City of Cheyenne
Board of Public Utilities

Volume 4 – Potable Water Treatment

Final

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Board of Public Utilities

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Abbreviations and Acronyms

BOPU	Board of Public Utilities
CAD	Computer-Aided Design
DOC	Dissolved organic carbon
gal	Gallon
gpm	Gallons per Minute
GIS	Geographic Information System
Master Plans	2013 Cheyenne Water and Wastewater Master Plans
mgd	Million Gallons per Day
O&M	Operations and Maintenance
ROW	Right-of-Way
SCWSD	South Cheyenne Water & Sewer District
TM	Technical Memorandum
Volume 2	Volume 2 – Future Capacity Requirements
Warren AFB	F.E. Warren Air Force Base
WDEQ	Wyoming Department of Environmental Quality

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4.1 Introduction

This Volume describes the existing water treatment facilities for the City of Cheyenne (Cheyenne) Board of Public Utilities (BOPU) and presents recommendations for improvements to those facilities. The current drinking water regulatory outlook is presented with a discussion of the impacts of those regulations on Cheyenne.

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4.2 Water Treatment Facilities

BOPU owns two water treatment facilities, the R.L. Sherard Water Treatment Plant (Sherard WTP) which treats surface water and the Round Top Facilities which treat ground water. In addition, the United States Army Corps of Engineers (USACE) operates a treatment plant, known as the Ground Water Treatment Facility (GWTF), which removes trichloroethylene (TCE) from a portion of BOPU's groundwater supply before it is blended with other water sources for chlorination.

Water sources providing raw water to the treatment facilities are discussed in detail in Volume 3 of the Master Plan. The surface water supply is provided from a series of reservoirs to the west of Cheyenne. From the terminal reservoir, Crystal Lake Reservoir, water is piped into the Sherard WTP for treatment. Water from North Crow Creek, South Crow Creek and Brush Creek can also be supplied to Sherard WTP through pipe interconnections at the North Crow Wye, but these sources are rarely utilized.

Ground water is supplied from four different well fields, which are known as the Federal, Bell, Happy Jack, and Borie well fields. Well water is disinfected at either the Round Top Facility or at the King II storage tank, which is located just downstream from the Sherard WTP. Water from the Federal and Bell well fields enters the distribution system through Round Top, so it must be disinfected there. Water from the other well fields is typically pumped to the King II tank.

4.2.1 Round Top Facilities

The Round Top Facilities that are currently in operation are the 11 MG Round Top Tank and a disinfection facility. The Round Top Water Treatment Plant was taken off line in 2002, with only the tank and disinfection facilities remaining in operation. The tank was constructed in the 1920's and since then BOPU has added baffles and valving. The previous Master Plan (B&V, 2003) recommended replacing the tank. In the 2008 Sanitary Survey, significant deficiencies were found in the tank and BOPU committed to the regulators that the tank would be replaced by 2024. Recent work on the tank included patching cracks, cleaning and screen repair/replacement. Funding for a 5 MG replacement tank has been earmarked in the existing capital improvement program for construction in 2019.

The tank provides disinfection contact time during summer months for ground water delivered from the Federal and Bell well fields since that water is not piped to the King II tank near Sherard WTP. BOPU obtains disinfection credit to meet 4-log inactivation of viruses to meet the Ground Water Rule by using the tank for contact time. While the current tank capacity is 11 MG, water levels in the tank can be very low on high water usage days in the summer, indicating that peak summer demands have a significant impact on its operation. Sizing of the replacement for the Round Top tank will be revisited in this plan and discussed as part of the distribution system evaluation in Volume 5.

A plan is already in place for design and construction of an on-site hypochlorite generation system to replace the existing calcium hypochlorite tablet system in 2013. The new system will be designed to deliver 100 lbs of chlorine per day. At the maximum chlorine dose of 2 mg/L, the chlorine system will be able to treat 6 mgd of ground water, which is adequate to treat the ground water produced from the Federal and Bell well fields and the additional ground water pumped to Round Top under normal operating conditions.

4.2.2 Sherard Water Treatment Plant

The Sherard WTP is a conventional treatment plant with intermediate ozone oxidation. A schematic diagram of the plant is shown in Figure 4.1. The Sherard WTP treatment process trains were designed to treat 35 mgd with nominally 10 percent waste flow, resulting in a production capacity of 32 mgd. The chemical systems are designed to provide adequate chemical storage and feed to the plant at the originally planned expansion to 50 mgd, with some increased sizing of feed pumps required.

Raw water is delivered from Crystal Lake Reservoir to Sherard WTP through two pipelines, a 30-inch PCCP and DI pipeline and a 50-inch and 36-inch steel pipeline. Because of the elevation difference between Crystal Lake and Sherard WTP, the water pressure is relieved through multiple PRVs located just upstream of the plant in a vault. Water is metered in each of two raw water pipelines by magnetic flow meters located in the chemical mixing vault. A chlorine dioxide feed point is located in the PRV vault. Originally, chlorine dioxide was used to oxidize manganese, but it is not now in use.

Two static mixers on each raw water pipeline provide rapid mixing for chemicals. Originally, the four static mixers were identical and designed to mix the design flow of 40 mgd through each raw water pipeline. Two of the mixers on one pipeline have been replaced, each with a 15 mgd mixer, to provide better mixing at low plant flows. The mixer that was replaced is being held in reserve for future use when flows are higher year around. The plant has feed lines to the rapid mixers for soda ash, chlorine, ferric sulfate and cationic polymer. At this time, only ferric sulfate and cationic polymer are fed to the rapid mix.

From the rapid mixers, water flows into one of three flocculation/plate settling treatment trains. The flocculation basins have a serpentine flow pattern with four chambers. Horizontal paddle flocculators are installed in all four chambers of each train and the flocculation energy is tapered. The paddle assemblies have been retrofitted with axial baffles to prevent short-circuiting.

Flow from each flocculation basin is dedicated to a single settling basin by the plant design, reducing the plant flexibility to use any combination of flocculation basins with any combination of settling basins. Solids are collected on the plate settlers and slough off to the bottom of the basins where they are collected by pneumatic driven vacuum sludge collectors. Settled water flows over V-notch weirs and is piped to the ozone system or the ozone by-pass pipeline.

The ozone system is an in-line reactor supplied with ozone generated from a liquid oxygen storage and feed system. The ozone system was designed to disinfect for 1-log inactivation of *Cryptosporidium*. The system has not been operated since the plant came on line, with the exception of a short period of time in which ozone was used to try to oxidize manganese during a major manganese event. Some time after the event, the leased liquid oxygen tank was removed from the plant site, but within the past year a new 6,000 gallon tank was purchased by BOPU and installed on site. At the outlet of the ozone contactors, calcium thiosulfate can be fed to the water to quench residual ozone.

Settled water (or settled and ozonated water) is fed through pipelines to the dual-media filters. Chemical addition points ahead of the filters are in place for feeding chlorine and cationic polymer. The eight dual-media filters are constant rate filters and each is equipped with a flow meter and control valve. Typical filter operations call for one filter off line to be brought on line when another filter is in backwash. The media configuration was designed to allow for biologically active filtration when ozone is in use.

The filter backwash sequence includes air scour prior to initiating backwash. The sequence for backwashing includes a low flow segment, a high flow segment and a low flow segment.

Filtered water flows into the plant baffled clearwell, which is divided by a weir wall into two sections. The first section serves as the wet well for the backwash pumps and has feed points for chlorine, fluoride, and soda ash. The plant is currently applying chlorine and an initial soda ash dose at this point. Chlorine addition can also be delayed until water reaches the second section (flow over the clearwell mid-point weir wall), which still provides for adequate disinfection contact time at the plant's design flow rate. An ammonia feed point at the weir overflow of the second section was designed for chloramination, but it is not used by the plant. Finally, feed points downstream of the weir wall of the second section are currently being used for fluoride and supplemental soda ash addition.

Treated surface water leaves the Sherard WTP and flows by gravity to the King II Reservoir, which is a 15 MG buried concrete storage tank. Three baffle walls within the tank create a four-pass serpentine flow pattern that provides additional contact time. Near the beginning of the first pass, Sherard WTP treated water is blended with ground water from one or more of the well fields. The ground water is disinfected and fluoridated by mixing with the treated surface water. Water from the King II tank flows through the King I tank and to the northeast toward the Round Top tank through a 36-inch King Intertie. King I Reservoir can be bypassed with water flowing directly from King II to the distribution system.

Backwash water is discharged to two washwater recovery basins and decant from these basins is typically recycled to the head of the Sherard WTP through the washwater recovery pumping station. The recycle stream enters Sherard WTP downstream of the PRV vault.

Slurry from the bottom of the washwater recovery basins and settled sludge are sent to Pond 3 solids handling basin. BOPU has tried multiple approaches for dewatering and disposing of sludge. Most recently, sludge was applied to prairie land in an experimental program (discussed in more detail below).

Table 4-1 lists the design capacities of the unit processes at Sherard WTP. This table was originally developed in the 2003 Master Plan and has been modified herein to reflect the latest plant configuration.

Table 4-1
Unit Processes at Sherard WTP

Unit Process	Description
Raw Water Delivery	
PRVs	2 – 24-inch; 1 – 12-inch; 1 – 24-inch bypass
Capacity, mgd	2 at 35 (maximum); 1 at 5 (minimum)
Magnetic flow meters	2
Capacity, each, mgd	40
Rapid Mixing	
Number of mixers	4
Capacity, each, mgd	1 train at 40 (2 mixers in series) and 1 train at 15 (2 mixers in series)
Flocculation	
Number of trains	3
Number of stages per train	4; All contain paddle flocculators
Stage dimensions, ft	42 x 16
Side water depth, ft	16
Detention time, min	40
Plate Settling	
Number of trains	3
Inclination of plates, degrees	55
Train dimensions, ft	41 x 46

Unit Process	Description
Hydraulic loading on plates, gpm/sf	0.30
Projected plate area per train, sf	27,282
Ozonation	
Number of liquid oxygen tanks	1
Capacity, each, gal / lbs	6,000 / 57,168
Number of ozone generators	2
Capacity, each, ppd	460 at 12 percent O_3
Number of ozone contactors	3
Area, each, sf	2,500
Depth, each, ft	6.75
Volume, each, cf	16,875
Dual Media Filtration	
Number of filters	8
Filter dimensions, ft	24 x 32.3
Design loading rate, gpm/sf	4.5
Max Backwash water, percent	10
Backwash wetwell volume, gal	438,300
Backwash pumps	3
Rated capacity, each, gpm	9,750
Motor size, each, hp	200
Disinfection	
Chlorine contact chamber volume, gal	251,700
Chamber assumed T_{10}/T ratio	0.9
King II Reservoir volume, million gal	15
King II assumed T_{10}/T ratio	0.7

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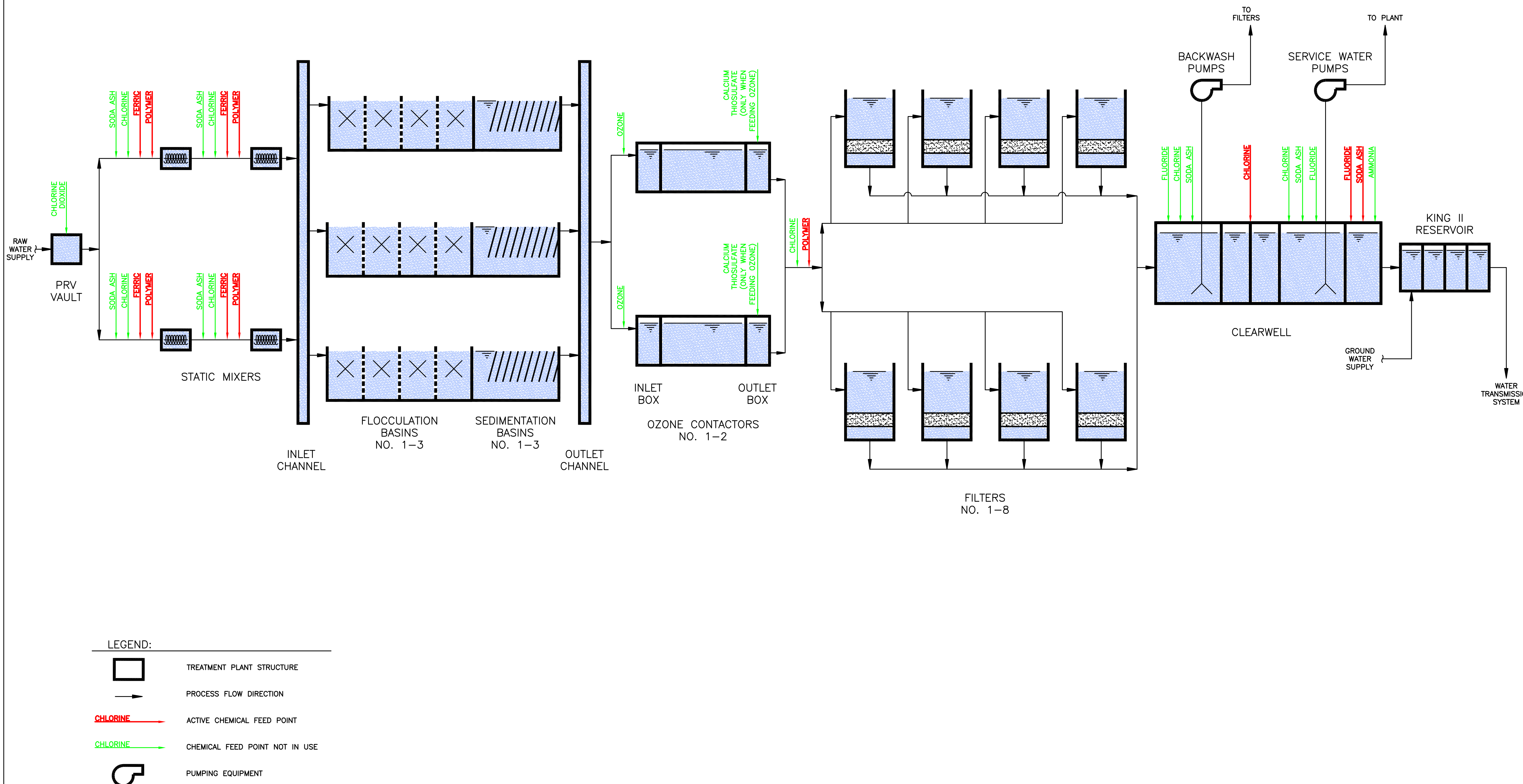

HDR

City of Cheyenne
Existing Water Supply System
Sherard WTP

PROCESS FLOW DIAGRAM

DATE: MAY 2013

FIGURE: 4-1

Alterations to treatment facilities and process improvements at the plant have occurred over the past 10 years that have resulted in a number of new operational parameters for the plant.

Aeration at Crystal Lake Reservoir

Crystal Lake Reservoir supplies raw water to Sherard WTP through 14 miles of parallel pipelines. In June 2009, a hypolymnetic aeration system was installed in Crystal Lake Reservoir to deliver oxygen through a liquid oxygen-supplied diffuser system to the hypolimnion in the lake. The purpose of installing this system was to minimize the oxidation of iron and manganese from lake bottom soils, thereby reducing the dissolved iron and manganese in the raw water delivered to the Sherard WTP. Over the past several years, the system has reduced the levels of iron and manganese in the raw water to near zero and eliminated concerns for delivering colored water to customers.

Chlorine dioxide, previously used for iron and manganese oxidation, has not been used at the plant since the aeration system came on line, so the cost of chlorine dioxide chemical and the analytical testing required when using chlorine dioxide have been eliminated. A summary comparison of chemical costs before and after the aeration system was implemented in 2009 is shown in Table 4-2. The system is operated from May to early September, when the lake turns over.

The plant has made some improvements to the liquid oxygen (LOx) system which delivers oxygen to the hypolimion in the reservoir. The original LOx feed system targeted higher levels of delivered oxygen than turned out to be necessary to maintain hypolimnetic oxygen levels above 4 mg/L. BOPU made alterations to the feed system to allow staff to trim the oxygen feed to a lower dose which still meets the oxygenation requirements, so that optimization of the whole system can progress.

Table 4-2
Summary of Chemical Costs Related to Aeration System

	2008	2009	2010	2011	2012
Chlorine Dioxide Cost	$15,700	Not used	Not Used	Not Used	Not Used
Chlorine Dioxide Analytical Tests	150	0	0	0	0
Liquid Oxygen Cost	Not used	$14,400	$10,000	$10,500	$14,300*

*System was operated 10 days longer than in previous years.

Reduction of the raw water manganese to a very low level has eliminated the need to treat for manganese removal in the plant. In addition, it has allowed the plant operating staff to make several changes in treatment that have downstream benefits to the plant. These are discussed below with the appropriate treatment process.

Raw Water Piping and Pressure Reduction

Currently, the hydraulic capacity of the raw water piping system is 58 mgd. This capacity is adequate, in conjunction with an assumed minimum ground water supply of 8 mgd, to meet BOPU potable demand until 2063. As BOPU moves forward with the design of the proposed hydroelectric facility at Sherard WTP, attention to maintaining adequate raw water flow into the plant will be critical.

Rapid Mixing Modifications

Originally, two 36-inch in-line mixers were installed in each of the raw water pipelines in the chemical mixing vault (CMV) downstream of the PRV vault bringing water into the plant. The in-line mixers provide chemical mixing for ferric sulfate and cationic polymer, which are currently utilized for coagulation. In an effort to obtain better mixing during plant low flow periods (less than 15 mgd production), one of the mixing trains was replaced with two 24-inch in-line mixers in series to improve mixing characteristics for plant flows between 7 and 15 mgd. The plant staff now utilizes the pipeline with the smaller mixers through the winter low-flow months, switching to the pipeline with the larger capacity mixers during summer high flow periods. The change in mixing effectiveness that this alteration has generated at low flows has not yet been documented, but the optimal mixing characteristics at all flows are better met with this change according to the manufacturer of the static mixers.

The plant utilizes ferric sulfate and a polymer for coagulation. Ferric coagulants typically have a small amount of manganese in them, so reduction of ferric doses can reduce manganese levels as well. To continue to meet TOC removal requirements, but minimize the extra manganese addition, the plant reduced the typical ferric sulfate dose from 39 - 42 mg/L to 33 mg/L, supplemented by 2 mg/L of cationic polymer. An additional dose of 0.2 mg/L of the same cationic polymer is now being added on top of the filters. These changes may have resulted in a slight decrease in TOC removal, but the plant remains in compliance for TOC removal and for disinfection byproducts, with TTHMs in the range of 20-30 μg/L and HAA5s in the range of 15-16 μg/L. Compliance levels are 80 μg/L for TTHMs and 60 μg/L for HAA5s, averaged over a year at each compliance sampling site.

Flocculation Modifications

The flocculation paddles have been retrofit to prevent short-circuiting of water along the length of the flocculation paddle shafts. This change was made to improve flocculation mixing by reducing the opportunities for short-circuiting of water through the basins. Changes in flow pattern resulting from this retrofit have not been documented through a tracer study at this time. Flow splitting between the flocculation basins may not be equal, but a complete evaluation of the flow split has not been undertaken.

Ozonation Modifications

The ozone system has been used only intermittently at the plant, with the last use occurring during the manganese event of 2006. For a period of time after 2006, the lease on the liquid oxygen tank that feeds the ozone system was terminated and the tank was removed. Recently, BOPU purchased a liquid oxygen tank that is now installed at the plant so that operation of the ozone system can be resumed, if needed. Plant operators indicate that the most likely use of ozone will be to control taste and odor issues and the system will initially be operated during the summer months when taste and odor events are most common.

Filtration Modifications

The media filters in the plant are designed to operate at 4.5 gpm/sf for a total filtration capacity of 35.2 mgd with one filter off-line. The filters have been tested at a 5 gpm/sf filtration rate and a notification letter has been sent to WDEQ. In addition, pilot study data is available for Sherard WTP which demonstrates that the filter performance at 6 gpm/sf produces water that meets regulatory limits. To increase rated filter capacity, the plant could request permission from WDEQ to operate at 6 gpm/sf, which would likely require provision of documentation of the adequacy of filtered water quality at the higher filtration rate. This may be worthwhile to delay filter additions in the future.

Since the aeration system at Crystal Lake Reservoir came on line, the plant operators have determined that the manganese coating that had been established on the filter media was no longer needed to assist in removing manganese. Likewise, the chlorine dose at the head of the filters for manganese oxidation was not necessary as the dissolved manganese was no longer present in the water at that point. As a result, the operations staff developed a method for cleaning the manganese off the filter media and proceeded to clean each filter bed, one at a time. The process was successful with all filters cleaned between March and May, 2011. Removal of the manganese on the filter media allowed for the removal of the chlorine feed to the filters, saving chemical costs, reducing the formation potential for disinfection byproducts, and improving the overall distribution system water quality. In addition, removing the chlorine feed allows the possibility for the filters to develop biologically so that if ozone oxidation is utilized, the filters may be biologically active enough to remove any unstable assimilable organic carbon that is formed in the ozonation process. Removal of AOC from the water is preferred prior to leaving the plant to prevent it from serving as a food source for biofilms that exist in the distribution system pipe interiors.

Chemical Feed Systems Modifications

Alterations to the chlorine feed system were implemented to allow the plant staff to have more options for feeding chlorine. For example, if a particular injector or chlorinator malfunctions, the piping changes that have been made allow for the use of any other injector and chlorinator as an alternative.

Cationic polymer piping changes were made to allow for the option of feeding cationic polymer into the former non-ionic polymer pipeline which goes to the filters. This allows the use of cationic polymer as a filter aid to improve filter ripening times after backwashing.

A 1-inch soda ash feed pipeline was added to allow the plant to feed soda ash to the clearwell without the necessity of splitting the flow between two feed points. Using a single pump to feed soda ash allows for better control of the feed rate to the clearwell and better management of corrosion control, particularly within plant piping. In conjunction with this change, the soda ash feed system was re-piped to allow multiple options for feeding soda ash to the chemical mixing vault and the clearwell.

Drawings showing as-built piping alterations are included in Appendix 4-A.

Solids Management

Since the last Master Plan, BOPU undertook a study of the solids management program at Sherard WTP. However, recommendations from that study were not implemented due to the cost. Operations staff at the plant initiated a test program for spreading residuals on fields this year. The first spreading has occurred, with exceptionally green grass resulting in the area of application. Measurement of chemical parameters in the soil is ongoing to determine the impacts of spreading residuals. BOPU may consider spreading as a long-term option for disposal if impacts are minimal and permission is granted for use of City owned prairie land.

4.2.3 TCE Removal Facilities

TCE is removed from water produced by the Borie Well Field wells in the GWTF. This treatment facility is owned by the USACE and is operated under contract to the USACE by McMillen LLC, of Boise, Idaho. Contamination of the wells with TCE was attributed to activities carried out by the US military, so the legal responsibility for removing the TCE from the water was assigned to the USACE. The facility is located partly on private property with an easement from the King Ranches and partly on City owned property. An easement and access agreement with the City is under development.

The facility is composed of QED Environmental Systems, Inc., low-profile aeration units. Each unit (4 units total – 3 available for service and one standby) is designed at a maximum 1,000 gpm water flow and 6,400 cfm air flow rate. The facility monitors the ground water flow rate and automatically starts and stops units as the flow increases and/or decreases. The air flow is constant and can only be changed by adjusting a manual damper on the fan discharge. The units are 6-tray aeration units and each unit has a 75 hp blower.

Currently, the GWTF can treat 3,000 gpm, which allows for treatment of the Borie Well Field production (currently just over 2,200 gpm) and an additional two contaminated wells from the Belvoir Ranch (Belvoir 5 at 500 gpm and Belvoir 6 at 300 gpm). Belvoir 5 and 6 have been drilled but are not equipped or piped at this time. Ultimately, the USACE has indicated that they are prepared to treat a total ground water production of 8,000 gpm, which will result if the ground water from the Belvoir Ranch is fully developed and brought to the GWTF site.

Sampling of treated water at the facility is completed by the operators, with monthly reports and copies of laboratory reports delivered to BOPU about one to two months after the sampling has occurred. The reports are routed through the local USACE office, delaying delivery to BOPU. The regulatory maximum contaminant level (MCL) for TCE is 5 μg/L and the results from treatment are all below the minimum reporting limit (MRL) of the analytical method which is 0.5 μg/L. The treatment units have been operated at the maximum water and air flow rates with success, but they have not been tested at the maximum design TCE concentration of 100 μg/L. The highest measured influent TCE concentration has been 29 μg/L.

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4.3 Regulatory Requirements and Impacts

4.3.1 Current Regulatory Framework

The US Environmental Protection Agency (EPA) has finalized 19 drinking water regulations since 1975, nine prior to the 1996 Safe Drinking Water Act (SDWA) Amendments and ten after 1996. Several of the early rules have been revised, some of them more than once. The later rules are generally more complex in nature with multiple requirements and deadlines. Table 4-3 lists the regulations and the basic requirements of each rule as they pertain to BOPU.

Table 4-3: Current Drinking Water Regulations

SDWA Regulation	Compliance Date	General Requirements
National Interim Primary Drinking Water Regulations	1976	Set first MCLs for inorganic and organic chemicals, turbidity, total coliform and radioactive constituents. Mercury, nitrate, and selenium MCLs still stand, others have been revised.
Lead and Copper Rule (LCR) and Revisions to LCR	1992 & 2000	Ensure pH control and other corrosion control strategies are appropriate to meet action levels.
Phase I, Phase II and Phase V Synthetic and Volatile Organic Chemicals	1987, 1991, 1992	Multiple requirements for monitoring and removal to MCL levels for organic chemicals
Surface Water Treatment Rule (SWTR)	1989	Disinfection requirements continue in force although turbidity superceded by IESWTR; 4-log removal of viruses, 3-log removal of *Giardia*
Total Coliform Rule (TCR)	1990	Ensure disinfection strategy and pH control to maintain distribution system water quality; weekly monitoring in distribution system
Interim Enhanced Surface Water Treatment Rule (IESWTR)	Jan 2002	Combined filter effluent turbidity of 0.3 NTU 95 percent of time, not to exceed 1 NTU; continuous monitoring of filters
Stage 1 Disinfectant/ Disinfection Byproduct Rule (DBPR1)	Jan 2002	Meet TTHM/HAA5 $\leq$ 80/60 μg/L; disinfectant MRDLs; TOC removal; monitoring plan
Filter Backwash Rule	Dec 2003	Notify WDEQ of recycle practices; return all recycle flow to head of plant
Radionuclides	Dec 2003	Meet MCLs for radioactive contaminants
Arsenic	Jan 2006	Meet MCL for arsenic

SDWA Regulation	Compliance Date	General Requirements
Ground Water Rule	Dec 2009	Maintain 4-log inactivation of viruses to avoid source water monitoring that is triggered by total coliform positive sample in distribution system
Stage 2 Disinfectant/ Disinfection Byproduct Rule (DBPR2)	October 2012	Initial Distribution System Evaluation required to determine monitoring sites; Meet TTHM/HAA5 $\leq$ 80/60 μg/L based on locational running annual averages
Long-term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)	October 2012 - Treatment Technique October 2015 – 2nd round of sampling	Monitor for *Cryptosporidium* to determine treatment requirement and provide additional treatment if required; disinfection profiling
Revised Total Coliform Rule (RTCR)	April 2016	Continue monitoring for total coliform at same level as TCR; if exceed TC-positive trigger, complete appropriate assessment to find and fix the total coliform problem

BOPU is consistently in compliance with the current regulations. The sampling requirements for the TCR (and RTCR) and LCR rules are based on population served. Recently, the size of BOPU system moved up a tier for population served to 60,069, which requires adding to the total number of samples taken each sampling period. BOPU has submitted revised sampling and monitoring plans to EPA as required by the rules.

The RTCR was just finalized in April 2013. The RTCR shifts the regulatory focus from public notification for total coliform positive occurrences to a “find and fix” framework. Two tiers of assessment requirements in the rule are set to require either the utility or a third party to complete an evaluation to determine the cause of the total coliform positive results and to make changes to eliminate them in the future. The revised rule does not change the number of samples required for systems the size of BOPU.

Public Law 111-380 revised the definition of “lead-free” from lead < 8.0% to <0.25% for pipes, fixtures, and appurtenances (meters, pipe fittings, etc.). Saddles, meters, and parts all have to meet the new definition by January 4, 2014. This requires water systems to manage their existing inventory to meet the 2014 deadline.

4.3.2 Future Regulations and Impacts to BOPU

Likely regulatory actions occurring in the 2014-2015 timeframe will come from the preliminary Third Regulatory Determination, the proposed Long-Term Lead and Copper Rule, the proposed carcinogenic Volatile Organic Compounds Rule, or the proposed Perchlorate Rule. Actions further out in time will arise from the third six-year review process or from separate actions directed by legislation.

Third Regulatory Determination

Over the next five to ten years, the regulatory changes coming from EPA depend somewhat on the decisions made based on the Third Regulatory Determination process. EPA is required to make decisions (regulatory determinations) on at least five contaminants every five years. The decisions can be negative (no regulation needed) or positive determinations. A positive determination means that EPA is going to move ahead to develop a drinking water rule, and if positive determinations are made for a number of contaminants, the schedule could slip because it creates more work for the EPA staff. The preliminary Third Regulatory Determination is due in late 2013 and will be finalized in 2014 – 2015. The Federal budget may impact the determinations.

Potential positive determinations from the Third Regulatory Determination include nitrosamines (NDMA is the most prevalent nitrosamine), chlorate, and strontium. Positive determinations require that EPA propose a drinking water regulation within 24 months of the final regulatory determination and a final rule 18 months later. This means that regulations for nitrosamines, chlorate or strontium would not be finalized until 2018 – 2020.

BOPU is not expected to be impacted by regulations on nitrosamines, chlorate, or strontium. Testing to date has not found any evidence of NDMA in the drinking water. Factors contributing to the formation of NDMA include raw water ammonia, chloramination, and use of polydadmac polymers. Chlorate is a byproduct resulting from the use of chlorine dioxide: the Sherard WTP no longer feeds chlorine dioxide although the equipment is still present to do so. Strontium is a radioactive metal that might be expected to occur in Rocky Mountain water supplies. At Sherard WTP, traces of uranium are present, so it would be wise to test for the presence of strontium. However, since the uranium levels are extremely low, high levels of strontium would be very unlikely. As yet, we do not know what level will be proposed for the strontium MCL.

Proposed Long-Term Lead and Copper Rule

EPA has been working on the content of the Long-Term Lead and Copper Rule for some time, but the regulatory proposal is not expected until sometime in 2014. The Revisions will likely include some requirements related to partial lead service line replacement (PLSLR). Research results are not clear whether PLSLR increases or decreases lead exposure, so EPA may hold stakeholder outreach to address the complex scientific and technical issues. Also included in the Revisions will be requirements for optimization of corrosion control and water quality parameters. Sample site selection criteria may be altered to include schools and day care centers and may shift the focus to homes with lead service lines with less attention to lead solder. Sampling protocols may change to represent water that has "overnighted" in lead service lines as opposed to first flush samples.

Some of these changes will certainly impact the manner in which BOPU implements sampling for lead and copper and may impact the approach to corrosion control at the Sherard WTP. When the rule is proposed, BOPU should review the proposed requirements and begin making plans to meet the new requirements.

Proposed Carcinogenic Volatile Organic Compounds (cVOC) Rule

EPA is currently collecting more occurrence and treatment data to determine which cVOCs to include in the regulation. The intent is to construct a rule that regulates a group of contaminants, but at this point which contaminants will be include is still in question. They plan to build on the existing risk assessments for TCE and PCE, so these two compounds are very likely to be included in the regulated group. Potential co-occurrence and common treatment will be considered by EPA in selecting the cVOCs. TCP (1,2,3-trichloropropane) is likely to be included because it is highly carcinogenic. A rule proposal is expected in 2014.

While this rule may lower the MCL for TCE, the impact of such an action on BOPU would be minimal because the existing GWTF removes TCE to below the analytical method reporting limit. EPA has not yet set an MCL that is below the level that can be accurately measured for an inorganic chemical. BOPU should take the precaution of testing the TCE-contaminated wells for TCP to determine whether it is present. TCP has been used as an industrial solvent and cleaning and degreasing agent and typically appears in ground water where disposal control has been inadequate. The EPA Fact Sheet on TCP can be found in Appendix 4-B. Other evaluations of the impacts of this rule to BOPU can only be determined after the contaminants to be included are determined.

Proposed Perchlorate Rule

The perchlorate rule has a checkered past with EPA because the original determination for perchlorate was negative (no regulation needed). Then due to various pressures, EPA reversed that decision and made a positive determination to regulate. Along with that pressure came a statutory deadline to propose a perchlorate rule by February 2013, which was missed by EPA. Multiple scientific and technical issues have been raised by a special committee of the Science Advisory Board (SAB), which was consulted by EPA on perchlorate issues. The SAB recommended setting an MCLG (maximum contaminant level goal) for perchlorate but with additional analyses required. The SAB final report is expected to be delivered to EPA in 2013. Setting an MCLG is complex with respect to iodide deficiency, dose/response needed to change iodide levels, the use of EPA's pharmacokinetic/pharmacodynamic model, and the incorporation of "life stages" (infants) in the analysis.

Perchlorate health advisory levels have been set by a number of states, ranging from 1 to 18 μg/L. Potential regulatory levels for a national rule range from 2 to 10 μg/L. The rule proposal may be delayed until 2015.

BOPU has tested and found no perchlorate in any of the well fields, so the perchlorate rule should have no impact on the utility.

Regulatory Actions Beyond 2015

The SDWA requires EPA to review all drinking water regulations every six years for possible revision. New information pertaining to health effects, analytical methods, occurrence, or treatment data can lead EPA to include a rule on the list for revision. Preliminary notice of the rules that EPA expects to revise is due in 2015, with the finalized list of rules for revision in 2016-2017. Actual revisions would then be proposed and finalized in the 2020 – 2025 timeframe. Expectations are that the following rules will be included for revision: the Stage 1 and Stage 2 Disinfection Byproduct Rules, Interim Enhanced Surface Water Treatment Rule, and the Long-Term 1 and Long-Term 2 Enhanced Surface Water Treatment Rules.

In addition, chromium is likely to be included as part of the six-year review list because hexavalent chromium (Cr-6) is of concern. EPA is developing a Cr-6 toxicological review now as preparation for the rule revision. Both Cr-6 and total chromium are part of the third Unregulated Contaminant Monitoring (UCMR3) program which is currently underway. Systems are required to sample finished water at entry points and at the maximum residence time locations in the distribution system at a detection level of 20 ng/L for Cr-6. Widespread occurrence is expected and a regulation is likely that includes both total chromium (currently regulated) and hexavalent chromium.

For an idea of what compounds might be regulated further out in time, one source is the list of contaminants on the UCMR3 monitoring program. That list includes a few metals and some VOCs, several perfluorocarbons, 1,4-dioxane, two viruses and seven hormones, along with total chromium and hexavalent chromium. The evaluation of occurrence of contaminants is one of the criteria for EPA to regulate – if a contaminant does not occur in drinking water in significant amounts, it will not be regulated. BOPU should track the results of the UCMR3 monitoring to understand which contaminants may be candidates for regulation in the future. The UCMR3 monitoring occurs from 2013-2015, so by the end of 2016, data should become available and will be discussed and presented at conferences and in regulatory discussions. Based on the population served by BOPU, the utility will be sampling the List 1 contaminants for UCMR3 and will have an idea whether any of those constituents may be an issue. List 1 does not include the hormones, which are only required for sampling by systems serving more than 100,000 people. If BOPU is concerned about the hormones, some samples could be analyzed for the UCMR3 List 2 contaminants to determine whether they are present in the raw water and provide some advance knowledge regarding these compounds which could be regulated. The UCMR3 contaminant lists are shown in Appendix 4-C.

4.4 Treatment Concerns

The treatment processes at the Sherard WTP are robust and flexible, so the plant has only a few concerns regarding treatment. Changes in the regulatory framework as they are now projected do not pose any treatment issues for the plant. However, two treatment issues that are of concern are taste and odor events and the potential impacts of a wildfire in the surface water supply watershed.

4.4.1 Taste and Odor Events

In the recent past, the Sherard WTP has experienced taste and odor events associated with a significant increase in dissolved organics when heavy rains have followed long dry periods. Nutrient levels increase in the reservoirs when this happens, causing algae blooms which can lead to taste and odor issues arising from MIB and geosmin. MIB and geosmin are byproduct compounds released by growing algae. In addition to seasonal taste and odor events, the plant has recently experienced an influx of pine pollen as a short-term event.

Efforts at the Sherard WTP have been initiated to bring the ozone system back on line with the thought that ozonation will help reduce the taste and odor compounds. In fact, ozone can oxidize taste and odor compounds along with other organic molecules. However, the result of ozonating organic compounds is the formation of smaller organic molecules which are often called assimilable organic carbon (AOC). AOC can be problematic in the distribution system as it serves as an easy source of food for biofilms in the water distribution system pipes. Removal of AOC downstream of the ozone system and ahead of the distribution system requires operation of biologically active filters. Biological activity in filters is hard to maintain unless the food source (AOC) is relatively constant and of adequate quantity.

As an alternative to using ozone, a simple, rapid response to taste and odor compounds is to feed powdered activated carbon (PAC). During occasional taste and odor events, the Sherard WTP would benefit from being able to feed PAC to the raw water as it enters the plant. PAC adsorbs organic compounds, taking them out of the water entirely. PAC can be procured in forms that are optimized for removing MIB and geosmin. Thus, implementation of a PAC feed system is recommended.

4.4.2 Wildfire in the Watershed

Most of the scientific literature regarding the impacts of forest fires on watersheds and water quality arises from the sciences of forestry, biology, and hydrology. Historically, the water supply and treatment industry ignored fire impacts because fires in the past typically occurred in remote watershed areas far from public water systems. While this has changed over the past ten years with fires encroaching on the urban/forest interface, the fact remains that little information exists in the literature that addresses the potential changes in surface water quality of most concern to drinking water utilities.

Data collected after previous watershed forest fires typically addresses the recovery of streams to their pre-fire condition with respect to stream flows, sediment loads, organisms in the water and wildlife in the burn areas. Water utilities are interested in a somewhat different set of parameters regarding water supply reliability and quality. Supply reliability pertains to both short and long-term fire impacts on the availability and quality of surface water at the utility's point of supply. Water availability concerns relate to the impacts of debris from the burn area in the stream flows during runoff events and potential reductions or blockages of flow to the water supply system intakes or diversions. Water quality concerns include turbidity, metals, alkalinity, pH, total organic carbon, nitrate, phosphate and ammonia. The degree to which fire effects surface water availability and quality is dependent on factors that determine the intensity and severity of a fire, slope steepness, weather conditions during and following the fire, and the cation exchange capacity of the soil. Factors such as climate, tree type and density, ground cover type, fire history, and fire cycle affect the intensity and severity of a fire.

Figure 4-2
High Park Fire watershed after 2012 fire (USGS photo)

Fires affect watersheds by changing the hydrologic processes on burned hillsides and terrain. A number of different mechanisms can cause water availability and quality changes after a fire (Tiedemann, 1978), with the primary concern being the erosion rate and the changes in stream runoff volume. Changes in water availability occur due to flushing of debris, ash and sediment into streams and reservoirs. Debris can block or reduce flow into water plant intakes. Sediment volume collecting in reservoirs can be of such a magnitude that the reservoir capacity is significantly reduced. Water quality changes typically arise from dissolution of compounds from the sediment and ash that are washed into the streams and reservoirs by runoff. Surface waters in unburned watersheds can also be susceptible to the effects of fire if wind and rain during and following a fire deposit ash and smoke into the watershed (Ranalli, 2004).

4.4.3 Erosion

Rainfall is normally intercepted by watershed vegetation and ground cover during a rain event, reducing the impact of the rain on the soil surface. The degree of soil erosion that can occur during runoff is dependent on the amount of vegetative cover. When vegetation is damaged or removed by fire, the impact energy from rain results in erosion of sediment. In areas where fires are most intense, soil properties can be changed due to intense heating. When the soil surface is subjected to extreme heat, the soil surface can be cemented into a surface that is "glassified". The result of this surface "glassification" is that surface debris is easily washed out of the watershed and runoff coefficients are significantly increased. As the impediments to runoff decrease, transport of sediment by erosion into streams increases.

Erosion rates are highest in the first year after a fire and do not generally return to normal for up to 10 years after a fire, although some researchers report that vegetation recovers enough within four years to control erosion (Robichaud, et al, 1999). In the first year after fire, erosion rates have been measured as high a 35 times the normal rate. The most critical time of concern following a forest fire in a watershed is the first major rain or snow melt event following the fire.

The clearing effect of fire in the forest allows the free flow of debris and ash to occur, with the runoff overwhelming streams and drainage ways. Debris and ash can block streams, causing impoundments to form or the stream to shift course. Water supply intakes along streams can experience flow blockage to the intake as well as plugging of the intake.

USGS (1998) reported debris flows triggered by torrential rains two months after the 1994 Storm King Mountain fire. Debris flow was so significant after this fire that a 3-mile stretch of Interstate 70 was inundated with 70 tons of mud, rock and other debris.

Denver Water experienced such a significant volume of debris collection in Strontia Springs Reservoir after the Hayman fire of 2002 that a dredging effort was undertaken in 2010 to restore the storage volume of the reservoir. Debris accumulation is shown in Figure 4-3. The dredging contract to remove 625,000 cubic yards of material from the reservoir cost Denver Water $30 million.

Figure 4-3
Debris in Strontia Springs Reservoir (Denver Water) after the Hayman Fire in 2002

4.4.4 Runoff Rates

Accompanying the increase in erosion is an increase in flow from runoff. Effects include increased peak spring discharge, increased total annual discharge, greater storm flows and increased base flow (Tiedemann, et al., 1979). Total discharge amounts have been reported at two to eight times greater than normal. Peak flows during storms can be two to 45 times greater than normal peaks. Storm runoff flows typically remain higher than normal for seven to ten years after a fire. All these higher flows bring eroded sediments, nutrients and fire material into the receiving stream or reservoir and can do so for as long as 9 years after a fire (Simon, 1999).

Snow accumulations may increase in open areas after a fire, although wind impacts in large cleared areas may reduce snow. Snowmelt is often accelerated due to increased radiation in areas where there is no shade from trees. Combined, these impacts tend to increase the rate of spring runoff and consequently, increase erosion. High intensity burn areas are difficult to revegetate because the high temperatures dessicate all grass seed and create hydrophobic soil conditions. Sloughing of slopes and mudslides is typical after a fire because the stability provided by plant roots is eliminated. In addition, very high soil water pressures contribute to the likelihood of mudslides.

Monitoring of runoff above and below the Fourmile Canyon burn area near Boulder (Writer, et al., 2012) showed that during high intensity rain events, the discharge in Fourmile Creek downstream of the burned area was as much as 8,000 percent above pre-storm discharge, while upstream of the burned area the discharge increased by 50 percent. The storms causing this difference were typical of Front Range thunderstorms (having a 20 – 50 percent chance of occurring each year). The Fourmile Canyon fire burned in 2010 and this monitoring took place during July 2011. The same study found elevated levels of dissolved organic carbon (DOC), nitrate and turbidity in the creek due to spring snowmelt and runoff in the year following the fire.

4.4.5 Water Quality Changes

Water quality changes in receiving waters are dramatic after a fire, with sediment and turbidity loadings showing the most significant responses to fire. Metals released from plants when they are burned are converted to oxides and deposited as ash. When the ash reaches the receiving water and dissolves, the alkalinity and pH of the water increase. Concentrations of total nitrogen, organic nitrogen, ammonium, potassium, magnesium, iron, calcium and other cations in the form of carbonates have been shown to increase significantly in runoff after a fire. Levels of cations typically remain elevated 2 to 3 years after a fire.

Phosphorus has been found at 2 to 3 times the normal level in streams after fires due to the increased mobilization of total phosphorus in runoff and possibly due to the phosphates present in fire retardants. Ammonium increases in surface water after a fire are due to the dissolution of ammonium volatilized from the combustion of organic matter into precipitation or a stream or lake. Nitrate-nitrogen concentrations increase, primarily due to nitrification of ammonium following a fire, but also likely due to the reduced demand for nitrate-nitrogen by vegetation.

Subsequent to the Bobcat Fire (west of Ft. Collins, CO) in June 2000, monitoring showed that nitrate, ammonia, organic carbon, iron, and manganese levels were 10 to 100 times higher than in similar unaffected watersheds in the same area (Lange, 2001).

Water quality data obtained from the Pecos and Gallinas Rivers after the Viveash fire (May 2000) in the Sangre de Christo mountains of New Mexico indicated elevated levels of turbidity (31,000 ntu maximum), total dissolved solids, TOC (14.3 mg/L maximum), and calcium, iron, magnesium, manganese, and silica (Hopkins, 2001). In addition, the total phosphorus, sulfate and chemical oxygen demand were elevated in the Pecos River in the first few months after the fire. Mercury and aluminum concentrations exceeded chronic standards at least once in the months following the fire.

Increased levels of cyanide may be found in water after a fire. Sodium ferrocyanide is often used as an anticorrosion agent in fire retardants and has been shown to release cyanide ions when exposed to high temperatures or ultra-violet radiation from the sun. (Little and Calfee, 2000). Fire retardant containing sodium ferrocyanide was used on the Viveash fire and Hopkins reported levels of cyanide in both water and sediment at the Pecos River at levels up to 120 μg/L.

In the first flush after the Missionary Ridge fire in southern Colorado in 2002, water was sampled from the Florida River within six hours of a major rain event. Turbidity in this normally pristine mountain water reached over 3500 NTU, a significant change from the usual peak turbidity of 2 NTU. Elevated levels were also measured for alkalinity, ammonia-N, dissolved organic carbon, iron and manganese as shown in Table 4-4 (Clark, et al, 2003). When the water was sampled several days after the rain event, the water was still far from normal with respect to turbidity and TOC. Variability in the water quality in the Florida River was dependent in large part on the amount of rain that occurred in the watershed and the length of time after the rain event that the water was sampled.

Table 4-4
Raw Water Characteristics of Pre- and Post-Fire Runoff at Durango WTP Stream Intake

Water Quality Parameter	Jan-June 2002 Pre-fire	7/29/02 First Flush	8/3/02 6 hours after rain	May 2003 Spring runoff
Turbidity, ntu	1.8	38.5	3640	23.2
pH	8.4	8.2	7.8	8.12
Total alkalinity, mg/L as $CaCO_3$	102	123	361	108
UV_{254}, cm-1		0.208	4.0	0.056
DOC, mg/L	1.4	3.32	18.7	21.2
Iron, mg/L		0.045	5.55	0.17
Manganese, mg/L		0.077	5.60	0.08

Data collected after the Rodeo-Chediski fire in eastern Arizona in 2002 showed significant increases in the Salt River of total organic carbon (higher than normal by a factor of 100), dissolved organic carbon, dissolved phosphorus, total nitrogen, and suspended sediment (higher by a factor of 10). Comparative data for before and after the fire are shown in Table 4-5.

Table 4-5
Raw Water Characteristics of Pre- and Post-Fire Runoff at Salt River

Parameter	Average Concentration (mg/L) Pre-fire	Average Concentration (mg/L) Post-fire
Ammonia	0.020	0.18
Total Nitrogen	0.74	52.8
Dissolved Organic Carbon	2.16	7.66
Dissolved Phosphorus	0.019	0.12
Total Arsenic	0.0053	0.05
Total Iron	3.25	23.7
Total Manganese	0.49	9.04
Suspended Sediment	293	4050

In April 2009, the City of Santa Barbara, CA, experienced a large fire that burned part way around their two supply reservoirs. Water characteristics after that fire are shown in Table 4-6. The treatment plant experienced significant difficulties in treating the water due to the elevated organic content. As a result, the plant staff installed granular activated carbon pressure vessels to remove TOC. Without the GAC the water system would exceed the disinfection byproduct MCLs.

Table 4-6
Raw Water Characteristics of Post-fire Runoff at Santa Barbara, CA

Reservoir	Parameter	January 2008 First Flush	January 2009	January 2010
Gibraltar Reservoir	Turbidity, NTU	23	12	6.7
	pH	7.55	8.0	7.2
	Alkalinity, mg/L as $CaCO_3$	165	300	255
	DOC, mg/L	23	7.9	6.8
	Manganese, mg/L	NA	NA	0.08
Lake Cachuma	Turbidity, NTU	15	4.6	7.6
	pH	8.1	8.2	8.0
	Alkalinity, mg/L as $CaCO_3$	164	178	178
	DOC, mg/L	4.8	4.1	4.0
	Manganese, mg/L	NA	NA	0.038

The longer-term prospects for altered water quality after a fire are less well documented for the parameters of concern to water utilities. Studies of recovery of watersheds in the Greater Yellowstone Area after the Yellowstone fires of 1988 indicate that four years after the burn, changes in the biotic elements of streams were still evident. This included reduction in abundance and diversity of microinvertebrates as well as alterations in the algal populations (Minshall and Robinson, 1992). Nitrate and phosphate levels in streams remained elevated five years after the fire (Franke, 2000). Total organic carbon continues to be higher than before the Missionary Ridge fire in Colorado (Clark, et al., 2003). Long term effects of increased phosphorus and nitrogen include escalation of algal growth in the warm seasons following a fire.

In summary, a fire in Cheyenne's watershed has the potential to have very serious consequences for water treatment immediately after the fire and persisting from five to ten years after the fire. Primary impacts of concern to the utility are:

- Significant immediate and long-term water quality changes that make water difficult to treat to meet regulatory standards

- Significant debris and sediment accumulation in reservoirs, impacting storage volume and water quality
- Increased runoff rates that may impact ability to optimize the storage and use of water
- Increase erosion in the watershed, impacting runoff conditions and potentially damaging infrastructure in the watershed
- Significant costs to mitigate fire impacts in the watershed and potential for increased water treatment costs

Preparation for a potential watershed forest fire is similar to emergency planning for other events and is highly recommended.

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4.5 WTP Capacity and Expansion Analysis

Potable water demand projections were developed in Volume 2 for both low and high service area growth rates. In evaluating the Sherard WTP capacity and expansion requirements, the projected maximum day demands using the high service area growth rates are used for this analysis. These values are shown in the far right column of Table 4-7.

Table 4-7
Potable Water Demand Projections

Year	Planning Period	Average Day (ADD) (mgd)	Maximum Day (MDD) (mgd)
2013	Existing	15.7	35.8
2023	Near-Term	18.0	40.9
2033	Mid-Term	21.2	47.7
2043	Long-Term	24.2	54.0
2053		27.1	60.1
2063		29.6	65.3

The sources for the required supply of potable water include ground water supplied from multiple well fields and treated surface water from the Sherard WTP. Current ground water availability for BOPU is adjudicated by the State of Wyoming and is dependent on the production of existing well fields. Currently, the use of ground water is maximized during summer peak demand months, with BOPU utilizing between 8 and 11 mgd of ground water during the summer months over the past few years. The total volume of ground water produced recently has been in the range of 4,000 to 4,300 ac ft/yr.

Water quality comes into play with respect to the amount of ground water and surface water utilized. Most of the ground water and all of the surface water are typically blended before entry to the distribution system in the King II tank so that the ground water is disinfected and the blended water has adequate alkalinity to control corrosion in the distribution system. Low alkalinity from the surface water source requires buffering with the high alkalinity ground water. The target for blending is a 20 percent minimum ratio of ground water to surface water to ensure that the alkalinity is adequate for corrosion control. Thus, when the demands are higher in the summer, more ground water is produced to maintain the blend. When the demands are extremely high, sometimes the percentage of ground water falls to near 15 percent. When that occurs for multiple days running, optimal water quality conditions for corrosion control may be impacted.

The following sections will describe the capacity of the existing unit processes at the Sherard WTP with respect to WDEQ regulations and future expansion needs.

4.5.1 Unit Process Capacity Requirements

The primary unit processes at Sherard WTP were evaluated for treatment capacity including rapid mixing, flocculation, sedimentation, ozonation, filtration, and disinfection. Chemical feed systems and internal plant piping were not evaluated. The capacity required for the unit processes was determined based on the following two assumptions:

1. The ground water portion of the potable supply is assumed to be at least 8 mgd.
2. The difference between the raw water supplied to the Sherard WTP and the treated water produced by the plant is 4 percent, representing losses through the treatment system such as filter backwash water. (Note, the 2003 Master Plan assumed a 10 percent plant loss during design; however, actual operational data from the plant supports a loss of 2-4%. Thus, a 4 percent loss will be assumed for this analysis to be conservative.)

Table 4-8 summarizes the capacities required for the plant unit processes based on the assumptions listed above.

Table 4-8
Unit Process Capacity Requirements

	2013	2023	2033	2063
Potable Water Supply Required (mgd)(1)	35.8	40.9	47.7	65.3
Ground Water Supply Available (mgd)(2)	8	8	8	8
WTP Finished Water Capacity Required (mgd)(3)	27.8	32.9	39.7	57.3
WTP Unit Process Capacity Required (mgd)(4)	28.9	34.2	41.3	59.6

(1) Potable water capacity based on the maximum demand projections in Table 4-7.

(2) Available ground water supply is assumed to be 8 mgd as a conservative amount of supply into the future.

(3) "WTP Finished Water Capacity Required" = "Potable Water Supply Required " - "Ground water Supply Available".

(4) WTP Unit Process represents the capacity needed through the unit processes of the WTP including coagulation, flocculation, sedimentation, ozonation, and filtration. "WTP Unit Process Capacity Required" = "WTP Finished Water Capacity Required" plus an additional 4 percent.

4.5.2 WDEQ Regulatory Requirements

The State of Wyoming does not have primacy for the Safe Drinking Water Program. However, WDEQ does have regulatory requirements pertaining to drinking water facilities as outlined in Chapter 12 "Water Quality Rules and Regulations". This regulation is intended to be used for evaluation of permit applications involving construction, installation, or modification to drinking water plants. Table 4-9 summarizes the design criteria from Chapter 12 that are applicable to the unit processes at the Sherard WTP and also provides the recommended values from HDR and the current operational values at the WTP.

Table 4-9
Unit Process Design Criteria Summary

Unit Process	Criteria	WDEQ Regulation	HDR Recommendation	Existing Condition at WTP[(1)]
Rapid Mix	Detention Time	30 Seconds (Maximum) in Rapid Mix Basin	60 Seconds (Minimum) in Rapid Mix Basin for Cold Water Conditions	Existing WTP has static mixers and no rapid mix basin, therefore criteria is not applicable
Flocculation	Detention Time	10 Minutes (Minimum)	30 Minutes for Temp. < 45-deg F and 20 Minutes for Temp. > 45-deg F (Minimum)	36 Minutes
Sedimentation	Overflow Rate	1,000 gpd/ft2 (Maximum) or 0.69 gpm/ft2 (Maximum)	0.35 to 0.45 gpm/ft2 depending on plate length	0.25 gpm/ft2
Ozonation	Detention Time	No criteria when ozone not used for disinfection	3 to 5 minutes of contact time at ozone doses of 0.5 – 2 mg/L for MIB and Geosmin oxidation	10 minutes of contact time with ozone doses to provide 1.0-log inactivation of Cryptosporidium
Filtration	Loading Rate	5 gpm/ft2 (Maximum)	6 gpm/ft2 based on existing pilot plant data from WTP	3.7 gpm/ft2 with 1 filter off line

(1) Values are calculated based on the 2013 finished water capacity in Table 4-7.

4.5.3 Unit Process Capacity Analysis

Using the design criteria outlined above, each of the unit processes was evaluated to determine its ability to meet the projected capacity needs. The following sections will summarize the results of the capacity analysis for each unit process.

Rapid Mixing

As previously stated, BOPU utilizes a smaller 24-inch static mixer during winter low flow months and a larger 36-inch mixer during summer high flow months. The capacity of the 36-inch mixer is 40 mgd as stated by the manufacturer. Although both mixers are not typically operated simultaneously in parallel, there is no reason why the WTP could not be operated in this mode. Furthermore, the 24-inch mixer could easily be replaced in the future with the original 36-inch mixer. By nature, a static mixer should not need to be taken out of service unexpectedly due to the lack of moving parts. Therefore, the rapid mixing capacity of the Sherard WTP could be stated as the combined capacity of two 36-inch mixers, or 80 mgd, which is more than adequate to meet the long-term capacity needs of the WTP. That being said, the performance of the existing static mixers has never been tested with a challenging water quality condition or at higher plant flow rates. Based on HDR's past experience, it is possible that the existing static mixers will not provide adequate rapid mixing at the plant flows that are projected after the 2033 mid-term planning horizon. Therefore, HDR recommends that BOPU consider constructing a true rapid mix basin with 60 seconds of detention time (in cold water conditions) in this time frame. A new rapid mix basin could be constructed on the east side of the existing flocculation basins.

Flocculation

The Sherard WTP flocculation basins consist of a 3-train system with 4-stages of mixing in each train. Table 4-10 summarizes the available flocculation detention time at the WTP using the projected unit process capacity requirements.

Table 4-10
Flocculation Detention Times at Projected Capacity Requirements

Year	2013	2023	2033	2063
WTP Unit Process Capacity Required (mgd)	28.9	34.2	41.3	59.6
Detention Time (min)	48.0	40.6	33.6	23.3

WDEQ requires 10 minutes of flocculation detention time. However, HDR recommends a minimum of 20 minutes based on the water quality delivered to the Sherard WTP during summer warm water conditions when high demands occur. As shown in the table above, the plant has more than adequate flocculation detention time in the existing basins to meet the long-term projected capacity requirements. It is possible that the mixers may need to be reconfigured to provide additional mixing energy after the 2033 mid-term planning horizon. This would most likely require a reconfiguration of the paddles on the mixers themselves and/or an increase in motor horsepower.

As previously mentioned, there is some concern that the flow split to the flocculation basins and downstream sedimentation basins may not be equal. The mixers themselves were recently modified to prevent short-circuiting; however, the dimensions of the basins are not consistent among the treatment trains. HDR recommends that BOPU perform a follow-up tracer study to evaluate both the mixing efficiency following the flocculation mixer modifications and the flow split among the three flocculation/sedimentation treatment trains.

Sedimentation

The sedimentation process at the Sherard WTP consists of three trains of basins all equipped with plate settlers. Table 4-11 summarizes the basin overflow rate using the projected unit process capacity requirements.

Table 4-11
Sedimentation Overflow Rates at Projected Capacity Requirements

Year	2013	2023	2033	2063
WTP Unit Process Capacity Required (mgd)	28.9	34.2	41.3	59.6
Overflow Rate Based on Projected Plate Area (gpm/sf)[(1)]	0.25	0.29	0.35	0.51

(1) Project plate area assumed to be 27,282 square feet per train per the 2003 Master Plan.

WDEQ limits sedimentation basin overflow rates to 0.7 gpm/sf, which is also the upper limit of industry standards. As shown in the table above, the basin overflow rate is still only 0.35 (based on the projected plate area) at the mid-term capacity requirement in 2033. The 2003 Master Plan expressed some concern with increasing the sedimentation basin overflow rate beyond 0.35 gpm/sf. Based on HDR's experience with plate settlers in similar applications, this concern might be unfounded and should be field verified. It should be possible to operate the sedimentation basins at higher loading rates (i.e. up to 0.45 to 0.5 gpm/sf) if the downstream filters can handle a nominally higher influent turbidity. One way to test the robustness of the sedimentation process would be to take one or two basins out of service to achieve an overflow rate greater than 0.35 gpm/sf and monitor the turbidity of the filter influent.

Ozonation

The ozonation system at the Sherard WTP has been offline since 2006. However, BOPU has been considering bringing the system back online to address taste and odor issues. A recent purchase of a LOx tank was completed in preparation for operating the ozone system.

The ozone system was designed to treat 35 mgd with a minimum of 10 minutes of contact time to achieve 1.0-log inactivation of Cryptosporidium at 2 ^{o}C. Since the WTP is classified in Bin 1 under the Long-term 2 Enhanced Surface Water Treatment Rule and there is very little likelihood that the classification will change, inactivation of Cryptosporidium with ozone is unnecessary.

Treatment of taste and odor compounds such as geosmin and MIB at relatively low levels typically calls for ozonation times of 3 to 5 minutes at doses in the range of 0.5 to 2 mg/L. The existing system is adequate to provide this level of treatment for the plant at the mid-term treatment capacity.

Filtration

As previously discussed, BOPU executed a successful filter cleaning in 2011, which removed the manganese coating on the filter media. Without the requirement for manganese adsorption onto the filters, filtration rates can be established based on turbidity removal alone.

Table 4-12 summarizes the filter loading rates using the projected unit process capacity requirements. Table 4-13 shows the specific unit process capacities that can be achieved with varying filter loading rates.

Table 4-12
Filter Loading Rates at Projected Capacity Requirements
(With Existing Filters)

Year	2013	2023	2033	2063
WTP Unit Process Capacity Required (mgd)	28.9	34.2	41.3	59.6
Loading Rate with One Filter Offline (gpm/ft^2)	3.7	4.4	5.3	7.6

Table 4-13
Potable Water Supply Available Using Various Filter Loading Rates
(With Existing Filters)

Filter Loading Rate (gpm/ft^2)	5.0	5.5	6.0	6.5	7.0
WTP Unit Process Capacity with One Filter Offline (mgd)	39.1	43.0	46.9	50.8	54.7
WTP Finished Water Capacity with One Filter Offline (mgd)(1)	37.5	41.3	45.0	48.8	52.5
Potable Water Supply Available with One Filter Offline (mgd)(2)	45.5	49.3	53.0	56.8	60.5

(1) Assumes a 4 percent plant water loss.

(2) Assumes 8 mgd of ground water supply available.

BOPU has already performed successful pilot testing at a filter loading rate of 6.0 gpm/ft^2. As seen in the table above, this loading rate would provide 52.5 mgd of potable water supply assuming a 4 percent plant water loss combined with the 8 mgd of ground water supply capacity. This is enough potable water supply to take BOPU beyond the 2033 mid-term planning horizon, but not quite enough to achieve the long-term potable water supply need of 65.3 mgd. Furthermore, even at a filter loading rate of 7.0 gpm/sf, the potable water supply available is still 60.5 mgd and falls just short of the long-term need. Consequently, two new filters would need to be constructed to meet the long-term potable water supply requirement.

Table 4-14 shows the available potable water supply at varying filter loading rates with 2 new filters for a total of 10 filters.

Table 4-14
Potable Water Supply Available Using Various Filter Loading Rates
(With 2 New Filters)

Loading Rate (gpm/ft^2)	5.0	5.5	6.0	6.5	7.0
WTP Unit Process Capacity with One Filter Offline (mgd)	50.2	55.3	60.3	65.3	70.3
WTP Finished Water Capacity with One Filter Offline (mgd)(1)	48.2	53.0	57.9	62.7	67.5
Potable Water Supply Available with One Filter Offline (mgd)(2)	56.2	61.0	65.9	70.7	75.5

(1) Assumes a 4 percent plant water loss.

(2) Assumes 8 mgd of ground water supply available.

As shown in the table above, BOPU can achieve the long-term potable water supply requirement (65.3 mgd) by constructing two new filters and operating at a loading rate of 6.0

gpm/ft^2. However, the construction of two new filters is not needed until the distant future. HDR encourages BOPU to petition WDEQ to test the existing filters at 6.0 gpm/ft^2 and to perform pilot testing at greater loading rates to assess the true performance capability of the Sherard WTP filtration process. Based on our experience, conventional filters in similar applications are capable of successfully operating at loading rates up to 8 gpm/ft^2.

Disinfection

The disinfection process at the Sherard WTP benefits from the King II reservoir detention time, which provides additional chlorine contact time downstream of the plant's clearwell. King II reservoir has a 15 million gallon capacity, which will be more than adequate to meet the CT requirements for the long-term potable water supply requirement.

4.5.4 Sherard WTP Capacity Summary

The results of the capacity analysis performed for this TM show that no major unit process additions are necessary to meet the 2033 mid-term potable water supply requirements of BOPU. Sometime after 2033, the existing filters will be required to operate at loading rates greater than 6.0 gpm/sf, which might very well be possible based on similar applications around the country. The rapid mix unit process is of some concern after 2033. It is HDR's experience that static mixers do not provide adequate rapid mixing in the type of cold water, low alkalinity water conditions experienced at the Sherard WTP. It may be necessary to construct a true rapid mix basin with adequate detention time to support the remainder of the treatment process in this time period.

The Sherard WTP was designed for a rated production capacity of 32 mgd in its current configuration and an ultimate capacity of 50 mgd assuming the addition of a fourth flocculation basin and sedimentation basin train and the addition of 4 filters. These configurations were previously referred to as "Phase 1" and "Phase II".

In reality however, the plant should be capable of providing at least 45 mgd of finished water capacity (not including ground water) in its current configuration (i.e. Phase I) and probably more if the filters can be shown to operate effectively at loading rates greater than 6.0 gpm/ft^2 and if the existing static mixers can provide adequate rapid mixing. The ability of the WTP to produce more finished water than originally designed and currently portrayed is primarily due to three factors:

1. The original WTP design was inherently conservative. For example, the filters were designed to operate at 4.5 gpm/sf and the plate settlers were designed for a maximum overflow rate of 0.35 gpm/ft^2. BOPU has pilot plant data to show that the filters can operate effectively at 6.0 gpm/ft^2. Similarly, plate settlers can be loaded up to twice the design overflow rate based on WDEQ regulations and industry standards.

2. Plant water losses were assumed to be 10 percent. However, operating data from the WTP shows that actual plant water losses range from 2-4 percent.
3. Recent water system projects have improved the WTP's treatment capability. These projects include:
   - Addition of aeration system at Crystal Reservoir for manganese control
   - Improved flow pattern through the flocculation basins
   - Removal of manganese coating from filter media

In conclusion, the Sherard WTP is well positioned to meet BOPU potable water system supply needs in the future without major unit process additions. However, there are some treatment related projects that HDR recommends to ensure the WTP's success and reliability into the future. The following section will address those projects.

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4.6 Recommended Projects

This section addresses recommended projects in the water treatment division. Some of the projects are primarily operational efforts but may require some assistance from external resources.

4.6.1 Tracer Test for Mixing and Flocculation

As follow-up to making changes in the rapid mixers and eliminating the short-circuiting in the flocculators, Sherard WTP staff should consider completing a follow-up tracer study to confirm that mixing has been improved. The test plan should also include evaluation of the flow split to each of the flocculation/sedimentation treatment trains. The previous tracer study was completed with assistance from HDR and some volunteers to help take samples. If plant staff is comfortable doing the tracer study in-house, this project could be part of operational optimization.

4.6.2 Justification and Request for 6 gpm/sf Filtration Rate

The Sherard WTP has already completed pilot testing at a filtration rate of 6 gpm/sf and the plant operations staff has confidence that operation at that rate will be successful. HDR recommends development of a letter and technical memo to WDEQ requesting confirmation that continual operation at 6 gpm/sf is acceptable. In fact, when data is collected as a full-scale demonstration, the option of testing at even higher filtration rates is an option. Other utilities in the west have shown that conventional filters with normal bed depths similar to BOPU's filters can adequately filter water at 7 and 8 gpm/sf. As the system demand grows, the option for operating at a higher filtration rate will save BOPU significant funds because construction of additional filters can be delayed or avoided altogether. BOPU might consider installing new piping to route a flow stream from the sedimentation basin effluent to the pilot plant facility for the purposes of testing higher filtration rates.

The request WDEQ will require a technical memorandum that describes the testing and results in detail to support the proposed increased filtration rate.

4.6.3 Evaluation of Extended Terminal Subfluidization Wash

BOPU requested that HDR review the current filter backwash sequence as part of the filtration capacity analysis. Specifically, BOPU requested that HDR provide feedback on the last step of the sequence, which involves filter media restratification. The current practice at the plant is to slowly decrease the high rate wash flow in a linear approach in lieu of using a step approach where a constant low flow wash rate is maintained for a set duration. The step approach is sometimes termed, "extended terminal subfluidization wash (ETSW)". Based on industry research and HDR's experience, we feel that ETSW is a better approach for two reasons. First, ETSW allows for a set duration of low flow wash at the optimal rate for media restratification, which ensures that the filter bed is optimally layered in accordance with the design. Second, ETSW has been shown to reduce the magnitude of turbidity and particle count spikes when a filter is put back online after backwash (Amburgey, et al., 2003).

Implementation of an ETSW requires selection of an effective subfluidization wash rate and duration. The cost of implementation is minimal. ETSW may require an increased duration of the backwash cycle (on the order of a few minutes) because the lower ETSW rates require more time to move water through a filter bed. In some cases, wash water usage may increase slightly. However, the benefits of improved media restratification and filter ripening make an ETSW worth consideration. HDR recommends that BOPU evaluate the use of an ETSW by observing filter turbidity and particle count spikes using the current approach (i.e. decreasing the high rate wash flow in a linear fashion) versus using an ETSW (i.e. a step approach with a constant low flow wash rate for a set duration). A supplementary evaluation could include taking filter media cores after a backwash using both approaches to observe the effectiveness of media restratification.

4.6.4 Plan for Distribution System Sampling with Ozone On Line

Prior to initiating operation of the ozone system, BOPU should develop a sampling plan for the distribution system to evaluate biological activity at several sites in the water distribution system. Sampling sites that are used for other purposes would be ideal, since some of the existing historical data may become useful if biological activity changes. This plan should include evaluation of HPCs, pH, and Cl_2 residual at selected sampling sites at regular intervals.

4.6.5 Powdered Activated Carbon (PAC) Feed System

PAC feed systems for larger plants typically use a superbag system that feeds a batch tank or a mixed basin that can accept a truckload of PAC to form a PAC solution. The solution is fed using metering pumps to the rapid mix. Due to the intermittent need for PAC feed and the 6 month life for a PAC slurry mix, the superbag system makes the most sense. At the Sherard WTP, the ammonia system is no longer in use, so that space could be used to house the PAC feed system as it really requires an enclosed separate space. The cost for installing a PAC feed system in the plant is based on the cost of a package superbag system and reusing the ammonia feed space.

HDR received a conceptual level proposal from Shick to provide a PAC feed system for the Sherard WTP. The system footprint is approximately 6 ft by 7 ft by 20 ft tall and includes a modular bulk bag support frame with lifting hoist, pneumatic bag massager, gravimetric feeder, and blower. A slurry tank and feed pumps are required in addition to the superbag system. The budget price for this equipment is $120,000. A copy of the preliminary proposal from Shick is included in Appendix 4-E along with the cost estimate for construction (in 2013 dollars).

For the purposes of addressing taste and odor issues in the future, plant staff can use two approaches. The first approach would be to put the existing ozone system back online, which may also cause the filters to go biological. The second approach would be to install the new PAC feed system and leave the ozone system offline. To evaluate these two approaches, a rudimentary NPV analysis was performed. A summary of the analysis follows.

Capital costs for the ozone system were not included in the NPV analysis as the ozone system is already constructed and in place. To address taste and odor events, it was assumed that the ozone system would operate between mid May and mid September, or approximately 16 weeks a year. The PAC feed system is estimated to cost $514,000 for design and construction, factored in as a capital cost in 2013 dollars. The PAC system would be used intermittently throughout the year during taste and odor events with a total cumulative operation time of 4 weeks per year. The ozone system would be operational between mid May and mid September. Both the ozone and PAC options were evaluated using an average flow rate of 28 mgd based on the 2012 Sherard WTP treated flow rates from May through September with 4% added for plant water loss.

Evaluation of the cost of ozonation for removal of taste and odor compounds is dependent on the characteristics of the particular compounds occurring in the water supply. For typical metabolic byproducts of algae growth such as MIB and geosmin, reports in the literature indicate that a dose of 1.5 to 2 mg/L of ozone can typically remove between 35 to 40 percent of these two compounds. Doses of 4 to 8 mg/L may be necessary to remove 95 percent of MIB and geosmin, depending on the alkalinity of the water. The odors present in ozonated water are determined by the sweet and pungent odors of the ozone byproducts that are formed (aldehydes, keotnes, and carboxylic acids). This NPV analysis is based on an ozone dose of 2 mg/L and a PAC dose of 4 mg/L. Chemical costs were assumed to be $0.43 per gallon for liquid oxygen to supply the ozone system and $1.17 per pound for premium bituminous PAC. Operation and maintenance (O&M) labor costs for the two systems were estimated at 10.5 manhours per week for the ozone system and 2 manhours per week for the PAC feed system with a labor rate of $15 per hour for both systems. Power costs for the PAC feed were almost negligible with a daily cost of only $1.16 using the WTP's current power rate of $0.052 per kilowatt-hour. Power costs for the ozone system were much more substantial with over 3,400 kW-hr of power use per day totaling just under $20,000 for a year's operation.

The total O&M costs for the PAC system are estimated at $25,000 per year compared to the ozone system at $38,000 per year. Although the PAC feed system will be less costly to operate on an annual basis, the initial capital investment required to install a new PAC feed system means the NPV (capital cost plus O&M) of the PAC system does not approach the NPV of operating the existing ozone system until roughly 50 years. That being said, HDR believes that installing a new PAC feed system should be considered in lieu of operating the existing ozone system for the following reasons:

- PAC is more likely to effectively remove the taste and odor compounds of concern both during normal water quality operation and particularly during a potential wild fire scenario.
- The assumption that ozonation will allow for continuous biological filtration is questionable due to the minimal organic content of the Sherard water.
- Ozonated water can be unstable and may encourage regrowth of biological substrates in the distribution system, which can reduce chlorine residuals.

A full summary of the NPV analysis is included in Appendix 4-E.

4.6.6 Wildfire Emergency Response Plan

The extent and severity of watershed forest fires are not predictable and when fires occur, the time is often short for utility organizing to manage impacts. Development of a wildfire emergency plan will provide a backbone for the response to a fire in the watershed. Some items the plan should include:

- Discussion of fire risk monitoring tools and how BOPU might include those in regular evaluations of water resource availability.
- Description of the watershed areas at high risk and the flow patterns for water from those watersheds to BOPU, with the intent of determining where the hydraulic and debris impacts would be most likely to occur.
- Discussion of known impacts to watersheds and water quality and how these changes would impact the ability of BOPU to produce water meeting the drinking water regulations.
- Discussion of potential impacts to availability of useable water for potable supply and water use restrictions that may need to be implemented.
- Discussion of regulatory impacts and key parameters of concern.
- Discussion of financial impacts, both capital and O&M.
- Development of a short-term response plan with actions and roles for utility staff.
- Potential modifications to the Sherard WTP to prepare for fire such as addition of a PAC feed system to manage significant intermittent total organic carbon and taste and odor issues.
- Emergency measures that could be implemented quickly (i.e., temporary solids pre-treatment or chemical feed systems).

The plan should incorporate input from utilities that have dealt with fire recently and may be used as a method of establishing relationships with other governmental agencies that are involved in watershed fire management and suppression.

4.6.7 Managing Distribution System Water Quality with Less than 20% Ground Water

If the quantity of ground water available to BOPU remains relatively constant over the next ten years while the quantity of surface water utilized increases, the current blend of 80% surface water to 20% ground water will be difficult to maintain. This could occur in the near-term period.

A distribution system water quality evaluation was completed at the time of the previous master plan, addressing the issue of complaints and distribution system water quality. At that time, part of the concern with complaints appeared to arise from manganese in the water distribution system. Now that the manganese in the finished water is minimized, any manganese issues would arise from legacy manganese in the water distribution system.

Of greater concern in altering the surface water/ground water blend would be the issue of altering the corrosion control conditions of the finished water. An evaluation that includes bench scale testing is recommended to determine the best approach for optimizing corrosion control under blending conditions where ground water sources are less than 20 percent of the total finished water. Soda ash addition may be warranted, or there may be alternative corrosion control products that should be tested. Based on the demand projections, such a study would be necessary between 2020 and 2023.

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4.7 Capital Improvement Plan

The recommended projects described in the previous section are all focused on improving operations for efficiency and reliability of the Sherard WTP. A capital improvement plan was developed to provide an implementation timeframe and costs for the projects.

The projects are all assigned a capital improvement ID with the following format: Planning Period-System-Project Number.

- Planning Periods include:
  - 2013 – In Progress/Completed
  - NT - Near Term (2014-2023)
  - MT - Mid-Term (2024-2033)
  - LT - Long Term (2034-2063)
- Systems include:
  - SWTP – Sherard Water Treatment Plant

Project Number is a sequential number for each planning period.

Annual cost estimates were developed for each of the capital improvement projects from 2015 to 2023. Years 2013 and 2014 are currently budgeted years and the cost estimates from the financial projections provided by BOPU were not revised.

The cost estimates developed are order of magnitude costs to give an indication of probable cost to implement. All of these estimates are preliminary in nature. Project order and customer's water needs are two of many variables that may impact the cost estimates provided for the near-term. It is normally expected that an estimate of this type would be accurate within +50% or -30%. A 30% design contingency was applied to the total construction costs and a 3.5% per year escalation rate was used to account for inflation. The estimates provided should be reevaluated prior to construction of the facilities.

Table 4-15 summarizes the estimated project costs and timing of completion. The projects are listed in recommended priority.

The Wildfire Emergency Response Plan and PAC Feed System projects are identified as high priority for the near-term since the risk of fire is a serious concern that could occur at any time. These two projects may be related in that the Wildfire plan may well recommend addition of PAC feed to the Sherard WTP as a preparatory measure for fire response.

The projects are all assigned a capital improvement ID with the following format: Planning Period-System-Project Number.

- Planning Periods include:
  - 2013 – In Progress/Completed
  - NT - Near Term (2014-2023)
  - MT - Mid-Term (2024-2033)
  - LT - Long Term (2034-2063)
- Systems include:
  - SWTP – Sherard Water Treatment Plant

Project Number is a sequential number for each planning period.

Annual cost estimates were developed for each of the capital improvement projects from 2015 to 2023. Years 2013 and 2014 are currently budgeted years and the cost estimates from the financial projections provided by BOPU were not revised.

The cost estimates developed are order of magnitude costs to give an indication of probable cost to implement. All of these estimates are preliminary in nature. Project order and customer's water needs are two of many variables that may impact the cost estimates provided for the near-term. It is normally expected that an estimate of this type would be accurate within +50% or -30%. A 30% design contingency was applied to the total construction costs and a 3.5% per year escalation rate was used to account for inflation. The estimates provided should be reevaluated prior to construction of the facilities.

Table 4-15
Sherard WTP Capital Improvement Projects

Item #	CIP ID	Project	Proposed Budget	Projection	Projection	Projection	Projection	Projection	Projection	Projection	Projection	Projection	Near-term Expenditures
			FY 2014	FY 2015	FY 2016	FY 2017	FY2018	FY2019	FY2020	FY2021	FY2022	FY2023	Based on Year of Construction Dollars
1	NT-SWTP-1	Wildfire Emergency Response Plan		$30,000									$30,000
2	NT-SWTP-2	Powdered Activated Carbon (PAC) Feed System				$589,800							$589,800
3	NT-SWTP-3	Justification and Request for 6 gpm/sf Filtration Rate		$30,000									$30,000
4	NT-SWTP-4	Plan for Distribution System Sampling with Ozone On-Line(1)											By BOPU
5	NT-SWTP-5	Evaluation of Extended Terminal Subfluidization Wash											By BOPU
6	NT-SWTP-6	Tracer Test for Mixing and Flocculation(2)							$19,100				$19,100
7	NT-SWTP-7	Managing Distribution System Water Quality with Less than 20% Ground Water										$56,400	$56,400
		Total Projects by Year	$0	$60,000	$0	$589,800	$0	$0	$19,100	$0	$0	$56,400	$725,300
												Average Cost per Year (over 10 years)	$72,500

(1) Only necessary if ozone system is operated to address taste and odor in lieu of PAC system.
(2) Can be completed anytime in the near-term.

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4.8 References

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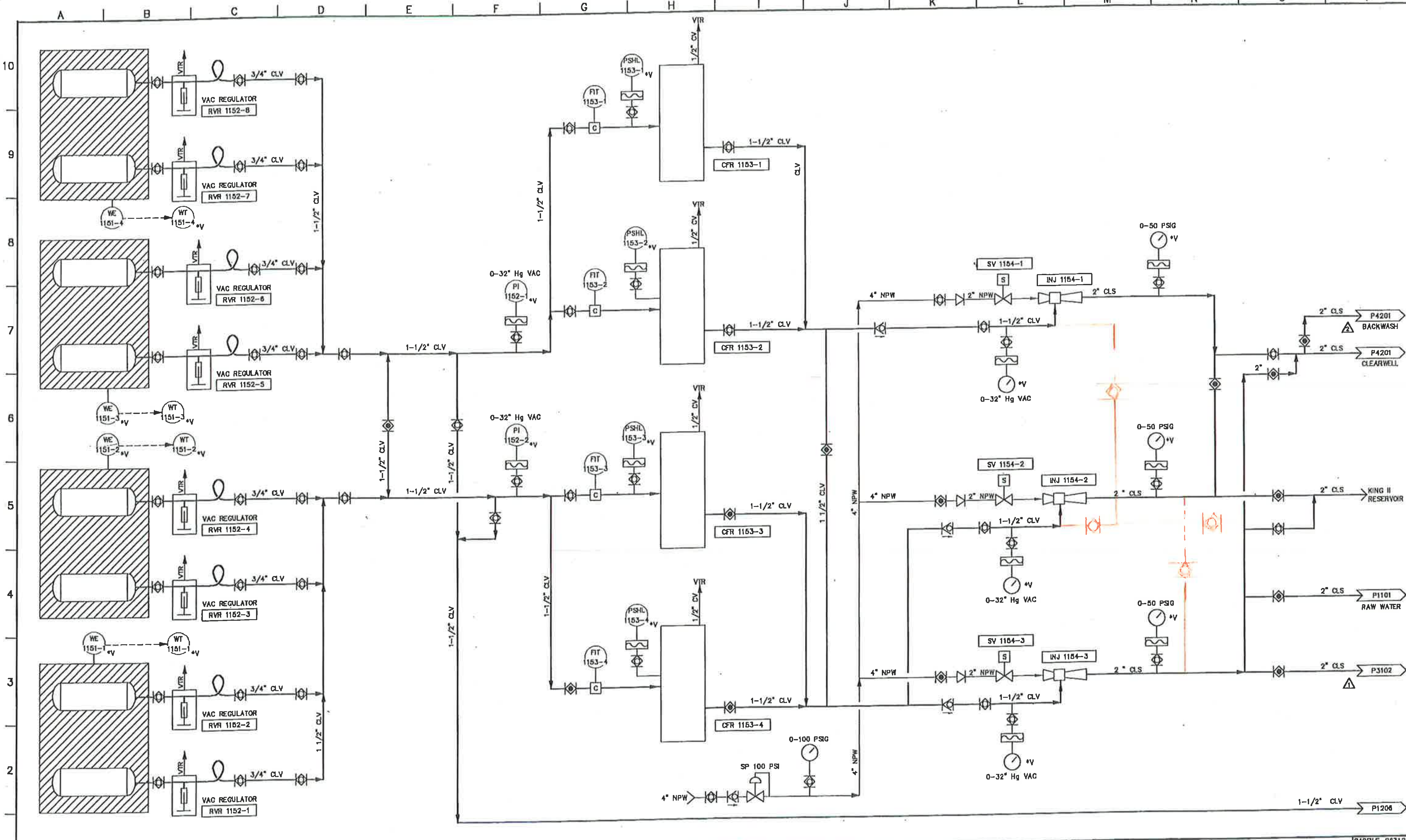
Appendices

Volume 4 – Potable Water Treatment

Appendix 4-A
Sherard WTP Piping Changes – As-Built Drawings



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APPROVED:	DATE:

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FILE 6411
DRAWN BY JPC
DESIGNED BY WAP
CHECKED BY RAF
CHECKED BY

REVISIONS

ZONE	REV.	DESCRIPTION	BY	DATE	APP.
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	2	ADDED CLS LINE PER ADDENDUM 3	JPC	4/99	

CHEYENNE, WYOMING
BOARD OF PUBLIC UTILITIES

R. L. SHERARD WATER TREATMENT PLANT EXPANSION

PROCESS DIAGRAM

CHLORINE SYSTEM

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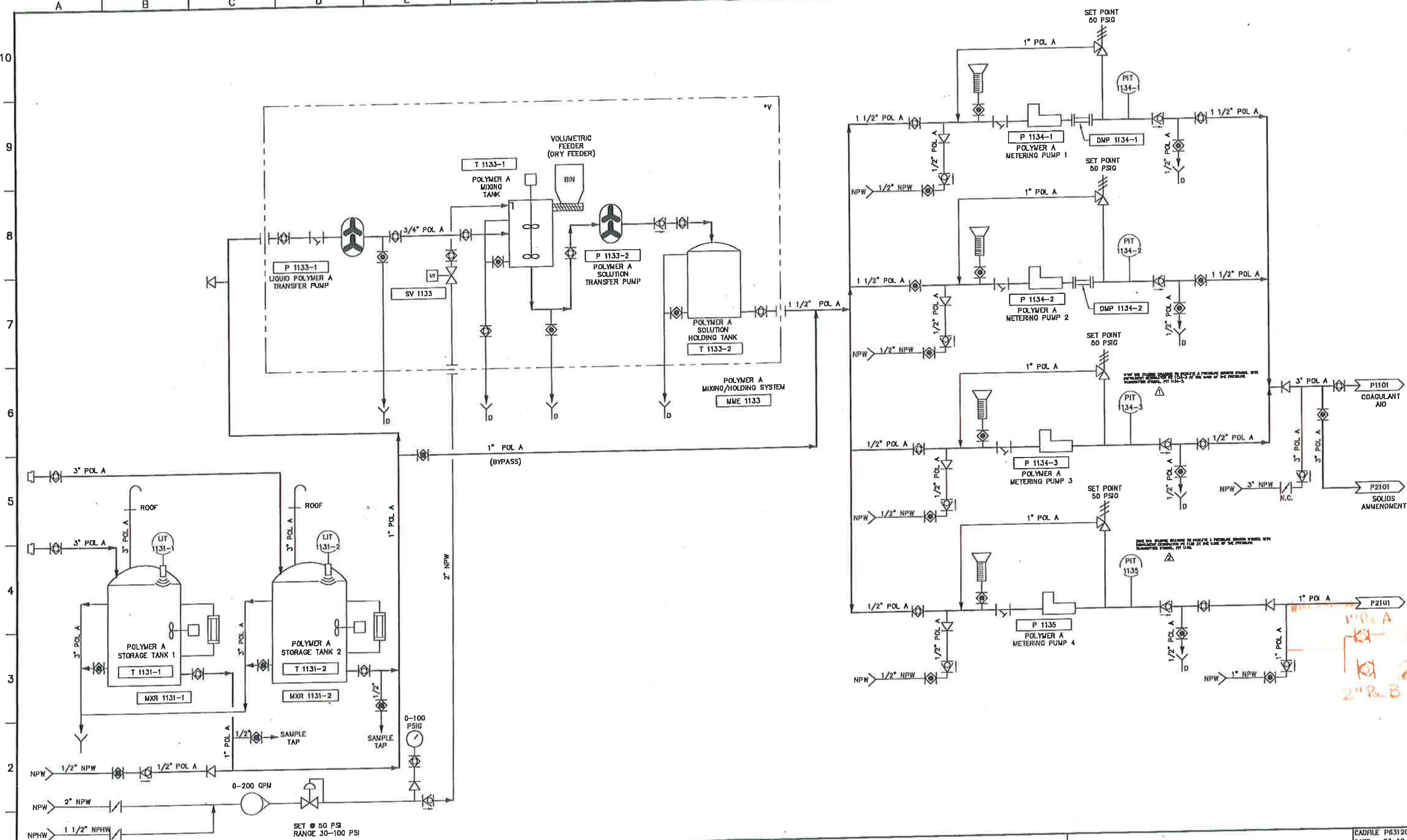
DATE 05-06-99
OPERATOR JChesebro

DRAWING NO. P1205

SHEET NUMBER 47 OF 328



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APPROVED: ______ DATE: ______	DESIGNED BY WAP CHECKED BY RAF CHECKED BY		

REVISIONS

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N4	2	ADDENDUM 3 3.42	SCO	7/99	

CHEYENNE, WYOMING
BOARD OF PUBLIC UTILITIES

R. L. SHERARD WATER TREATMENT PLANT EXPANSION

PROCESS DIAGRAM

POLYMER "A" SYSTEM

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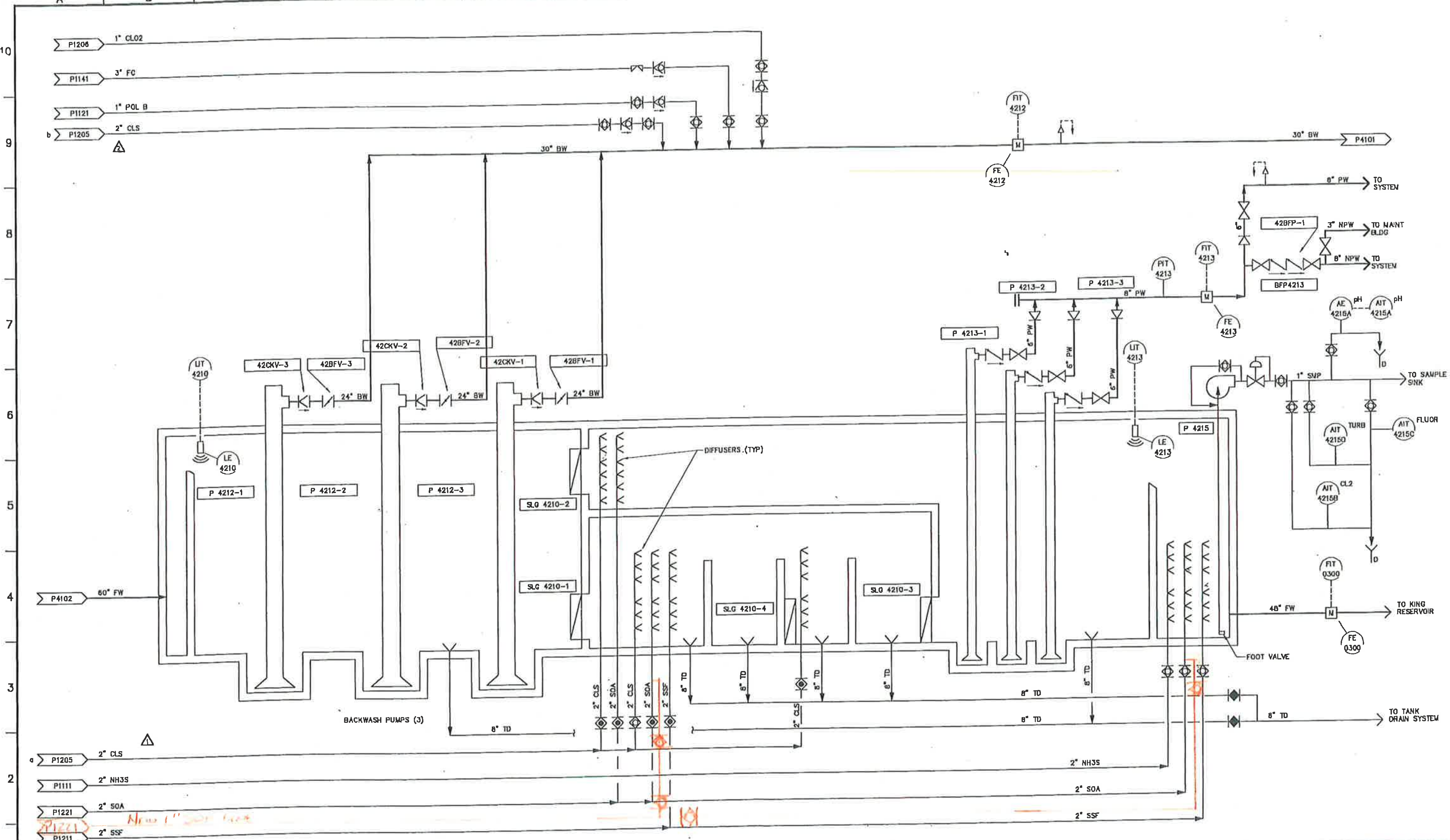
OPERATOR JChesebro

DRAWING NO.
P1131

SHEET NUMBER
43 OF 328



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DENVER, COLORADO

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LINE IS 2 INCHES AT FULL SIZE (IF NOT 2"-SCALE ACCORDINGLY)

FILE 6312
DRAWN BY JPC
DESIGNED BY JEW
CHECKED BY RAF
CHECKED BY

RECORD DRAWINGS

AS BUILT INFORMATION PROVIDED BY DANIS ENVIRONMENTAL INDUSTRIES

REVISIONS

ZONE	REV.	DESCRIPTION	BY	DATE	APP.
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CHEYENNE, WYOMING
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R. L. SHERARD WATER TREATMENT PLANT EXPANSION

PROCESS DIAGRAM

CLEARWELL AND PUMPING SYSTEMS

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DATE 03-10-99
OPERATOR JChesebro

DRAWING NO.
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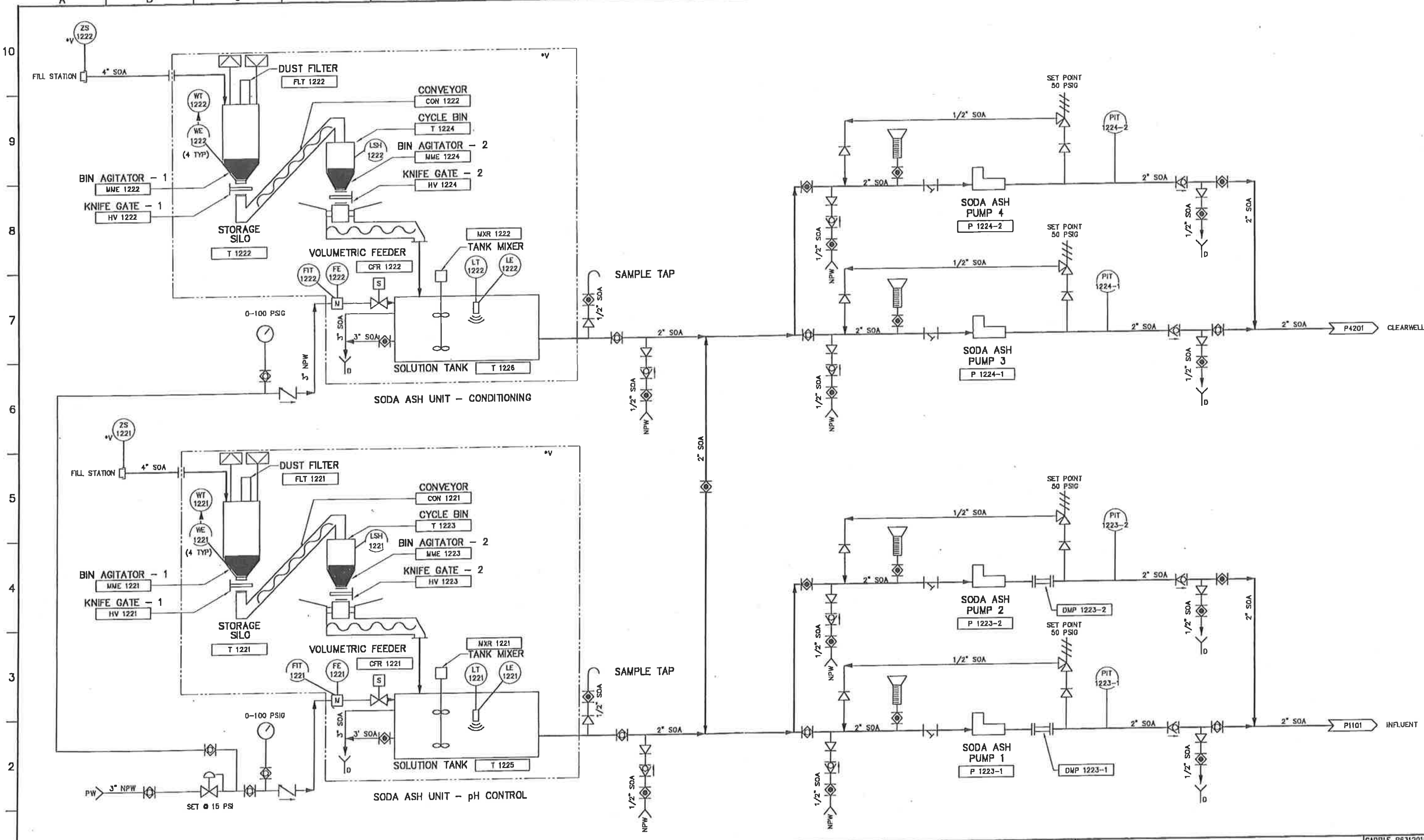
SHEET NUMBER 60 OF 328



BROWN AND CALDWELL
DENVER, COLORADO

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APPROVED: ____________ BROWN AND CALDWELL DATE: ______
APPROVED: ____________ DATE: ______

LINE IS 2 INCHES AT FULL SIZE (IF NOT 2"–SCALE ACCORDINGLY)

FILE 6411
DRAWN BY JPC
DESIGNED BY WAP
CHECKED BY RAF
CHECKED BY

REVISIONS

ZONE	REV.	DESCRIPTION	BY	DATE	APP.

CHEYENNE, WYOMING
BOARD OF PUBLIC UTILITIES

R. L. SHERARD WATER TREATMENT PLANT EXPANSION

PROCESS DIAGRAM

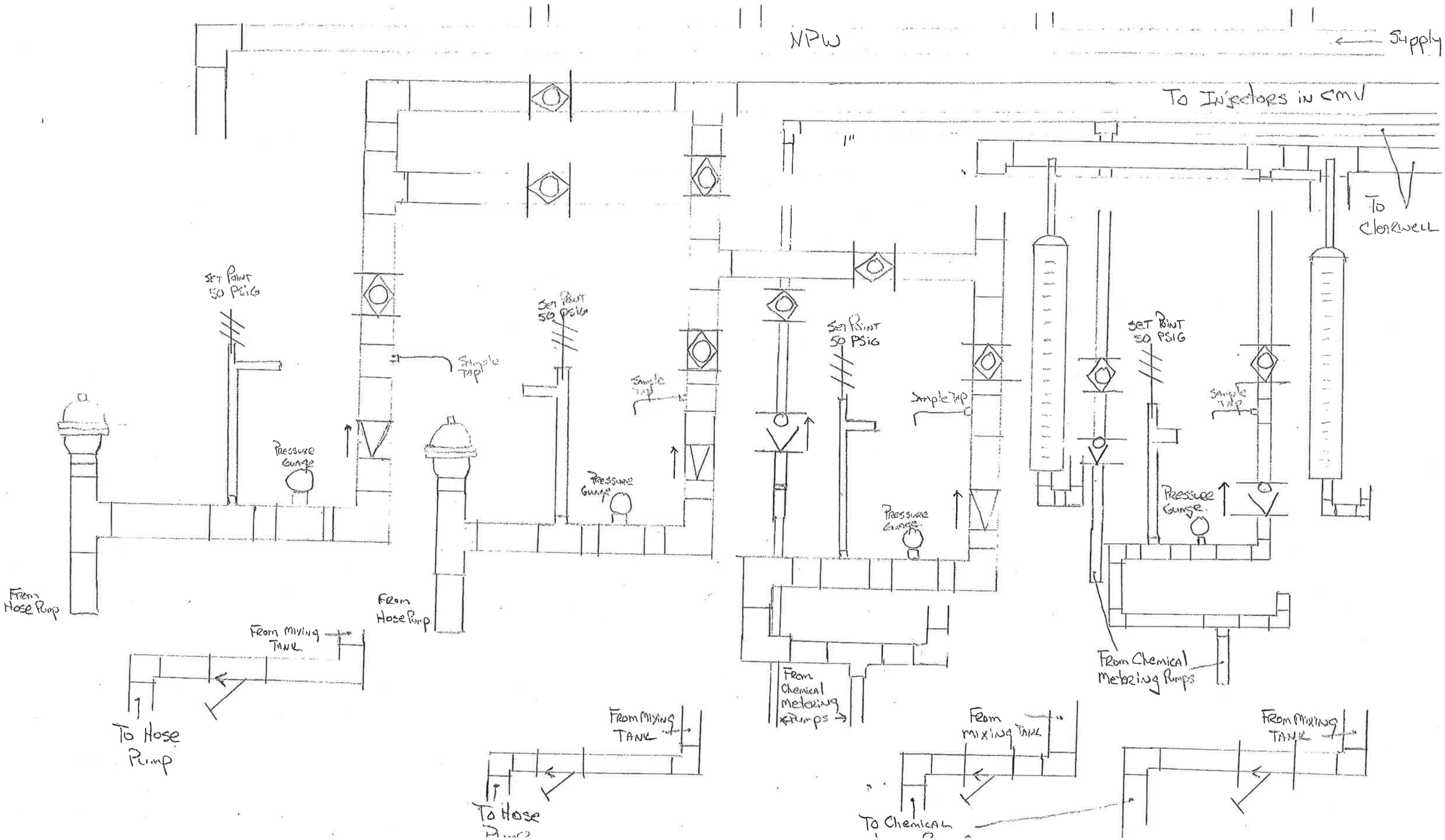
SODA ASH SYSTEM

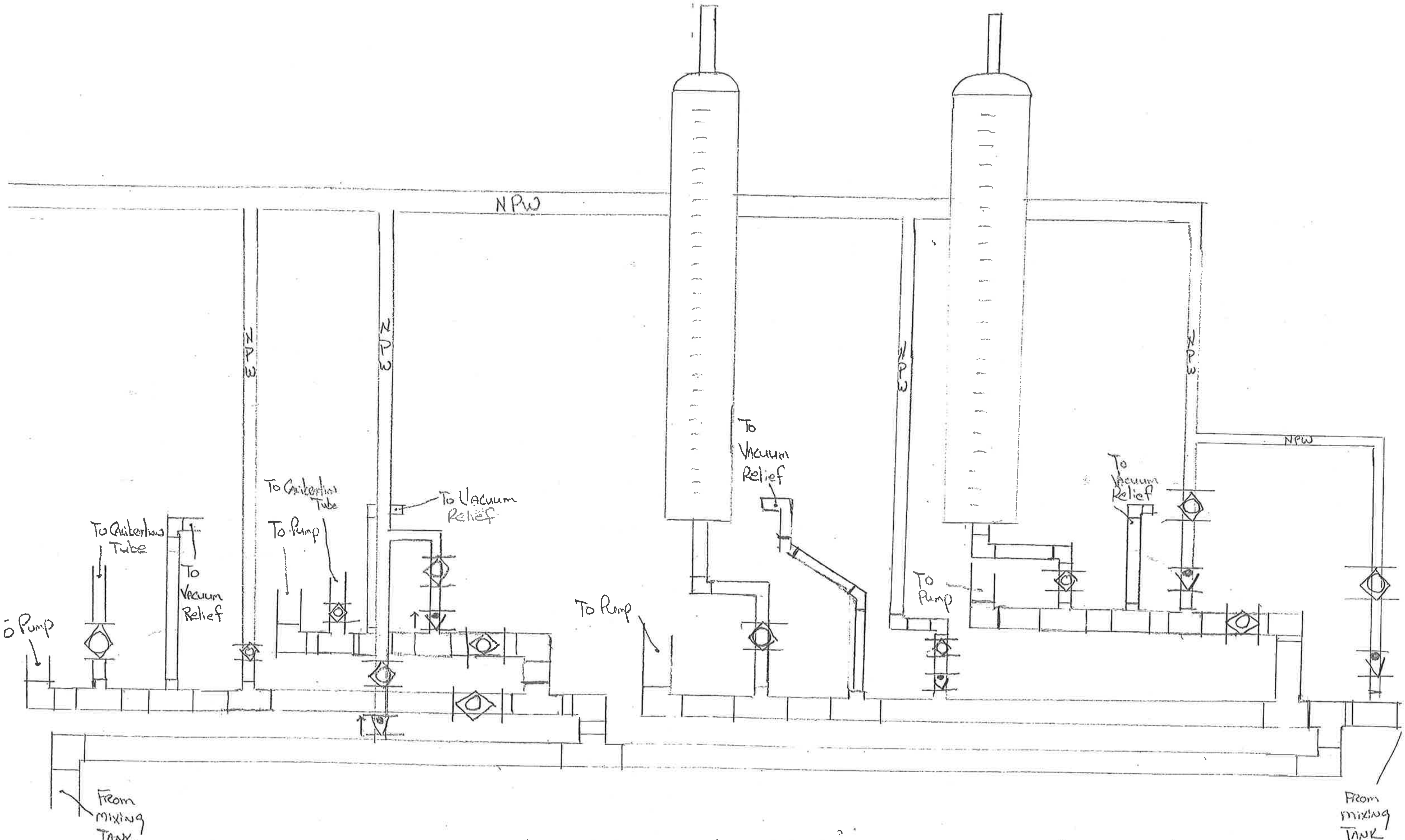
CADFILE P6312018
DATE 03-10-99
OPERATOR JChesebro

DRAWING NO.
P1221

SHEET NUMBER
50 OF 328

Front of Rack Soda Ash System





Back of Rack. Soda ash System

Appendix 4-B
EPA TCP Fact Sheet

EPA
United States
Environmental Protection
Agency

Technical Fact Sheet – 1,2,3-Trichloropropane (TCP)

May 2012

TECHNICAL FACT SHEET – 1,2,3,-TCP

At a Glance

- Colorless to straw-colored liquid.
- Not found in nature – completely man-made.
- Not likely to sorb to soil and has low solubility in water. In the pure form, likely to exist as a dense nonaqueous phase liquid (DNAPL).
- Exposure occurs from industrial settings or hazardous waste sites.
- EPA has classified TCP as "likely to be carcinogenic to humans" and lists an oral reference dose (RfD) of 4×10^{-3} milligrams per kilogram per day (mg/kg-day).
- State of California recognizes TCP as a human carcinogen. Short-term exposure may cause eye and throat irritation; long-term exposure led to kidney failure in mice.
- Federal maximum contaminant level (MCL) not established. State of Hawaii has established a state MCL of 0.6 micrograms per liter.
- Numerous methods are available for detection, including gas chromatography, mass spectroscopy, and liquid-liquid extraction.
- Remediation technologies available to treat TCP contamination in ground water and soil include granular activated carbon (GAC), soil vapor extraction (SVE), and others.

Introduction

This fact sheet, developed by the U.S. Environmental Protection Agency (EPA) Federal Facilities Restoration and Reuse Office (FFRRO), provides a brief summary of the contaminant 1,2,3-trichloropropane (TCP), including physical and chemical properties; environmental and health impacts; existing federal and state guidelines; detection and treatment methods; and sources of additional information.

TCP is a contaminant of interest to the government, private sector, and other parties. It is recognized by the State of California to cause cancer and is a known toxin. The State of Hawaii has established a state maximum contaminant level (MCL) of 0.6 micrograms per liter (µg/L). This fact sheet is intended for use by site managers and other field personnel in addressing TCP contamination at cleanup sites or in drinking water supplies.

What is TCP?

- TCP is a chlorinated hydrocarbon (Stepek 2009).
- Synonyms include allyl trichloride, glycerol trichlorohydrin, and trichlorohydrin (OSHA 2011).
- TCP is exclusively a man-made chemical, typically found at industrial or hazardous waste sites (Dombeck and Borg 2005; TOSC 2004).
- TCP has been used as an industrial solvent, as a cleaning and degreasing agent, and in the production of pesticides (DHHS 2011; TOSC 2004).
- TCP is currently used as a chemical intermediate in the creation of other chemicals (including polysulfone liquid polymers and dichloropropene), and in the synthesis of hexafluoropropylene. In addition, it is used as a crosslinking agent in the creation of polysulfides (DHHS 2011).
- TCP is typically found at industrial or hazardous waste sites.

United States
Environmental Protection Agency

Office of Solid Waste and
Emergency Response (5106P)

EPA 505-F-11-008
May 2012

Exhibit 1: Physical and Chemical Properties of TCP
(ATSDR 1992; DHHS 2011; Dombeck and Borg 2005; IRIS 2009; OSHA 2011)

Property	Value
CAS Number	96-18-4
Physical Description (at room temperature)	Colorless to straw-colored liquid
Molecular weight (g/mol)	147.43
Water solubility (mg/L)	1,750 (slightly soluble)
Boiling point (^{o}C)	156.8
Vapor pressure at 25^{o}C (mm Hg)	3.1
Specific gravity	1.39
Octanol-water partition coefficient (log K_{ow})	1.98 to 2.27 (temperature dependent)
Soil organic carbon-water partition coefficient (log K_{oc})	1.70 to 1.99 (temperature dependent)
Henry's law constant (atm m^3/mol)	3.43 x 10^{-4}

Notes: g/mol – gram per mole; mg/L – milligrams per liter; ^{o}C – degrees Celsius; mm Hg – millimeters of mercury; atm m^3/mol – atmosphere-cubic meters per mole.

What are the environmental impacts of TCP?

- TCP is not likely to sorb to soil based on its low soil organic carbon-water partition coefficient; therefore, is likely to leach from soil into ground water (TOSC 2004).
- TCP will sink to the bottom of a ground water aquifer because its density is heavier than water (TOSC 2004). Therefore, TCP in pure form is likely to exist as DNAPL (Stepek 2009).
- TCP evaporates from surface soil and water (ATSDR 1995).
- When in the atmosphere, TCP is subject to photodegradation, with a half-life of 15 days (ATSDR 1995).
- TCP is unlikely to become concentrated in plants, fish, or other seafood because of its low bioconcentration factor (BCF is about 9.2) (ATSDR 1992, 1995).

What are the health effects of TCP?

- Exposure occurs through vapor inhalation, dermal exposure, or ingestion (DHHS 2011).
- Exposure is most likely to occur near hazardous waste sites where TCP was improperly stored or disposed of, or at locations that manufacture the chemical (ATSDR 1992, 1995).
- EPA has classified TCP as "likely to be carcinogenic to humans" (IRIS 2009).
- The Health Effects Assessment Summary Tables (HEAST) identifies an oral cancer slope factor of 7.0 per milligrams per kilogram per day (mg/kg-day) (EPA OSWER 1997).
- The EPA Integrated Risk Information System (IRIS) lists an oral reference dose (RfD) of 4 x 10^{-3} mg/kg-day and an inhalation reference exposure (RfC) of 3 x 10^{-4} milligram per cubic meter (mg/m^3) (EPA IRIS 2009).
- The oral slope factor for carcinogenic risk is 30 mg/kg/day (IRIS 2009).
- TCP is recognized by the State of California as a human carcinogen (State of California 2007).
- Animal studies have shown that long-term exposure to TCP may cause kidney failure, reduced body weight, and increased incidences of tumors within numerous organs (DHHS 2011; IRIS 2009; Stepek 2009).
- Short-term exposure through inhalation of air with a TCP concentration of 100 milligrams per liter (mg/L) can cause eye and throat irritation (ATSDR 1995) and can affect concentration and muscle coordination (Stepek 2009).

Are there any federal and state guidelines and health standards for TCP?

- No federal MCL has been set for TCP. The State of Hawaii has established a state MCL of 0.6 µg/L (Hawaii Department of Health Administrative Rules 2005).
- The California Department of Public Health (DPH) has established a notification level of 0.005 µg/L for drinking water based on a 1 in 10^{-6} lifetime excess cancer risk and a final public health goal of 0.0007 µg/L (DPH 2006; OEHHA 2009).
- The Occupational Safety and Health Administration (OSHA) has established a permissible exposure limit (PEL) of 50 mg/L (OSHA 2011).
- The National Institute for Occupational Safety and Health (NIOSH) has set a recommended exposure limit (REL) of 10 mg/L (60 mg/m^3) and an immediately dangerous to life and health (IDLH) level of 100 mg/L (DHHS 2011).
- The American Conference of Government Industrial Hygienists (ACGIH) has set a threshold limit value – time-weighted average limit (TLV-TWA) of 10 mg/L (DHHS 2011).

What detection and site characterization methods are available for TCP?

- EPA Method 8260B, based on gas chromatography (GC)/mass spectrometry (MS) for solid matrices (Stepek 2009).
- EPA Method 504.1, based on microextraction and GC, for ground water and drinking water (EPA ORD 1995a; Stepek 2003).
- EPA Method 551.1, based on liquid-liquid extraction and GC with electron-capture detection, for drinking water, water being treated, and raw source water (Stepek 2009; EPA 1990).
- EPA Method 524.2, based on capillary column GC/MS, for surface water, ground water, and drinking water in any stage of water treatment (EPA ORD 1995b; Stepek 2009).
- California DPH method, based on liquid-liquid extraction and GC and purge and trap GC, for trace-level detection in drinking water (DPH 2002a, 2002b).

What technologies are being used to treat TCP?

- Treatment technologies for ground water that are available for remediation of chlorinated hydrocarbons include pump and treat, permeable reactive barriers, in situ oxidation, biodegradation, and dechlorination by hydrogen release compound (Stepek 2009).
- TCP in water can be removed using GAC (Dombeck and Borg 2005; Molnaa 2003).
- TCP in soil may be removed by SVE (TOSC 2004).
- Treatment for TCP in ground water has been successful using ultraviolet (UV) radiation and chemical oxidation with potassium permanganate (Dombeck and Borg 2005; Stepek 2009).
- A laboratory-scale oxidation process (HiPOx) using ozone and hydrogen peroxide has been used for removal of TCP from ground water (Dombeck and Borg 2005).

Where can I find more information about TCP?

- Agency for Toxic Substances and Disease Registry (ATSDR). 1992. “Toxicological Profile for 1,2,3-Trichloropropane.” Atlanta, Georgia: U.S. Department of Health and Human Services, Public Health Service.
- ATSDR. 1995. ToxFAQs - “1,2,3-Trichloropropane.”
- California Department of Public Heath (DPH). 2002a. Determination of 1,2,3-Trichloropropane in Drinking Water by Continuous Liquid-Liquid Extraction and Gas Chromatography/Mass Spectrometry. Available on-line at www.cdph.ca.gov/certlic/drinkingwater/Documents/Drinkingwaterlabs/TCPbyLLE-GCMS.pdf.

Where can I find more information about TCP? (continued)

- DPH. 2002b. Determination of 1,2,3-Trichloropropane in Drinking Water by Purge and Trap Gas Chromatography/Mass Spectrometry. www.cdph.ca.gov/certlic/drinkingwater/Documents/Drinkingwaterlabs/TCPbyPT-GCMS.pdf
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- Stepek, 2009. "Ground Water Information Sheet 1,2,3-Trichloropropane (TCP)." State Water Resources Control Board (SWRCB), Division of Clean Water Programs, Ground Water Special Studies Unit.
- Technical Outreach Services for Communities (TOSC). 2004. "Hazardous Substance Fact Sheet 1,2,3-Trichloropropane (1,2,3-TCP)." Western Region Hazardous Substance Research Center Oregon State University. February. Available on-line at http://tosc.oregonstate.edu/about/news/newsletters/TCP%20FACT%20SHEET_FINAL.pdf.
- U.S. Department of Health and Human Services (DHHS). 2011. "Substance Profiles Report on Carcinogens, Twelfth Edition." Public Health Service, National Toxicology Program.
- U.S. Environmental Protection Agency (EPA). 1990. Method 551.1, Determination of Chlorination Disinfection Byproducts, Chlorinated Solvents, and Halogenated Pesticides/Herbicides in Drinking Water by Liquid-Liquid Extraction and Gas Chromatography with Electron-Capture Detection.
- EPA Integrated Risk Information System (IRIS). 2009. "1,2,3-Trichloropropane (CASRN 96-18-4)." www.epa.gov/iris/subst/0200.htm.
- EPA Office of Research and Development (ORD). 1995a. Method 504.1, 1,2-Dibromoethane (EDB), 1,2-Dibromo-3-chloropropane (DBCP), and 1,2,3-Trichloropropane (123TCP) in Water by Microextraction and Gas Chromatography. National Exposure Research Laboratory.
- EPA ORD. 1995b. Method 524.2, Measurement of Purgeable Organic Compounds in Water by Capillary Column Gas Chromatography/Mass Spectrometry. National Exposure Research Laboratory.
- EPA Office of Solid Waste and Emergency Response (OSWER). 1997. "Health Effects Assessment Summary Tables (HEAST) FY 1997 Update." EPA 540-R-97-036-PB97-921199.

Contact Information

If you have any questions or comments on this fact sheet, please contact: Mary Cooke, FFRRO, by phone at (703) 603-8712 or by email at cooke.maryt@epa.gov.

Appendix 4-C
UCMR3 Contaminant List

List 1: Assessment Monitoring Chemical Contaminants

(Monitored by all systems serving > 10,000 and selected systems serving < 10,000)

Contaminant	Minimum Reporting Level	Sampling Location	Method
1,2,3-trichloropropane	0.03 ug/L	EPTDS	EPA 524.3 (GC/MS)
1,3-butadiene	0.1 ug/L	EPTDS	
chloromethane	0.2 ug/L	EPTDS	
1,1-dichloroethane	0.03 ug/L	EPTDS	
bromomethane	0.2 ug/L	EPTDS	
chlorodifluoromethane (HCFC-22)	0.08 ug/L	EPTDS	
bromochloromethane (Halon 1011)	0.06 ug/L	EPTDS	
1,4-dioxane	0.07 ug/L	EPTDS	EPA 522 (GC/MS)
vanadium	0.7 ug/L	EPTDS and DSMRT	EPA 200.8, ASTM D5673-10, SM3125
molybdenum	1. ug/L	EPTDS and DSMRT	
cobalt	1. ug/L	EPTDS and DSMRT	
strontium	0.3 ug/L	EPTDS and DSMRT	
chromium-6	0.03 ug/L	EPTDS and DSMRT	EPA 218.7
chlorate	20 ug/L	EPTDS and DSMRT	EPA 300.1, ASTM D6581-08, SM 4110D
perfluorooctanesulfonic acid (PFOS)	0.04 ug/L	EPTDS	EPA 537
perfluorooctanoic acid (PFOA)	0.02 ug/L	EPTDS	
perfluorononanoic acid (PFNA)	0.02 ug/L	EPTDS	
perflluorohexanesulfonic acid (PFHxS)	0.03 ug/L	EPTDS	

List 1: Assessment Monitoring Chemical Contaminants (Monitored by all systems serving > 10,000 and selected systems serving < 10,000)			
perfluoroheptanoic acid (PFHpA	0.01 ug/L	EPTDS	
perfluorobutanesulfonic acid (PFBS)	0.09 ug/L	EPTDS	
List 2: Screening Survey (Monitored by systems serving > 100,000)			
Contaminant	**Minimum Reporting Level**	**Sampling Location**	**Method**
17-β-estradiol	0.0004 ug/L	EPTDS	
17-α-ethynylestradiol	0.0009 ug/L	EPTDS	
estriol	0.0008 ug/L	EPTDS	
equilin	0.004 ug/L	EPTDS	
estrone	0.002 ug/L	EPTDS	
testosterone	0.0001 ug/L	EPTDS	
4-androstene-3,17-dione	0.0003 ug/L	EPTDS	EPA 539
List 3: Pre-Screen Testing (Monitored by non-disinfecting ground water systems)			
Microbiological Contaminants			
enteroviruses	NA	EPTDS	NA
noroviruses	NA	EPTDS	NA
Total Chromium Monitoring (Monitored by all systems serving > 10,000 and selected systems serving < 10,000)			
total chromium	0.2 ug/L	EPTDS and DSMRT	EPA 200.8, ASTM D5673-10, SM 3125

Appendix 4-D
Vendor Equipment List and Information for PAC Feed System

"Description of Equipment"

ITEM	QTY	DESCRIPTION
1100	1	Custom Bulk Bag Discharge System • Tubular carbon steel frame with forklift style bulk bag hanging support • Guards, warnings and safety advisories • Control package to include motor contactor, start/stop switch, e-stop button, and jog button housed in a NEMA 12 enclosure.
1101	1	2 ton trolley and hoist, electric with pennant
1105	1	Bulk bag tie box assembly, 304 s/s, vent sock
1110	1	8" manual emergency slide gate assembly
1115	1	Airlock, complete with: • Cast iron housing • Stainless steel beveled rotor • 1 HP-TEFC premium efficiency Baldor motor VEPC3541-4 • gear reducer, chain drive, and OSHA approved guard • Carbon steel transition • Air purge with ASCO solenoid EFHB8320G200MO and fisher regulator/filter 67 series.
1120	1	Gravimetric screw feeder Brabender model FW-80 includes: • flex trough massaged by an external paddle to condition the ingredient to a uniform bulk density, consistently filling the flights of the feed screw • Stainless solid core steel helix and feed screw • AC motor, ½ HP SEW motor and gear reducer WA20DT71D4 460/230/60/3 inverter duty, with 1:12 turndown capability • 5 cubic foot extension hopper, with ports for level indicator
1121	1	Miltronics high level indicator-tuning fork
1122	1	Miltronics low level indicator-tuning fork
1125	1	3" Carbon steel solids conveying eductor; machined from plain carbon steel bar stock, 1 1/2" male NPT Motive, 3" male NPT suction and discharge. • Eductor instrument blow off solenoid, ASCO 3-way • 304 stainless instrument tubing and fittings
1130	1	Model No. 4506 Blower Assembly, complete with: • Positive displacement blower Gardner Denver 4506, (final size determined during engineering)

- 25 HP-TEFC Baldor motor ECP82334T-4 premium effecency
- Common motor and blower base
- V-belt drive and OSHA guard
- Inlet and outlet silencers Universal model UB
- Intake filter, with Dwyer 1950-20 pressure switch
- Outlet check valve, Kunkle 337 pressure relief valve, Aschoft pressure gauge and Assembled and painted manufacturer's standard
- Lot of convey piping within silo skirt consisting of the following:
- Flexible hose connection from blower to eductor

ELECTRICAL CONTROLS

ITEM	QTY	DESCRIPTION
xxxx	1	Primary Control Panel

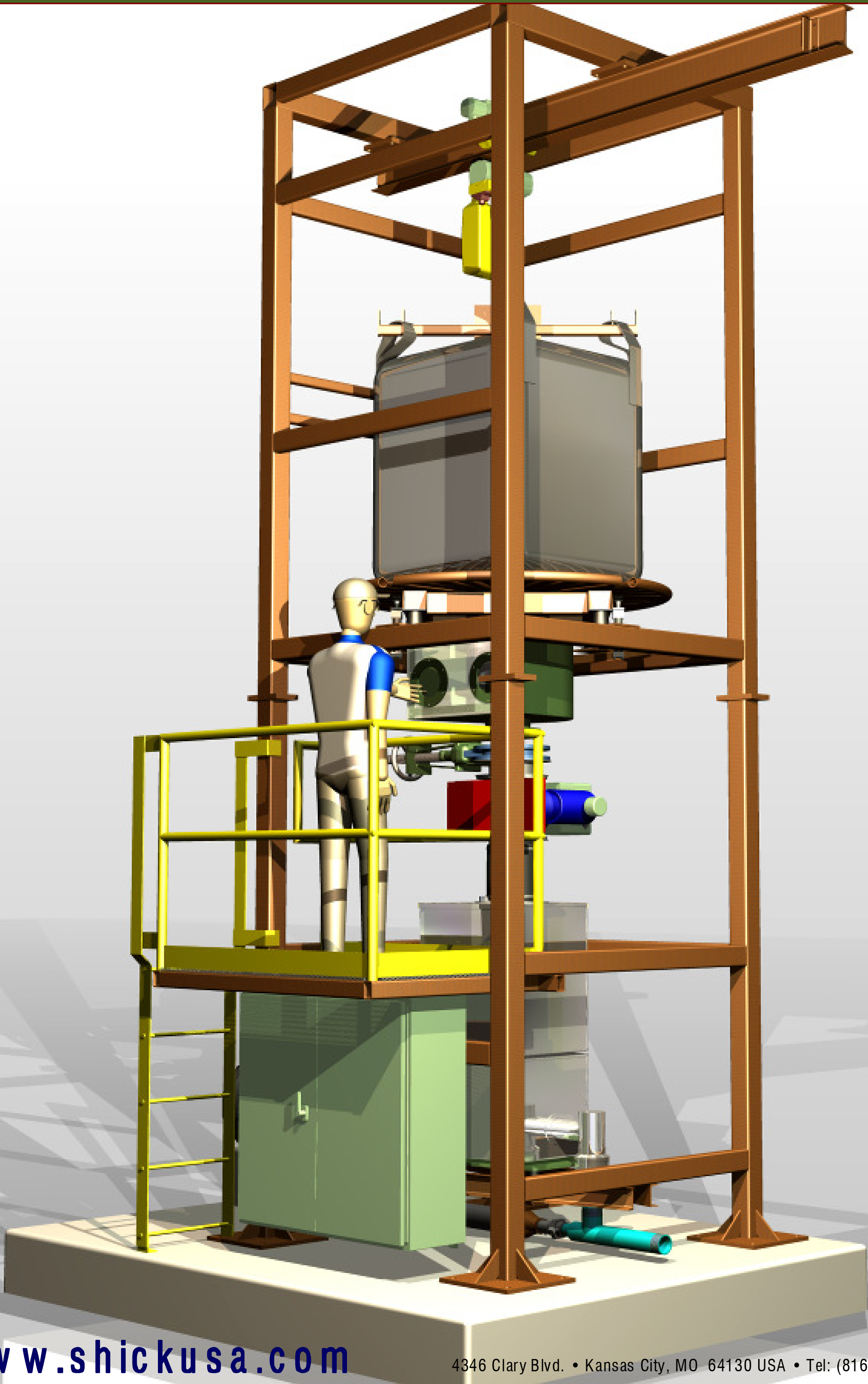
- Hoffman NEMA 4X, stainless steel enclosure, wall mount
- 460 volt circuit breaker with disconnect
- 460/115 Volt control transformer
- Allen-Bradley IEC-rated motor starters for FVNR motors control
- Allen-Bradley PowerFlex 40 Variable Frequency Drive (0.5 HP)
    - Analog speed reference and feedback
- Allen-Bradley 1769-L23E-QBFC1B PLC with embedded digital and analog I/O
    - Includes on-board Ethernet
- Hardy Instruments CompactLogix Feeder Control Module (1769-FC)
- Allen-Bradley PanelView Plus 6 700, color, touch, Ethernet
- Islatrol power conditioner for PLC power
- Allen-Bradley master control relay
- N-Tron 4 port Ethernet switch
- Allen Bradley 120VAC control relays
- 120 VAC supplemental circuit breakers
- Door mounted programming port with convenience receptacle

	1	Lot of Electrical Controls Engineering

- Electrical Hardware Engineering and Documentation
- Electrical Schematics
- Electrical Panel Fabrication
- PLC Programming
- PanelView Programming

MULTI-POLLUTANT SORBENT INJECTION

Hg, SO_2, SO_3, HCl



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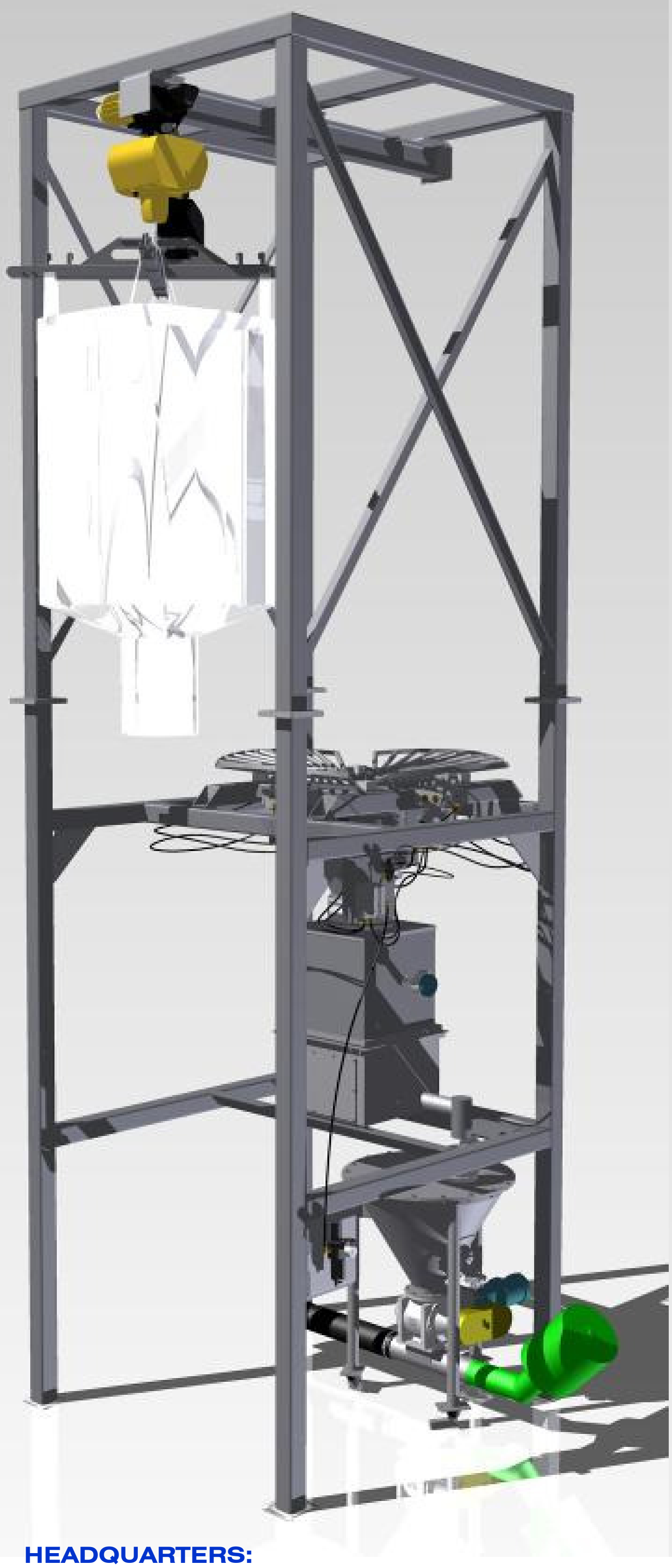
PACRACK - INTEGRATED SOLUTIONS



FEATURES:

- OPTIONAL ELECTRIC TROLLEY AND HOIST
- MODULAR BULK BAG SUPPORT FRAME
- SORBENT BULK BAG AREA (FITS ANY BULK BAG SIZE)
- PNEUMATIC BULK BAG MASSAGER SERVES TO SUPPORT THE BAG WHILE BREAKING UP PRODUCT IN THE BULK SACK BY ADJUSTING THE HOPPER FROM 15° TO 45°
- GRAVIMETRIC FEEDER
- MOTOR DISCONNECTS & JUNCTION BOXES
- BAG MASSAGER CONTROL
- EDUCTOR OR ROTARY VALVE FEED
- INCLUDES MOTIVE BLOWER

BENEFITS:

- SHICK FOUNDED IN 1956
- PRE-WIRED, PRE-PIPED, AND PRE-TESTED
- SHIPS IN 2 PIECES
- CAN BE CONFIGURED FOR DRY BULK OR SLURRY DELIVERY
- MINIMAL FIELD ERECTION AND STARTUP
- COMPLETE FAT BEFORE SHIPMENT
- INNOVATIVE FEEDER CONTROL

The modular frame is adaptable for any combination of equipment below the bulk bag. Whether the application is a dry transfer system or a slurry system the PacRack can be configured to match your process needs.

HEADQUARTERS:
ShickUSA
4346 Clary Blvd.
Kansas City MO 64130
(816) 861-7224
www.ShickUSA.com

ShickAP
Blk 5000 Ang Mo Koi Ave 5
#05-07 Techplace II
Singapore 569870
Tel: (65) 64824600

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Appendix 4-E
NPV Analysis and Cost Estimate Comparison for Ozone and PAC

NPV Calculation for Ozone vs PAC
Cheyenne MP - Volume 4
Prepared By: Caitlin Kodweis 07/24/2013

Ozone				**PAC**				*Conversion Values*		
Capital Costs:		0		PAC Feed System Cost	$	514,000.00		1 mg =	2E-06	lb
System Operation		16	weeks	System Operation		4	weeks	1 gal =	3.7854	L
Avg. Plant Flow Rate		159.05	MG/week	Avg. Plant Flow Rate		159.05	MG/week	1 gal LOX =	9.52	lb
Ozone Dose		2	mg/L	PAC Dose		4	mg/L	$(P/A_{3\%,5yr})$=	4.5797	
LOX Cost	$	0.43	/gal	PAC Cost	$	1.17	/lb	$(P/A_{3\%,10yr})$=	8.5302	
Manhours/week		10.5	hrs/week	Manhours/week		2	hrs/week	$(P/A_{3\%,20yr})$=	14.878	
Labor rate	$	15.00	/hr	Labor rate	$	15.00	/hr	$(P/A_{3\%,50yr})$=	25.730	
Power Usage		3460	kW*hr/day							
Power Cost	$	0.052	/kW-hr							
LOX to O3 efficiency		0.12								

Yearly Oxygen Cost	$	15,987.52	Yearly PAC Cost	$	24,847.73
Yearly Labor Cost	$	2,520.00	Yearly Labor Cost	$	120.00
Yearly Power Cost	$	19,980.53	Yearly Power Cost	$	32.48
Total Yearly O&M	$	38,488.05	Total Yearly O&M	$	25,000.21

5-yr NPV Analysis

NPV (2013 dollars) = Capital Cost + (Cost Ozone/yr + Labor cost/year + power usage/year)(P/A $_{3\%,5yr}$)*

5-yr Ozone Cost:	$	176,263.74	5-yr PAC Cost:	$	628,493.48
			5-yr PAC Cost O&M:	$	114,493.48

10-yr NPV Analysis

NPV (2013 dollars) = Capital Cost + (Cost Ozone/yr + Labor cost/year + power usage/year)(P/A $_{3\%,10yr}$)*

10-yr Ozone Cost:	$	328,310.80	10-yr PAC Cost:	$	727,256.82
			10-yr PAC Cost O&M:	$	213,256.82

20-yr NPV Analysis

NPV (2013 dollars) = Capital Cost + (Cost Ozone/yr + Labor cost/year + power usage/year)(P/A $_{3\%,20yr}$)*

20-yr Ozone Cost:	$	588,593.54	20-yr PAC Cost:	$	885,940.67
			20-yr PAC Cost O&M:	$	371,940.67

50-yr NPV Analysis

NPV (2013 dollars) = Capital Cost + (Cost Ozone/yr + Labor cost/year + power usage/year)(P/A $_{3\%,50yr}$)*

50-yr Ozone Cost:	$	990,289.93	50-yr PAC Cost:	$	1,157,250.49
			50-yr PAC Cost O&M:	$	643,250.49