SECTION 5

Treatment Process Selection

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Introduction

Building on work from the May 2007 *Lebanon Water System Master Plan*, city staff and CH2M HILL engaged in a four-pronged approach to identify and evaluate suitable treatment processes for a new water treatment plant (WTP). Activities included the following:

- Workshops to identify evaluation criteria, review existing and possible future regulatory requirements, and identify appropriate treatment processes
- Site visits to representative water treatment facilities
- Laboratory analyses to confirm the effectiveness of in-line coagulation in reducing disinfection byproduct (DBP) precursors for the membrane filtration treatment option
- External review of process selection methodology and water quality data by three independent water industry professionals

Following an analysis and comparison of a wide range of treatment options, two process alternatives were identified for detailed capital and life cycle cost analysis using CH2M HILL's proprietary water treatment plant facility sizing and cost estimation software (CPES).

Evaluation Criteria

All identified treatment alternatives were expected to provide finished water quality in compliance with all current and proposed regulatory requirements and meeting the aesthetic goals of producing water with acceptable taste and odor characteristics. Therefore, finished water quality was not used as an evaluation criterion. The following four criteria for comparing treatment alternatives were identified and prioritized:

- **Operations and maintenance**: requirements for energy use; number, type, and amounts of chemicals needed; level of operator attention; materials and equipment replacement needs such as for membrane modules; and the intensity and complexity of equipment operation and maintenance.
- **Expandability**: ability of the process to be phased with an initial capacity of at least 6 mgd and an ultimate capacity of 14 mgd. Processes that can be expanded more rapidly, in smaller-capacity increments (for example 2-mgd increments) were rated more highly.
- **Raw water quality robustness**: ability of process to handle rapid changes in raw water quality. These changes have been observed periodically in the South Santiam River

during storm events or resulting from reservoir operations or turnover events in the upstream Corps of Engineers' reservoirs.

- **Flexibility**: ability of the process to adapt to or be modified to achieve the potential treatment goals presented by future regulations (for example reduction in turbidity levels, pharmaceutical concentrations, etc.).

Exhibit 5-1 presents the ranking and weighting of these criteria, as developed jointly by the City of Lebanon-CH2M HILL team for this project. Operations and maintenance considerations were ranked as most important, followed in order by the robustness of the process to handle changes in raw water quality, the ability to modify the process to handle potential future regulatory requirements, and the ease of expanding treatment capacity.

EXHIBIT 5-1
Lebanon Treatment Process Criteria Weighting (Pair-Wise Comparison)
City of Lebanon Water Improvement
Lebanon, OR

Criteria[1]	O&M Requirements	Expandability	RW Robustness	Flexible Process	Weighting	Rank
O&M requirements		5	5	4	14	1
Expandability	1		2	3	6	4
RW robustness	1	4		4	9	2
Flexible process	2	3	2		7	3

[1] Finished water quality (not included because all alternatives will provide high FW quality)
5 = much more important than
4 = more important than
3 = equal to
2 = less important than
1 = much less important than

Design Capacities

Based on findings from the 2007 *Lebanon Water Master Plan*, and as decided early in this project by the City of Lebanon, the conceptual design for the WTP shall be based on the following production capacities:

- Initial construction: 6 mgd
- Ultimate: 14 mgd

The 6-mgd capacity represents a 50 percent increase over the existing WTP's 4-mgd capacity. Demand projections indicate that at the current ratio of industrial to residential water consumption, a 6-mgd WTP would serve the community until approximately 2040. Therefore, the 6 mgd capacity could accommodate a sudden step-increase in water demand if a new industry, requiring a relatively large quantity of potable water, were to locate in the city in the near future. Lebanon staff indicated that a priority was for that the new plant allow for rapid and easy expansions to accommodate possible future industrial customers.

The ultimate 14-mgd capacity represents projected buildout demands within the city, according to the 2007 *Lebanon Water Master Plan*. As noted in Exhibit 4-8 of the master plan, the 14 mgd assumes full use of the land within the city's urban growth boundary. The 14 mgd ultimate capacity is slightly more than the city's certificated water rights of 12.3 mgd but less than the total of the city's permitted and certificated rights, which is 23.9 mgd.

Raw and Finished Water Quality

Lebanon's new WTP will be supplied with water from either the South Santiam River or the Santiam Canal. The Santiam Canal is fed by the South Santiam River approximately 2 miles upstream from city limits.

The two sources have nearly identical water quality. Turbidity in the canal is slightly lower than the river because water velocities in the canal are lower allowing some settling of particles that contribute to turbidity.

As documented in the 2007 *Lebanon Water Master Plan*, the canal is considered to be more susceptible than the river to contamination events from spills and non-point source storm runoff. Quantifying this risk is difficult. In this study, based on past experience, city staff did not consider the risk of possible contamination to be significant enough to justify a river intake at a higher cost.

Raw water quality data for the canal and river were obtained from four sources: 1) the city's records for the existing WTP operations; 2) the membrane filtration pilot testing program conducted by CH2M HILL for the City of Albany in February through May 2003; 3) United States Geological Survey (USGS) on-line data; and 4) bench-scale testing that was performed as a part of the current project. These data are summarized in the following paragraphs according to the parameters that were measured.

Finished water quality data from the city's existing WTP, including chlorine residuals, TOC, and DBPs also are presented.

Turbidity

Records from the city's existing WTP indicate that the average turbidity in the canal from January 1, 2006, through January 31, 2009, was 4.8 ntu. Turbidity ranged from a low of 0.6 ntu to a high of 59 ntu during this period. The 95th percentile for all readings (the value at which 95 percent of the data were equal to or less than) was 13 ntu. The average turbidity during the summer months (May through September) for this period was 2.5 ntu. The 95th percentile for the summer months was 4.5 ntu.

Raw water turbidity in the Santiam Canal at the location of the city's existing WTP was monitored during the membrane pilot testing that was performed for the City of Albany in 2003. From February 7, 2003, to May 15, 2003, the turbidity averaged 8.9 ntu, and ranged from a minimum of 1.8 ntu to a maximum of 41.1 ntu. The 95th percentile was 20.2 ntu.

South Santiam River turbidity records were obtained from the USGS for 2001-2002 from their station at Waterloo (USGS 14187500), which is approximately 2 miles upstream from Santiam Canal diversion on the river. The 95th percentile turbidity by month ranged from a low of 1.8 ntu in August to a high of 38 ntu in February. The months of May through

September had 95th percentile turbidity value of less than 5 ntu. March, April, October, and November had 95th percentile turbidity values between 5 and 20 ntu. January, February, and December had 95th percentile turbidity values between 20 and 40 ntu.

Temperature

Santiam Canal temperature data were collected during the Albany pilot testing program. The average temperature for the period February 7, 2003, through May 15, 2003, was 9.8 degrees C. The range was 5.8 degrees C to 12.6 degrees C.

The USGS have collected temperature measurements at the Waterloo station on the South Santiam River from 1978 through 2002. Monthly records have been recorded for about 50 percent of the months during this period. The averages for all readings have ranged from a low of 6.1 degrees C for January to a high of 15.2 degrees C in August. The months of November through April had average temperatures of less than 10 degrees C.

Total Organic Carbon

Operators of the Lebanon WTP monitored raw and finished water total organic carbon (TOC) at the canal intake monthly during 2007 and quarterly during 2008. The average raw water TOC for these 16 readings was 1.0 mg/L. The raw water TOC ranged from 0.7 to 1.3 mg/L. The average reduction in TOC through the existing WTP was approximately 50 percent, with a range of 30 to 70 percent.

Measurements of the canal TOC at the existing WTP intake were made approximately twice-weekly during the Albany pilot testing that was conducted from February 2003 to May 2003. The average of these measurements was 1.37 mg/L and the range was 0.85 to 1.96 mg/L.

Chlorine Demand

The operators of the Lebanon WTP do not routinely monitor chlorine demand and therefore, no data were available from the existing operations. Chlorine demand was measured during the Albany pilot testing, and following completion of the Albany-Millersburg WTP, CH2M HILL developed a correlation between chlorine demand and disinfection by-product formation based on full-scale operating data. The filtered (using membranes) water chlorine demand during the Albany pilot testing averaged 1.06 mg/L after 24 hours. This was found to correlate with a total trihalomethane (TTHM) formation of 54 μg/L and a haloacetic acid 5 (HAA5) level of 61 μg/L. The TTHM value is below the TTHM standard of 80 μg/L but the HAA5 value exceeds the HAA5 standard of 60 μg/L. This indicates that membrane filtration alone, without using a coagulant for organics removal, may not produce water that complies with current standards.

Chlorine Residual

Chlorine residual data were obtained from the city's records for July 2004 through October 2005, and December 2005 through November 2008. During these periods, the average distribution system free chlorine residual was 0.80 mg/L. The range was 0.12 mg/L to 1.9 mg/L. The 95th percentile value was 1.06 mg/L. The city has not experienced problems with maintaining a chlorine residual throughout the system.

Disinfection Byproducts

Disinfection byproducts (DBP) data for the city's existing system were available for 2003-2008. The city monitored DBP levels quarterly from four sample locations in 2003, 2004, and 2005, and then from one site only (considered the worst-case location) in 2007 and 2008. Total trihalomethanes (TTHMs) averaged 20 μg/L during this period, compared to the standard of 80 μg/L. The range was from 12 to 36 μg/L. The five regulated haloacetic acids (HAA5) average was 15 μg/L for this period, compared to the standard of 60 μg/L. The range was from 5 to 33 μg/L.

Regulatory Considerations

The following current and proposed water treatment and distribution system regulations were considered in developing treatment process alternatives:

Maximum Contaminant Levels for Organics and Inorganics

Between 1992 and 2000, regulated organics were detected four times and mercury was detected once. All occurrences were below the MCL for the contaminants. No organics or inorganics have been detected since 2000.

Although not currently regulated, trace contaminants detected in some water supplies have been identified as "compounds of emerging concern." These include pharmaceuticals, endocrine disrupters, personal care products, and a product of some wastewater and water treatment processes, N-Nitrosodimethylamine (NDMA). More research is required to determine the effect of the extremely low concentrations that have been detected, but there is a possibility that these compounds may be regulated in the future. Although not effective for NDMA or some other contaminants, ozonation is the treatment method of choice for the removal of a large range of these compounds. Detections of these compounds of emerging concern are not anticipated because Lebanon's source water does not have a large number of municipal wastewater discharges upstream of the point of diversion. However, CH2M HILL and Lebanon staff agreed that any treatment process should allow for future addition of ozone.

Ozone oxidizes large molecular weight organic compounds and converts them to smaller, readily biodegradable compounds also known as assimilable organic carbon (AOC). Increased concentrations of AOC in the finished water could increase the growth of biofilms within the distribution system. Therefore, the recommended approach is to install biological filtration (biologically activated carbon or BAC filtration) downstream of the ozone addition point. In addition, best management practices, including a flushing program and chlorine residual management throughout the distribution system, must be followed to prepare the distribution system before an ozone system comes on-line.

Total Coliform Rule

The city had several TCR violations between January 2002 and October 2004. No cause was identified, and no violations have occurred since. All proposed treatment alternatives provide excellent removal of microbial contaminants, and adequate disinfection. Membrane filtration options provide the most fail-safe alternative for removal of bacteria because they act as a positive barrier for many types of organisms that is not dependent on filter operation and backwash cycles.

Maintaining stable disinfectant residual concentrations and stable finished water pH are important to help reduce biofilm containing scale and sediment buildup and sloughing within the distribution system. All treatment options use a coagulant to reduce disinfectant demand, and have automatic finished water pH monitoring and control.

Lead and Copper Rule

The action level for lead was exceeded in 2002, 2003, and 2004. The city remedied the problem by increasing the pH of the finished water by adding sodium hydroxide (caustic). Although the city has achieved compliance using caustic, because of the city's history of recently exceeding the lead action level and a similar experience at the Albany-Millersburg WTP (which also uses the South Santiam River as its source), the CH2M HILL team recommend that soda ash be used for pH and alkalinity adjustment for all treatment options. Soda ash provides both pH control and carbonate alkalinity to buffer the pH within the distribution system. It provides more reliable compliance with the Lead and Copper Rule and is a safer chemical to handle than caustic. Lebanon may find that setting an alkalinity target, rather than a pH target, provides a better level of confidence in achieving compliance with the Lead and Copper Rule.

Using common water quality software (WaterPro), the chemical and water quality conditions for the two processes under consideration were modeled to determine the anticipated dose of soda ash. **Exhibit 5-2** provides a summary of the raw and finished water quality and the chemical feed conditions. For the conventional filtration plant, to achieve at least 25 mg/L of alkalinity requires a soda ash dose of approximately 21 mg/L. For the membrane filtration plant, the required soda ash dose is approximately 9 mg/L. The membrane filtration option requires less soda ash because less alum is needed for coagulation; alum consumes alkalinity in the coagulation reaction. In both examples, the finished water pH was increased to 7.5 units. The finished water alkalinity levels were adjusted to 35 mg/L as CaCO3 for the conventional filtration alternative and to 30 mg/L as CaCO3 for the membrane filtration alternative. Whether these values are sufficient or higher pH or alkalinity values are necessary to control lead and copper is unknown and should be closely examined during full scale operations. As noted previously, an alkalinity target rather than pH target may be preferable for operational control.

An alternative coagulant such as polyaluminum chloride or aluminum chlorohydrate consumes less alkalinity. If one of these coagulants were used instead of alum, soda ash requirements would be lower for both process alternatives. Conversely, a change from alum (aluminum sulfate) to polyaluminum chloride or aluminum chlorohydrate results in a change (lowering) of the sulfate-to-chloride ratio, which may negatively impact lead levels. A recently published article indicated that a decrease in the sulfate to chloride ratio may result in higher customer tap lead levels.[1] This topic is being further examined in an American Water Works Research Association study that is scheduled for completion in

[1] Edwards and Triantafyllidou, "Chloride to Sulfate Mass Ratio and Lead Leaching to Water," Journal American Water Works Association, July 2007.

2009.[2] As a minimum, the findings indicate that a change in coagulants must be carefully examined and implemented to avoid unintended consequences on distribution system lead levels. A period of increased monitoring for lead and copper should follow a change in coagulant type. Operators should maintain the flexibility of adjusting pH, reverting to alum, or adding a phosphate inhibitor if necessary.

EXHIBIT 5-2
Raw Water Characteristics and Theoretical Chemical Dosing to Achieve Finished Water pH of 7.5 and Alkalinity of at Least 25 mg/L as $CaCO_3$
City of Lebanon Water Improvement
Lebanon, OR

Parameter	Conventional Filtration Alternative	Membrane Filtration Alternative
Raw Water Characteristics		
Total dissolved solids (mg/L)	100	100
Temperature (C)	9	9
pH	7.53	7.53
Alkalinity (mg/L as CaCO3)	25	25
Calcium (mg/L)	10	10
Theoretical Chemical Additions		
Alum dose (mg/L)	16	4
Chlorine dose (mg/L)	2.0	2.0
Fluoride dose (mg/L)	1.0	1.0
Soda ash dose (mg/L)	21	9
Finished Water Characteristics		
pH	7.5	7.5
Alkalinity (mg/L as CaCO3)	35	30

Long-Term 2 Enhanced Surface Water Treatment Rule

After 6 months (two rounds) of source water monitoring, no *Cryptosporidium* have been detected in samples from the city's existing source on the Santiam Canal. It appears that the city's canal source will be classified as Bin 1 for compliance with the LT2ESWTR, although this cannot be known with certainty until further monitoring is accomplished. If the water is classified as Bin 1, this means that the city will not need to provide additional treatment steps specifically to address concerns about *Cryptosporidium*.

[2] Evaluation of the Effect of Changing Coagulants on Lead Release from Leaded Plumbing Materials, AwwaRF project 4088.

Microbial and Disinfection Byproducts Rule

The city has been in compliance with the microbial and disinfection byproducts (DBPs) rules to date. However, the new Stage 2 DBP rule requires utilities to select the worst-case locations for sampling and will no longer allow system-wide averaging of DBP concentrations. The Albany-Millersburg immersed membrane WTP, which also draws water from the South Santiam River, periodically has experienced elevated DBP concentrations. In-line addition of relatively low concentrations of a coagulant has provided sufficiently-enhanced organics removal to lower DBP concentrations to acceptable levels. Conventional media filtration alternatives always include coagulation as a core part of the process and, if chlorine is added downstream of the filters, should provide acceptable control of DBPs. Based on the experience of the Albany-Millersburg WTP, and the results of pilot-scale laboratory tests, all membrane filtration options will include provisions for coagulation of organics.

National Pollutant Discharge Elimination System (NPDES)

Lebanon holds an NPDES permit for discharge of settling pond supernatant to the Santiam Canal and anticipates that a similar permit can be obtained for the new WTP. Future federal requirements (Environmental Protection Agency *Potential Drinking Water Treatment Guidelines)*, or state requirements related to pollutant discharges or water conservation, may require the supernatant to be recycled to the head of the WTP. Recent requirements related to discharge temperature may also impact the plant's ability to discharge directly to the canal or river. Recycle of the waste flow was not included in the process alternatives in accordance with the city's preference. If future rules are more stringent with respect to discharge quality, then the city can provide treatment of this discharge flow stream or implement recycle. The most likely treatment process for a recycle flow is ultraviolet light (UV) disinfection to reduce the risk of recycling pathogens. For the membrane filtration alternative, an additional membrane rack may be installed that is dedicated to recycle of the waste flow.

Summary of Regulatory Impacts and Their Treatment Implications

In summary the water quality drivers and corresponding treatment solutions include the following:

- Surface Water Treatment and Turbidity Regulations—Either conventional media or membrane filtration will achieve compliance with turbidity and particle removal regulations. Additional treatment steps do not appear to be needed to address *Cryptosporidium* but that conclusion remains uncertain until the city completes further source water analyses.
- Lead and Copper Rule—Soda ash is recommended to ensure compliance with lead corrosion in Lebanon's system
- Disinfection Byproducts Rule—Either conventional media filtration with post-filtration disinfection or in-line coagulation/membrane filtration with post-filtration disinfection are expected to achieve compliance with the more stringent, new DBP rule. The city's existing conventional media filtration plant has successfully controlled DBPs. The

Albany-Millersburg WTP, using a very similar source water and a membrane process with in-line coagulation, has successfully controlled DBPs.

- Coagulant—The process facility sizing (chemical facilities, solids handling) and capital costs for alternatives were developed assuming that alum would be used because other coagulants will generally require a lower dose. In actual practice, it may be found that alternative coagulants (aluminum chlorohydrate, polyaluminum chloride) provide improved treatment or provide other advantages such as lower required dosages.
- Disinfection—Chlorine is suitable for primary and secondary disinfection provided that the primary feed point is located downstream of filtration.
- Backwash Waste and Solids Handling—Solids lagoons with supernatant discharge to the canal are planned. This assumes that an NPDES permit can be obtained for the discharge. Obtaining a permit is less certain than in past years.

In addition, all process alternatives included space for future ozone addition to address future regulation of contaminants of emerging concern, possible taste and odor issues, or to provide additional disinfection credit.

Bench-Scale Laboratory Test to Determine DBP Control

The Albany-Millersburg WTP, which treats water from the South Santiam River that is withdrawn just a few miles downstream of the Santiam Canal diversion, has successfully controlled DBP levels using coagulation followed by immersed membranes. A similar process consisting of in-line coagulation with a 1-2 minute coagulation time, followed by pressure membranes is expected to be successful for Lebanon's new WTP.

A bench-scale test was conducted to confirm the effect of coagulant addition prior to pressure membrane filtration on the chlorine demand and ultraviolet (UV) light absorbance of the treated water. Chlorine demand has been used successfully by Albany-Millersburg as a surrogate parameter for DBP precursor concentration and UV absorbance at a wavelength of 254 nanometers is another commonly used surrogate parameter.

In-line coagulant addition was simulated using a series of continuously-stirred, small beakers containing raw water. Alum was added to the first beaker and allowed to disperse for 20 seconds before the beaker's contents were pumped through the membrane. This process was repeated with subsequent beakers in series until a sufficient sample size was collected for the chlorine demand test. Using this technique, coagulation time was limited, and ranged from 20 to 80 seconds. Alum doses of 2 mg/L and 5 mg/L were used to provide a comparison with a non-coagulated, control sample. All samples received an initial dose of 2 mg/L of free chlorine.

Results from the bench scale experiment are shown in **Exhibits 5-3 through 5-5**. An alum dose of 5 mg/L and a contact time less than two minutes resulted in a 40 percent reduction in chlorine demand after 24 hours compared to the sample with no coagulant addition. An alum dose of 2 mg/L and a contact time less than two minutes resulted in a 20 percent reduction in chlorine demand after 24 hours compared to the sample with no coagulant addition. These results, in combination with experience at the Albany-Millersburg WTP, suggest that provision for in-line coagulant addition prior to membrane filtration is prudent and should be sufficient to reduce DBP precursors to acceptable levels; a more extensive 20-minute flocculation basin process is not warranted.

EXHIBIT 5-3
Bench-Scale Test Results; Raw Water Sampling by Rob Emmons, City of Lebanon.
Test conducted in Corvallis CH2M HILL Laboratory, November 2008.
City of Lebanon Water Improvement
Lebanon, OR

Condition	Sample Time (minutes)	Free Chlorine Demand (mg/L)	Free Chlorine Demand Reduction Compared to no Coagulation (mg/L)	Percent Reduction Compared to Raw
Raw	1	0.31	–	–
	120	0.95	–	–
	1,440	1.6	–	–
Membrane filtration with 2 mg/L alum*	1	0.12	0.19	61%
	120	0.86	0.09	9%
	1,440	1.29	0.31	19%
Membrane filtration with 5 mg/L alum*	1	0.12	0.19	61%
	120	0.64	0.31	33%
	1,440	0.90	0.70	44%

* Alum injected in-line, with approximately 2 minutes flocculation time prior to membrane filtration with a Pall membrane. Initial chlorine dose = 2 mg/L.

EXHIBIT 5-4
Free Chlorine Concentration with Time After No Coagulation, and Coagulation with 2 and 5 mg/L of Alum
City of Lebanon Water Improvement
Lebanon, OR

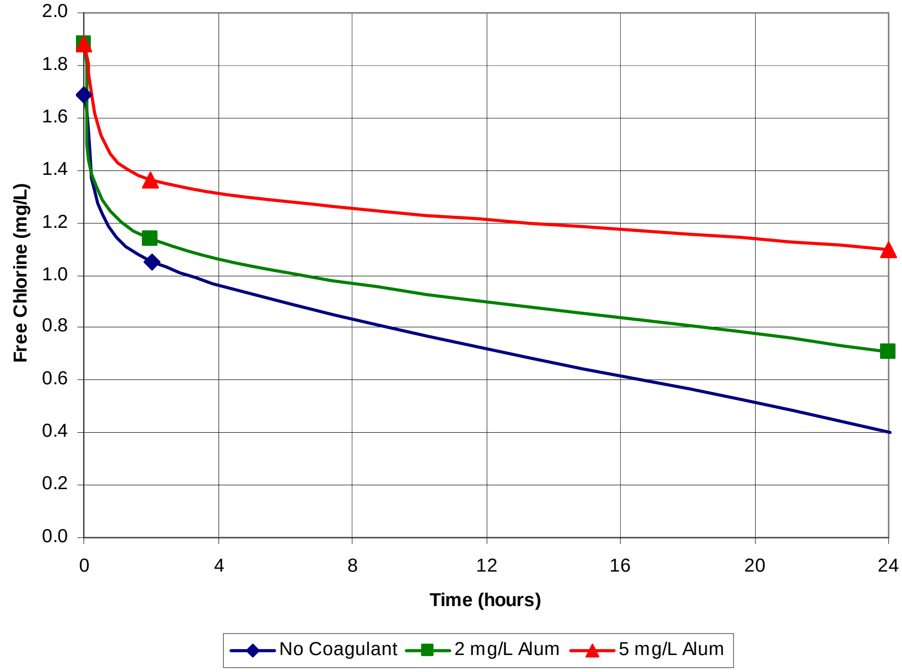
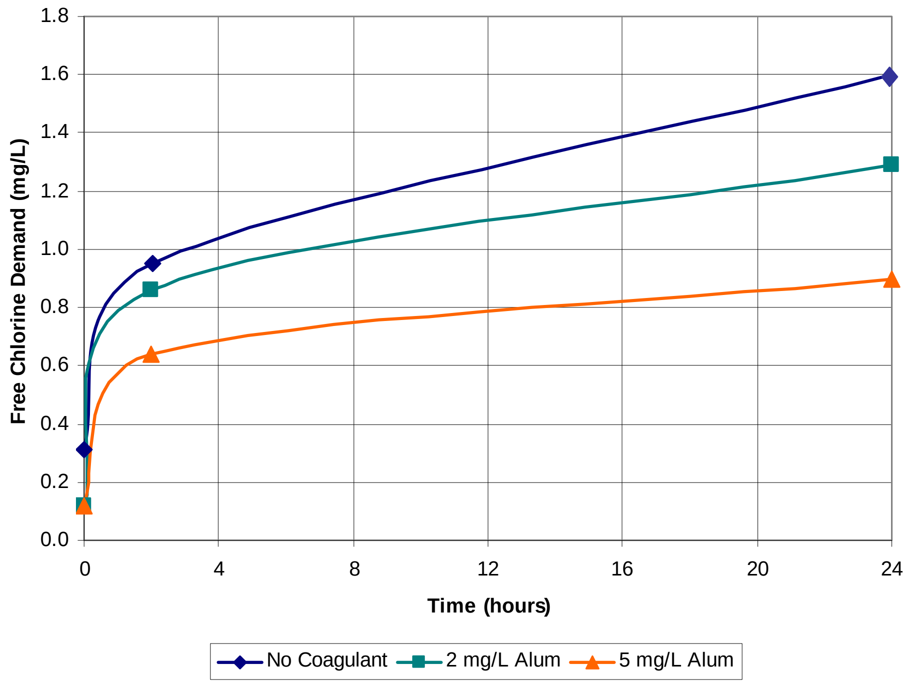


EXHIBIT 5-5
Free Chlorine Demand with Time After No Coagulation, and Coagulation with 2 and 5 mg/L of Alum
City of Lebanon Water Improvement
Lebanon, OR



Clearwell Sizing

The finished water storage provided at WTPs is called clearwell storage. A clearwell is necessary to meet the following needs:

- Disinfection. The drinking water regulations establish minimum chlorine detention times based on the water quality conditions of temperature, pH, and the chlorine residual. This disinfection volume is also called the CT volume, where CT is the product of the chlorine residual and the detention time.
- Backwash. The clearwell provides finished water that is used for backwashing either membrane or conventional media filters.
- Plant use. Water treatment plants use water for sampling, process testing, cleaning of basins and facilities, and for the operations staff. This is a relatively minor flow but nevertheless should be considered in sizing the clearwell.
- Level fluctuation. The clearwell volume allotted to level fluctuation allows the flow through the treatment plant to remain relatively constant while the high service pumping into the distribution system varies in response to storage levels in distribution reservoirs and to some extent, as system demands vary.
- Short-term shutdowns. The clearwell provides storage to allow for short-term shutdowns of the plant for maintenance activities or because of a significant raw water

quality upset. A clearwell is often sized to accommodate either the level fluctuation or the short-term shutdown, whichever is larger, because both are not needed at one time. In addition, Lebanon would be supplied by water stored in the two distribution reservoirs during times when the plant is not operating.

The volume credited for disinfection is reduced by the reservoir efficiency factor, which accounts for short-circuiting from the inlet to the outlet. Baffling will be provided for Lebanon's clearwell to improve the reservoir efficiency and thereby reduce the volume needed for disinfection. A reservoir efficiency of 25 percent has been assumed for sizing the required disinfection volume. This requires positioning the inlet and outlet on opposite sides of the clearwell and baffling to achieve a length to width flow path of approximately 20 to 1.

Exhibit 5-6 displays an analysis of the disinfection storage volume needed for expected water quality conditions for the Lebanon WTP. To meet the primary disinfection standard, the CTcalc/CT99 must be equal to or greater than 1.0. The analysis shows the critical (worst-case) conditions for three seasonal periods, summer, winter, and the shoulder (late spring and early fall). The worst case conditions reflect the highest flow, coldest water temperature, and highest pH expected for each season. Colder water temperatures require longer disinfection detention times but these conditions are offset by lower demand requirements during non-summer periods.

The summer season dictates the minimum sizing for the disinfection storage volume, as it yields the lowest CTcalc/CT99 values. According to this analysis, 500,000 gallons is sufficient to meet the CT requirements for the phase one, 6-mgd plant, and 1,100,000 gallons is sufficient for the ultimate 14 mgd plant. The volumes allotted to operations (1,500,000 and 2,900,000 gallons) provide a factor of safety for each phase of plant capacity.

Exhibit 5-7 provides a summary of the recommended minimum clearwell sizing for both the 6- and 14-mgd treatment capacities. A volume of 1.8 million gallons is the recommended minimum for the initial 6 mgd plant. To allow the city to meet the ultimate clearwell need with a second, same-sized tank, the phase one tank size was set at a volume of 2.0 million gallons for the plant layout and cost analysis. Two tanks of 2.0 million gallons will meet or nearly meet the buildout clearwell needs. The specific need can be reevaluated when future phases of the plant are designed and constructed.

Because all of the water produced in the WTP passes through the clearwell, stagnant water conditions in the clearwell are not a particular concern. For this reason and to take advantage of economies of scale, the city may wish to increase the size of the clearwell over the minimum recommended volume to satisfy growing distribution storage needs for fire flows, peak hour demands, and emergencies.

EXHIBIT 5-6
Clearwell CT Sizing for ½-Log Disinfection Credit Under Different Seasonal Conditions
City of Lebanon Water Improvement
Lebanon, OR

Conditions					Clearwell Use					CT Compliance				
Season	Flow (mgd)	Flow (gpm)	Low temp. (C)	High pH	Total clearwell volume (gal)	Clearwell volume reserved for disinfection (gal)	Operational volume in clearwell (gal)	Clearwell efficiency	Available detention time (min)	Chlorine residual (mg/L)[1]	CTcalc = time x residual	CT required (0.5 log)	CTcalc/ CT99 (0.5 log)	Meets standard?
Phase 1 (6 mgd)														
Summer (July-Aug)	6.0	4,170	11.3	7.8	2,000,000	500,000	1,500,000	25%	30	1.0	30	23	1.3	Yes
Shoulder (May, Jun, Sep)	4.0	2,780	8.2	7.8	2,000,000	500,000	1,500,000	25%	45	1.0	45	27	1.6	Yes
Winter (Oct-Apr)	3.0	2,080	4.6	7.8	2,000,000	500,000	1,500,000	25%	60	1.0	60	34	1.7	Yes
Ultimate (14 mgd)														
Summer (July-Aug)	14	9,860	11.3	7.8	4,000,000	1,100,000	2,900,000	25%	28	1.0	28	23	1.2	Yes
Shoulder (May, Jun, Sep)	9.5	6,580	8.2	7.8	4,000,000	1,100,000	2,900,000	25%	42	1.0	42	27	1.5	Yes
Winter (Oct-Apr)	7.1	4,930	4.6	7.8	4,000,000	1,100,000	2,900,000	25%	56	1.0	56	34	1.6	Yes

Notes/Assumptions:

1. Chlorine residual represents the value at the outlet of the clearwell (not the value fed at the inlet, which might be higher)
2. CT compliance based on achieving 0.5 log inactivation. (Filtration process is credited with 2.5 log removal.)
3. The clearwell efficiency assumes inlet and outlet at opposite sides and baffles.
4. Values for temperature are from USGS data, coldest 5th percentile.
5. Values for pH are approximate and may vary depending on treatment process--values used are relatively high.

EXHIBIT 5-7
Summary of Recommended Minimum Clearwell Sizing for Phases 1 and 2
City of Lebanon Water Improvement
Lebanon, OR

Plant Production (mgd)	Purpose	Basis	Volume (MG)
	A. Disinfection contact time (CT)	Baffled clearwell; 25% efficiency; sufficient volume to meet worst-case seasonal condition; provides 1/2 log, which is sufficient for either conventional or membrane process	0.5
	B. Backwash supply	Provide for consecutive backwashes at 5% of production volume	0.3
6	C. In-plant use	20 gpm average for cleaning, sample flows, etc	0.03
	D. Level fluctuation for balancing production and high service pumping	Based on providing approximately 4 feet of level fluctuation out of clearwell depth of 15 feet	0.5
	E. Short-term shut downs	Allow for 4-hour shutdown at peak production	1.0
	TOTAL (=A + B + C + largest of D or E)	Provide at least storage for CT, backwash supply, in-plant use, and the larger of level fluctuation or short-term shutdown volumes	**1.8**
	A. Disinfection contact time (CT)	Baffled clearwell; 25% efficiency; sufficient volume to meet worst-case seasonal condition; provides 1/2 log, which is sufficient for either conventional or membrane process	1.1
	B. Backwash supply	Provide for consecutive backwashes at 5% of production volume	0.7
14	C. In-plant use	20 gpm average for cleaning, sample flows, etc	0.03
	D. Level fluctuation for balancing production and high service pumping	Based on providing approximately 4 feet of level fluctuation out of clearwell depth of 15 feet	1.0
	E. Short-term shut downs	Allow for 4-hour shutdown at peak production	2.4
	TOTAL (=A + B + C + largest of D or E)	Provide at least storage for CT, backwash supply, in-plant use, and the larger of level fluctuation or short-term shutdown volumes	**4.2**

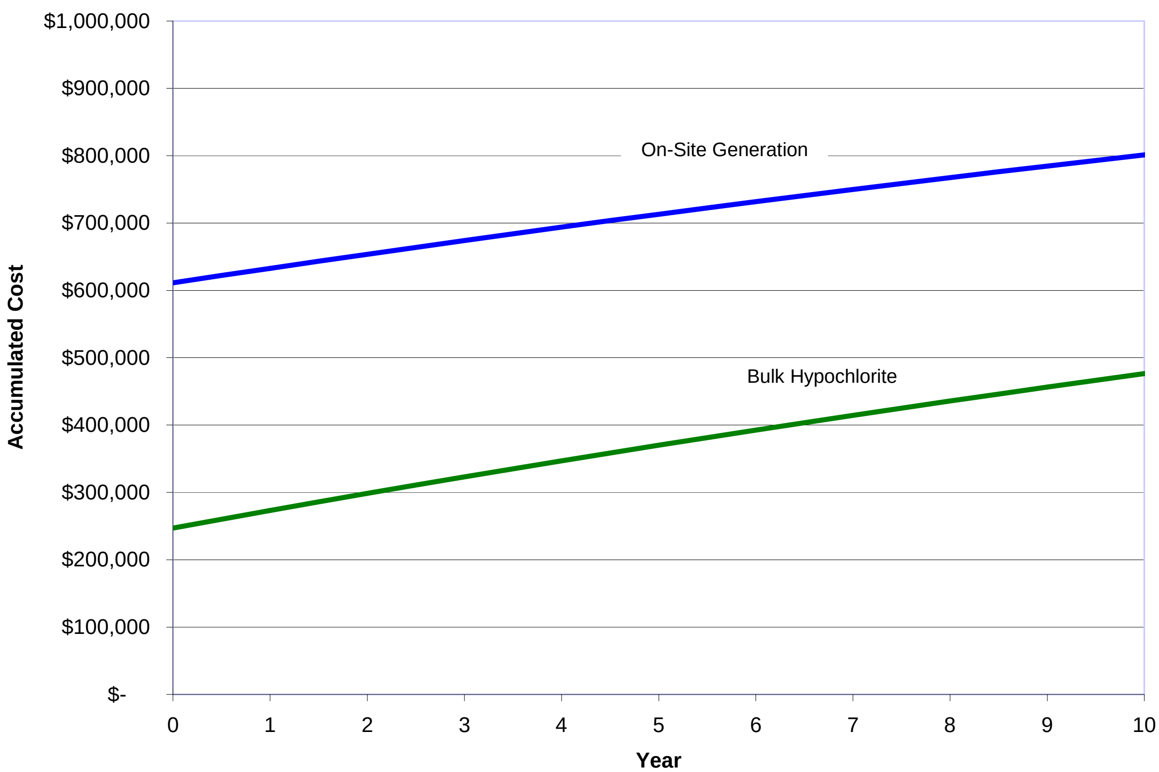
Chlorine System Alternatives

Chlorine can be supplied in gas form (pressurized cylinders of liquid with gas draw-off), solid form (tablets or granules), liquid form (bulk hypochlorite), or can be generated onsite. Neither gas nor solid forms of chlorine are appropriate for Lebanon’s new plant. Gas is not recommended because of the safety issues, particularly because of the surrounding residential area in which the city’s new WTP will be located. Very few, if any, new WTPs use gas chlorine because of the potential for a catastrophic failure that could injure operators or others in the vicinity. The plant capacity of 6 mgd is considered too large for economical and practical use of solid chlorine, which is generally limited to plant capacities of less than 1-2 mgd.

The two remaining approaches to obtaining chlorine supply, bulk hypochlorite and onsite generation, are both viable alternatives for Lebanon's plant. The facilities to use bulk hypochlorite generally have a lower capital cost than for the onsite generation system. Depending on the costs of bulk hypochlorite versus the cost of electricity and salt for onsite generation, the annual costs may favor one approach over the other.

Exhibit 5-8 provides a life-cycle cost comparison of these two approaches over a period of 10 years. An applied chlorine dose of approximately 1.5 mg/L was assumed, and the unit costs for chemicals were obtained from information provided by neighboring utilities and chemical suppliers. The cost for electricity was provided by Lebanon staff. Bulk hypochlorite was estimated at $1.30 per gallon, food grade salt for onsite generation was estimated at $0.115 per pound, and electricity was estimated at $0.11 per kilowatt-hour (the electricity cost being an "all in" value, accounting for both demand and use charges). As shown in this chart, the cost analyses indicate that bulk hypochlorite has a lower capital cost (year zero value) and a lower life-cycle cost throughout the 10-year period.

EXHIBIT 5-8
Life Cycle Comparison for Bulk Hypochlorite and Onsite Generation Alternatives
City of Lebanon Water Improvement
Lebanon, OR



The city currently uses bulk hypochlorite at both its WTP and WWTP, dividing a single load between the two facilities. Because there are no compelling reasons to switch to onsite generation and the cost for bulk hypochlorite is lower, the city prefers to keep its bulk hypochlorite delivery arrangement. Another alternative the city may consider during final design is to provide bulk hypochlorite storage initially, with space for future onsite generation if desired.

Water Treatment Plant Site Visits

City staff visited the four WTPs listed in **Exhibit 5-9.** Based on site visits alone, staff reported that they favored a pressure membrane alternative. The St. Helens, Oregon, WTP most closely resembles the membrane option Lebanon is considering. Staff's overall impression of the St. Helen's plant was of a well-maintained and operated, and aesthetically pleasing plant located in a residential area similar to the residential areas that may surround Lebanon's new plant. The plant has been operating for two years with very few membrane problems. Lebanon staff was favorably impressed with the level of automation of the process. The St. Helen's plant is run by two operators, and has a computer system designed for remote operation. When staff is not at the plant, the on-call operator carries a lap-top computer for monitoring and controlling operations, and responding to alarm conditions.

EXHIBIT 5-9
WTPs Visited by City Staff
City of Lebanon Water Improvement
Lebanon, OR

Name	Source	Capacity (mgd)	Process Type
St. Helens, Oregon	Columbia River	8	Pressure membranes (membranes supplied by Pall, Inc.)
Wilsonville, Oregon	Willamette River	50	Conventional filtration, deep bed filters, Actiflo ballasted clarification
Corvallis, Oregon	Willamette River	21	Conventional filtration, plates, tubes and open sedimentation basin
Albany-Millersburg, Oregon	South Santiam River	18	Immersed membranes (membranes supplied by US Filter)

Alternative Identification

Two general categories of treatment processes were evaluated: conventional media filtration options similar to the city's existing WTP, and membrane filtration options using both pressure and immersed membrane systems. Subsets of these general categories differed primarily in the degree of pre-treatment prior to filtration.

All conventional filtration options included deep-bed media filters. The deep beds allow for higher hydraulic loading and provide greater treatment robustness than the shallower beds designed in the past.

Both immersed and pressure membrane systems initially were considered, but immersed membranes were eliminated for two reasons. First, because an immersed membrane system would require an additional pump station (intermediate pumping) compared to a pressure membrane system in which the raw water intake pumps could be sized to pump water through the membranes directly to an above ground clearwell, and second because of problems with membrane failures in small, immersed-membrane systems such as the Albany Millersburg system. CH2M HILL recommended, and Lebanon staff concurred that only the pressure membrane systems receive subsequent evaluation.

Membrane filtration systems are compact, requiring a smaller footprint than conventional media filters with pretreatment. The modular configuration also allows for more rapid expansion to increase capacity. Another advantage of membrane filters is that their effectiveness in removing pathogens does not depend on day-to-day operator control. The membranes provide a positive barrier to pathogens without respect to balancing coagulant and alkalinity adjustments. This contrasts with the operation of conventional media filtration plants, in which the microorganism removal effectiveness is dependent on the operator's knowledge, skill, and care in managing the coagulant dose, pH, alkalinity, and filter operations.

Most municipal water treatment applications use polymer-based membranes, and these were the basis for the conceptual designs presented herein. A significant disadvantage of membrane systems is the need for periodic membrane replacement, which currently must be sole-sourced from the membrane equipment supplier. Utilities generally negotiate the initial membrane replacement contract as part of equipment acquisition. The required frequency of membrane replacement is not yet fully known because too few membrane plants have operated for a long enough time to develop an extensive database of membrane life under varying conditions. The estimated replacement frequency may vary from 8-15 years. The actual value depends on the source water quality, the membrane flux rate used for design, the actual production compared to the plant design capacity, and other site-specific factors. This variability results in uncertainty in developing life cycle cost estimates for membrane plants. The cost of replacement membranes has generally trended downward over the past 10 years but the cost in future years is uncertain, in part because third party suppliers may one day enter the market.

Ceramic membranes currently are used in industrial applications, but are beginning to be developed for municipal water treatment. At the time of this conceptual design study, the cost of ceramic membranes was prohibitively high. However, they have the advantage of lower maintenance requirements and longer service life than polymer-based membranes. Depending on the state-of-the-art at the time of design, Lebanon may want to revisit ceramic membranes as an alternative to polymeric membranes. The use of ceramic membranes with powdered activated carbon and higher coagulant dosages would provide a robust treatment process. The powdered activated carbon could substitute for the future use of ozone as a taste and odor barrier, if one is needed.

A difference between membrane and conventional media filtration plants is the type of skills needed by the operator. An operator of a conventional media plant must be more skilled in adjusting the chemical coagulation process to achieve successful operation. The operator of a membrane plant needs to be capable of operating and maintaining more complex control packages because so much of the system is automated. It is generally the case that on a day-to-day basis, the operation of a membrane filtration plant can be reliably and successfully performed with less labor than for a conventional media filtration plant.

Several pretreatment processes were considered for the conventional media filtration plant. These included in-line or direct filtration (with no or minimal flocculation and sedimentation stages), open basin sedimentation, plate settlers, tube settlers, ballasted flocculation, upflow clarification, and pulsed bed clarification. Parallel plate settlers were judged as the most favorable selection for Lebanon's plant. Parallel plate settlers result in a smaller footprint, more reliable treatment, and lower cost when compared to an open basin for sedimentation. Compared to more compact systems (ballasted flocculation, upflow clarification, and pulsed bed clarification), parallel plate settlers have lower operation and maintenance requirements while providing an equally reliable level of treatment. In particular, the use of ballasted flocculation was rejected because its use is not recommended without downstream ozone, which prevents excess polymer carry-over to the filters.

As noted, provisions for the future addition of ozone treatment were included with all options because of possible future regulatory requirements. In the conventional media filtration options, providing ozone upstream of the filters allows the easily biodegradable (assimilable) compounds, produced during ozonation of large organic molecules, to be removed by biological activity within the filters. Because of the system hydraulics, addition of ozone downstream of the membrane filters is probably the likely location. This feed location also avoids possible long-term damage to the membranes that could be caused by ozone carry-over from an upstream feed point. Prior to an ozone system coming on line, the city needs to assess the impact of ozonation on AOC formation, and to take appropriate precautions (Best Management Practices) to avoid problems from biofilm growth in the distribution system.

Ultraviolet (UV) disinfection is becoming more commonplace in the waterworks industry. It provides an additional barrier against pathogens, particularly *Giardia* and *Cryptosporidium*. In some cases, utilities have used UV disinfection followed by chloramines to reduce levels of TTHMs and HAA5s. UV disinfection can also be applied on recycle streams.

The use of UV does not appear to be necessary for Lebanon for pathogen control as the city's source water has low levels of *Cryptosporidium*. However, there could be value in designing the plant to allow for the future addition of UV disinfection downstream of filtration and upstream of the clearwell. This would provide flexibility to the city if higher levels of disinfection are needed or if UV becomes a part of a control plan for DBPs.

Solids Handling

The solids handling systems proposed for the new WTP, whether for a conventional media or membrane filtration plant, were selected to simulate the city's existing WTP system. The concept preferred by the city is to discharge the waste streams directly to sludge drying beds. The supernatant from these drying beds will be discharged to the canal under an NPDES permit. Periodically, a drying bed will be removed from service, allowed to dry, and then solids will be manually removed for disposal at the landfill. The city has found that this has been a cost-effective approach at the existing plant. City staff were not favorable to recycle of the waste flow unless future discharge regulations make that a necessary consideration. The use of gravity thickeners was considered to make the process more efficient. Although not included in this conceptual design for the project, gravity thickeners could be evaluated during the final design to determine if they provide a cost-effective modification to the process.

Alternative Ranking

Each treatment process alternative was rated based on a scoring of the four criteria. Staff collectively decided if a particular alternative was very favorable, favorable, neutral, undesirable, or very undesirable when a given criterion was considered. The scoring and final ranking of all eleven alternatives is shown in **Exhibit 5-10**.

EXHIBIT 5-10
Lebanon WTP Process Alternatives Evaluation
City of Lebanon Water Improvement
Lebanon, OR

Scoring: 5 = Very favorable; 4 = Favorable; 3 = Neutral; 2 = Undesirable; 1 = Very undesirable

	Weighting	14	6	9	7			
	Process Alternatives	O&M requirements	Expandability	RW robustness	Flexible process	Total Score	Rank	
a	**Direct filtration process**: Rapid mix, flocculation basin, deep bed dual media filters	3.5	3	1	2	90	11	
b	**Conventional sedimentation process**: rapid mix, flocculation basin, open sedimentation basin, deep bed dual media filters	3.5	2	4	3.5	121.5	5	
c	**Plate settler process**: rapid mix, flocculation basin, plate settlers, deep bed dual media filters	3.5	2.5	4	3.5	124.5	3	*
d	**Conventional sedimentation-GAC cap process**: rapid mix, flocculation basin, open sedimentation basin, GAC-capped deep bed filters	3	2	4.5	4	122.5	4	
e	**Plate settler-GAC cap process**: rapid mix, flocculation basin, plate settlers, GAC-capped deep bed filters	3	2	4	4	118	8	
f	**In-line pressure membrane process**: In-line coagulation (1-2 minutes), pressure membranes	3	5	4	4	136	1	*
g	**Flocculation pressure membrane process**: Rapid mix, flocculation basin (open basin, break head), pressure membranes	2.5	4.5	4.5	4	130.5	2	
h	**Plate settler pressure membrane process**: Rapid mix, flocculation basin, plate settlers, membrane filtration	2	3.5	4.5	4.5	121	7	
i	**In-line immersed membrane process:** In-line coagulation (1-2 minutes), immersed membranes	3	4.5	3.5	3	121.5	5	
j	**Flocculation immersed membrane process**: rapid mix, flocculation basin (open), immersed membranes	2.5	4	3.5	3	111.5	10	
k	**Plate settler immersed membrane process**: rapid mix, flocculation basin (open), immersed membranes	2	3	4.5	4	114.5	9	

Two of the membrane filtration options were ranked most highly. The modularity and ease of capacity expansion of pressure membranes and the lower labor requirements were particularly appealing to Lebanon staff. The smaller footprint was also an advantage of pressure membrane systems. Disadvantages included greater mechanical complexity and greater reliance on computers for controlling many valves and related mechanical systems.

Based on the experience at Albany-Millersburg WTP and results of the pilot test, the consensus was that there is no compelling need for full-fledged flocculation and sedimentation to achieve solids removal prior to the membranes.

While conventional filtration with flocculation and sedimentation pretreatment ranked lower than the top two membrane alternatives, treatment with this process was considered to be excellent, and a conventional media alternative with flocculation and plate sedimentation was retained for cost analysis. A direct media filtration system was rejected because of lack of treatment robustness and lack of flexibility to meet future regulatory requirements.

The following two treatment alternatives were evaluated further including order of magnitude cost estimates:

- Alternative No. f, Pressure membrane filtration preceded by in-line coagulation
- Alternative No. c, Conventional media filtration preceded by coagulation, flocculation, and plate settlers

Exhibits 5-11 and 5-12 present process flow diagrams for these treatment alternatives.

Design Criteria

The following values summarize the design criteria that were used to develop physical sizing and cost estimates for the treatment facilities:

Conventional Media Filtration

- In-line rapid mix: mixing intensity = 2000 seconds^{-1} (sec^{-1})
- Flocculation: 3-stage, serpentine flow with graduated mixing intensity (60, 40, 20 sec^{-1}); overall detention time at maximum flow = 20 minutes.
- Parallel plate settlers: projected plate hydraulic loading rate = 0.55 gallons per minutes per square foot (gpm/sf)
- Media filters: maximum hydraulic loading = 8 gpm/sf; 60 inches of anthracite on top of 12 inches of sand.
- Chemical systems:
  - Alum: average dose = 16 mg/L; maximum dose = 30 mg/L
  - Filter aid polymer: average dose = 0.1 mg/L; maximum dose = 0.3 mg/L
  - Soda ash: average dose = 12 mg/L; maximum dose = 16 mg/L
  - Hydrofluorosilicic acid: average dose = 1 mg/L
  - Bulk hypochlorite: average dose = 1.5 mg/L; maximum dose = 2.0 mg/L
- Drying beds: dry solids produced per day = 300 pounds; final sludge percent dry solids = 4 percent; clean out twice per year

EXHIBIT 5-11
Pressure Membrane Filtration WTP Flow Diagram
City of Lebanon Water Improvement
Lebanon, OR

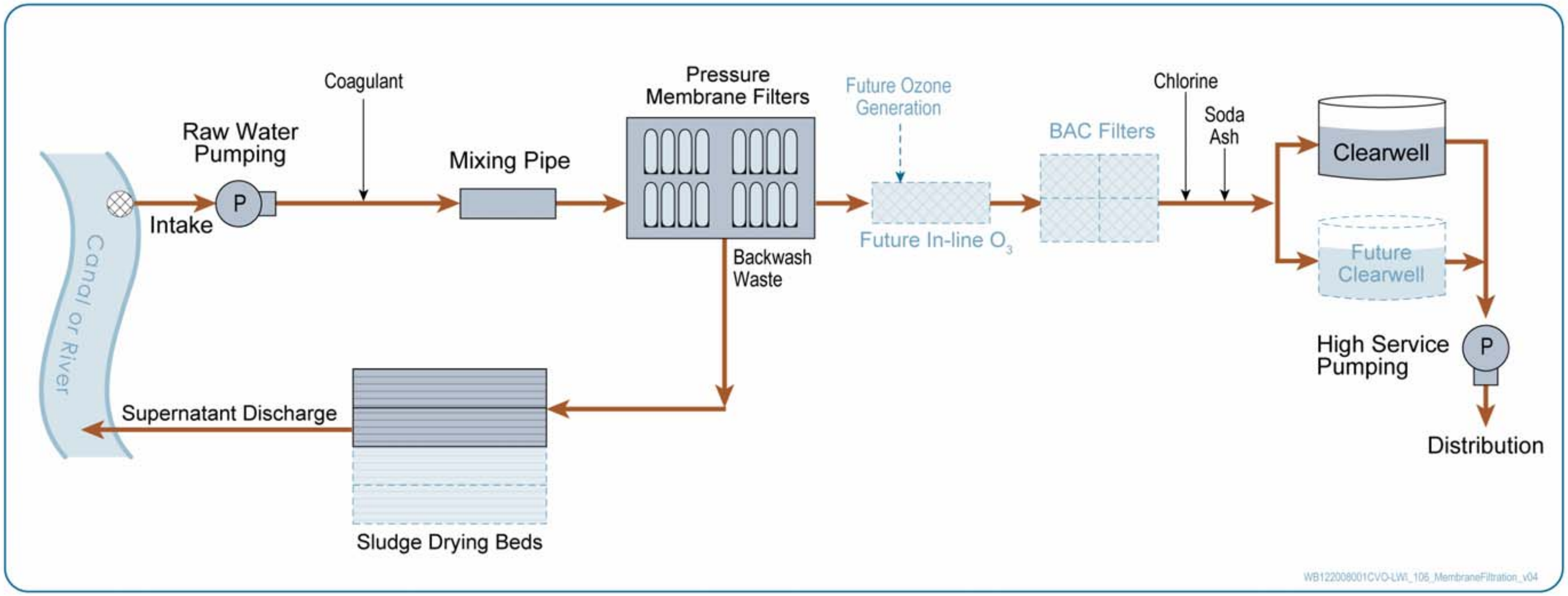
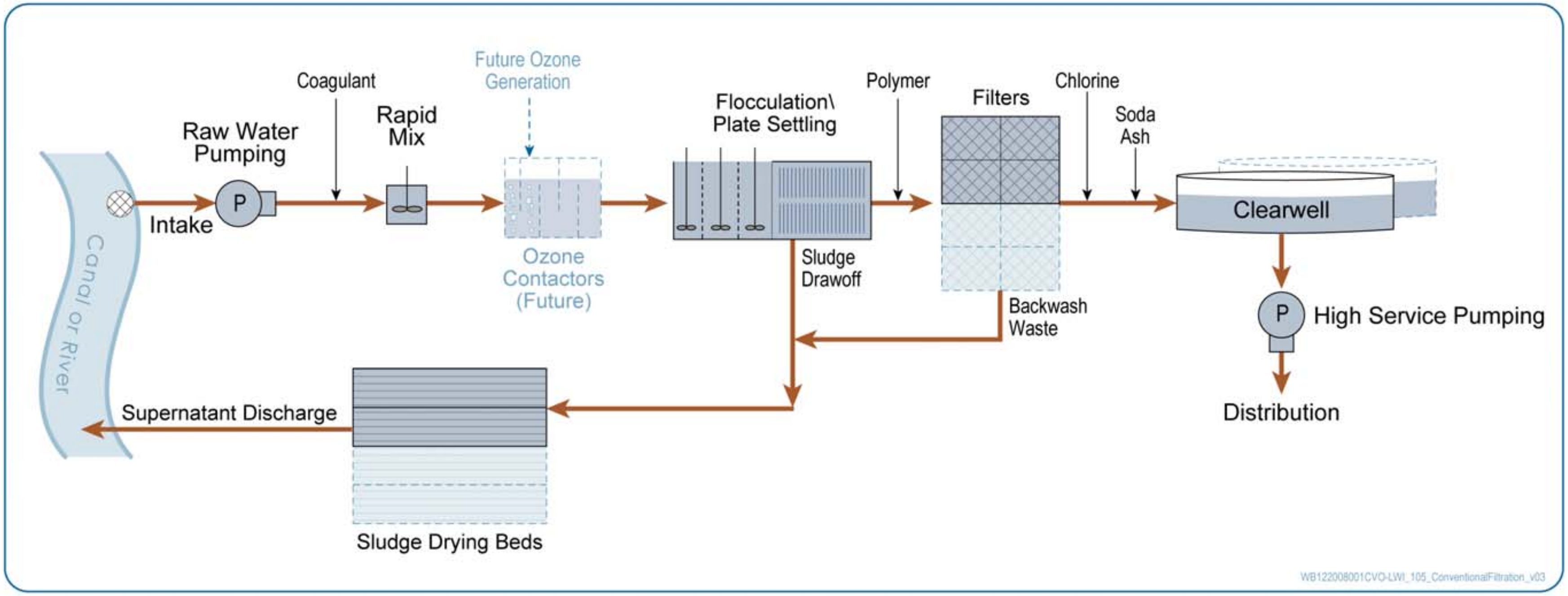


EXHIBIT 5-12
Conventional Filtration WTP Flow Diagram
City of Lebanon Water Improvement
Lebanon, OR



Membrane Filtration

- Membrane filtration: design temperature = 5.2 degrees C; instantaneous flux rate = 30.2 gallons per square feet per day (gfd)
- Chemical systems:
  - Alum: average dose = 4 mg/L; maximum dose = 5 mg/L
  - Soda ash: average dose = 5 mg/L; maximum dose = 7 mg/L
  - Hydrofluorosilicic acid: average dose = 1 mg/L
  - Bulk hypochlorite: average dose = 1.5 mg/L; maximum dose = 2.0 mg/L
- Drying beds: dry solids produced per day = 170 lbs; final sludge percent dry solids = 4 percent; clean out twice per year

Site Layout

Exhibits 5-13, 5-14, and 5-15 present conceptual site layouts for the membrane and conventional filtration WTP options, respectively, at the Tree Farm site. The Tree Farm site was used to illustrate potential layouts for various options but this is not to suggest that the Tree Farm site is the selected site. Three sites are under consideration and the city had not made a final decision at the time of publishing this report.

Both phase one (6 mgd) and phase two (ultimate, 14 mgd) structures are indicated on the exhibits because the phase one layout should allow for construction of the ultimate facilities in the future. Exhibit 5-15 illustrates the option of providing a third 2 million gallon clearwell on the site, if the city chooses to add distribution storage at the WTP. This is discussed in the storage chapter of this report.

The membrane treatment process alternative has a smaller footprint than the conventional media filtration alternative. The smaller footprint of the membrane filtration option may allow wetlands, if they are present at a site, to be avoided during initial construction or for the city to use a smaller site. This will not be known until final decisions are made regarding the site and treatment process selection. Also, space for additional distribution storage is available with the membrane layout, but not the conventional layout.

Costs

Both capital and life cycle costs were estimated for the two treatment process alternatives, conventional media filtration and pressure membrane filtration.

Capital Costs

Construction costs for the two 6-mgd alternatives were estimated as follows:

- Pressure membrane filtration: $19,500,000
- Conventional filtration: $ 20,000,000

These costs are for November 2008 and include a 30 percent contingency. These costs do not include costs for engineering, administration, or permitting. Cost summaries that include line item breakdowns of costs are presented in **Appendix A.** At this conceptual design level of cost estimation, capital costs for the two alternatives are virtually identical. Further discussions relating to the level of cost estimating and factors that will affect the final project cost are presented in the cost chapter of this report. Note that these cost estimates were prepared at a time of highly variable market conditions, with significant escalation in material prices, fluctuating oil costs, and difficult-to-predict labor costs.

Life-cycle Costs

Exhibit 5-16 presents the assumptions and **Exhibit 5-17** presents the results of a life cycle analysis for each alternative. Under the assumptions presented in Exhibit 5-16, the membrane filtration alternative had a slightly higher annual operating cost than the conventional filtration alternative. However, as shown in Exhibit 5-17, in combination with a somewhat lower capital cost for the membrane alternative, the resulting net present value of the two alternatives could be considered equal at approximately $30,000,000.

The life cycle cost comparison for the two treatment process alternatives is sensitive to the labor assumption for each. As noted earlier in this chapter, St. Helens currently staffs their similar sized membrane plant with two operators, although it is unsure if they have assigned two full time equivalents (FTE) to the operation of the plant or have two individuals that are capable of operating the plant. The information in Exhibit 5-16 suggests a single FTE for the membrane plant. This assumption was based on the city’s input and also reflects the experience of other communities in operating their membrane plants, such as Pendleton, Oregon. Pendleton’s membrane plant has a capacity of approximately 7 mgd and they currently staff the plant at less than one FTE. In comparison, two FTEs have been assumed for the operation of a conventional plant. The city may determine that different labor amounts are required but the relative comparison between the two treatment types appears to be a realistic assumption.

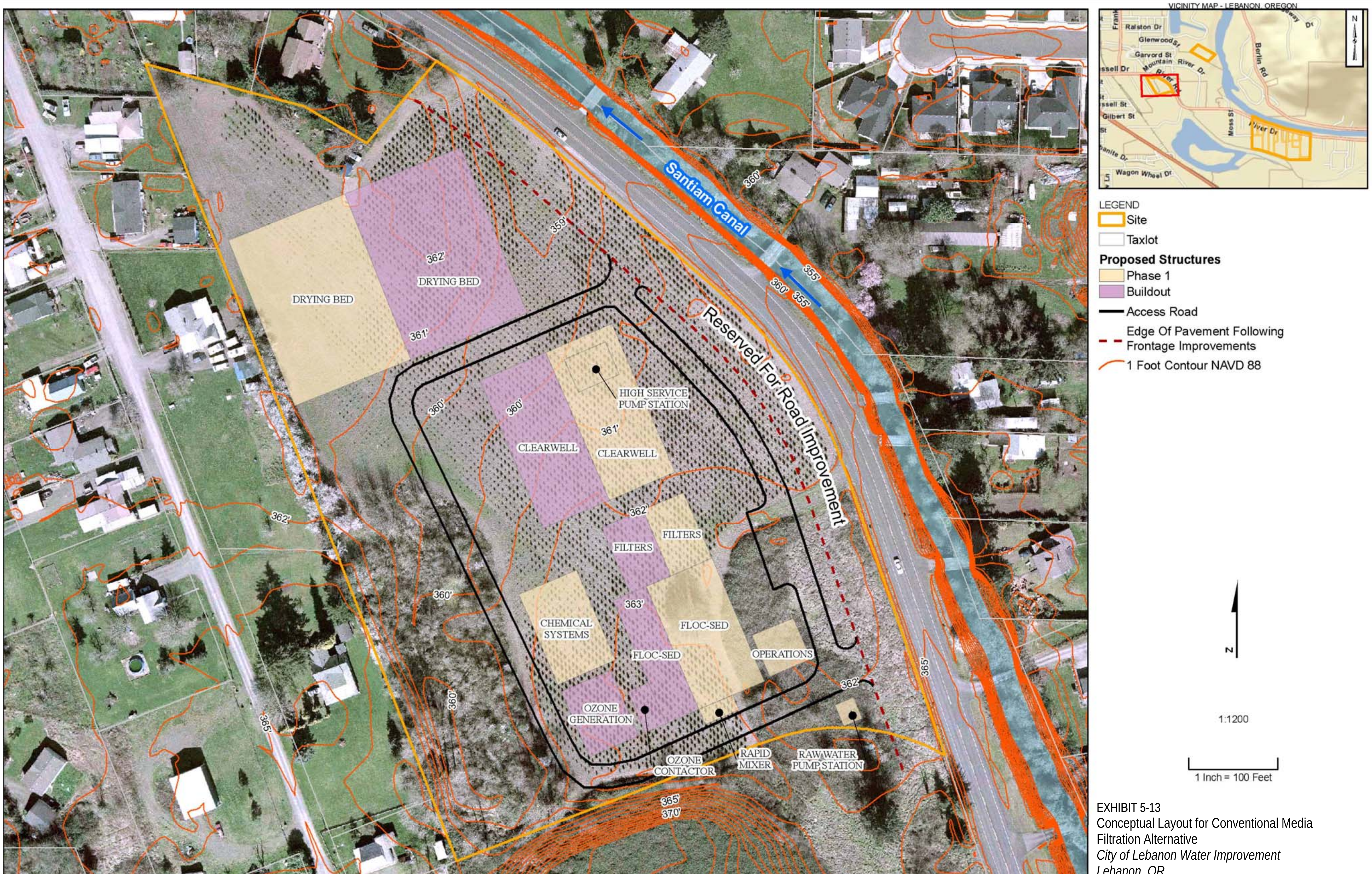


EXHIBIT 5-13
Conceptual Layout for Conventional Media Filtration Alternative
City of Lebanon Water Improvement
Lebanon, OR

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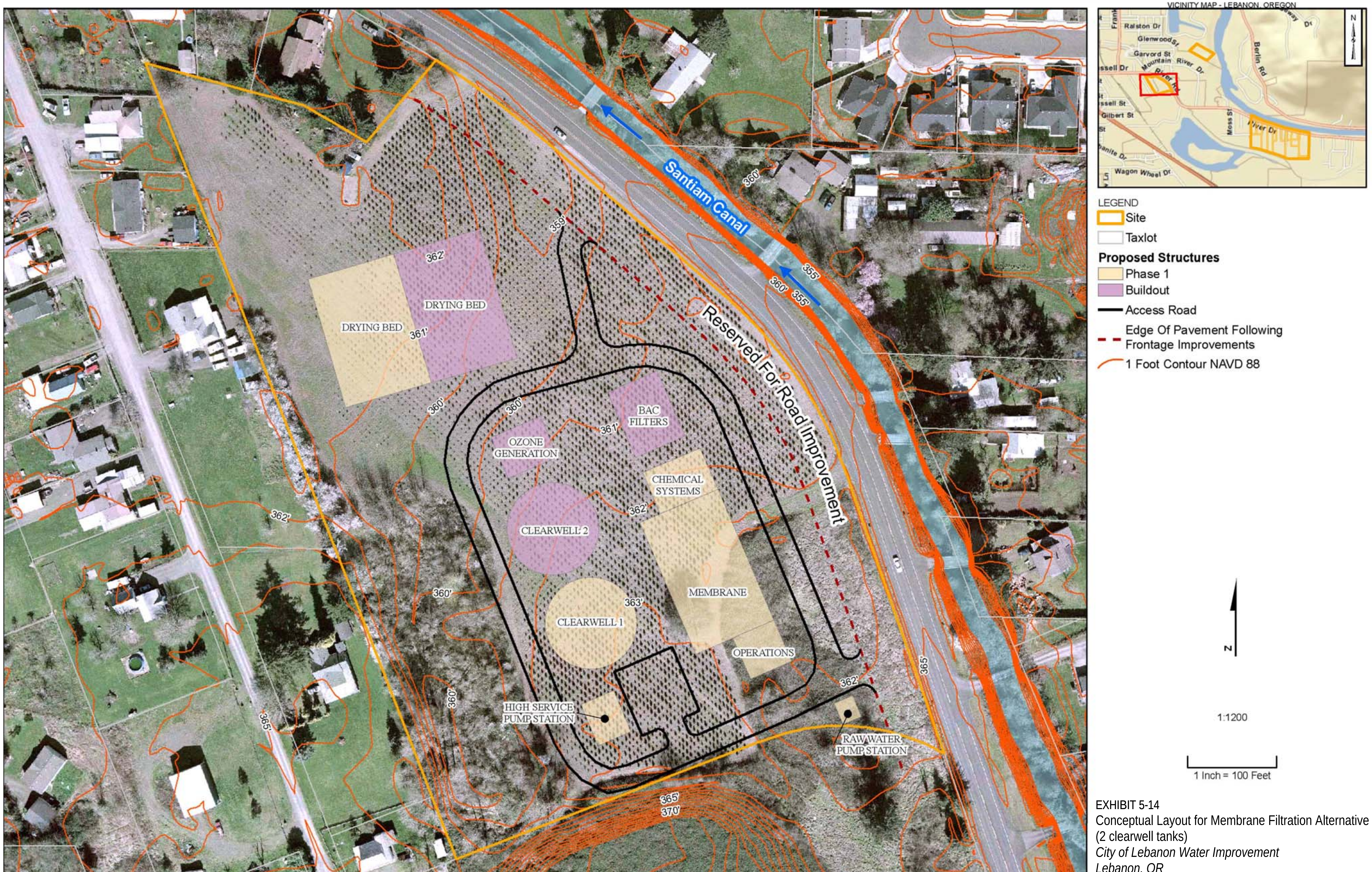

EXHIBIT 5-14
Conceptual Layout for Membrane Filtration Alternative (2 clearwell tanks)
City of Lebanon Water Improvement
Lebanon, OR

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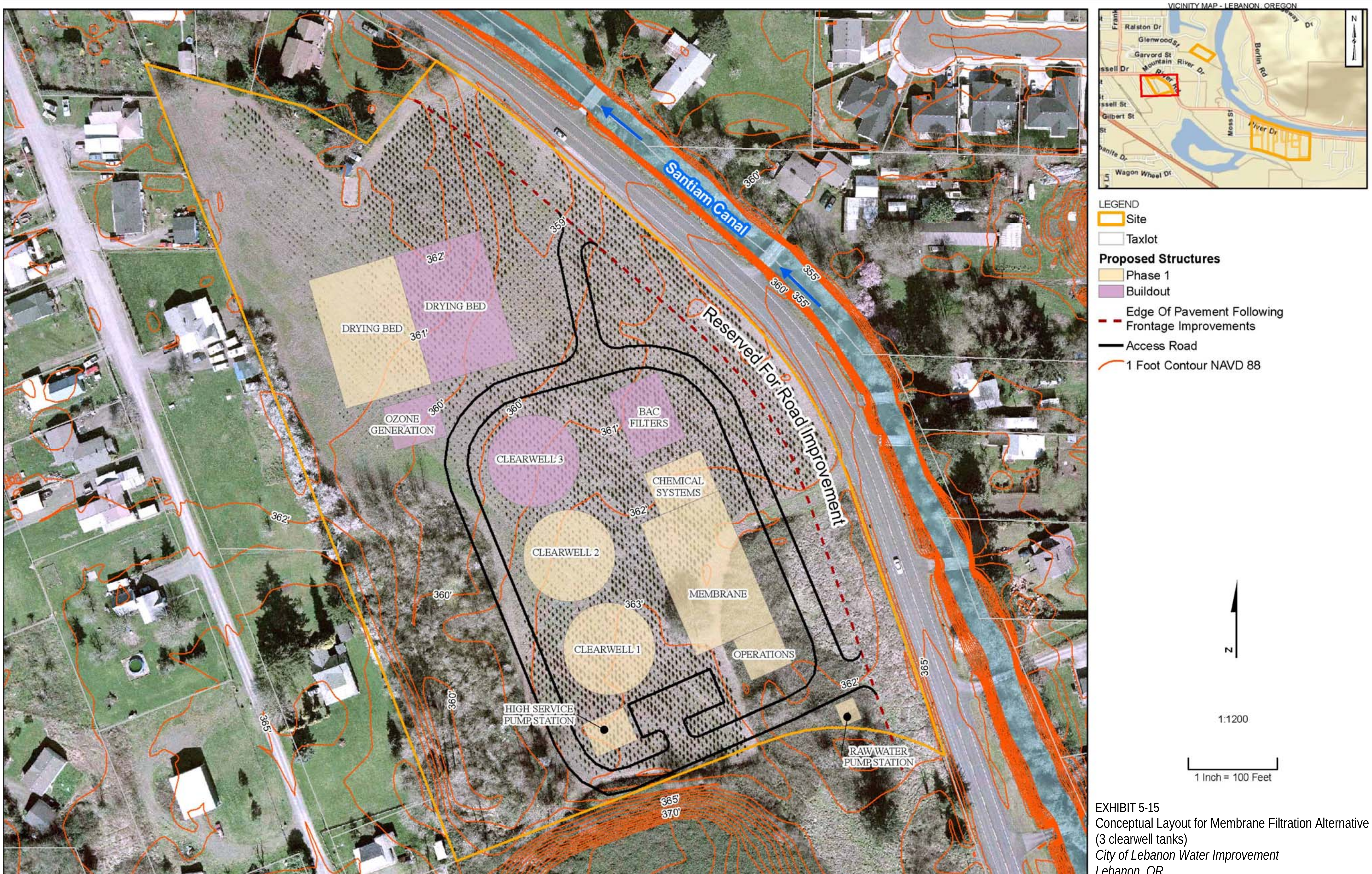

EXHIBIT 5-15
Conceptual Layout for Membrane Filtration Alternative (3 clearwell tanks)
City of Lebanon Water Improvement
Lebanon, OR

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EXHIBIT 5-16
Treatment Process Life Cycle Cost Assumptions
City of Lebanon Water Improvement
Lebanon, OR

Input Values		Value	Units
1	Annual discount rate	7%	
2	Annual inflation rate	5%	
3	Life cycle period for comparison	25	years
4	Plant maximum capacity	6	mgd
5	Plant average production	3	mgd
6	Labor time, conventional media filtration plant	80	hours/week
7	Labor time, membrane filtration plant	40	hours/week
8	Labor rate (burdened): Single operator (lead)	$44	$/hour
9	Labor rate (burdened): Second operator	$32	$/hour
10	Electrical power (“all in,” use plus demand)	$0.11	$/KWH
11	Membrane replacement frequency	10	years
12	Membrane replacement cost per module	$1,400	$/module
13	Alum	$0.15	$/lb
14	Soda ash	$0.20	$/lb
15	Onsite chlorine generation salt	$0.12	$/lb
16	Polymer	$3.30	$/lb
17	Fluoride	$0.43	$/lb
18	Solids disposal	$5,000	$/year

EXHIBIT 5-17
Treatment Process Life Cycle Cost Comparison
City of Lebanon Water Improvement
Lebanon, OR

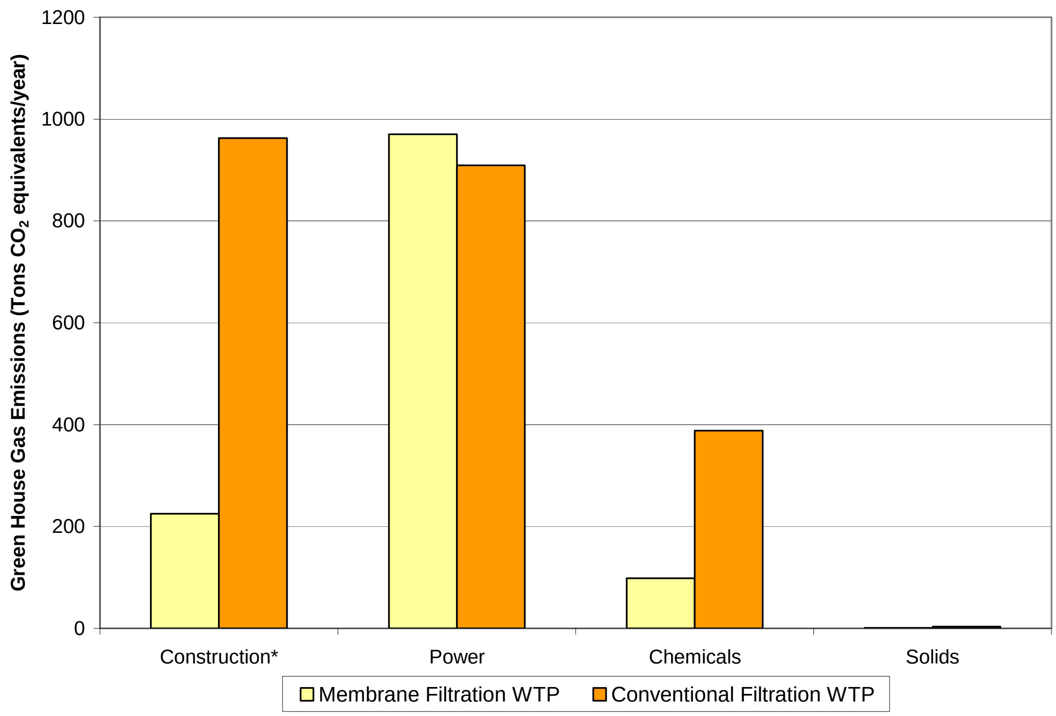
Membrane filtration option	
Capital cost	$19,500,000
Annual O&M	$1,000,000
Net present value	$30,200,000
Conventional media filtration options	
Capital cost	$20,000,000
Annual O&M	$960,000
Net present value	$30,000,000

A sensitivity analysis was performed to evaluate the effects of assumptions regarding interest and inflation rates, labor requirements, membrane replacement frequency, and electrical costs. The results of these analyses are presented in **Appendix B.** The results of the sensitivity analyses did not change the overall conclusion that the two alternatives have nearly equal costs.

Carbon Footprint

A computer model was used to assess the effect of either treatment alternative on greenhouse gas emissions. The total green house gas emissions (converted to Imperial tons, 2,000 pounds, of carbon dioxide equivalents) resulting both from construction and from operation of the two alternative plants were estimated. Data for the green house gas emission model were imported from the cost estimating software, so detailed estimates including excavation requirements, material quantities, fuel requirements, power consumption, chemical use, and solids handling were included in the emissions estimations. **Exhibit 5-18** presents results from this analysis.

EXHIBIT 5-18
Green House Gas Emission Comparison between Membrane Filtration and Conventional Media Filtration Alternatives
City of Lebanon Water Improvement
Lebanon, OR



*Note: Construction emisisons are a single emission event, not a life cycle emission, but are shown for comparison.

Construction of a conventional filtration WTP was estimated to release approximately four times the green house gas emissions as construction of the membrane filtration plant. The reason for the disparity in this "single-emission" event is largely because of the larger amounts of concrete required for the conventional filtration plant, and the greater excavation required for below-grade reservoirs.

Power consumption is the largest ongoing contributor to green house gas emissions for both types of plants. Membrane filtration had a larger contribution to green house gas emissions from power requirements than a conventional filtration option because of the greater energy required to pump water through the membranes. The opposite was true for chemical use; the conventional filtration option requires higher doses of coagulant and other chemicals than the membrane option and has correspondingly higher emissions associated with chemical manufacture and transport. Higher chemical use also contributed to greater emissions associated with solids disposal for the conventional filtration option, although this difference is a minor contributor to greenhouse gas emissions.

Considering only life cycle emissions from power-, chemical- and solids-related activities, the membrane filtration plant was estimated to produce approximately 1.0 ton of CO_2-equivalent emissions per million gallons of water treated, and the conventional filtration plant was estimated to produce approximately 1.2 tons of CO_2-equivalent emissions per million gallons of water treated.

Independent Review Panel

Along with review by several of CH2M HILL's senior water technologists, the following three water industry professionals provided an independent review of the treatment selection process:

- Melinda Friedman, Consulting Engineer, Confluence Engineering
- Dave Anderson, Public Works Director, City of The Dalles
- Chuck Kingston, WTP Supervisor, City of Hillsboro, Joint Water Commission

All three external reviewers agreed that the decision methodology was sound; appropriate questions were addressed and appropriate alternatives were considered. The reviewers agreed that the two treatment process alternatives, pressure membrane filtration and conventional media filtration, were similar in costs and that either alternative could provide successful treatment.

All three reviewers expressed concern over the low alkalinity in Lebanon's source water, and favored soda ash for pH adjustment and alkalinity addition. Chuck Kingston, concurred with the choice of parallel plate sedimentation for a conventional media filtration process and expressed the JWC's positive experience with parallel plates. Melinda Friedman expressed concerns about the potential for increasing assimilable organic carbon (AOC) in the distribution system if ozone is one day used downstream of membranes. CH2M HILL concurs that this is a valid concern and warrants further investigation if the use of ozone is to be implemented. As a minimum, the city should embark on a uni-directional flushing program in advance of introducing ozonated water into the distribution system. Two of the reviewers questioned the assumption that the city could obtain an NPDES permit for discharging backwash waste water into the canal. They indicated that the Oregon Department of Environmental Quality has become more stringent in issuing these permits in recent years. Also, two of the reviewers suggested that the city consider a larger clearwell volume, if the budget allows, to account for short-term shutdowns because of poor raw water quality conditions.

Other independent reviewer comments have been considered and incorporated into this report.

Recommendations

The recommended treatment process option is the use of pressure membrane filtration, based on the following comparison between the two options:

- The capital costs for the two options are nearly equal
- The net present values (present worth) of the two options are nearly equal
- The greenhouse gas emission projections for the two options are nearly equal but slightly favor membrane filtration
- The non-cost factor analysis, summarized in Exhibit 5-10, favors the membrane filtration option
- The membrane option has a smaller land area requirement, which gives the city greater flexibility in selection of a site and may reduce permitting investment
- Lebanon staff was favorably impressed with membrane plants they visited
- The membrane option allows for less-expensive additions of distribution storage at the WTP location

Although, membrane filtration is the recommended option, conventional media filtration has a long history, and therefore has slightly less uncertainty associated with long-term operation and maintenance. Uncertainties associated with membrane filtration include expected membrane life, and future membrane supply. Membranes are currently proprietary, so if the membrane alternative is pursued, the city will enter into a long-term relationship with a particular membrane supplier.

At this time, the Lebanon staff favors the membrane alternative as shown in the criteria scoring presented in Exhibit 5-10. The membrane alternative is expected to provide reliable treatment and offers operational advantages, when compared to the conventional media filtration alternative. However, if the city's LT2ESWTR Bin classification is greater than expected, or if in the future the city anticipates that organic contaminants are likely to dictate the use of ozone, CH2M HILL favors a conventional media process because of its effectiveness for controlling organics, its better fit with the use of ozone, and its lower energy requirements.

Additional recommendations from the process evaluation include the following:

- In-line coagulation is recommended for control of disinfection byproducts for the membrane process
- Soda ash is recommended for alkalinity and pH adjustment, to achieve compliance with the Lead and Copper Rule

- Bulk hypochlorite is the recommended form of chlorine to be used
- The clearwell volume should be at least 2 million gallons for the phase one facility. If possible during initial construction, adding another 2 million gallons of storage at the WTP site to address distribution storage needs (as described in Section 6 of this report) is advantageous.