Full Containment from Carter Lake to BRWTF	Pipeline protection against intrusion and degradation of Carter Lake supply.
Partial Containment from Nelson Road to BRWTF	Degradation along the BFC upstream of Nelson Road expected, but the significant further degradation to the BRWTF eliminated through pipeline containment.
New Terminal Reservoir	BFC contamination remains, but no further degradation by human activities in the new reservoir as opposed to those that continue on the Boulder Reservoir supply.
New Forebay	Improved dispersal of BFC supply into Boulder Reservoir to reduce potential for peak contamination through short-circuiting while operating year-round in the Boulder Reservoir.

1. Boulder Reservoir Management

The expected improvement to pathogen water quality for the Boulder Reservoir management alternative results primarily from the reduced total pathogen load by restricted human and animal access, stormwater runoff BMPs, and the physical impact of dilution and settling potentially available by eliminating direct use of the BFC. While the watershed control program for the Boulder Reservoir is important and can address peak loads of pathogens from human and animal sources around the reservoir, this program does not affect the quality of the water in the BFC. The Monte Carlo simulation model was also used to estimate the expected average *Cryptosporidium* concentration for the reservoir management option. These results are shown on Figure 8-4.



BLACK & VEATCH	CITY OF BOULDER, CO SOURCE WATER QUALITY PLANNING STUDY	PREDICTED AVERAGE CRYPTOSPORIDIUM CONCENTRATIONS	FIGURE 8-4

2. *Full Containment from Carter Lake to the BRWTF*

In this option, a pipeline would provide water directly from Carter Lake to the BRWTF. No further degradation of water quality would be expected under this scenario beyond the future degradation of Carter Lake, which is considered negligible. Since a long history of *Cryptosporidium* monitoring data for Carter Lake is not available, the quality of this supply was assumed to be comparable or no worse than the quality of a pristine drinking water reservoir; namely, the Bull Run Reservoir located in Oregon, for which substantial monitoring records were available. The Monte Carlo simulation model was also used to estimate the expected average *Cryptosporidium* concentration for the full containment option. The only difference was the definition of the distribution for the historical observed *Cryptosporidium* counts which were as follows for this analysis: 0 count = 98.1%, 1 count = 1.2%, 2 count = 0.2%, 3 count = 0.4% and 5 count = 0.1%.

As shown in Figure 8-4, a substantial reduction in pathogen content entering the BRWTF is expected under this alternative. The most probable estimate of the average concentration of *Cryptosporidium* is reduced to 0.0 oocysts/L as compared to the predicted concentrations of 0.16 oocysts/L for the baseline condition and 0.12 oocysts/L under the reservoir management alternative. Further, the upper 95th percentile concentration for this option is substantially lower than the baseline condition (0.1 oocysts/L compared to 0.5 oocysts/L).

3. *Partial Containment from Nelson Road to BRWTF*

The partial containment of the BFC supply from Nelson Road to the BRWTF is intended to mitigate the impact of the worst-case area of the BFC for pathogen contamination. Since *Cryptosporidium* data along the BFC is not available, the fecal coliform results from the City's monitoring program were benchmarked to national reservoir and river supplies monitored as part of the ICR. As discussed in Chapter 2, the upper reaches of the BFC represent the 74th percentile of U.S. reservoirs and the 15th percentile of U.S. rivers.

To estimate the expected *Cryptosporidium* levels, source water monitoring results for ICR utilities were consolidated for those systems representing either the 60th to 85th percentile of reservoir sources or the 10th to 20th percentile of river sources. The composite distribution of *Cryptosporidium* counts found for those systems resulted in an input distribution of historical values as follows: 0 counts

= 95.5%, 1 count = 3.8%, 4 counts = 0.5%, and 12 counts = 0.2%. This distribution was used for the seasonal operation of the BFC with distribution of *Cryptosporidium* counts for the Boulder Reservoir source used for the remaining six-months of BRWTF operation.

The resulting prediction of *Cryptosporidium* load to the BRWTF was reduced from the baseline condition by over half where the most probable estimate of average *Cryptosporidium* concentration was found to be 0.07 oocysts/L. This value represents the bin boundary for the LT2ESWTR classification of source waters requiring additional *Cryptosporidium* control beyond conventional treatment. A slight reduction in the 95th percentile average concentration was also found as compared to the status quo conditions, lowered from 0.52 oocysts/L to 0.41 oocysts/L.

4. New Terminal Reservoir

In this option, a new terminal reservoir would be built for year-round operation of the BRWTF. The seasonal operation would be similar to the reservoir management option described previously, only the new terminal reservoir would not be used for recreation or other human-based activities and therefore, should not be subject to those sources of contamination. However, the size the reservoir, while of sufficient capacity to meet the City's storage and production needs, would not be as large as the current Boulder Reservoir. The ability of protozoa to effectively be settled in the new reservoir is limited. In fact, studies have shown that unless protozoa organisms like *Cryptosporidium* are associated with settleable particles in the source water, these organisms will remain in suspension indefinitely. The dilution effects seen in many reservoirs are typically due to the inflow of multiple streams with varying contamination levels. This is not the case for the City as this new terminal reservoir would only receive inflow from one source, the BFC.

While observed data do not exist to describe this option within the simulation model, the new reservoir option was characterized by its ability to potentially reduce *Cryptosporidium* through dilution and the limited settling of particle-associated organisms. As such, a 50 percent "hit rate" was assumed to describe the effects of the new reservoir. This means *Cryptosporidium* would only be found in one sample event for every two events where it currently occurs in the BFC supply. With this "odds ratio" for *Cryptosporidium* in the simulation model, the most probably average concentration found was 0.08 oocysts/L and

the 95th percentile average concentration was found to be 0.32 oocysts/L, both substantially lower the predicted baseline condition.

5. *New Forebay*

The new forebay alternative was modeled under the scenario of the BFC supply flowing into a forebay prior to flowing into the Boulder Reservoir. This scenario represents an attempt to improve the dispersion of flow into the Boulder Reservoir and potentially capture particle-associated protozoa prior to their entry to the main body of the reservoir. It should be noted that this scenario is slightly different than the one described in Chapter 7.

For the modeled scenario, it was assumed that reservoir management activities would accompany the forebay construction as a best management practice for the Boulder Reservoir supply. Therefore, some improvement in water quality beyond reservoir management might be expected for this option.

Since observed data are not available to describe the impacts of this option, an assumed improvement in Boulder Reservoir water quality with respect to *Cryptosporidium* concentration was used. Once more, a "hit ratio" was used within the simulation model where only 80 percent of the current events finding *Cryptosporidium* present for the Boulder Reservoir supply were assumed to also be present under the new forebay option. As a result, the most probably estimate of the average *Cryptosporidium* concentration was lowered to 0.10 oocysts/L and the 95th percentile of the average concentrations was 0.49 oocysts/L, both of which are slightly lower than the respective estimates for the baseline prediction and reservoir management options.

C. Summary of Predicted Pathogen Quality

Each of the source water management strategies explored in this study offer some benefit to the control of pathogens. As shown in Table 8-3, the predicted baseline condition consistently has the highest expected *Cryptosporidium* levels among the various options. However, with the exception of the full containment option, the BRWTF remains susceptible to the LT2ESWTR classification for additional treatment. Therefore, the expectation of countering the cost of treatment with source water management activities is not feasible. However, with respect to pathogen risk management, source water management does provide the City with additional tools and capabilities to

mitigate continuing degradation in source water quality and the challenges (peaks) that could stress any treatment system installed at the BRWTF.

Table 8-3

Summary of Expected Average *Cryptosporidium* Concentrations (oocysts/L) for the Source Water Management Alternatives

Source Water Management Option	25th Percentile	50th Percentile*	75th Percentile	95th Percentile
Existing Source Water System (baseline)	0.08	0.16	0.28	0.52
Reservoir Management	0.03	0.12	0.25	0.51
Full Containment to the BRWTF	0.00	0.00	0.03	0.13
Partial Containment to the BRWTF	0.02	0.07	0.16	0.41
New Terminal Reservoir	0.04	0.08	0.15	0.32
New Forebay	0.03	0.10	0.21	0.49

*The Most Probable Estimate of average *Cryptosporidium* concentration for each option.

Chapter 9

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CHAPTER 9
ALTERNATIVE EVALUATION AND RECOMMENDATIONS

This chapter evaluates the source water management alternatives and provides recommendations of which alternatives to carry forward for the Phase 2 Study.

A. Source Water Management Alternatives

The following section summarizes the components and issues of the source water management alternatives.

1. Existing Source Water System

The existing source water delivery system served as the baseline condition for the alternative evaluation. This alternative represents the current seasonal operation of the BFC and Boulder Reservoir as source water supplies, which is not expected to change significantly in the future. However, growth and development could impact the current water quality due to the vulnerabilities associated with the current system such as non-point sources discharges, algae, illegal dumping, canal maintenance activities, recreational activities, or groundwater seepage.

2. Boulder Reservoir Management

This alternative is based on using Boulder Reservoir as a year-round terminal reservoir to provide dilution, settling, and natural processes to break down contaminants before the water is pumped to the BRWTF. This alternative would require that all raw water be pumped from the reservoir to the BRWTF throughout the year. This alternative appears to offer an advantage for near-term implementation since source water can be delivered using existing facilities and a number of the suggested improvements could be implemented at relatively low cost over a period of years.

To address the compromised reservoir water quality associated with seasonal recreational activities and the presence of manganese and algae, a multi-tiered reservoir management approach would be implemented to provide an improved, consistent water quality throughout the year. Recommended

improvements include in-reservoir treatment, watershed and nutrient control, and human source control. These and other short and long-term improvements could be implemented over time. However, the compromised water quality of the reservoir needs further study. For example, pathogen risk has not been adequately studied and controls to reduce human sources may not be received well by the public.

3. *Full Containment from Carter Lake to the BRWTF*

This alternative involves the construction of a new 21-mile raw water pipeline that would contain, protect, and deliver CBT source water from Carter Lake directly to the BRWTF year-round using gravity flow. Costs for this alternative were developed based on the assumption that the City would be able to participate with several other municipal agencies using this pipeline to deliver CBT source water to their individual treatment works.

This approach would provide year-round high quality source water from Carter Lake directly to the BRWTF, which closely matches the raw water quality delivered to the City's other WTP. At the same time, a totally enclosed, buried pipeline would offer a relatively high level of security while having relatively low environmental and public acceptance impacts.

4. *Partial Containment from Nelson Road to the BRWTF*

This alternative is similar to the full containment alternative except that the pipeline would be constructed for a much shorter distance. The concept is to contain the source water as it travels through the more highly developed areas, thereby minimizing the potential for contaminants to enter the water. Since the length of the pipeline would be significantly less than the full pipeline, the capital cost would also be less.

For the purpose of the Phase 1 Study, the beginning of the pipeline was established just north (upstream) of Nelson Road, which is approximately 5 miles north of the BRWTF. From this point, raw water would be diverted from the BFC at a new intake structure and delivered to the BRWTF in a new buried pipeline. This pipeline would only be in operation during the months when the BFC was in operation. During the remainder of the year, raw water would have to be pumped from Boulder Reservoir, as is the current practice.

Like the full-containment alternative, partial containment would provide a relatively high level of security for that portion of the route that is contained. However, since the majority of the route from Carter Lake would be the open SVSC and BFC, this alternative is greatly much more vulnerable to source water contamination than the full-containment alternative.

5. New Terminal Reservoir

This alternative is based on the construction of a new 4,000 acre-foot earthen terminal reservoir to be located upstream of the Boulder Reservoir and the BRWTF. This approach would provide the following:

- A large terminal reservoir to provide dilution, settling, and natural processes to break down contaminants before the water is transferred to the BRWTF.
- Avoidance of the water quality conflicts inherent in using Boulder Reservoir for both recreation activities and a drinking water supply by denying public access.
- An increase in the City's total reservoir storage.

The reservoir, as proposed, is sited to provide gravity flow from the BFC into the reservoir and gravity flow out of the reservoir directly to the BRWTF. The new reservoir is sized to provide enough storage for the City's needs during a normal year, so that the BRWTF can utilize this source year-round, even though the BFC is operated seasonally.

Although there will be some water quality benefits as a result of the exclusion of recreation on or around the reservoir, a new reservoir will be subject to many of the water quality issues associated with Boulder Reservoir such as surface run-off and algae formation. In addition, even if the reservoir were lined, the potential for the uptake of soluble manganese into the raw water will increase as the reservoir matures.

It is anticipated that there would be significant environmental and public acceptance issues associated with the permitting and construction of a new terminal reservoir.

6. *New Forebay*

This alternative similar to the new terminal reservoir alternative, but includes much less storage. This alternative includes construction of a new 200 acre-foot earthen forebay located upstream of the Boulder Reservoir and the BRWTF. This approach would provide some amount of dilution and settling to reduce the contaminant load entering the BRWTF.

The forebay, as proposed, is sited to provide gravity flow from the BFC into the forebay and gravity flow out of the forebay directly to the BRWTF. The new forebay is not sized to provide long-term water storage and would not operate during the winter months when the BFC is out of service. During the winter, the BRWTF would have to pump raw water from Boulder Reservoir, as is the current practice.

Although a new forebay would be much smaller in scale than a new terminal reservoir, it is anticipated that there would still likely be significant environmental and public acceptance issues associated with permitting and construction.

B. Alternative Evaluation

Alternatives were evaluated based on the following criteria:

- Water quality impacts including pathogens such as fecal coliforms, viruses, *Giardia* and *Cryptosporidium*. Treatability issues were also examined including turbidity, manganese, TDS and algae.
- Estimated capital and O&M costs.
- Operational impacts including reliability, security, and any potential impacts to water rights or the ability to supply water to the BRWTF.
- Community impacts including environmental and public acceptance issues.
- Potential impacts on the City's water quantity and water quality goals.
- Implementation timeframe.

Two alternative evaluations are discussed in the following section. The first alternative evaluation was performed at a meeting of the participants and was somewhat abbreviated to expedite the process. The second evaluation incorporates the results of the evaluation performed by the participants, but has been expanded to reflect additional information discussed in the previous chapters.

1. Alternative Evaluation by Study Participants

The participants met to collectively consider the relative merits of the alternatives and determine which to carry forward for further investigation and analysis in Phase 2. To rank the alternatives, a matrix was developed as shown in Table 9-1. In general, the evaluation criteria shown in the matrix are representative of the criteria discussed in the technical memoranda. A numbered rating system of 1 to 3 was used, with 1 being the most desirable outcome and 3 being the least desirable.

As represented by the matrix in Table 9-1 and agreed upon by the participants, the alternatives selected for further analysis as part of the Phase 2 work were as follows:

- Full Containment Pipeline from Carter Lake to the BRWTF
- Boulder Reservoir Management

Table 9-1

Evaluation Matrix Developed by Participants

Evaluation Criteria	Existing Raw Water Delivery System	Manage Boulder Reservoir	Pipeline From Carter Lake	Pipeline From Nelson Road	New Terminal Reservoir	New Forebay
Cost	1	2	3	2	3^{+}	2
Water Quality	3^{+}	3	1	2	2	3
Water Resource Operations*	2	2	2	2	2	2
Security	3^{+}	2	1	3	2	3
Time to Implement	1	1	3	3	3^{+}	3
Environment/ Community	1	2	1	1	2	2
Total*	**11^{++}**	**12**	**11**	**13**	**14^{++}**	**15**

*At the time the participants performed the evaluation, Water Resources was not represented and the issues were not clear to the participants. The ratings included here are the recommendations contained in the January 17, 2003 memorandum from Joanna Stansbury.

The "+" indicates a large difference between that aspect as compared to the other alternatives.

2. *Expanded Alternative Evaluation*

Table 9-2 presents an evaluation matrix for the source water alternatives containing the full range of evaluation criteria originally developed by the study participants and documented in the technical memoranda. The expanded alternative evaluation uses a numbered rating system of 1 to 6 with 1 being the most desirable outcome and 6 being the least desirable.

Table 9-2

Expanded Alternative Evaluation Matrix

Criteria	Existing Raw Water Delivery System	Boulder Reservoir Management	Full Containment	Partial Containment	New Terminal Reservoir	New Forebay
Water Quality Impacts						
Pathogens	6	3	1	5	2	4
Treatability	4	3	1	2	3	3
Cost						
Capital	1	2	5	4	6	3
O&M	2	6	1	4	3	5
Operational Impacts						
Water Supply/Rights	1	2	1	2	1	2
Reliability	4	3	1	2	2	2
Security	6	3	1	5	2	4
Community Impacts						
Environmental	1	1	2	2	4	3
Public Acceptance	1	2	1	1	3	3
Impact on City's Goals	5	2	1	3	2	4
Time to Implement	1	2	3	3	3	3
Total	**32**	**29**	**18**	**33**	**31**	**36**

This expanded evaluation incorporates the results represented by the matrix in Table 9-1. Although the range of resulting scores is broader, the overall results in terms of the most desirable alternatives, were as follows:

- Full Containment From Carter Lake to the BRWTF
- Boulder Reservoir Management

C. Recommendations

Phase 1 of the source water planning process was designed to provide an overview of the range of source water alternatives available to the City and evaluate the relative merits of each. Overall, this process has worked effectively to pare down the range of possible alternatives and yet still carry forward three very different approaches to source water quality protection with the Phase 2 work.

The Phase 2 work will be more comprehensive in nature by considering both source water quality and treatment at the BRWTF. To achieve meaningful results in this context, the analysis will need to consider the following:

- The relationship of source water protection measures in combination with treatment requirements and their overall impact on the requirements of the Long-term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). This analysis will define the scope of alternative comprehensive projects (projects that include both source water and treatment process elements).

- Final evaluation of the alternatives developed in Phase 2 will likely be heavily weighted on total cost. An important component of the overall cost will be the ongoing operation and maintenance costs associated with both source water protection and treatment.

Appendix

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CONFERENCE MEMORANDUM

Boulder, Colorado
BRWTP Source Water Quality Planning
Kick-off Meeting

B&V Project 132441.100
B&V File A
November 1, 2002

The kick-off meeting for the Boulder Reservoir Water Treatment Plant Source Water Quality Planning was held on Wednesday, October 30, 2002 at the Boulder Reservoir Water Treatment Plant (BRWTP).

Recorded by: Kerry Heidel

Attending:

City of Boulder

Randy Crittenden
Carol Ellinghouse
Bob Harberg
Annie Noble
Terry Reichenberger
Chris Rudkin
Jim Shelley
Joanna Stansbury
Amy Struthers

McGuire Environmental

Michelle Frey

University of Colorado

Dr. Bill Lewis

Black & Veatch

Kerry Heidel
Lela Parsons
Perri Standish-Lee

The meeting was conducted according to the agenda that is attached to this memorandum.

Meeting Objectives

Kerry Heidel opened the meeting and pointed out that the schedule that was attached to the agenda called for two additional meetings and that a firm date for those meetings would be established within a few days. Kerry noted that the purpose of the kick-off meeting was to: (1) have the group identify specific study objectives, and (2) introduce specific methods the group could use to achieve the stated objectives. On the basis of initial discussions with the City, the Black & Veatch presentation would include preliminary ideas to share with the group as a starting point for the discussions.

Data Review

Michelle Frey presented a review of the BRWTP source water quality assessment work that has been ongoing over the past year or so. On the basis of the available data and projections of increased human and animal activities within the tributary drainage areas along the BFC, Michelle presented the following conclusions about the BFC:

- Pathogen load is expected to increase and could increase substantially depending on the growth of trail usage and flow patterns through the canal.

- Increased accessibility to the canal could lead to increased incidence of illegal dumping, traffic accidents, or accidental spills.

- Human and animal activities can also lead to increased nutrient and organic loading, increasing potential algae issues in BFC water.

- Trace contaminants are likely to increase from the drainage of parking lots, new structures, and the overall increase in surface runoff to the canal from changes in surface characteristics.

The following conclusions were presented as the vulnerability assessment for source water quality in the Boulder Reservoir:

- Degradation of BRWTP source water quality from the reservoir is anticipated as a result of degradation expected to occur in the BFC.
- The potential need to use the Reservoir as a raw water source for the WTP during the warmer months of the year will pose additional problems because pathogen and trace contaminant loads are highest during that period of the year due to recreational activities.
- Short-circuiting of flow could make the Reservoir intake vulnerable to extreme or unknown events that could occur in the BFC.
- During the summer, stratification of the water column increases the potential for soluble manganese being present in the raw water.
- During the summer, there are increased levels of algae in the water.

Michelle also presented an update on the BFC microbiological water quality trends that had emerged as a result of a fecal coliform study the City had performed during the spring and summer of 2002. The study consisted of a series of 4-hour grab samples gathered twice per month from April to September and represented dry weather water quality behavior since there were no precipitation events that resulted in surface run-off to the canal. The conclusions were as follows:

- The data collected was insufficient to detect any clear trends.
- Even with minimum data, variability was detected although the sources of the variability were unclear.
- Additional study should include exploration of wildlife and human activities along the BFC as well as water quality monitoring.

Project Approach

This portion of the presentation began with a discussion to try to define a specific goal for the study. It was argued that although the project is ostensibly about finding the best way to protect and improve source water quality, this effort should not be performed without consideration of the level of treatment provided by the BRWTP. There appeared to be general agreement that the study should consider the contributions of a combination of barriers in order to arrive at a solution or recommendation that would optimize the use of all barriers to achieve the most effective overall treatment.

As part of the alternative evaluation process, it will be determined what combination of watershed management and BRWTP treatment will be required, first, to satisfy regulatory requirements and secondly, to satisfy the City's higher level water quality goals. Considering what additional expenditures may be required to provide a higher level of treatment will provide a rough cost/benefit analysis.

Although a definitive goal statement has not yet been agreed upon, the following elements were discussed in relation to establishing a goal:

- Optimize of a combination of source water management and water treatment plant process barriers.
- Most cost-effective means of achieving City's water quality and quantity goals.
- Need to consider the level of control that can realistically be applied to control of the watershed.
- Need to protect City's investment in equipment from catastrophic event.
- Goal needs to include delivered water goals.

The presentation then progressed to a general overview of the decision process. The process is designed to provide an organizational structure for a logical evaluation of a number of alternatives developed to achieve the stated goal. The group was referred to diagrams attached to the agenda that represented the basic elements of the decision process. The following principal elements make up the decision process:

- The stated goal
- Multiple alternatives for reaching the goal
- Evaluation criteria by which to evaluate the alternatives

The alternatives that were presented were as follows:

- BFC watershed management.
- Boulder Reservoir management to allow year-around use for providing source water to the BRWTP.
- Containment (closed conduit to isolate source water from tributary flows).
- Full treatment at the BRWTP.
- New terminal reservoir fed by BFC with piped outlet to BRWTP.

Perri Standish-Lee presented an overview of source water assessments and source water protection in watersheds. A major point of her presentation was that significantly more data would have to be gathered for the watershed contributing to the BFC in order to perform a meaningful source water assessment or to develop a meaningful source water protection strategy.

The meeting concluded with a brainstorming session to identify evaluation criteria. From the discussion, the following criteria and sub-criteria were proposed:

- Cost
  - Capital Cost
  - O&M Cost
- Water Quality
  - Pathogen goals
  - DBPs
  - LCR (pH, alkalinity)
  - Distribution goals
- Hardness
- Alkalinity
- Sulfate
- Sodium
  - Treatability goals
- Manganese
- Algae
- Operations
  - Delivery requirements
  - Storage requirements
  - System reliability
- Security
- Time to implement
- Environmental Impacts
- Public acceptance

KCH:LSP:alh
Attachment

cc: All Attendees

City of Boulder, Colorado - Source Water Planning
Kick-off Meeting Agenda

Meeting Date: October 30, 2002

General Milling About and Introductions – (9:00 – 9:10)

Meeting Objectives (9:10 – 9:15)

Data Review (9:15 – 9:45)

1. Summarize Existing Data
    a. Canal
    b. Reservoir
2. Conclusions and Recommendations

Project Approach (9:45 – 10:30)

1. Water Quality Goals
2. Preliminary Alternative Water Quality Approaches
3. Preliminary Evaluation Criteria
4. Decision Matrix

Break (10:30 – 10:40)

Establish Objectives for Workshop No. 1 (10:40 – 12:00)

1. Goals
2. Alternatives
3. Evaluation Criteria
4. Schedule

Lunch – Working lunch if necessary – (12:00 – 1:00)

BLACK & VEATCH CORPORATION

CONFERENCE MEMORANDUM

Boulder, Colorado
BRWTP Source Water Quality Planning
Workshop No. 1

B&V Project 132441.100
B&V File A
December 11, 2002

Workshop No. 1 for the Boulder Reservoir Water Treatment Plant Source Water Quality Planning was held on Thursday, December 5, 2002 at the Boulder Reservoir Water Treatment Plant (BRWTP).

Recorded by: Kerry Heidel

Attending:

City of Boulder	Black & Veatch
Randy Crittenden	Kerry Heidel
Carol Ellinghouse	Perri Standish-Lee
Bob Harberg	
Annie Noble	
Chris Rudkin	
Jim Shelley	
Brad Siegel	
Amy Struthers	

McGuire Environmental

Dr. Michelle Frey

University of Colorado

Dr. Bill Lewis

The meeting was generally conducted according to the attached agenda. In addition, Dr. Frey presented a water quality assessment of the source water alternatives. The following materials are also available for reference as a supplement to these meeting minutes:

- Information packet distributed at the Workshop No. 1. Cover sheet of information packet reads: City of Boulder, CO, Source Water Planning, Workshop No. 1, December 5, 2002. The packet includes the Workshop No. 1 Agenda, the meeting minutes from the October 30, 2002 Kick-off Meeting, and several draft technical memorandums (TMs).

- Power Point presentation by Dr. Michelle Frey. Water Quality Assessment of Alternative Source Water Strategies, December 5, 2002.

Meeting Objectives

Kerry opened the meeting by explaining that the TMs included in the information packet were draft versions that were not intended to be finished documents. The draft TMs were to be used as a basis for discussion. The TMs would be completed based on feedback from the City and as additional information became available.

At the conclusion of the source water planning effort, it is anticipated that the following final technical memorandums will be issued as a complete set to document the source water planning process:

Technical Memorandum	Title
1	Executive Summary
2	Water Quality
3	Reservoir Management Alternative
4	Full Containment Alternative
5	Partial Containment Alternative
6	New Terminal Reservoir Alternative
7	Forebay Alternative

The primary objective of Workshop No. 1 was to generate discussion among the participants by presenting a conceptual basis of design as well as a preliminary assessment of the evaluation criteria for each of the source water alternatives. The anticipated result of the discussion would be agreement upon a definitive scope for each alternative and a better understanding of the evaluation criteria.

An additional objective was to familiarize the participants with the computer software that had been proposed for use as a tool in the City's decision making process. Conducting a preliminary evaluation of the alternatives using the computer software would also be instructive for the participants and provide some insight into how the process should ultimately be conducted.

TM-3 - Reservoir Based Solution

Perri presented a general overview of the Reservoir Management Alternative that included variety of actions that could be undertaken in and around Boulder Reservoir to improve and protect source water quality. The measures fell into three different categories; in-reservoir treatment options, watershed source control options, and human source control options. Perri stated that the City should undertake a program of reservoir water quality monitoring in order to be able to project the potential benefit that these types of actions would have for the Reservoir.

In-reservoir treatment options include the following:

- Addition of a system to provide aeration of the hypolimnetic layer to reduce the accumulation of soluble manganese.
- Modifications to the BRWTP intake structure such as raising or providing multiple intakes.
- Relocation of the Feeder Canal discharge or BRWTP intake to prevent short-circuiting.

A watershed source control approach would include a combination of structural and landscape based treatment systems to filter and treat flows entering the Reservoir from a variety of sources.

- Natural drainages
- Storm water discharges
- Start-up and flow peaks occurring in the Feeder Canal

The range of human source controls included limitations on access to the reservoir or parts of the reservoir (such as around the BRWTP intake), public education, surveillance and patrols, the construction of a separate swimming pool or isolated swimming lagoon, and the installation of additional toilet and refuse disposal stations.

The following comments were received regarding reservoir based solutions to the source water quality.

1. Hypolimnetic aeration would be aeration specific to the hypolimnetic layer in contrast to an aeration system designed to destratify the entire reservoir. Dr. Lewis pointed out that the exact depth and capacity of the hypolimnetic zone would have to be determined in order to estimate the benefits of an aeration approach.

2. Amy pointed out that a previous wetlands development project at the reservoir had resulted in creating higher levels of sodium in the Reservoir.

3. Amy suggested that it would be useful to have flow data for the Reservoir that would provide the quantities discharged for irrigation and pumped to the BRWTP for treatment.

4. Chris noted that there are ongoing discussions between Water Quality and the Recreation Department about operation and activities at the Reservoir. He suggested that a representative of the Recreation Department be invited to participate in the source water planning.

5. Brad suggested that there might be more effort put towards trying to monitor and understand the impacts of special events at the Reservoir.

6. Jim noted that water quality monitoring has been performed during special events, but the monitoring has generally failed to clearly indicate a deterioration of water quality.

7. Carol noted that if the Reservoir alternative were selected, the implementation would likely include additional Utilities staff to patrol and monitor activities at the Reservoir. In addition, if flow was to be pumped from the Reservoir to the BRWTP as part of normal operations, the pump station would have to be rehabilitated to provide increased capacity and redundant pumps. All of these costs need to be included as part of the alternative evaluation.

8. Dr. Lewis pointed out that if the Reservoir Alternative were selected, the additional inflow from the Feeder Canal would likely improve water quality. Others stated that water quality would remain variable since the City had little control over the way NCWCD chooses to conduct their operations using the Feeder Canal and Reservoir.

TM-4 – Full Containment

Kerry presented the Full Containment Alternative that would be comprised of a new pipeline to deliver source water directly from Carter Lake to the BRWTP. There is a possibility that other municipal entities would also participate in such a pipeline. The majority of the pipeline would parallel an existing NCWCD pipeline and then branch off to the BRWTP. For the purposes of discussion, advantages and disadvantages of full containment as compared to the other alternatives were presented as follows:

Advantages

- Best source water quality
- Water quality consistent with other sources (Silver Lake, Barker Reservoir)
- Most reliable and secure method of delivery
- Minimal environmental and public acceptance issues

Disadvantages

- Higher up-front cost
- Long-term storage issues

The following comments were received regarding the Full Containment Alternative:

1. Carol pointed out that the City has significant storage capacity in Boulder Reservoir that has great importance from a cost standpoint especially in drought years. If the BRWTP switched its operational mode exclusively to a pipeline, the storage rights in Boulder Reservoir could be lost. As a result the City could end up, in drought years, paying significant carry over fees to NCWCD to carry over water from one year to the next. Although there may be some room to negotiate this arrangement with NCWCD for the short-term, in the long-term the issue would present itself again.

2. It was suggested that to overcome the long-term storage issues, the City could look into exchanging the Reservoir storage rights.

3. Brad offered that he could see the future situation where, if BRWTP received a consistent, high quality, source water from Carter Lake through a full containment pipeline, BRWTP and the Betasso WTP could switch their roles so that BRWTP would provide the base load of treated water for the entire system and Betasso would become the peaking plant.

4. Dr. Lewis questioned whether there would be federal monies available to partially offset Boulder's cost for participation in a pipeline. Others agreed that it would be worthwhile to investigate these types of alternative financing.

5. Jim explained that Carter Lake is somewhat unique in being able to provide a very high source water quality as a result of having three buffering reservoirs upstream as well as a watershed that is quite small resulting in limited impacts from runoff. Jim Amy, and Bill, supported the idea that delivering Carter Lake water using full containment would provide the most reliable, highest quality source water to the BRWTP.

6. Jim pointed out that full containment of Carter Lake water would allow the City to eliminate the efforts it now spends monitoring source water quality and adjusting its treatment strategies to compensate for variable source water quality. Alternatively, the City could dedicate more resources towards cooperative efforts with the other municipal entities to preserve and protect water quality in Carter Lake for the long-term.

TM-5 – Partial Containment

Kerry presented the Partial Containment Alternative that would be comprised of a new pipeline to deliver source water directly from the Feeder Canal north of Nelson Road (5 miles north of BRWTP) to the BRWTP. There may be a possibility that Left Hand Water District would also participate in such a pipeline. The pipeline would be located almost exclusively in the existing road R.O.W. For the purposes of discussion, advantages and disadvantages of partial containment as compared to the other alternatives were presented as follows:

Advantages

- Improved source water quality
- Minimal environmental and public acceptance issues
- Lower cost than full containment

Disadvantages

- Less reliable source of delivery
- Not secure where Feeder Canal remains exposed
- Inconsistent water quality over time
- Relatively high cost for marginal water quality improvement

TM-6 – New Terminal Reservoir

The New Terminal Reservoir Alternative is based on constructing a new reservoir to provide year-around source water storage similar to that provided by Boulder Reservoir, but without the problems associated with public access to Boulder Reservoir. The most logical site available for the new Terminal Reservoir was one located just to the north of Boulder Reservoir. This site provides gravity flow into and out of the reservoir and requires a minimum length of piping. The New Terminal Reservoir Alternative would include the following principal elements:

- Year-around raw water storage (approximately 4,000 acre-feet)
- Reservoir lining to control leakage and manganese formation
- Divert from Feeder Canal into new reservoir only during the summer months
- No public access
- Provide landscape based surface water run-off controls around new reservoir

The following comments were received regarding the New Terminal Reservoir Alternative:

1. Dr. Lewis commented that, in the early years, the new lined Terminal Reservoir would be free from the manganese problems that can develop in the summer in Boulder Reservoir. However, over time a natural deposition of manganese would occur in the new Terminal Reservoir so that the same issues would eventually have to be confronted in the new reservoir.

2. Jim pointed out that if the new reservoir was to provide approximately 4,000 acre-feet of usable storage, the overall capacity of the reservoir would have to be significantly greater.

3. The issue of evaporative losses was brought up in relation to the pipeline versus reservoir alternatives. Carol stated that under the current agreement, NCWCD absorbs all evaporative and other losses in the Feeder Canal and Reservoir. This situation should not change if the City were to build a new Terminal Reservoir.

4. Carol and Chris pointed out that there were a number of operation and maintenance costs that need to be taken into account for the various alternatives. These include, but are not limited to costs for pumping, chemical addition, and staff positions to patrol, monitor, maintain and operate the facilities associated with the different source water alternatives.

TM-7 – Forebay Alternative

The Forebay Alternative is based on constructing a new forebay upstream of the BRWTP. The forebay would be constructed in place of and in the same location as the New Terminal Reservoir. The Forebay would be much smaller that the Terminal Reservoir and would be used only during those months that the Feeder Canal was operating. The Forebay Alternative would include the following principal elements:

- Pretreatment and emergency storage (approximately 200 acre-feet) for BRWTP source water.
- Approximately 200 acre-feet volume
- Forebay lining to control leakage and manganese formation
- Divert from Feeder Canal into forebay only during months when the feeder canal is operated.

The following comments were received regarding the Forebay Alternative:

1. Chris pointed out that in addition to the settling and storage that would be provided by the Forebay, the basin could be equipped with additional mechanical treatment processes to provide greater benefit.

Water Quality Assessment

Dr. Frey presented a model for assessing the water quality impacts associated with each of the source water alternatives. The baseline established for the analysis was the existing operational mode of using the Feeder Canal to deliver source water to the BRWTP. Beginning with the observed cryptosporidium data from the historical monitoring program, the analysis was used to predict the cryptosporidium load that would be expected to result from the implementation of each of the alternatives.

Using available data on a preliminary basis, the model was used to predict the probability that the water quality resulting from implementation of each alternatives would exceed "Bin 1" Levels in Long-Term 2 ESWTR. The preliminary results were as follows:

Alternative	Probability of Exceeding "Bin 1"
Baseline Alternative	88%
Reservoir Alternative	80%
New Reservoir or Forebay	56%
Partial Containment Pipeline	25%
Full Containment Pipeline	10%

Decision Matrix Software

Considering that there are a number of source water alternatives and evaluation criteria currently under discussion, there may be a need to provide an organizational framework to facilitate decision making. One tool available to serve this function is a computer software program called "Criterium Decision Plus". The workshop concluded with a demonstration of the "Criterium" software that required the participants, to collectively perform a preliminary evaluation of the source water alternatives.

A copy of the preliminary decision matrix that was evaluated is attached for reference.

Workshop No. 2 Schedule

Workshop No. 2 is currently scheduled for Tuesday, January 7, 2003.

KCH:bsc
Attachments

cc: All Attendees
Terry Reichenberger
Joanna Stansbury

City of Boulder, Colorado - Source Water Planning
Workshop No. 1 Agenda

Meeting Date: December 5, 2002

General Milling About – (9:00 – 9:10)

Meeting Objectives (9:10 – 9:15)

Present Source Water Alternative Development (9:15 – 10:30)

1. Reservoir Based Solution
2. Full containment pipeline from Carter Lake to Reservoir WTP
3. Partial containment pipeline from Nelson Road to Reservoir WTP
4. New terminal reservoir (4000 acre-ft)
5. New forebay (200 acre-ft)

Break (10:30 – 10:40)

Review Decision Matrix Software (10:40 – 11:50)

1. Test decision matrix
2. Refine evaluation criteria

Establish Objectives for Workshop No. 2 (11:50 – 12:00)

BLACK & VEATCH CORPORATION

CONFERENCE MEMORANDUM

Boulder, Colorado
BRWTP Source Water Quality Planning
Workshop No. 2

B&V Project 132441.100
B&V File A
January 23, 2003

Workshop No. 2 for the Boulder Reservoir Water Treatment Facility Source Water Quality Planning was held on Tuesday, January 7, 2003 at the Boulder Reservoir Water Treatment Facility (BRWTF).

Recorded by: Kerry Heidel

Attending:

City of Boulder

Randy Crittenden
Bob Harberg
Annie Noble
Chester Phillips
Chris Rudkin
Jim Shelley
Brad Segal
Joanna Stansbury
Amy Struthers
Vicki Smith

Black & Veatch

Kerry Heidel
Lela Parsons

McGuire Environmental

Dr. Michelle Frey

University of Colorado

Dr. Bill Lewis

Meeting Objectives

The purpose of Workshop No. 2 was to bring the participants together to review the information presented to date and establish the future direction for the planning effort. For the benefit of the participants including two participants that were new to the process, Dr. Frey and Kerry Heidel conducted a brief review of the information presented in Workshop No. 1. Dr. Frey made a summary presentation of the Source Water Quality Assessment that she had presented at Workshop No. 1. Kerry reviewed the five source water alternatives that were discussed in some detail at Workshop No. 1 and were currently under consideration.

In response to Dr. Frey's presentation that used ICR monitoring results to simulate the conditions in Carter Lake and the BFC, Dr. Lewis questioned whether there might be water quality data available from reservoirs and streams in the Front Range that might be used to more closely characterize Boulder's situation. It was decided that there probably were not other Front Range conditions that would be readily comparable to Boulder.

Jim Shelley pointed out that regardless of which data might be used to simulate Boulder's situation, it should be remembered that it is only a representation of current condition and that the analysis should not loose sight of changing conditions in the future.

New Information

Amy Struthers shared that in conversations with the Left Hand Water District (LHWD), she had learned that LHWD had in the early 1990s begun planning for a new 1,000 acre-foot storage reservoir, similar in concept, to the new reservoir alternative the City had under consideration. LHWD had discontinued that effort during the permitting process approximately 10 years ago.

Brad Segal and Chester Phillips distributed a preliminary estimate for chemical feed and pumping costs for the BRWTF if it were assumed that Boulder Reservoir did become a year-around terminal reservoir for the BRWTF. They emphasized the cost estimates were preliminary, but that an accounting of these costs would have to be included in any final assessment of the relative advantages and disadvantages of the using the Boulder Reservoir in a terminal reservoir capacity. The participants generally agreed that such costs would need to be included at the time a comprehensive alternative analysis was performed. It was mentioned that capital expenditures for improvements to the pumping station would also have to be considered.

Jim Shelley informed the participants that another seep containing VOCs had been discovered the Boulder Reservoir watershed. It was not known to whether there would be any resulting impact to Boulder Reservoir or the BFC.

Alternative Evaluation

After some additional discussion, there was support for a collective evaluation of the five source water alternatives to determine whether enough information was available to rate the alternatives relative to one another. The following matrix was developed and the participants rated the criteria collectively to arrive at the results shown. The rating system used the numbers 1 through 3 with 1 being the most desirable outcome. Plus symbols were used to represent a marginal increase in ratings. The lowest totals represented the more desirable alternatives as selected by the participants.

Evaluation Criteria	Exist. Condition	Manage Boulder Reservoir	New Pipeline From Carter	New Pipeline From Nelson Road	New Terminal Reservoir	New Forebay
Cost	1	2	3	2	3	2
Water Quality	3^{+}	3	1	2	2	3
Operations	?	?	?	?	?	?
Security	3	2	1	3	2	3
Time to Implement	1	1	3	3	3	3
Environ/Community	1	2	1	1	2	2
Total	**9^{++}**	**10**	**9**	**11**	**12^{++}**	**13**

Because it could not be decided whether "operations" criteria represented operations at the BRWTF or operations in terms of long-term water storage reliability, it was not used as part of the evaluation.

Conclusions

As shown by the matrix, the most advantageous alternatives as selected by the participants were the Boulder Reservoir Management and Full Containment Pipeline from Carter Lake. Because there remains a number of water resource questions related to long-term water storage, the New Terminal Reservoir alternative was also retained for further investigation.

In addition, Bob Harberg requested that a section be added to each of the draft technical memorandums to clarify any particular water resource issues associated with the individual source water alternatives. He suggested that Carol Ellinghouse and Joanna Stansbury could assist with the development of those sections.

There was agreement among the participants that regardless of the long-term source water strategy yet to be identified, the Boulder Reservoir Management Alternative was the most readily available, cost-effective means for improving source water quality in the near-term. Some the measures that could eventually be implemented were discussed in Technical Memorandum 3 and included the addition of multiple restrooms around the reservoir, elimination of full-body contact in the reservoir, hypolimnetic aeration, and moving or modifying the BRWTF intake structure.

Dr. Frey reinforced the reservoir approach by stating that, in her opinion, the City would be unable to satisfy the requirements for the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) if they continued the practice of taking the BRWTF source water directly from the BFC. However, the City could obtain much improved protozoa reductions and satisfy the LT2ESWTR if Boulder Reservoir was used on a full-time basis as the source water for the BRWTF.

Next Steps

Considering that the ongoing pilot testing at BRWTF would not conclude until March, Bob Harberg made the point that there was little else to accomplish to complete Phase 1 of the source water planning process. Therefore, Phase 1 would conclude with the City's comments being incorporated into the draft technical memorandums. A tentative deadline of January 31 was set to have the draft technical memorandums distributed to the City for review.

After the pilot test results become available in March 2003, it is anticipated that the following tasks will be performed by the participants to complete Phase 2 of the source water planning process:

1. The most advantageous source water alternatives identified during Phase 1 will be considered in relation to the treatment alternatives being considered as part of the ongoing BRWTF facility planning process.

2. Source water alternatives will be further developed to provide additional information deemed necessary by the participants in order for them to thoroughly evaluate the alternatives and identify an optimum approach to achieve the City's stated water quality goals.

3. At the conclusion of the Phase 2 process, the City desires to have documented a definitive approach to achieving its water quality goals through a comprehensive program of both source water protection and treatment at the BRWTF.

KCH:alh

cc: All Attendees
Carol Ellinghouse
Terry Reichenberger